NEAR-SURFACE ACID MINE WATER POOLS
AND THEIR IMPLICATIONS FOR MINE ABANDONMENT,
COEUR D'ALENE MINING DISTRICT, IDAHO

A Thesis
Presented in Partial Fulfillment of the Requirements for the
DEGREE OF MASTER OF SCIENCE
with a
Major in Hydrology
in the
College of Graduate Studies
University of Idaho

by
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December, 1989

AUTHORIZATION TO SUBMIT THESIS

This thesis of Bart Bretherton, submitted for the degree of Master of Science with a major in Hydrology and titled "Near-Surface Acid Mine Water Pools and Their Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho," has been reviewed in final form, as indicated by the signatures and dates given below. Permission is now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

Acid water drainage at the Bunker Hill Mine in northern Idaho is a persistent problem that requires costly treatment for compliance with NPDES regulations for point source discharges. A reconnaissance of the upper workings of the mine revealed that pools are present in the workings. This research is directed toward understanding the role of these pools in acid water production within the mine. Monitoring of these pools, their inter-level conveyances, and the mine atmosphere indicates that water quality deterioration occurs on the upper mine levels.

The quality of the water is a function of its proximity to: 1) disturbed ground overhead, 2) ore zones, 3) pyrite rich zones, and 4) the molar concentration of iron in the water entering the drift from fractures. Water quality data indicate that discharge to the drifts from fractures has already been degraded in quality prior to entry. Condensation from the mine atmosphere also is of poor quality. Seasonal recharge events flush the pooled water into the mine water flow system that moves through fractures and man-made conveyances to discharge at the Kellogg Tunnel. This flushing action produces 2-4 pounds per day of zinc from the Homestake workings during the seasonal recharge period. This zinc load is 0.2 percent of the Kellogg Tunnel zinc load. It is carried by a discharge which is 0.02 percent of the mean discharge of the Kellogg Tunnel.

ACKNOWLEDGMENTS

This project was funded by the United States Bureau of Mines; first under the Mining and Minerals Resources Research Institute Generic Center Program (Grant number G1125132) and secondly under the cooperative agreement (number C0278001). Both sources were directed by Dr. Roy E. Williams and Dr. Dale R. Ralston, professors of Hydrology at the University of Idaho.

The management of Bunker Ltd. as well as Bunker Hill mine personnel are gratefully acknowledged also. Without their knowledge, assistance and approval this study would not have been possible.

Thanks also to Tom Brooks and Sue Line for all of their editorial suggestions and work which helped produce the final form of this document.

A special thanks goes to my parents. Without their financial and moral support this project would never have been attempted.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF TABLES

CHAPTER 1
INTRODUCTION

Statement of the Problem

Acid mine drainage from underground and surface mines is a problem that commonly is experienced by mining operations where sulfides are present. Acid mine drainage is encountered in coal mines in the eastern and western United States and hard rock mines in many western states. The Bunker Hill Lead-Zinc Mine located in the Coeur d'Alene Mining District in Idaho (Figure 1), has an acid drainage problem. To prevent detrimental effects on the surrounding surface water and ground water resources this drainage must be treated to meet National Pollutant Discharge Elimination System discharge permit requirements of the Federal Water Pollution Control Act Amendment of 1972 (amended 1980, 1987). This treatment process is expensive; according to the law it must continue in perpetuity.

The acid mine drainage at the Bunker Hill Mine is difficult to abate due to the semi-ubiquity of pyrite and the mining methods used in past years. Flooding of underground workings sometimes successfully abates acid mine drainage in coal mines. This technique is not a viable method at the Bunker Hill Mine and in most hard rock mines because: 1) acid water production occurs in the vadose zone and; 2) numerous existing and caved portals in highly fractured rock act as discharge points during and after flooding.

Acid production is localized at the Bunker Hill Mine; it predominantly occurs in the eastern portion of the mine workings above the 9 level (Riley, 1985). Proximity to the surface and good

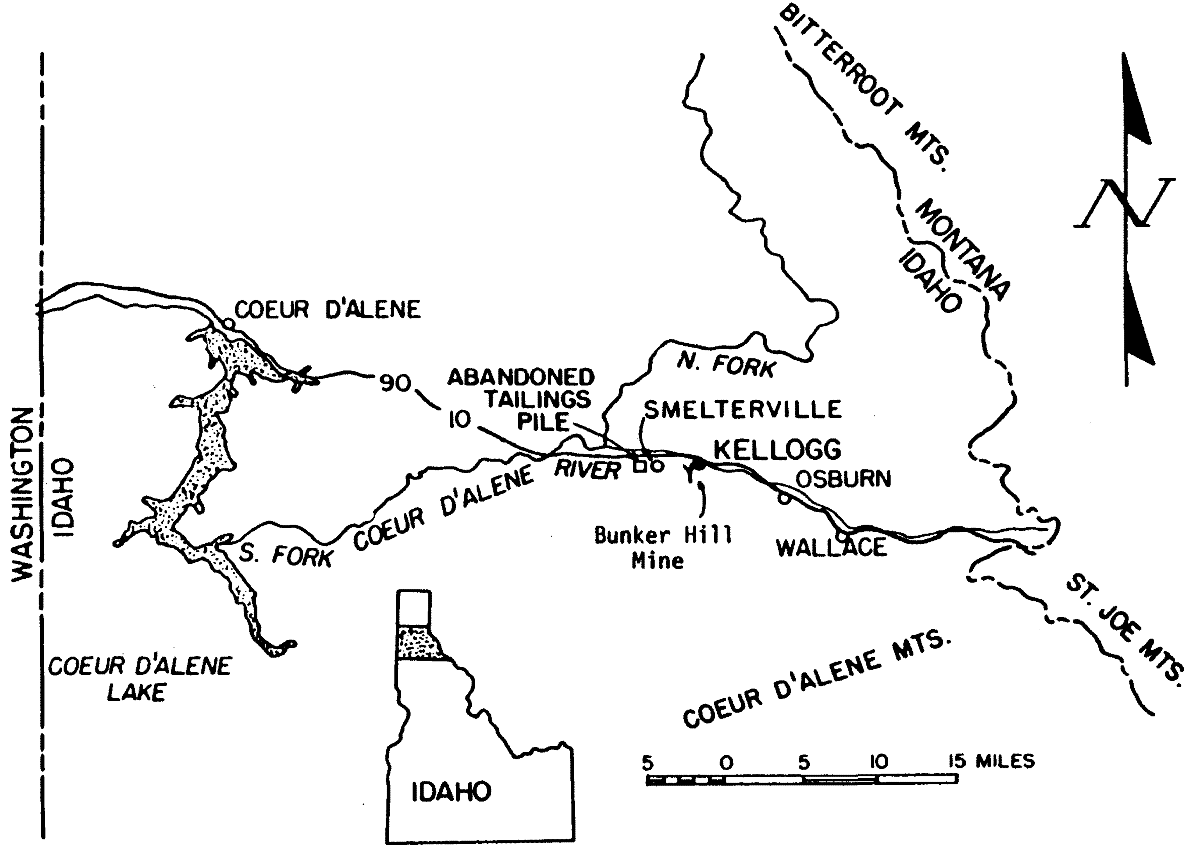


Figure 1. Map of part of Northern Idaho and adjacent areas showing the location of the Bunker Hill Mine (after Eckwright, 1982)

interconnection of the various levels allow pyrite oxidation products to be flushed into the mine drainage system by intermittent surface flood events. The majority of these oxidation products are flushed by the first recharge event in each season, typically the first major snow melt. Successive recharge events tend to dilute or only slightly increase the concentration of the oxidation products within the mine drainage system (Trexler and others, 1975). These responses indicate a process which involves the accumulation of oxidation products during periods of low surface flow which are then mobilized by the first recharge event. Riley (1985) observed the formation and draining of poor quality pools of water from the Homestake workings of the Bunker Hill Mine during ground water recharge events.

The Homestake workings offer a unique opportunity to study the spatial variation of acid production in the near surface environment. The Homestake workings are located along one of the major structures of the mine at the top of the acid producing ore body. The pools found in these workings are at the surface of the ore body and have a high degree of variability in the water quality of pooled water and fracture discharge into the drifts. Average values of pH and metal concentrations range from very high metal concentrations and low pH to low metal concentrations and near neutral pH. The average pH ranges between 2.3 and 4.5 while zinc concentrations vary from 18 mg/l to 1820 mg/l. The characteristics of these pools and their importance in the acid drainage problem is the subject of this research.

Purpose and Objectives

The purpose of this research is to better understand acid water pooling in order to identify possible reclamation procedures for reducing the impacts of acid mine drainage from the Bunker Hill Mine and other hard rock mines with similar problems. The general objective of this study is to describe the temporal, physical, and chemical characteristics of the pooled water in the Homestake workings and describe their relative importance in acid water formation relative to the overall spatial and temporal distribution of water quality within the mine. These relationships and an understanding of the factors controlling water quality in the near surface workings are then used to evaluate possible reclamation procedures. The specific objectives of the research are to:

1) review the literature concerning acid production in the Bunker Hill Mine, in its associated tailings, and other geologically similar mines.
2) establish and operate an underground monitoring system to document the spatial and temporal variation of water quality and quantity within the Homestake workings.
3) chemically characterize the recharge to the Homestake workings, the water quality changes that occur in the acid pools within the Homestake workings, and the discharge from the Homestake workings.
4) estimate the volume of water which: a) flows to lower collection points in the mine via fractures and interconnections of the upper mine levels and b) remains in the workings as permanent pools.

5) characterize the hydrologic cycle of evaporation and condensation observed in the workings and its role in acid production.
6) describe the contribution of acid water pooling in the Homestake workings with respect to the total mine drainage.
7) evaluate possible reclamation procedures to minimize acid water formation and movement based on the results of this study.

Concurrent Studies

Two other concurrent studies in the upper country of the Bunker Hill Mine are:

1) application of multivariate statistical techniques to the analysis of mine water quality data. The purpose of this research is to evaluate the utility of statistical methods for the analysis of subsurface water quality data to identify sources of acid mine drainage and possible mitigative measures,
2) application of aquifer testing techniques to study and characterize the hydraulic properties of the geologic structures contributing to mine water inflow to the upper country of the Bunker Hill Mine.

All three research efforts are part of a larger study to define methods which will help characterize and mitigate acid mine drainage in this and other hard rock mines.

Previous Investigations

Previous investigations of the hydrogeology in the Bunker Hill Mine are quite extensive. They may be divided into categories of geology, hydrochemistry, and hydrogeology.

Geology

Ransome and Calkins (1908) and Hobbs and others (1965) are the most extensively cited geologic references. They provide a broad and in-depth overview of the district stratigraphy, lithology, structure, ore paragenisis, and structural deformation history. Caddey (1974) and Duff (1978) define the structural geology and geometry of the lower workings of the Bunker Hill Mine. Juras (1977) correlates the structural geology of the upper country with the overall mine and regional structure. White and Winston (1977) redefine the contact between the St. Regis and Revett formations.

Hydrogeology

Trexler (1975) is the first effort to characterize recharge to the mine, water flow through the mine, and the mechanisms controlling acid production within the mine. Erikson (1985) describes spatial and temporal variations of flow within the mine workings above the 9 level. Eckwright (1982) correlates mine level water production with depth. Hunt (1985) delineates where surface drainages lost streamflow to some of the central structural features of the mine such as the Cate Fault and its associated shears. Hartman (1985) uses water age dating to demonstrate the temporal responsiveness of the fracture flow system and to help determine the residence time of the water in the fracture system.

Hydrochemistry

Reece (1974) describes the chemistry of acid water formation and the quality of water within the Bunker Hill Mine. This thesis also examines the chemistry associated with the mine rocks and mineral assemblages. Reece performed column studies on a number of ore and gangue bearing rocks and determined that pyrite and ferric sulfate are the primary sources of acid water production. Other acid producing minerals are not present.

Marcy (1979) examines the kinetics and mechanisms of pyrite oxidation and the resulting heavy metal leaching from the unsaturated sediments in the Smelterville Flats, near Kellogg. The report describes the catalytic action of micro-organisms for the Fe(II)-Fe(III) oxidation reaction. All of these mechanisms are pertinent in the production of acid water underground in the Bunker Hill Mine.

Trexler and Reece identified the Flood-Stanly ore body as a primary source of acid water production within the mine. This ore body is mined in the upper workings, predominantly above the 9 level of the mine. Riley (1985) confirms that the majority of acid production occurs in the Flood-Stanly ore body located in the eastern portion of the upper nine levels of the mine and describes the spatial and temporal variation of water quality in these upper workings. Four sites within Riley's study area contribute 75 percent of the zinc load while contributing only 3 percent of the flow to the mine discharge flow rate. Riley concludes that metals primarily are introduced to the mine discharge by acid reaction products flushed from drifts, stopes, and stagnant pools of water during recharge from annual spring runoff events.

Method of Study

A reconnaissance of the near surface workings was conducted early in 1984 to establish that extensive seasonal pooling of low quality water occurred in the near surface portion of the mine referred to as the Homestake workings. In the fall of 1985, accessible workings above and below the Homestake workings were observed concerning the extent of individual pools, and the possible flow paths from the Homestake workings to the 5 level Reed workings below, and to determine the most suitable sites for water quality sampling.

A monitoring system of tarps, flumes, and pond stage measurement points was installed in 1986 and 1987. The monitoring system allowed observation of changes in water quality and water quantity with time before, during, and after the annual spring runoff or recharge event. This system consisted of 24 sites: 15 sites in the Homestake workings, 4 sites on the 4 level Cherry workings, and 5 sites on the 5 level Reed workings.

Routine sampling of these sites for water quality was conducted from May, 1986 to April, 1988. Measurement of pH, specific conductance, and temperature was done in the field. Metal ion concentrations of water samples for were determined by laboratory analysis.

Changing pool volume and flow rate between pools was monitored using:

1) cutthroat flumes for flow,
2) bucket and stop watch measurements of discharge from fractures collected by tarps and,
3) staff gauges for measuring changes in pooled water depth.

The role of evaporation and condensation in the production of acid water also was investigated from November, 1986 to April, 1988. The data collection system was a series of simple imitations of class A evaporation pans and air particle impactor devices for water vapor capture. Condensate samples were collected as often as there was sufficient sample for analysis.

A one time bacterial sampling effort also was performed by Dr. Keith Prisbrey and his graduate group from the Metallurgy Department at the University of Idaho. The purpose of this sampling was to correlate bacterial activity with mine water quality. Water samples and sludge samples were taken at eight sites on the 5 level and the Homestake workings during late summer of 1987. These samples represent all of the water quality types found in the workings above the 9 level. Four thousand samples including replicates were generated. These samples were then cultured for 2 months for their bacterial content using the "Most Probable Number" methodology for determining bacterial counts (Prisbrey, 1987). The results of Prisbrey's study are used to relate high iron concentrations to poor quality water and the changes of ferric hydroxide seen in different pool environments.

