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PHASE I
REMEDIAL INVESTIGATION REPORT

CALIFORNIA GULCH
Leadville, Colorado

53-8L29.0/W63781.R1

May 1987

DE/CALGU8/024

EXECUTIVE SUMMARY

INTRODUCTION

The California Gulch Superfund site is located in and near Leadville, Colorado, which is approximately 100 miles southwest of Denver. Surface water and groundwater from the 11.5-square-mile study area are contaminated with iron, zinc, cadmium, lead, copper, manganese, and other metals. Potential contaminant sources include the Yak Tunnel, which is a major underground mine drainage system, and various types of mine wastes found throughout the study area.

Water can react with some of these mineralized wastes, form acids, and mobilize (dissolve) heavy metals. Contaminated waters drain into California Gulch and subsequently into the Arkansas River.

SITE DESCRIPTION AND BACKGROUND

The site is situated in a highly mineralized area of the Colorado Rocky Mountains, with elevations ranging from 9,520 feet to approximately 14,000 feet above sea level. The development of Leadville dates back to the 1850's with the mining development of the rich mineralized zones containing principally gold, silver, lead, zinc, and copper. Mining, processing, and/or smelting operations in the area have been active for more than 125 years and varied in degree with economic demand and technological improvements. Early activities consisted of placer mining for gold in California Gulch. Later, underground mines were developed to the southeast of Leadville where the ores were extracted and then processed into metallic concentrates. These concentrates were either shipped elsewhere or further processed at the numerous smelters that were in the Leadville area. Many areas of the site received mining-related wastes including mine waste rock, tailings, and slag piles.

Tunnels were developed to drain the ore bodies and to facilitate mining. The Yak Tunnel, developed from 1895 to 1923, extends approximately 4 miles into Iron Hill, which is located in upper California Gulch. The tunnel drains numerous underground mines. The tunnel drainage water discharges into California Gulch, which flows 4.5 miles west to the Arkansas River.

Mining activity has declined to a much slower pace due to lower metal prices. Presently there are only a few moderately sized mining operations in the Leadville area, and the Leadville population has decreased significantly from past levels.

SUPERFUND PROCESS

Under Section 104(a) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or also known as Superfund), and the Superfund Amendments and Reauthorization Act of 1986, (SARA), the United States Environmental Protection Agency (EPA) is authorized to respond to the actual or threatened releases of hazardous substances, or pollutants and contaminants that may present an imminent and substantial danger to public health or welfare. This process involves several steps but discussion here is limited to a remedial investigation (RI).

The purpose of the RI is to determine the nature and extent of the problem presented by the release of hazardous substances, pollutants, or contaminants. This includes sampling and monitoring as necessary and includes the gathering of sufficient information to determine the necessity for and the proposed extent of remedial action.

The Phase I RI activities for the California Gulch site included: (1) studies of mine drainage and mine waste leachates and impacts on water quality; (2) investigation of groundwater quality, geology, and aquifer characteristics; (3) investigation of surface water contamination and interaction with groundwater; and (4) an investigation to determine potential receptors and the probable effects of contamination on them.

REMEDIAL INVESTIGATION ACTIVITIES

Due to the extensive area of the site and its complexities, the RI was conducted in a phased approach. Phase I, which is the basis for this report, focused primarily on literature review, site reconnaissance, and the subsequent development and installation of an extensive surface water and groundwater monitoring system. Water sampling and preliminary mine waste sampling was conducted from September 1984 through November 1985.

The large areal extent of potential contamination sources and the surface water and groundwater flow patterns into the California Gulch drainage is a very complex hydrologic system. Initial site assessments determined that the following should be considered potential sources of contamination:

- Upper California Gulch drainage
- Yak Tunnel discharge

- Three major tailings impoundments in California Gulch

- Starr Ditch, which intercepts the drainage from the north side of Iron and Carbonate Hills (Stray Horse Gulch)

- Oregon Gulch tributary, which contains a fourth major tailings impoundment

- Storm drains from Leadville

- Other tributary drainages

- Slag pile areas near Stringtown

- Discharge from the Leadville sewage treatment plant (STP)

A detailed water quality monitoring plan and a soils/tailings geochemical sampling and testing plan were developed to evaluate these potential contaminant source areas.

The surface water sampling program included the installation of five Parshall flumes to provide continuous flow measurements. These were located at the Yak Tunnel discharge; in the upper Gulch above the three tailings impoundments; in Starr Ditch; and two in lower California Gulch. In addition, 17 supplemental sampling and flow measuring points were selected at critical locations along the drainage to be used when flows were present.

The groundwater sampling program included the use of numerous privately owned wells at critical locations and the installation of 21 new monitoring wells. The new wells were designed and located to provide more reliable data than were available from the privately owned wells. To provide more information on water exchange between surface water and shallow groundwater, piezometer pipes were installed at various locations in the Gulch and water levels were taken on one occasion.

The preliminary soils/sediments and tailings characterization program consisted of collecting one surface sample from each of the four major tailings impoundments and two samples near the confluence of the Gulch and the Arkansas River. These samples were tested and categorized as characteristic or noncharacteristic waste.

The hydrologic cycle for this region has a significant influence on the mobilization and transport of contaminants. Snowmelt in May and June causes a large surface water runoff to occur during this period; whereas surface flows are more constant for other periods of the year with the exception of winter when hard freezing occurs. To take this into consideration, a long-term surface and groundwater sampling program was conducted during the Phase I RI. Using the sampling network previously described, water sampling was conducted in October and November 1984; and in March, June, September, and November 1985. Two aquifer pump tests were also conducted in November 1985.

NATURE AND EXTENT OF CONTAMINATION

Major findings and conclusions determined from the Phase I RI are summarized as follows:

1. The predominant geochemical system in the project area is an acid-sulfate system caused by the oxidation of sulfide minerals. Interactions among surface water, groundwater, and the sulfide minerals generate acid

that reacts with other minerals to release dissolved metals such as lead, copper, cadmium, iron, manganese, zinc, and iron to the waters on the site.

2. The acid forming and dissolution reactions occur at widely differing rates depending upon hydrologic and geohydrologic conditions and the type of metal bearing materials they contact. The site is very large; the hydrologic and geohydrologic regimes vary from location-to-location with the topography, geology, and other surficial characteristics. The solids that the waters react with vary dramatically in chemical composition. The site is extremely complex geochemically.

3. Analytical results of the soils/sediments and tailings samples varied widely in metals content. For example, two tailings samples and one soils/sediment sample were very high in iron content, indicating a high concentration of iron pyrite (a strong acid generator). The other tailings samples and soils/sediment samples had dramatically lower iron contents.

4. EP-Toxicity tests for characteristic waste on soils/sediment and tailings samples determined that one tailings sample failed the criteria for cadmium and one soils/sediment sampled failed for lead. It should be noted that erosion in the drainage system by surface water from the hundreds of waste piles, and from tailings and slag areas make soils/sediment characterization extremely difficult.

5. Surface water flows in the site drainage system act as the primary contaminant transport system for soluble metal contaminants as well as metal-laden sediments. Flow data indicate that the California Gulch mainstem

accepts continuous flows from both the Yak Tunnel and STP discharge. Other tributaries to the Gulch are ephemeral and generally only flow during snowmelt (May and June) and during high intensity summer thunderstorms. Representative high and low flows appear to occur in June and November, respectively.

6. Surface water quality information is extensive over the five sampling periods. Comparisons of surface water quality results with primary drinking water standards (called "maximum contaminant levels" or "MCL's") and federal water quality criteria for fresh water aquatic life listed for comparative purposes are summarized as follows:

- Cadmium has a primary MCL of 10 micrograms per liter (µg/l) and a chronic aquatic life criterion of 1.1 µg/l. Cadmium concentrations in California Gulch ranged from 12 µg/l in upper California Gulch to 431 µg/l at the tailings area. In the ephemeral drainages, cadmium ranged from detection level to 380 µg/l in Oregon Gulch. The Yak Tunnel discharge varied in cadmium concentration from 169 µg/l to 552 µg/l.

- Copper has a chronic aquatic life criterion of 11.8 µg/l. Copper concentrations in the Gulch ranged from 20 µg/l near the slag area to 4,670 µg/l just below the Yak Tunnel. In the ephemeral drainages, copper ranged from 3.3 µg/l in Georgia Gulch to 9,520 µg/l in Oregon Gulch. Copper in the Yak Tunnel discharge varied from 437 µg/l to 5,970 µg/l.

- Iron and manganese in the California Gulch and its tributaries ranged from 152 µg/l to 677,000 µg/l for iron, and manganese concentrations ranged from 146 µg/l to 708,000 µg/l.

- Lead has a primary MCL of 50 µg/l and a chronic aquatic life criterion of 3.2 µg/l. Lead concentrations in California Gulch ranged from detection to 382 µg/l in upper California Gulch. In the ephemeral drainages, lead values varied from detection to 310 µg/l at Oregon Gulch. The Yak Tunnel discharge ranged from detection to 116 µg/l.

- Zinc has a chronic aquatic life criterion of 86 µg/l. Zinc concentrations in California Gulch varied from 1,506 µg/l to 85,300 µg/l in upper California Gulch. The Yak Tunnel discharge ranged from 43,700 µg/l to 109,000 µg/l.

- Water quality at the Arkansas River upstream of California Gulch routinely exceeded the aquatic criterion for zinc.

- Water quality at the Arkansas River downstream of California Gulch met primary MCL's for all periods except March 1985, when the cadmium standard was exceeded. Aquatic criteria were routinely exceeded for zinc and cadmium.

7. Surface water data further indicate that some dissolved metals (cations) such as zinc and cadmium stay principally in dissolved form in the surface waters along the Gulch. Other cations such as iron, aluminum, and to a lesser degree, manganese, are oxidized and precipitated as oxy-hydroxides. These precipitates have a high sorptive capacity and can remove other dissolved metals from solution. These precipitate settle to the bottom of the drainage at low flows.

During snowmelt, higher stream velocities carry more sediments from various waste areas. These mix with the previously settled sediments and precipitates that are then re-entrained in the water. The buffering, precipitation, and re-entrainment further complicate water chemistry interpretation. For this reason, zinc, cadmium, manganese, and sulfate are used to further study the system since they are the most mobile.

8. Review of the data for groundwater indicates that groundwater chemistry, particularly dissolved metals concentrations, is more strongly affected by depth than by location along California Gulch. The water level data demonstrated that recharge and drainage is most active in the shallow alluvial material and decreases with depth. The groundwater chemistry reflects the active exchange between surface water and groundwater. Specific conductance, a measure of the total ionic material dissolved in the water, including metals, is highest in the upper 25 to 50 feet of the California Gulch alluvial groundwater.

9. Groundwater quality data for the five sampling periods is extensive. Primary drinking water standards (MCL's), secondary drinking water standards (secondary MCL's), and proposed "maximum contaminant level goals" were listed for comparative purposes. Preliminary observations from these comparisons are summarized as follows:

   - Sulfate is closely associated with the oxidation of sulfides. Sulfate, like specific conductivity, decreases with depth. The mean sulfate concentration in the upper 25 feet of the California Gulch alluvium ranges from less than 100 mg/l to more than 1,000 mg/l. The secondary MCL is 250 mg/l.

Many of the private and new wells in the California Gulch alluvium exceed this concentration, particularly those completed in the upper 50 feet of the alluvium.

- Manganese, zinc, and cadmium are trace metals that are quite mobile in the groundwater system; iron and lead are not very mobile in oxidized, sulfate-rich groundwater. Manganese, zinc, and cadmium were used to determine the extent of vertical contamination in the California Gulch alluvial groundwater system resulting from recharge from the surface water.

- Manganese has a secondary MCL of 50 µg/l. Manganese concentrations in groundwater in the upper 20 feet of the alluvium ranged from below the standard to as much as 15,000 µg/l. In the 20- to 50-foot depth range, manganese concentrations decrease to less than 4,000 µg/l; below 50-foot depths, manganese generally meets the standard.

- Zinc has a secondary MCL of 5,000 µg/l. Zinc concentrations in the groundwater are highest in the upper 25 feet of the alluvium ranging from below the standard to as much as 35,000 µg/l. Zinc concentrations in the 25- to 50-foot depth range from below standard to as much as 1,000 µg/l. Below an approximate 50-foot depth, the typical zinc concentration is less than 500 µg/l.

- Cadmium has a primary MCL of 10 µg/l. Like manganese and zinc, the highest concentration of cadmium is found in the upper 25 feet of the California Gulch alluvium. Concentrations range from below the drinking water standard to as much as 100 µg/l. Mean cadmium concentrations decrease to less than 10 µg/l in the 25- to 50-foot depth ranges and to less than 5 µg/l in deeper parts of the groundwater system.

- The upper 25 to 50 feet of the California Gulch groundwater system contain metals in concentrations in excess of both primary and secondary drinking water standards. These excessive concentrations result in part from infiltration of California Gulch surface water.

- A number of privately-owned wells exceeded primary MCL's. Four wells exceeded the cadmium limit of 10 µg/l. Typically, the exceedance ranged from 10 µg/l to 116 µg/l, but one well ranged from 28 µg/l to 1,124 µg/l for all sampling events. One well exceeded the lead limit of 50 µg/l. It was measured of 296 µg/l in November 1984. This value is suspect since lead was not detected on four subsequent sampling events.

10. Based upon review of surface water flows and chemistry, groundwater levels and chemistry, and data from the piezometer program, it was suspected that the shallow groundwater system was intimately connected with the Gulch mainstem surface waters. Chemical profiles were developed along the Gulch for the surface water and groundwater systems. Seasonal flow and water level differences were also considered. This analysis supported the postulation that surface water/shallow alluvium groundwater is acting as a single conduit along which contaminated waters move to the Arkansas River. Pump tests also indicated no significant groundwater

contribution from the Gulch alluvium directly to the Arkansas River.

11. Based upon the single conduit theory, it was possible to conduct a mass loading analysis to better define areal and point source contribution of contaminants to the Gulch mainstem. Mass loadings were calculated along the Gulch conduit for each sampling event using appropriate surface water chemistry and flow data. The individual mass loading analyses were then adjusted for the contribution during snowmelt to determine average annual contaminant contributions from the suspected sources, considering the mobile ions such as zinc, cadmium and sulfate. Results of this analysis are summarized as follows:

Source	Percentages of Zinc	Percentages of Cadmium	Percentages of Sulfate
Yak Tunnel	80.4	84.8	74.7
Upper Gulch	4.8	7.0	6.1
Stray Horse Gulch (Starr Ditch)	2.0	3.5	1.8
Oregon Gulch	1.6	0.5	5.6
Slag Area	1.9	0.2	3.9
Sewage Treatment Plant	0.4	0.7	3.7
Miscellaneous Tributaries	8.9	3.3	4.2

NOTE: These percentages are not necessarily representative for other specific contaminants.

PHASE II RI SAMPLING PROGRAM

Completion of the Phase I RI has provided an indication of water quality problems at various locations in the study area; probable sources and relative contribution of contaminants to the water system; and an initial assessment of the hydrology, geology, geohydrology, and geochemistry of the system.

In order to complete the site FS, the following data are needed to permit further characterization of contaminant sources:

- Tailings stability and surface chemistry
- Waste dump stability, surface and bulk chemistry
- Slag stability and bulk chemistry
- Air quality data
- Sediment chemistry
- Seismic activity in the study area
- Soil data in the Stray Horse Gulch drainage
- Information to approximate baseline chemistry of soils, surface water, and groundwater
- Additional surface water flow, groundwater levels, and water chemistry during snowmelt runoff

Data gathered will be synthesized and published as the Phase II RI report.

ABBREVIATIONS

BLM	Bureau of Land Management
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfs	Cubic feet per second
CLP	Contract Laboratory Program
COC	Chain of Custody
COE	Corps of Engineers
EA	Endangerment Assessment
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
gdf	Gallons per day per foot
gpm	Gallons per minute
IA	Interpretive Addenda
ICP	Inductive Coupled Plasma
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
mg/l	Milligrams per liter
mgd	Million gallons per day
mm	Millimeters
mph	Miles per hour
MSL	Mean Sea Level
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
OUFS	Operable Unit Feasibility Study
ppm	Parts per million
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance and Quality Control
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act of 1986
SCS	Soil Conservation Service
STP	Sewage Treatment Plant
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
µg/l	Micrograms per liter
µmhos	Micromhos

CONTENTS

TABLES

TABLES (continued)

FIGURES

PLATES

APPENDICES
VOLUME 1 OF 2
CONTENTS

APPENDICES
VOLUME 2 OF 2
CONTENTS

Introduction

Section 1
INTRODUCTION

This document is the Phase I Remedial Investigation (RI) Report for the California Gulch site. The purpose of the Phase I RI report is to characterize the site, and summarize the data collected during the Phase I investigations. The report also identifies additional work which will be completed during the Phase II RI activities.

The RI is one element of the Superfund process. This introductory section describes background information on the California Gulch site, the Superfund process, RI goals and objectives, and an overview of the contents of this report.

SITE BACKGROUND

The California Gulch site is located in and near Leadville, Colorado, which is approximately 100 miles southwest of Denver (Figure 1-1). The study area encompasses an 11.5 square-mile watershed that drains along California Gulch and into the Arkansas River just west of Leadville.

The origin of Leadville dates back to the 1850's with the mining development of a large, rich, sulfide mineralized zone containing principally gold, silver, lead, zinc, and copper. The mining, processing, and smelting of these metals have continued for more than 125 years. The level of these activities has varied in degree with economic demand and technological improvements.

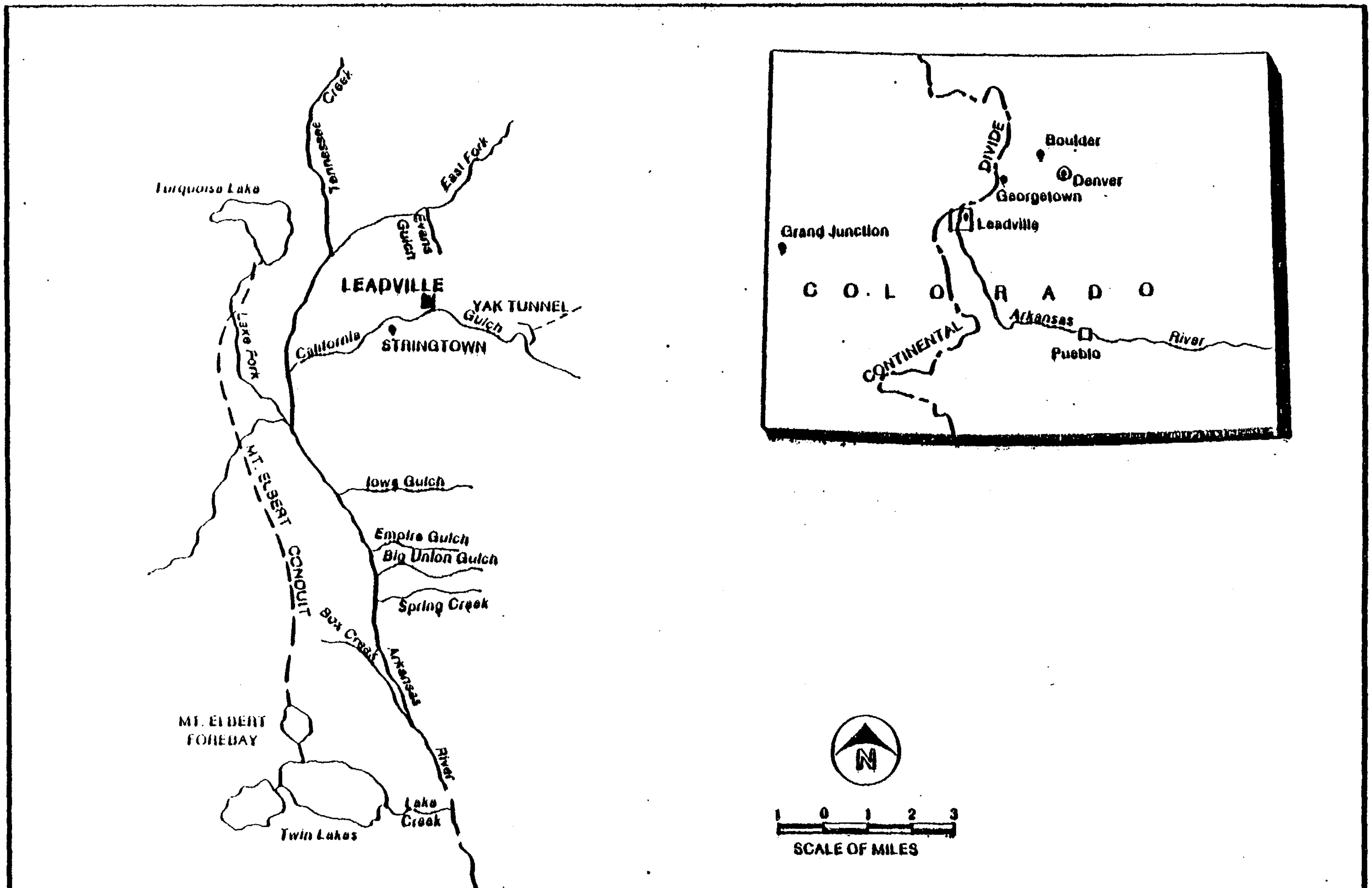


FIGURE 1-1
LOCATION MAP
CALIFORNIA GULCH
LEADVILLE, COLORADO

Early activities consisted of placer mining for gold. Later, underground mines were developed southeast of Leadville, where the ores were extracted and then processed into metallic concentrates. These concentrates were either shipped elsewhere or further processed at the numerous smelters that were in the Leadville area (Griswold, 1951; Emmons, et al., 1927). Extensive mining and processing activities continued in varying degrees until the end of the Korean War in 1953. Since smelting stopped, mining activity has occurred at a much slower pace (LaBounty, 1975). Presently, there are only a few moderate-size active mining and milling facilities in the Leadville area.

Mining wastes, including rock, tailings, and slag piles, were deposited in many areas of the study area. Figure 1-2 indicates how these various wastes relate to mining and processing activities.

Historically, miners created the underground adits and drifts (tunnels) to reach the orebody by hauling much of the blasted rock to the surface as waste. The waste rock was deposited in piles, typically near the mine shaft or adit portal. Extracted material was processed in mills, which concentrated the lead, zinc, copper, gold, and silver ores. The wet mill waste materials, called tailings, were placed in impoundments, which were typically located in valleys that provided adequate storage capacity. The concentrated ores were smelted, which created a dark-colored, fused waste residue called slag. Slags were deposited near the smelter facilities. Plate 1 shows typical mine wastes and slag piles that are located in the study area.

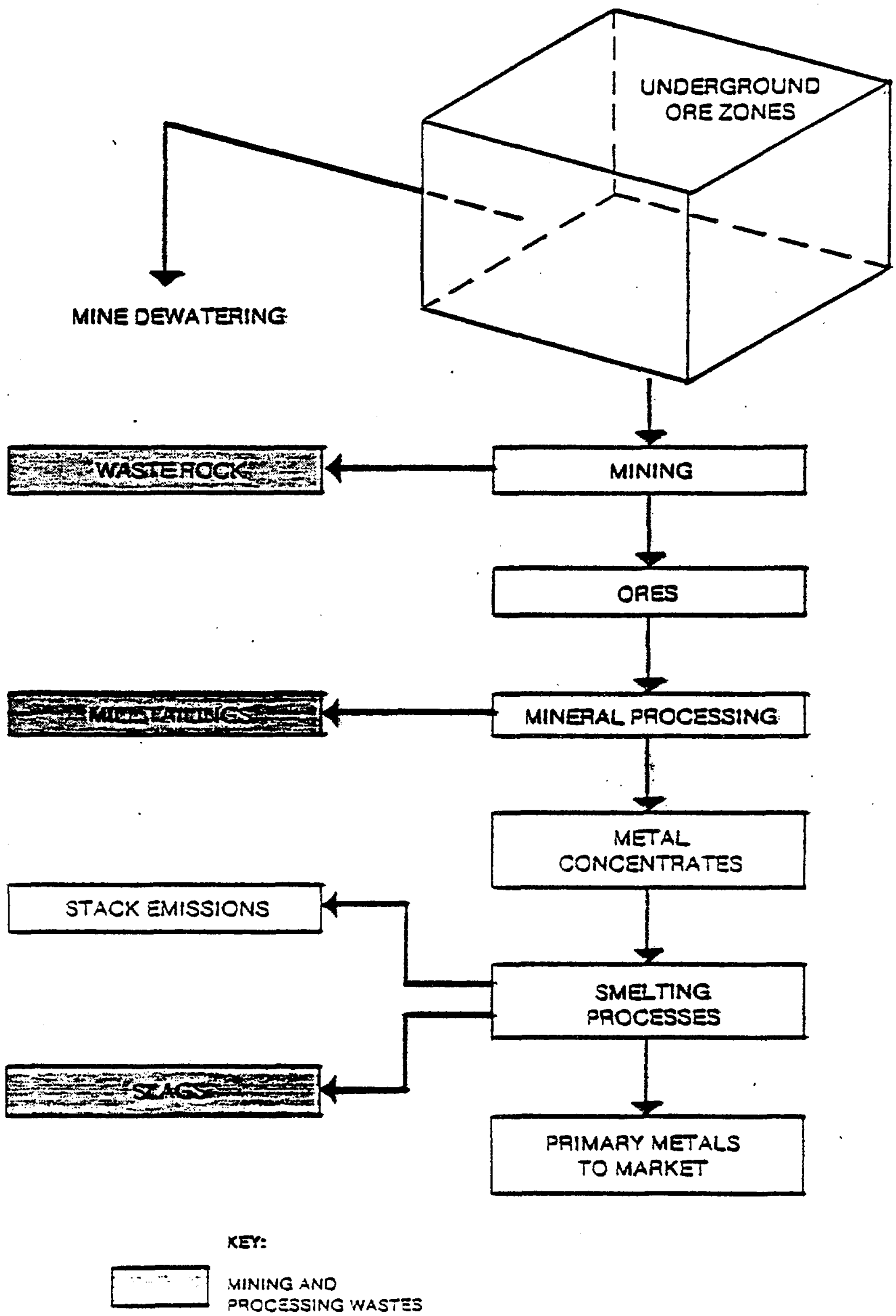
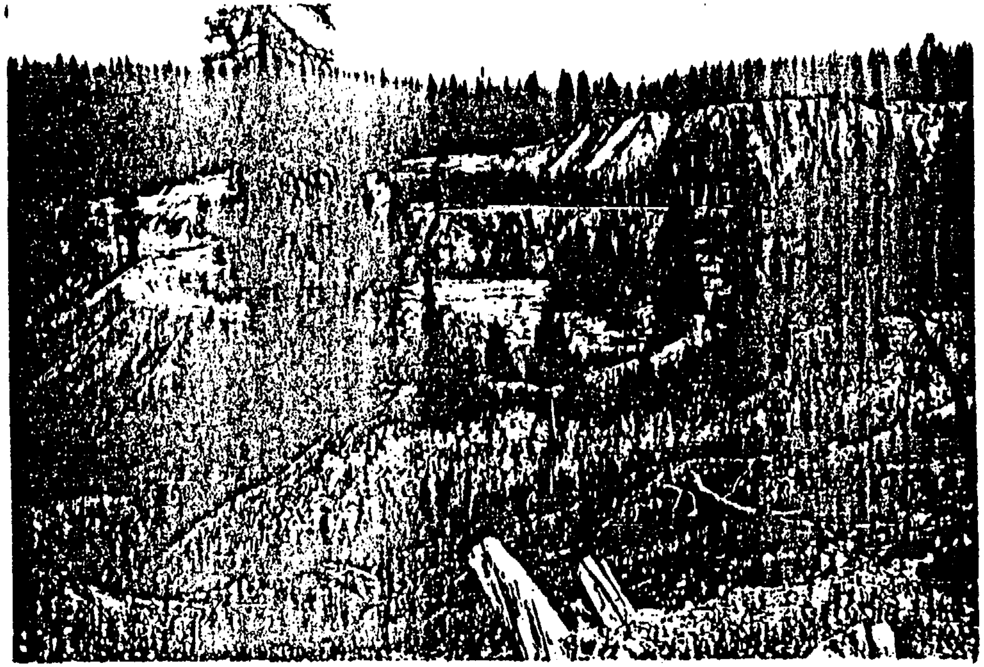
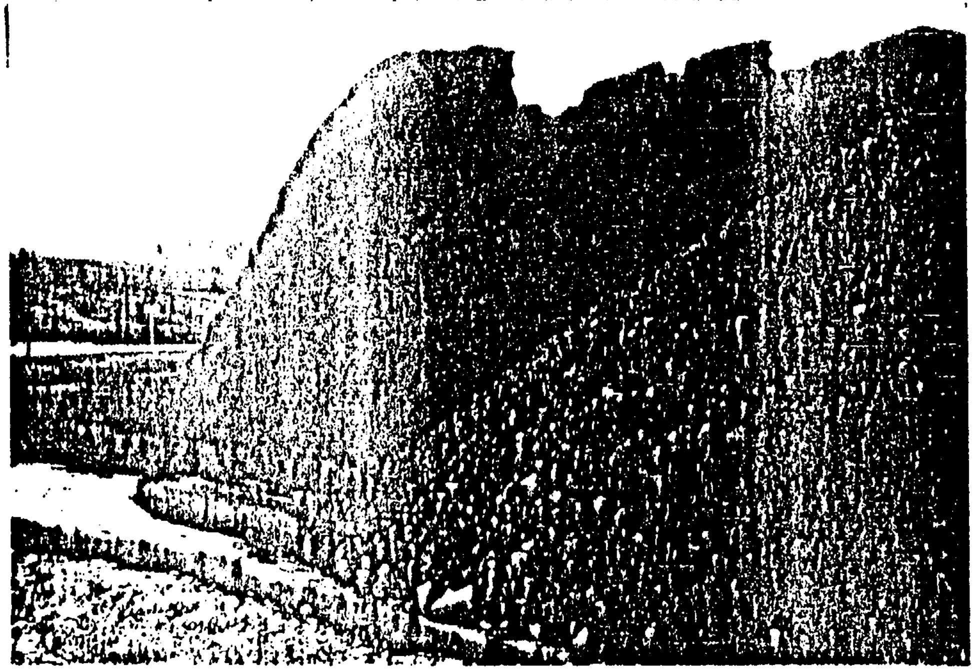


FIGURE 1-2
MINING/PROCESS SCHEMATIC
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

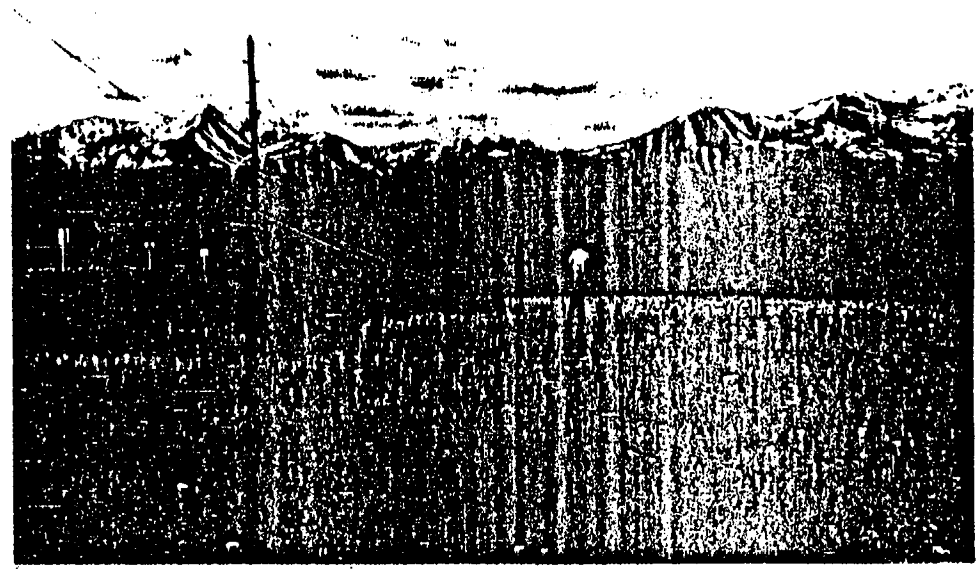


MINE WASTE—UPPER CALIFORNIA GULCH

MINE WASTE—STRAY HORSE GULCH



SLAG PILE



SLAG PILE

PLATE 1

TYPICAL MINE WASTES AND SLAGS

Within the study area there are several types of mining and processing wastes. The major types and locations are as follows:

- Four major inactive tailings impoundments. Three major tailings impoundments are located in California Gulch between the Resurrection Mill Yard and Harrison Street. The fourth impoundment is in Oregon Gulch.

- Three major slag piles. One pile is located on Harrison Street and two piles are located near Stringtown.

- Over 2,000 waste dumps, varying in size from a few tons to several hundred thousand tons. These dumps are located in upper California Gulch, Stringtown, Carbonate Hill, and Stray Horse Gulch. Some of the piles in Stray Horse Gulch are near residential areas. Many of these dumps contain mixed types of waste including tailings, waste rock, and low grade ore, which was not economical to process at the time.

Tunnels were developed in the area to drain ore bodies and facilitate mining. The Yak Tunnel, developed from 1895 through 1923, extends approximately 4 miles into Iron Hill and Breece Hill, which are southeast of Leadville. This tunnel drains water from numerous sulfide and carbonate underground mines. The tunnel empties into California Gulch, which in turn conveys these mine waters westward 4.5 miles to the Arkansas River.

The mine wastes and water from the Yak Tunnel are potential sources of metal contamination to California Gulch, and subsequently the Arkansas River. Metals of concern are: cadmium, copper, arsenic, iron, lead, manganese, and zinc.

SUPERFUND PROCESS

Under Section 104(a) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 [42 U.S.C. § 9604(a) (1982)], also known as CERCLA or Superfund, the United States Environmental Protection Agency (EPA) is authorized to respond to the actual or threatened releases into the environment of hazardous substances or releases or substantial threats of release of pollutants or contaminants that may present an imminent and substantial danger to the public health or welfare.

EPA has developed a process to fulfill the Superfund statutory requirements. This process consists of six steps:

- A preliminary evaluation of a site, consisting of an assessment of existing data and a site inspection. These activities were conducted for the California Gulch site in 1982.

- Inclusion on the National Priorities List (NPL) of sites, which are the highest priority for EPA response action. The California Gulch site was placed on the NPL in September 1983.

- A remedial investigation (RI), which is a field-oriented effort to collect sufficient site characterization data to permit the development and evaluation of remedial action alternatives. This document is the report describing the California Gulch site Phase I remedial investigation. Due to the size and complexity of the site, additional site information will be collected at a later date to supplement this report.

A remedial investigation also includes an endangerment assessment (EA), which assesses the threat to the public health, welfare, and environment posed by the site contamination. An EA, based on the California Gulch RI findings, will be separately published.

- A feasibility study (FS) developing and evaluating remedial action alternatives for a site. An FS involves (1) identification of alternatives; (2) initial screening of alternatives, based on health and environmental protection goals, cost, engineering feasibility, and effectiveness; and (3) performance of a detailed environmental, engineering, and cost analysis. Feasibility study work for the California Gulch site is underway.

- Selection of a cost-effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment. The remedial alternative for the California Gulch site will be selected in accordance with the requirements of Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

- Design of the selected remedial actions, actual site remediation, and long-term site observation to determine the effectiveness of selected actions. For the California Gulch site, this work will begin after selection of the remedial action alternative.

A more detailed description of the Superfund process followed by EPA is contained in the National Oil and Hazardous Substances Pollution Contingency Plan, known as the National Contingency Plan (NCP) (U.S. EPA, 1985).

GOALS AND OBJECTIVES OF THE REMEDIAL INVESTIGATION (RI)

The goals and objectives of the Phase I of the California Gulch RI are to:

- Identify and monitor contaminants that are in the surface water within the California Gulch drainage area.

- Identify the nature and extent of groundwater contamination along California Gulch.

- Determine the nature of contamination in the Arkansas River at the confluence with California Gulch.

- Determine identifiable sources of metal contamination within the California Gulch drainage basin and their relative contributions to water quality degradation in the Arkansas River at the confluence with California Gulch.

REPORT SCOPE/ORGANIZATION

This report presents the scope of work, events, data gathering, and data interpretations based on work completed from March 1984 through June 1986. Supplemental Phase II RI activities are discussed later in this report. The sections of the Phase I RI report following this Section I are summarized as follows:

SECTION 2--SITE DESCRIPTION

This section includes information on site location, site history, local demography, local water supplies, hydrology and geology, and site geochemistry. An interpretive addenda (IA) is included as a supplement to this RI to provide further details on site description and data interpretation.

SECTION 3--REMEDIAL INVESTIGATION ACTIVITIES

This section summarizes activities at the site, explains specific tasks assigned to various contractors, and defines the chronology of the sampling activities and key events.

SECTION 4--NATURE AND EXTENT OF CONTAMINATION

This section summarizes the data interpretation and presents conclusions on the nature and extent of site contamination. The IA contains additional interpretive details.

All data collected during the RI are presented in two volumes of appendices. Appropriate technical memoranda, chemistry data, health and safety plans, and other pertinent information regarding the comprehensive sampling program are presented in the Appendices.

SECTION 5--PHASE II REMEDIAL INVESTIGATION PROGRAM

This section defines the data gaps that still exist at the completion of the Phase I RI activities. The planned approach to obtain necessary information during the supplemental Phase II RI program is presented.

Site Description

Section 2
SITE DESCRIPTION

The California Gulch site encompasses an 11.5-square-mile study area, which includes Leadville and its outlying area. The study area is shown in Figure 2-1. The main features of the study area are described below.

The major surface water drainage is California Gulch (hereafter called "the Gulch"), which receives water from a number of ephemeral drainages: upper California Gulch, Stray Horse Gulch, Oregon Gulch, Starr Ditch, Georgia Gulch, Pawnee Gulch, Airport Gulch, and Malta Gulch. The Gulch empties into the Arkansas River at the western boundaries of the study area. Plates 2 and 3 show these various surface water drainages.

The four major tailings impoundments within the study area are located in Section 25 of Township 9S, Range 80W. There are three major impoundments in California Gulch and one in Oregon Gulch (Figure 2-1). Plate 4 shows two of these tailings impoundments.

From recent aerial photographs, over 2000 waste dumps have been identified within the study area. These dumps range in size from a few tons to over 100,000 tons; they are primarily located in upper California Gulch, Carbonate Hill, Stringtown, and Stray Horse Gulch. Many of these dumps are near shafts or portals, which are indicated on Figure 2-1. Plates 5 and 6 show typical waste dumps in upper California Gulch and Stray Horse Gulch.

There are three large slag piles within the study area. One pile is located on Harrison Street (within Leadville city limits) and two are located near Stringtown. Plate 7 shows the Harrison Street pile and one of the Stringtown piles.

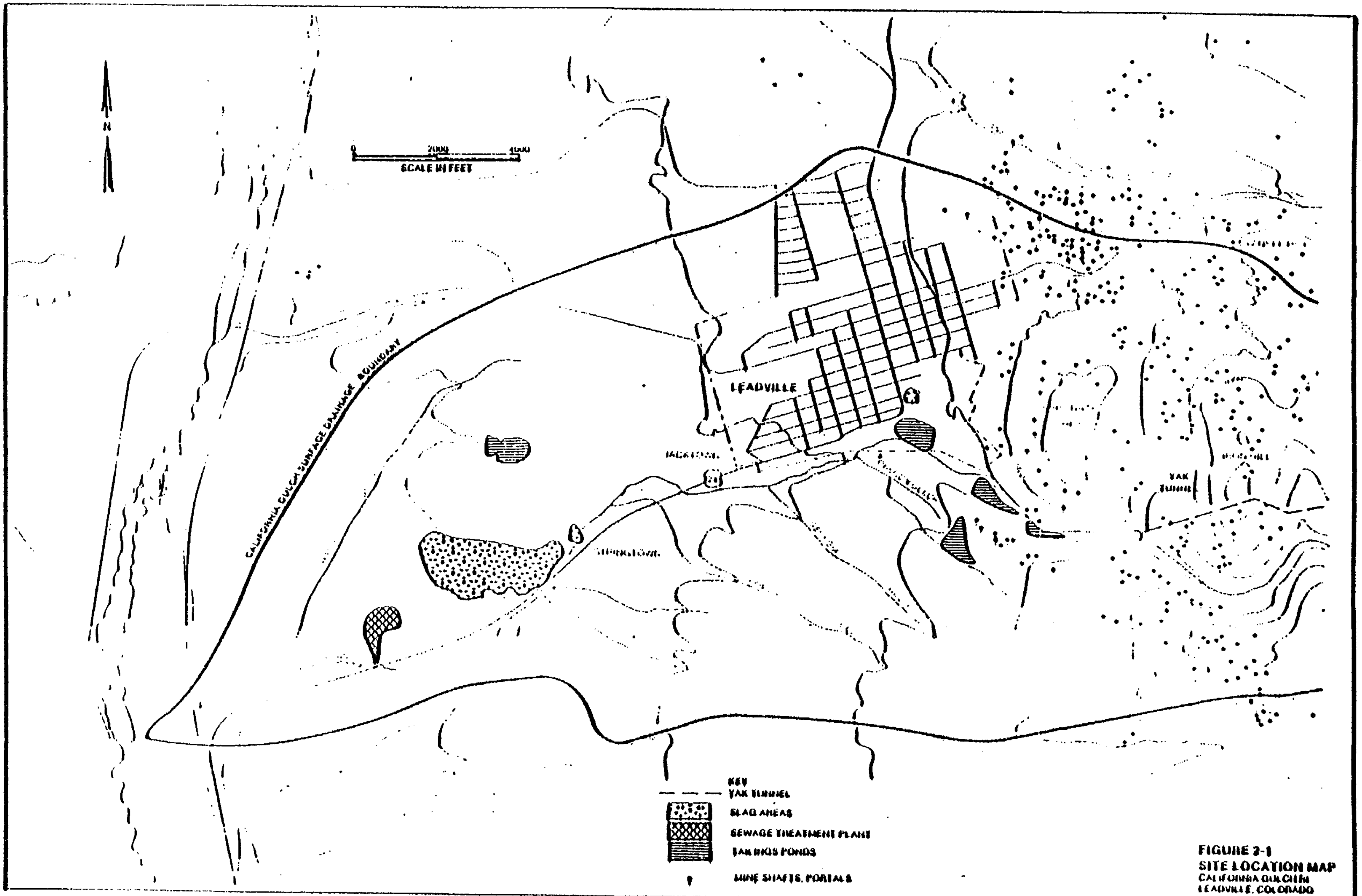
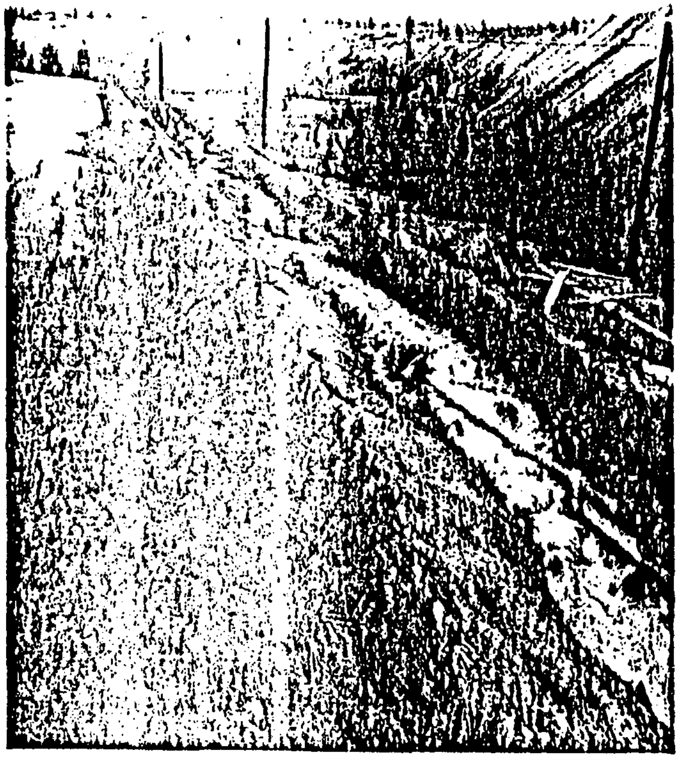
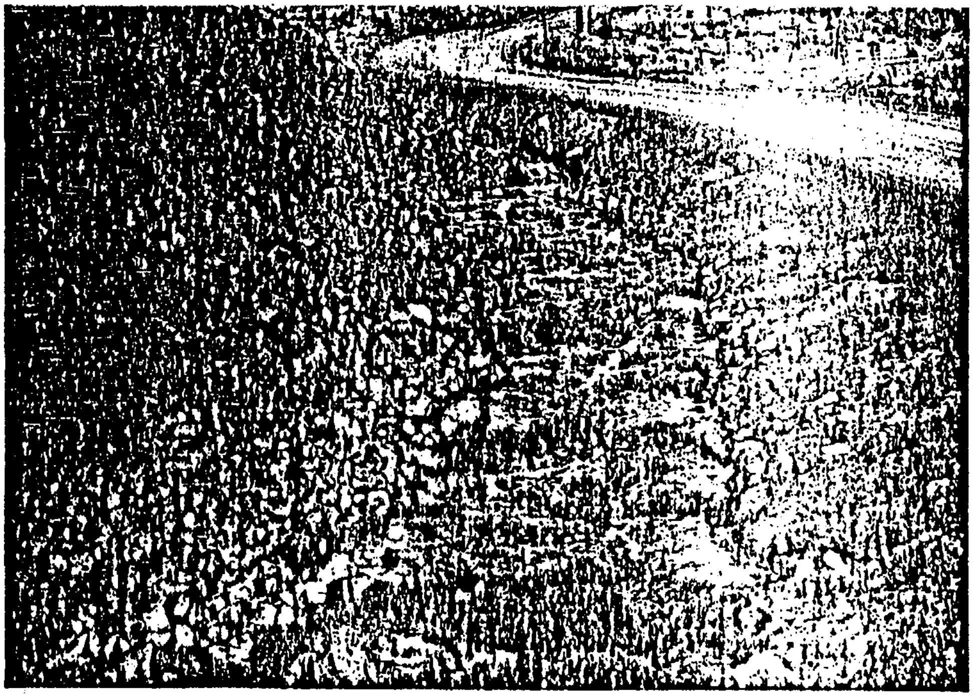