CHAPTER 2

GEOLOGIC AND HYDROGEOLOGIC SETTING

Regional Geology

Stratigraphy and Lithology

The Coeur d'Alene Mining District is underlain by Precambrian metasediments known as the Belt Supergroup. The formations included in the Belt Supergroup, from oldest to youngest, are: the Prichard, Burke, Revett Quartzite, St. Regis, Wallace, and the Striped Peak. These formations are composed predominantly of argillite and quartzite with intercalated minor carbonate-bearing dolomitic rocks (Hobbs and others, 1965). A generalized stratigraphic section of the Belt Supergroup in the district is presented in Table 1.

Small intrusive stocks and diverse igneous dikes also occur in the district. These Cretaceous units include: monzonitic stocks and dikes, assorted dikes of diabase, lamprophyre, diorite, apilite rock type and some badly weathered andesite and latite dikes (Hobbs and others, 1965).

Regional Structure

The Coeur d'Alene Mining District is characterized by extremely complex folding and faulting. The district exists in a Precambrian basin which has been correlated from British Columbia to northern Idaho (Hobbs and others, 1965). The structure is dominated by a west-northwest trending system of tear faults collectively known as the Lewis and Clark Line (Juras, 1977; Green, 1977). The Osburn Fault (Figure 2) is the dominant feature of this line in the district. The Osburn Fault strikes N 75° W, dips 55-85° SW and has an apparent horizontal offset of 16 miles (26 km.) (Hobbs and others, 1965). Folds and faults south of the Osburn

Table 1. Generalized stratigraphic section of the Belt Supergroup in the Coeur d'Alene mining district (Hobbs and others, 1965).

	Formation		Lithology	Thickness
Missoula Group	Striped Peak Formation		Interbedded quartzite and argillite with some arenaceous dolomite beds. Purplish gray and pink to greenish gray. Ripple marks, mud cracks common. Top eroded.	1,500+ ft (450+ m)
	Wallace Formation	Upper Part	Mostly medium- to greenish-gray finely laminated argillite. Some arenaceous dolomite and impure quartzite, and minor gray dolomite and limestone in the middle part.	4,500 - 6,500 ft (1,370 - 1,980 m)
		Lower Part	Light-gray more or less dolomitic quartzite interbedded with greenish-gray argillite. Ripple marks, mud cracks, and mud chips common. Occasional small scours. Cross-bedding uncommon.	
Ravalli Group	St. Regis Formation	Upper Part	Light greenish-yellow to light green-gray argillite; thinly laminated. Some carbonate-bearing beds.	1,400 - 2,000 ft (420 - 610 m)
		Lower Part	Gradational from thick-bedded pure quartzite at base to interbedded argillite and impure quartzite at top. Red-purple color characteristic; some green-gray argillite. Some carbonate-bearing beds. Ripple marks, mud cracks, mud-chip breccia, and graded bedding common; occasional small scours. Sandstone bodies absent.	
	Revette Quartzite		Thick to thin bedded, vitreous, gray to nearly white pure quartzite, interbedded with greenish siltites and argillites. Tops and bases of quartzite beds may be sharp or graded. Cross-stratification common. Sandstone bodies common. Mud chips and mud cracks scarce, scours common.	1,200 - 3,400 ft (360 - 1,040 m)
	Burke Formation		Light greenish-gray impure quartzite. Some pale red and light yellowish-gray pure to nearly pure quartzite. Ripple marks, swash marks, and pseudo-conglomerate.	2,200 - 3,000 ft (670 - 910 m)
	Prichard Formation	Upper Part	Interbedded medium-gray argillite and quartzose argillite and light-gray impure to pure quartzite. Some mud cracks and ripple marks.	12,000+ ft (3,650+ m)
		Lower Part	Thin- to thick-bedded, medium-gray argillite and quartzose argillite; laminated in part. Pyrite abundant. Some discontinuous quartzite zones. Base buried.	

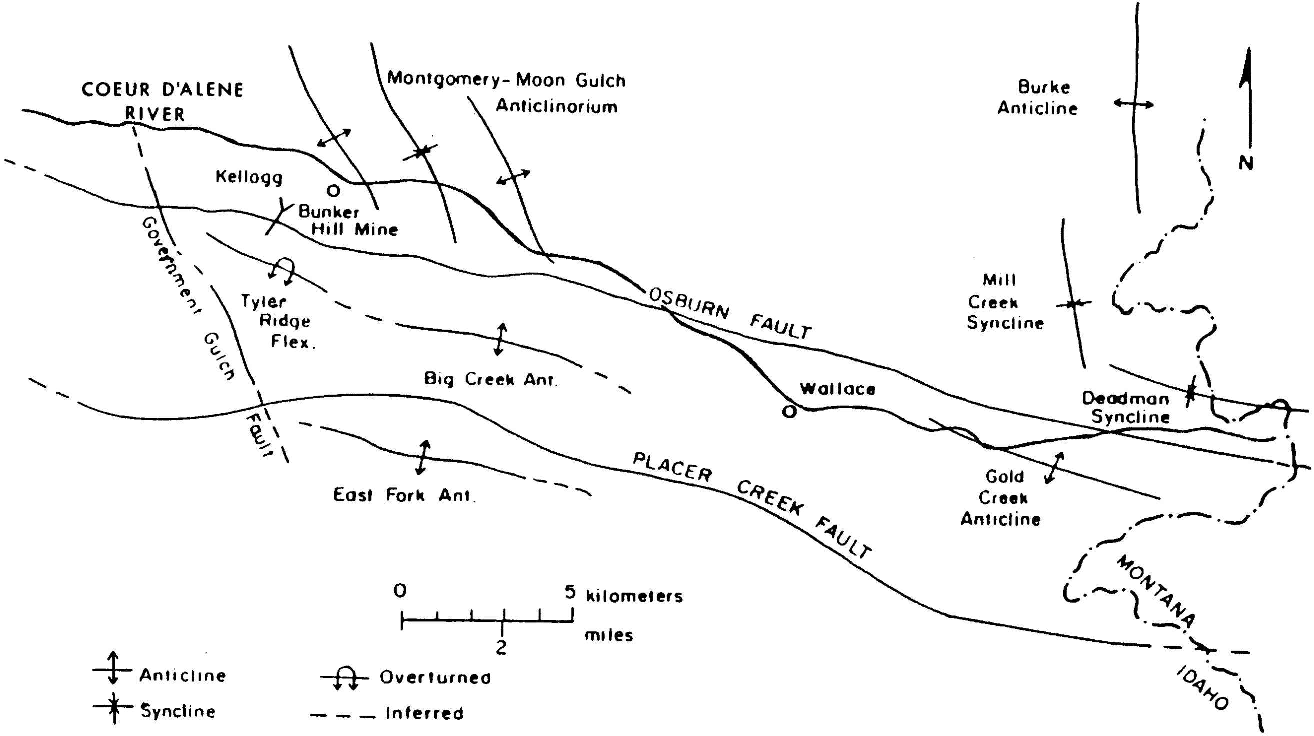


Figure 2. Geologic structures of the Coeur d'Alene Mining District (Eckwright, 1984, p. 19).

Fault trend parallel or subparallel to it. North of the Osburn Fault, folds and faults trend perpendicular (northerly) to the fault. The Cretaceous stocks are aligned and elongated parallel to this northerly trend (Hobbs and others, 1965).

Deposition of the Belt sediments ended approximately 850 million years ago. This deposition was followed by major periods of structural deformation (Juras, 1977). The timing and progression of these deformations is widely debated (Hobbs and others, 1965; Caddey, 1974; Juras, 1977; Reid, 1977).

According to Reid (1977), deformation began in the Precambrian with the formation of north-northwest trending folds and lower greenschist facies metamorphism. The Montgomery-Moon Gulch Anticlinorium, north of the Osburn Fault (Figure 2) is a structural example of this episode. The north-northwest folds exist on the south side of the fault but have been over-printed by more recent folding episodes. Their locations can be determined by studying the plunge directions of the fold axes south of the Osburn Fault (Juras, 1977).

A second folding trend was generated by reorientation of stresses and is oriented predominantly west-northwest. As this second period of deformation progressed, the west-northwest trending folds overturned to the north. The mining district is centered along these overturned, west-northwest trending folds.

Mineralization is thought to have occurred prior to completion of this second period of deformation (Meyer, 1977). Evidence for this time of mineralization is the displacement of ore bodies by bedding plane movements which occurred as a result of further overturning of the folds to the north (Juras, 1977). Reverse right-lateral oblique slip faulting and reverse left-lateral oblique slip faulting accompanied these periods of deformation (Caddey, 1974).

The deformational history was completed by more faulting after emplacement of the ore. This period of deformation included normal block faulting and simple right lateral strike slip faulting (Caddey, 1974). Right lateral movement produced the large displacement along the Osburn Fault noted earlier and developed shear zones which strongly controlled the development of the Bunker Hill Mine (Meyer, 1977).

Mine Geology

Stratigraphy and Lithology

The Bunker Hill Mine is within the Revett Formation (White and Winston, 1977). The Revett Formation (Figure 3; Table 1) comprises three major rock types: quartzite, sericitic quartzite and siltite-argillite (Table 2). This sequence comprises the approximately 3900 feet (1200 m) of Revett formation found in the mine vicinity. A generalized stratigraphic section is presented in Table 3.

Structure

The Bunker Hill Mine is located within three regional structures (Figure 2). The mine is bounded on the north by the Osburn Fault. The Alhambra Fault, a major thrust feature, lies to the east. A large anticline (the Big Creek Anticline) plunging to the S.W. bounds the mine on the south and west (Meyer, 1977).

The mine is located in the north limb of this anticline. The anticline bedding trends west-northwest to northwest and dips steeply to the northwest or is steeply overturned to the south or southwest (Meyer, 1977). Smaller parasitic folds are superimposed on this north limb

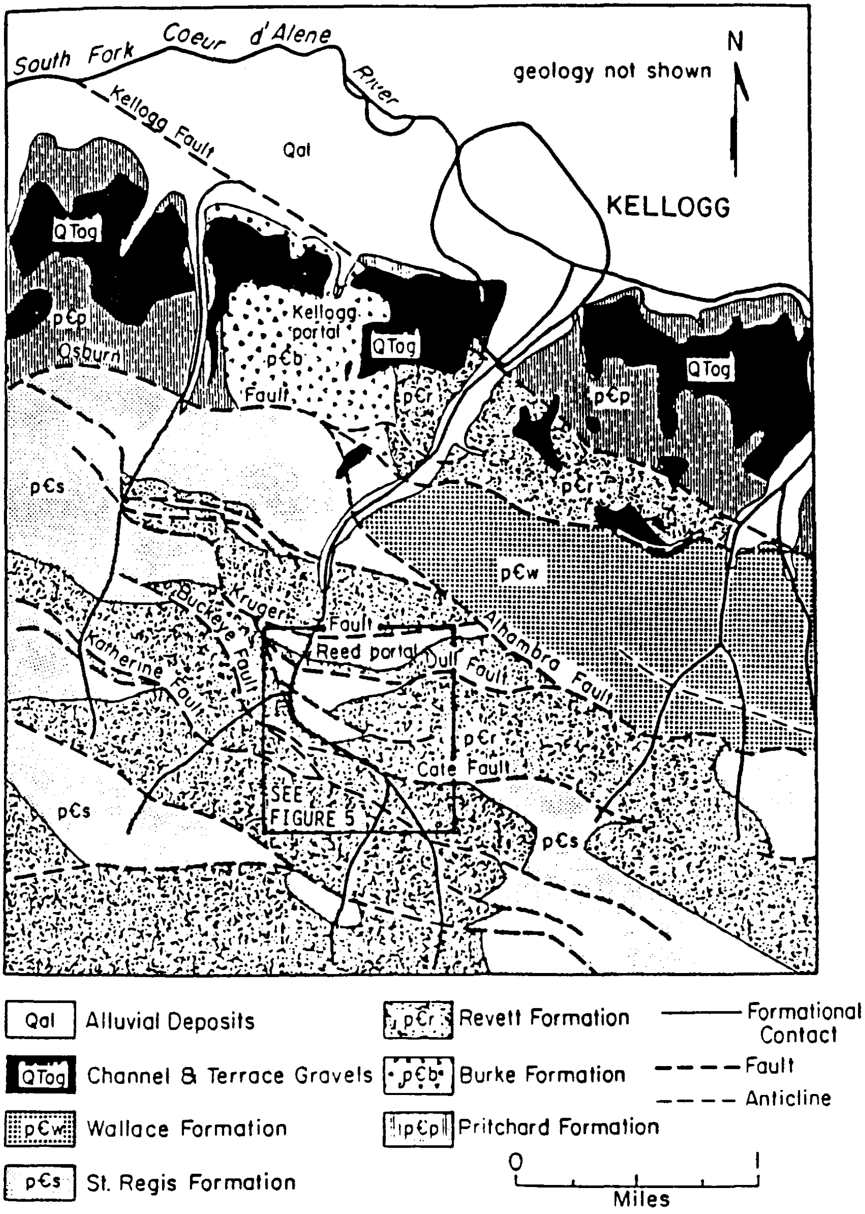


Figure 3. Surface geology in the vicinity of the Bunker Hill Mine (Hampton, 1985, p. 17).

Table 2. Revett Formation lithology and fracture properties (White and Winston, 1977; from Eckwright, 1982).

Lithology	Quartzite	Sericitic Quartzite	Siltite-Argillite
COLOR	Light gray to white	Pale green Sericite; sub-vitreous luster	Gray-green or yellowish-green; may show iron staining
SEDIMENTARY FEATURES	Well sorted planar crossbeds; -horizontally laminated beds 2-3 ft. (1 m.) thick	Horizontally laminated beds; cross beds less common, climbing ripple x-laminations; thin to thick bedded	Ripple cross and horizontal laminations, mud inclusions and thin bedded oscillation ripples
GRAIN SIZE	Fine-grained sands	Very fine-grained sand to coarse silt	Silt
FRACTURE	Very hard, competent; fracture cleavage common	Softer than Quartzite; and flow cleavage common	Soft, incompetent; flow cleavage common

Table 3. General Revett Formation stratigraphy in the Bunker Hill Mine vicinity (White and Winston, 1977).

Member	Lithology	Thickness
Upper	Thick alternating intervals of quartzite and siltite-argillite	1968 ft. (600 m.)
Middle	Primarily siltite-argillite becoming more quartzitic east of the Bunker Hill Mine	1082 ft. (330 m.)
Lower	Thick intervals of vitreous quartzite and sericitic quartzite	850+ ft. (260+ m.)

plunging 20 to 40 degrees to the west. These parasitic folds, referred to as the Tyler Ridge Flexure (Figure 2), are heavily fractured by reverse shears that trend approximately northwest and east-northeast to north-northeast (Juras, 1977). Fold generated structural fabrics (Figure 4) located in the hinge or near hinge limbs of this broad flexure are the sites of complex ore zones (Meyer, 1977).

The Cate Fault (Figure 3) is the mine's central structural feature. It is a strongly sinuous and braided shear zone. Strike averages N 27° W and dip averages 41° WSW. A series of moderate to steeply dipping shears join the Cate Fault in the upper levels of the mine or parallel it at lower levels. These associated shears include the Dull Fault, the Sullivan Fault, and the Kruger Fault (Figure 5). They appear to be contemporaneous; they have normal movement with some right lateral movement (Meyer, 1977).

The relationship of the ore bodies to the Cate Fault controlled the mine development. However, Juras (1977) has proposed that the Cate Fault and its associated shears are post ore in age. Most evidence now points to ore emplacement being controlled by the Tyler Ridge Flexure and its associated structural fabrics (Meyer, 1977).

Mineralogy

Galena, sphalerite, tetrahedrite, pyrite, siderite and quartz make up the primary constituents of the ore and gangue minerals of the Bunker Hill Mine (Meyer, 1977). Minerals, their abundance, and ore type are listed in Table 4.

The three general ore types classified by mineralogy, are Bluebird, Bunker Hill, and Jersey (Trexler and others, 1975). The Jersey ore principally is Galena with lesser quantities of sphalerite, chalcopyrite,

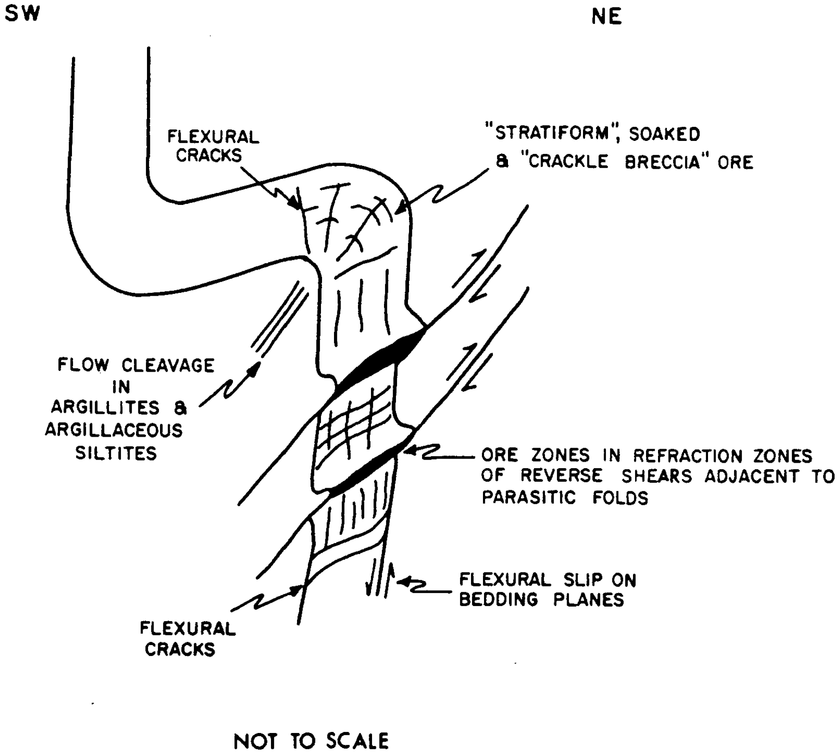


Figure 4. Structures of the Tyler Ridge Flexure, looking N.W. through the vertical profile (Juras, 1977, p. 32).

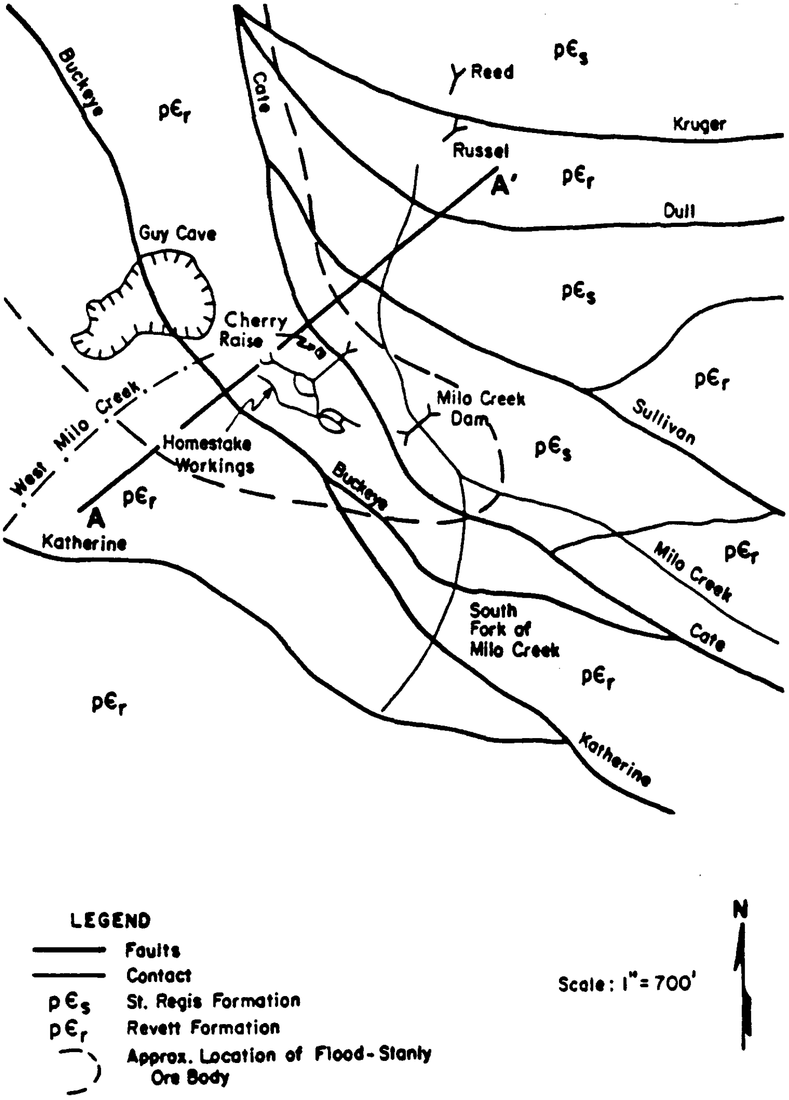


Figure 5. Bedrock geology and structural map in the vicinity of the Homestake workings, expanded from Figure 3.

Table 4. Mineralogical composition of three ore types in the Bunker Hill Mine (from Williams, 1975).

Minerals	Ore Types		
	Bluebird	Bunker Hill	Jersey
Galena, PbS	A	A	A
Sphalerite, ZnS	A	R - P	A
Pyrite, FeS_2	A	R - P	R
Arsenopyrite, $FeAsS$	P	N	N
Chalcopyrite, $CuFeS_2$	P	P	N
Tetrahedrite, $(Cu,Fe,Zn,Ag,)_{12}Sb_4S_{13}$	P	P	P - A
Siderite, $FeCO_3$	A	A	P - A
Ankerite, $Ca\ (Mg,Fe)(CO_3)_2$	A	A	P - A
Quartz, SiO_2	A	P	A
Bournonite, $PbCuSbS_3$	R	N	N
Boulangerite, $Pb_5Sb_4S_{11}$	R	N	N
Stibnite, Sb_2S_3	R	N	N
Sericite, $KAl_2(AlSi_3O_{10})(OH)_2$	A - P	A - P	A - P
Chlorite, $Mg_3(Si_4O_{10})OH_2Mg_3(OH)_6$	P	P	P
Limonite, $FeO(OH) \cdot H_2O$	A	N	N
Cerussite, $PbCO_3$	R	N	N
Calcite, $CaCO_3$	P	P	P

NOTE: A = very abundant; P = present; R = rare; N = none noted.

and tetrahedrite. Boulangerite and pyrargyrite are rare but present (Meyer, 1977). The Bunker Hill ore predominantly is galena with only remnants of sphalerite, siderite and quartz. The Bluebird ore is sphalerite and galena. Sphalerite is in excess of galena; pyrite is present in abundant yet variable amounts (Meyer, 1977). This ore type is most strongly connected to acid production in the upper levels of the mine. Large quantities of pyrite are present in the ore; also, the ore zones are oxidized in the upper levels of the mine (Trexler and others, 1975).

Mine Hydrology

Surface Hydrology

Milo Creek and Deadwood Creek (Figure 6) drain most of the surface area over the mine and discharge into the South Fork of the Coeur d'Alene River. The Coeur d'Alene River enters the Coeur d'Alene Lake, the Spokane River and the Columbia River.

Milo Creek and Deadwood Creek are perennial, steep mountain streams fed by springs and snowmelt runoff. There are no long-term precipitation, temperature or stream flow rate for these creeks. The only hydrologic data are snow course surveys on Kellogg Mountain (Figure 6), the southern ground water divide of these drainages. Snow water on Kellogg Mountain is given in Table 5 for the years 1986-1988. These figures are 70 percent of normal (Water Supply Outlook, 1988).

Ground water is in narrow stream alluvium, thin soil and colluvium, and fractures in the metasediments. The alluvial deposits average 10 feet or less (Trexler and others, 1975) but can be more than 20 feet

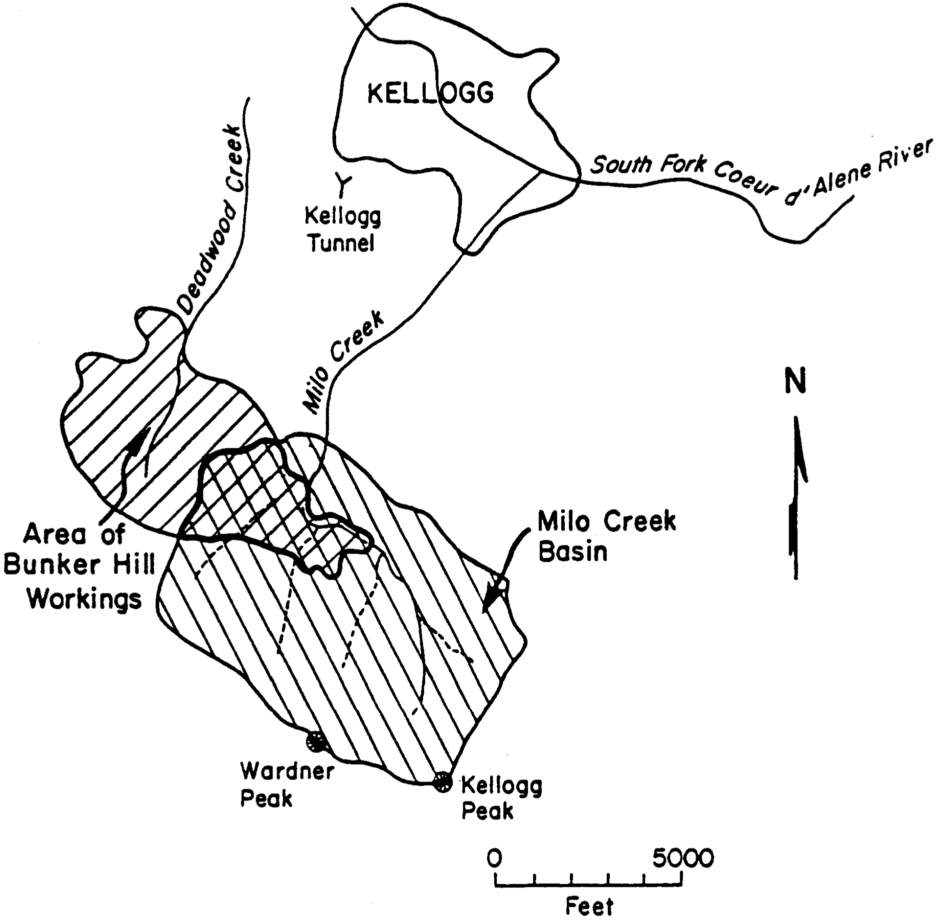


Figure 6. Location map of the Milo Creek Drainage (Hunt, 1984, p. 11).

Table 5. Snow pack as inches of water on the Kellogg Mountain snow course as of April 1.

Year	Snowpack (inches)	Equivalent inches of water
1986	58	21.1
1987	60	24.4
1988	57	20.0

thick in some locations (Hunt, 1984). Snow melt and streamflow recharge the sediments and metasediments.

Mine Hydrology

Eckwright (1982) categorized mine water inflow as:

1) Direct discharge of water from fracture systems and from diamond drill holes into drifts, stopes, and shafts.
2) Water movement through man-made openings from the ground surface to the underground workings and from level to level. These openings include winzes, shafts, raises, manways, drifts, stopes, and ore passes.

The first type of inflow is highly dependent on the hydraulic conductivity of the surrounding geologic material. The Belt Supergroup has very low primary hydraulic conductivity (Trexler and others, 1975). Secondary hydraulic conductivity is responsible for ground water flow. The secondary hydraulic conductivity results from the numerous structural deformations and mining. These fracture systems include shears, faults, and fold fabrics of flexure cracks and slips (Eckwright, 1982). The Cate Fault and its associated shear structures are the major fractures of interest to this study. Fractures associated with movement along these features form the major zones of secondary hydraulic conductivity in the region of the Flood-Stanly ore body.

Man-made openings function as highly efficient drains and channels. All mine levels are connected by a maze of openings. Many of these openings are poorly mapped or unmapped. All mine water drainage discharges from the mine via the Kellogg Tunnel portal, located on the 9 level.

Description of the Homestake Workings

The Homestake workings are a set of near-surface drifts and stopes within the Milo Creek drainage. The workings are in close proximity to the Flood-Stanly ore body along the Cate Fault (Figure 5). The Homestake is located between two important mine recharge features: the Guy Cave Area, a man-made subsidence feature, and the intersection of the south fork of Milo Creek with the Cate Fault shear zone (Figure 5).

The Homestake workings are excavated in the Revett Formation of the Belt Supergroup (Figure 5). The workings range from 80 to 150 feet below the surface and are approximately 250 feet above the 5 level Reed workings. The Homestake workings provide access to the Flood-Stanly zinc ore body. The workings are located approximately 100 feet southeast of the Cherry Raise collar (Figure 5). This ore body encompasses the Cherry Raise and extends from the surface to below the 5 level.

Water enters into the Homestake workings through faults, bedding plane structures, and man-made conveyances such as ore chutes. The faults, associated with the Cate Fault shear zone, strike from northwest to west; dip varies from 30° SSW to vertical. The shear zone is observed to be sinuous, braided, and variable in thickness. The Cate Fault shear zone in the Homestake workings is filled with a pyritic, clayey gouge. The bedding structures are nearly vertical and strike west-southwest. Poor quality water discharges from the bedding plane fractures and deposits various precipitates where fracture openings are exposed to air.

Ore chutes, manways, ventilation passes, and break-throughs to workings overhead and below conduct flow of poor quality water downward from workings and stopes above the Homestake workings to collection pools on the floor of the Homestake workings. The Homestake workings also receive a small amount of inflow through the portal.

CHAPTER 3

MONITORING NETWORK AND PROCEDURES

Network Description

Water chemistry of fracture discharge to the workings, drainage within the workings, and the pooled water varies with location in the mine and with time. Flow and water chemistry were regularly monitored at 24 sites in the Homestake workings, the 5 level Reed workings, and the Southeast end of the 4 level Cherry workings. Water quality data also were collected at three atmospheric sites in the Homestake workings.