FIGURE 2-1
SITE LOCATION MAP
CALIFORNIA GULCH
LEADVILLE, COLORADO

CALIFORNIA GULCH



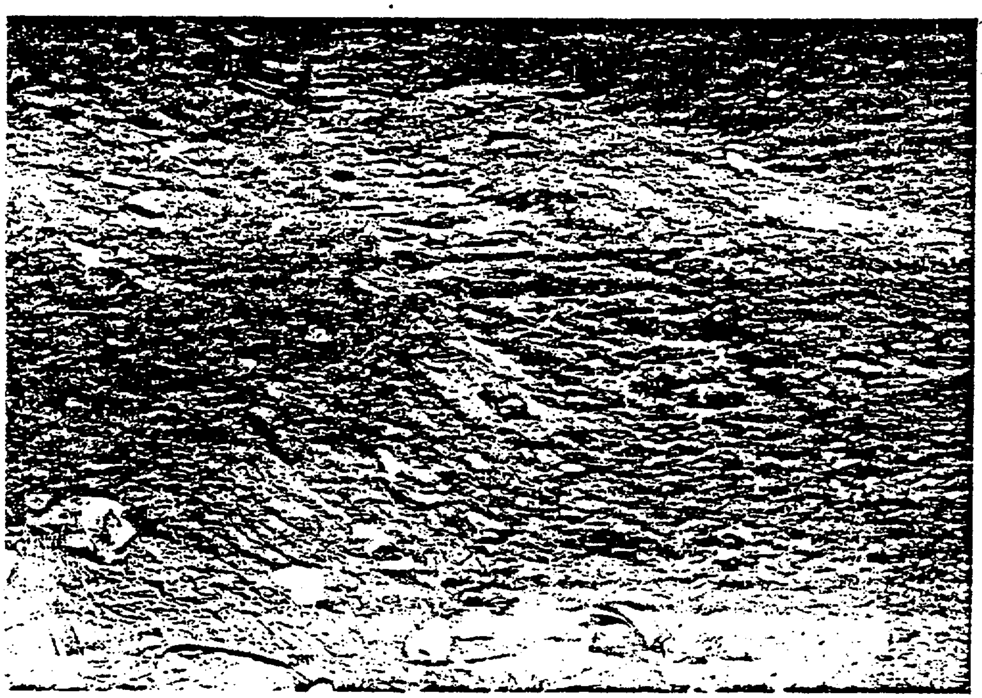
UPPER CALIFORNIA GULCH



STARR DITCH

PLATE 2
SURFACE WATER DRAINAGES

GEORGIA GULCH



OREGON GULCH

PLATE 3
SURFACE WATER DRAINAGES

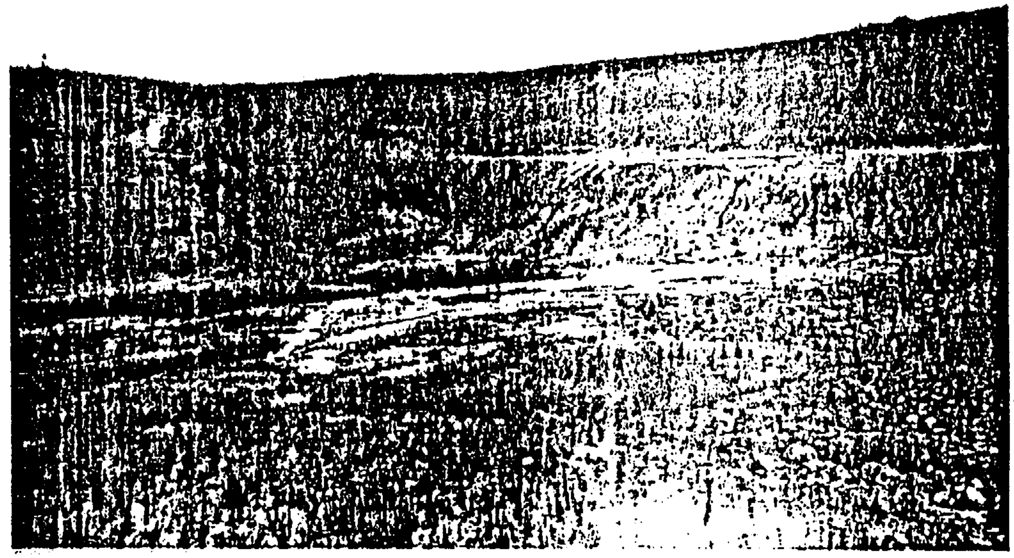


PLATE 4
TAILINGS IMPOUNDMENTS

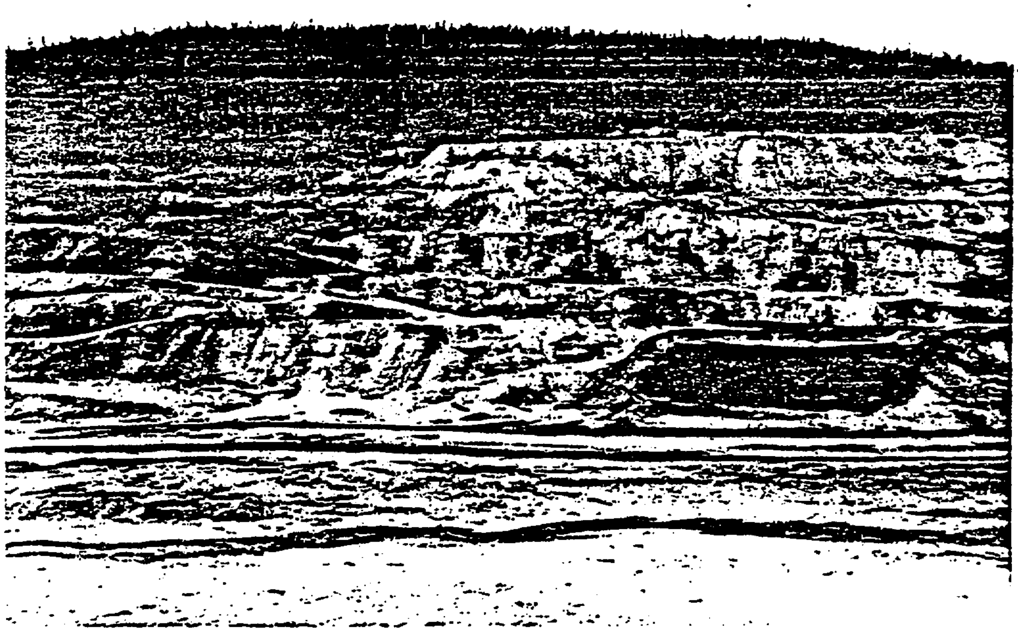
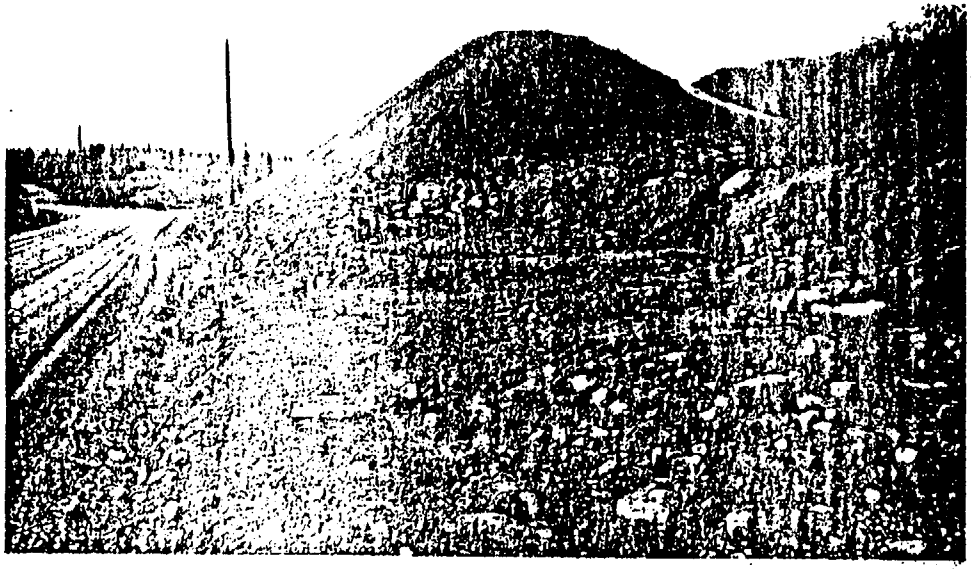
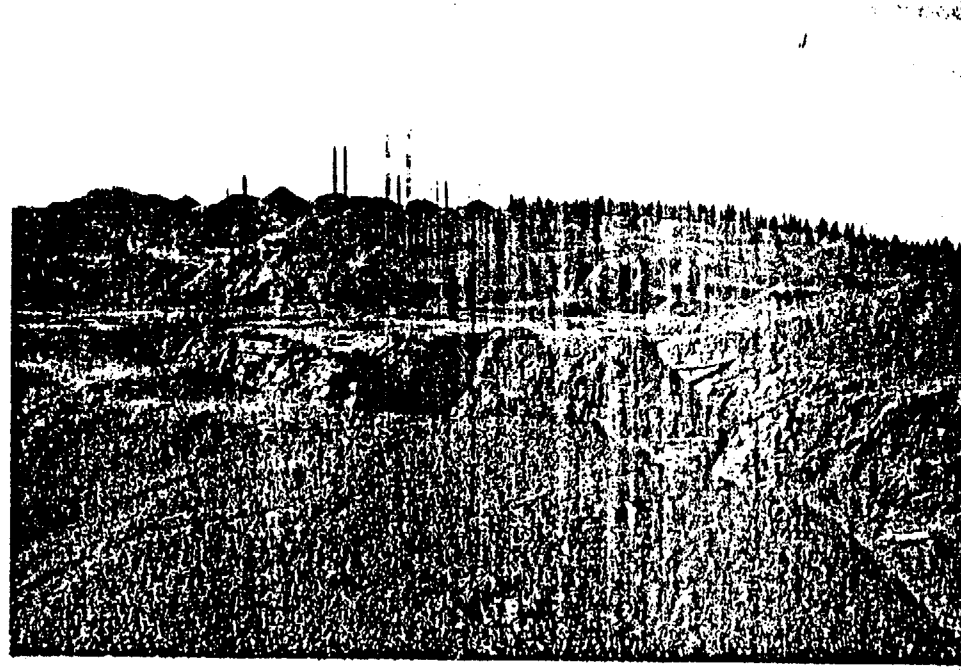


PLATE 5
WASTE DUMPS
UPPER CALIFORNIA GULCH





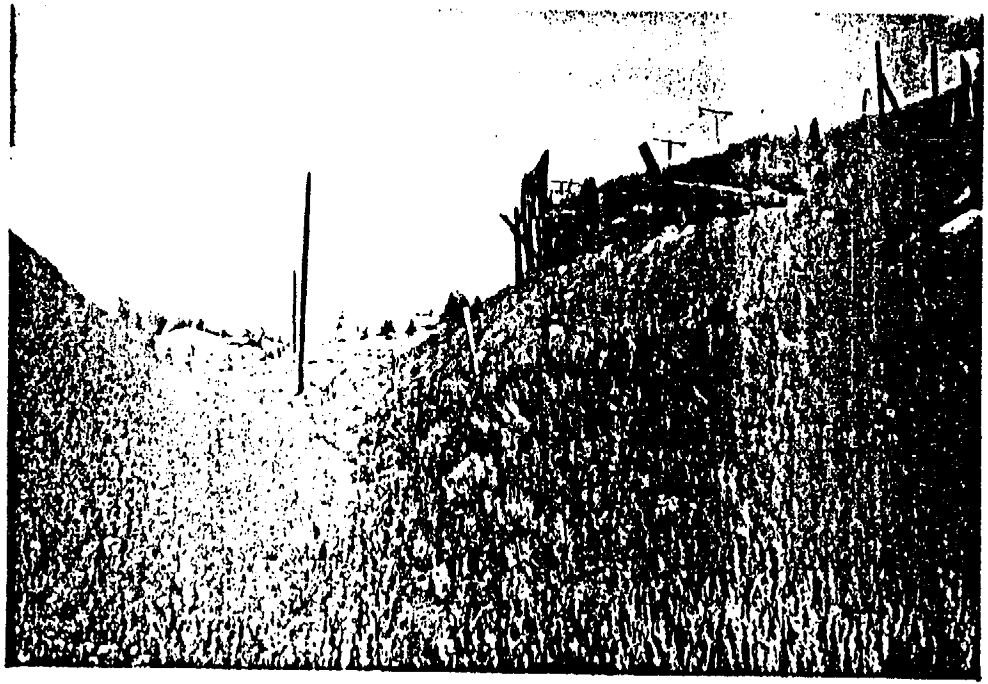
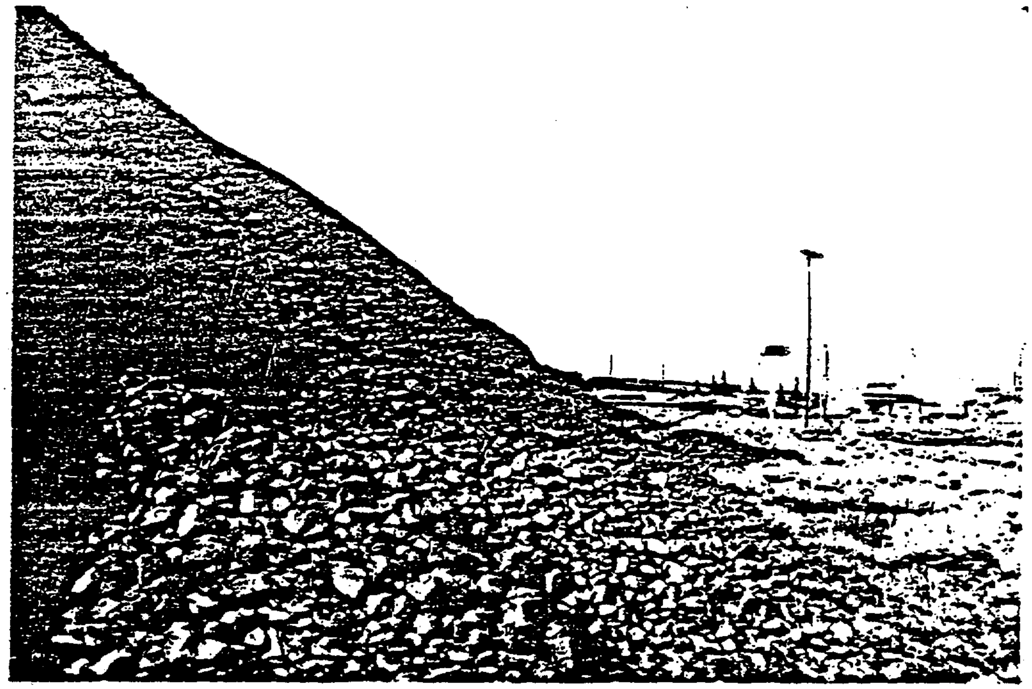
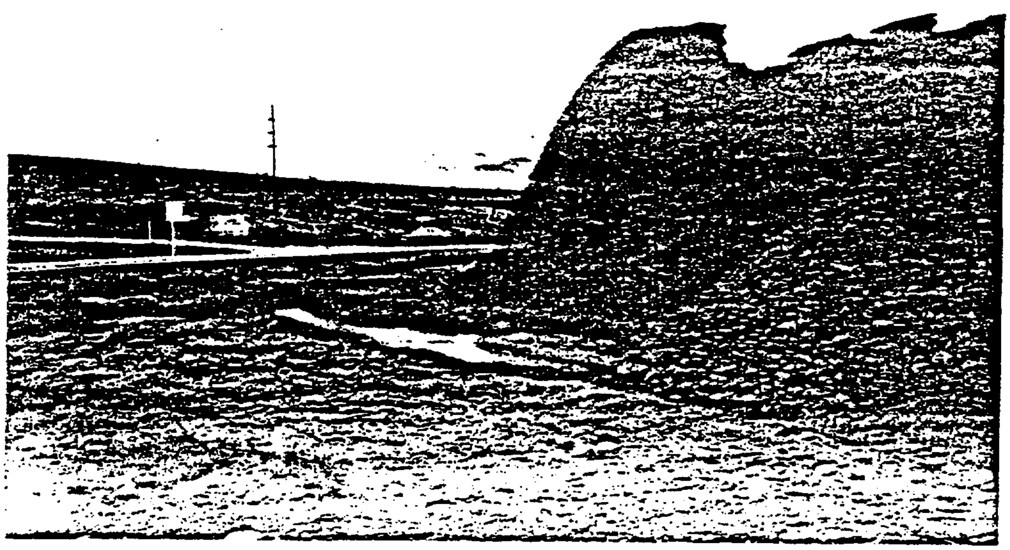


PLATE 6
WASTE DUMPS
STRAY HORSE GULCH



HARRISON ST. SLAG PILE



STRINGTOWN AREA SLAG PILE

PLATE 7
SLAG PILES

The Yak Tunnel, which discharges metal-laden water to California Gulch, is located just east of the Resurrection Mill Yard. Plate 8 shows the Yak Tunnel portal.

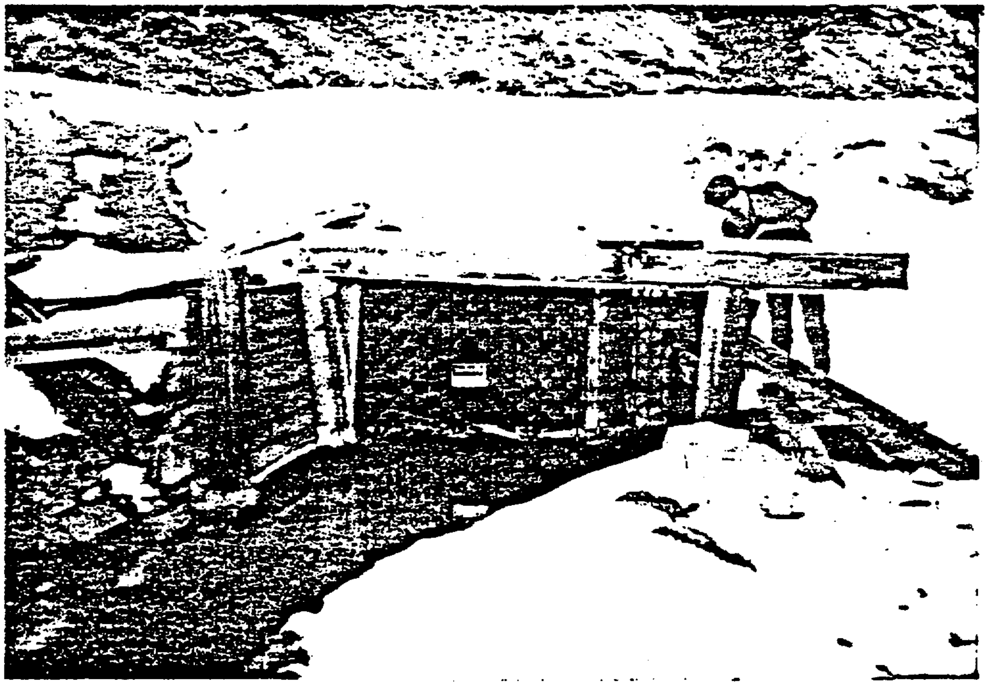
The city of Leadville is part of a Historic Mining District. Since the mid-1800's, mining activities have been prevalent within the boundaries of the site. The area has been extensively disturbed by past mining activities (Emmons, et al., 1927; Emmons, 1886; Griswold, 1951; Tweto, 1963).

SITE CHARACTERISTICS

The following subsections present a background description of the physical characteristics of the site. This includes information regarding geology, soils, surface water, groundwater, vegetation, wildlife, climate, etc. These characteristics are influenced to varying degrees by the effects of the sulfide minerals and mineral development activities present within the study area. Lake County, which includes the Leadville Mining District, is located within the Colorado Mineral Belt. This belt (see Figure 2-2) is a geochemically enriched zone that is present in the central Colorado mountains (Tweto, 1963). Elevations within the site range from 9,520 feet above Mean Sea Level (MSL) to approximately 14,000 feet MSL. The low point is at the confluence of California Gulch and the Arkansas River.

GEOLOGY

The Upper Arkansas River Valley is located between the Mosquito Range to the east and the Sawatch Range to the west. California Gulch drains from the western slope of the Mosquito Range and cuts through glacial and glaciofluvial sediments on its way to the Arkansas River.



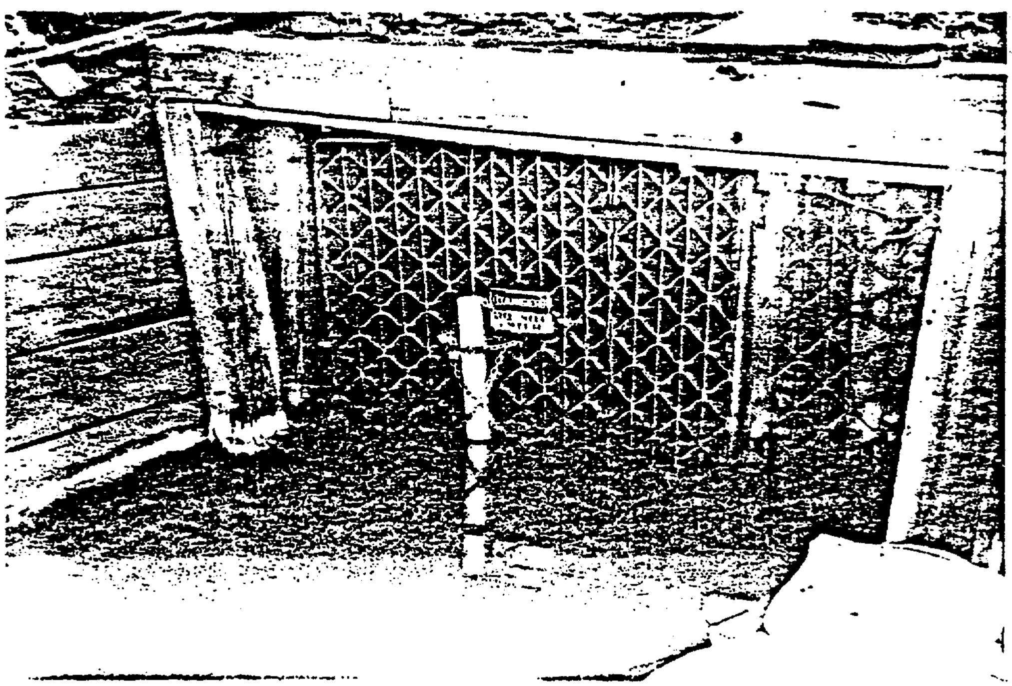
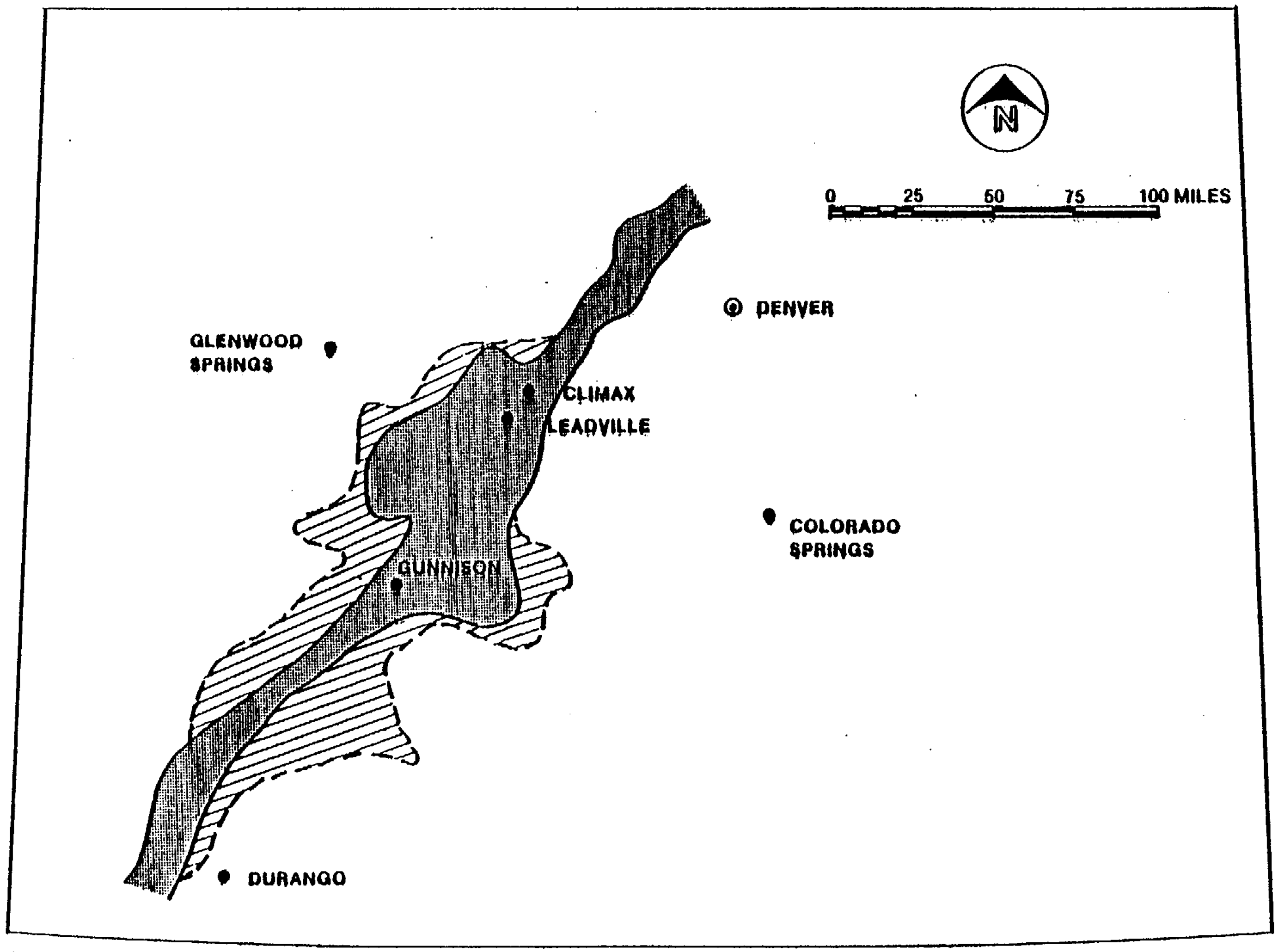


PLATE 8
YAK TUNNEL PORTAL



Colorado mineral belt as defined by principal mining districts of Laramide age (modified after Tweto and Sims, 1963)

Area added to Colorado mineral belt when defined to include all intrusive porphyry bodies and mineralized areas of Laramide age, and mining districts of Tertiary age in the San Juan Mountains (modified after Tweto and Sims, 1963)

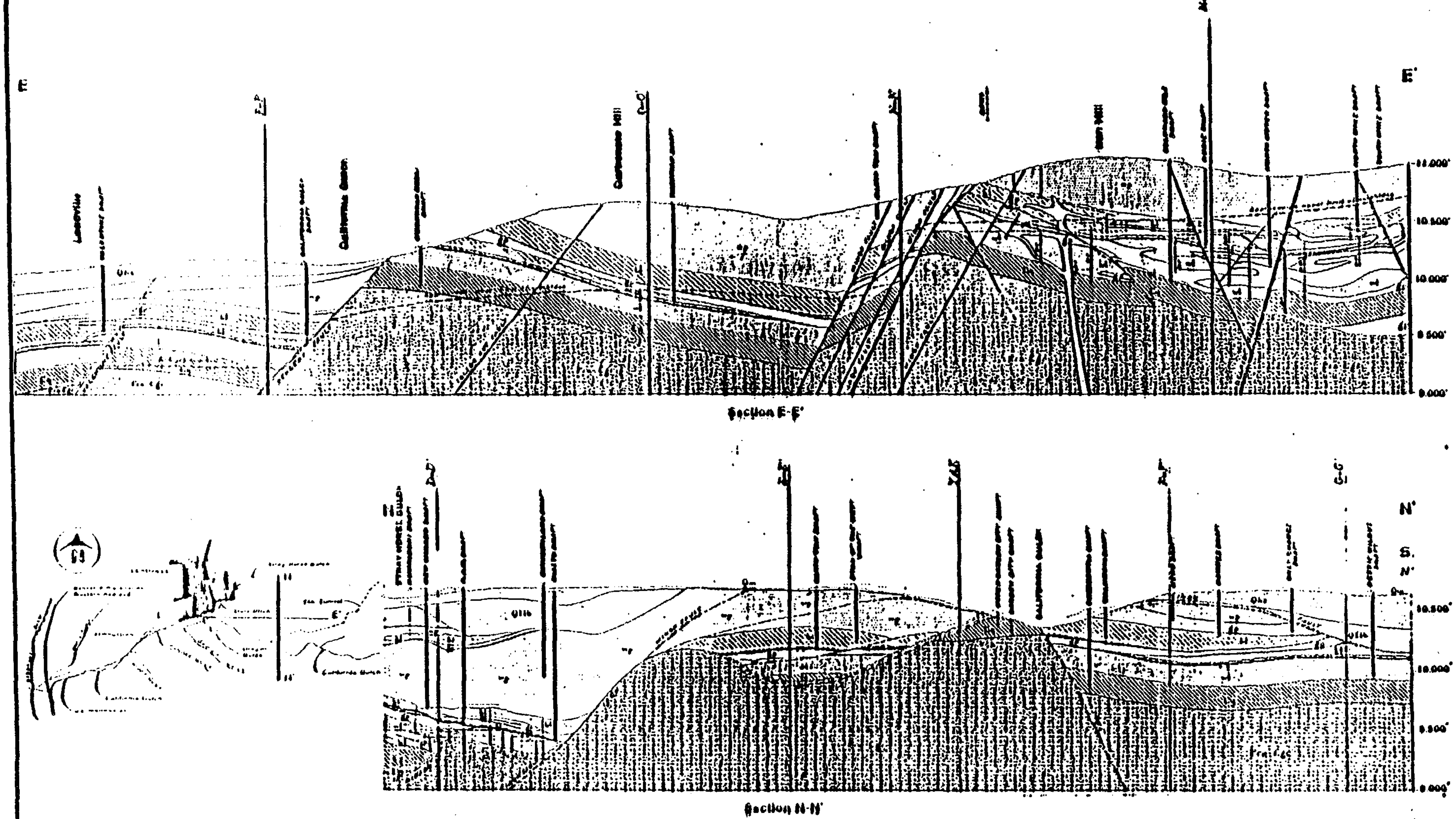
FIGURE 2-2
COLORADO MINERAL BELT
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

The geology of the Leadville Mining District is complex (Emmons, 1886, and Emmons, et al., 1927) (Figure 2-3). Bedrock consists of Precambrian crystalline rocks overlain by quartzites, shales, limestones, dolomites, and sandstones of paleozoic age. A brief description of the bedrock units and a stratigraphic column is presented in the Geology section of the IA.

Several types of surficial deposits occur in the project area. These include talus debris, landslide deposits, and rock glaciers. Glacial, glaciofluvial, and alluvial deposits are found in areas of lower elevations (Emmons, et al., 1927; Emmons, 1886). These deposits are the primary surficial deposits that have been disturbed by mining activities. Two, possibly three, glacial stages have been recognized within the project area. Alpine glaciers carved U-shaped valleys, eroded the surface, and subsequently deposited large quantities of earth materials (Emmons, et al., 1927).

Numerous faults exist within the general area of the site. Several of these faults are shown in Section E-E' of Figure 2-3. Faulting along the western side of the Mosquito Range consists of both high-angle normal and reverse faults. Most of the faults trend north-south, and have dips that approach vertical. Fault zones range in width from several feet to hundreds of feet. Surficial evidence of faulting is obscured in many places by glacial deposits. Many of the faults have been extensively mapped from underground workings, and their structures are quite well understood. Minor drag folding and breccia or gouge zones are commonly associated with the faults. Several episodes (premineralization, postmineralization) of faulting have been documented (Emmons, et al., 1927).

Ore deposits of the area are discussed in detail in U.S. Geological Survey (USGS) Professional Paper 148 (Emmons,



(See Figure 2-5 for Cross Section Locations)

0 1/8 1/4 1/2

Scale in Mile

Ref: USGS Professional Paper 148, Plate 17, Plate 15 1927

EXPLANATION OF LETTER SYMBOLS

Qm, Glacial moraines
Qht, High terrace gravel
QTlb, Lakebeds
wp, White porphyry
Cq, Cambrain quartzite
gp, Gray porphyry
bl, Blue limestone
pq, Parting quartzite
wl, White limestone
Pre Cgr, Pre Cambrain granite

FIGURE 2-3
GEOLOGICAL CROSS SECTIONS
CALIFORNIA GULCH, LEADVILLE, COLORADO

et al., 1927). Deposition of sulfide ores occurred from hydrothermal solutions that intruded the quartzite and limestone sediments of the area. These fluids contained high concentrations of metals and sulfur. When the fluids permeated the sediments, metal sulfides were precipitated in veins along fractures. Precipitation also occurred as blanket replacement deposits in the strata that were more susceptible to dissolution, particularly the limestones. The suite of minerals that constituted the ore bodies was a complex assemblage including: native copper, silver, and gold; and sulfides, carbonates, and silicates of these and other metals. The primary minerals were predominately sulfides of iron, zinc, and lead.

Late-Teritiary tectonic activity faulted the mineralized zones into blocks and exposed them to oxygenated groundwaters. Sulfide minerals were oxidized, formed sulfuric acid, and released metals into solution. These solutions were transported to carbonate zones where reactions occurred between the mineralized sulfuric acid solutions and the carbonate rock. These reactions resulted in the precipitation and deposition of carbonate and silicate ore minerals such as manganosiderite, smithsonite, and cerussite. This deposition zone of secondary, or remobilized, metal ores is termed the oxidized zone. These carbonate ores were the dominate ore zones in many of the mines in the area (Emmons, et al., 1927).

Ore minerals, gangue minerals, and their alternation products are presented in the Geochemistry section of the IA. A condensed list of the most prominent minerals is presented in Table 2-1. These minerals include iron, manganese, zinc, lead, copper, and minor amounts of gold and silver. Waste rock materials include quartz, sericite, chlorite, dolomite, limestone, and low-grade ore.

Table 2-1
MOST PROMINENT MINERALS OF THE ORE DEPOSITS OF THE LEADVILLE MINING DISTRICT

Mineral	Chemical Formula
Calcite	$CaCO_3$
Gold	Au
Silver	Ag
Arsenopyrite	FeAsS or $FeS_2 \cdot FeAs_2$
Barite	$BaSO_4$
Dolomite	$CaMg(CO_3)_2$
Galena	PbS
Manganosiderite	$(Fe, Mn, Mg) CO_3$
Pyrite	FeS_2
Quartz	SiO_2
Sericite	$KH_2Al_3(SiO_4)_3$
Sphalerite	ZnS
Specularite	Fe_2O_3
Hematite	Fe_2O_3
Siderite	$FeCO_3$
Melanterite	$FeSO_4 \cdot 7H_2O$
Limonite	$Fe(OH)_3$
Jarosite	$KFe_3(SO_4)_2(OH)_6$
Pyrolusite	MnO_2
Smithsonite	$ZnCO_3$
Cerusite	$PbCO_3$
Pyromorphite	$Pb_5(PO_4)_3Cl$
Chalcanthite	$CuSO_4 \cdot 5H_2O$
Chlorite (Clinochlore)	$H_4Mg_3Si_2O_9 \cdot H_4Mg_2Al_2SiO_9$

Source: (Emmons, et al., 1927)

DE/CALGU6/007.40

The Leadville Mining District has a history of production that places it among the more important mineralized areas of the world (Kleff, 1941). According to official estimates, past production has been in excess of 20 million tons of ore (Kleff, 1941). Gold, silver, lead, zinc, iron, and manganese were produced from the ore zones (Kleff, 1941). Because of the numerous faults within the District, the ore bodies were cut off and displaced. This faulting created the many discontinuous orebodies that subsequently resulted in the development of numerous mining operations (Kleff, 1941).

SOILS

The predominant soil association for California Gulch, as reported by the U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS), is the Troutville-Leadville Association. The most prevalent soils found in the Gulch are classified as Bross, Leadville, Pierian, and Troutville series; mine wastes are also prevalent soil materials. A complete soil description is presented in Soil Survey of the Chaffee-Lake Area, Colorado (Fletcher, 1975).

From aerial photographs and on-site observations, other major surface materials in the study area are mine dumps, mine workings, slag piles from smelter operations, and mill tailings. Based on preliminary estimates from aerial photographs, approximately 5 percent of the overall study area has been covered with mining or processing wastes. Some specific areas are greatly disturbed as shown on the previous plates. These various materials range in size from very large boulders to fine silts.

No background information is available concerning the geochemistry of site soils prior to mining activities. Other literature sources (Emmons, 1886; Emmons, et al., 1927; Griswold, 1951) state that placer mining, hydraulic mining, and early milling practices resulted in significant alteration of surface materials and structure in and along California Gulch. Placer and hydraulic mining created very mixed and reworked alluviums, and probably altered natural streambeds and flood plains. Uncontrolled mine wastes from early milling operations in upper California Gulch added sediments to the lower Gulch. These practices probably altered the geochemical equilibrium of the mineralization, soils, groundwater, and surface water at the site.

GROUNDWATER

The complex geology of the area limits understanding of groundwater movement. Groundwater in the region occurs in both bedrock stratigraphy and alluvial stratigraphy. With the geologic and geohydrologic complexity of the study area, there appears to be no way of quantifying pre-mining groundwater quality.

In the upper portions of California Gulch, particularly above the Pendry Fault, groundwater occurs primarily in the various bedrock formations (Figure 2-4). These formations include various types of granite, limestone, porphyry, and sandstone units with varying degrees of permeability and porosity. Groundwater migrating through the bedrock system in the mining areas discharges to California Gulch surface waters; discharges to the mine workings, collected by the Yak Tunnel and discharges to California Gulch; or moves through the bedrock groundwater system downgradient from upper California Gulch.

Downstream from the Pendry Fault, the change in geology is significant. As shown in Figure 2-5, three identifiable geologic units are noted: bedrock, lake bed sediments, and high terrace gravels. The thickness of the upper and middle stratigraphic units increases from east to west. Turk and

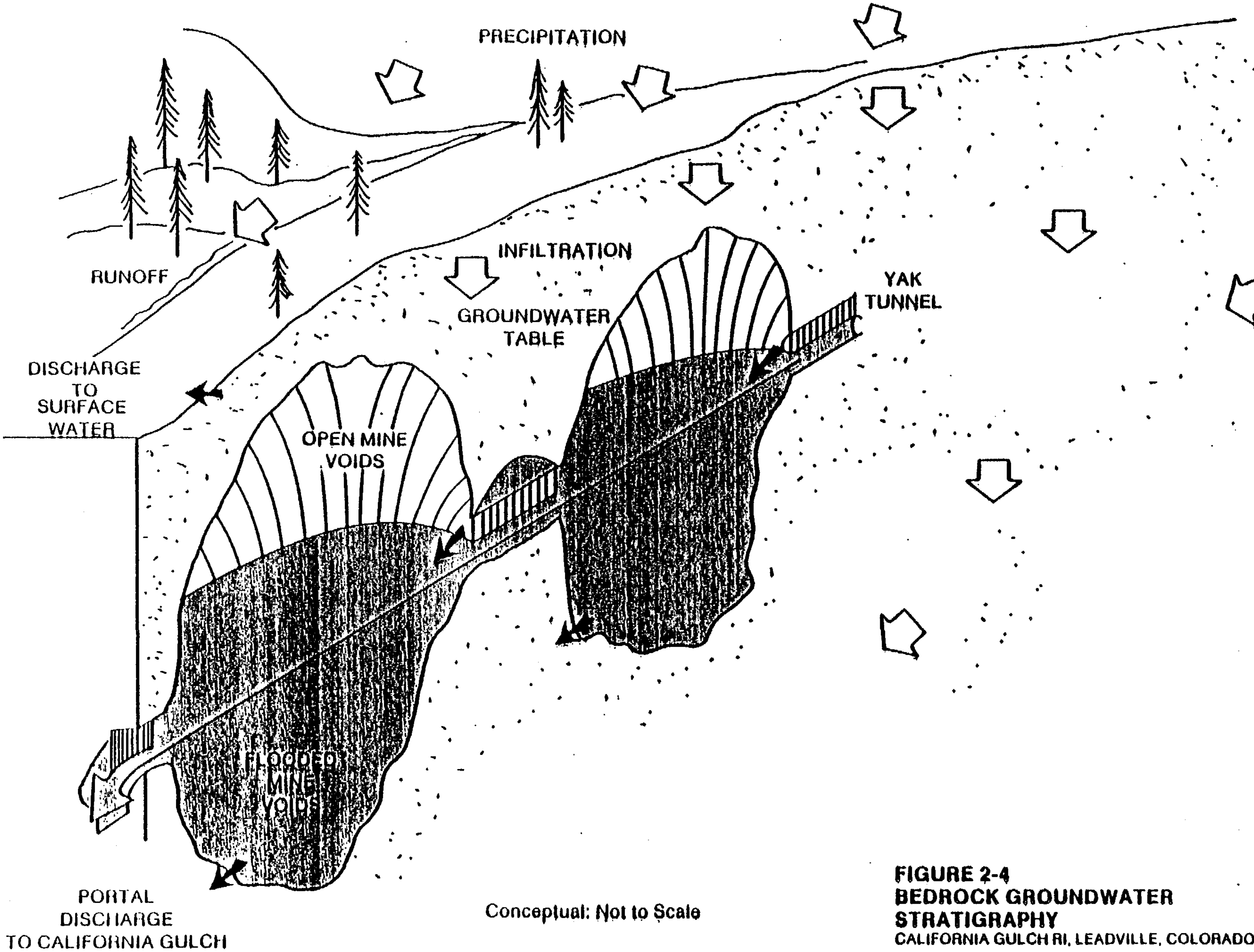
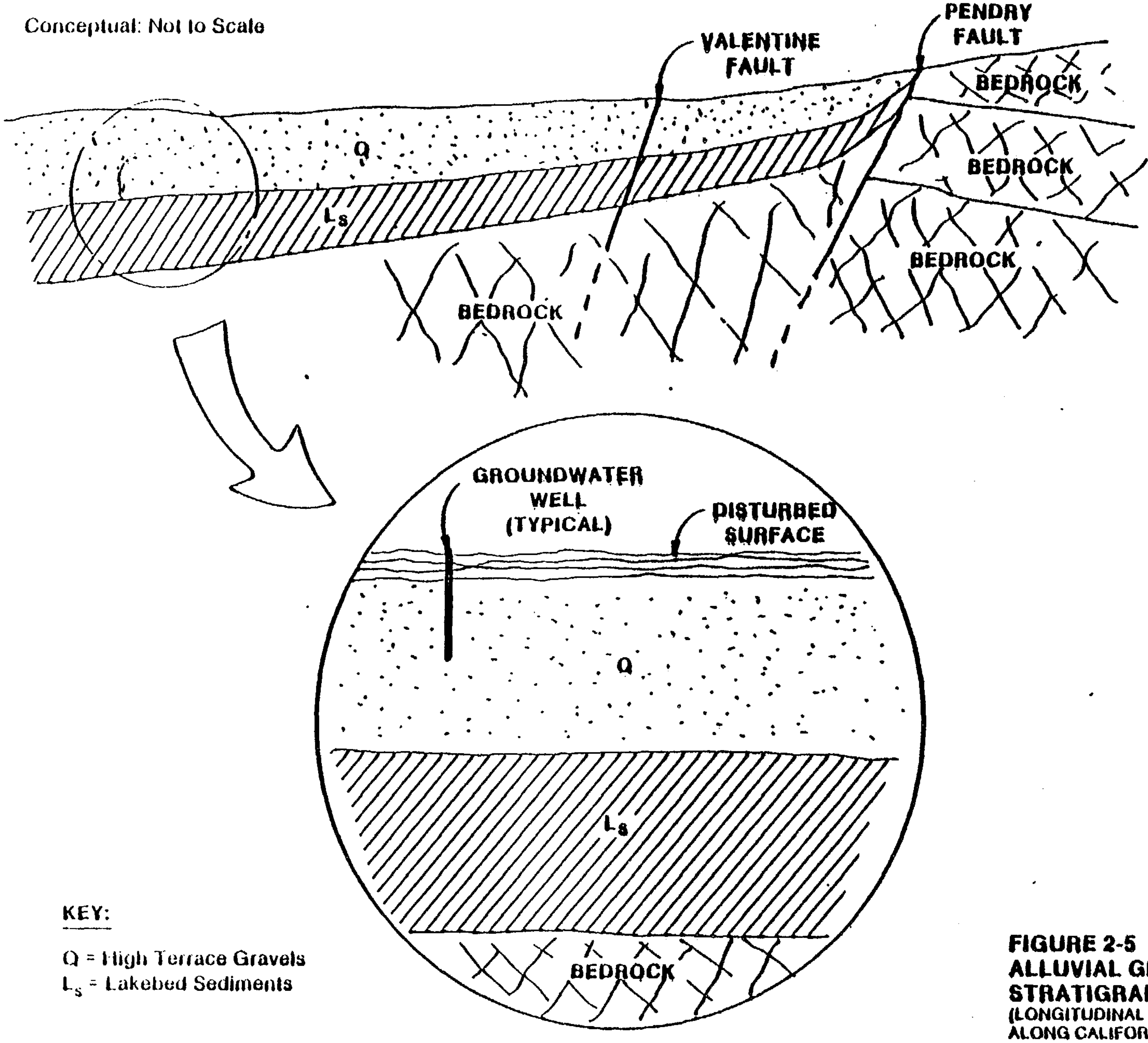


FIGURE 2-4
BEDROCK GROUNDWATER STRATIGRAPHY
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

Conceptual: Not to Scale



KEY:

Q = High Terrace Gravels
L_s = Lakebed Sediments

FIGURE 2-5
ALLUVIAL GROUNDWATER STRATIGRAPHY
(LONGITUDINAL SECTION ALONG CALIFORNIA GULCH)
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

Taylor (1979) and Topielec (1977) estimate depth to bedrock near the Arkansas River to be 600 to 800 feet. The upper unit (high terrace gravels), appears to be in excess of 50 feet thick near the Pendry Fault and thickens to several hundred feet in depth near the Arkansas River. Placer operations and disposal of mine wastes probably altered the surface features of this stratigraphic unit. Existing wells in the middle and lower sections of the Gulch typically penetrate the upper stratigraph unit.

Recharge to the aquifer system is principally from infiltration of snowmelt and rainfall. The average annual precipitation is approximately 18 inches. Observed fluctuations in the water table indicate that recharge occurs principally during the snowmelt, and that short duration summer thunderstorms are of little consequence (Turk and Taylor, 1979).

SURFACE WATER

The upper Arkansas River headwaters start at an elevation of 12,540 feet MSL, and the mainstem flows downstream past Leadville over 34 miles to its confluence with Lake Creek at an elevation of 9,038 feet MSL. The drainage system includes 877 miles of tributaries, in addition to the mainstem. This stream system joins the mainstem Arkansas River that flows eastward across Colorado. Further information, including a stream order analysis, profiles, and seasonal flows, is presented in the Hydrology section of the IA.

California Gulch drains approximately 7,400 acres of watershed into the Arkansas River (see IA Hydrology section). The mainstem of the Gulch receives water from several ephemeral drainages: Starr Ditch, upper California Gulch, Oregon Gulch, Georgia Gulch, Pawnee Gulch, Airport and Malta Gulches, etc. It also receives perennial discharges from the Yak Tunnel and the Leadville Sewage Treatment Plant (STP).

Starr Ditch drains Stray Horse Gulch and other areas east of Leadville. Average flow at the Gulch's confluence with the Arkansas River ranges between 2.2 and 6.4 cubic feet per second (cfs) (LaBounty, 1975) with infrequent flood flows also being observed. Flooding at this elevation usually occurs as a result of rapid snowmelt in May and June. The 10-year, 7-day low flow in the Arkansas River at the California Gulch confluence is about 24 cfs. Low flows observed from the Yak Tunnel are about 1.1 cfs. The balance of California Gulch low flow is approximately 1.0 cfs being contributed by the STP. Combining these flows yields a normal low flow of about 2.1 cfs at the Arkansas River confluence, which produces a dilution ratio of approximately 11 (LaBounty, 1975). Digerness (1977) indicates that prior to construction of the Yak Tunnel and the STP, California Gulch was an ephemeral system. It was noted that various ditches, including the Starr Ditch, were built in the late 1860's to convey water for placer mining operations to California Gulch from Evans Gulch.

The flood potential in the area, particularly in the upper Gulch, is quite high because of relatively sparse vegetation. The Corps of Engineers (COE, 1983) estimates the upper California Gulch channel capacity at 50 cfs. Their estimate of the 100-year flood event is 270 cfs at the confluence of the Gulch and the Arkansas River and, by ratio, 90 cfs at the Yak Tunnel portal. Investigation of historic and paleogeologic floods at this elevation indicates the worst floods occur during snowmelt and not from short duration, high-intensity thunderstorms during the summer months (Turk and Taylor, 1979). Using data from COE (1983) the 100-year floodplain was estimated and is shown on Figure 2-6. Potential wetlands within the Gulch were identified from aerial photographs (EPA, 1982), and are shown on the same figure.

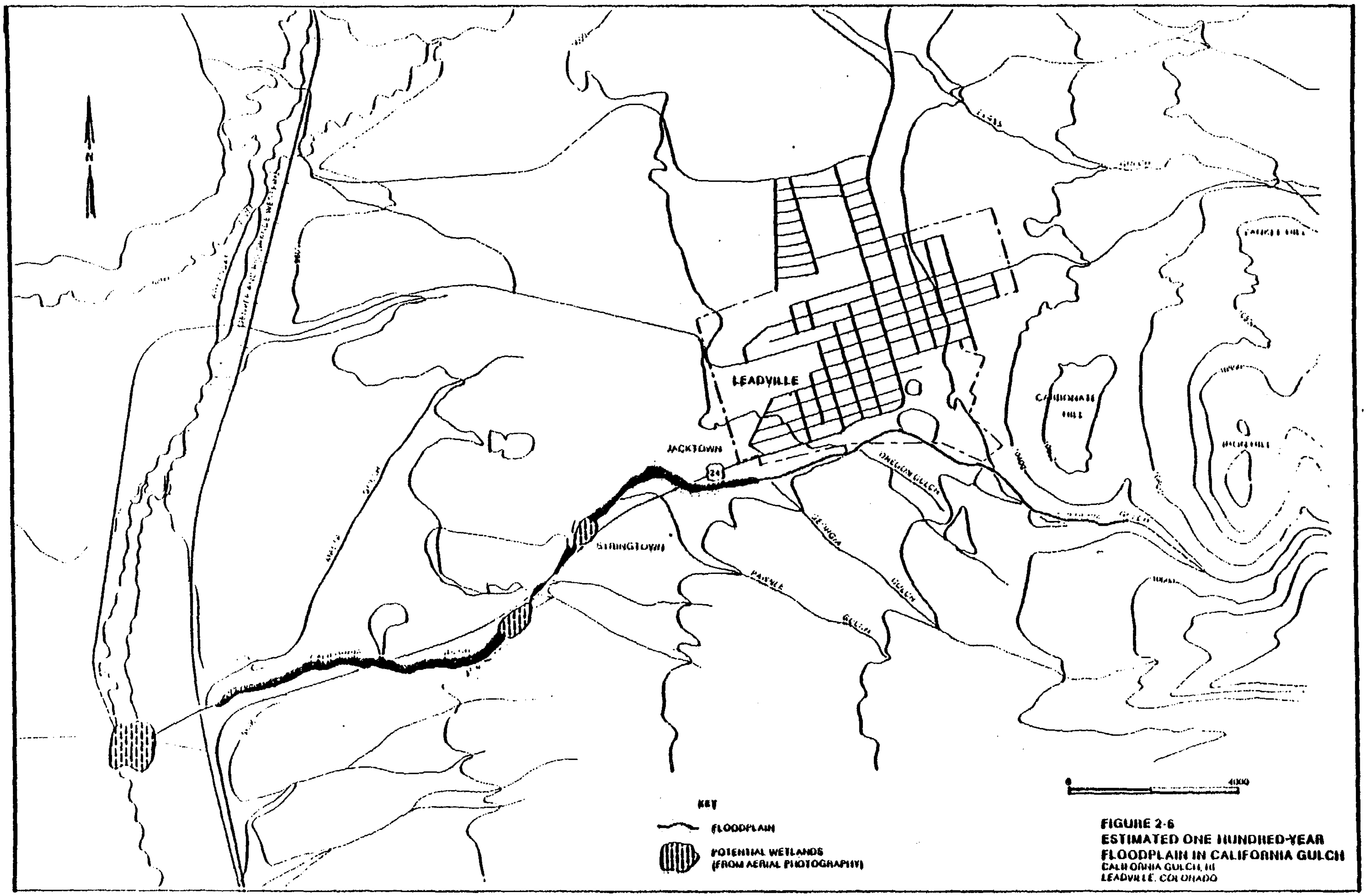


FIGURE 2-6
ESTIMATED ONE HUNDRED-YEAR FLOODPLAIN IN CALIFORNIA GULCH
CALIFORNIA GULCH, III
LEADVILLE, COLORADO

VEGETATION

The species diversity and percent cover of vegetative communities of California Gulch are limited in the drainage bottoms. This has been caused by physical disturbances associated with the presence of tailings impoundments and waste piles, and placer activities. Small pines and aspen grow alongside the Gulch in the upper portions of the drainage.

A wide variety of vegetation exists in the upper Arkansas River Basin, primarily because of the variation in elevation. Elevations within the site range from 9,520 feet MSL to approximately 12,200 feet MSL. The higher elevations follow the Carbonate Hill-Iron Hill ridge that separates California Gulch from Stray Horse Gulch. Timberline occurs at approximately 11,500 feet MSL; the vegetation above that elevation is alpine tundra. The tundra is composed of grasses, sedges, and herbs. In the Subalpine Zone (10,000 to 11,500 feet MSL), the existing forests are dominated by Englemann spruce and Alpine fir. Stands of aspen and lodgepole pine can also be found in this Subalpine Zone. In the valley bottoms around Leadville (9,000 to 10,000 feet MSL), sedge-grass meadows are common, and marshy areas along stream banks support willows and dwarf birch (Topielec, 1977).

Areas southwest of Leadville are in the Montane Zone (8,000 to 10,000 feet MSL). Douglas fir and Ponderosa pine are found in this zone. Open or transition areas, such as the Malta Gulch area, may contain bearberry and juniper; stands of aspen and lodgepole can be found. In this zone, cottonwoods can be found along the stream bottoms along with alder, birch, and willow (riparian vegetation). However, there is limited riparian vegetation along California Gulch and its tributaries. The limited riparian habitats are found near the Malta Gulch confluence (Topielec, 1977).

Inquiries with the Colorado Natural Areas Program (O'Kane, 1986) noted that Lake County has two threatened or exemplary plant communities: Porter Needlegrass and Alpine braya. However, these species are not located in the site study area.

WILDLIFE

There is little specific information on wildlife within the site study area. The wildlife found within the study area should be similar to those found in the general Leadville area. However, the disturbed landscape and level of past and present human activity in both Leadville and the California Gulch area may tend to minimize the number and diversity of wildlife within the site.

The mountain forests and meadows elsewhere in Lake County support large numbers of deer and elk. Much of the area along the Arkansas River Valley is important winter range for deer and elk. Elk calving grounds are found around Twin Lakes, which are several miles downstream from Leadville. Black bear, bighorn sheep, and Rocky Mountain goats are also found in the area (Topielec, 1977).

Numerous smaller animals are present, including furbearers such as beaver, mink, racoon, weasels, and muskrats; small game such as cottontails and jackrabbits; and rodents such as mice, moles, chipmunks, squirrels, and marmots. Coyotes are very common in the Upper Arkansas Basin; bobcat, red fox, and mountain lions are occasionally seen. Pika are common on the talus slopes near timberline (Topielec, 1977).

Waterfowl, such as mallards, teal, and coots, use the marshlands along the Arkansas River as resting areas. Turquoise Lake, west of Leadville, may support a breeding population of ducks. American kestrel (Sparrow hawk) are common in the area, and there are a few nesting goshawks and golden eagles in the mountains along the river valleys. Bald eagles, red-tailed hawks, and ferruginous hawks are sometimes present as transients. There is a wide variety of small birds in the Leadville area. Upland game birds are not common (Topielec, 1977).

O'Kane (1986) stated that the lynx had been noted to exist in the study area. The tiny hawksbeard was also noted to exist in Lake County, but not specifically in the study area.

FISH AND BENTHIC MACROINVERTEBRATES

The Arkansas River, upstream of Leadville (Tennessee Creek and East Fork), supports a fair population of brown and brook trout; however, most fish are small with an average length of 180 millimeters (mm) (LaBounty, 1975). The bottom-dwelling macroinvertebrates include a variety of mayflies, stoneflies, and caddisflies.

California Gulch waters do not support any fish because of heavy metal concentrations and high turbidities. Reports indicate that no fish and only a few limited species of aquatic invertebrates are found in the Arkansas River for 1.5 miles downstream of the confluence with California Gulch (LaBounty, 1975, and McLaughlin, 1981).

Some stoneflies and mostly diptera larvae, being relatively tolerant of heavy metals, were collected in another investigation all along the Arkansas River. Genera of mayflies and caddisflies, being sensitive to lower water quality, with few exceptions, were not found immediately below the confluence of California Gulch and the Arkansas River (LaBounty, 1975, and Roline, 1981).

Studies by the Colorado Division of Wildlife have shown a marked decrease in the diversity of aquatic organisms in the Arkansas River immediately below California Gulch. Diversity increases within a few miles because tributaries, such as Lake Fork and Halfmoon Creek, discharge high-quality water into the Arkansas River. Trout populations increase down-river of these tributaries and include brown, brook, and rainbow trout. Analyses of brown trout livers for heavy metals (collected downriver of California Gulch) indicated that these fish had been chronically exposed to high levels of metals and had bioaccumulated copper and zinc (Roline, 1981).

CLIMATE

The climate in the California Gulch study area is considered to be normal for the mountainous areas of central Colorado. The severe local topographic features strongly influence local climatic variations in Lake County. The City of Lead-ville is at an elevation of approximately 10,000 feet MSL. Weather conditions are recorded at the National Weather Service's Leadville airport station located 2 miles southwest of Leadville. Elevation of the Leadville station is 9,938 feet MSL.

The normal temperature extremes range from 86° F to -30° F, with the average minimum temperature being 21.9° F (Topielec, 1977). The average frost-free season is 79 days. The wind is predominately from the northwest and ranges from calm to 30 miles per hour (mph) (Gilgulin, 1985). No wind rose is available.

Average annual precipitation is 18 inches. July and August record 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, 1977). 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).

Precipitation data were extracted from National Oceanic and Atmospheric Administration (NOAA) climatological data records for Colorado. The monthly precipitation data for the study period and 10-year average (1975 through 1985) at the Leadville Weather Reporting Station are tabulated in Table 2-2 and graphed in Figure 2-7. The annual peak snowmelt usually occurs in June and is depicted in the hydrograph for the middle flume presented in the stream flow section of Appendix N.

Table 2-2
REPORTED AND 10-YEAR AVERAGE PRECIPITATION

	1983		1984		1985		10 Year Average	
Month	Month	Annual Cumulative	Month	Annual Cumulative	Month	Annual Cumulative	Month	Annual Cumulative
November	0.28	0.28	1.18	1.18	0.40	0.40	1.06	1.06
December	0.53	0.81	3.51	4.69	0.59	0.99	1.37	2.43
January	0.47	1.28	0.17	4.86	0.58	1.57	1.42	3.85
February	0.31	1.59	0.27	5.13	0.12	1.69	1.35	5.20
March	0.93	2.52	0.98	6.11	1.77	3.46	1.43	6.63
April	1.24	3.76	0.79	6.90	2.21	5.67	1.70	8.33
May	2.18	5.94	0.47	7.37	1.15	6.82	1.22	9.55
June	0.37	6.31	0.92	8.29	0.62	7.44	1.05	10.60
July	1.22	7.53	2.40	10.69	2.45	9.89	1.98	12.58
August	1.71	9.24	4.25	14.94	0.62	10.51	1.86	14.44
September	0.57	9.81	0.62	15.56	1.91	12.42	1.22	15.66
October	0.27	10.08	0.87	16.43	1.13	13.55	1.16	16.82
Total	10.08		16.43		13.55		16.82	

Note: Measurements presented in inches.

Source: National Weather Service

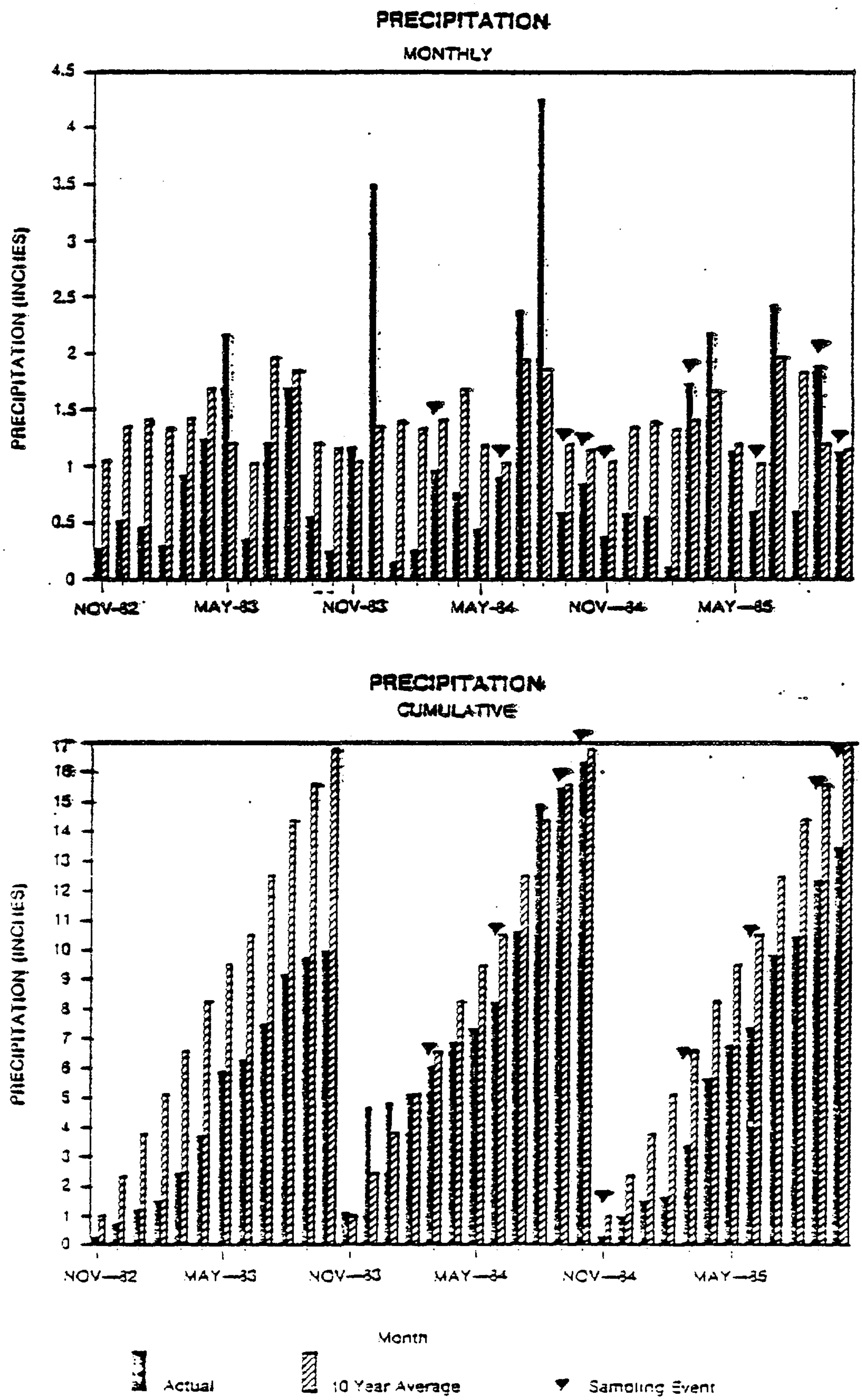


FIGURE 2-7
PRECIPITATION
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

Limited air quality information for the Leadville area is available from the Colorado Department of Health (CDH) for suspended particulates and lead. These data will be evaluated during the Phase II RI.

LAND USE

Approximately 2/3 of the land in Lake County is federally owned; the study area is principally privately-owned land. Most of the federal land is within the San Isabel National Forest, with the Bureau of Land Management (BLM) overseeing most of the remaining land. Land use in the California Gulch area is predominantly mining, commercial, and residential. Along the Arkansas River Valley, land use includes agricultural areas (pastures, rangeland), recreation areas, and residential areas (Topeliec, 1977). A land use map is shown as Figure 2-8 (Lake County, 1980).

DEMOGRAPHY AND SOCIOECONOMICS

California Gulch and the City of Leadville are in Lake County, a relatively small (380 square miles) rural area with a current estimated population of approximately 6,600 (Shroyer, 1986). Lake County is dependent upon agriculture, tourist, and mining industries. Its past employment and economic base stemmed primarily from mining and mine-related industries, which have diminished significantly since 1977. Mine lay-offs have dramatically reduced employment in Lake County. Currently ASARCO employs a work force of about 140, but Climax Molybdenum Company recently closed its operation, furloughing about 500 people (Shroyer, 1986).

Table 2-3 shows past and present estimated populations that clearly demonstrate the impact of mine closures on population. The population of Leadville has remained relatively constant

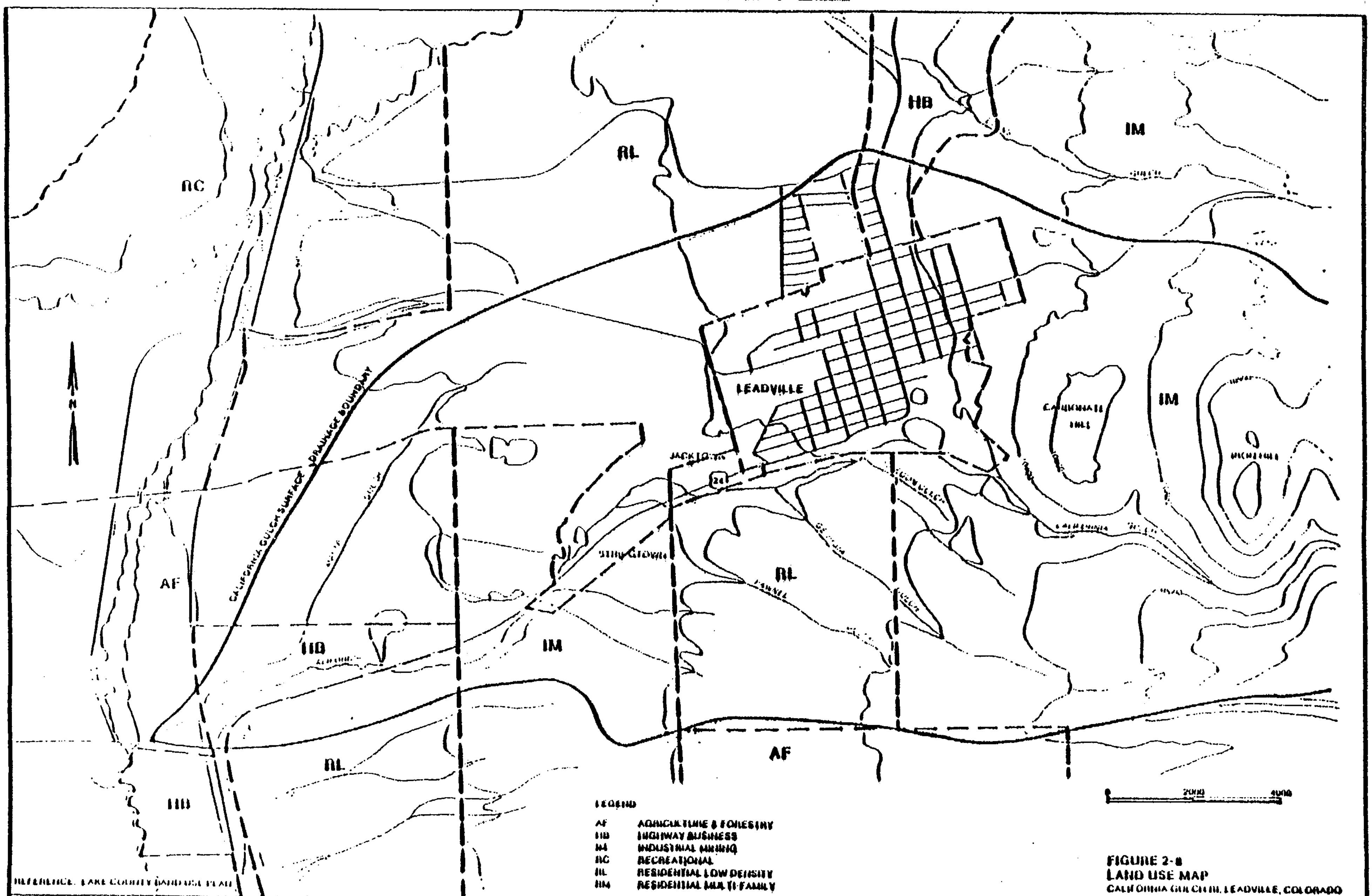


FIGURE 2-8
LAND USE MAP
CALIFORNIA GULCH, LEADVILLE, COLORADO

since approximately 1920. No official growth projections or income levels of the population are available.

Table 2-3
LAKE COUNTY POPULATION DATA
AND CURRENT ESTIMATED POPULATION

Area	1960	1970	1975	1980	1985[a]
Lake County	7,101	8,282	9,445	8830	6,600
Leadville	4,008	4,314	4,745	4356	3,800
Unincorporated	3,093	3,968	4,700	4474	2,800

[a]Shroyer estimate, 1986.

Source: Topielec, 1977.

Leadville has a current population of about 3,800, with an approximate age distribution as follows (Shroyer, 1986):

- 0-16 years--25 percent
- 17-21 years--15 percent
- 22-41 years--25 percent
- 42-60 years--15 percent
- 60-100 years--20 percent

WATER SUPPLY

The Parkville Water District supplies water to Leadville, Stringtown, Silver Hills, and Matchless and has 1,807 paying customers (Herald Democrat, 1985). In 1979, this number was 1,909 (Shroyer, 1986), which corroborates the declining area population. The district's sources of water include the Canterbury Tunnel, the Elkhorn Shaft, wells, and the Big Evans Gulch Reservoir. There is also a report of a diversion from Iowa Gulch, but this has not been fully substantiated.

The Parkville water system has a filter/chlorination treatment system with a capacity of 1.6 million gallons per day (mgd) and treated storage capacity of 1.5 mgd. Water samples are taken monthly and have routinely met water quality standards.

The northwestern boundary of the Parkville system includes Silver Hills subdivision, Matchless Estates subdivision, and West Park subdivision. The northern boundary is at the junction of U.S. Highways 24 and 91. The eastern boundary extends the Leadville city limits. The southern boundary extends from Apache Energy and Minerals Company's tailings impoundment to Stringtown (including the Colorado Mountain College). The southwestern boundary is known as the "dividing line" road that runs north from U.S. Highway 24 at the junction with Colorado Mountain College road. This includes St. Vincents Hospital and the Leadville schools.

Outside of the Parkville Water Service Area, well water is used for domestic supplies, irrigation, commercial, municipal, and industrial uses. There are 624 wells in Lake County, based on well permitting information. Approximately 35 of these existing wells are located in the study area (see Section 3, Figure 3-3). A number of people in Stringtown and the lower part of California Gulch have domestic wells. The current usage of these wells is presented in Section 3. Within the study area, this well water primarily comes from the shallow groundwater system in the upper terrace gravels.

SITE HISTORY

Mining and mining-related activities have occurred in the Leadville area since the mid-1800's. Early mining-related activities at Leadville included the following: placer operations; lode mining of silver and lead ores; and lode mining of zinc ores (Emmons, 1927). Hundreds of mines, more than 40 smelters, and several placer operations contributed to the economy and environmental problems in Leadville. Emmons (1927) identified 1,329 mine shafts, 155 tunnels, and 1,628 prospect holes in the Leadville District having an estimated aggregate length of 75 miles. In the surrounding area, Behre (1953) identified an additional 1,800 openings of various types.

Environmental degradation occurred from mining-related activities, including the following:

- Discharge of mineral processing wastes and tailings; smelter flume emissions and dust; and disposal of smelter slags. Mining-related wastes were disposed of on the land, in surface waters, and in the atmosphere of the Leadville area. By 1881, 14 smelters were operating at the same time (Ubbelohde, Benson, & Smith, 1972).

- Discharge of mine waters from dewatering pumps and tunnels into surface waters, resulting in decreased water quality. By the 1890's, as much as 15 mgd were pumped from the mines (Emmons, 1927).

- Placer and hydraulic mining disturbances that stripped surface soils and alluvium (Digerness, 1977).

- Construction of the Yak Tunnel to dewater mines in the Iron Hill, Breece Hill, Ibex, and Resurrection areas. By 1923, the Tunnel produced a flow of 15,000 gallons per minute (gpm) (Labounty, et al., 1975).

- Local deforestation for fueling the smelters, constructing diversion flumes, and supplying underground mine workings. This removal of vegetation increased runoff rates and contributed to increased erosion and sediment transport (Emmons, et al., 1927).

Additional information on Leadville can be found in Frank Hall's multi-volume set, History of the State of Colorado, and D. L. and J. H. Griswold's The Carbonate Camp Called Leadville. Additional details on the history of the Yak Tunnel are presented in the following section.

YAK TUNNEL HISTORY

Historically, the Yak Tunnel was one of several drainage tunnels constructed to dewater mines in the Leadville District. Started by A. A. Blow in 1895, the Yak Tunnel was targeted to drain the Iron Hill area (McLaughlin, 1981). Previous studies have indicated that the Yak Tunnel is the major contributor of acid and metals to the California Gulch drainage system (McLaughlin, 1981; LaBounty, et al., 1975; and Moran and Wentz, 1974).

With the portal at an elevation of 10,330 feet 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, it was terminated at the Resurrection No. 2 Mine. The total length, including principal laterals, is over 4 miles (McLaughlin, 1981). Figure 2-9 presents the major mining

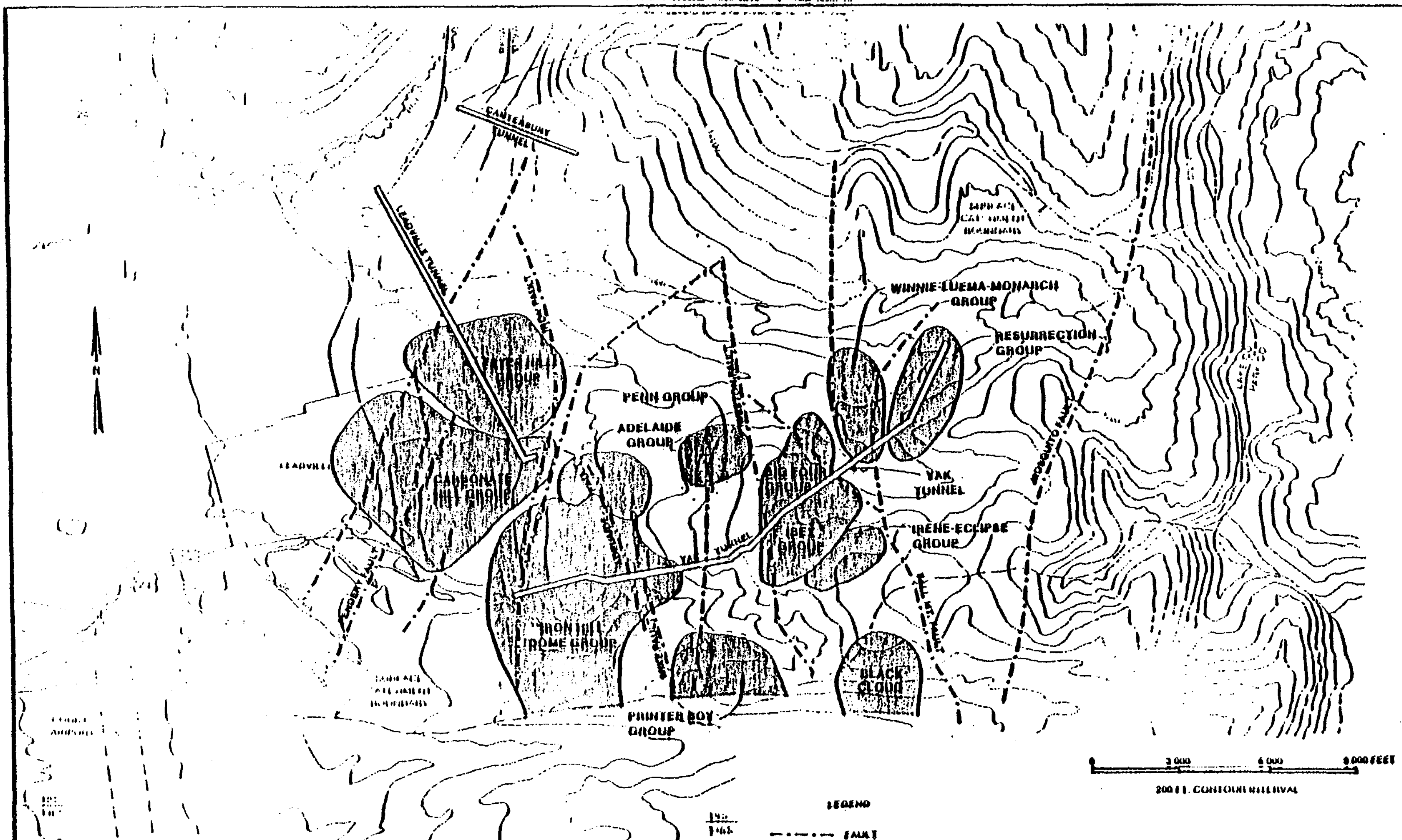


FIGURE 2-9
LOCATION OF MAJOR MINING AREAS
IN THE LEADVILLE MINING DISTRICT
CALIFORNIA GULCH CLUES
LEADVILLE, COLORADO

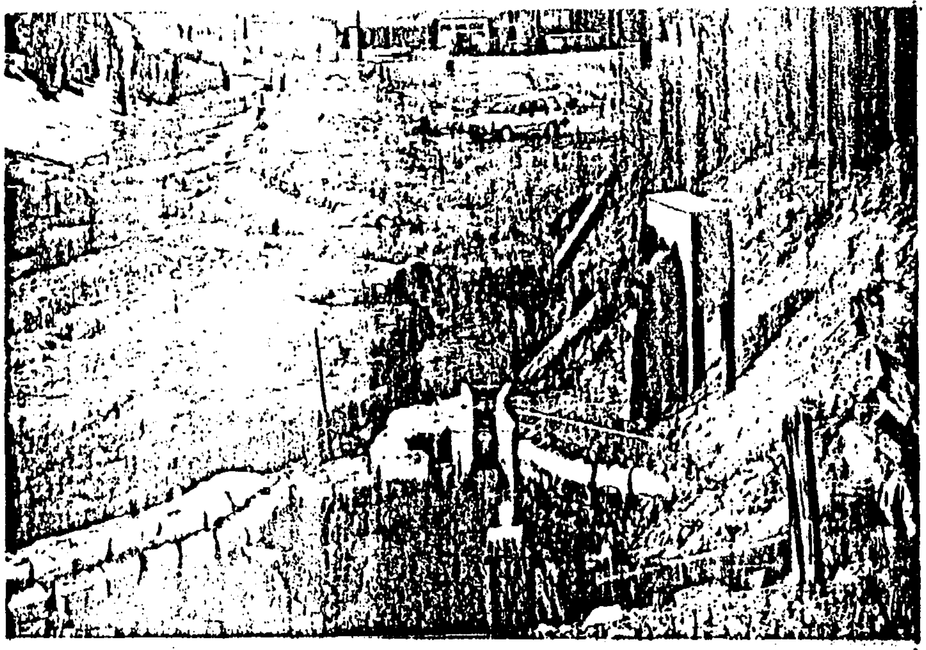
areas in the Leadville Mining District, the faults of importance, and the tunnels draining the area.

A surge of mining activity in the early 1920's 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, and produced a flow of 15,000 gpm (LaBounty, et al., 1975). This flow rate had diminished to approximately 8,700 gpm by June of 1924. By that time, the tunnel drained a complex area of massive sulfide and carbonate mines through a maze of underground mine workings.

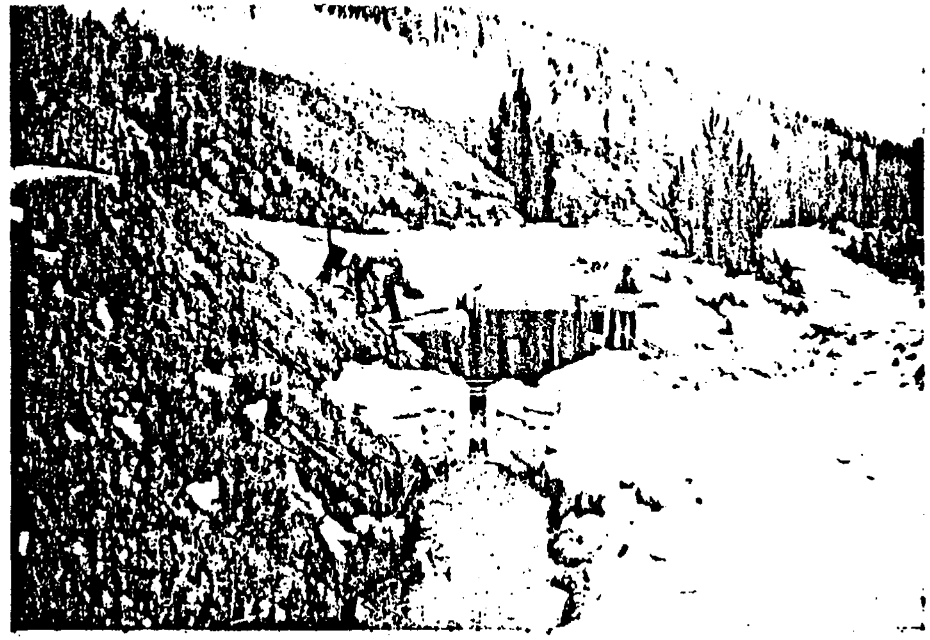
Determination of all underground connections is impossible, but many of the major areas such as the White Cap, Ibex, Resurrection, and Irene Mine groups are known (McLaughlin, 1981). According to previous studies (URS/Ken R. White Company, 1974), drifts extend from the Yak Tunnel to the Horseshoe Mine, Ruby Mine, North Mike Mine, South Mike Mine, Ibex No. 4 Mine, Little Vinnie Mine, Resurrection No. 1 Mine, and the Black Cloud Mine through the Irene No. 2 Mine. Other nearby mines also drain to the Yak Tunnel through interconnections with these and other mines, or through faults, cracks, and fissures in the rock surrounding the tunnel. Lower portions of many of the mines described above are at elevations lower than the Yak Tunnel and were pumped during mining.

In 1983 and 1985, surge events occurred at the Yak Tunnel. Surge events are short-duration, high-flow events from the sudden release of impounded water within the tunnel or its laterals. When the tunnel was maintained as part of ongoing mining operations, surge events did not occur. Once maintenance stopped, the tunnel likely began to decay. Roof rock and timbers have probably collapsed, creating water impoundments. When the hydraulic pressure becomes high enough, it bursts the impoundment and a surge occurs. Flow rates and volumes of a surge event are not predictable; the rates and volumes are determined by the location and size of the water impoundments in the tunnel.

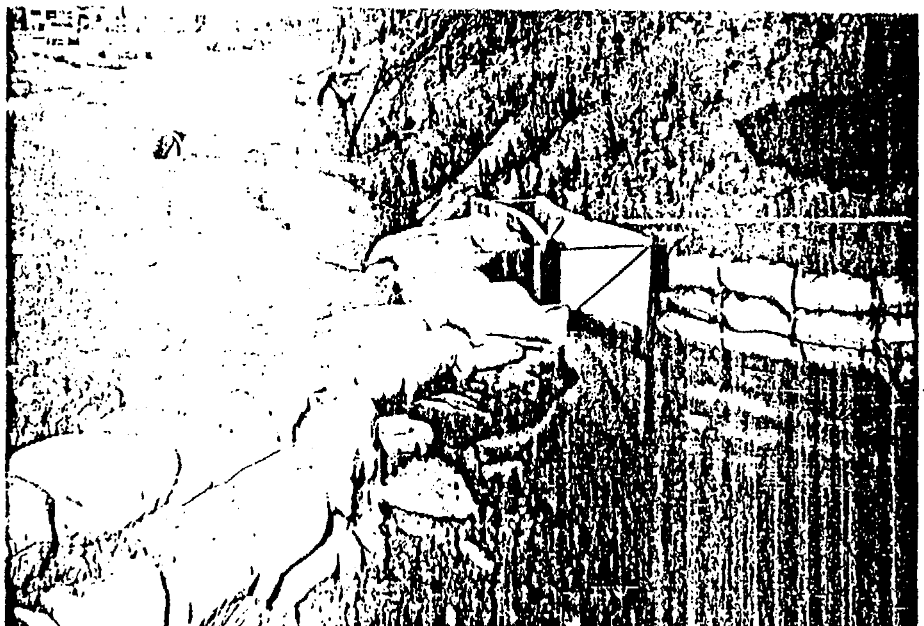
The 1983 event was caused by ASARCO personnel removing collapsed timbers; the 1985 event was likely related to lack of tunnel maintenance. Plate 9 shows some of the results of the 1985 surge event. The event in 1985 lasted about 15 hours, and had a release of approximately 1,000,000 gallons with an estimated instantaneous peak flow rate of 10 cfs.



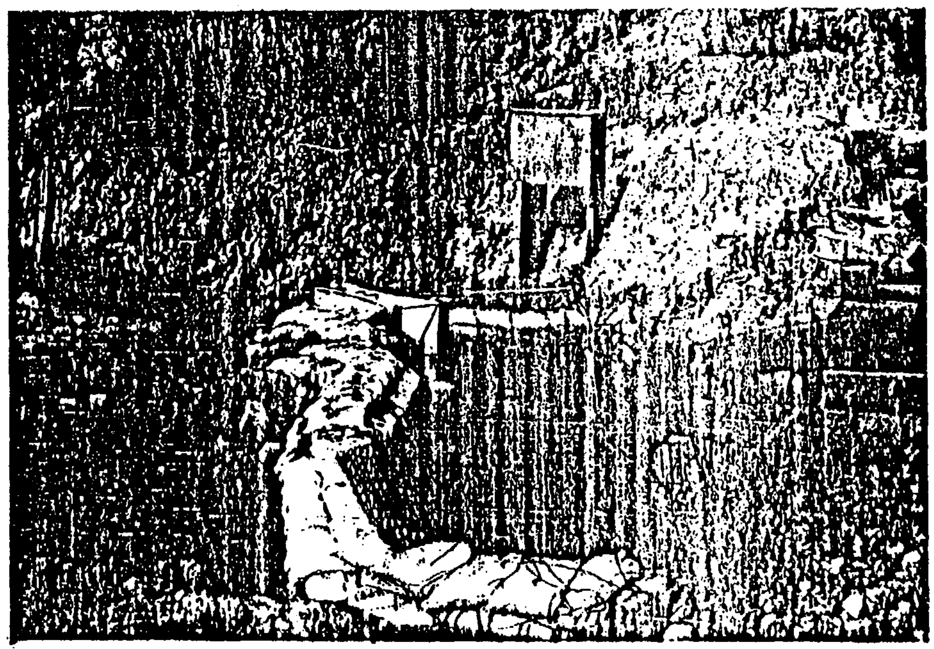
LOOKING WEST FROM THE YAK TUNNEL PORTAL INTO THE RESURRECTION MILL YARD



LOOKING UPSTREAM (EAST) TO YAK TUNNEL PORTAL



SW-3 BEFORE SURGE



SW-3 AFTER SURGE

PLATE 9
YAK TUNNEL PORTAL OCTOBER 1985 SURGE EVENT

Remedial Investigation Activities

Section 3

REMEDIAL INVESTIGATION ACTIVITIES

Preliminary RI activities on the project started in June 1983 with a site visit and development of a draft work plan. The specific details on how the RI was conducted are extensive; the RI approach evolved with increasing knowledge of the site. This section summarizes information about the RI goals and subsequent data gathering activities.

REMEDIAL INVESTIGATION GOALS AND OBJECTIVES

According to requirements of the National Contingency Plan, the RI process was designed to determine the nature and extent of the threat presented by the release or threatened release of hazardous substances. Sources of contamination and migration pathways for the contaminants were identified. Information generated from the RI process will be used to complete an Endangerment Assessment (EA) and a Feasibility Study (FS). The FS will evaluate remedial action alternatives.

Goals of this phase of the RI were to:

- Identify and monitor contaminants that are in the surface water within the California Gulch drainage area.
- Identify the nature and extent of groundwater contamination along California Gulch.
- Assess the nature of contamination in the Arkansas River at the confluence with California Gulch.

- Assess identifiable sources of metal contamination within the California Gulch drainage basin and their relative contributions to water quality degradation in the Arkansas River at the confluence with California Gulch.

WORK SCOPE

Preliminary RI work planning for the project was directed to the known surface water quality problems in California Gulch and the Arkansas River. In late July 1984, the project management team, after conducting a thorough site reconnaissance, determined that a broader investigation than was originally planned was necessary to address potential site concerns. In August and September 1984, the Phase I RI work scope was developed. This scope of work took into account the areal extent of potential sources of contamination and surface water flows into the California Gulch drainage area. The site was conceptually divided into areas of potential sources of contamination. A conceptual model of these areas is shown in Figure 3-1. A field sampling program was designed to sample the following areas:

- Upper California Gulch.
- Yak Tunnel discharge.
- Three tailings piles located in the Gulch's 100-year flood plain.
- Starr Ditch drainage intercepting the north side of Iron and Carbonate Hill and discharging into the Gulch.