Monthly samples were collected on all levels during low flow periods. Biweekly samples were collected on the Homestake level during the recharge period of spring 1987 and weekly samples were collected during spring 1988. Sampling frequency was increased because of observed quick responses in 1987 to recharge events in the near-surface workings of Homestake and Cherry 4. Biweekly samples were collected on the 5 level Reed workings during the recharge periods of 1986-1988. Discharge rates at some sites were too low to allow sampling for water quality during part of the year.

Flow rates within the workings were monitored using cutthroat flumes. Fracture discharge rates were measured using bucket and stop watch measurements of water flowing off of tarps hung below areas of fracture discharge. Pool depths were measured with a staff gauge at the center of the pool. Pool discharge was estimated by changes of pool volume with time.

Vapor Collection Devices

Mine air vapor was collected using water-filled pans and plates suspended in the air stream. Water samples were collected from both the plates and the pans biweekly or as sample accumulation allowed.

The pans are 13 inches in diameter and 3 inches in depth. The pan shape and depth are an attempt to mimic a class "A" evaporation pan. A minimum water depth of 2.5 inches was maintained in the pans. Two pans were present to allow one pan to be sampled regularly while the other was left undisturbed to document long term effects. Covers were constructed to prevent rock or water from the ceiling from contaminating the pan water.

Water in the short term pan was changed at each sampling. The pan was scrubbed and rinsed three times to remove any precipitates. EC, pH and HCO^{-}_{3} concentrations were taken to establish the new water base level characteristics after refilling the pan. Kellogg municipal water was used to fill the pans. The tap water characteristically had EC values of 35 to 50 micromhos/cm, pH values of 5.6 to 6.0 and HCO_3^- concentrations of 8 to 13 mg/l.

One foot square by 3/8 inch thick Plexiglas plates, similar to inertial sampling devices (EPA, 1983), were hung vertically in the vicinity of the pans to collect the mine air vapor. The plates rotated slowly in the mine air flow. This rotation and the air flow velocity caused air born water droplets to collide with the plate. The water droplets drained downward to the collection bottle at the base of the plate. Tarps were suspended over the plates to prevent contamination by ceiling drips or splashes while allowing free air circulation around the plate. The plates were rinsed with distilled water and wiped dry to prevent carryover from one sampling period to another.

Field and Laboratory Procedures

Sampling Procedures

Field sampling procedures followed Environmental Protection Agency sampling guidelines. Water samples were collected in 250 ml and 500 ml polyethylene bottles. The bottles were rinsed twice in the sample stream before sample collection. Any air remaining in the bottle was squeezed from the bottle prior to transport to the laboratory. Bottles were not reused.

The specific electrical conductance, water temperature, and pH of the samples were measured in the field. A sample-rinsed beaker was used and samples were measured in order of increasing conductance to prevent possible carry over between samples. Specific electrical conductance was measured on a Yellow Springs Instrument model 33 SCT meter. The pH was determined using a VWR model 55 Digital Mini pH meter. Accuracy of the conductance meter and probe were checked using a 0.1 percent NaCl solution. The pH meter was field calibrated with pH 4.0 and pH 7.0 buffers.

Samples were filtered at the Bunker Hill Mine laboratory within 4 to 6 hours of collection. Filtering was accomplished through a 0.45 micron filter. Samples were then acidified with nitric acid to keep metals in suspension for analysis. Only filtered samples of pools and fracture discharges were chemically analyzed.

Analytical procedures for cation and anion analysis followed those of Riley (1985). This maintains continuity of the 5 level data base and allows comparison of water quality data from the two studies. Analysis of the samples was performed in order of increasing conductance to prevent carry over from one sample to the next. Analytical standards for different metal concentrations were produced synthetically. Samples with metal concentrations greater than 1.5 times that metal's largest standard concentration were diluted and reexamined for that metal. The laboratory procedures and the metal ion concentration determinations were preformed by staff of the Analytical Services Laboratory of the College of Agriculture at the University of Idaho. Metal concentrations were determined on an Applied Research Laboratories Model 35000 Inductively Coupled Plasma Atomic Emission Spectrometer (ICP).

Precision of the ion concentrations reported is plus or minus 10 percent. In some cases, high concentrations of zinc and iron produced emission wavelength peaks which interfered with analysis for cadmium and aluminum respectively. This interference produced concentrations of aluminum and cadmium several orders of magnitude greater than actually existed. As a result, aluminum values from Jan. 14, 1987 to the completion of the study have not been considered in any analysis of the data. The same is true for cadmium values between the dates of May 21, 1987 to June 17, 1987.

Cation-Anion Balances

Ion balance errors are calculated with the following formula (Mathess, 1982, p. 294):

$$\text{ION BALANCE ERROR} = \frac{(\text{SUM OF CATIONS} - \text{SUM OF ANIONS})}{(\text{SUM OF CATIONS} + \text{SUM OF ANIONS})} \times 100$$

Ion concentrations are in MEQ/L.

Acceptable ranges for this error vary. Hem (1985) states that +/- 1 to 2 percent in natural waters is possible with careful analytical techniques. Mathess (1982) states that +/- 5 percent is a more realistic range for natural ground water samples. The major assumption of this formula is that no unknown ionic species or metal complexes remain unreported. This assumption may not apply to strongly colored solutions and solutions which have a few constituents with concentrations greater than 1000 mg/l. Complexes are formed with the metal ions and large metal concentrations decrease the ability to accurately determine concentrations of less prevalent ions.

Water samples collected for this study are colored solutions with iron, zinc, and sulfur commonly present at concentrations greater than 1000 mg/l. For these reasons the standard error range of +/- 10 to 15 percent are considered acceptable for data interpretation. Seventeen percent of the analyses have an ion balance error greater than +/- 10 percent. Six percent of these values, or 2 samples, are greater than 15 percent. These anomalous samples likely result from analytical error caused by hardware and software problems with the ICP; sulfur values were difficult to reproduce. These anomalous values were removed from the data set.

The Role of Zinc As A Water Quality Indicator

Riley (1985) uses the zinc ion concentration to indicate water quality in the Bunker Hill Mine. Zinc was chosen due to its higher solubility, its affinity to stay in solution rather than form hydrolysis precipitates, and its good correlation with specific electrical conductance (EC) readings.

Zinc sulfate ($ZnSO_4$) is more soluble than other sulfate compounds that occur in the mine flow environment. Table 6 is a summation of the solubilities of various metal sulfates in order of decreasing solubility. Zinc sulfate solubility is 8.5 times greater than manganese sulfate ($MnSO_4$), the next most soluble metal sulfate. The total range of solubilities is five orders of magnitude.

Table 6. Solubilities of compounds in water at 20°C (Rosler and Lange, 1972, p. 76-89; Riley, 1985, p. 16).

Compound	Solubility [g] in 100g of H_2O at 20°C
$ZnSO_4$	544
$MnSO_4$	64
$MgSO_4$	36
$FeSO_4 \cdot 7H_2O$	26.5
Na_2SO_4	19.5
Ag_2SO_4	0.79
$CaSO_4$	0.200
$PbSO_4$	4.1×10^{-3}

[g] indicates grams of solute.

Zn(II) solubility is pH dependent. Solubility decreases 100 fold with an increase of one full pH unit. This linear solubility-pH relationship is expressed by the following formula (Lindsay, 1979, p. 211):

$$\log Zn(II) = 5.8 - 2(pH) \qquad \text{(eq. 1)}$$

Zn(II) is in moles per liter.

The pH values for the Homestake samples range between 2.0 and 5.8. These pH limits yield theoretical Zn(II) solubility of greater than 3.0 E06 mg/l zinc at pH equal to 2.0 and solubility equal to 0.01 mg/l zinc at pH equal to 5.8. The majority of the Zn(II) concentrations observed in the Homestake workings fall within these limits.

Zinc and iron are the dominant cations in the water samples collected for this study. Though both indicate water quality, iron precipitates more readily than zinc. Hydrolysis reactions and their equilibrium constants (K°) for both ions illustrates why Zn(II) was chosen over Fe(III) (Lindsay, 1979, pp. 130, 213).

Equilibrium Reaction	log K°
$\mathrm{Fe(III)} + 3\ H_2O \Longleftrightarrow \mathrm{Fe(OH)}_3 + 3H^+$	-13.09
$\mathrm{Zn(II)} + 2\ H_2O \Longleftrightarrow \mathrm{Zn(OH)}_3 + 2H^+$	-16.80

The larger negative K° value for Zn(II) shows that zinc hydrolysis species are more soluble than the iron species.

Zinc concentrations also are a reflection of the type of ferric hydroxide being precipitated. Lindsay (1979) states that Zn(II) is less soluble in the presence of more soluble ferric hydroxides such as yellow boy. Zn(II) is more soluble in the presence of less soluble ferric hydroxides such as limonite. Therefore, Zn(II) can be used with pH and variations of total iron concentrations to evaluate which ferric hydroxide should be precipitating.

Iron Equilibria

Iron equilibria reactions directly affect pool water quality. Fe(III) is the primary oxidant of pyrite after the pyrite oxidation reaction has been initiated by oxygen and water. The pyrite oxidation reaction involving Fe(III) is spontaneous and occurs whether the pyrite is in saturated or unsaturated conditions. The oxidation reaction of ferrous to ferric iron requires the presence of iron-oxidizing acidophilic bacteria. A direct correlation exists between high iron molal concentrations, poor water quality, and iron oxidizing bacteria in the pools found in the Homestake workings (Prisbrey, 1987).

The fate of the ferric iron produced by the microbial oxidation of ferrous iron is controlled by two reactions: 1) the spontaneous reduction to ferrous iron by pyrite oxidation, and 2) the precipitation of ferric hydroxides. The spontaneous reduction of ferric iron to ferrous iron completes a self-perpetuating cycle by producing more ferrous iron for microbial oxidation to ferric iron. The precipitation reaction acts as a "buffer" by forming more insoluble ferric hydroxides with increasing molal concentrations of iron. Fe(III) is removed from the system while more acid is produced according to the half reaction:

$$\mathrm{Fe(III)} + 3\mathrm{H_2O} == \mathrm{Fe(OH)_3} + 3\mathrm{H^+}$$

The Fe(III) tied up by this precipitation reaction is a ready source of Fe(III) should the microbial oxidation of Fe(II) be interrupted. A complete discussion of pyrite oxidation is presented in Appendix A.

Calculation of Pool Volumes

Volumes of individual pools in the Homestake workings were determined by global estimation, kriging, and geometric solids. Pool volumes for site 3 and site 7 are determined by two geostatistical methods, global estimation and kriging. Other pool volumes are determined using theoretical geometric solids.

ometric Solids Method

The geometric solids method is the simplest, yet most tedious of the three methods. The pools were profiled at regular intervals. These profiles determined the theoretical three dimensional solids, or "blocks", which are used to determine the total volumes. Using known geometric shapes and linear relationships permitted the use of standard algebraic formulas for the volume of a solid. Using these theoretical solids also allows incrementing changes in the dimensions of the solid with changes in pool depth. Incrementing estimates changes of pool length and pool width as the pool fills and drains. This process removed the necessity of continuous surveying of pool dimensions with changing pool depth.

A plane table and alidade were used to survey the intersection of the profile lines with the center line of the drift. A Brunton compass was used to orient the profiles to the drift and other profiles in that pool. String lines were run across the drift level with the high water line. This high water line is usually denoted by a cessation of the yellow boy crust or discoloration lines on the drift wall. A measuring tape was used to measure drift width along the high water line and across the drift at the track level.

Depths were measured from the string line to the floor or rib. Depth measurements were taken every six inches as the drift wall (rib) merged with the floor. Depth measurements then varied between every foot or every two feet away from the center line of the drift. The distance between measurements was determined by the regularity of the drift floor. The more level the floor the greater the distance between measurements.

The differences between the theoretical and the measured cross sectional areas have been computed when possible. These comparisons indicate that the theoretical cross sections both underestimate and overestimate the measured cross sectional area. The overestimation and underestimation ranged between 5 percent and 15 percent. Table 7 is a summation of volumes.

Table 7. Results of the pool volume calculations using the Geometric Method.

Pool site	1987 volumes (ft^3) Maximum	1987 volumes (ft^3) Minimum	Ranges Max. Volume	Ranges Min. Volume
13	2200	100	2000 - 2500	90 - 110
14	820	60	700 - 900	50 - 70
11	200	0	180 - 220	0
9	640	0	580 - 700	0
10	590	0	530 - 650	0
4	590	35	530 - 650	30 - 40
6	4000	0	3600 - 4400	0
1	520	45	470 - 570	40 - 50

Note: Estimated error equals +/- 20 percent.

Geostatistical Methods

Two geostatistical methods were used to estimate the pool volumes for sites 3 and 7. The geostatistical methods yield estimates of error while accounting for the nonstationarity of the depth data. Nonstationarity is the result of the depth data behaving as a regionalized variable. A regionalized variable is a variable whose value is related in some way to its position (Royal, 1979). This type of variable has continuity from point to point but changes in nature in a manner that is too complex for a deterministic function to characterize (Davis, 1986).

The variance of the regionalized variable is characterized and modelled through use of the semivariogram. The semivariogram is a graph of the variance of the regionalized variable. The semivariogram is a measure of the degree of spatial dependence of the regionalized variable along a specific support. Support in this case refers to the size, shape, orientation and spatial arrangement of the samples that constitute the sample population of the regionalized variable (Royal, 1979).

The semivariogram is constructed by computing the mean squared difference for variables with a particular separation distance, (h), between them. These mean squared differences are computed using the general formula: (Clark, 1979, p.92)

$$\text{Gamma}^*(h) = 1/2N(h) \quad (V_i + V_{i+h})^2 \qquad \text{eq. (2)}$$

The value of Gamma*(h) at h=0 is designated the nugget and represents the random variance observed in the calculation. As the separation distance increases, the variance computed by the equation 2 approaches the population variance forming a sill. As the Gamma*(h) function approaches this sill the spatially dependent variance approaches zero. The range of influence of the semivariogram is the point where the variance of the variable is a random feature and no longer controlled by the position of the variable. Figure 7 illustrates these semivariogram characteristics.

The semivariogram construction yields the values necessary to begin modelling the regionalized variable. These values are: the range of influence, (a), the sill, (sigma^2), the nugget, (C_0). Ideally the nugget value should equal zero so the model can rise smoothly from the origin. A number of models exist and are discussed in the literature (Davis, 1986; Royal and others, 1980). This study will discuss only the spherical model.

The spherical model is one which is used with data that form a sill. The spherical model is defined as: (Royal and others, 1980, p. 27)

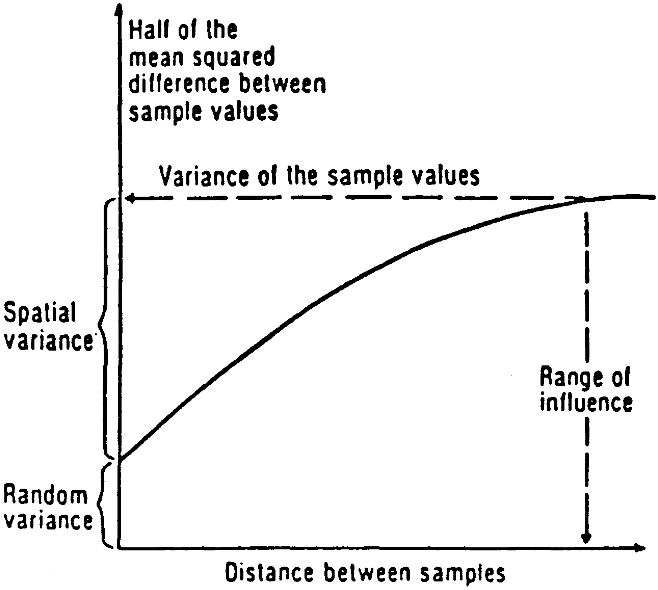


Figure 7. General semivariogram components (Royal, 1979, p. 92).

$$\text{gamma}(h) = \text{sigma}^2\,[3h/2a - h^3/2a^3] \quad \text{for } h < a \qquad \text{eq. (3)}$$

or

$$= \text{sigma}^2 \quad \text{for } h > a \qquad \text{eq. (4)}$$

where: gamma(h) = the theoretical semivariogram
sigma^2 = the population variance
h = the separation distance
a = the range of influence

The nugget value and the sill value of the regionalized variable are obtained by matching the theoretical semivariogram of the spherical model to the experimental semivariogram constructed using equation 6. Global estimation or kriging are performed after this spatial analysis.

Semivariogram theory, construction and modelling are discussed extensively in the geomathematical literature so it has been discussed only briefly here. For in-depth discussions the reader is referred to David (1977), Davis (1986), Royal and others (1980), Journel and Huijbregts (1978), and Rendu (1978).

Global Estimation by Random Stratified Grid

Global estimation includes geostatistical methods used by mining to estimate ore grade and tonnage of large stopes and open pits based on limited sampling. Local means are estimated for individual areas by placing a grid over the mapped sample locations. The sum of the local means is used to estimate the global mean of the variable. The standardized areas (grid panels) are used to obtain an estimation of error. The methodology is described by Royal (1977) and Rendu (1978). Only the pertinent procedural aspects are described in this report.

A random stratified grid (RSG) is used to divide the pool surface areas into discrete panels. The RSG is considered the best method for equalizing the panel estimation variances and is the grid which can be fitted best to the irregularly spaced data (Royal, 1977). The grid panels are 1 ft x 5 ft rectangles for this study. These grid dimensions are based on the range of influence of the semivariogram and the difference in lengths of the primary axes of the drift that contains the pool. The grid is oriented so that, on the average, each grid panel contains one sample point. The mean depth of the panel is the arithmetic mean of all the sample points within the panel, if a panel contains more than one sample point. The global mean depth is assigned to panels with no sample points.

The global mean depth (Z*) is calculated using the following relationship: (Royal, 1977, p. A12)

$$Z^* = [\quad z^*]/n \qquad \text{eq. (5)}$$

where: z^* = local mean depth
n = the number of grid panels with z^* present

The variance for the global mean is a function of the distribution of the data within the pool area and the frequency distribution of each of the local volumes about the mean value for the overall volume (Parker, 1977). The dispersion variance (O_G^2) accounts for this volume-variance relationship and is calculated by equation 6 (Royal, 1977, p. A13).

$$O_G^2 = 1/N[\ D^2(O/s)\ ] \qquad \text{(eq. 6)}$$

where: O_G^2 = the global variance of depth
N = the number of panels comprising the pool surface area
$D^2(O/s)$ = the dispersion variance = $F(L,l)$

The dispersion variance, $D^2(O/s)$, is obtained from a predefined chart of the auxiliary function, $F(L,l)$, for a common geometric shape. To determine the dispersion variance it is necessary to know: the geometric shape and dimensions of the grid panel, the type of semivariogram model, the nugget, and the range of influence. A spherical model with a nugget equal to 0.0 and range of influence equal to 3.5 feet for site 7 or 5.0

et for site 3 are used for this analysis. The F chart used is for the ommon case of a rectangle with L equal to 5 and l equal to 1. Figure 8 is a reproduction of the F chart used in this analysis. Figure 8 shows the areal relationships of L, l, and s also.

The dispersion variance was used to calculate a biased estimate of volume with a 95 percent confidence interval. This calculation was performed using the relationship: (Sprenke, 1988, Royal, 1977, p. A13)

$$\text{Volume} = S \times Z^* \; +/- \; 2[\, S \times (\mathrm{sqrt}(O_G^2))] \qquad \text{eq. (7)}$$

where: S = the pool surface area determined by the grid panels
Z^* = the global mean depth
O_G^2 = the global variance of depth

Global Mean Depths by Kriging

Pool volumes were estimated by kriging maximum and minimum pool depths at sites 3 and 7. Kriging is a best linear unbiased estimation method. Kriging is a local estimator which limits the domain used to derive the estimated value of the variable. Kriging solves a system of linear equations that assign weights to the data values used to calculate the estimated variable with the minimum estimation variance. The estimation variance is the scatter of the error of the estimation about the mean estimation error of zero (Journel and Huijbregts, 1978). Kriging is described extensively by Journel and Huijbregts (1978) and David (1977).

Kriging also is accompanied by a structural analysis of the spatial dependence of the data through use of the semivariogram. Kriged estimations of the pool depth were computed using a public domain geostatistical software package, GEO-EAS (EPA, 1988). This software has been developed for the E.P.A. to allow interactive semivariogram

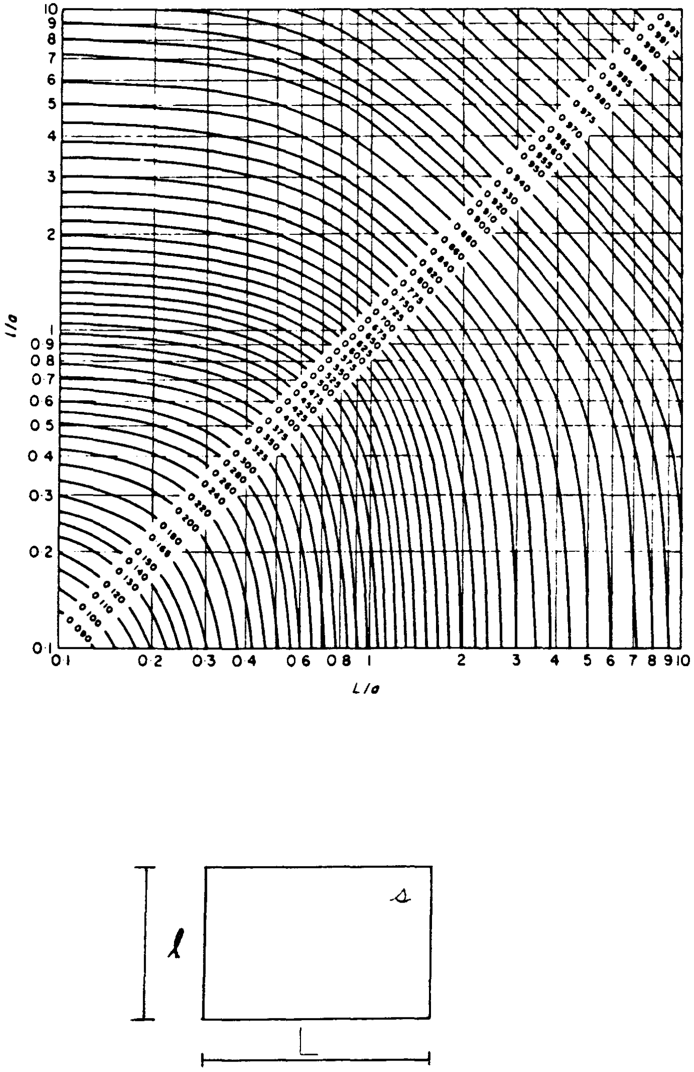


Figure 8. Chart of the auxillary function F(L,l) assuming a spherical model and a nugget equal to 0.0 (Journel and Huijbregts, 1978, p. 128).

modelling, cross-validation of the semivariogram model with the data base, and kriging of an estimated value using the cross-validated semivariogram model and the data base.

Kriging Model Parameters

The experimental semivariogram for this study used 0.5 foot increments of separation distance (lags) from 0.0 to 8.0 feet (Figure 9). The kriging model parameters for the pool levels kriged are listed in Table 8. A search ellipse was constructed and the semivariogram model cross-validated using these kriging parameters.

Table 8. Kriging model parameters for site 3 and site 7 pools.

	Site 3 Depth	Site 7 Depth	
Parameters	Maximum	Maximum	Minimum
Nugget	0.0	0.0	0.0
Sill	0.172	0.052	0.004
Range of Influence	5.40	3.76	3.76
Numbers of Pairs	6943	6766	3493
Search Ellipse			
Max. Radius (ft)	6.0	6.0	4.0
Min. Radius (ft)	2.0	2.0	1.3
Angle (degrees)	135	100	100

Minimum depth for site 3 = 0.0; the pool drains entirely

A search ellipse is used to delineate the neighborhood from which the program locates points to be used in the kriging estimation of the pool depth at a point. The major axis of the ellipse is oriented parallel to the center line of the drift. The minor axis of the ellipse is oriented along the profile lines parallel to the direction of greatest variation.

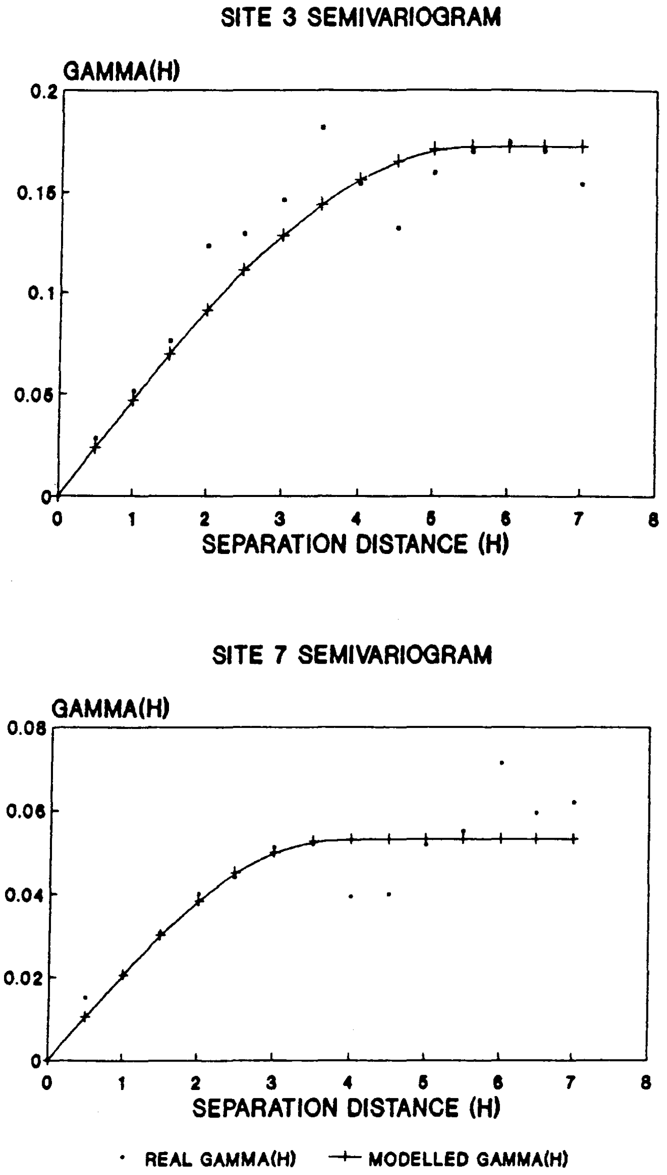


Figure 9. Experimental semivariograms with fitted spherical models for sites 3 and 7.

This orientation of the ellipse axes minimizes the anisotropic effects of the profile data. The lengths of the axes of the search ellipse have a ratio of 3:1, using the range of influence as the length for the major axis. The optimum search ellipse axial lengths and ellipse axis orientation (Table 8) were established through successive trial and error runs utilizing the cross-validation routine of the GEO-EAS software.

Cross-validation is the process of estimating known data values at each data site by kriging the surrounding neighbors. The kriged estimates are compared with the measured values to test the accuracy of the semivariogram model and the search ellipse parameters in reproducing the spatial variability of the data. The accuracy of the final model is a balance between minimizing the mean difference between estimated and calculated mean variable values and minimizing the kriging standard deviation (the square root of the estimation variance).

The mean of the differences between the estimated values and the measured values (Table 9) are within acceptable limits. The kriging standard deviations are quite high (Table 9). These high kriging standard

Table 9. Statistics computed by cross-validation using the model parameters.

Pool	Variable		Estimated Variable		Difference		Kriging s.d.	
site	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
3	0.229	0.230	0.240	0.195	0.011	0.122	0.124	0.034
7 Max.	0.469	0.415	0.485	0.368	0.017	0.134	0.209	0.066
7 Min.	0.026	0.062	0.028	0.055	0.001	0.037	0.122	0.033

deviations are the result of the preferred orientation and distribution of the sample locations. This preferred orientation and distribution produced a skew in the data values which prevents the minimizing of the estimation variance. This skew does not affect the ability of the algorithm to krige an unbiased estimation of a grid point accurately.

Method Correlation

Table 10 is a tabulation of the volumes calculated for site 3 and site 7 by the geostatistical methods. The maximum pool volumes are the most precisely estimated. The 95 percent confidence interval of the Global Estimation of sites 3 and 7 are +/- 9 percent and +/- 18 percent respectively. The volumes calculated from global mean depths derived by kriging estimation fall within these confidence intervals.

Table 10. Comparison of estimates made by the geostatistical methods of Kriging and Global Estimation.

	Site 7 Volume				Site 3 Volume	
	Mean Maximum		Mean Minimum		Mean Maximum	
	Kriged	Global Est.	Kriged	Global Est.	Kriged	Global Est.
Est. Volume (ft^3)	164	196	14	39	553	576
Surface Area (ft^2)	522*	450	191*	215	906*	875
Global Mean Depth (ft)	.314	.44	.075	.18	.61	.66
Variance of Mean Depth	.034	.008	.002	.016	.134	.002
Mean Volume s.d.	.185	.089	.050	.126	.366	.045

Note: (*) indicates digitized surface area.

The minimum pool volume of site 7 is the least precise of the three sets of calculations. The 95 percent confidence interval for the Global Estimation method results in a bracket of +/- 25 percent. This +/- 25 percent does not encompass the volume value calculated by kriging. This lack of precision appears to be due to the preferred orientation of the data support and to a less accurate spatial analysis than that performed for site 3. The two values for each set of calculations likely define a range for given stages and flow period.

CHAPTER 4

SPATIAL VARIATION OF MINE WATER QUALITY

Introduction

This chapter includes a discussion of the spatial distribution of mine water quality in the upper workings. The monitored sites on the Homestake workings level, the Cherry 4 level workings and the Reed 5 level workings are shown on Figures 10 to 12. Table 11 is a summation of the key water quality indicators for the monitor sites. The complete data list is in Appendices B and C.