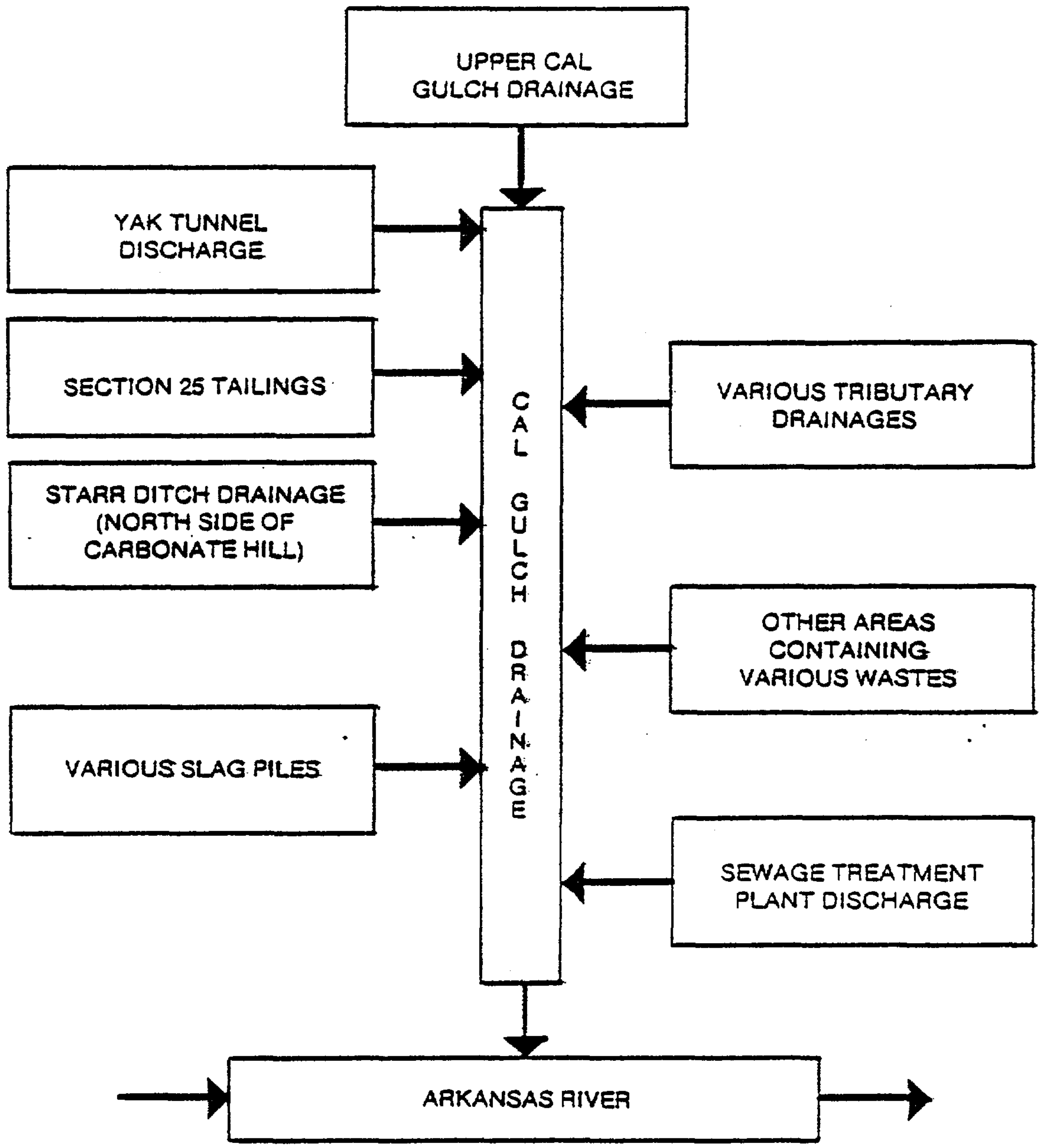


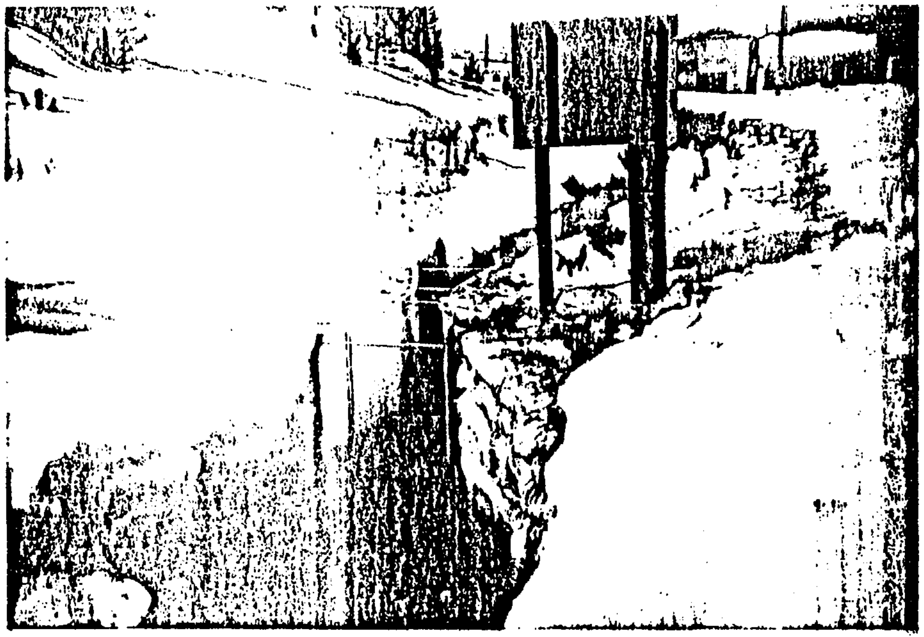
FIGURE 3-1
CONCEPTUAL SAMPLING NETWORK MODEL
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

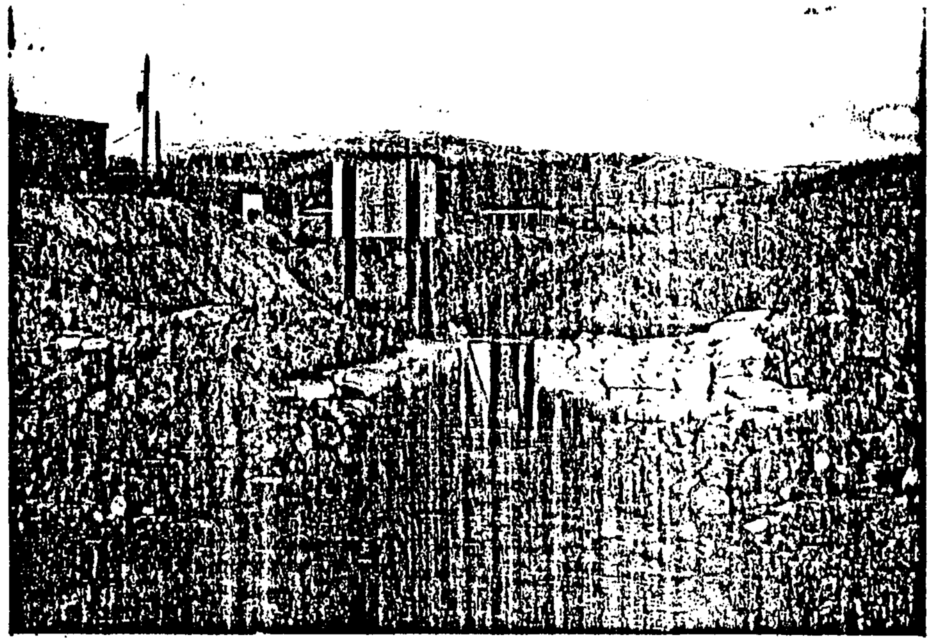
- o Tailings pile in Oregon Gulch.
- o Storm drains from Leadville.
- o Other tributary drainages.
- o Slag pile areas near Stringtown.
- o Discharge from the Leadville sewage treatment plant.

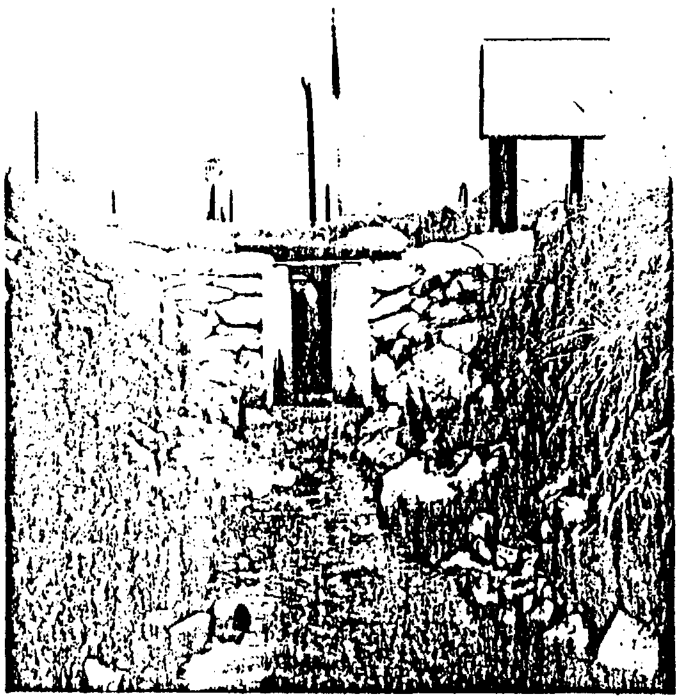
A water quality monitoring plan and a soils/tailings geochemical sampling and testing plan were developed. Meetings were held with private property owners and several mining companies to review these plans and to gain site access approvals. After review, a final surface water and groundwater sample plan was developed and implemented. The groundwater program utilized the numerous private wells in the vicinity, as well as new monitor wells.

The surface water sampling plan required: (1) installation of five Parshall flumes with continuous flow recording instrumentation in strategic locations, and (2) the selection of 17 additional surface water quality sampling and flow locations to be used when appropriate. Plates 10 and 11 show several of these flumes and selected surface water sampling locations. These surface flow monitoring facilities, along with 21 new groundwater monitoring wells, were installed in October and November 1984. Figure 3-2 shows the location of the respective surface water sampling locations. Table 3-1 describes each location and identifies the types of flow measurement used at each location.

A literature review of the geology and geohydrology of the area was completed to select specific sites for new ground-


MILL YARD FLUME (SW-3A)


MIDDLE FLUME (SW-7)


STARR DITCH FLUME (SW-5)

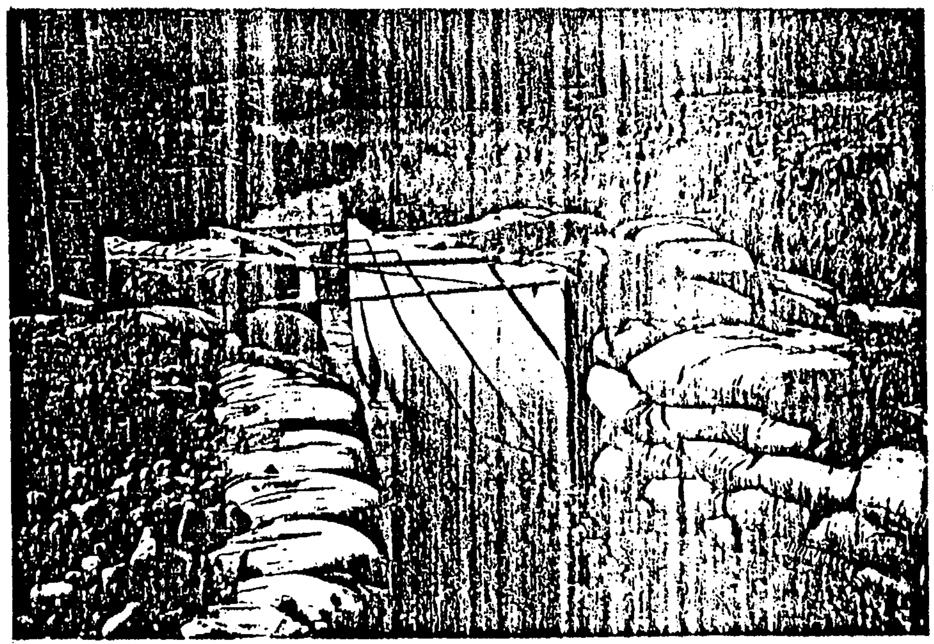
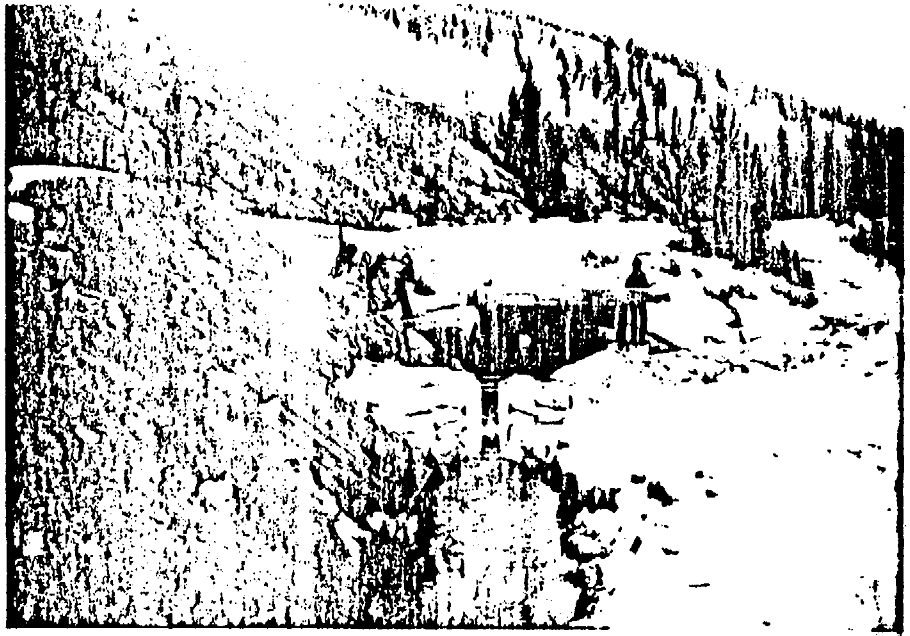
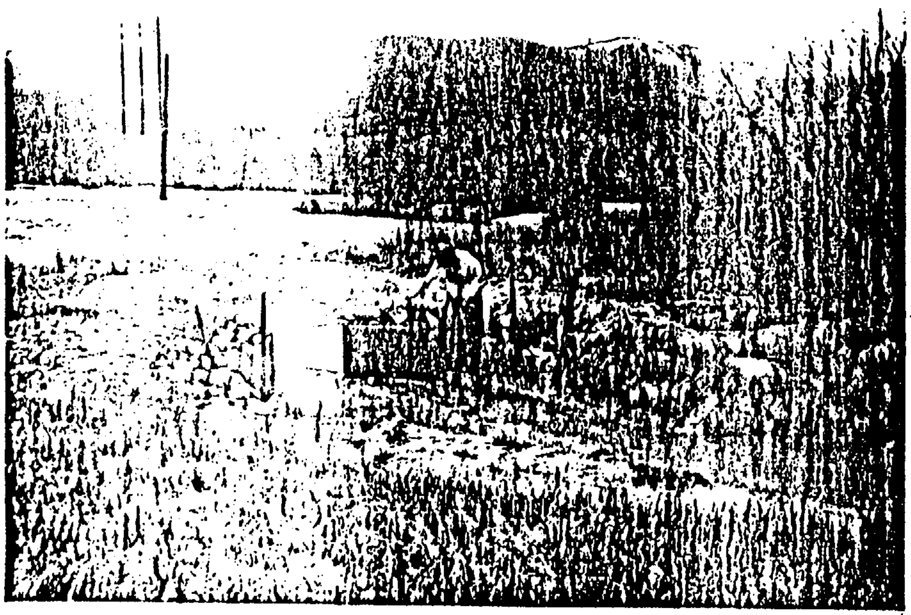

LOWER FLUME (SW-12)

PLATE 10
PARSHALL FLUMES



UPPER FLUME AT YAK PORTAL (SW-3)

MIDDLE FLUME (SW-7)



LOWER FLUME (SW-12)

UPPER FLUME WASHOUT (1984) (SW-1)

PLATE 11
PARSHALL FLUMES

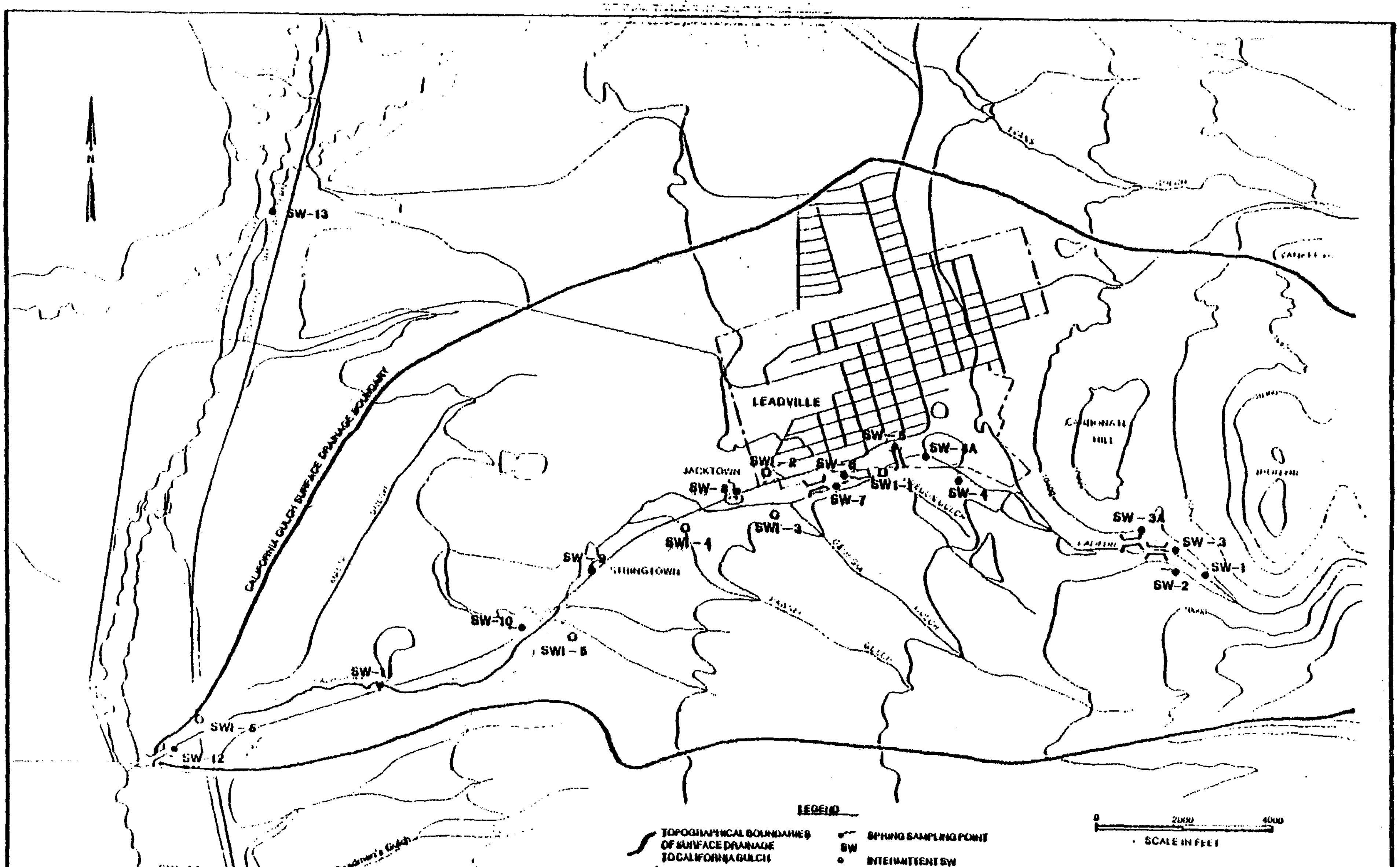


FIGURE 3-2
SURFACE WATER SAMPLING MAP
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

Table 3-1
SURFACE WATER SAMPLING LOCATIONS

	Location	Flow Measurement Method
SW-1[a]	California Gulch above the Yak Tunnel	8" Cutthroat flume
SW-2	Parkville Water Line Break	4" Cutthroat flume
SW-3	Yak Tunnel Discharge at Portal	9" Parshall flume
SW-3A[a]	California Gulch just below the Yak Tunnel (Resurection Mill Yard)	12" Parshall flume
SW-4[a]	California Gulch below Tailings Pile No. 2 (above Apache Energy and Minerals Co.)	8" Cutthroat flume
SW-4A[a]	California Gulch below Apache Energy and Minerals Co.	Current Meter
SW-5	Starr Ditch at Hwy 24, Landfill Road Jct	12" Parshall flume
SW-6	Spring behind Berthod Trucking Co.	4" Cutthroat flume
SW-7[a]	California Gulch behind Berthod	12" Parshall flume
SW-8	Super 8 Spring	4" Cutthroat flume
SW-9[a]	California Gulch above Slag Pile (Sec 27)	Current Meter
SW-10	Spring below Slag Pile (Sec 27)	4" Cutthroat flume
SW-11	Leadville Wastewater Treatment Plant Discharge	STP Recorder and/or Current Meter
SW-12[a]	California Gulch at Confluence with the Arkansas River	18" Parshall flume
SW-13	Arkansas River at the USGS Gauging Station (USGS #070812)	USGS Staff Gauge and/or Current Meter
SW-14	Arkansas River below Lake Fork Trailer Park	Current Meter
	Intermittent Sampling Locations	
SWI-1	Oregon Gulch Culvert	4" Cutthroat Flume
SWI-2	Storm Drainage from the west side of Leadville (in Jackson)	4" Cutthroat Flume
SWI-3	Georgia Gulch Culvert	4" Cutthroat Flume
SWI-4	Pawnee Gulch Culvert	4" Cutthroat Flume
SWI-5	Airport Road Gulch Culvert	4" Cutthroat Flume
SWI-6	Malta Gulch Culvert	4" Cutthroat Flume

[a]Indicates locations directly on mainstem of California Gulch

DE/CALGU6/008

water monitor wells. The location and depths of the new monitoring wells were planned to compliment the use of existing private wells and to study groundwater primarily in the upper terrace gravels. While drilling individual wells, field observations resulted in slight modifications to planned depths and screened intervals. Figures 3-3 and 3-4 identify the locations of the new monitoring wells and existing wells, respectively. Tables 3-2 and 3-3 describe new and existing well construction, including depths and screened intervals. In addition, about 40 piezometer pipes were installed at various locations in the drainage to better understand the fluctuations of shallow groundwater levels with variations in surface water flows. Details of the installation of these facilities are found in Appendix F.

During 1984 storm and runoff events, considerable alterations to the natural drainage channel occurred adjacent to several tailings ponds in the upper Gulch. These alterations caused surface flows to meander over the tailings piles. In November 1984, ASARCO realigned the channel to its previous course, and the flow path was restored.

SAMPLING PROGRAM

The annual hydrologic cycle is important to the understanding of pollutant concentrations and transport mechanisms. For this reason, a five-quarter sampling program was initiated for surface water and groundwater as follows:

- November 1984--early winter (low flows).
- March 1985--early spring (low to medium flows).
- June 1985--early summer (high snowmelt runoff).
- September 1985--fall (medium to low flows).
- November 1985--early winter (low flows).

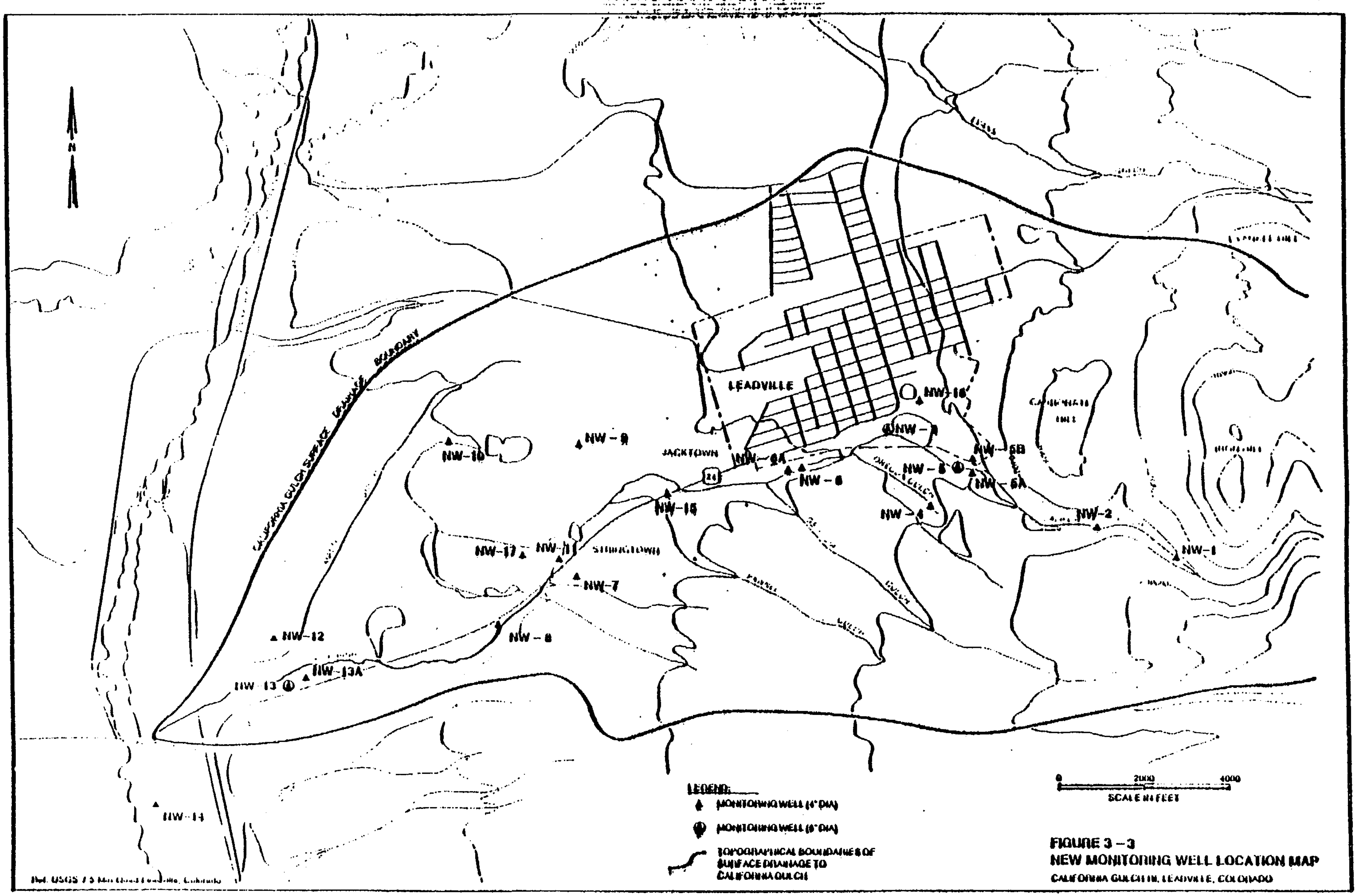


FIGURE 3 – 3
NEW MONITORING WELL LOCATION MAP
CALIFORNIA GULCH, LEADVILLE, COLORADO

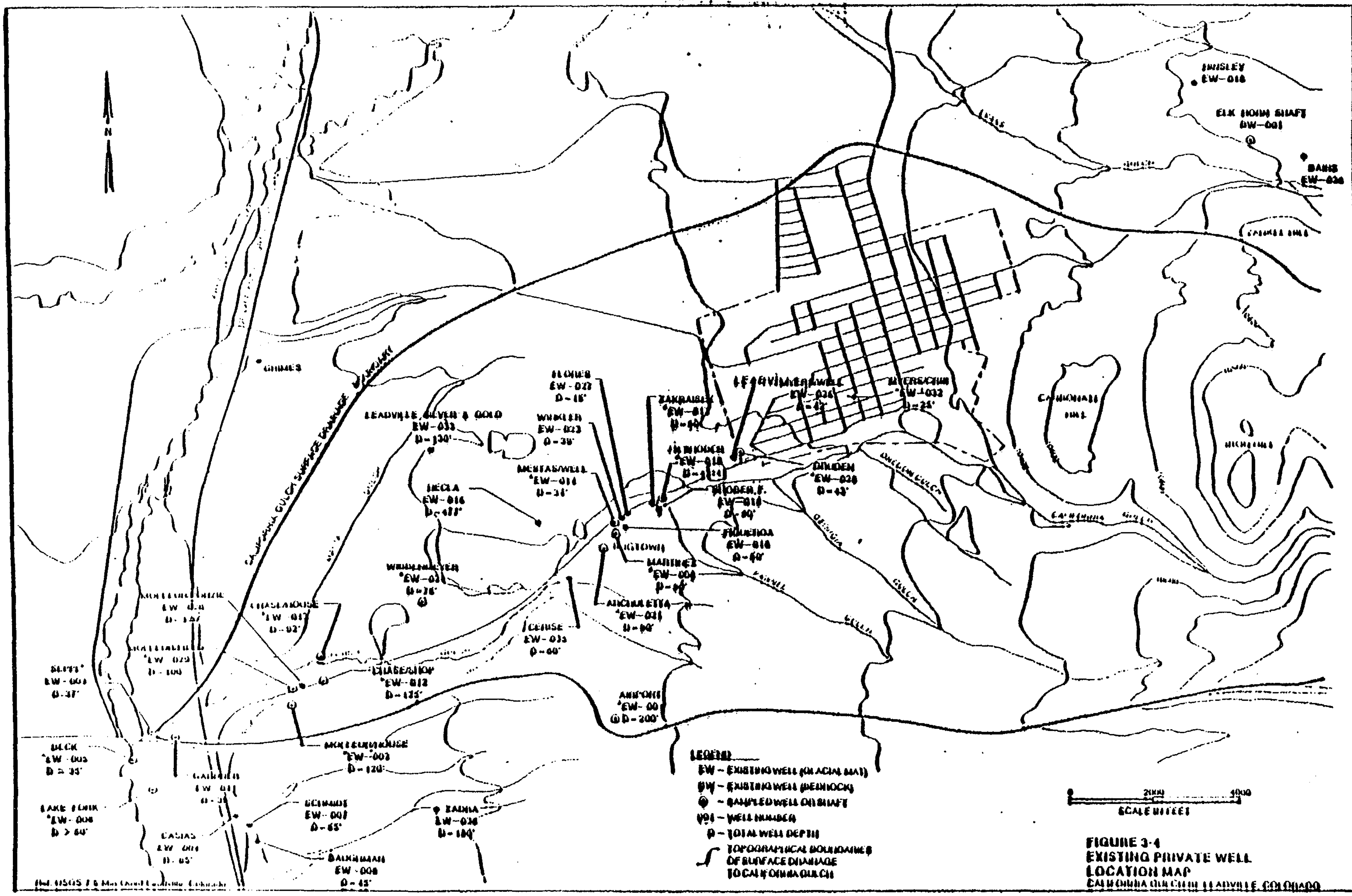


FIGURE 3-4
EXISTING PRIVATE WELL LOCATION MAP
CALIFORNIA GULCH, LEADVILLE, COLORADO

Table 3-2
SUMMARY OF NEW MONITORING WELL CONSTRUCTION DATA

Well No	Location	Total Depth (ft)	Screened Interval (ft)	Top of Steel Casing Elevation (ft)	Casing Stickup (ft)	Ground Level Elevation (ft)	Completion Date
NW-1	Yak Tunnel upgd[a]	22	5-22	10,340.47	2.08	10,338.39	11/01/84
NW-2	Yak Tunnel dngd[b]	28	8-28	10,324.16	1.92	10,322.24	11/02/84
NW-3	Apache	96	26-76	10,067.15	1.50	10,065.65	10/25/84
NW-4	Oregon Gulch	45	5-45	10,135.23	1.75	10,133.48	11/03/84
NW-5	ASARCO/Intermediate	108	48-108	10,114.83	2.60	10,112.23	10/25/84
NW-5A	ASARCO/Shallow	35	15-35	10,114.78	2.02	10,112.76	11/02/84
NW-5B	ASARCO/Deep	220	160-220	10,115.45	2.00	10,113.45	11/13/84
NW-6	Mid Flm/Deep	123	90-110	9,974.11	2.15	9,971.96	10/20/84
NW-6A	Mid Flm/Shallow	29	9-29	9,974.23	2.00	9,972.23	11/02/84
NW-7	Asphalt Plant	130	90-130	9,809.27	1.96	9,807.31	10/22/84
NW-8	Diedrich Slag dngd[b]	53	16-53	9,746.34	2.35	9,743.99	11/06/84
NW-9	Hecla upgd[a]	50	10-50	9,874.62	1.94	9,872.68	11/04/84
NW-10	Hecla dngd[b]	50	10-50	9,787.71	2.71	9,785.00	11/03/84
NW-11	Diedrich House	55	25-55	9,816.24	2.17	9,814.07	11/04/84
NW-12	Malta Gulch	50	10-50	9,615.40	2.31	9,613.09	11/06/84
NW-13	Molleur Fld/Deep	100	20-100	9,621.59	2.58	9,619.01	10/23/84
NW-13A	Molleur Fld/Shallow	25	14.5-25	9,622.27	2.58	9,619.69	11/05/84
NW-14	Trailer Park	50	10-50	9,530.49	2.92	9,527.57	11/05/84
NW-15	Super 8	35	14-35	9,897.61	2.13	9,895.48	11/06/84
NW-16	Starr Ditch	80	40-80	10,125.42	1.46	10,123.96	11/07/84
NW-17	Diedrich Slag upgd[a]	100	60-100	9,818.19	2.67	9,815.52	10/23/84

[a]Upgradient

[b]Downgradient

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Table 3-3
SUMMARY OF EXISTING PRIVATE WELL CONSTRUCTION DATA

Well No	Location	Total[a] Depth (ft)	Screened[b] Internal (ft)	Top of Steel Casing Elevation (ft)	Casing Stickup (ft)	Ground Level Elevation (ft)	Completion Date
BW-1	Elk Horn Shaft	500.00	0-500	NA	NA	10,600.00	NA
EW-1	Airport	200.00	170-200	NA	NA	9,930.00	11/20/72
EW-2	Molleur/House	120.00	85-120	NA	NA	9,615.00	10/25/72
EW-3	Seppi	37.00	NA	NA	NA	9,530.00	01/01/57
EW-4	Casias	65.00	NA	9,528.15	-5.92	9,534.07	01/01/79
EW-5	Beck	35.00	NA	NA	NA	9,525.00	07/01/78
EW-6	Lk Fk Trlr Park	50.00	NA	NA	NA	9,515.00	01/01/78
EW-7	Schmidt	55.00	31-55	NA	NA	9,530.00	07/13/66
EW-8	Baughman	45.00	21-45	9,530.97	-10.97	9,541.94	08/01/66
EW-9	Martinez	50.00	25-50	9,840.14	1.08	9,839.06	08/30/73
EW-10	Figuero	30.00	0-30	9,853.27	1.75	9,851.52	NA
EW-11	Gardner	39.00	27-39	9,545.85	-3.50	9,549.35	09/30/74
EW-12	Chase/Shop	125.00	NA	9,627.50	-7.50	9.635.00	01/01/62
EW-13	Chase/House	92.00	77-92	9,660.61	2.17	9,658.44	09/15/83
EW-14	Mestas	34.00	22-34	9,838.08	-5.50	9,843.58	09/16/63
EW-15	Hecla	575.00	161-575	NA	NA	9,855.00	06/01/59
EW-16	Hinsley	530.00	500-530	NA	NA	10,600.00	09/01/80
EW-17	Zakraisek	50.00	NA	9,866.15	-6.17	9,872.32	01/01/65
EW-18	F. Shober	90.00	66-90	9,871.87	-5.75	9,877.62	12/16/66
EW-19	R. Shober	45.00	NA	9,874.99	-4.50	9,879.49	01/01/62
EW-20	Bain	90.00	NA	NA	NA	10,620.00	01/01/80
EW-21	Archuletta	90.00	NA	9,829.15	-5.75	9,834.90	01/01/65
EW-23	Winkler	39.00	17-39	9,839.67	-3.67	9,843.34	09/12/72
EW-24	Wibbenmeyer	76.00	NA	NA	NA	9,750.00	01/01/76
EW-25	Myers/Well	42.00	NA	9,930.15	-5.92	9,936.07	NA
EW-26	Gruden	43.00	NA	9,958.13	0.17	9.957.96	10/01/85
EW-27	Flores	15.00	0-15	9,854.50	2.67	9,851.83	NA
EW-28	Molleur/Ponzie	110.00	85-110	9,626.52	-6.71	9,633.23	10/12/72
EW-29	Molleur/Field	100.00	65-100	9,622.15	2.00	9,620.15	09/28/74
EW-32	Myers/Cribbed	20.00	0-20	9,928.71	-7.08	9,935.79	NA
EW-33	Leadville Gold	130.00	NA	9,812.09	2.00	9,810.09	NA
EW-35	Cerise	60.00	NA	9,502.05	-4.52	9,806.57	NA
EW-36	Zadra	180.00	135-180	NA	NA	9,685.00	01/01/79
EW-37	Lk Fk Trlr Aban	40.00	NA	9,822.00	2.00	9,520.00	NA
EW-M.S.	Molleur/Shop	32.00	NA	9,634.00	1.00	9,633.00	NA

[a]Well construction information limited. Best available information used, but specific details of well construction unknown.

Note: NA=Information not available.

DE/CALGU6/009.2

Soils and tailings samples were collected in October 1984. In November 1984, the following samples were taken: surface water samples; groundwater samples from the 21 new monitoring wells; and samples from approximately 20 existing private wells. All water samples were submitted to laboratories in the EPA Contract Laboratory Program (CLP) for analysis. This effort was consistent with the Quality Assurance Project Plan (QAPP) shown in Appendix A and designated by the Sample Tracking Codes in Appendix B.

All subsequent sampling rounds were conducted in a similar manner and are documented chronologically in detail in Appendices C through N. Included with each sampling round are technical memoranda documenting the following: field work, resultant water chemistry data, field health and safety plans, data quality control statements, and documentation of any concurrent special activities.

Special activities that occurred during the sampling program consisted of (1) specific surface water flow measurements conducted in August 1985 (Appendix K); (2) sampling and flow measurements because of a surge event from the Yak Tunnel on October 22, 1985 (Appendix M); and (3) aquifer pump tests in conjunction with the November 1985 routine field sampling event (Appendix N).

DETAILED CHRONOLOGY OF THE RI

To assist in the understanding of project development, a monthly chronology of RI activities is presented as follows:

June 1983--Initial site visit conducted and preliminary work plan developed.

July 1983--Draft work plan submitted to EPA for review and comment.

August 1983--Revised work plan resubmitted to EPA for review.

October 1983--Project team kickoff meeting was implemented; work plan not yet approved.

November 1983--Project team site visit made. Canvassing of existing private wells was conducted.

December 1983--Work plan was approved by EPA. COE Report on tailings impoundments received and reviewed. A plan for winter drilling activities was prepared.

January 1984--Drilling was not conducted due to extremely poor weather conditions. Ground and surface water monitoring plans were submitted. Agricultural sampling and geotechnical investigation plans were developed.

February 1984--The QAPP was completed and approved (Appendix A); groundwater monitoring plans were approved by EPA.

March 1984--A sampling round of existing wells was completed (see Appendix B for Sample Tracking Codes and Appendix C for groundwater data). A draft work plan for tailing stability studies was completed. The draft agricultural sampling plan was prepared and underwent review by EPA.

April 1984--Groundwater data from March 1984 sampling round were received and audited. The formal agricultural sampling plan and tailings impoundment work plan revision request were submitted; significant work scope expansions were anticipated.

May 1984--A meeting with the CDH, EPA, and ASARCO was conducted regarding the Yak Tunnel. Four flumes were installed in the California Gulch drainage. A revised work plan for an alluvial groundwater investigation was submitted. The agricultural work plan was not approved.

June 1984--Surface water and groundwater sampling was conducted (see Appendix D for field memoranda and chemical data); extremely rapid snowmelt and several intense thunderstorms caused breaching of the existing drainage course in upper California Gulch. The high runoff washed out several of the flumes.

July 1984--Flume washouts occurred again due to high precipitation and runoff. Flume repairs were made. Addenda to groundwater sampling plans were submitted. The project management team conducted a thorough site reconnaissance.

August 1984--Meetings were organized and conducted with ASARCO, Hecla Mining Co., and Apache Energy and Minerals Co. concerning such items as site access agreements and sampling plans. Draft technical memoranda were then developed regarding revised Phase I RI activities with primary emphasis being given to the water quality program.

September 1984--Limited surface water sampling was conducted (Appendix E). Revisions to the proposed sampling and monitoring program (Phase I work plan revisions) were completed after additional review meetings with appropriate interested parties. Work scopes and requests for proposals (RFP's) for contractor field work were developed and submitted to EPA for review. Assignment of tailings stability analysis and special water supply issues were given to EPA's Emergency Response Team (ERT).

October and November 1984--Field work began on a fast-track basis: five Parshall flumes were reconstructed and/or relocated; 21 new groundwater monitoring wells were installed; approximately 40 shallow piezometer pipes were installed; all well casings were field surveyed for vertical control; surface and groundwater sampling was conducted; tailings and soils samples were taken; (Appendix F details activities for field construction; Appendices G and H detail soils and water sampling activities, respectively). ASARCO repaired erosion breaches that occurred adjacent to Tailings Pond No. 2 during the summer and rechannelled flow away from the impoundment.

December 1984--A project meeting with EPA was conducted to develop project surface water quality data goals, physical project boundaries, cost estimates, and revised project schedules.

January and February 1985--Quality assurance and quality control (QA/QC) reviews were conducted on November 1984 water quality data that resulted in selective re-analysis by EPA laboratories (Appendix H). A Draft Technical Report documenting October and November 1984 field work was completed and distributed.

March 1985--The Technical Report (Appendix F) was finalized, and early spring water sampling was conducted (Appendix I).

April and May 1985--Data analysis was conducted. A field maintenance program for surface water facilities was developed and implemented.

June 1985--The summer water quality sampling program was conducted (Appendix J).

July and August 1985--Data analysis continued. Special surface water flow measurements were conducted within California Gulch and on the upper and lower segments of the Arkansas River to determine groundwater contributions, if any, from California Gulch to the Arkansas River (Appendix K).

September 1985--The fall water quality sampling program was conducted (Appendix L).

October 1985--Consideration was given to the development of a pump test program to gather additional data for the groundwater issues raised earlier. A surge from the Yak Tunnel occurred on October 22 that resulted in a two-day field visit where water and sludge samples were taken and flume maintenance was conducted (Appendix M).

November 1985--The early winter water quality sampling program and aquifer pump tests were conducted (Appendix N).

December 1985, January 1986--Data interpretation and preparation of the draft RI Report was undertaken.

February to June 1986--EPA reviewed the draft Phase I RI Report.

May 1986--Phase II and RI supplemental data gathering activities commenced. Data gathering primarily occurred on tailings pile stability, Yak Tunnel geology and mining records, and mine waste piles.

July to September 1986--Phase I RI Report revised for additional review by EPA. Surface solids stability assessed and surface solids sampling occurred.

October to December 1986--Phase I RI Report revised. Operable Unit Feasibility Study (OUFS) on the Yak Tunnel authorized and started. Field sampling portion of Phase II RI completed.

January to April 1987--OUFS on the Yak Tunnel revised to incorporate SARA requirements. State reviewed and commented on drafts of the RI and OUFS.

DATA BASE

The data collected during the California Gulch RI are shown in Volumes 1 and 2 of the Appendices. The types of data include:

- Water Quality Data
  - New Monitoring Wells
  - Existing Private Wells
  - Surface Water
- Tailings/Soils/Precipitate
  - Total Metals and Anions
  - EP-Toxicity

- X-Ray Diffraction (XRD Analysis on Yak Tunnel surge event precipitate)

- Field Measurements

  - pH (instantaneous and continuous)
  - Specific Conductivity
  - Water Temperature
  - Water Levels
    - Wells
    - Piezometers
  - Pump Test Data
  - Surface Flow
    - Parshall Flumes and Continuous Recorders
    - Cutthroat Flumes
    - Marsh-McBirney Current Meter
    - USGS Gauging Station
  - Lithologic Drilling Logs for New Wells
  - Representative Geophysical Logs for New Wells

All samples and field measurements were collected according to procedures outlined in the QAPP (Appendix A) and the Technical Report (Appendix F). The purpose of these documents was to assure QA/QC of field and laboratory procedures and to validate the data.

Major steps in the data validation process for the California Gulch site are:

- Chain-of-custody (COC)
- Field QA/QC
- Laboratory QA/QC
- Cation/anion balances

CHAIN-OF-CUSTODY (COC)

COC is an step in the data validation process whereby the field team and the laboratory personnel maintain a sample custody chain. This involves the use of COC records to inventory all samples and seals to prevent sample tampering. This system was developed by the CLP and is outlined in Appendix A.

FIELD QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Water samples collected in the field to verify QA/QC are:

- Field blanks
- Bottle blanks
- Field replicates

Field blanks were collected to verify that no cross-contamination is entering the sample due to sample collection procedures. Sampling equipment was decontaminated between each sampling location, and QA/QC samples of this process were collected at a frequency of 1 in 20. Double-distilled, deionized water was run through the sampling process (including filtration) and then analyzed.

Bottle blanks are run by the container distributor to determine cross-contamination. Field replicates were also collected at a frequency of 1 in 20 to verify the representativeness of the samples collected.

LABORATORY QA/QC

The CLP laboratories conduct the following QA/QC procedures at a frequency of 1 in 20:

- Laboratory reagent blanks

- Laboratory preparation blanks
- Laboratory replicates
- Laboratory natural matrix spikes
- Inductive Coupled Plasma (ICP) interference check samples
- Instrument detection limits
- Instrument calibration
- Instrument calibration blanks
- Initial calibration verification
- Continuing calibration verification

The QA/QC review of the above laboratory procedures is included in the Appendix for each sampling event. The review criteria for laboratory data are in the CLP Statement of Work, Inorganics Analysis, 1984 contract.

CATION/ANION BALANCE

Following QA/QC, the data were entered into a database management system. This system incorporates dBase III and TDM II. Samples were coded with the following designation for QA types:

- O--Original
- S--Spike sample
- R--Replicate sample
- FB--Field blank
- BB--Bottle blank

Only original samples were run on the cation/anion balances program. This was to check the validity of the data based on criteria of less than 20 percent error in the balance. This program served to check both data input and laboratory errors. In summary, all data so far have been checked for QA/QC, and the data in the appendices are acceptable for use.

STATISTICAL ANALYSIS

To assist in understanding data presentation and analysis covered in the next section of the report, a brief explanation of statistical analysis of data is useful. A more detailed description is offered in Section 4. The laboratory analytical results were subjected to statistical analysis that determined which cations and anions correlated well and could be used as surrogates to better describe and understand the water quality data. Significant correlation between certain cations were established and a subsequent factor analysis performed. Use of this technique identified cadmium, zinc, and sulfate as useable surrogates for the California Gulch geochemical system.

Nature and Extent of Contamination

Section 4

NATURE AND EXTENT OF CONTAMINATION

The Phase I RI investigation primarily centered upon assessing the nature and extent of groundwater and surface water contamination. In this section, the results of the sampling program for surface solids, surface water, and groundwater are presented. Chemical reactions that mobilize metals are discussed. Air, a potential contaminant transport pathway, was not sampled as part of this program. Air quality is discussed in Section 5.

The California Gulch drainage accepts continuous flows from both the Yak Tunnel and the sewage treatment plant discharge. Other tributaries to the Gulch are ephemeral and generally flow during snowmelt (May and June) and high intensity summer thunderstorms.

Figure 4-1 presents the conceptual model of potential sources of contamination and likely media interaction at the site. Statistical analyses have been conducted on the data, which identified appropriate cations and anions that are used to assess the relationships between surface water and groundwater. Surface water and groundwater data are compared using seasonal flows, water levels, and chemistry. Pump tests were conducted to better understand alluvial aquifer characteristics. Piezometer information was analyzed and demonstrated the interconnection between the shallow groundwater and surface water system in the mainstem of the Gulch. This relationship allowed the use of mass-loading analysis to assess both area and point sources of contamination and the relative contribution of each to the mainstem of California Gulch. Subsequently, water quality was assessed for the Arkansas River at its confluence with the Gulch.