The water quality monitoring system within the Homestake workings was located along a SE to NW trend (Figure 13) and identified various degrees of water degradation. The ore type in the drift grades from very low-grade ore material with no mining activity directly overhead at site 15 to low-grade ore material in extensively mined ground near site 1.

Homestake Workings

The areal extent of water pooling in the Homestake workings is a direct function of the spring recharge event. The high water line in the drifts indicates that a single large pool fills the Homestake workings in high runoff years. Precipitation, as measured by snow accumulation, was 70 percent of normal during the study period (USDA-SCS, 1988). Nine discrete pools formed during the study period of January 1986 to April 1988. Sample site locations are identified in Figure 10.

The general absence of seepage or springs around the portal suggests that water in the Homestake workings discharges to lower mine workings. Water movement to lower levels occurs through fractures and

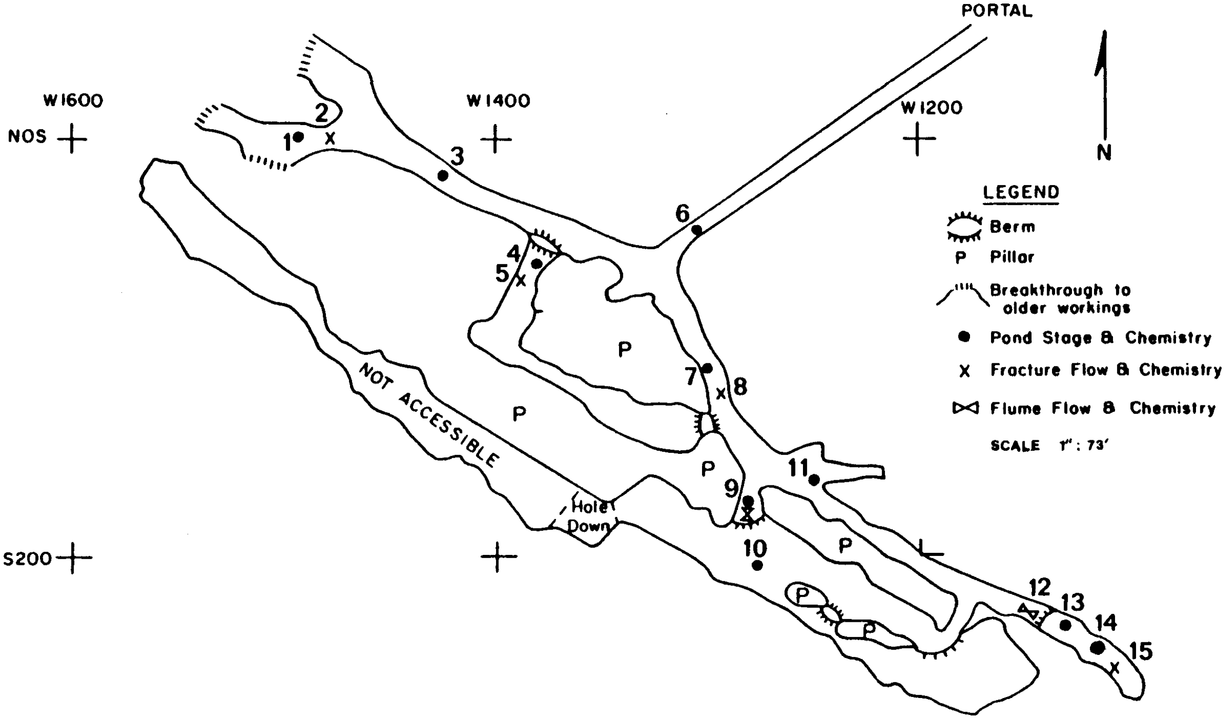


Figure 10. The Homestake workings monitoring sites, Bunker Hill Mine.

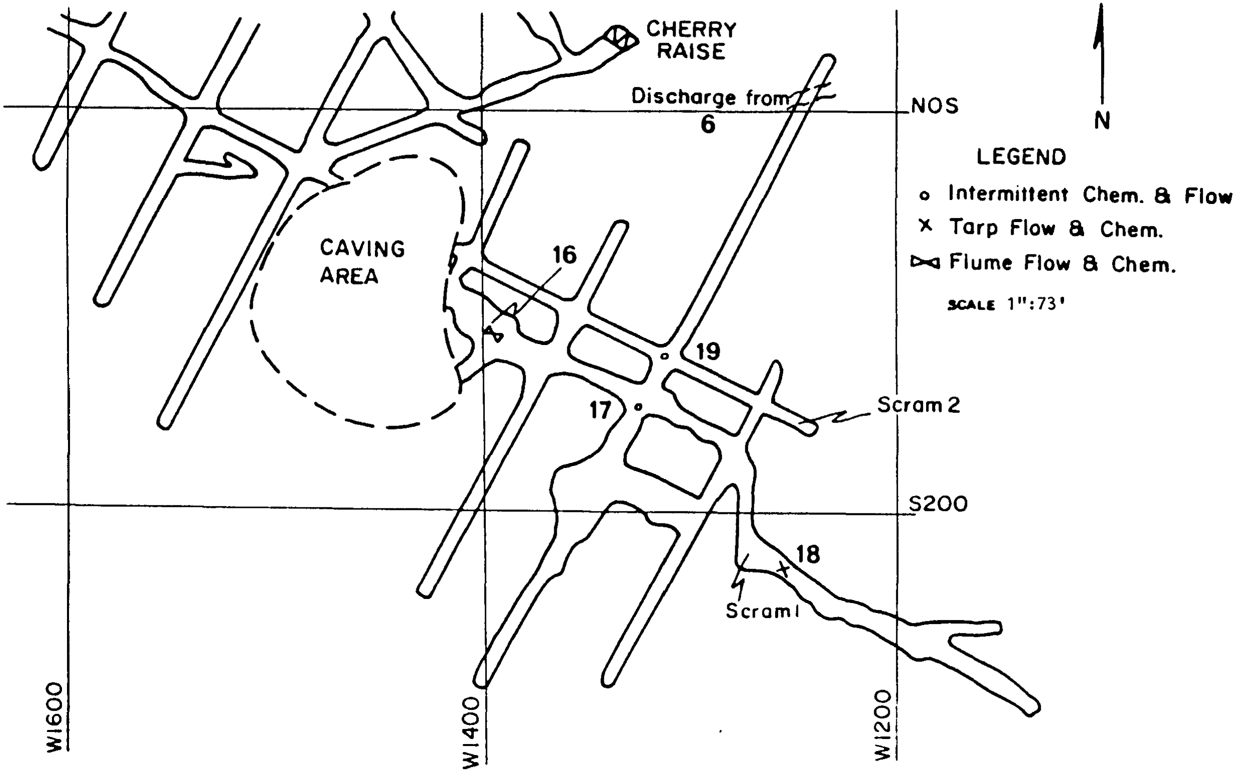


Figure 11. The Cherry 4 workings monitoring sites, Bunker Hill Mine.

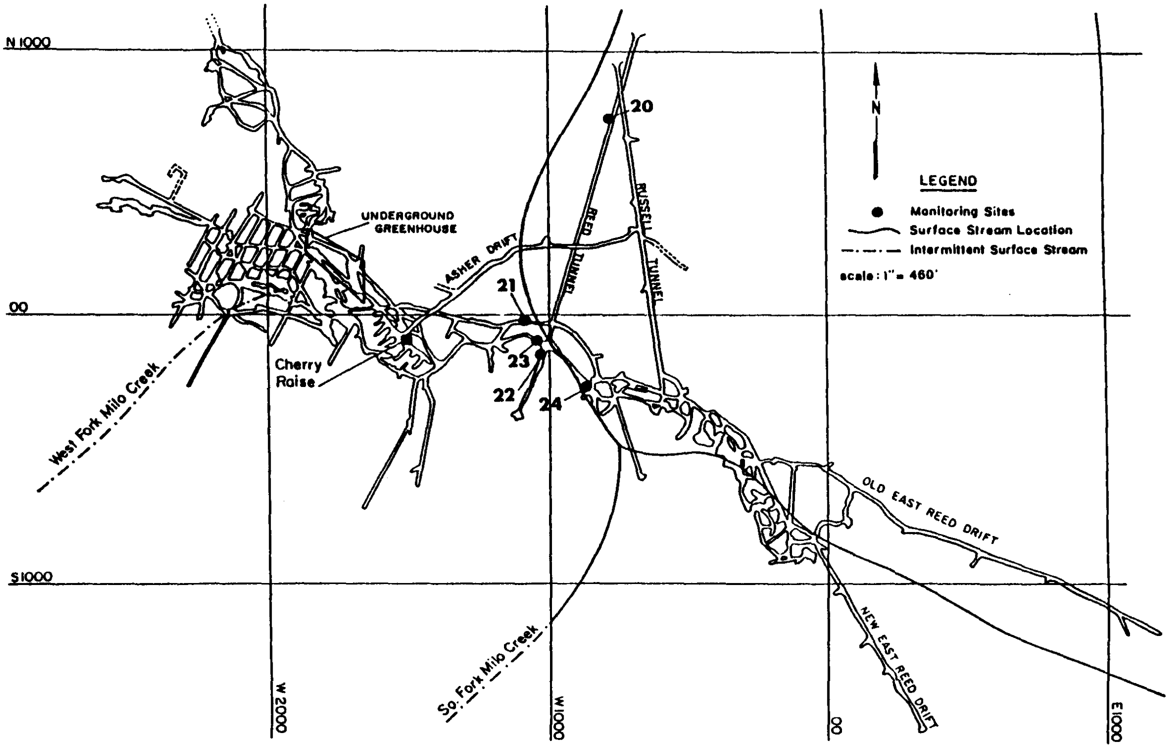


Figure 12. Monitoring sites on 5 level, Bunker Hill Mine (Riley, 1985, p. 20).

Table 11. Location and key acid indicator data for the monitored sites in the Homestake, Cherry 4, and Reed 5 level workings.

Site	Mine Level	B.H. Mine Map Coor.	Sources of Water	Date Available		Number of Samples	Mean Zinc Conc. mg/liter	Mean Conductance mhos/cm	Mean pH
				from	to				
1	3	N 03 W 1500	Pooled site 2 discharge	5/20/86	4/14/88	40	1820	8509	2.3
2	3	N 07 W 1482	Bedding plane structure	2/12/87	4/14/88	24	3424	15200	2.7
3	3	S 12 W 1430	Fracture discharge, drift flow from 1	5/20/86	4/14/88	24	2637	9084	2.3
4	3	S 57 W 1380	Ore chute drainage that has pooled	3/12/86	4/14/88	41	2905	12200	2.3
5	3	S 66 W 1390	Ore chute drainage from multiple sources	3/12/86	4/14/88	15	2180	7740	2.2
6	3	S 42 W 1300	Fracture discharge, interflow to portal, drift flow	1/29/87	4/14/88	18	1635	8406	2.3
7	3	S 105 W 1307	Pooled bedding plane discharge and drift flow	3/12/86	4/14/88	40	1234	5045	2.3

Table 11. continued.

Site	Mine Level	B.H. Mine Map Coor.	Sources of Water	Date Available		Number of Samples	Mean Zinc Conc. mg/liter	Mean Conductance mhos/cm	Mean pH
				from	to				
8	3	S 114 W 1295	Bedding structure discharge	2/12/87	4/14/88	24	348	3018	2.4
9	3	S 175 W 1285	fracture discharge, drift flow from site 13	5/20/86	4/14/88	30	331	3326	2.2
10	3	S 205 W 1280	Bedding structure discharge and drift flow from site 9	3/20/87	10/21/87	9	-	2929	2.5
11	3	S 165 W 1238	fracture discharge, breakthrough drips drift flow from site 13	3/12/86	4/14/88	27	288	3112	2.2
12	3	S 222 W 1150	site 13 berm seepage, fracture discharge	7/21/86	4/14/88	21	303	3535	2.2
13	3	S 237 W 1124	Pooled Cate Fault discharge	3/12/86	4/14/88	35	38	775	2.6

Table 11. continued.

Site	Mine Level	B.H. Mine Map Coor.	Sources of Water	Date Available		Number of Samples	Mean Zinc Conc. mg/liter	Mean Conductance mhos/cm	Mean pH
				from	to				
14	3	S 270 W 1103	Pooled Cate Fault discharge	10/11/86	4/14/88	28	25	714	3.0
15	3	S 294 W 1105	Cate Fault discharge	2/12/87	4/14/88	26	18	541	4.5
16	4	S 120 W 1370	Stopes, fractures ore chute	4/10/87	10/21/87	14	473	3076	2.5
17	4	S 175 W 1305	fractures and stopes	4/24/87	8/14/87	*			
18	4	S 225 W 1260	fractures and ore chute discharge from Homestake	3/20/87	9/16/87	13	289	2744	2.5
19	4	S 140 W 1280	fracture flow from site 6	4/24/87	7/14/87	*			
20	5	N 725 W 725	fractures, rockbolts ore chute	3/13/86	4/14/88	21	2.1	134	5.2
21	5	S 35 W 1070	Ore chutes, stopes fractures	3/13/86	4/14/88	33	809	4012	2.5

Table 11. continued.

Site	Mine Level	B.H. Mine Map Coor.	Sources of Water	Date Available		Number of Samples	Mean Zinc Conc. mg/liter	Mean Conductance mhos/cm	Mean pH
				from	to				
22	5	S 120 W 975	fractures, stopes bolt holes, ground water, ore chutes	3/13/86	4/14/88	31	253	1652	2.7
23	5	S 110 W 970	ore chutes, stopes, fractures	3/13/86	4/14/88	22	5.2	137	5.4
24	5	S 280 W 800	drill holes, rock bolts, fractures, ore chutes, stopes, faults	3/13/86	4/14/88	30	27	270	3.7

* indicates only flow data exist for this site.

\- indicates no chemistry exist for this site.