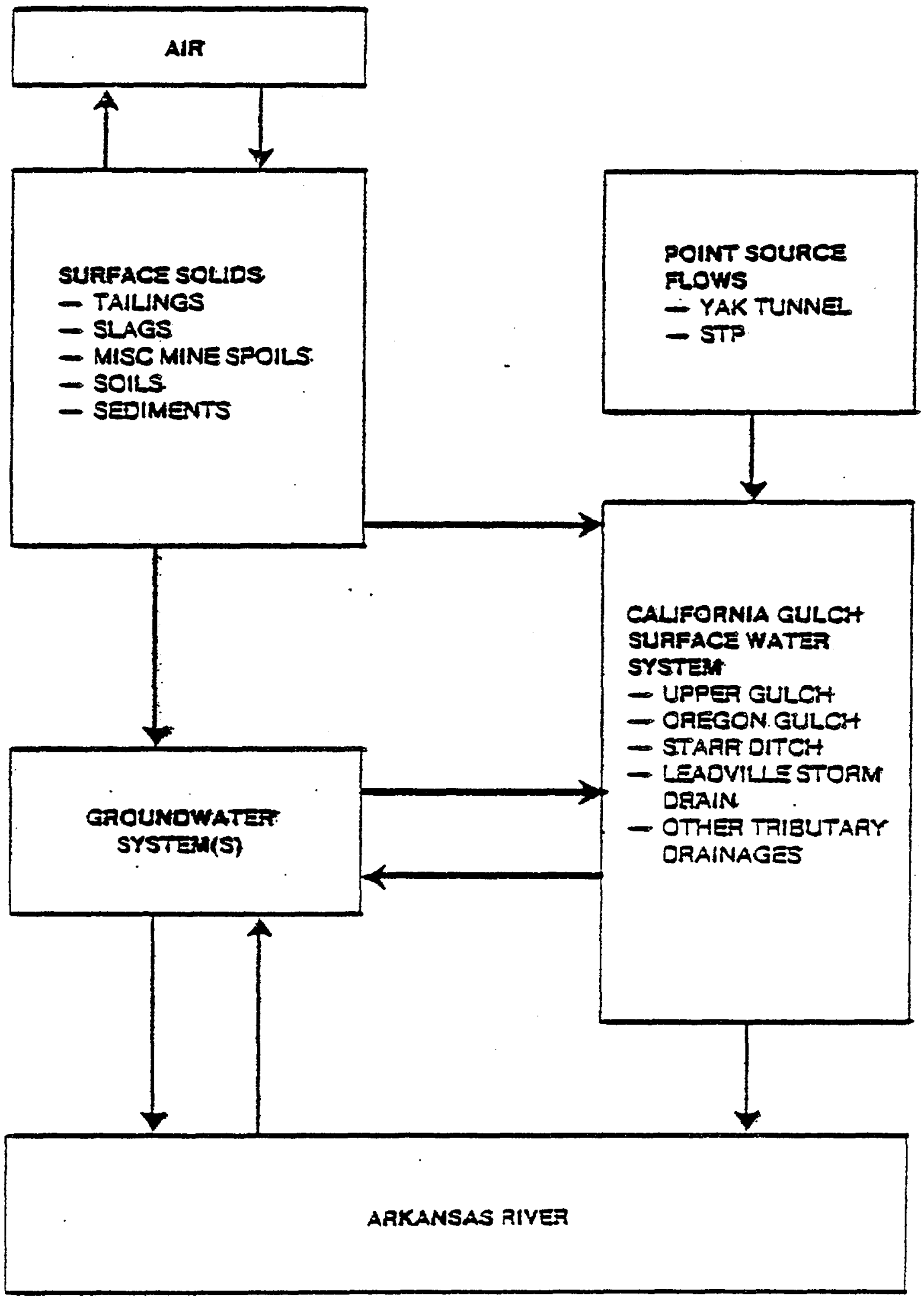

FIGURE 4-1
POTENTIALLY CONTAMINATED MEDIA
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

With an understanding of the water quality and the identification of contaminant sources, a focused Phase II RI program has been outlined in Section 5.

SURFACE SOLIDS

Surface solids include mill tailings, miscellaneous mine waste dumps, slag piles, soils, and sediments. These remnant mining-related wastes are potential sources of metal contamination to surface water and groundwater. The wastes are composed of materials taken from below ground and exposed to an oxidizing environment. Oxidation of the surface solids causes release of metals from the sulfide minerals by converting the metals to more soluble forms. These soluble forms can be transported into the surface water and groundwater systems. In addition, surface solids can be carried by surface water runoff as suspended sediments.

Seasonal runoff can carry large quantities of sediments to the Arkansas River. Suspension, deposition, and further chemical oxidation can occur when this mobilization of sediments occurs.

MINERAL - WATER INTERACTIONS

The predominant geochemical system in the project area is an acid-sulfate system caused by the oxidation of sulfide minerals. Mine wastes, tailings, slags, and waste rock material contain various concentrations of numerous sulfide minerals. The oxidation of pyrite (iron sulfide-FeS_2) is one of the most acidic weathering reactions known. Oxygen sources include the surrounding air and dissolved oxygen in water. The process has been described in detail by Nordstrom (1985).

The overall reaction is commonly described as follows:

(1) $4\ FeS_2 + 15\ O_2 + 14\ H_2O \rightarrow 4\ Fe(OH)_3 + 8H_2SO_4$

The key to the high acid production in pyrite oxidation lies in the generation of ferric ion (Fe^{+3}), which also attacks pyrite.

(2) $FeS_2 + 14\ Fe^{+3} + 8H_2O \rightarrow 15Fe^{+2} + 2\ SO_4^{=} + 16H^+$

These reactions are directly related to pH, because reactions 2, 3, and 4 involve hydrogen ions (H^+). However, the oxidizing rate of the ferric ion occurs extremely slowly in the pH range of typical acidic drainage. A catalytic agent, bacterial microorganisms, substantially increases the reaction rates (Singer and Stomm, 1970).

The oxidation of other metal sulfide minerals (such as CuS, PbS, ZnS, and Ag_2S) does not contribute to the formation of acid water (Wentz, 1974). These metals are mobilized as metal ions by the acid created with the generation of ferric ion (see reaction #2 above). Mobilization of metals (Me) from sulfide ores is described as follows:

(3) $MeS + 2\ H^+ \rightarrow Me^{++} + H_2S$

When acidic mine water mixes with oxygen, the metal cations in solution are oxidized. The oxidized metals may form precipitates. This reaction is exemplified by the formation of ferric hydroxide precipitate:

(4) $2\ Fe^{++} + 1/2O_2 + 5\ H_2O \rightarrow 2\ Fe(OH)_3 + 4\ H^+$

The formation of ferric hydroxide, mixed with various forms of basic ferric sulfates, gives rise to the accumulation of "yellow boy" (Emmons, 1927). Yellow boy is a limonitic precipitate which forms along the bottom of stream channels and drainage tunnels.

Acid-sulfate water also reacts with the limestone contained within certain mineralized zones of the Iron Hill and Carbonate Hill ore bodies. This reaction moderates the concentration of metals in solution by the formation of carbonates.

There are a variety of buffering reactions possible between acids and limestone. These reactions seek equilibrium based on the amount of oxidized pyrite and availability of limestone and bicarbonate in solution.

TAILINGS

The mill tailings pose a threat to water quality because of the presence of sulfide minerals, particularly pyrite. Sulfides, being the metal-bearing ore, were processed to remove lead, zinc, copper, gold, and silver. The iron sulfide, or pyrite, remained in the tailings. During the milling process, the sulfide ores were ground to a small grain size to separate out the metals; particles could be as small as 200 mesh (0.074 millimeters), which is a common grinding size for massive-sulfide ores. These small particles have then been exposed to the oxidizing atmosphere and surface water.

The general chemical composition of the tailings material, when deposited, likely changed on a monthly or quarterly basis, because mined ores were mixed from different portions of the underground workings. Extensive comingling of wastes occurred. Sulfide wastes were mixed with carbonate wastes; sulfide wastes that were high in lead were mixed with sulfide wastes high in zinc. This mingling and layering of chemically varying wastes made the tailings chemically heterogeneous. Thus, the tailings are difficult to properly sample to obtain representative results.

An initial evaluation of the chemical characterization of the four major abandoned tailings impoundments at the site was undertaken. Three impoundments (ASARCO Resurrection, ASARCO #2, and Apache) are located in California Gulch, adjacent to the southeast boundary of the City of Leadville. The fourth is located in Oregon Gulch, a tributary to California Gulch. These impoundments are shown in Figure 4-2.

The volume of tailings in each impoundment was estimated from existing topographic maps; ASARCO Resurrection - 155,000 cubic yards; ASARCO #2 -322,000 cubic yards; Apache Energy and Mineral Co. - 725,000 cubic yards; and Oregon Gulch - 523,000 cubic yards (Steffen Robertson and Kirsten, 1986).

The tailings characterization program was designed to assess if any of these impoundments contained a potential source of the metals that are found in nearby surface water and groundwater. A secondary assessment was undertaken to categorize the tailings materials as characteristic or non-characteristic waste. This characterization was done using the EP-Toxicity test.

Samples from each of the tailings impoundments were collected by auger to an approximate 7-foot depth; see Figure 4-2 for sample locations. These samples were analyzed for the total metals presented in Table 4-1. The samples were also analyzed

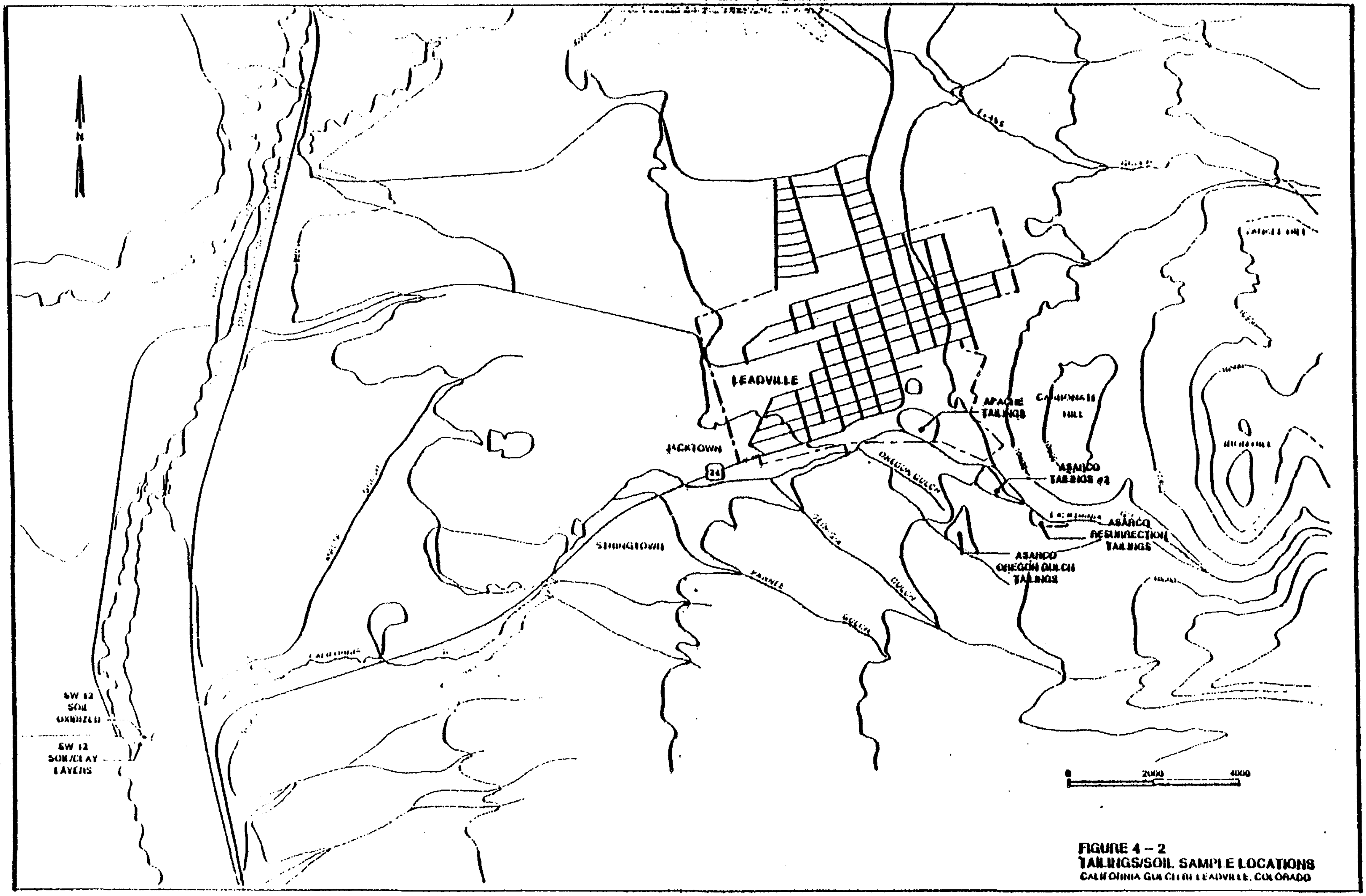

FIGURE 4 – 2
TAILINGS/SOIL SAMPLE LOCATIONS
CALIFORNIA GULCH LEADVILLE, COLORADO

Table 4-1
ANALYSIS OF TAILINGS SAMPLES

Parameter as mg/Kg	ASARCO Resurrection Tailings		ASARCO Tailings #2		ASARCO Oregon Gulch Tailings		APACHE Tailings	
	As Rec'd[a]	Dry	As Rec'd	Dry	As Rec'd	Dry	As Rec'd	Dry
Aluminum, Al	225	258	252	296	242	303	534	578
Chromium, total Cr	2.91	4.49	4.10	4.82	1.59	1.99	1.63	1.76
Barium, Ba	2.15	2.47	1.80	2.12	2.65	3.32	1.96	2.12
Beryllium, Be	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	0.2
Cadmium, Cd	90.0	103	29.2	34.3	34.4	43.1	18.6	20.1
Cobalt, Co	4.31	4.94	5.41	6.36	6.12	7.68	5.09	5.51
Copper, Cu	354	406	254	298	460	577	166	180
Iron, total Fe	15,500	17,800	21,600	25,400	2,630	3,300	8,680	9,390
Lead, Pb	5.28	6.06	12.9	15.2	29.4	36.9	2.16	2.34
Nickel, Ni	7.24	8.31	7.70	9.05	8.93	11.2	8.81	9.53
Manganese, Mn	5,560	6,380	4,320	5,080	1.14%	1.43%	2,580	2,790
Zinc, Zn	9,350	10,700	3,800	4,470	5,720	7,180	2,500	2,700
Boron, B	78	89	<16	<19	<17	<21	<20	<21
Vanadium, V	<2	<2	<2	<2	<2	<2	<2	<2
Calcium, Ca	9,350	10,700	7,960	9,360	20,500	25,700	13,100	14,200
Magnesium, Mg	6,540	7,500	4,420	5,200	9,750	1.22%	4,660	5,040
Sodium, Na	3.33	3.82	2.46	2.89	4.14	5.19	3.52	3.81
Potassium, K	1.17	1.34	1.47	1.73	<0.83	<1.00	<1.0	4.0
Arsenic, As	54.8	62.9	59.0	69.4	18.2	22.9	1.96	2.12
Antimony, Sb	15.7	18.0	11.5	13.5	14.9	18.7	9.8	10.6
Selenium, Se	0.29	0.33	0.18	0.21	0.25	0.31	0.14	0.15
Thallium, Tl	1.9	2.2	<0.2	<0.2	1.6	2.0	3.9	4.2
Mercury, Hg	0.090	0.100	0.135	0.159	0.070	0.088	0.048	0.052
Tin, Sn	<20	<23	<16	<19	<17	<21	<20	<21
Silver, Ag	0.20	0.23	0.16	0.19	0.33	0.41	0.30	0.22
Cyanide, total CN	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulfur, total S	3,770	-	5,890	-	3,060	-	2,960	-
pH	5.8	-	5.7	-	5.2	-	6.7	-
Moisture	128,000	-	150,000	-	203,000	-	76,000	-
Sulfate (SO_4) Soluble	8,540	-	9,120	-	7,780	-	6,200	-
Chloride, Cl	1,070	-	978	-	751	-	227	-

[a]As received, including moisture.

by the Resource Conservation and Recovery Act (RCRA) extraction procedure for toxicity, (40 CFR 260.20). The results are shown against the criteria in Table 4-2.

Tailings samples were analyzed both on a wet (as received) and dry basis. The wet analysis provides an indication of the moisture content existing in the tailings. Tailings are measured as metal weight per unit weight of tailings; the weight of the water (soil moisture) increases the unit weight of the tailings, thus decreasing the metal concentration. Dry analyses indicate the actual metal concentrations in the tailings.

Moisture content of the tailings ranged from 7.6 to 20.3 percent, which if oxygenated could be partially responsible for sulfide oxidation. Soluble sulfate, which is a surrogate of the oxidation process, ranged from 6,200 to 8,540 milligrams per liter (mg/l). Water, in large amounts, can transport the soluble metals into the surface water and groundwater systems.

On a dry basis, the metals concentration in the tailings were high; zinc ranged from 2,700 parts per million (ppm) to 10,700 ppm; lead from 2.34 to 36.9 ppm; and cadmium from 20.1 to 103 ppm. The ASARCO Resurrection tailings sample contained the highest concentrations of zinc (10,700 ppm), cadmium (103 ppm), and iron (17,800 ppm). The Oregon Gulch tailings sample contained the highest concentration of lead (37 ppm) and manganese (14,300 ppm).

The RCRA extraction procedure for toxicity (EP-Toxicity) results are presented in Table 4-2. These results indicated the material in the Resurrection tailings impoundment as a characteristic hazardous waste. The ASARCO Resurrection

Table 4-2
TAILINGS EP-TOXICITY DATA

Parameter as mg/L	ASARCO Resurection Tailings	ASARCO Tailings #2	ASARCO Oregon Tailings	APACHE Tailings	Criteria
Arsenic, As	§0.005	§0.005	§0.005	§0.005	5.0
Barium, Ba	0.07	0.07	0.06	0.06	100
Cadmium, Cd	1.68[a]	0.640	0.026	0.043	1.0
Chromium, total Cr	§0.005	§0.005	§0.005	§0.005	5.0
Lead, Pb	1.80	0.42	1.20	§0.005	5.0
Mercury, Hg	§0.0005	§0.0005	§0.0005	§0.0005	.2
Selenium, Se	§0.005	§0.005	§0.005	§0.005	1.0
Silver, Ag	§0.001	§0.001	§0.001	§0.001	5.0

[a]Exceeded criteria for the determination of characteristic waste.

DE/CALGU6/011.2

tailings material exceeded the EP-toxicity criteria for cadmium, which is 1.0 mg/l. This was the only metal in any of the four tailings samples that exceeded EP-Toxicity criteria.

Physical stability of the tailings impoundments is important because of potential mass wasting. Mass wasting is the removal of material by two mechanisms: (1) having the material solubilized, and (2) having the material transported as suspended solids. Mass wasting was observed during site visits, and is of concern because three tailings impoundments are located within the 100-year floodplain of California Gulch. The major factor affecting the potential for failure of the impoundments appears to be embankment erosion from surface runoff rather than typical slope failures (Steffen Robertson and Kirsten, 1986).

In summary, the four major abandoned tailings impoundments within the site boundary can act as a source of heavy metals to the surface water and groundwater. The primary migration mechanisms are release of solubilized metals through leaching and mass wasting.

STREAM SEDIMENTS

Surface water flows within California Gulch vary by season. The stream flow is generally controlled by the relatively steady discharge from the Yak Tunnel and STP. However, during snowmelt and heavy rainstorms, the ephemeral drainages (such as upper California Gulch, Oregon Gulch, and Starr Ditch, etc.) contribute significant amounts of additional flow as discussed later in this section.

The additional flow during runoff and rainstorms increases stream velocities; this can transport significant quantities of sediments. Near the confluence of the Gulch and the

Arkansas River, the near-level topography has resulted in the formation of a delta. This delta was formed from stream sediments dropping out of suspension because of lower flow velocities. In the delta, sediments from both the surface and several feet below surface are likely representative of the sediments carried down California Gulch over time.

Two soils/sediment samples were collected during construction of the lower flume (SW-12) to characterize this type of material. One sample was taken at the surface and one sample at a depth of approximately 4 feet. The analytical results for these samples are shown in Table 4-3. Samples were analyzed on both a wet and dry basis. The surface soil sample has higher levels than the subsurface sample for cadmium, copper, iron, lead, manganese, zinc, arsenic, mercury, and silver. Active deposition of these metals is occurring in the stream sediments. The metals concentrations in the two sediment samples, as compared to tailings, indicate similar iron values; lower cadmium, zinc, and manganese; and higher lead concentrations.

The sediment samples were also subjected to the EP-Toxicity test to categorize them as characteristic or non-characteristic waste. These results are presented in Table 4-4. The upper (oxidized) sediment/soil sample indicates that this sample is a characteristic waste. Because the analysis technique does not identify the lead compound, the ability of the lead to mobilize in the surface water is not known.

These initial sediment analyses indicate that further characterization of various mine spoil areas and collection of additional sediment samples should be conducted in the Phase II RI program to better define the impacts of sediments and sediment transport.

Table 4-3
ANALYSES OF SOIL SAMPLES

Parameter as mg/Kg	SW-12 Soil (Surface) As Rec'd	SW-12 Soil (Surface) Dry	SW-12 Soil/Clay (at Depth) As Rec'd	SW-12 Soil/Clay (at Depth) Dry
Aluminum, Al	1,680	1,920	9,590	140,000
Chromium, total Cr	3.55	4.05	20.9	30.6
Barium, Ba	154	176	78.3	115
Beryllium, Be	<0.2	<0.2	1.26	1.85
Cadmium, Cd	9.89	11.3	0.088	0.129
Cobalt, Co	2.17	2.48	4.92	7.21
Copper, Cu	52.6	60.2	8.08	11.8
Iron, total Fe	13,600	15,500	6,550	9,600
Lead, Pb	1,790	2,040	15.9	23.3
Nickel, Ni	2.37	2.71	8.21	12.0
Manganese, Mn	1,030	1,180	454	665
Zinc, Zn	1,550	1,770	351	514
Boron, B	39	44	12.6	18.5
Vanadium, V	3.9	4.4	26.5	38.8
Calcium, Ca	456	521	2,310	3,390
Magnesium, Mg	266	304	2,640	3,870
Sodium, Na	26.4	30.2	15.1	22.1
Potassium, K	185	211	258	378
Arsenic, As	18.4	21.0	4.17	6.11
Antimony, Sb	<10	<11	6.3	9.2
Selenium, Se	<1.10	<1.10	0.10	0.15
Thallium, Tl	<2	<2	<1	<2
Mercury, Hg	4.21	4.81	0.660	0.967
Tin, Sn	<20	<23	<13	<19
Silver, Ag	5.73	6.55	0.13	0.19
Cyanide, total CN	<0.02	<0.02	<0.02	<0.02
Sulfur, total S	2,260	-	1,200	-
pH	3.9	-	5.0	-
Moisture	125,000	-	318,000	-
Sulfate (SO_4), Soluble	6,580	-	2,620	-
Chloride, Cl	696	-	2,680	-

DE/CALGU6/011.3

Table 4-4
SOILS EP-TOXICITY DATA

Parameter as mg/L	SW-12 Soil (Surface)	SW-12 Soil/Clay (4 ft Depth)	Criteria
Arsenic, As	<0.005	<0.005	5.0
Barium, Ba	<0.05	<0.05	100
Cadmium, Cd	0.068	0.0007	1.0
Chromium, total Cr	<0.005	<0.005	5.0
Lead, Pb	9.20[a]	0.031	5.0
Mercury, Hg	<0.0005	<0.0005	.2
Selenium, Se	<0.005	<0.005	1.0
Silver, Ag	<0.001	<0.001	5.0

[a]Exceeded criteria for the determination of characteristic waste.

DE/CALGU6/011.4

In addition, precipitate samples from the October 1985 surge event were also collected. The precipitate was analyzed semi-quantitatively, using a X-Ray diffractometer. It was determined that the major trace constituents of the precipitate included lead, arsenic, zinc, and copper. A summary of the results is presented in Table 4-5. Detailed results are found in Appendix M.

SLAGS

Up to 40 smelters were located in the study area (Emmons, 1927), each using a variety of processes and feedstock concentrates. There were both copper smelters and lead smelters. Slags from these operations probably varied in chemical composition and metal concentration. During this initial investigation phase, slag samples were not collected. Instead, literature (Schuhmann, 1952) was reviewed to determined typical slag chemistry from copper and lead smelters. These slags contain constituents typically in the concentration ranges shown in Table 4-6.

Lead slags are primarily comprised of silica, calcium, and iron; unrecovered zinc and leads are present. Copper slags are also primarily comprised of silica, calcium, iron, and alumina; unrecovered copper is present. Both types of slags contain sulfur, which is a by-product of turning sulfides into metal oxides. The slags located within the site probably contain the types of metals that have been found in the nearby surface water and groundwater. These slags also probably contain sulfur that could, when oxidized, produce acids that would mobilize these metals.

SURFACE WATER

Surface water acts as the primary transport mechanism for both soluble metals and metal-laden sediments. The surface

Table 4-5
XRD RESULTS OF OCTOBER 1985 SURGE EVENT PRECIPITATE

Major Elements	Weight (%)
Fe_2O_3 [$Fe_2(OH)_3$]	88.3
SiO_2	5.1
S	3.2
Al_2O_3 [$Al_2(OH)_3$]	1.9
K_2O	.4
P_2O_5	.2

Major Trace Elements	(ppm)
Zinc (Zn)	1128
Copper (Cu)	1046
Lead (Pb)	551
Arsenic (As)	158

DE/CALGU6/018

Table 4-6
TYPICAL FURNACE SLAG CHEMISTRY

Compound	Lead Blast Furnace Weight Percent	Copper Reverb Furnace Weight Percent
SiO_2	26.8 - 35.0	37.3 - 38.3
CaO	8.0 - 20.5	4.7 - 20.3
FeO[a]	28.7 - 36.8	22.3 - 46.0
MgO	1.7 - 4.9	trace - 2.1
Al_2O_3	3.4 - 5.7	6.9 - 10.9
S	1.1 - 3.0	0.14 - 1.1
Cu	trace - 0.3	0.44 - 1.1
Pb	0.9 - 1.6	-
ZnO	5.6 - 12.5	-

[a]Total iron content expressed as FeO.

Source: (Schuhmann, 1952)

DE/CALGU6/019

waters of the California Gulch drainage were measured for flow rate and sampled for chemistry numerous times, generally in conjunction with groundwater sampling and water level measurements. Data from the sampling episodes are tabulated and presented in Appendices D, E, H, I, J, L, and N. A summary of the data is presented in the following sections.

SURFACE WATER FLOW

The principal contributors to surface water flow in the main-stem of the Gulch are the discharges of the Yak Tunnel and the STP. Flow from the Yak Tunnel seasonally varies between 1 and 2 cfs; and the STP flows at a nearly constant 1 cfs. The Yak Tunnel flow generally peaks in June, about the same time as peak runoff of snowmelt occurs. During snowmelt, and during intense, short duration summer thunderstorms, ephemeral drainages such as upper California Gulch, Starr Ditch, and Oregon Gulch carry a considerable flow volume. Flow was measured at key locations during the major five quarterly sampling periods and is shown in Tables 4-7 to 4-11. These tables also include pH and chemistry data at various locations along the Gulch, its tributaries, and the Arkansas River upstream and downstream of its confluence with the Gulch. Overall, the November and June events appear representative of low and high flows, respectively. The flow data for November and June are summarized in Table 4-12. All surface water flow measurements are summarized in the Hydrology Correlation section of the IA.

SURFACE WATER CHEMICAL DATA AND SEASONAL INFLUENCE

Tables 4-7 to 4-11 contain the results of analyses of surface water samples collected during the five quarterly sampling periods. For comparison purposes, there is a listing of the primary drinking water standards and federal water quality criteria for aquatic life.

TABLE 4-3
SURFACE WATER CHEMICAL ANALYSES AND FLOWS
November 1986

Description	Station	Flow (cfs)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
CALIFORNIA GULCH MAINSTEM																					
Upper Cal Gulch	SW-1	.31	8.1	10 U	73	12	10 U	25 U	171/5,359	149	265/354	0.2 U	40 U	5 U	10 U	1,506	1,380	43,000	5,500	18,000	10 U
Mill Yard Flume	SW-3A	1.57	6.0	10 U	65	162	10 U	419	3,010/3,468	10	9,835/3,804	0.2	40 U	5 U	10 U	37,170	650	295,000	1,000 U	422,000	10 U
Tailings Area	SW-4	.89	3.7	10 U	65	201	10 U	72	11,630/25,900	6	15,840/15,890	0.25	32	5 U	10 U	52,920	690	500,000	35,000	630,000	10 U
Below Apache	SW-4A	NA																			
Middle Flume	SW-7	2.53	6.3	10 U	61	117	10 U	41	2,610/6,573	5 U	17,860/13,530	0.25	29	5 U	10 U	36,100	690	425,000	34,000	692,000	10 U
Stringtown	SW-9	2.38	5.5	10 U	200 U	159	10 U	16	6,394/18,950	5 U	23,860/21180	0.30	52	5 U	10 U	48,070	860	475,000	19,000	738,000	10 U
TRIBUTARIES																					
Parkville Leak	SW-2	0.15	7.4	10 U	95	5 U	10 U	25 U	100 U/2,747	25	150/36	0.32	40 U	5 U	10 U	111	1,500	5,000	4,500	34,000	10 U
Yak Tunnel	SW-3	1.10	6.0	10 U	67	244	10 U	736	4,704/9,852	5 U	15,230/14,260	0.35	33	5 U	10 U	5,850	570	750,000	35,000	676,000	10 U
Starr Ditch	SW-5	.58	7.6	10 U	126	5 U	10 U	25 U	30/1,595	5 U	109/204	0.28	40 U	5 U	10 U	362	1,600	23,000	35,000	138,000	10 U
Oregon Gulch	SWI-1	Dry																			
Berthod Spring	SW-6	Dry																			
Storm Drain	SWI-2	Dry																			
Georgia Gulch	SWI-3	0.03	6.8	10 U	200 U	72	10 U	21	7,681/7,005	5 U	27,460/23,470	0.2 U	79	5 U	10 U	68,480	170	118,000	7,000	1,078,000	10 U
Super 8 Spring	SW-8	.01	7.5	10 U	200 U	62	10 U	41	41/342	47	214/206	0.2 U	40	5 U	10 U	9,120	6,900	158,000	11,000	534,000	10 U
Pawnee Gulch	SWI-4	Dry																			
Airport Gulch	SWI-5	Dry																			
Slag Pile Spring	SW-10	0.11	6.3	10 U	200	91	10	25 U	164/1,037	5 U	882/759	0.22	92	5 U	10 U	44,170	350	1,040,000	45,000	1,000,000	10 U
STP	SW-11	1.13	8.3	10 U	200 U	5 U	10 U	25 U	43/160	5 U	292/281	0.2 U	23	5 U	10 U	720	9,400	75,000	7,000	360,000	10 U
Malta Gulch	SWI-6	Dry																			
CONFLUENCE																					
Lower Flume	SW-12	1.57[a]	7.0	10 U	200	47	10 U	13	56/1,092	5 U	9,074/9,232	0.22	40	5 U	10 U	14,710	6,200	375,000	13,000	400,000	10 U
Upper Arkansas River	SW-13	30	8.0	10 U	55	5 U	10	25 U	101/619	5 U	103/145	0.25	40 U	5 U	10 U	240	170	30,000	4,000	42,000	10 U
Lower Arkansas River	SW-14	NA	8.5	10 U	64	5 U	10 U	25 U	38/459	5 U	649/657	0.2 U	40 U	5 U	10 U	1,317	690	58,000	4,000	5,000	10 U

Comparative Standards

Standard				As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
• Primary Maximum Contaminant Level (MCL)				50	1,000	10	50			50		2		10	50						
• Water Quality Criteria Aquatic Life--CCC				190		1.1[b]	11	12[b]		3.2[b]		.012	160	35	.12	86[b]					5.2
--CMC				360		3[b]	16	18[b]		83[b]		2.4	1,400	260	4.1	90[b]					22

[a] Ice jam upstream of flume--flow rate questionable.
[b] Based on a water hardness of 100 mg/l $CaCO_3$.

Notes: Dry--Indicates no flows during sample period.
U--not detected; value set at detection limit.
NA--not analyzed/not available.
All Chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals only unless otherwise noted with two subcolumns (__/__); The first value shown is dissolved and the second value as total; values for Hg, NO_3, SO_4, Cl, TDS, and CN are total concentrations.
CCC--Criterion Continuous Concentration--4-day average not to be exceeded more than once every 3 years.
CMC--Criterion Maximum Concentration--1 hour average not to be exceeded more than once every 3 years.

DR/CALGU6/016.1

TABLE 4-8
SURFACE WATER CHEMICAL ANALYSES AND FLOWS
March 1988

Description	Station	Flow (cfs)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
CALIFORNIA GULCH MAINSTEM																					
Upper Cal Gulch	SW-1	Dry																			
Mill Yard Flume	SW-3A	0.99	6.25	10 U	70	172	3 U	456	1,610/5,520	5 U	16,400/15,500	0.2 U	20	25 U	3 U	46,100	440	502,000	2,300	721,000	10 U
Tailings Area	SW-4	0.55	6.32	10 U	67	167	3 U	49	10/8,950	5 U	13,900/15,400	0.2 U	24	5 U	3 U	42,600	370	526,000	2,100	715,000	10 U
Below Apache	SW-4A	NA																			
Middle Flume	SW-7	2.74	5.82	10 U	51	71	3 U	28	452/47,100	5 U	13,300/19,000	0.2 U	12	5 U	3 U	21,200	390	385,000	2,600	610,000	10 U
Stringtown	SW-9	NA	6.09	10 U	37	56	3 U	20	139/72,900	5 U	35/489	0.2 U	10 U	5 U	3 U	3,330	510	169,000	23,200	442,000	10 U
TRIBUTARIES																					
Parkville Leak	SW-2	Dry																			
Yak Tunnel	SW-3	1.06	6.13	10 U	67	169	3.5	437	1,570/5,450	5 U	13,700/15,300	0.2 U	21	5 U	3 U	43,700	440	502,000	2,300	706,000	10 U
Starr Ditch	SW-5	0.16	7.40	10 U	51	5	3 U	14	1,060/11,700	5 U	834/1,240	0.2 U	10 U	5 U	3 U	1,620	350	92,400	8,700	168,000	10 U
Oregon Gulch	SWI-1	Dry																			
Malta Gulch Spring	SW-6	0.04	5.10	10 U	13	177	3 U	45	3,830/8,340	176	17,100/18,100	0.2 U	38	25 U	3 U	45,700	240	681,000	7,600	1,050,000	10 U
Storm Drain	SWI-2	0.05	5.87	10 U	100	11	3 U	24	26/17,500	16	606/21,600	0.2 U	10 U	5 U	3 U	1,390	170	216,000	5,700	164,000	10 U
Georgia Gulch	SWI-3	0.03	6.58	10 U	23	32	3 U	3.3	4,660/12,200	5 U	16,800/24,400	0.2 U	19	25 U	3 U	30,000	420	770,000	4,700	1,070,000	10 U
Super 8 Spring	SW-8	NA	6.78	10 U	35	33	3.5	4.4	38/1,150	5 U	35/489	0.2	10 U	5 U	3 U	3,330	660	169,000	23,200	442,000	10 U
Pawnee Gulch	SWI-4	Dry																			
Airport Gulch	SWI-5	Dry																			
Slag Pile Spring	SW-10	0.03	6.30	10 U	11	69	3 U	11	113/1,830	5 U	16,304/1,780	0.2 U	21	25 U	3 U	35,600	60	921,000	5,100	1,310,000	10 U
STP	SW-11	1.38	7.08	10 U	53	5 U	3 U	6.9	179/89	5 U	440/21	0.2 U	10 U	5 U	3 U	1,100	320	46,400	15,000	52,000	10 U
Malta Gulch	SWI-6	Dry																			
CONFLUENCE																					
Lower Flume	SW-12	5.02	5.91	10 U	37	61	3 U	15	13/13,400	5 U	12,500/13,200	0.3	20	5 U	3 U	19,300	2,300	334,000	6,600	502,000	10 U
Upper Arkansas River	SW-13	9.2	6.49	10 U	72	5 U	3 U	4.1	80/322	5 U	257/273	0.2 U	10 U	5 U	3 U	569	6,590	78,200	1,400	205,000	10 U
Lower Arkansas River	SW-14	NA	6.79	10 U	55	11	3 U	8.1	29/8,280	5 U	2,100/2,520	0.2	10 U	5 U	3 U	2,970	1,690	108,000	2,100	263,000	10 U

Comparative Standards

Standard				As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
o Primary Maximum Contaminant Level (MCL)				50	1,000	10	50			50		2		10	50						
o Water Quality Criteria Aquatic Life--CCC				190		1.1[a]	11	12[a]		3.2[a]		.012	160	35	.12	86					52
--CMC				360		3[a]	16	18[a]		82[a]		2.4	1,400	260	4.1	90					22

[a]Based on a water hardness of 100 mg/l $CaCO_3$.

Notes: Dry--indicates no flows during sample period.
U--not detected; value set at detection limit.
NA--not analyzed/not available.
All Chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals only unless otherwise noted with two subcolumns (___/___): The first value shown is dissolved and the second value as total; values for Mg, NO_3, SO_4, Cl, TDS, and CN are total concentrations.
CCC--Criterion Continuous Concentration--4-day average not to be exceeded more than once every 3 years.
CMC--Criterion Maximum Concentration--1 hour average not to be exceeded more than once every 3 years.

DE/CAGU06/016.3

TABLE 4-9
SURFACE WATER CHEMICAL ANALYSES AND FLOWS
June 1985

Description	Station	Flow (cfs)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
CALIFORNIA GULCH MAINSTEM																					
Upper Cal Gulch	SW-1	2.67	3.4	3 U	15	81	4 U	444	5,140/5,000	382	4,100/3,390	0.1 U	27	5 U	3 U	12,700	180	230,000	3,000 U	400,000	10 U
Hillyard Flume	SW-3A	3.52	3.2	3 U	31	420	4.0	4,670	22,000/30,300	310	24,300/21,800	0.1 U	65	50 U	3 U	83,100	310	1,020,000	3,000 U	1,125,000	10 U
Tailings Area	SW-4	6.15	3.2	3 U	30	431	4.0	4,610	19,500/28,109	356	24,700/21,800	0.1 U	67	50 U	3 U	85,300	300	1,600,000	3,000 U	1,180,000	10 U
Below Apache	SW-4A	NA																			
Middle Flume	SW-7	3.88	3.2	3 U	20	390	4.7	3,750	12,900/24,400	318	26,700/25,500	0.1 U	65	50 U	3 U	79,800	190	1,450,000	3,000 U	1,235,000	10 U
Stringtown	SW-9	5.76	3.3	3 U	34	405	5.6	3,900	8,080/21,400	362	26,700/25,300	0.1 U	64	50 U	3 U	81,000	310	1,050,000	3,800	1,210,000	10 U
TRIBUTARIES																					
Parkville Leak	SW-2	Dry																			
Yak Tunnel	SW-3	2.70	3.2	3	38	552	12	5,970	28,200/42,000	316	31,600/29,000	0.1 U	87	50 U	3 U	109,000	290	1,760,000	3,000 U	1,440,000	10 U
Starr Ditch	SW-5	0.35	3.3	3 U	66	285	4 U	531	10,200/13,500	310	10,400/9,430	0.1 U	22	50 U	3 U	37,100	140	316,000	3,000 U	565,000	10 U
Oregon Gulch	SWI-1	0.04	2.8	90	120 U	380	154	9,520	71,600/677,000	310	661,000/708,000	0.1 U	640	50	30	263,000	674,000	10,800,000	10,000	13,500,000	97
Buckhead Spring	SW-6	0.08	4.1	3 U	29	166	4.9	20	27,600/2,810	838	33,400/20,300	0.1 U	63	50 U	3 U	56,200	100 U	1,700,000	7,500	1,435,000	10 U
Storm Drain	SWI-2	Dry																			
Georgia Gulch	SWI-3	0.03	6.6	3 U	19	30	4 U	7.5	1,360/1,400	2 U	7,820/7,860	0.1 U	23	5 U	3 U	21,700	410	322,000	9,500	645,000	10 U
Super 8 Spring	SW 8	1.02	7.8	3 U	37	34	4 U	75	15 U/152	46	288/274	0.1 U	5 U	5 U	3 U	6,390	5,500	195,000	17,000	415,000	10 U
Pawnee Gulch	SWI-4	Dry																			
Airport Gulch	SWI-5	Dry																			
Slag Pile Spring	SW-10	0.03	6.4	3 U	12	87	4 U	18	234/293	2.0	648/583	0.1 U	26	5 U	3 U	32,500	100 U	1,850,000	21,000	1,280,000	10 U
STP	SW-11	0.93	7.4	3 U	73	4 U	4 U	4.7	58/258	2 U	330/374	0.1 U	5 U	5 U	3 U	188	2,900	63,000	18,000	320,000	16
Malta Gulch	SWI-6	Dry																			
CONFLUENCE																					
Lower Flume	SW 12	3.05	4.0	3 U	39	272	4 U	2,500	4,110/16,900	388	38,400/38,500	0.1 U	47	30 U	3 U	55,600	820	850,000	5,900	990,000	10 U
Upper Arkansas River	SW-13	300	7.4	3 U	25	4 U	4 U	4.9	83/324	2 U	40/58	0.1 U	5 U	3 U	3 U	109	160	12,000	3,000 U	40,000	10 U
Lower Arkansas River	SW 14	NA	7.1	3 U	30	3.3	4 U	21	88/664	2 U	218/253	0.1 U	5 U	3 U	3 U	594	210	20,000	3,000 U	60,000	10 U
Comparative Standards																					
o Primary Maximum Contaminant Level (MCL)				50	1,000	10	50			50		2		10	50						
o Water Quality Criteria Aquatic Life--CCC				190		1.1[a]	11	12[a]		3.2[a]		.012	160	35	.12	86[a]					5.2
--CMC				360		3[a]	16	18[a]		82[a]		2.4	1,400	260	4.1	90[a]					22

[a] Based on a water hardness of 100 mg/l $CaCO_3$.

Notes: Dry--Indicates no flows during sample period.
U--not detected; value set at detection limit.
NA--not analyzed/not available.
All Chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals only unless otherwise noted with two subcolumns (__/__): The first value shown is dissolved and the second value as total; values for Mg, NO_3, SO_4, Cl, TDS, and CN are total concentrations.
CCC--Criterion Continuous Concentration--4-day average not to be exceeded more than once every 3 years.
CMC--Criterion Maximum Concentration--1 hour average not to be exceeded more than once every 3 years.

DE/CALGU6/016.3

TABLE 4-10
SURFACE WATER CHEMICAL ANALYSES AND FLOWS
September 1985

Description	Station	Flow (cfs)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
CALIFORNIA GULCH MAINSTEM																					
Upper Cal Gulch	SW-1	Dry																			
Hillyard Flume	SW-3A	1.35	5.0	5.3	52	310	45	1,520	7,230/12,700	5 U	21,700/21,600	0.1 U	49	50 U	3 U	69,300	100 U	720,000	3,000 U	1,080,000	5 U
Tailings Area	SW-4	1.23	5.1	10 U	52	308	4 U	1,070	5,620/12,200	4 U	21,800/20,500	0.1 U	51	30 U	3 U	69,500	100 U	800,000	3,500	1,080,000	5 U
Below Apache	SW-1A	1.28	5.1	3 U	54	319	4 U	1,100	5,840/11,700	5 U	23,300/20,500	0.1 U	50	5 U	3 U	70,800	100 U	750,000	4,200	1,090,000	5 U
Middle Flume	SW-7	1.47	4.9	3 U	51	323	4 U	1,230	5,780/12,300	36	30,500/27,000	0.1 U	64	5 U	3 U	76,100	140	900,000	3,500	1,210,000	5 U
Stringtown	SW-9	1.28	5.4	10 U	47	273	4 U	598	3,050/12,160	2 U	26,600/24,200	0.1 U	55	50 U	3 U	65,700	140	820,000	5,200	1,140,000	5 U
TRIBUTARIES																					
Parkville Leak	SW-2	Dry																			
Yak Tunnel	SW-3	1.37	5.2	4.5	56	310	4 U	1,490	7,300/13,400	5 U	21,900/21,700	0.1 U	52	50 U	3 U	70,000	100 U	700,000	4,000	1,080,000	5 U
Starr Ditch	SW-5	Dry																			
Oregon Gulch	SWI-1	Dry																			
Berthod Spring	SW-6	0.07	4.8	3 U	12 U	124	4 U	28	1,620/2,410	62	23,000/22,000	0.1 U	58	5 U	3 U	55,900	100 U	1,150,000	11,000	1,700,000	5 U
Storm Drain	SWI-2	Dry																			
Georgia Gulch	SWI-3	0.05	6.7	10 U	34	40	6.6	6.5	9,350/9,520	2 U	29,100/27,400	0.1 U	47	50 U	3 U	52,500	100 U	800,000	30,000	1,270,000	5 U
Super 8 Spring	SW-8	Dry																			
Pawnee Gulch	SWI-4	Dry																			
Airport Gulch	SWI-5	Dry																			
Slag Pile Spring	SW-10	NA	6.6	6.2	18	44	4 U	12	1,450/1,770	12	1,840/1,810	0.1 U	25	50 U	3 U	30,900	100 U	970,000	8,000	1,400,000	5 U
STP	SW-11	1.59	8.2	10 U	27	3 U	4 U	9.3	80/1,160	2 U	143/265	0.1 U	5 U	3 U	3 U	66	150	72,000	23,000	320,000	5.1
Malta Gulch	SWI-6	Dry																			
CONFLUENCE																					
Lower Flume	SW-12	2.6	7.5	10 U	34	60	4 U	52	30/7,350	50 U	10,800/10,800	0.1 U	20	5 U	3 U	13,000	130	390,000	16,000	600,000	6.8
Upper Arkansas River	SW-13	36.1	7.0	10 U	94	3 U	4 U	3 U	55/265	2 U	95/121	0.1 U	5 U	3 U	3 U	217	230	67,000	3,000 U	160,000	5 U
Lower Arkansas River	SW-14	36.3	7.7	10 U	71	7.3	4 U	7.4	26/749	2 U	854/858	0.1 U	5 U	5 U	3 U	1,260	140	60,000	3,100	200,000	5 U
<u>Comparative Standards</u>																					
o Primary Maximum Contaminant Level (MCL)				50	1,000	10	50			50		2		10	50						
o Water Quality Criteria Aquatic Life--CCC				190		1.1[a]	11	12[a]		3.2[a]		.012	160	35	.12	86[a]					5.2
--CMC				360		3[a]	16	18[a]		83[a]		2.4	1,400	260	4.1	90[a]					22

[a] Based on a water hardness of 100 mg/l $CaCO_3$.

Notes: Dry--indicates no flows during sample period.
U--not detected; value set at detection limit.
NA--not analyzed/not available.
All Chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals only unless otherwise noted with two subcolumns (__/__): The first value shown is dissolved and the second value as total; values for Hg, NO_3, SO_4, Cl, TDS, and CN are total concentrations.
CCC--Criterion Continuous Concentration--4-day average not to be exceeded more than once every 3 years.
CMC--Criterion Maximum Concentration--1 hour average not to be exceeded more than once every 3 years.

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TABLE 4-11
SURFACE WATER CHEMICAL ANALYSES AND FLOWS
November 1985

Description	Station	Flow (cfs)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
CALIFORNIA GULCH MAINSTEM																					
Upper Cal Gulch	SW-1	Dry																			
Millyard Flume	SW-1A[a]	1.21																			
Tailings Area	SW-4	0.69	6.14	2 U	63	330	5.9	356	1,360/15,400	5 U	19,300/19,200	0.45	45	5 U	3 U	62,100	150	545,000	13,000	830,000	5 U
Below Apache	SW-4A	0.95	5.83	3 U	62	365	4 U	132	3,340/9,690	6 U	30,000/27,100	0.2 U	44	20 U	3 U	63,200	310	606,000	6,000	860,000	5 U
Middle Flume	SW-7	1.07	4.72	2 U	53	350	6.3	407	1,980/11,800	10	32,900/28,500	0.10	58	20 U	3	67,400	150	680,000	7,400	1,080,000	5 U
Stringtown	SW-9	1.37	4.44	2 U	50	280	4 U	619	7,900/23,300	65	33,900/29,000	0.1 U	57	20 U	3 U	67,300	210	640,000	6,600	1,060,000	5 U
TRIBUTARIES																					
Parkville Leak	SW-2	Dry																			
Yak Tunnel	SW-3	1.10	5.41	2 U	69	370	4.8	714	5,300/12,900	30 U	20,500/19,700	0.13	48	5 U	3 U	65,900	160	578,000	8,000	820,000	5 U
Starr Ditch	SW-5	Dry																			
Oregon Gulch	SWI-1	Dry																			
Hartland Spring	SW-6	0.01	5.31	2 U	13 U	133	4 U	28	3,400/3,890	36	38,000/33,200	0.1 U	72	50 U	3 U	69,500	100 U	1,180,000	16,000	1,740,000	5 U
Storm Drain	SWI-2	Dry																			
Georgia Gulch	SWI-3	0.02	6.29	2 U	30	50	8.3	12	28,800/25,200	100	41,400/38,600	0.13	66	50 U	3 U	77,100	5,000 U	850,000	8,500	1,480,000	5 U
Super 8 Spring	SW-8	Dry																			
Pawnee Gulch	SWI-4	Dry																			
Airport Gulch	SWI-5	Dry																			
Slag Pile Spring	SW-10	0.01	6.32	2 U	13 U	77	4 U	16	53/492	5 U	810/728	0.1 U	29	50 U	3 U	37,500	100 U	785,000	14,000	1,400,000	5 U
STP	SW-11	1	7.37	2 U	25	3 U	4 U	6.7	70/220	20 U	157/146	0.1 U	7 U	2 U	3 U	222	5,400	56,000	22,000	260,000	5 U
Malta Gulch	SWI-6	Dry																			
CONFLUENCE																					
Lower Flume	SW-12	1.94	6.63	2 U	22	73	4 U	25	21/6,680	5 U	4,400/13,000	0.1 U	26	5 U	3 U	22,400	3,200	326,000	14,000	570,000	5 U
Upper Arkansas River	SW-13	34	7.43	2 U	71	3 U	4 U	3 U	52/222	2 U	160/135	0.1 U	7 U	2 U	3 U	638	130	44,600	5,400	140,000	5 U
Lower Arkansas River	SW-14	37	7.13	2 U	69	4.8	4 U	3.4	31/863	2 U	990/869	0.1 U	7 U	2 U	3 U	1,740	360	50,000	5,400	160,000	5 U
Comparative Standards																					
o Primary Maximum Contaminant Level (MCL)				50	1,000	10	50			50		2		10	50						
o Water Quality Criteria Aquatic Life--CCC				190		1.1[b]	11	12[b]		3.2[b]		.012	160	35	.12	86[b]					5.2
--CMC				360		3[b]	16	18[b]		82[b]		2.4	1,400	260	4.1	90[b]					22

[a] With no flow at SW-1, no sample necessary--use SW-3 since only flow into Gulch.
[b] Based on a water hardness of 100 mg/l $CaCO_3$.

Notes: Dry--indicates no flows during sample period.
U--not detected; value set at detection limit.
NA--not analyzed/not available.
All Chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals only unless otherwise noted with two subcolumns (__/__): The first value shown is dissolved and the second value as total; values for Hg, NO_3, SO_4, Cl, TDS, and CN are total concentrations.
CCC--Criterion Continuous Concentration--4-day average not to be exceeded more than once every 3 years.
CMC--Criterion Maximum Concentration--1 hour average not to be exceeded more than once every 3 years.

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Table 4-12
SURFACE WATER FLOW RATES AND pH
CALIFORNIA GULCH-ARKANSAS RIVER
AT HIGH AND LOW FLOW PERIODS

Station Name	High Flow June 1985 Flow (cfs)	High Flow June 1985 pH (s.u.)	Low Flow November 1984 Flow (cfs)	Low Flow November 1984 pH (s.u.)
SW-1	2.67	3.4	0.31	8.1
SW-2	Dry	NA	0.15	7.6
SW-3	2.70	3.2	1.10	6.0
SW-3A	3.52	3.2	1.57	6.0
SW-4	6.15	3.2	0.89	3.7
SW-4A	NA	NA	NA	NA
SW-5	0.35	3.3	0.58	7.6
SWI-1	0.04	2.8	Dry	NA
SW-6	0.08	4.1	Dry	NA
SW-7	3.88	3.2	2.53	6.3
SWI-2	Dry	NA	Dry	NA
SWI-3	0.03	6.6	0.03	6.8
SW-8	1.02	7.1	0.01	7.5
SWI-4	Dry	NA	Dry	NA
SW-9	5.76	3.3	2.38	5.5
SWI-5	Dry	NA	Dry	NA
SW-10	0.03	6.4	0.11	6.3
SW-11	0.93	7.4	1.13	8.3
SWI-6	Dry	NA	Dry	NA
SW-12	3.85	4.0	1.52	7.0
SW-13	300	7.4	30	8.8
SW-14	NA	7.1	NA	8.5

NA = Not available/not analyzed.

DE/CALGU6/012

Under the Safe Drinking Water Act, EPA has established primary drinking water standards to protect human health called "maximum contaminant levels" or "MCL's." The current MCL's for inorganic contaminants found in 40 CFR § 141.11(b) are included in each table. The State of Colorado's primary drinking water regulations establish identical standards for inorganic contaminants.

Under the Clean Water Act, EPA has developed water quality criteria based on the effects of concentrations of various contaminants on human health and aquatic species. The criteria for contaminants measured during the surface water sampling are listed in each table. The criteria for both acute and chronic toxicity to freshwater aquatic life from EPA's Quality Criteria for Water, 1986, are listed. The acute criteria (CMC) are the 1-hour average concentrations that are not to be exceeded more than once every 3 years on average. The chronic criteria (CCC) are 4-day average concentrations that are not to be exceeded more than once every 3 years on average.

Preliminary observations from these comparisons are summarized as follows:

- Cadmium has a primary MCL of 10 micrograms per liter (µg/l) and a chronic aquatic life criterion of 1.1 µg/l. Cadmium concentrations in California Gulch ranged from 12 µg/l in upper California Gulch to 431 µg/l at the tailings area (SW-4). In the ephemeral drainages, cadmium ranged from detection level to 380 µg/l in Oregon Gulch (SWI-1). The Yak Tunnel (SW-3) discharge varied in cadmium concentration from 169 µg/l to 552 µg/l.

- Copper has a chronic aquatic life criterion of 11.8 µg/l. Copper concentrations in the Gulch ranged from 20 µg/l at Stringtown (SW-9) to 4,670 at the Resurrection Mill Yard (SW-3A). In the ephemeral drainages, copper ranged from 3.3 µg/l in Georgia Gulch (SWI-3) to 9,520 µg/l in Oregon Gulch. Copper in the Yak Tunnel discharge varied from 437 µg/l to 5,970 µg/l.

- Iron and manganese in the California Gulch and its tributaries ranged from 152 µg/l to 677,000 µg/l for iron, and manganese concentrations ranged from 146 µg/l to 708,000 µg/l.

- Lead has a primary MCL of 50 µg/l and a chronic aquatic life criterion of 3.2 µg/l. Lead concentrations in California Gulch ranged from detection to 382 µg/l in upper California Gulch. In the ephemeral drainages, lead values varied from detection to 310 µg/l at Oregon Gulch. The Yak Tunnel discharge ranged from detection to 116 µg/l.

- Zinc has a chronic aquatic life criterion of 86 µg/l. Zinc concentrations in California Gulch varied from 1,506 µg/l in upper California Gulch to 85,300 µg/l at the Resurrection Mill Yard area. The Yak Tunnel discharge ranged from 43,700 µg/l to 109,000 µg/l.

- Water quality at SW-13, the Arkansas River upstream of California Gulch, routinely exceeded the aquatic criterion for zinc.

- Water quality at SW-14, the Arkansas River downstream of California Gulch, met primary MCL's for all periods except March 1985, when the cadmium standard was exceeded. Aquatic criteria were routinely exceeded for zinc and cadmium.

Figure 4-3 presents data for dissolved cadmium, zinc, and sulfate in profile form along the Gulch at the low flow (November 1984) and high flow (June 1985) periods. Key surface water flow locations and potential contributors of contamination are also identified. Relatively low concentrations occur at the upper Gulch sampling site (SW-1). There was a rapid increase in concentration of metals due to the Yak Tunnel discharge. During low-flow periods, the contribution of metals from the tailings impoundments was seen by the rise in concentrations at SW-4. The concentrations remain elevated, with little change, until SW-9. From SW-9 to SW-12, there was a marked decrease in concentration reflecting dilution by the STP. The relatively high alkalinity of the STP discharge changed stream pH and probably caused precipitation of the less mobile metals. These metals would include iron and aluminum. Downstream from SW-12, California Gulch enters the Arkansas River.

The STP discharge was directly sampled; see Table 4-7 to 4-11, station SW-11. The STP discharge consistently had high pH and high concentrations (relative to the other Gulch tributary sampling stations) of nitrate and chloride.

Figures 4-4 and 4-5 present zinc and cadmium concentrations observed during the November 1984 and June 1985 sampling periods at the Yak Tunnel (SW-3), the middle flume (SW-7), Stringtown (SW-9), and the lower flume (SW-12). During high flow conditions, the observed increase in metal concentrations is probably associated with the entrainment of sediments. Small variances, where dissolved metals concentrations are slightly greater than total metals concentrations, are within analytical variability.

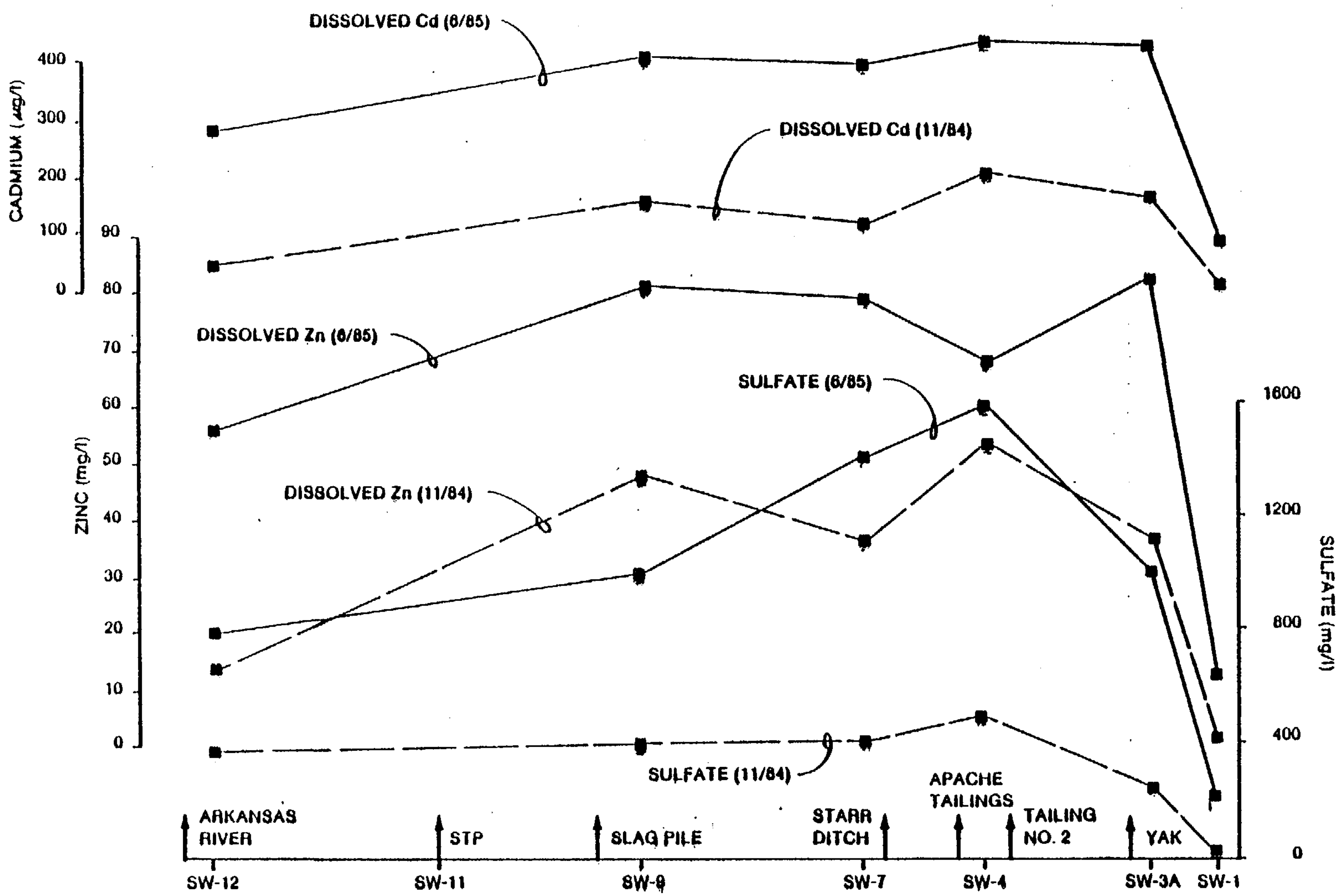

FIGURE 4-3
SURFACE WATER PARAMETER VARIANCE ALONG CALIFORNIA GULCH
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

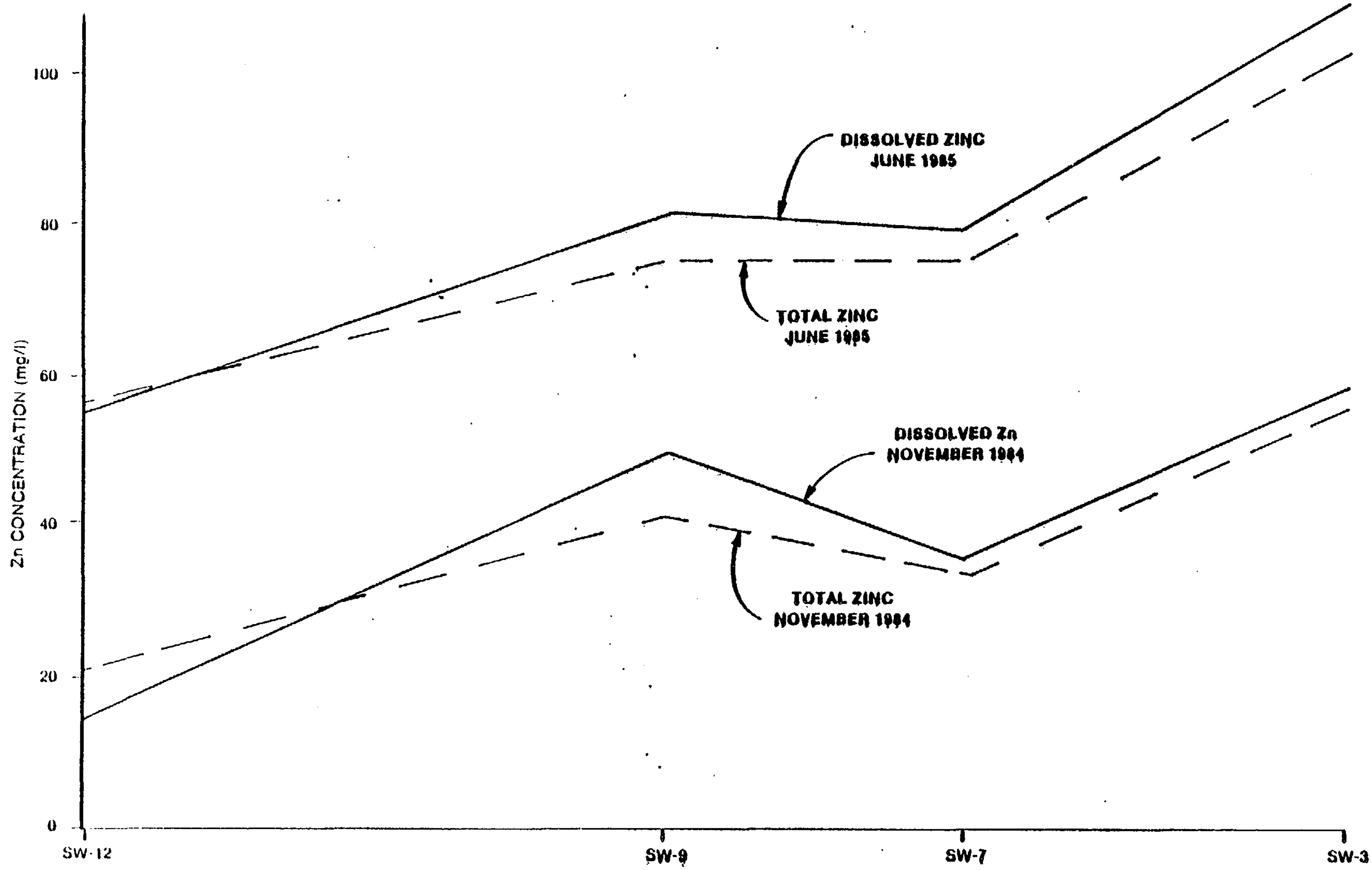

FIGURE 4-4
ZINC SEASONAL SURFACE WATER PROFILE
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

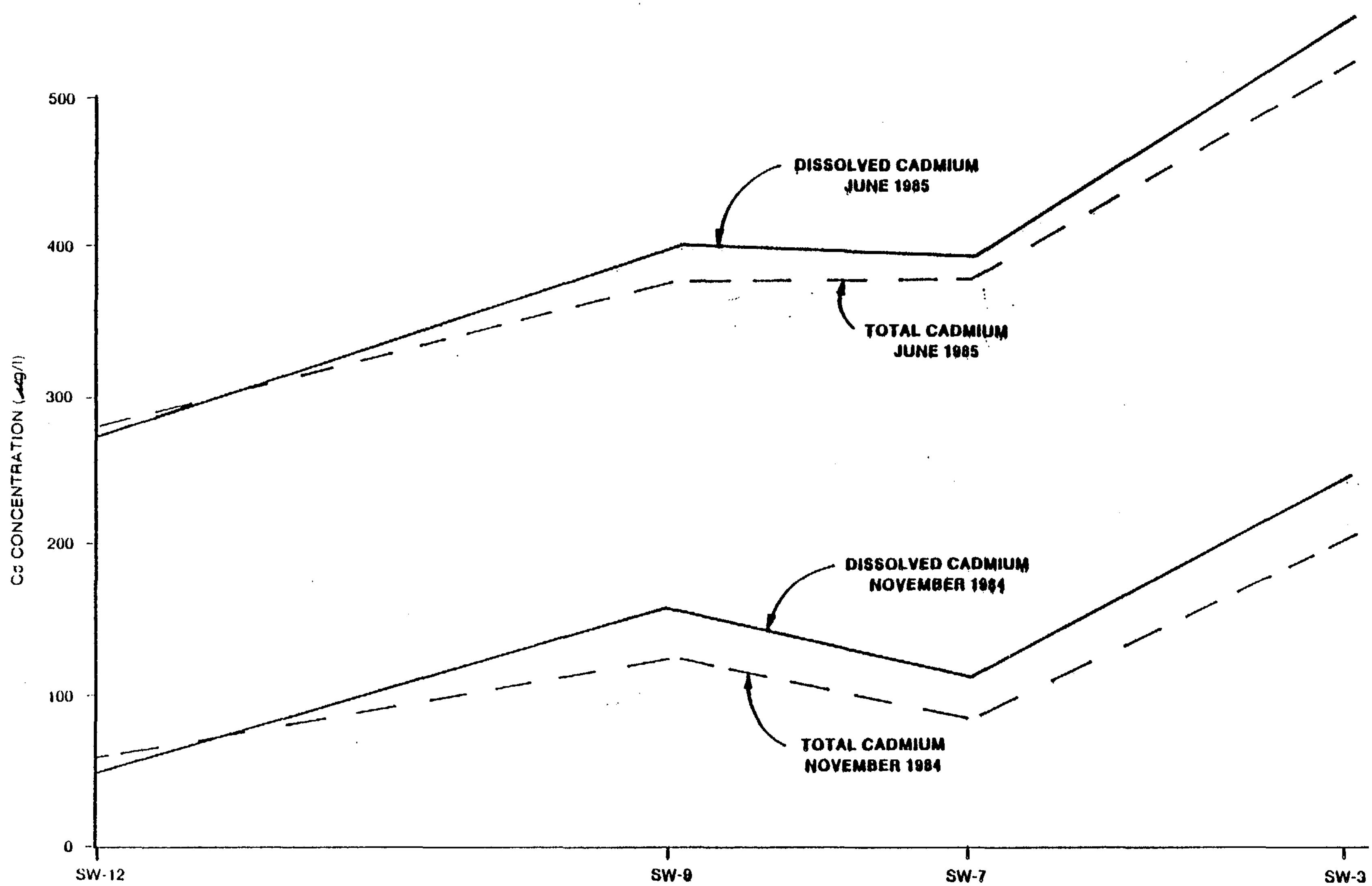

FIGURE 4-5
CADMIUM SEASONAL SURFACE WATER PROFILE
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

Total-metal and dissolved-metal concentrations of zinc and cadmium parallel each other, which indicates that these metals stay principally in the dissolved form along the length of the Gulch. This implies that the geochemical environment in the stream channel is stable with respect to solubilities of those metals (for example, dissolved species are in equilibrium with their associated solid phases).

However, this is not the case for iron; iron is easily oxidized and precipitated as iron oxy-hydroxides. These limonitic precipitates, commonly referred to as "yellow boy," have a high sorption capacity and can remove dissolved metals from solution. Higher stream velocities, which occur during snowmelt, scour the bottoms and banks of the drainages.

This re-entrains sediments and yellow boy into the surface waters, which can release more contaminants into the stream, both as dissolved species and suspended solids. Visual observations during field sampling confirm the mobilization of iron precipitates in the lower portion of the Gulch.

Potential sources of heavy metal contaminants include Yak Tunnel (SW-3), Starr Ditch (SW-5), and the Stringtown area (above SW-9). Starr Ditch contributes metals that are probably originating from mine waste areas located on the north side of Carbonate Hill and Stray Horse Gulch. SW-9, which has consistently high values of metals and sulfate, may be receiving metals from nearby slag piles. Yak Tunnel appears to be a major contributor of heavy metals to California Gulch, and subsequently the Arkansas River.

Metal concentrations at locations near the confluence with the Arkansas River are shown in Table 4-13 for both high and low flow periods. For the California Gulch discharge at SW-12 during high flow, virtually every parameter significantly increases in concentration, probably due to the increased suspended solids. Water quality at SW-13 was

Table 4-13
METAL CONCENTRATIONS (ug/l)
CALIFORNIA GULCH - ARKANSAS RIVER
AT HIGH AND LOW FLOW PERIODS

HIGH FLOW (June 1985)

Parameter	Lower end of Cal Gulch (SW-12) Dissolved	Lower end of Cal Gulch (SW-12) Total	Ark River above Confl (SW-13) Dissolved	Ark River above Confl (SW-13) Total	Ark River below Confl (SW-14) Dissolved	Ark River below Confl (SW-14) Total
Aluminum (Al)	3,920	5,140	26	144	49	355
Cadmium (Cd)	277	282	U	U	7.3	4.0
Calcium (Ca)	101,000	109,000	9,950	10,500	11,500	12,200
Copper (Cu)	2,500	2,560	4.9	4.0	21	29
Iron (Fe)	4,110	16,900	83	324	88	664
Magnesium (Mg)	50,200	50,000	3,960	3,980	4,730	4,730
Manganese (Mn)	18,400	19,500	40	58	218	253
Zinc (Zn)	55,600	57,700	109	132	594	709

LOW FLOW (November 1984)

Parameter	Lower end of Cal Gulch (SW-12) Dissolved	Lower end of Cal Gulch (SW-12) Total	Ark River above Confl (SW-13) Dissolved	Ark River above Confl (SW-13) Total	Ark River below Confl (SW-14) Dissolved	Ark River below Confl (SW-14) Total
Aluminum (Al)	U	368	81	265	U	419
Cadmium (Cd)	47	62	U	U	U	U
Calcium (Ca)	66,510	67,270	23,030	17,600	28,160	28,380
Copper (Cu)	13	26	U	12	U	U
Iron (Fe)	56	1,092	101	619	38	459
Magnesium (Mg)	33,530	32,020	8,450	7,039	11,860	11,120
Manganese (Mn)	9,074	9,222	103	145	649	657
Zinc (Zn)	14,710	20,170	240	331	1,317	1,625

Note: U=Undetected at detection limits.

DE/CALGU6/011.8

opposite to SW-12 at high flow; that is, water quality improved during run-off.

It appears that high pollutant concentrations occur in the Gulch during peak run-off, but the resultant concentrations in the Arkansas River (SW-14) are much lower, due to the large flows of better quality water from upstream (SW-13). The runoff effect resulted in generally improved water quality at SW-14.

GROUNDWATER

As mentioned in the Geology subsection in Section 2, down-gradient of the Pendry Fault several stratigraphic units exist that have a direct bearing on the local groundwater system. Twenty-one newly installed monitoring wells (NW), 19 of which are below the Pendry Fault, were sampled over the same five quarterly periods as the surface water. In addition, approximately 20 existing private wells (EW) were also sampled on the same schedule. New wells were installed because little information was known about the construction details of the existing wells. New monitoring well water quality data will be used for data interpretation because design and development are known; EW information will be considered supportive where appropriate. Most of the wells (NW and EW), with the exception of EW-15 and EW-16, were completed at varying depths into the California Gulch alluvium (high terrace gravels). These results will establish site-specific groundwater activity and behavior principally in the upper 125 feet of this unit. Detailed groundwater data are described in Appendices C, D, E, H, I, J, L, and N. A summary of data is presented in the following sections.

GROUNDWATER FLOW

Groundwater flow depends upon a complex, balanced mixture of recharge, hydraulic gradient, physical aquifer characteristics, and discharge. The flow direction and hydraulic gradient are typically defined by water levels. Groundwater levels were measured in accessible wells in conjunction with the water quality sampling programs. Water level data are shown in Appendix N where they have been both tabulated and contoured to show the water table during each sampling event.

The basic physical aquifer characteristics are the transmissivity (field permeability times saturated thickness) and storativity (the volume of water taken into or released from storage in the aquifer). These characteristics were determined for two different depth intervals in the California Gulch alluvial system to determine the amount of groundwater moving from California Gulch alluvium into the Arkansas River alluvium. The two pump test results are shown in Appendix N and described in the pump test section of the report.

Water Levels

The water level data for the wells in the California Gulch high terrace gravels (Emmons, et al., 1927) indicate that groundwater level essentially follows the topography. Recharge is from snowmelt, rainfall, and California Gulch surface water percolating into the alluvial groundwater system. Three well nests were completed to varying depths in the high terrace gravels: in the tailings area (NW-5, NW-5A, and NW-5B); below the tailings area, but above Jacktown (NW-6 and NW-6A); and above the confluence with the Arkansas River alluvium (NW-13 and NW-13A). Water levels measured during the RI investigation indicate that groundwater moves to deeper levels at all three locations. There are no significant upward (artesian) heads indicated by the water level measurements.

Groundwater levels measured on both the NW and EW wells along California Gulch indicate as much as 14 feet of fluctuation in shallow wells. The nested well set at NW-5, NW-5A, and NW-5B has perforated depth intervals of 15 to 35, 48 to 108, and 160 to 220 feet. The water level fluctuation ranges from: 10 feet in the shallowest well to 5.62 feet in the intermediate well and to 0.25 foot in the deepest well. This pattern of fluctuation in the groundwater, with the shallowest wells having the highest fluctuation and the fluctuation declining with depth, is common in alluvial systems with recharge moving from the surface downward. The recharge reaches its highest level between May and June, based on the water level measurements. The water levels then decline for the rest of the year, as the water drains from the California Gulch alluvial system.

A major source of year-round recharge to the California Gulch alluvium is the snowmelt that percolates from the mountain surfaces, through the mine workings, to the Yak Tunnel. The Tunnel drains as a point discharge to the California Gulch surface water system that, in turn, recharges the alluvial groundwater system. The changes in groundwater level suggest that the amount of recharge decreases with depth. The upper 10 feet of the groundwater system at the nested well NW-5 group, is recharged and drained from the alluvial system during the year and is replenished by recharge in the next snowmelt period. By contrast, less than 1 foot of groundwater drained from the deepest well in the nest over the same time period.

Piezometer Tube Program

To define the amount of groundwater flowing through various levels of the California Gulch alluvial system per unit time, however, requires determining the hydraulic gradient and developing the basic physical characteristics that are determined by pump testing. Surface water flow measurements noted several segments of the Gulch that were losing flow to the groundwater (losing stream). To verify this intimate connection of surface water with the shallow zone (up to 10 feet) of the alluvium, a piezometer tube program was implemented.

Hand-driven piezometer devices are traditionally used to examine groundwater/surface water interactions in situations where shallow groundwater may be discharging to a lake or stream. Lee and Cherry (1978) present a detailed description of the design of such devices and their role in examining groundwater hydraulic potential beneath lake or streambeds of interest.

The use of piezometers in groundwater/surface water interaction studies involves observing the hydraulic head potentials where a stream is either gaining flow or losing flow as a result of interaction with the underlying shallow groundwater body. Hydraulic head will decrease with depth below the stream under conditions where the stream is losing flow to the groundwater system, and will increase with depth under conditions where the groundwater system is discharging to the stream. The water levels observed in piezometers completed at different depths beneath a stream bed are an indication of the hydraulic head at that particular depth. By comparing water levels in piezometers completed at different depths to one another and to stream level, a rapid assessment as to whether the stream is gaining flow (upward hydraulic gradient), or losing flow (downward hydraulic gradient) can be made.

Twenty-one piezometer stations were installed within or immediately adjacent to the California Gulch stream channel in November 1984. The section of stream under study included the approximately 5-mile segment between the Yak Tunnel and the Arkansas River confluence. The stations consisted of either: one piezometer (the water levels of which could be compared to stream level); or 2 to 3 piezometers which could allow comparisons of water levels to one another as well as to stream level. The piezometers consisted of 5- to 10-foot lengths of 3/4-inch iron pipe containing a short (3- to 5-inch) section of slotted surface and drive point. The piezometers were hand-driven into place to either a desired depth or to refusal. The piezometers were checked for openness with a response test by filling with water and allowing the water level to drop to a stable level. Piezometers which were not open or operating successfully were removed and either redriven or replaced. A full-suite of water level measurements were obtained from the piezometers on November 20, 1984, and an assessment was made regarding gaining and losing stream conditions in existence at that time. The results show that the California Gulch stream channel is in hydrologic connection with shallow groundwater and that there are several major transition sections where the stream goes from gaining to losing conditions.

Figure 4-6 shows the locations of the piezometer stations and identifies whether gaining or losing conditions were observed on the November 20, 1984 date of study. The results show that there are several stream segments that are receiving groundwater discharge (gaining) as evidenced by the stream-groundwater hydraulic conditions observed on the November 20, 1984 test date. Other segments of the stream were observed to be losing flow to the shallow groundwater regime beneath the stream channel.

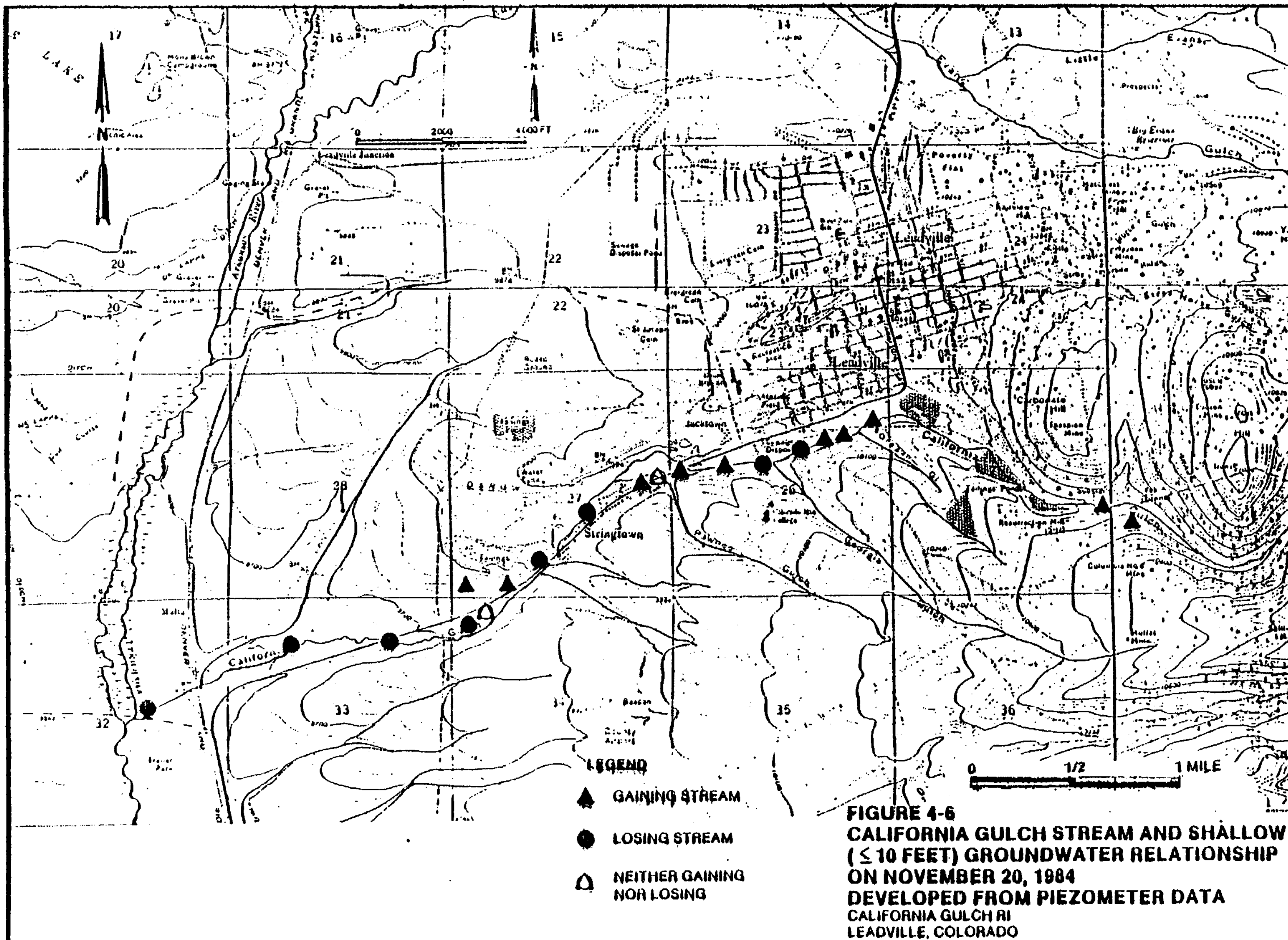

FIGURE 4-6
CALIFORNIA GULCH STREAM AND SHALLOW (≤ 10 FEET) GROUNDWATER RELATIONSHIP ON NOVEMBER 20, 1984 DEVELOPED FROM PIEZOMETER DATA
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

Three main stream segments were observed to be losing flow on the test date. The most prominent area of losing flow conditions was the lowermost section of the Gulch, from the Arkansas River confluence upstream to about 1.5 miles above the confluence. All piezometer stations within this reach showed downward hydraulic gradients. The other two areas where losing conditions were observed, as shown on Figure 4-6, are in the vicinity of Stringtown in Section 27, and just upstream of the California Gulch-Georgia Gulch confluence in Section 26.

Downward hydraulic gradients were observed at two successive piezometer stations in each of these two respective stream segments. Based on these findings and the locations of the stations, the Section 27 losing segment may be approximately 1/2 to 3/4 of a mile in length; the Section 26 segment may be approximately 1/4 to 1/2 mile in length. All remaining piezometer stations along the 5-mile long test section showed upward or neutral hydraulic gradients indicating, for the most part, gaining-flow stream conditions.

The piezometer station data indicate that groundwater - surface water hydraulic interactions are occurring within the California Gulch watershed. The locations and conditions under which the interactions occur (losing or gaining conditions) may change from the November "snapshot" of hydraulic relationships that were observed.

Pump Tests

Two pump tests were performed in the California Gulch alluvium. The first was performed on well NW-15, located near Stringtown, that evaluated the transmissivity of the upper 35 feet of the alluvial (gravel) system. This location (NW-15) was chosen to evaluate the possibility of surface infiltration into the alluvial aquifer used for domestic purposes on the site. A second pump test was performed on well EW-29, located near the confluence of the California Gulch alluvium and Arkansas River alluvium, to evaluate groundwater movement from the Gulch into the Arkansas River alluvium.

The pump test on well NW-15 indicated a relatively low transmissivity [316 gallons per day per foot (gdp)] and, therefore, a relatively low permeability (6.3 gallons per day per square foot) in the upper 35 feet of California Gulch alluvial material above Stringtown. This level of permeability is comparable to a silty-sand grain size in unconsolidated deposits (Freeze and Cherry, 1979). This confirms what was observed from the drilling data.

The pump test on well EW-29 involved the monitoring of six other wells completed in different depths of the alluvial (gravel) aquifer. Well EW-29 has a perforated interval of 85 to 110 feet, representing a deeper part of the alluvial than the pump test on well NW-15. The pump test indicated a transmissivity of 1,280 gdf, resulting in a permeability of 25.6 gallons per day per square foot. This permeability is comparable to a clean sand grain size distribution in unconsolidated deposits.

Table 4-14 compares the drawdown in the pumped well EW-29 with the four monitoring wells. The monitoring wells are arranged in order of drawdown; NW-13, EW-28, NW-12, and NW-13A. The nested well pair, NW-13 and NW-13A, are located approximately 92 feet from the pumped well. However, well NW-13, perforated from 20 to 100 feet, had a drawdown of almost 5 feet whereas well NW-13A, perforated from 14.5 to 25 feet, had a much lower drawdown of 0.14 foot. This strongly suggests a limited vertical hydraulic connection

Table 4-14
COMPARISON OF DRAWDOWNS IN MONITORING WELLS DURING PUMP TESTING IN NOVEMBER 1985

	Distance from Pumped Well (ft)	Well Total Depth (BGL)	Screened Interval (ft BGL)	Pumping Elapsed Time (hr)	Drawdown (ft)
EW-29	0	100	65-100	11.75	13.86
NW-13	92.4	100	20-100	12.16	4.95
EW-28	447	110	85-110	11.90	0.53
NW-12	630	50	10-50	12.17	0.38
NW-13A	92.0	25	14.5-25	12.07	0.14

Notes: Comparison of drawdowns in monitoring wells is a result of pumping Well EW-29 for approximately 12 hours.
BGL-Below Ground Level.

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(low vertical permeability) between the upper approximately 25 feet and the 85- to 110-foot zone of the California Gulch alluvium.

Well NW-12, approximately 630 feet from pumped well EW-29, had a drawdown of only 0.38 foot after approximately 12 hours of pumping, indicating a potentially large area of lateral hydraulic connection of the California Gulch alluvial aquifer.

Pump test data were also used to calculate the groundwater discharge to the Arkansas River alluvium from the California Gulch alluvium. The calculation is described in Appendix N. The transmissivity of the California Gulch alluvium was approximated by combining the results of both pump tests, resulting in a total calculated groundwater flow of 0.06 cfs. This analysis indicates that groundwater moves very slowly from California Gulch alluvium into the Arkansas River alluvium. This was also verified by water measurements and balance done at SW-12, SW-13 and SW-14 in August and September 1985. No groundwater flow component was found to exist to the Arkansas River. See Appendix K for additional details.

GENERAL GROUNDWATER CHEMISTRY

All groundwater chemical data resulting from the analysis of samples collected from both existing private wells (EW) and new monitoring wells (NW) are tabulated in Appendices H, I, J, K, and N. The concentrations of contaminants for the five quarterly sampling events for both EW and NW wells, and with relevant water quality standards are presented in Tables 4-15 through 4-24. The water quality data are compared to primary and secondary drinking water standards and proposed maximum contaminant goals.

Under the Safe Drinking Water Act, EPA has established primary drinking water standards to protect human health called

Table 4-15
GROUNDWATER CHEMICAL ANALYSES FOR NEW MONITORING WELLS
November 1984

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Yak Tunnel upgd	NM-1	22	5-22	NA	3.8	5	200 U	1,220	10 U	936	93	88	21,640	0.66	63	5 U	10 U	175,600	460	825,000	2,000	1,190,000	10 U
Yak Tunnel dngd	NM-2	28	8-28	8.39	3.9	10 U	200	305	10 U	249	2,815	338	34,440	0.64	73	5 U	10 U	78,110	100 U	675,000	2,500	938,000	10 U
Apache	NM-3	96	26-76	9.58	7.8	10 U	128	5 U	10 U	25 U	100 U	50	327	0.37	40 U	5 U	10 U	81	1,700	150,000	8,500	230,000	10 U
Oregon Gulch	NM-4	45	5-45	5.75	3.6	10 U	200 U	706	10 U	5,276	2,750,000	472	1,403,000	1.58	3,438	NA	10 U	783,600	330	25,000,000	12,000	31,166,000	10 U
ASARCO/Intermediate	NM-5	108	48-108	35.92	11.9	10 U	2,000 U	50 U	82	114	1,582	5	1,028	0.5	400 U	5 U	100 U	2,353	330	625,000	3,500	1,940,000	10 U
ASARCO/Shallow	NM-5A	35	15-25	Dry																			
ASARCO/Deep	NM-5B	220	160-220	40.21	7.5	10 U	200 U	5 U	10 U	25 U	107	50 U	90	0.72	40 U	5 U	10 U	32	1,500	338,000	4,500	524,000	10 U
Middle Flume/Deep	NM-6	123	90-110	14.75	8.3	100 U	200 U	5 U	10 U	34	41	5 U	45	0.2	40 U	5 U	10 U	121	100 U	5,000	3,500	4,546,000	10 U
Middle Flume/Shallow	NM-6A	29	9-29	16.25	7.0	10 U	96	40	10 U	25 U	100 U	118	3,490	0.2 U	40 U	5 U	10 U	14,270	14,700	625,000	138,000	1,122,000	21
Asphalt Plant	NM-7	130	90-130	20.35	7.2	10 U	78	5 U	10 U	13	54	5 U	366	0.35	40 U	5 U	10 U	117	4,200	190,000	19,000	516,000	10 U
Diedrich Slag dngd	NM-8	53	16-53	10.70	6.8	10 U	200 U	46	10 U	25 U	76	50 U	1,117	0.2 U	61	5 U	10 U	15,330	460	800,000	7,500	1,166,000	10 U
Hecla upgd	NM-9[a]	50	10-50	NA	8.0	10 U	168	5 U	15	97	5,088	67	514	0.2 U	28	5 U	10 U	1,897	NA	90,000	6,500	110,000	10 U
Hecla dngd	NM-10	50	10-50	46.00	6.3	10 U	200 U	207	10 U	25 U	81	5 U	15,040	0.2 U	210	5 U	10 U	30,160	4,800	550,000	15,000	953,000	10 U
Diedrich House	NM-11	55	25-55	8.58	7.6	10 U	66	5 U	10 U	25 U	71	50 U	88	0.2 U	47	5 U	10 U	124	8,600	238,000	11,000	552,000	10 U
Malta Gulch	NM-12	50	10-50	14.33	7.6	10 U	70	5 U	10 U	25 U	88	5 U	10	0.2 U	40 U	5 U	10 U	42	5,700	208,000	7,000	378,000	10 U
Molluor Field/Deep	NM-13	160	70-100	11.75	7.4	10 U	56	14	10 U	25 U	62	102	941	0.64	40 U	5 U	10 U	1,938	1,700	410,000	21,000	626,000	10 U
Molluor Field/Shallow	NM-13A	25	14.5-25	NA	5.0	10 U	200 U	301	10 U	240	312	50 U	18,870	0.2 U	185	5 U	10 U	43,780	7,000	383,000	6,500	762,000	10 U
Trailer Park	NM-14	50	10-50	18.83	7.3	10 U	74	14	10 U	25 U	81	5 U	12	0.25	40 U	5 U	10 U	1,829	3,100	200,000	7,000	344,000	10 U
Super 8	NM-15	35	14-35	5.33	7.4	10 U	200 U	30	10 U	25 U	41	50 U	635	0.2 U	40 U	5 U	10 U	7,867	6,800	418,000	16,500	622,000	175
Starr Ditch	NM-16	80	40-80	41.17	6.8	10 U	200 U	6.2	10 U	33	4,072	10	1,032	0.2 U	70	5 U	10 U	5,994	2,400	550,000	12,000	912,000	10 U
Diedrich Slag upgd	NM-17	100	60-100	45.58	6.7	10 U	200 U	107	10 U	25 U	39	5 U	453	0.2 U	163	13.5	10 U	722	3,600	1,125,000	41,000	2,144,000	10 U
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

[a]Metal values for NM-9 are total because not enough sample volume was available to filter the sample.