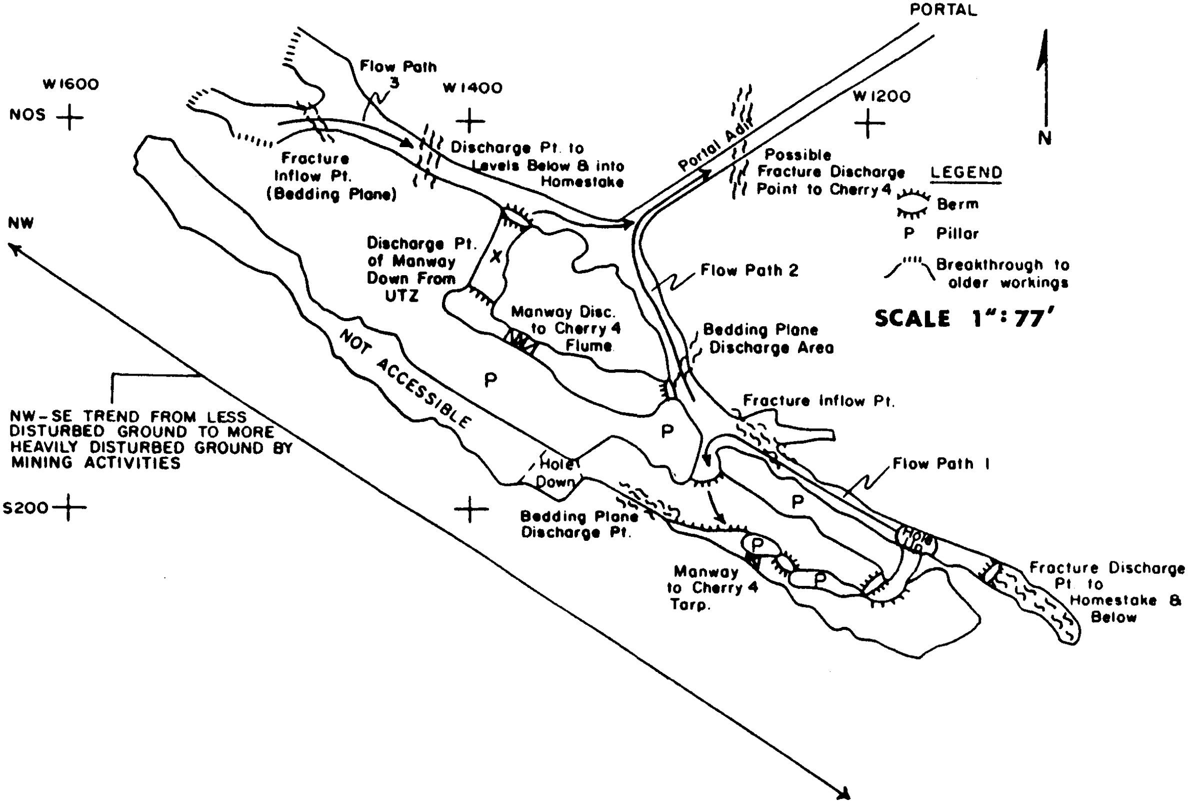


Figure 13. Homestake workings fracture discharge sites and inter-pool flow paths.

down manmade conveyances such as ore chutes. Some water flows out of the portal to Milo Creek drainage during wetter than normal years (Riley, 1988).

Flow Path Descriptions

Water flows between individual pools along the floor of the drifts by three paths. Path 1 (Figure 14) begins at site 15 and flows to a manway discharge point below site 10. Path 2 (Figure 15) begins at site 8 and site 5 and converges at site 6. Observations and underground mapping suggest that this flow path discharges downward to the Cherry 4 level via fracture flow along the Cate Fault. Path 3 (Figure 16) consists of fracture discharge into sites 1 and 3 and discharges via fracture flow to lower levels.

Flow Path One

Flow path 1 shown in Figure 14 includes most of the pools studied in the Homestake workings. Flow path one includes sites 9 through 15. Site 15 monitors the discharge from the Cate Fault into the Homestake workings. The fault varies in width, is sinuous, and filled with a clayey, pyritic gouge. Site 15 had an average pH value of 4.5 and average concentrations of 18 mg/l zinc and 45 mg/l iron.

The water quality at site 15 does not always behave as predicted by equation 5 in Chapter 3. Above the pH of 5.0, site 15 has zinc values two orders of magnitude greater than the predicted value for that pH. Contamination of the collection pool by acidic mine air vapor may cause the combination of higher than normal zinc concentrations with near normal ground water pH values.

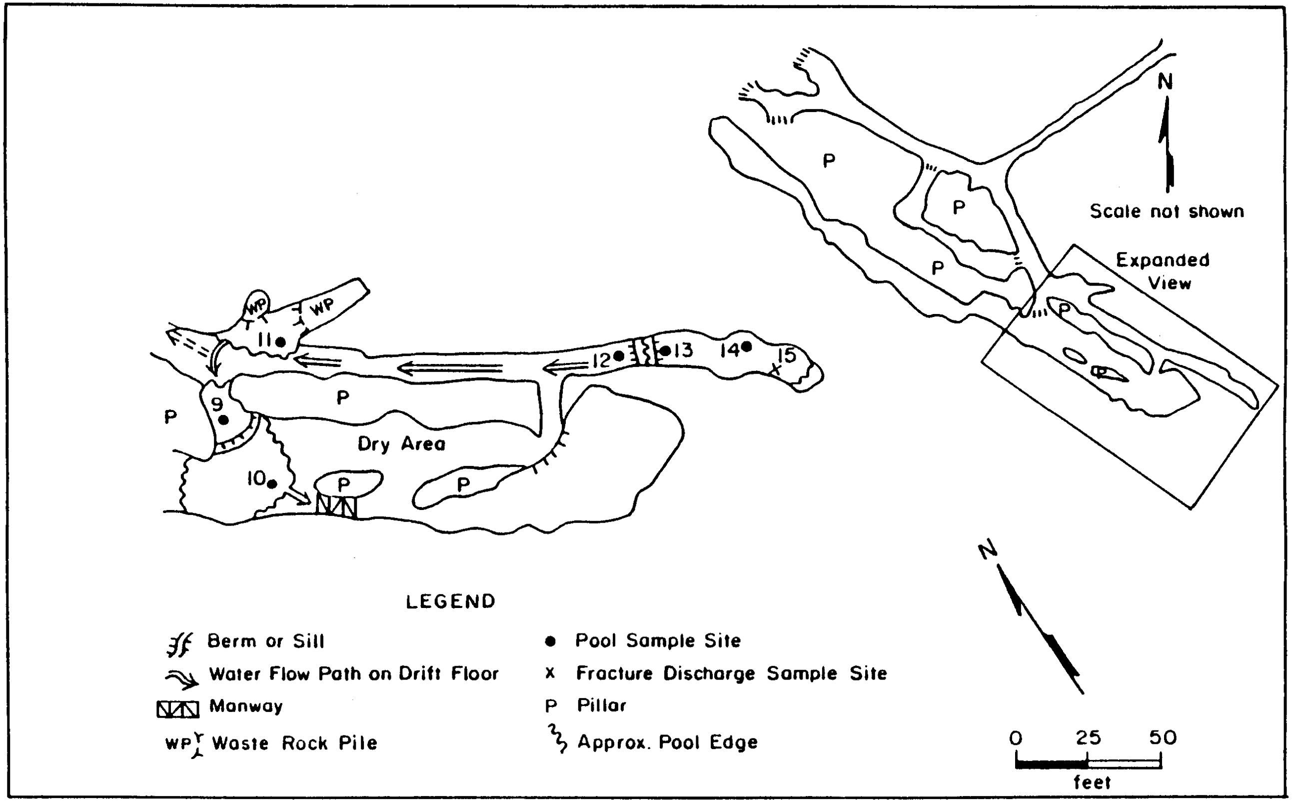


Figure 14. Flow path one, Homestake workings.

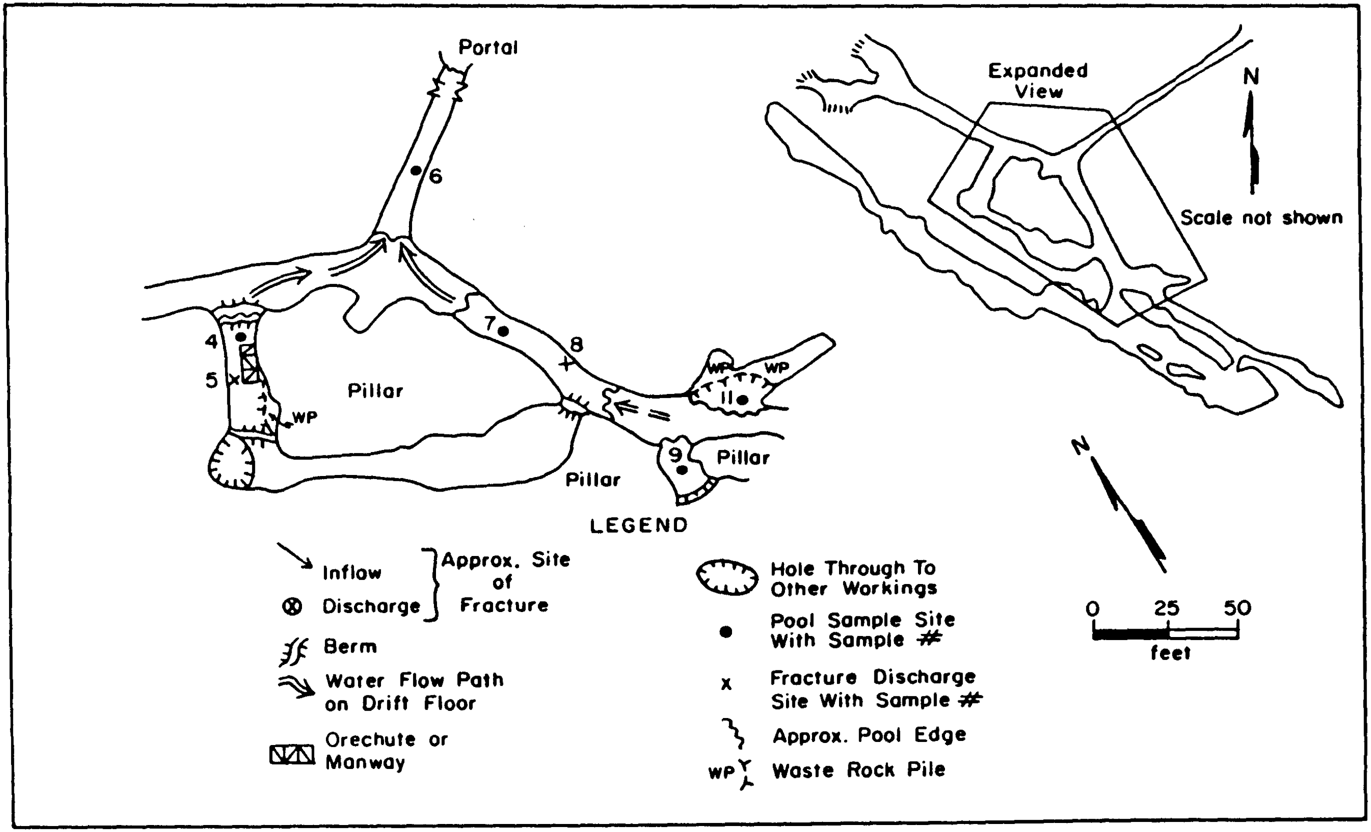


Figure 15. Flow path two, Homestake workings.

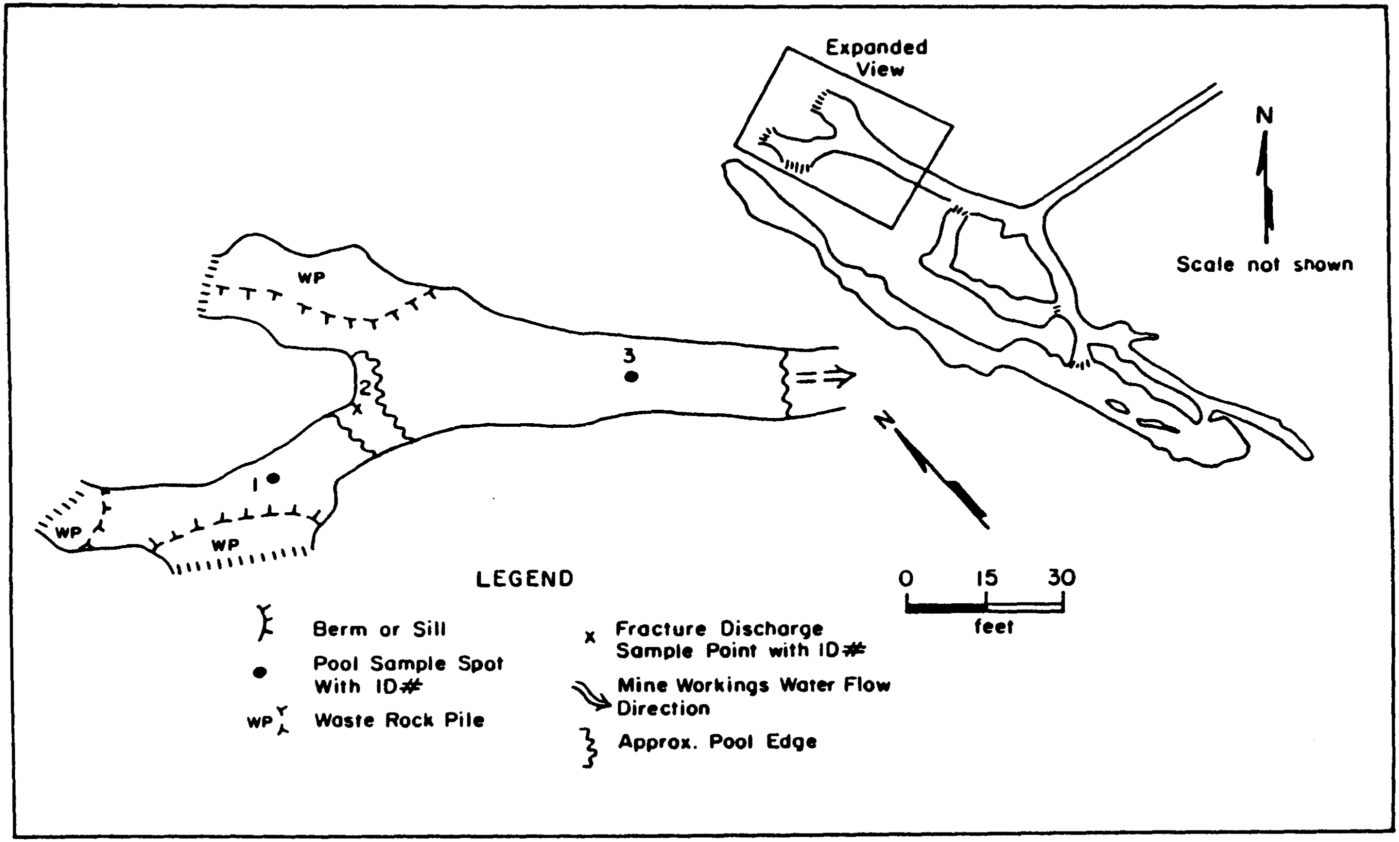


Figure 16. Flow path three, Homestake workings.

Site 15 discharges into sites 13 and 14 at low and intermediate stages of pool depth. At greater than 2 feet of water depth the two pools merge. Even after merging, the two pools maintain their individual character. Site 13 averaged 2.6 in pH and had mean concentrations for both zinc and iron of 38 mg/l. Site 14 had a mean pH of 3.0 and mean concentrations of 24 mg/l zinc and 33 mg/l iron.

Flow from site 12 passes a 1 inch x 18 inch cutthroat flume on the seepage side of the berm that impounds sites 13 and 14. The berm material is heterogeneous, varying from abundant clay with pyrite to large boulders and rock slabs. The grain size distribution indicates that the berm was created by collapse of the drift ceiling. Water samples collected from site 12 had mean pH values of 2.2 and mean concentrations of 303 mg/l zinc and 587 mg/l iron. These are the highest metal concentrations along flow path 1 on the Homestake level.

Site 11 is located at the entrance to a small room excavated for zinc ore. Three inflows enter this pool: 1) mine water flowing down the ore car track grade from sample site 12, 2) drainage downward through a man-made opening from 3 level workings, and 3) fracture discharge from the Cate Fault. All inflow to this site collects in a depression in the floor. This pool had a mean pH of 2.2. Mean concentrations for the site were 288 mg/l zinc and 496 mg/l iron.