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CAIG06/032.1

Table 4-16
GROUNDWATER CHEMICAL ANALYSES FOR NEW MONITORING WELLS
March 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Field pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Yak Tunnel upgd	HH-1	22	5-22	13.88	5.5	10 U	9.3	1,120	30 U	829	30	69	20,300	0.2 U	42	5 U	3 U	151,000	1,080	791,000	1,400	1,160,000	5 U
Yak Tunnel dngd	HH-2	28	8-28	11.42	5.0	10 U	18	438	30 U	744	8,920	570	18,900	0.2 U	42	5 U	3 U	66,900	50 U	594,000	1,900	825,000	5 U
Apache	HH-3	96	16-76	11.25	6.0	10 U	97	5 U	3 U	2.9	83	5 U	84	0.2 U	10 U	5 U	3 U	332	1,150	29,300	5,600	232,000	5 U
Oregon Gulch	HH-4	45	5-45	4.00	2.4	100 U	422	1,130	300 U	3,930	4,920,000	50 U	2,180,000	1.1	900	25 U	300 U	982,000	NA	32,100,000	5,600	44,800,000	6.9
ASARCO/Intermediate	HH-5	108	48-108	37.75	10.0	10 U	73	5 U	19	2 U	34	25 U	2 U	0.2 U	10 U	5 U	3 U	21	640	1,170,000	3,300	1,700,000	5 U
ASARCO/Shallow	HH-5A	35	15-25	Dry																			
ASARCO/Deep	HH-5B	220	160-220	44.58	5.5	10 U	22	5 U	3 U	3.1	29	5 U	46	0.2 U	10 U	5 U	3 U	26	1,300	324,000	2,800	531,000	5 U
Middle Flume/Deep	HH-6	123	90-110	16.92	6.0	10 U	38	5 U	3 U	5.9	268	5 U	114	0.2 U	10 U	5 U	3 U	715	100	5,500	1,000 U	148,000	5 U
Middle Flume/Shallow	HH-6A	29	9-29	16.60	6.0	10 U	30	52	3 U	7.6	188 U	5 U	1,990	0.2 U	10 U	5 U	3 U	14,300	10,300	687,000	61,400	1,290,000	2.5 U
Asphalt Plant	HH-7	130	90-130	68.83	6.0	10 U	70	5 U	3 U	8.9	157	5 U	463	0.2	13	5 U	3 U	1,020	6,080	180,000	15,900	504,000	5 U
Diedrich Slag dngd	HH-8	53	16-53	11.58	6.0	10 U	32	37	3 U	4.4	58	25 U	692	0.2 U	21	5 U	3 U	14,800	180	1,090,000	7,700	1,470,000	2.5 U
Hecla upgd	HH-9	50	10-50	Dry																			
Hecla dngd	HH-10	50	10-50	43.75	5.5	10 U	21	7.1	3 U	6.3	107	5 U	270	0.2 U	10 U	5 U	3 U	1,040	3,980	91,700	9,600	269,000	2.5 U
Diedrich House	HH-11	55	25-55	9.58	6.5	10 U	38	5 U	3	27	115	5 U	19	0.2 U	10 U	5 U	3 U	239	7,390	292,000	13,500	185,000	2.5 U
Malta Gulch	HH-12	50	10-50	14.50	6.0	10 U	87	5 U	3 U	2.3	88	5 U	3.1	0.2 U	10 U	25 U	3 U	102	6,850	253,000	10,900	503,000	89
Hollner Field/Deep	HH-13	100	20-100	23.29	6.0	10 U	32	63	3 U	48	132	5 U	3,620	0.2 U	19	5 U	3 U	9,070	3,560	450,000	15,300	759,000	83
Hollner Field/Shallow	HH-13A	25	14.5-25	19.67	5.0	10 U	14	231	6.4	711	82	19	14,800	0.2 U	57	5 U	3 U	33,000	5,290	640,000	8,900	694,000	2.5 U
Trailer Park	HH-14	50	10-50	15.63	7.0	10 U	47	5 U	3 U	2.9	233	5 U	3 U	0.2 U	10 U	5 U	3 U	1,730	3,070	206,000	8,000	345,000	6.9
Super 8	HH-15	35	14-35	6.29	5.5	10 U	15	27	3 U	4.4	46	5 U	721	0.2 U	10 U	5 U	3 U	6,780	4,170	391,000	12,000	660,000	5 U
Starr Ditch	HH-16	80	40-80	43.50	5.5	10 U	26	5.6	3 U	8.5	70	50 U	1,040	0.2	13	5 U	3 U	1,450	1,550	563,000	11,700	811,000	5 U
Diedrich Slag upgd	HH-17	100	60-100	49.67	6.0	10 U	26	30	3 U	11	102	50 U	369	0.2 U	10 U	110	3 U	553	3,150	1,580,000	3,600	2,030,000	2.5 U
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CALGO6/037.2

Table 4-12
GROUNDWATER CHEMICAL ANALYSES FOR NEW MONITORING WELLS
June 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Yak Tunnel upgd	MW-1	22	5-22	7.67	4.0	3 U	59	1,290	4 U	964	116	80	22,600	0.1 U	75	5 U	3 U	165,000	1,100	1,120,000	3,000 U	1,350,000	10 U
Yak Tunnel dngd	MW-2	28	8-28	8.67	3.4	3,000	68	611	4.9	328	9,520	3,340	21,100	0.1 U	41	5 U	3 U	65,800	100 U	850,000	3,000 U	960,000	10 U
Apache	MW-3	96	26-76	9.00	7.8	3 U	105	4 U	4 U	3.2	15 U	3 U	33	0.1 U	5 U	3 U	3 U	160	1,100	55,000	3,700	31,000	10 U
Dragon Gulch	MW-4	45	5-45	6.17	3.6	430	130 U	742	158	3,200	1,250,000	55	764,000	0.1 U	710	3 U	31 U	411,000	100 U	8,680,000	3,000 U	15,400,000	32
ASARCO/Intermediate	MW-5	100	40-100	32.92	8.6	3 U	43	4 U	9.3	3 U	65	5 U	5 U	0.1 U	5 U	5 U	3 U	51	860	2,300,000	3,800	1,990,000	10 U
ASARCO/Shallow	MW-5A	35	15-35	19.00	7.7	3 U	56	4 U	4 U	3 U	15 U	5 U	16	0.1 U	5 U	0	3 U	574	910	3,100,000	3,000 U	3,060,000	10 U
ASARCO/Deep	MW-5B	220	160-220	42.08	8.0	3 U	109	4 U	4 U	3.5	15 U	5 U	42	0.1 U	5 U	5 U	3 U	95	1,000	266,000	3,000 U	600,000	10 U
Middle Flume/Deep	MW-6	123	90-110	15.67	8.0	3 U	45	4 U	4 U	4.1	15 U	3 U	5 U	0.1 U	5 U	0 J	3 U	103	100 U	60,000	3,000 U	145,000	10 U
Middle Flume/Shallow	MW-6A	29	9-29	17.00	7.3	3 U	33	61	4 U	6.1	15 U	5 U	2,760	0.1 U	18	5 U	3 U	16,700	14,000	800,000	82,000	1,060,000	10 U
Asphalt Plant	MW-7	130	90-130	65.67	6.6	3 U	292	4 U	4 U	3.3	146	3 U	395	0.1 U	5 U	5 U	3 U	658	4,900	159,000	32,000	350,000	10 U
Diedrich Slag dngd	MW-8	53	16-53	10.08	5.9	3 U	65	116	4 U	7.7	1,630	5 U	1,560	0.1 U	32	5 U	3 U	31,400	310	785,000	7,400	1,250,000	10 U
Hecla upgd	MW-9	50	10-50	8.67	6.2	3 U	514	4 U	4 U	5.6	375	11	61	0.1 U	5 U	2 U	3 U	320	100 U	96,000	6,400	45,000	10 U
Hecla dngd	MW-10	50	10-50	43.61	6.8	3 U	37	32	4 U	3.6	15 U	5 U	3,660	0.1 U	17	5 U	3 U	4,930	2,800	126,000	11,000	255,000	10 U
Diedrich House	MW-11	55	25-55	9.33	7.4	3 U	158	4 U	4 U	3 U	77	5 U	31	0.1 U	8 U	5 U	3 U	200	6,900	276,000	22,000	465,000	10 U
Malta Gulch	MW-12	50	10-50	12.08	7.8	3 U	45	4 U	4 U	3 U	34	5 U	11	0.1 U	5 U	3 U	3 U	112	8,500	192,000	9,600	400,000	41
Molinar Field/Deep	MW-13	100	20-100	20.75	7.3	3 U	28	72	4 U	53	41	5 U	3,570	0.1 U	20	5 U	3 U	9,600	3,800	377,000	16,000	800,000	41
Molinar Field/Shallow	MW-13A	25	14.5-25	16.78	4.4	3 U	17	240	4 U	608	66	16	14,300	0.1 U	62	5 U	3 U	31,500	6,000	825,000	6,500	1,010,000	10 U
Stoller Park	MW-14	50	10-50	6.67	7.4	3 U	45	4 U	4 U	3 U	16 U	3.2	5 U	0.1 U	5 U	5 U	3 U	571	380	50,000	3,000 U	10,000	10 U
Super 8	MW-15	35	14-35	6.17	7.6	3 U	149	32	4 U	6.3	28	5 U	595	0.1 U	6.2	5 U	3 U	6,200	3,100	386,000	12,000	615,000	10 U
Starr Ditch	MW-16	80	40-80	43.25	7.4	3 U	105	4 U	6.3	8.2	52	4.4	866	0.1 U	8.2	5 U	3 U	1,110	2,300	725,000	13,000	835,000	10 U
Diedrich Slag upgd	MW-17	100	60-100	44.67	6.8	7.3	52	27	4 U	17	246	5 U	420	0.1 U	5 U	0	3 U	463	2,300	1,320,000	36,000	1,900,000	10 U
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--Indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CAL686.3

Table 4-18
GROUNDWATER CHEMICAL ANALYSES FOR NEW MONITORING WELLS
September 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Yak Tunnel upgd	NW-1[a]	22	5-22	NA																			
Yak Tunnel dngd	NW-2[a]	28	8-28	NA																			
Apache	NW-3	96	26-76	11.33	8.0	3 U	116	4 U	4 U	3.1	17	3 U	29	0.1 U	5 U	3 U	3 U	120	1,400	40,000	5,700	180,000	10 U
Oregon Gulch	NW-4[a]	45	5-45	NA																			
ASARCO/Intermediate	NW-5	108	48-108	32.13	7.1	3 U	25	4 U	6.2	3 U	33	5 U	5 U	0.1 U	5 U	50 U	3 U	13	1,100	1,850,000	3,300	2,160,000	10 U
ASARCO/Shallow	NW-5A[a]	35	15-25	29.00																			
ASARCO/Deep	NW-5B	220	160-220	40.17	8.2	3 U	17	4 U	4 U	4	15 U	5 U	7.7	0.1 U	5 U	5 U	3 U	19	1,200	278,000	3,300	600,000	10 U
Middle Plume/Deep	NW-6	123	90-110	16.83	8.1	3 U	81	5.9	4 U	5.3	45	2 U	5 U	0.1 U	5 U	5 U	3 U	71	140	6,100	3,000 U	160,000	10 U
Middle Plume/Shallow	NW-6A	29	9-29	17.75	7.1	3 U	29	50	4 U	6.5	23	2 U	838	0.1 U	5 U	5 U	3 U	11,100	16,000	600,000	46,000	1,120,000	10 U
Asphalt Plant	NW-7	130	90-130	63.92	7.6	3 U	42	4 U	4 U	7.3	22	5 U	108	0.1 U	5 U	3 U	3 U	153	5,100	170,000	16,000	445,000	10 U
Diedrich Slag dngd	NW-8	53	16-53	9.75	6.9	3 U	33	106	4 U	3.1	15	5 U	169	0.1 U	30	5 U	3 U	22,900	130	1,200,000	5,700	1,340,000	10 U
Hecla upgd	NW-9[a]	50	10-50	16.25	7.5	3 U	56	4 U	4 U	4	103	5 U	21	0.1 U	5 U	5 U	3 U	264	100 U	220,000	16,000	120,000	10 U
Hecla dngd	NW-10	50	10-50	43.00	7.4	3 U	17	19	4 U	3.1	22	5 U	535	0.1 U	14	3 U	3 U	3,510	5,500	140,000	12,000	390,000	10 U
Diedrich House	NW-11	55	25-55	12.17	7.5	3 U	55	4 U	4 U	3 U	15 U	5 U	6.7	0.1 U	5 U	3 U	3 U	303	7,400	245,000	12,000	590,000	10 U
Malta Gulch	NW-12	50	10-50	12.17	7.8	3 U	38	4 U	4 U	3 U	54	5 U	12	0.1 U	5 U	5 U	3 U	59	6,300	225,000	8,200	530,000	81
Molluer Field/Deep	NW-13	100	20-100	20.00	6.6	3 U	21	114	4 U	61	71	5 U	5,990	0.1 U	29	5 U	3 U	13,700	4,200	570,000	13,000	850,000	10 U
Molluer Field/Shallow	NW-13A	25	14.5-25	17.67	4.4	3 U	22	204	6.9	517	100	51	12,900	0.1 U	62	50 U	3 U	29,500	4,900	600,000	6,100	910,000	10 U
Trailer Park	NW-14	50	10-50	12.17	7.3	3 U	61	9.8	4 U	3 U	15 U	5 U	5 U	0.1 U	5 U	5 U	3 U	1,410	2,300	97,600	3,500	260,000	10 U
Super 8	NW-15	35	14-35	6.33	7.2	3 U	19	35	4 U	3.2	25	5 U	583	0.1 U	6.8	5 U	3 U	6,180	4,200	500,000	11,000	720,000	10 U
Starr Ditch	NW-16	80	40-80	41.08	6.7	3 U	24	4 U	4 U	3.5	166	3	519	0.1 U	5 U	5 U	3 U	627	2,500	670,000	12,000	840,000	10 U
Diedrich Slag upgd	NW-17	100	60-100	44.33	7.3	7.3	17	13	4	6.2	54	5 U	113	0.1 U	5 U	37	3 U	157	3,200	1,520,000	36,000	2,060,000	10 U
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCL's						50	1,500	5	120	1,300		20		3		45			10,000				

[a]Metal values for NW-9 are total because not enough sample volume was available to filter the sample.

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CA1606/032.4

Table 4-19
GROUNDWATER CHEMICAL ANALYSES FOR NEW MONITORING WELLS
November 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Yak Tunnel upgd	MW-1	22	5-22	17.17	4.10	14	13 U	1,560	6.6	1,100	106	141	25,800	0.1 U	73	50 U	3 U	190,000	1,200	1,000,000	5,100	1,550,000	10 U
Yak Tunnel dngd	MW-2	28	8-28	13.50	4.56	2 U	13 U	461	9.5	410	623	240	47,300	0.1 U	61	20 U	3 U	83,100	100 U	825,000	6,000	1,280,000	10 U
Apache	MW-3	56	26-76	11.42	7.59	2 U	115	4 U	4 U	3 U	11	2 U	21	0.1 U	7 U	5 U	3 U	51	1,600	32,000	8,000	150,000	10 U
Oregon Gulch	MW-4	45	5-45	NA	2.62	1,320	13 U	1,270	535	4,570	4,060,000	50 U	2,030,000	0.1 U	1,550	NA	249	834,000	10,000 U	2,640,000	94,000	16,800,000	31
ASARCO/Intermediate	MW-5	108	48-108	34.58	8.06	2 U	16	4 U	4 U	4.3	15	2 U	26	0.1 U	7 U	5 U	3 U	181	1,300	321,000	6,400	580,000	10 U
ASARCO/Shallow	MW-5A	35	15-35	Dry																			
ASARCO/Deep	MW-5B	220	160-220	40.00	7.79	2 U	16	4 U	5.8	3 U	10 U	50 U	7.1	0.1 U	7 U	50 U	3 U	58	900	1,440,000	6,000	2,040,000	10 U
Middle Flume/Deep	MW-6	110	90-110	17.00	7.72	2 U	79	4 U	4 U	3.5	62	2 U	8.5	0.1 U	7 U	2 U	3 U	61	100 U	5,000	5,100	130,000	10 U
Middle Flume/Shallow	MW-6A	29	9-29	NA	6.79	2 U	37	63	4.4	37	37,200	8.8	11,000	0.1 U	16	50 U	3 U	17,700	1,600	380,000	53,000	1,020,000	10 U
Asphalt Plant	MW-7	130	90-130	63.17	7.46	2 U	47	4 U	4 U	7.0	23	2 U	67	0.1 U	7 U	5 U	3 U	110	8,700	191,000	20,000	360,000	10 U
Diedrich Slag dngd	MW-8	53	16-53	8.50	6.71	2 U	15	116	4.7	3.3	97	5 U	673	0.1 U	38	50 U	3 U	18,800	100 U	950,000	11,000	1,380,000	10 U
Hecla upgd	MW-9	50	10-50	Dry																			
Hecla dngd	MW-10	50	10-50	NA	7.22	2 U	16	6.7	4 U	4	35	2 U	30	0.1 U	7 U	5 U	3 U	1,549	4,300	162,000	14,000	240,000	10 U
Diedrich House	MW-11	55	35-55	13.13	7.23	2 U	31	4 U	4 U	3 U	62	2 U	5 U	0.1 U	7 U	5 U	3 U	113	6,400	300,000	18,000	510,000	10 U
Malta Gulch	MW-12	50	10-50	11.67	7.32	2 U	41	4 U	4 U	3 U	18	5 U	27	0.1 U	7 U	5 U	3 U	93	6,400	253,000	13,000	490,000	78
Mollner Field/Deep	MW-13	100	20-100	20.58	7.03	2 U	19	59	4 U	55	69	5 U	2,400	0.1 U	17	50	3 U	8,680	4,100	342,000	22,000	720,000	81
Mollner Field/Shallow	MW-13A	25	14.5-25	17.92	6.30	2 U	13 U	223	8.1	631	100	16	13,660	0.1 U	58	50 U	3 U	31,700	4,900	530,000	13,000	880,000	10 U
Trailer Park	MW-14	50	10-50	13.50	6.99	2 U	59	8.1	4 U	3 U	26	2 U	5 U	0.1 U	7 U	5 U	3 U	1,490	3,900	160,000	10,000	290,000	10 U
Super 8	MW-15	35	14-35	6.33	7.02	2 U	16	27	4 U	6.6	38	2 U	606	0.1 U	10	50 U	3 U	8,010	4,700	361,000	12,000	600,000	10 U
Starr Ditch	MW-16	80	40-80	41.33	6.71	2 U	24	4 U	4 U	6	208	5 U	497	0.1 U	7 U	50 U	3 U	664	2,200	470,000	13,000	800,000	10 U
Diedrich Slag upgd	MW-17	100	60-100	47.00	7.32	2 U	26	16	4 U	9.4	100	5 U	225	0.1 U	7 U	99	3 U	321	2,600	1,420,000	38,000	1,960,000	10 U
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--Indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CA1386/012.5

Table 4-20
GROUNDWATER CHEMICAL ANALYSES FOR EXISTING WELLS
November 1986

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Elk Horn Shaft	EH-1	500	0-500	NA																			
Airport	EH-1	200	170-200	NA	7.7	5	85	5 U	10 U	25 U	100 U	5 U	15 U	0.64	40 U	5 U	10 U	426	350	11,000	1,000 U	64,000	10 U
Molleur/House	EH-2	120	65-120	NA	7.7	10 U	200 U	5 U	10 U	25 U	50	5 U	35	0.2 U	36	5 U	10 U	20 U	3,700	383,000	25,000	808,000	10 U
Soppi	EH-3	37	NA	NA	7.9	10 U	125	5 U	10 U	10	71	5 U	11	0.35	40 U	5 U	10 U	51	1,200	18,000	4,000	210,000	10 U
Casias	EH-4	65	NA	11.28																			
Beck	EH-5	35	NA	NA																			
Lk Fk Trlr Park	EH-6	50	NA	11.34	7.4	10 U	105	5 U	10 U	25 U	193	5 U	16	0.2 U	31	5 U	10 U	106	690	83,000	5,500	236,000	10 U
Bemidt	EH-7	55	31-55	NA																			
Baughman	EH-8	45	21-45	NA																			
Martinez	EH-9	50	25-50	15.83																			
Figuero	EH-10	30	0-30	16.17																			
Gardner	EH-11	39	27-39	3.50	6.7	10 U	200 U	5 U	10 U	45	49	5 U	15 U	0.2 U	40 U	5 U	10 U	727	2,900	20,000	8,000	420,000	10 U
Chase/Shop	EH-12	125	NA	19.75	6.4	10 U	200 U	116	10 U	25 U	616	50 U	44	0.46	89	5 U	8.6	32,520	6,600	550,000	15,000	888,000	88
Chase/House	EH-13	92	77-92	35.50	7.6	10 U	200 U	5 U	10 U	25 U	105	5 U	15 U	0.2 U	22	5 U	10 U	249	5,900	280,000	44,000	520,000	46
Mratax	EH-14	34	22-34	6.65	7.6	10 U	200 U	5 U	10 U	25 U	300	5 U	390	0.2 U	40 U	5 U	10 U	732	230	350,000	11,000	502,000	10 U
Becla	EH-15	575	161-575	NA																			
Binsley	EH-16	530	500-530	NA																			
Zakrajsek	EH-17	50	NA	21.65	7.4	10 U	200 U	5 U	10 U	12	323	5 U	27	0.2	40 U	5 U	10 U	1,870	5,400	350,000	11,000	642,000	10 U
F. Shober	EH-18	90	66-90	44.76																			
R. Shober	EH-19	45	NA	NA	7.6	10 U	200 U	28	10 U	25 U	6,004	5 U	1,652	0.2 U	40 U	5 U	10 U	7,621	1,500	225,000	7,500	416,000	10 U
Bain	EH-20	90	NA	NA																			
Archuletta	EH-21	90	NA	9.74	7.4	10 U	200 U	5 U	10 U	25 U	94	50 U	28	0.2 U	70	5 U	11	122	11,000	90,000	11,000	294,000	10 U
Winkler	EH-23	39	17-39	5.55																			
Wibbenmeyer	EH-24	76	NA	NA	7.4	10 U	200 U	5 U	10 U	29	106	5 U	24	0.2 U	43	11	10 U	67	6,500	383,000	66,000	990,000	10 U
Myers/Well	EH-25	42	NA	NA																			
Gruden	EH-26	41	NA	30.13	7.8	10 U	200 U	5 U	10 U	25 U	296	296	38	0.2 U	91	5 U	10 U	101	7,400	100,000	7,500	308,000	10 U
Flores	EH-27	15	0-15	11.50																			
Molleur/Ponzie	EH-28	110	65-110	NA																			
Molleur/Field	EH-29	100	65-100	33.50	6.0	100 U	200 U	5 U	10 U	12	82	5 U	15 U	0.35	40 U	5 U	10 U	658	3,200	370,000	25,000	878,000	57
Myers/Cribbed	EH-32	20	0-20	10.85	7.0	10 U	200 U	10	10 U	25 U	100 U	5 U	15 U	0.6	40 U	5 U	10 U	2,843	7,400	140,000	9,500	376,000	10 U
Leadville Gold	EH-33	130	NA	NA																			
Carlise	EH-35	60	NA	19.28																			
Zadra	EH-36	180	135-180	135.00	8.3	10 U	106	5 U	10 U	25 U	59	5 U	16	0.75	23	5 U	10 U	22	810	7,000	4,500	8,000	10
Lk Fk Trlr Aban	EH-37	40	NA	NA																			
Molleur/Shop	EH-N.S.	32	NA	NA																			
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		2		45			10,000				

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

Table 4-21
GROUNDWATER CHEMICAL ANALYSES FOR EXISTING WELLS
March 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Elk Horn Shaft	DH-1	500	0-500	NA																			
Airport	LW-1	200	170-200	NA	5.5	10 U	22	5 U	3 U	5.6	30	5 U	3.3	0.2 U	10 U	5 U	3 U	366	340	1,000 U	1,200	97,000	5 U
Holliday/House	LW-2	120	85-120	NA	6.0	10 U	22	5 U	3 U	2 U	160	5 U	43	0.2 U	10 U	5 U	3 U	173	2,920	438,000	23,500	812,000	75.2
Seppi	LW-3	37	NA	NA	5.5	10 U	125	5 U	3 U	3.6	15	5 U	2 U	0.2 U	10 U	5 U	3 U	26	1,210	19,600	2,800	156,000	5 U
Canlas	LW-4	65	NA	NA																			
Beck	LW-5	35	NA	NA																			
Sk Pk Trlr Park	LW-6	50	NA	NA	5.5	10 U	22	5 U	3 U	6.6	22	5 U	7.5	0.2 U	10 U	5 U	3 U	70	660	90,000	4,100	318,000	5 U
Schmidt	LW-7	55	31-55	NA																			
Baughman	LW-8	45	21-45	NA																			
Martinez	LW-9	50	25-50	NA																			
Figuero	LW-10	30	0-30	16.23																			
Gardner	LW-11	39	27-39	NA	5.5	10 U	38	5 U	3 U	38	96	5 U	4.4	0.8	10 U	5 U	3 U	631	3,000	169,000	7,500	352,000	5 U
Chase/Shop	LW-12	125	NA	20.17	5.5	10 U	18	60	3 U	2 U	311	5 U	14	0.2 U	22	5 U	3 U	19,800	6,290	514,000	13,400	794,000	99
Chase/House	LW-13	92	77-92	35.40																			
Montez	LW-14	34	22-34	9.38	6.0	10 U	9.1	5 U	3 U	6.3	3,030	5 U	516	0.2 U	10 U	5 U	3 U	416	50 U	340,000	34,800	634,000	2.5 U
Hecla	LW-15	575	161-575	NA																			
Hinsley	LW-16	530	500-530	NA																			
Zahradnick	LW-17	50	NA	15.72	5.5	10 U	20	5 U	4	2.4	17	5 U	3.2	0.2 U	10 U	5 U	3 U	974	3,530	320,000	6,100	486,000	5 U
F. Sieber	LW-18	90	66-90	45.92																			
R. Sieber	LW-19	65	NA	0.67	6.0	10 U	13	44	3 U	2.7	89	5 U	1,460	0.2 U	10 U	5 U	3 U	9,990	3,320	372,000	12,000	671,000	2.5 U
Bain	LW-20	90	NA	NA																			
Archuletta	LW-21	90	NA	10.50	6.0	10 U	36	5 U	4.1	12	265	5 U	5.2	0.2 U	10 U	5 U	3 U	110	8,620	160,000	13,400	564,000	2.5 U
Winkler	LW-22	19	17-19	5.42																			
Hibbemeyer	LW-24	76	NA	NA	5.5	10 U	41	50 U	3.3	40	67	25 U	5.3	0.2 U	10 U	0.1	3 U	84	3,400	870,000	86,300	1,360,000	2.5 U
Myers/Well	LW-25	42	NA	NA																			
Gruden	LW-26	43	NA	29.54	5.0	10 U	25	5 U	3 U	2.8	394	5 U	3.4	0.2 U	10 U	5 U	3 U	29	4,240	111,000	6,300	296,000	2.5 U
Flores	LW-27	15	0-15	11.17																			
Holliday/Pourla	LW-28	110	85-110	NA																			
Holliday/Field	LW-29	100	65-100	23.42	6.0	10 U	25	5 U	3 U	2 U	137	5 U	2 U	0.2 U	10 U	25 U	3 U	557	3,080	431,000	23,400	943,000	162
Myers/Cribbed	LW-32	20	0-20	NA	6.0	10 U	23	11	3 U	5.0	126	5 U	13	0.2 U	10 U	5 U	3 U	2,330	4,080	132,000	9,000	453,000	2.5 U
Leadville Gold	LW-33	130	NA	NA																			
Carlsa	LW-35	60	NA	20.00																			
Jacks	LW-36	180	135-180	NA																			
Sk Pk Trlr Area	LW-37	40	NA	12.00																			
Holliday/Shop	LW H.S.	32	NA	NA																			
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

GW/CAIGDG/032.7

Table 4-22
GROUNDWATER CHEMICAL ANALYSES FOR EXISTING WELLS
June 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Elk Horn Shaft	EH-1	500	0-500	NA																			
Airport	EM-1	200	170-200	NA	7.8	3 U	84	4 U	4 U	6.2	41	2 U	5 U	0.1 U	5 U	3 U	3 U	335	310	53,000	3,000 U	105,000	10 U
Molleur/House	EM-2	120	85-120	NA	7.7	10	24	4 U	4 U	3.1	73	5 U	15	0.1 U	5 U	5 U	3 U	7.1	3,200	300,000	29,000	845,000	88
Seppi	EM-3	37	NA	NA	7.6	3 U	114	4 U	4 U	3 U	30	2 U	5 U	0.1 U	5 U	3 U	3 U	61	780	16,000	3,000 U	115,000	10 U
Castas	EM-4	65	NA	NA																			
Beck	EM-5	35	NA	NA																			
Lk Fk Trlr Park	EM-6	50	NA	NA	6.8	3 U	85	4 U	4 U	3 U	15 U	2 U	5 U	0.1 U	5 U	3 U	3 U	212	930	100,000	5,800	220,000	10 U
Schmidt	EM-7	55	31-55	NA																			
Baughman	EM-8	45	21-45	NA																			
Martinez	EM-9	50	25-50	NA																			
Figuero	EM-10	30	0-30	14.88																			
Gardner	EM-11	39	27-39	NA	7.3	3 U	393	4 U	4 U	24	23	5 U	11	0.1 U	5 U	3 U	3 U	633	850	60,000	3,000 U	100,000	10 U
Chase/Shop	EM-12	125	NA	17.25	6.3	3 U	16	85	4 U	3 U	65	5 U	16	0.1 U	24	50 U	3 U	22,100	5,700	480,000	14,000	805,000	93
Chase/House	EM-13	92	77-92	32.63	7.8	3 U	88	4 U	4 U	3 U	84	5 U	21	0.1 U	5 U	5 U	3 U	269	5,700	309,000	15,000	605,000	204
Mestas	EM-14	34	22-34	5.79	7.3	3 U	120	15	4 U	3 U	660	5 U	431	0.1 U	9.2	5 U	3 U	4,930	3,900	216,000	8,700	385,000	10 U
Hecla	EM-15	575	161-575	NA																			
Hinsley	EM-16	530	500-530	NA																			
Zakraisek	EM-17	50	NA	19.50	8.2	3 U	30	4 U	4 U	3 U	48	5 U	12	0.1 U	5 U	5 U	3 U	1,650	4,200	282,000	6,400	505,000	10 U
F. Shober	EM-18	90	66-90	37.31																			
R. Shober	EM-19	45	NA	4.92	6.5	3 U	144	114	4 U	9.8	335	2 U	3,030	0.1 U	21	5 U	3 U	23,300	2,400	318,000	13,000	500,000	10 U
Bain	EM-20	90	NA	NA																			
Archuleta	EM-21	90	NA	13.92	7.4	3 U	31	4 U	4 U	12	25	5 U	8.4	0.1 U	5 U	3 U	3 U	176	7,400	92,000	6,900	225,000	10 U
Winkler	EM-23	39	17-39	4.54																			
Wibbenmeyer	EM-24	76	NA	NA	8.0	3 U	49	4 U	4 U	24	15 U	5 U	5 U	0.1 U	5 U	3 U	3 U	56	6,800	203,000	35,000	625,000	10 U
Myers/Well	EM-25	42	NA	11.37																			
Gruden	EM-26	43	NA	28.71	7.0	3 U	36	4 U	4 U	4.6	102	5 U	16	0.1 U	5 U	5 U	3 U	138	3,400	122,000	4,400	235,000	10 U
Flores	EM-27	15	0-15	NA																			
Molleur/Puzzle	EM-28	110	85-110	NA																			
Molleur/Field	EM-29	100	65-100	20.92	7.8	3 U	19	4 U	4 U	4.1	62	2 U	26	0.1 U	5 U	5 U	3 U	267	3,200	365,000	23,000	830,000	165
Myers/Cribbed	EM-32	20	0-20	Dry	7.6	3 U	24	15	4 U	5.9	28	2 U	5.3	0.1 U	5.4	5 U	3 U	2,930	4,600	135,000	7,000	410,000	10 U
Leadville Gold	EM-33	130	NA	NA																			
Carlise	EM-35	60	NA	17.00																			
Zadra	EM-36	100	135-180	NA	7.5	3 U	135	4 U	4 U	3 U	17	2 U	5 U	0.1 U	5 U	3 U	3 U	64	310	5,000 U	3,000 U	40,000	10 U
Lk Fk Trlr Aban	EM-37	40	NA	5.00																			
Molleur/Shop	EM-M.S.	32	NA	NA																			
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

DE/CALGOG/032.8

Table 4-23
GROUNDWATER CHEMICAL ANALYSES FOR EXISTING WELLS
September 1983

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Elk Horn Shaft	EH-1	500	0-500	NA																			
Airport	LW-1	200	170-200	NA	7.9	3 U	80	4 U	4 U	5.7	83	2 U	5 U	0.1 U	5 U	5 U	3 U	306	360	5,000 U	3,000 U	140,000	10 U
Mollour/House	LW-2	120	85-120	NA	7.8	3 U	30	4 U	4 U	3 U	64	5 U	12	0.1 U	5 U	5 U	3 U	23	3,200	550,000	19,000	810,000	84
Beppl	LW-3	37	NA	NA	7.9	3 U	110	4 U	4 U	3 U	31	5 U	5 U	0.1 U	5 U	3 U	3 U	71	560	16,000	3,000 U	160,000	10 U
Caslas	LW-4	65	NA	NA																			
Bach	LW-5	35	NA	NA	8.0	3 U	96	4 U	4 U	39	19	2 U	5 U	0.1 U	5 U	3 U	3 U	150	120	12,000	3,000 U	140,000	
Lk Ck Trlr Park	LW-6	50	NA	NA	7.8	3 U	102	4.3	4 U	3.6	15 U	5 U	5 U	0.1 U	5 U	3 U	3 U	162	1,300	90,000	5,800	310,000	10 U
Schmidt	LW-7	55	31-55	NA																			
Baughman	LW-8	45	21-45	NA																			
Martinez	LW-9	50	25-50	NA																			
Figuero	LW-10	30	0-30	16.50																			
Gardner	LW-11	39	27-39	NA	7.6	3 U	38	4 U	4 U	3 U	83	2 U	15	0.1 U	5 U	3 U	3.6	220	2,600	152,000	10,000	360,000	10 U
Chase/Shop	LW-12	125	NA	NA	6.8	3 U	15	80	4 U	7.2	954	5 U	33	0.1 U	26	5 U	3.1	20,800	5,800	670,000	11,000	960,000	101
Chase/House	LW-13	93	77-93	NA	8.0	3 U	38	4 U	4 U	3.7	103	5 U	16	0.1 U	5 U	3 U	3 U	114	6,000	350,000	11,000	800,000	203
Mestas	LW-14	34	22-34	7.00	7.5	3 U	12 U	4 U	4 U	3 U	35	5 U	331	0.1 U	5 U	5 U	3 U	1,110	450	257,000	11,000	460,000	10 U
Mecla	LW-15	575	161-575	NA																			
Hinsley	LW-16	530	500-530	NA																			
Bokitsch	LW-17	50	NA	NA	7.7	3 U	23	4 U	4 U	3 U	41	5 U	7.9	0.28	5 U	3 U	3 U	1,090	3,700	280,000	8,800	600,000	10 U
F. Ghober	LW-18	96	66-90	42.83																			
R. Ghober	LW-19	45	NA	5.83	7.1	3 U	45	56	4 U	4.3	90	5 U	1,330	0.1 U	12	5 U	3 U	10,300	2,400	390,000	14,000	640,000	10 U
Bato	LW-20	90	NA	NA																			
Archuletta	LW-21	90	NA	NA	7.9	3 U	25	4 U	4 U	13	201	2 U	227	0.1 U	5 U	3 U	3 U	184	8,000	86,000	8,800	360,000	10 U
Winkler	LW-23	39	17-39	9.17																			
Wibbenmeyer	LW-24	76	NA	NA	7.5	3 U	40	4 U	4 U	18	15 U	5 U	6.9	0.1 U	5 U	5 U	4.5	110	6,500	850,000	90,000	1,320,000	10 U
Myers/Well	LW-25	42	NA	NA																			
Gruden	LW-26	43	NA	31.00	7.6	3 U	24	4 U	4 U	8	198	2 U	12	0.1 U	5 U	3 U	3.3	136	4,300	100,000	4,200	300,000	10 U
Flores	LW-27	15	0-15	NA																			
Mollour/Fonte	LW-28	110	85-110	NA																			
Mollour/Field	LW-29	100	65-100	21.00	7.0	3 U	19	5.9	4 U	3 U	83	5 U	7.9	0.1 U	5 U	5 U	3 U	650	3,700	550,000	28,000	820,000	165
Myers/Cribbed	LW-32	30	0-30	20.25	7.6	5 U	101	9.8	4 U	16	15 U	3 U	6.8	0.1 U	5 U	3 U	4.2	2,700	4,200	115,000	6,900	350,000	10 U
Leadville Gold	LW-33	130	NA	NA																			
Catiso	LW-35	60	NA	19.00																			
Zadra	LW-36	100	135-180	NA	7.9	5 U	157	4 U	4 U	4.7	41	2 U	6.4	0.1 U	5 U	3 U	3 U	173	680	4,000	3,000 U	110,000	10 U
Lk Ck Trlr Aban	LW-37	40	NA	10.08																			
Mollour/Shop	LW M.S.	32	NA	NA																			
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--Indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

Table 4-24
GROUNDWATER CHEMICAL ANALYSES FOR EXISTING WELLS
November 1985

Location	Well No.	Total Depth (ft BGL)	Screened Interval (ft BGL)	Water Level (ft BTOC)	Lab pH	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	NO_3	SO_4	Cl	TDS	CN
Elk Horn Shaft	EH-1	500	0-500	NA																			
Airport	EW-1	200	170-200	NA	7.62	2 U	27	4 U	4 U	6.1	103	2 U	22	0.1 U	7 U	2 U	3 U	328	240	30000 U	3,000 U	85,000	1,030
Molleur/House	EW-2	120	85-120	NA	7.63	2 U	20	4 U	4 U	3 U	109	5 U	8.9	0.1 U	7 U	5 U	3 U	20	3,200	400,000	24,000	750,000	165
Buppi	EW-3	37	NA	NA	7.83	2 U	124	4 U	4 U	3.7	40	5 U	5.5	0.1 U	7 U	5 U	3 U	256	1,200	23,000	8,500	150,000	20
Casias	EW-4	65	NA	NA																			
Beck	EW-5	35	NA	NA	7.82	2 U	93	4 U	4 U	36	23	2 U	5 U	0.1 U	7 U	5 U	3 U	334	100 U	16,000	4,300	110,000	10 U
Lk Fk Trlr Park	EW-6	50	NA	NA	7.48	10 U	73	4 U	4 U	3 U	32	5 U	5 U	0.1 U	7 U	5 U	3 U	68	770	102,000	4,600	230,000	2,060
Scmidt	EW-7	55	31-55	NA																			
Baughman	EW-8	45	21-45	NA																			
Martinez	EW-9	50	25-50	NA	7.49	2 U	31	4 U	4 U	25	293	5 U	201	0.1 U	7 U	5 U	3 U	88	5,700	200,000	21,000	380,000	10 U
Figuero	EW-10	30	0-30	NA																			
Gardner	EW-11	39	27-39	NA																			
Chase/Shop	EW-12	125	NA	11.67	6.72	2 U	14	88	4 U	3 U	42	5 U	13	0.1 U	23	2 U	3 U	12,900	5,600	500,000	16,000	860,000	5,270
Chase/House	EW-13	92	77-92	NA	7.71	2 U	39	4 U	4 U	3 U	100	5 U	73	0.1 U	7 U	5 U	3 U	217	6,000	340,000	16,000	660,000	476
Mestas	EW-14	34	22-34	7.17	7.20	2 U	13 U	9.1	4 U	3.9	26	5 U	273	0.1 U	7 U	5 U	3 U	1,300	190	293,000	14,000	460,000	14
Hecla	EW-15	575	161-575	NA																			
Hinsley	EW-16	530	500-530	NA																			
Zakraisek	EW-17	50	NA	NA	7.41	2 U	24	4.8	4 U	14	46	2 U	21	0.1 U	7 U	50 U	3 U	1,420	3,600	311,000	13,000	580,000	10 U
F. Shober	EW-18	96	66-90	NA																			
R. Shober	EW-19	45	NA	5.92	7.19	2 U	13 U	47	4 U	5.1	159	50 U	1,020	0.1 U	9.1	NA	3 U	9,110	3,000	366,000	17,000	580,000	10 U
Bain	EW-20	90	NA	NA																			
Archuletta	EW-21	90	NA	NA																			
Winkler	EW-23	39	17-39	NA																			
Wibbemeyer	EW-24	76	NA	NA	7.43	2 U	45	4 U	4 U	6.8	16	5 U	8.2	0.1 U	7 U	5 U	3 U	63	7,400	496,000	96,000	1,150,000	10 U
Myers/Well	EW-25	42	NA	NA																			
Gruden	EW-26	43	NA	NA	7.24	2 U	21	4 U	4 U	5.7	202	2 U	63	0.1 U	7 U	5 U	3 U	89	4,200	104,000	10,000	260,000	10 U
Flores	EW-27	15	0-15	NA																			
Molleur/Ponzio	EW-28	110	85-110	NA																			
Molleur/Field	EW-29	100	65-100	20.58	7.51	2 U	19	4.2	4 U	4.2	69	5 U	9.8	0.1 U	7 U	5 U	3 U	516	3,800	404,000	26,000	730,000	187
Myers/Cribbed	EW-32	20	0-20	NA	7.38	2 U	15	12		3.6	17	2 U	8.7	0.1 U	7 U	5 U	3 U	2,310	4,200	139,000	10,000	260,000	10 U
Leadville Gold	EW-33	130	NA	NA																			
Carlso	EW-35	60	NA	NA																			
Zadra	EW-36	180	135-180	NA	7.73	10 U	102	4 U	4 U	3 U	43	2 U	5 U	0.1 U	7 U	2 U	3 U	38	600	5,100	5,400	85,000	10 U
Lk Fk Trlr Aban	EW-37	40	NA	NA																			
Molleur/Shop	EW-M.S.	32	NA	NA																			
Primary D.W. Standards						50	1,000	10	50			50		2		10	50		10,000				
Secondary D.W. Standards										1,000	300		50					5,000		250,000	250,000	500,000	
Proposed MCLG's						50	1,500	5	120	1,300		20		3		45			10,000				

Notes: Dry--indicates the well did not produce enough water for complete sample volume.
U--not detected, value set at detection limit.
NA--not analyzed/not available.
All chemical data reported as ug/l unless otherwise noted.
Chemical data are shown for dissolved metals except values for NO_3, SO_4, Cl, TDS, and CN are total concentrations.
BGL--below ground level.
BTOC--below top of casing.

"maximum contaminant levels" or "MCL's." The current MCL's for inorganic contaminants found in 40 C.F.R. § 141.11(b). are included in each table. The State of Colorado's primary drinking water regulations establish identical standards for inorganic contaminants.

EPA has also established "secondary" MCL's which are welfare-based standards relating to public acceptance of drinking water (e.g., taste or odor). At much higher levels, health implications may also exist. Each table lists the secondary MCL's for inorganic contaminants from 40 C.F.R. § 143.3. The State of Colorado has not established secondary MCL's.

The 1986 amendments to the Safe Drinking Water Act provide for promulgation of "maximum contaminant level goals" or "MCLG's." MCLG's are to be set at levels at which no known or anticipated health effects occur, with an adequate margin of safety. Currently there are no MCLG's for inorganic contaminants, except fluoride. However, proposed MCLG's for other inorganic contaminants are found in the November 13, 1985, Federal Register. For comparison purposes, the proposed MCLG's are listed in each table.

Groundwater chemistry, particularly dissolved metals concentrations, is more strongly affected by depth than by location along California Gulch. The water level data demonstrated that recharge and drainage is most active in the shallower alluvial material and decreases with depth. The groundwater chemistry reflects the active exchange between surface water and groundwater. Specific conductance, a measure of the total ionic material dissolved in the water, including metals, is highest in the upper 25 to 50 feet of the California Gulch alluvial groundwater. Mean specific conductivity values for both new and existing wells in this depth range are approximately the same as the mean value for California Gulch surface water, approximately 1,000 micromhos (μmhos). Specific conductivity, in general, decreases with depth.

Sulfate is closely associated with the oxidation of sulfides. Sulfate, like specific conductivity, decreases with the depth. The mean sulfate concentration in the upper 25 feet of the California Gulch alluvium ranges from less than 100 mg/l to more than 1,000 mg/l. The secondary MCL is 250 mg/l. Many of the private (EW) and new wells (NW) in the California Gulch alluvium exceed this concentration, particularly those completed in the upper 50 feet of the alluvium.

Manganese, zinc, and cadmium are trace metals that are easily mobile in the groundwater system; iron and lead are not very mobile in oxidized, sulfate-rich groundwater. Manganese, zinc, and cadmium were used to determine the extent of vertical contamination in the California Gulch alluvial groundwater system resulting from the recharge from the surface water.

Manganese has a secondary MCL of 50 µg/l. Manganese concentrations for surface water at stations SW-4, SW-7, SW-9, and SW-12 ranged from 9,330 µg/l at SW-12 to 24,530 µg/l at SW-9. Manganese concentrations in groundwater in the upper 20 feet of the alluvium ranged from below the standard to as much as 15,000 µg/l. In the 20- to 50-foot depth range, manganese concentrations decrease to less than 4,000 µg/l; below 50-foot depths, manganese generally meets the standard.

Zinc has a secondary MCL of 5,000 µg/l. The zinc concentrations measured from the above surface water stations range from 25,000 µg/l at SW-12 to 62,500 µg/l at SW-4. The zinc content decreases in a downstream order; it is highest below the Yak Tunnel discharge and lowest at the confluence with the Arkansas River. Zinc concentrations in the groundwater are highest in the upper 25 feet of the alluvium ranging from below the standard to as much as 35,000 µg/l. Zinc concentrations in the 25- to 50-foot depth range from below standard to as much as 1,000 µg/l. Below an approximate

50-foot depth, the typical zinc concentration is less than 500 μg/l.

Cadmium has a primary MCL of 10 μg/l. Cadmium concentrations dissolved in the surface water of the four comparative surface water stations mentioned previously ranged from 104 μg/l at SW-12 to 267 μg/l at SW-4. Cadmium, like zinc, generally decreases with distance below the Yak Tunnel discharge. Like manganese and zinc, the upper 25 feet of the California Gulch alluvium contains the highest concentration of cadmium. Concentrations range from below the drinking water standard to as much as 100 μg/l. Mean cadmium concentrations decrease to less than 10 μg/l in the 25- to 50-foot depth ranges and to less than 5 μg/l in deeper parts of the groundwater system.

The upper 25 to 50 feet of the California Gulch groundwater system contain metals in concentrations in excess of drinking water standards. These excessive concentrations result in part from infiltration of California Gulch surface water.

Existing wells that exceed primary MCL's are noted as follows:

- Chase Shop, EW-12. Cadmium ranged between 65 and 116 μg/l for all five sampling events.

- Chase House, EW-13. Cyanide exceeded 200 μg/l on two occasions (204 μg/l in June 85 and 203 μg/l in September). Cyanide routinely appears at EW-12, EW-13, and occasionally at EW-29. To date, the source of the contamination has not been located. Several additional monitor wells would be required to locate the source, but until cyanide levels dramatically increase, no additional work is anticipated.

- Mestas, EW-14. A cadmium concentration in June 85 of 15 µg/l was noted. Based on this plus additional sampling data, EPA took action in May 1986 to connect the Mestas household to the Parkville public water system.

- Shoeber, EW-19. Cadmium ranged from 28 to 1124 µg/l over all five sampling events.

- Gruden, EW-26. Lead at 296 µg/l was noted during the November 1984 sampling episode. This value is suspect since lead was not detected for the four subsequent sampling events.

- Meyer, EW-32 (cribbed). Cadmium ranged from 10 to 15 µg/l on four of the five sampling events.

These wells, and others, exceeded secondary MCL's on several occasions. These data are presented in Tables 4-20 through 4-24.

Groundwater and Tailings Impoundments

Six new monitoring wells (NW) were installed downgradient of tailings impoundments: one below the Oregon Gulch tailings impoundment (NW-4), one below the semi-active Leadville Corporation tailings impoundment near Stringtown (NW-10), and four below the three impoundments on the California Gulch mainstem (NW-3, NW-5, NW-5A, and NW-5B). Well water below the tributary impoundments contains some of the highest concentrations of dissolved metals of any samples collected on the site. In comparison, well water from below the California Gulch impoundments sites contained several of the lowest concentrations of dissolved metals. Table 4-25 presents mean dissolved concentrations of sulfate, zinc, manganese, and cadmium in these six groundwater monitoring wells.

Table 4-25
MEAN DISSOLVED CONCENTRATIONS OF SULFATE AND SELECTED METALS IN NEW MONITORING WELLS BELOW SITE TAILINGS IMPOUNDMENTS FOR ALL SAMPLING EVENTS

Monitoring Well	Screened Interval (ft BGL)	Mean Dissolved Concentration Sulfate (µg/l)	Zinc (µg/l)	Manganese (µg/l)	Cadmium (µg/l)
NW-4	5-45	17,100,000	676,000	1,396,000	906
NW-10	10-50	240,000	8,240	3,700	54
NW-3	26-76	61,000	149	99	U
NW-5	48-108	1,253,000	524	211	U
NW-5A	15-25	3,100,000	574	16	U
NW-5B	160-220	529,000	46	99	U

Note: U=Undetected.
BGL=Below Ground Level

Monitoring well NW-4, below the Oregon Gulch impoundment, had metal and sulfate concentrations much higher than the mean dissolved constituents for the Yak Tunnel discharge to California Gulch surface water. The groundwater moving downgradient from the Oregon Gulch impoundment does not seem to influence California Gulch surface water quality between the NW-5 well nest and the NW-6 well nest. Groundwater quality improves (decreases in metals) in the mainstem of the Gulch between NW-2 and NW-6A.

Monitoring well NW-10, downgradient of the semi-active tailings impoundment (now owned by Leadville Corporation), on a tributary to Malta Gulch, had metal concentrations much lower than the groundwater concentration in well NW-4. The difference between the two sets of values is due to either dilution by groundwater or because of low quantities of sulfides in the impoundments. Compared to NW-4, the dissolved zinc to sulfate ratio is essentially the same, and the cadmium to zinc ratio is within one order of magnitude.

The three tailings impoundments in the California Gulch main-stem do not appear to significantly affect the water quality of the less than 30-foot-depth groundwater system in the California Gulch alluvium. Comparison of groundwater chemistry in monitoring wells NW-2 (Upper California Gulch) and NW-6A (below tailings impoundments) demonstrates the quality in the 5- to 30-foot interval (Table 4-26).

Table 4-26
MEAN DISSOLVED CONCENTRATIONS OF SULFATE AND SELECTED METALS FROM ABOVE AND BELOW TAILINGS IMPOUNDMENTS ON CALIFORNIA GULCH

Sample Site Number	Screened Interval (ft BGL)	Mean Dissolved Concentration			
		Sulfate (µg/l)	Zinc (µg/l)	Manganese (µg/l)	Cadmium (µg/l)
NW-2	8-28	736,000	74,700	30,400	404
SW-4	NA	794,000	62,500	19,100	267
SW-7	NA	768,000	56,120	24,300	230
NW-6A	9-29	618,000	14,800	4,020	53

Note: NA = Not Applicable (Surface Water Stations)
BGL = Below Ground Level

Well NW-2, in upper California Gulch, indicates groundwater quality above the tailings impoundments. However, this well may reflect influences of the Yak Tunnel discharge. Well NW-6A is approximately half a mile below the nearest tailing impoundment and approximately 1,500 feet downgradient of the Oregon Gulch confluence with California Gulch. However, according to data presented in Figure 4-6, California Gulch is a gaining stream in this half-mile stretch. Near NW-6A, the Gulch becomes a losing stream. Thus, leachate from the tailings impoundments could enter the Gulch and be transported downstream to the area of NW-6A. Here, they could enter the near surface groundwater system.

Sulfate, zinc, manganese, and cadmium all decrease in the shallow groundwater from the Yak Tunnel area to below the tailings impoundments on California Gulch. Sulfate shows little change in concentration, probably because it is near the minimum concentration for groundwater in the mineralized area. Zinc, cadmium, and manganese concentrations decrease by more than a factor of 5. A water chemistry comparison with the two surface water sites, SW-4 and SW-7 (located between the Apache Energy and Minerals Company's impoundment and Oregon Gulch), indicate that the surface water sulfate, zinc, and cadmium also decrease over this reach; however, manganese increases.

The cadmium to zinc ratios of the groundwater are reasonably constant, and strongly correlate with the cadmium to zinc ratios of surface water at both SW-4 and SW-7. This, plus the increase in concentration of manganese in the surface water, confirms that, in the tailings impoundment area on California Gulch, shallow groundwater (to 30 feet) is moving into the surface water. The subsurface area covered by the tailings impoundments is structurally complex. This includes several major fault zones that mark the beginning of the major alluvial system of lower California Gulch.

Groundwater and Slag Piles

Monitoring well NW-17 is adjacent to and upgradient from the major slag pile on lower California Gulch; well NW-8 is downgradient of the pile. A spring, SW-10, is adjacent to and downgradient of the slag, but upgradient of well NW-8. A comparison of the mean dissolved concentrations for sulfate and other metals for these three sampling sites is shown in Table 4-27. Results, in the order NW-17, SW-10, NW-8 indicated: (1) zinc increased by almost two orders of magnitude (81 and 47 times); (2) manganese concentrations essentially tripled; and (3) cadmium concentrations doubled. The slag apparently has an impact on the metal content in the groundwater.

Table 4-27
MEAN DISSOLVED CONCENTRATION OF SULFATE AND SELECTED METALS IN NEW MONITORING WELLS AND SURFACE WATER STATIONS BELOW STRINGTOWN SLAG PILE FOR ALL SAMPLING EVENTS

Monitoring Well	Screened Interval (ft BGL)	Mean Dissolved Concentration Sulfate (µg/l)	Zinc (µg/l)	Manganese (µg/l)	Cadmium (µg/l)
NW-8	16-53	969,000	21,175	884	76
NW-17	60-100	1,393,000	443	317	39
SW-10	NA	1,114,000	36,114	1,172	54

Note: NA=Not Applicable (Surface Water Station)
BGL=Below Ground Level

DATA INTERPRETATION

STATISTICS

Data management was an important tool in regard to data interpretation. Computer-assisted data reduction was made an integral part of this investigation to assure quality and efficiency of effort. As a first step to sorting and correlation of data, quality-audited laboratory analytical results were subjected to statistical analysis. A detailed description of the process is found in the Statistics and Water Chemistry Correlation sections in the IA.

The statistical analyses indicated that, in spite of the large range in concentration (variance) of most ions, especially the metals, many of the ions are strongly interrelated. Results of the correlation analysis (a measure of the strength of a relationship between two variables) between the dissolved ions suggested that the definition of a few ions would essentially define the behavior of many ions.

For example, iron is strongly correlated with zinc and copper. This indicates that the oxidation of the sulfides of iron (pyrite), zinc (sphalerite), and copper (chalcopyrite) essentially occurs at the same time and place. Therefore, any one of these elements could be used to define the general geochemical characteristics of the others. Zinc and cadmium are strongly correlated, suggesting that dissolved cadmium is probably coming from the oxidation of the zinc sulfide (sphalerite). Sulfate, resulting from the oxidation from the sulfides, is very strongly related to total dissolved solids, iron, zinc, and copper.

Surface Water/Groundwater Correlation

The geochemical weathering process (oxidation of sulfides to mobilize metals found in tailings, slags, and other mine wastes) results in metals contamination to the surface water and groundwater in the study area. Analysis of chemical profiles along the Gulch for surface water and alluvial groundwater indicates potential sources of contamination, i.e., the Yak Tunnel, tailings impoundments, Starr Ditch, and areas containing slags; see Figures 4-7 through 4-9. In addition, changes in seasonal surface flow and corresponding changes in the shallow zone of the alluvial groundwater levels indicate an intimate connection to each other. Pump tests further established a limited vertical connection between the upper and lower levels of the alluvial (high terrace gravel) groundwater system. Metal contamination levels typically decreased with depth into the alluvium. Results of the piezometer pipe program supported the surface water/ shallow alluvium groundwater connection, and the postulation that the mainstem of the Gulch is acting as a single conduit or pipeline along which contaminated waters are moving to the Arkansas River. Pump tests and field measurements also indicated no significant groundwater contribution from the Gulch alluvium directly to the Arkansas River.

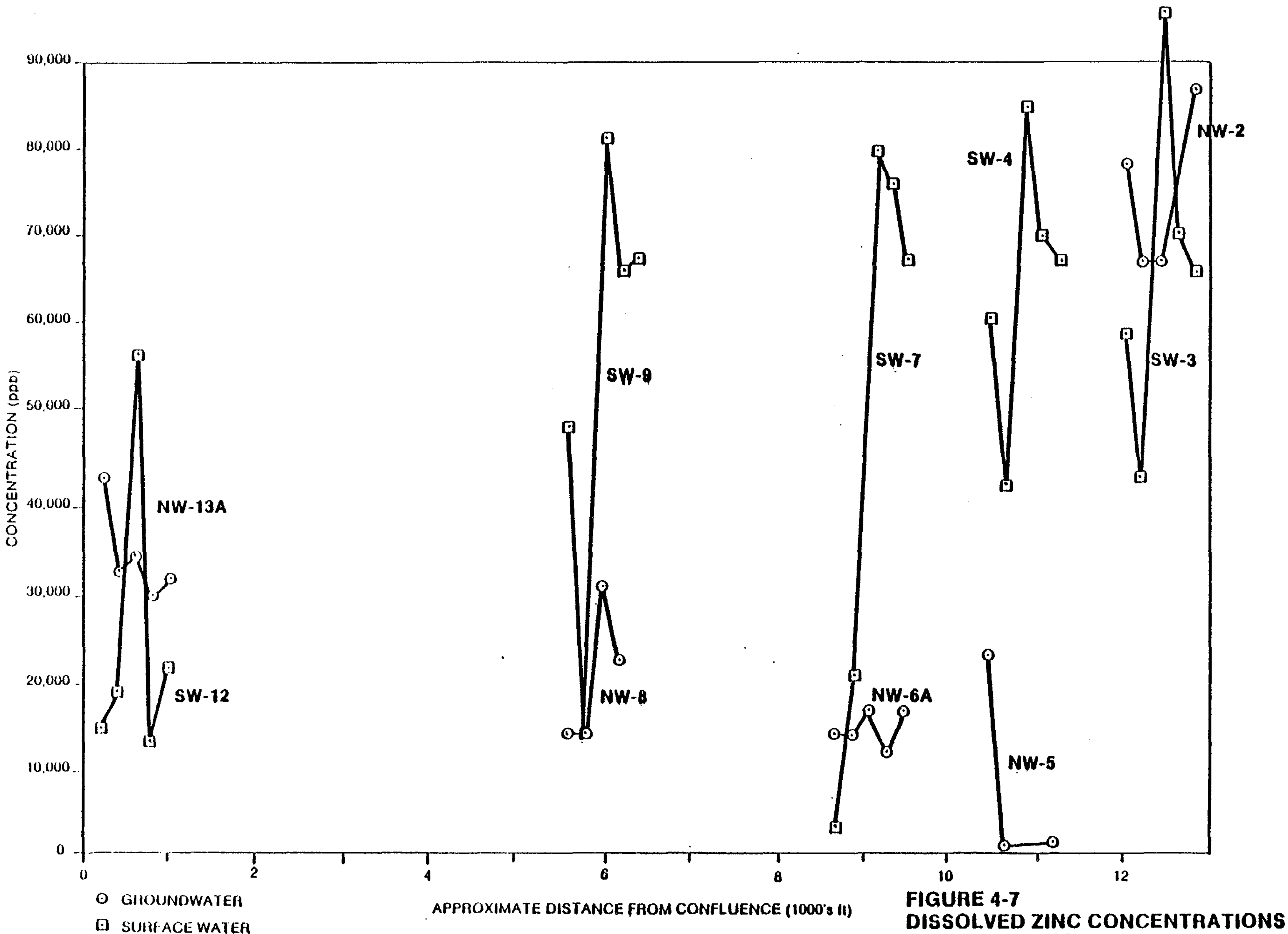


FIGURE 4-7
DISSOLVED ZINC CONCENTRATIONS
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

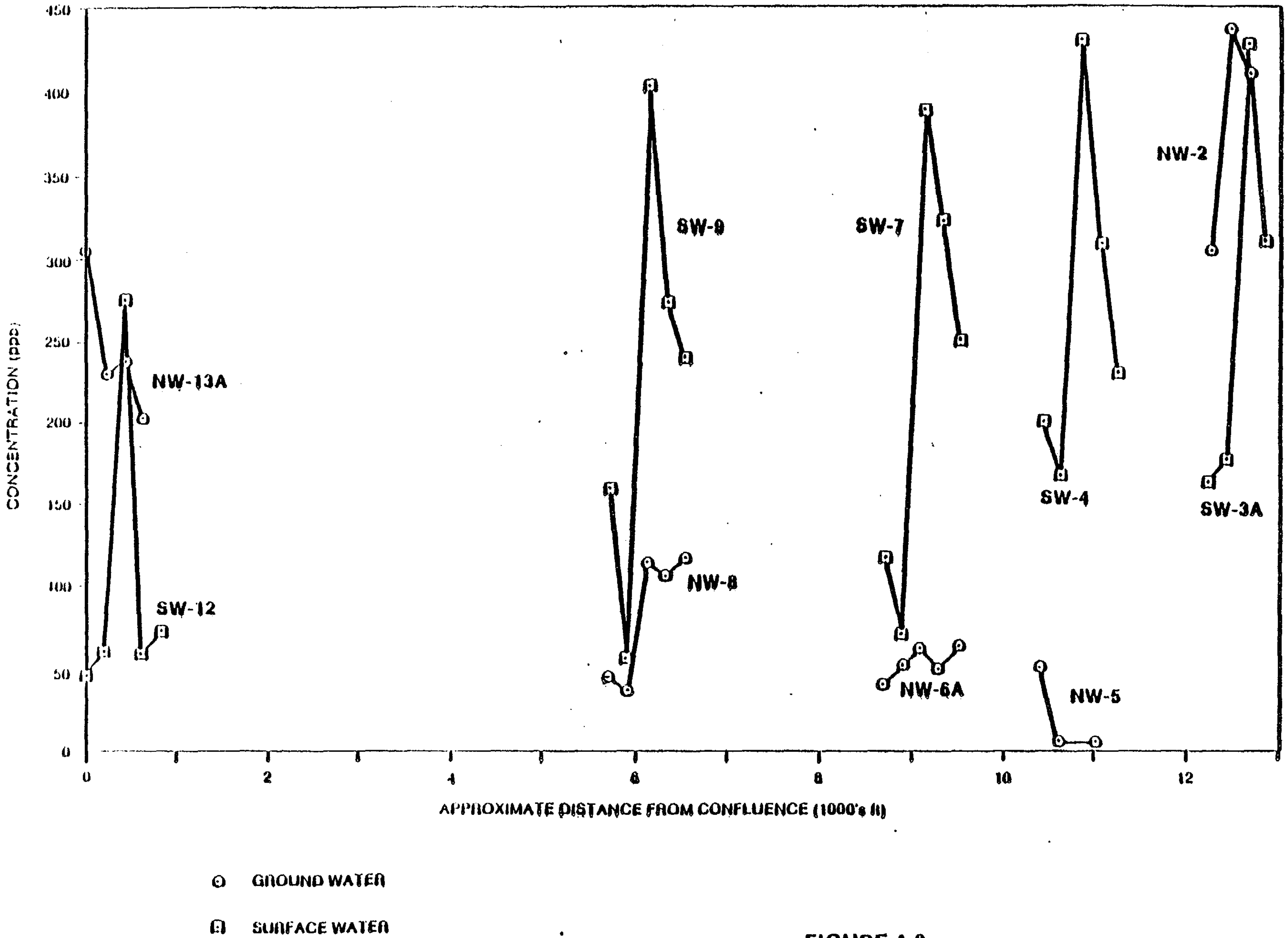


FIGURE 4-8
DISSOLVED CADMIUM CONCENTRATIONS
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

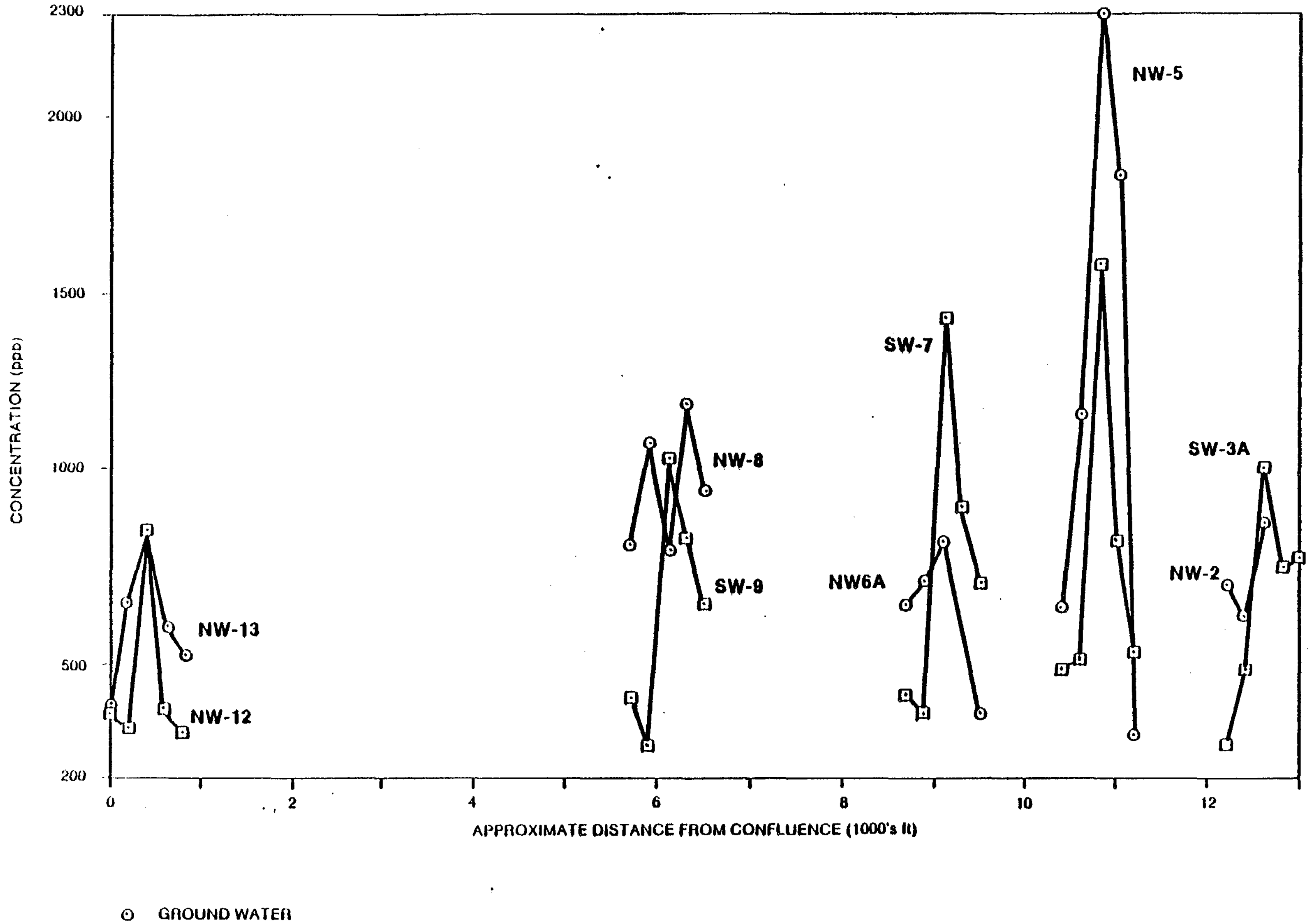


FIGURE 4-9
TOTAL SULFATE CONCENTRATIONS
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

MASS LOADINGS ANALYSIS

A mass loading analysis was undertaken to define area and point sources of contamination to the Gulch mainstem. This technique to identify sources of contamination is enhanced by demonstrating the physical and chemical similarities between the surface water and shallow alluvial groundwater.

Flow and chemistry data indicate a relatively constant contaminant load to California Gulch throughout the year, principally from the Yak Tunnel and the STP discharges. Other sources of contamination are more difficult to measure; these contaminant loads are generated from tailings or spoil piles, slag piles, and other areal sources. For example, an approximation of the annual relative contribution of contamination from the Stray Horse Gulch area can be made knowing flowrate, duration, and water quality over time. The same technique can be used for other tributary flows to the Gulch mainstem.

Contaminant mass loadings were calculated along the California Gulch conduit using measured surface flows and respective surface water quality data for a number of contaminants. The mass load calculations identified those areas that contributed significant contaminant loads to California Gulch. The mass load calculations were performed for each of the five principal sampling periods (i.e., November 1984 and March, June, September, and November 1985). Six key locations in the Gulch mainstem were selected for load calculations control. Fourteen additional tributary stations were included for analysis, when surface flows warranted this. Example mass load calculations for manganese and zinc are shown on Table 4-28. Calculations for appropriate anions and cations for all sampling periods can be found in the IA. Both dissolved and total mass loadings of key cations and anions were calculated and plotted to determine where precipitation and sorption were occurring in the stream. Examples for the June 1985 high flow period,

Table 4-28
WATER AND MASS BALANCE EXAMPLE FOR CALIFORNIA GULCH
SAMPLING PERIOD JUNE 17, 1985

								Manganese					Zinc				
Station Name	Cal. Gulch Control	Tributary Station	pH	Mainstem Flow (cfs)	Tributary Flow (cfs)	Cum. Inflow	Gain (+) Loss (-)	Diss. Conc. (ppb)	Mass Rate #/day	Total Conc. (ppb)	Mass Rate #/day	Percent of SW-12	Diss. Conc. (ppb)	Mass Rate #/day	Total Conc. (ppb)	Mass Rate #/day	Percent of SW-12
U. Cal Gulch		SW-1	3.2		2.67			4,100	59.0	3,790	54.6	13	12,700	182.9	11,600	167.1	14
Parkvile Leak		SW-2	NA		Dry			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yak Tunnel Flume		SW-3	3.7		2.70			13,400	457.3	29,000	422.3	104	10,500	1,587.4	101,000	1,470.9	123
Mill Yard Flume	SW-3A		4.3	3.52		5.37	-1.85	24,100	457.6	21,800	413.9	102	82,100	1,558.7	75,000	1,423.9	119
Tailings Area	SW-4		5.9	6.15		3.52	2.63	24,700	819.3	21,800	723.1	179	85,300	2,829.5	75,900	2,517.7	210
Below Apache	SW-4A		NA	Dry		6.15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Starr Ditch Flume		SW-5	5.0		0.35			10,400	19.6	9,430	17.6	4	37,100	70.0	33,400	63.1	5
Oregon Gulch		SWI-1	2.5		0.04			667,000	143.9	708,000	152.7	38	263,000	56.7	272,000	58.7	5
Berthod Spring		SW-6	5.5		0.08			22,400	9.7	20,300	8.8	2	56,200	24.2	50,000	21.9	2
Middle Flume	SW-7		4.0	3.88		NA	NA	26,700	558.8	25,500	533.6	132	79,800	1,670.0	76,600	1,603.0	134
Storm Drain		SWI-2	NA		Dry			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Georgia Gulch		SWI-3	5.5		0.03			7,820	1.3	7,860	1.3	0	21,700	3.5	21,600	3.5	0
Super-8 Spring		SW-8	6.5		1.02			288	1.6	274	1.5	0	6,190	34.1	5,660	31.1	3
Pawnee Gulch		SWI-4	NA		Dry			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stringtown	SW-9		4.0	5.76		4.93	0.83	26,700	829.5	25,300	786.0	194	81,000	2,516.5	77,300	2,401.5	200
Airport Gulch		SWI-5	NA		Dry			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Slag Pile Spring		SW-10	5.5	0.03				648	0.1	583	0.1	0	32,500	5.3	32,600	5.3	0
STP		SW-11	6.5	0.93				338	1.7	374	1.9	0	188	0.9	336	1.7	0
Malta Gulch		SWI-6	NA		Dry			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lower Flume	SW-12		5.0	3.85		6.72	-2.87	18,400	382.1	19,500	404.9	100	55,600	1,154.6	57,700	1,198.2	100
Upper Arkansas	SW-13		6.0	300.				40	64.7	58	93.8		109	176.4	132	213.6	
Lower Arkansas	SW-14		6.0	NA		303.85	NA	218	NA	253	NA		594	NA	709	NA	

Note: NA--Not available or not applicable.

DE/CALGU6/033

showing the mobile cation zinc (total and dissolved) profiles to compare with the iron cation (which is subject to buffering), are shown in Figures 4-10 and 4-11, respectively. All plots are shown in the Mass Loading Analysis section of the IA. Mass loading variations of cadmium for high and low flow events are shown on Figure 4-12, which demonstrate the significance of seasonal influences on mass loading rates.

Conclusions that were noted from the mass load analysis include:

- o Extensive precipitation of iron and aluminum, likely as oxy-hydroxides, occurred in the Gulch mainstem when buffered (high pH) water, such as the STP discharge, was introduced. The precipitation can be confirmed by noting the differences between dissolved and total mass loadings. To a lesser degree, other less reactive cations such as manganese and lead are also buffered, and are co-precipitated or sorbed with the iron/aluminum oxy-hydroxides.

- o Interpretation of mass load contributions of arsenic, lead, and copper are not meaningful because of their extremely low concentrations.

- o Zinc, cadmium, manganese, and sulfate are best suited for further discussion because of their higher concentrations and relatively high mobility in the environment of the Gulch.

- o There is a large increase in mass loadings of contaminants within the California Gulch drainage with snowmelt that occurred in June 1985.

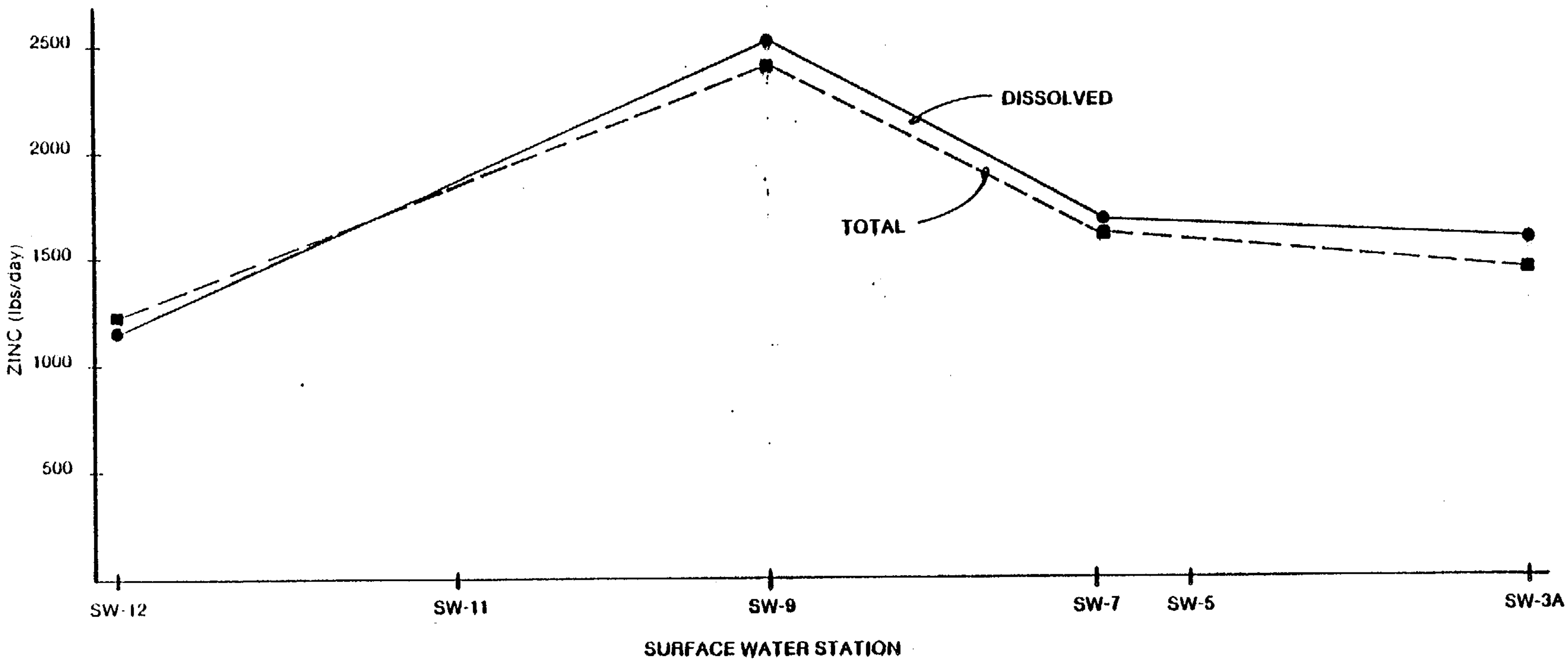


FIGURE 4-10
ZINC MASS LOADING PROFILE IN CALIFORNIA GULCH, JUNE 1985
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

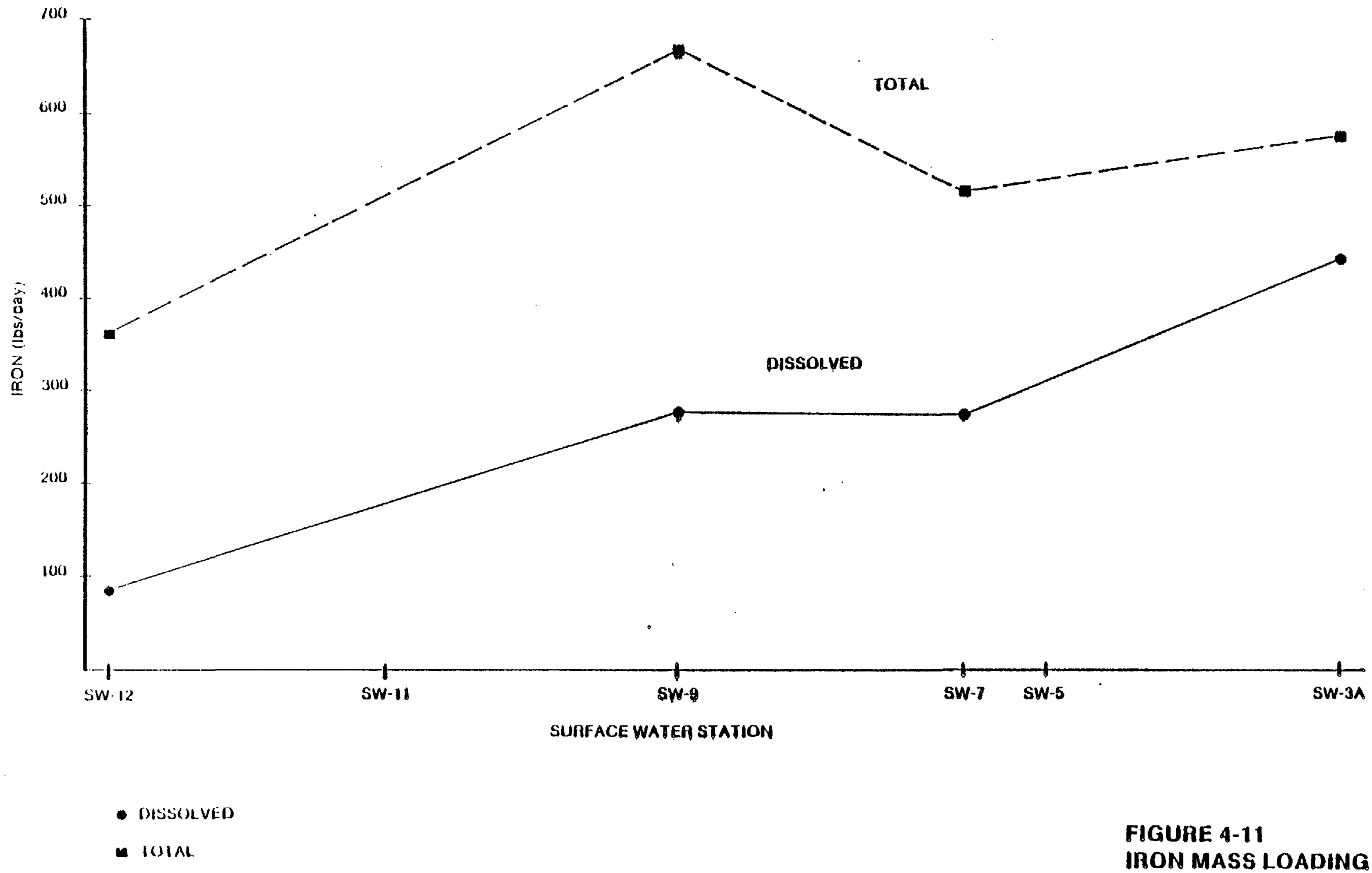


FIGURE 4-11
IRON MASS LOADING PROFILE IN CALIFORNIA GULCH, JUNE 1985
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

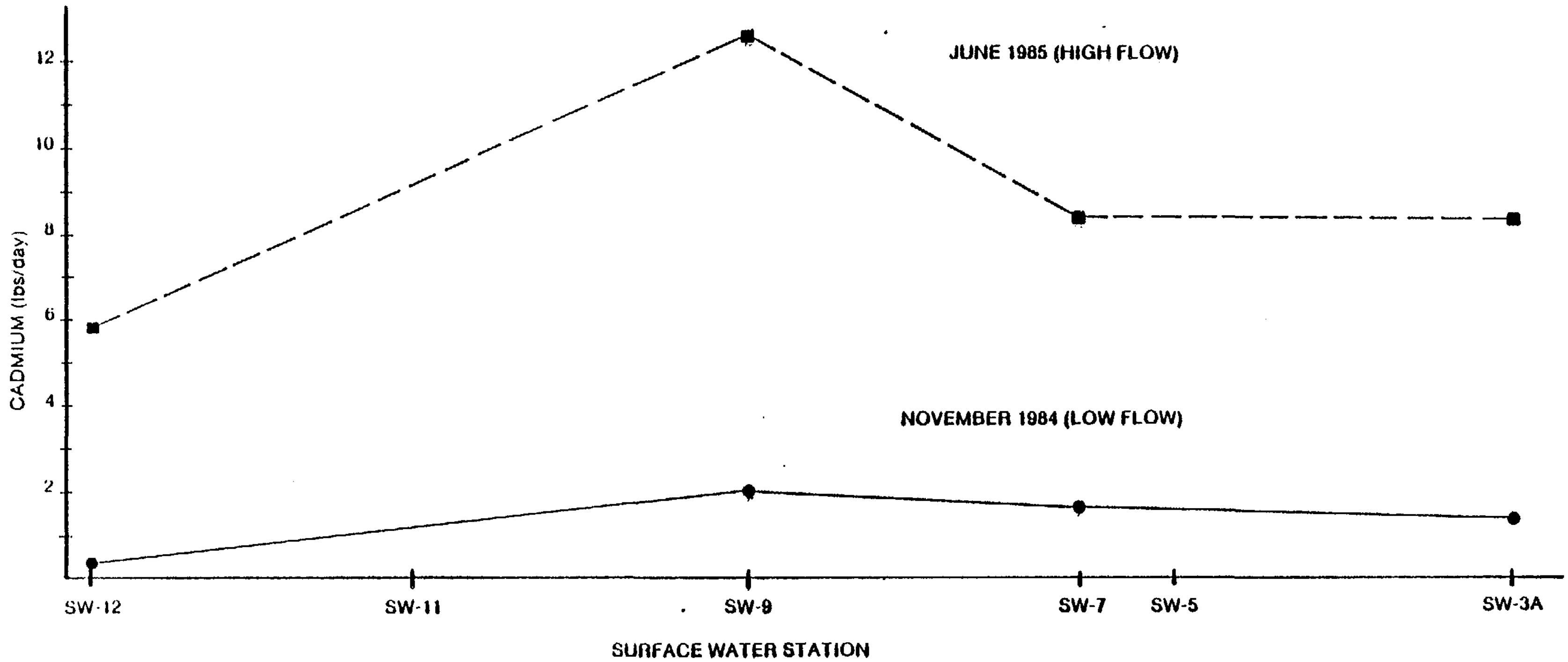


FIGURE 4-12
DISSOLVED CADMIUM MASS LOADING PROFILE IN CALIFORNIA GULCH, NOVEMBER 1984 AND JUNE 1985
CALIFORNIA GULCH RI
LEADVILLE, COLORADO

As demonstrated in the seasonal plot for cadmium (Figure 4-12), the significance of higher contaminant mass loads due to the June 1985 peak flow is evident. Additional data analysis must be conducted to normalize the contribution of the higher peak flow period to determine average annual contaminant contributions from the suspected sources. Consequently, seasonal flow dynamics had to be considered.

The mass load analysis for each sample period shows the contribution of various contaminant sources contained in tributary surface waters flowing to the Gulch mainstem. Contributions from these various contaminant sources were considered as a percentage of the discharged mass load in pounds per day at SW-12. The analysis was conducted for dissolved zinc, cadmium, and sulfate. The percent contribution of a source was determined by computing the mass load from the source and dividing it by the sum of the mass loads from all sources. The analysis was performed in segments of the Gulch. The analysis was accomplished by starting at the discharge segment (SW-12) and proceeding upstream. Segments on the Gulch were bound by: SW-12, SW-9, SW-7, SW-3A, and the upper Gulch. For clarity, the mechanics of the analysis are described as follows:

1. Calculate the mass load for all sources and the upstream control station for each segment.

2. Sum the mass loads on each segment.

3. Determine the percent contribution to the segment by dividing the source mass load from Step 1 by the sum of the segment mass loads from Step 2.

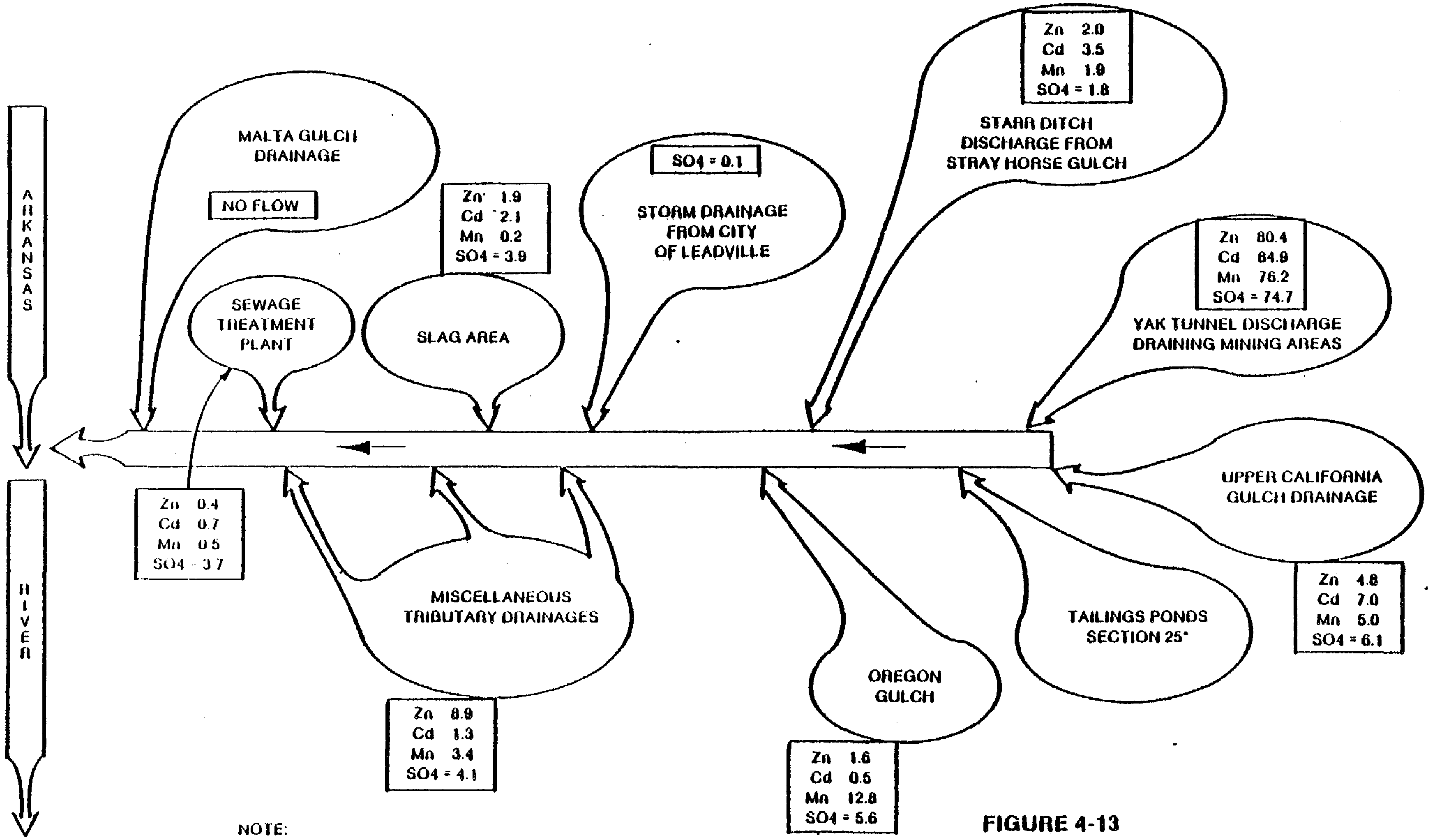
4. Multiply the source's percent contribution by the segment discharge to find the contribution of a source to the segment discharge.

5. Multiply the source's percent contribution by the stream segment's discharge percent contribution to find the contribution of a source to the discharge of the next downstream segment. This contribution is determined by analyzing the downstream segment, and the downstream mass loading rate. This procedure is continued for all segments up the stream. The percent contribution of the lowest segment's discharge is 100 percent, and is the only contribution known prior to the analysis.

6. Repeat steps 1 through 5 for all segments up the mainstem.

7. Repeat the above 6 steps for each specific sample period. The individual percent contributions resulting from this analysis for each sample period are shown in the Mass Loading Analysis section of the IA.

The average annual percent contribution over the five sample periods for each contaminant by source are shown in the Mass Loading Analysis section of the IA. The average annual percent contribution of dissolved zinc, cadmium, manganese, and sulfate from various sources to the Gulch are shown graphically in Figure 4-13. The Yak Tunnel discharge contributes about 80 percent of dissolved zinc, 85 percent of dissolved cadmium, and about 75 percent of the sulfate through SW-12 to the Arkansas River. Contributions of zinc and cadmium from the ephemeral drainages (such as the upper Gulch, Starr Ditch, Oregon Gulch, etc.) range from 1 to 7 percent.



NOTE:

ALL VALUES ARE IN WEIGHT PERCENT.
NOT INCLUDED IN THE ANALYSIS

FIGURE 4-13
AVERAGE ANNUAL CONTRIBUTION OF DISSOLVED CONTAMINANTS TO THE GULCH FROM VARIOUS SOURCES
CALIFORNIA GULCH RI, LEADVILLE, COLORADO

Phase II RI Sampling Program

Section 5
PHASE II RI SAMPLING PROGRAM

Completion of the Phase I RI activities has principally identified: (1) water quality problems at various locations in the study area; (2) probable sources and relative contribution of contaminants to the water system; and (3) an initial assessment of the geology, hydrology, geohydrology, and geochemistry of the system. The probable contaminant sources that have been identified are limited in number: mine wastes; tailings impoundments; slag piles; and the Yak Tunnel. As described in Section 4, the Yak Tunnel is the major contributor of metals to California Gulch, and subsequently to the Arkansas River.

The following specific data needs have been identified to permit further characterization of contaminant sources:

- Tailings stability and surface chemistry.
- Waste dump stability, surface chemistry, and bulk chemistry.
- Slag stability and bulk chemistry.
- Air quality to determine if this particular media presents a public health threat.
- Sediment chemistry.
- Potential for seismic activity within the general area to cause failure of tailings impoundments and waste piles.

- Soil and water quality in Starr Ditch from locations in close proximity to residences.

- Information to approximate baseline chemistry of soils, groundwater, and surface water.

- Tributary and gulch mainstem flows and water chemistry during snowmelt runoff. Several critical groundwater wells will be monitored also.

The following discussion details the activities for the Phase II remedial investigation work:

1. Tailings Stability and Surface Chemistry--Supplemental fieldwork was completed to investigate the stability of the three tailings impoundments in California Gulch and the impoundment in Oregon Gulch. Surface samples were obtained for total metals analysis.

2. Waste Dump Stability, Surface Chemistry, and Bulk Chemistry--Supplemental fieldwork prioritized and investigated the stability of key waste dumps that may pose potential threats to human health and welfare. Samples of these waste dumps were obtained to generate data on surface chemistry, bulk chemistry, and EP-Toxicity analysis.

3. Slag Pile Stability and Bulk Chemistry--Supplemental fieldwork obtained samples for bulk chemistry, and EP-toxicity analysis. Because slag piles were fused in place, stability data was not obtained.

4. Air Quality Data--Existing air quality data will be obtained and reviewed. Sampling of the mine wastes and tailings impoundments will include the chemical analyses

of the minus-80 mesh size fraction (fine-grained materials). This chemistry information may be used in air quality models to assess the potential health threats via inhalation; air quality modeling could be used as a check on the health assessment results derived from the existing air quality data.

5. Sediment Chemistry--Samples of California Gulch and Starr Ditch sediments were obtained during supplemental field activities; information on metals content will be determined.

6. Seismic Activity--A seismicity expert was selected to provide an opinion on the potential for seismic activity within the site area. This information will be used to determine the need for additional stability data on tailings impoundments and mine wastes.

7. Baseline Data--No baseline data exist for the project area. Soil samples were obtained to approximate baseline soil characteristics. No other sampling is planned.

8. Snowmelt Runoff--Surface water and selected monitor wells will be sampled over a 4- to 6-week period during snowmelt runoff. Flow rates and water levels will also be obtained. Flows through mine wastes, tributary and gulch mainstem flows and monitoring of the Arkansas River constitute the locations for this program. Data from this activity will be correlated with other Phase II data to provide the information necessary to complete the overall site FS.

Supplemental Phase II RI fieldwork has already been undertaken; analytical work will be completed during the initial phases of the FS. Data gathered during this field program will be synthesized and published as a Phase II RI Report.

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