Site 9 and site 10 represent the discharge point for flow path 1. The physical relationship of these two pools is similar to the pools at sites 13 and 14. Site 9, a small pool, is in a depression of a backfilled area. Channel flow enters the pool along the ore car track grade from sample site 11. Water flows over an embankment, through an 1 inch x 18 inch cutthroat flume, to site 10. Site 9 was the only one of the two pools to be sampled for metal concentrations. Temperature, pH, EC, and pool depth were measured at site 10. The discharge from site 10 was monitored on the Cherry 4 level. Mean values for pH, EC, and metal concentrations in site 9 were 2.2, 3,300 micromhos/cm, 330 mg/l zinc, and 321 mg/l iron, respectively. Site 10 had a mean pH of 2.5 and a mean EC value of 2,930 micromhos/cm.

Flow Path Two

Flow path 2 (Figure 15) consists of the drift area around the portal adit and the first crosscut of the Homestake workings inward from the portal. Flow path 2 consists of sites 4, 6, and 7, and fracture discharge as shown in Figure 10. This flow path is within the Flood-Stanly ore body. The flow path water quality is influenced by workings on the overlying levels. Flow during the study period discharged from this flow path downward through fractures to lower levels rather than out the portal to Milo Creek. A primary discharge area is approximately at the intersection of the Cate Fault and the portal adit on the Cherry 4 level (Figure 10). Mean pH, and mean zinc and iron concentrations in the portal adit pool were 2.3, 1,620 mg/l and 2,940 mg/l, respectively.

Site 7 forms in a large depression caused by backfilling around the track and is the least degraded water flowing into site 6. Mean metal concentrations were 1,230 mg/l zinc and 1,140 mg/l iron. The pH had a mean value of 2.3. Site 7 is in the pyrite gouge associated with the Cate Fault and produces large amounts of the amorphous ferric hydroxide yellow boy. Gob, a backfill material used by the miners in the late 1800's and early 1900's, is also present and can contain marketable concentrations of zinc, lead and silver. These metals were unrecoverable by the ore separation methods of that time.

The pool source is discharge from a bedding plane structure that had a mean flow rate of 4.8 cubic feet per day from March, 1987 to April, 1988. Ferric hydroxides precipitate at the fracture discharge point. Mean metal values of the water issuing from the bedding plane structure were 350 mg/l zinc and 600 mg/l iron with a mean pH of 2.4.

Site 4 (Figure 15) is the second major source of water flowing to site 6. Site 4 had mean metal concentrations of 2,900 mg/l zinc and 3,010 mg/l iron with a mean pH value of 2.3. The pool forms behind a berm of low grade ore and country rock at the bottom of a manway/ore chute. Fractures conduct water from this pool to the Cherry 4 level.

Inflow to the site 4 likely is from channels down ore car track grades of the workings above the Homestake workings and from fractures. Deterioration of the timbers and cribbing in the ore chute prevented visual inspection of this area.

A fracture system at the intersection of the crosscut and the portal adit contributes additional water to site 6. Large concentrations of ferric hydroxide exist at the air and fracture interface. Flows ranged from 36 gal/day to 20 gal/day).

Flow Path Three

Flow path 3 (Figure 16) is in the northwest most extension of the Homestake level and includes sites 1, 2, and 3. This flow path has the poorest quality water on the Homestake level and is greatly influenced by workings above and below the Homestake level.

The major source of inflow to this flow path is the fracture discharge at site 2. Site 2 is a set of bedding plane fractures which discharge to site 1 and site 3. Site 2 contains very poor quality water; ferric hydroxide precipitates rapidly after discharging from the fracture. Average values for pH, zinc concentration, and iron concentration were 2.7, 3,420 mg/l, and 4,590 mg/l, respectively.

Most discharge from site 2 enters site 1. This pool forms in a depression behind a sill in the ore car track grade. Two extensive waste rock and low-grade ore piles are at two breakthroughs to upper or lower workings. A breakthrough is an inadvertent connection with upper and lower workings after blasting on one of the levels. Site 1 discharges to site 3 over a sill and to lower mine workings through fractures. No observable water seeped through or flowed over the waste piles to the lower workings. Site 1 had average values of pH, metal concentrations of 2.3, 1,820 mg/l zinc, and 1,980 mg/l iron.

Site 3 is immediately down the ore car track grade from site 2 and site 1. Site 3 contains waste rock piles which contain low-grade ore. The pool forms in a depression formed by mining. Water discharges from this flow system through fractures to lower levels. These fractures have the highest hydraulic conductivity observed on the Homestake level. Site 3 filled and emptied at least twice in the year while the other pools filled only once. Site 3 averaged values for pH, zinc concentration, and iron concentration of 2.3, 2,640 mg/l and 3,930 mg/l, respectively.

Cherry Workings 4 Level

Only the most southeasterly end of the Cherry 4 level is accessible from the Homestake level because a large area caved directly under the northwest end of the Homestake workings (Figure 11). Homestake level flow paths 1 and 2 discharge separately, downward to the Cherry 4 level.

Flow path 1 continues along a haulage drift (scram 1 on Figure 11) from site 18 to site 16. Monitoring sites were maintained at both ends of flow path 1 on the Cherry level and at one ore chute discharge point, site 17. Flow path 2 discharges through fractures to another haulage drift (scram 2x on Figure 11) and could not be safely monitored.

The manway discharge from the Homestake level, site 18, was monitored using a tarp hung from the timbers. The Cherry workings discharge was monitored at site 16 using a 1 inch x 18 inch cutthroat flume. The average pH was 2.5 at both sites. Metal concentrations at the two sites were very different. Zinc and iron concentrations at site 18 averaged 290 mg/l and 230 mg/l. Zinc and iron concentrations at site 16 averaged 470 mg/l and 290 mg/l.

Reed Workings 5 Level

The 5 level Reed workings (Figure 12) are the deepest monitor sites for this study; these sites have been monitored since 1983. Full site descriptions are presented in Erikson (1985).

Erikson established nine sites in the Reed workings. Five of these sites were monitored from February, 1986 to April, 1988. These sites included Reed Tunnel Flume (site 20), West Reed Flume (site 21), Becker Weir (site 22), West Motor Flume (site 23), Williams Weir (site 24). Flow rate was measured at four of these sites with 1 inch x 18 inch or 4 inch x 36 inch cutthroat flumes. Flow rate at site 21 was measured using a trapezoidal flume. All sites were routinely monitored by measurement of pH, EC, temperature, and flow rate.

Water chemistry was sampled at sites 21 through 24 in the Reed workings through late March, 1987. After this date only sites 21, 22, and 24 were sampled. These sites most likely are the continuation of the flow paths from the Homestake and 4 level Cherry workings.

Water at site 20 had an average pH value of 5.2 from February, 1986, to March, 1987. Metal concentrations averaged values of 2.1 mg/l zinc and 0.32 mg/l iron. Site 23 averaged 5.2 mg/l zinc and 0.19 mg/l iron with an average pH of 5.4 for the same period. These values were consistent enough to end water sampling for metals at these two sites. Data are presented in Appendix B.

The 5 level drainage has two branches. Site 21 and site 22 monitor the first branch in the area of the greenhouse on the 5 level (Figure 12). Water at site 21 was badly degraded with a mean pH of 2.5. Zinc and iron concentrations had mean values of 810 mg/l and 1,310 mg/l, respectively. Tributary flow merges with this branch to dilute the poor water quality before it discharges to lower levels at site 22.

Site 22 had an average pH of 2.7 and mean metal concentrations of 250 mg/l zinc and 390 mg/l iron. This four-fold reduction in metal concentration from site 21 to 22 is accompanied by large amounts of ferric hydroxide precipitation along the entire length of this flow path immediately down stream of the greenhouse (Figure 12).

Site 24 monitors the second branch of the poor quality discharge from the 5 level Reed workings. The second branch is of higher quality than the first branch. Good quality water flowing from the eastern portion of the 5 level dilutes the poor quality stream water of the second branch (Riley, 1985). Mean metal concentrations were 27 mg/l zinc and 7 mg/l iron; mean pH was 3.7. Large quantities of yellow boy form along this flow path.

Mechanisms That Contribute to Spatial Variability

Pool water quality depends on the position of the pool in a flow path, iron equilibria, and the presence of micro-organisms that catalyze the Fe(II)/Fe(III) oxidation reaction.

The water quality of fracture discharge varies with position in the flow path. Water quality decreases with distance from seasonal recharge inflow to the workings. The inter-level flow is degraded by pyrite oxidation or by precipitation related to iron equilibrium reactions. The quality of water discharging from fractures decreases closer to the Flood-Stanly ore body and closer to active mining areas. A higher probability exists that water will contact and flush oxidation products in these areas.

Mining Activities and Position in the Flow Path

Mining activities increase the surface area of ore materials and pyrite, exposing them to oxidation. Many mining related activities also produce "channels" which route the recharge waters down to and through the pyritic Flood-Stanly ore body. These mechanisms are best illustrated by contrasting the fracture discharge at sites 15 and 2 and by examining the Homestake flow path delineated by the sites 9 through 14.

Site 15 and site 2 form the end members of a hypothetical flow path in the upper workings. Site 15 drains a splay of the Cate Fault. The country rock along the fault contains abundant pyrite and very low grade mineralization. Mining activities and development are very limited; they do not exist at all directly above the discharge point located at site 15. Because flow from surface recharge to site 15 is undisturbed there is minimal oxidation of the surrounding pyrite. The best water quality on the Homestake level is at site 15. This site represents the initial stages of acid production in the workings.

In contrast, site 2 is located directly in an ore zone of the upper country. Abundant pyrite, ore bearing material, and ferric hydroxides exist in the drift where the water discharges from bedding plane fractures. The area surrounding site 2 has been extensively mined. Mining activities have greatly disturbed the country rock. Drainage in this portion of the Homestake level discharges the poorest quality water. This site is typical of pools further from the recharge point where water quality has already been degraded by previous pooling.

Metal concentrations generally increase over short flow paths. Homestake flow paths 1, 2, and 3, as well as the Cherry 4 level flow path between site 18 and site 16 follow this trend. Flow path one (Figure 11) on the Homestake level best characterizes the degradation of water quality along a short flow path. Figure 17 shows water quality changes, using zinc as an indicator, from site 15 to site 9.

Relatively fair quality water discharges from sample site 15. Very little deterioration occurs in water quality from site 15 to site 14. Zinc concentration increases from 14 to 16 mg/l.

Zinc concentration increases to 61 mg/l at site 13. This sample site is located 8 feet from a pyrite-rich berm that impounds sites 13 and 14. Site 13 also is the first site along this flow path influenced by mining activities overhead. Yellow Boy ($Fe(OH)_3$) is abundant at this site. At site 12 flow has seeped through the pyrite-rich berm that impounds sites 13 and 14, flushing the oxidation products present in the berm. Zinc concentration increases to 270 mg/l.

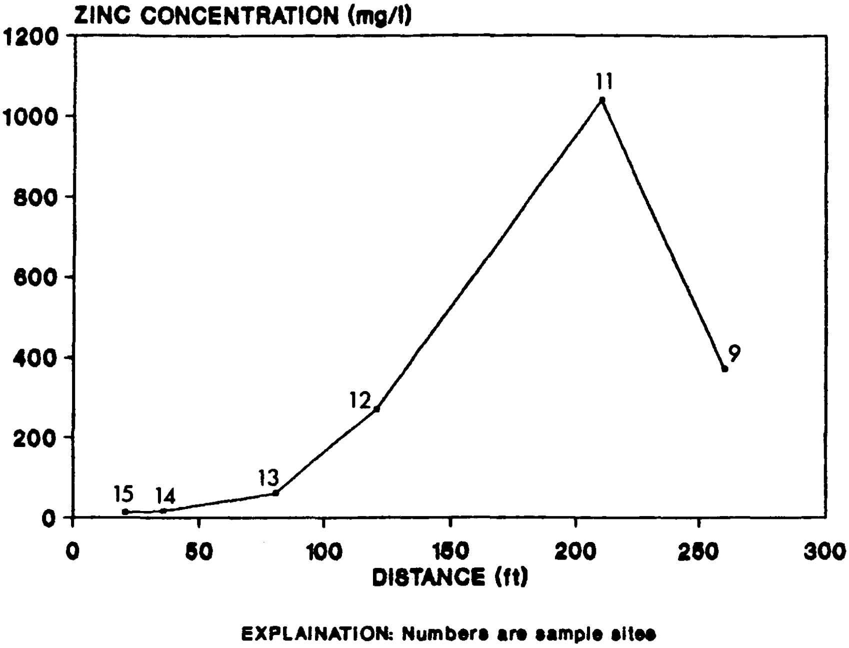


Figure 17. Variation of zinc concentration in pools along flow path one.

Prior to site 11, a tributary flow from a working above the Homestake level joins the downstream flow from site 12. This tributary had very poor quality water and zinc concentration increases to 1,040 mg/l at site 11.

Site 9 shows water quality improvement. Discharge from the bedding plane structure associated with site 8 diluted the water chemistry from site 11. Flow path one discharges water with a zinc concentration of 370 mg/l to the lower workings.

The Role of Bacterial Catalysts

Water quality in the upper country decreases as bacteria increase (Prisbrey, 1987). Micro-organisms such as genus *Thiobaccilus* accelerate the Fe(II)/Fe(III) reaction rate and enhance the production of acid mine water (Appendix A). Absence of these bacteria would make voluminous acid production unlikely (Marcy, 1979). Table 12 includes preliminary reconnaissance data at selected sites in the Homestake and 5 level monitoring system for acidophilic bacteria.

Table 12. Most probable number of bacteria present at selected upper country water sampling sites (Prisbrey, 1987, p. 55).

Site	Sludge	Water	Mean pH	Mean Zinc Concentration (mg/l)
20	L - VL	N	5.2	2.1
23	VL - N	N	5.4	5.2
22	H - L	VL - N	2.7	253
Greenhouse	H	VH - H	-	-
4	VH - H	VH - H	2.3	2905
1	VH - H	VH - H	2.3	1820
14	L - VL	VL - N	3.0	25

NOTE: N = none; VL = very low; L = low; H = high; VH = very high; (-) indicates no data available.

CHAPTER 5

TEMPORAL VARIATIONS

Introduction

Riley (1985) and Smith and Shumate (1971) describe seasonal variations of metal concentrations in acid mine drainage. Metal concentrations increase when recharge waters move downward through mined-out openings and flush oxidation products from underground waste piles and drift floors. This flushing mechanism also was observed in the pools and their associated fracture discharge in the Homestake workings.

Seasonal variations are described for 6 sites within the upper country, above the 5 level Reed workings. Three are pool sites (sites 13, 7, and 1) and their associated fracture inflow (sites 15, 8, and 2). One site (site 16) is mine drainage along the ore car track gradient which typically pools by mid-summer. Two sites (sites 22 and 24) on the 5 level Reed workings likely collect the Homestake workings drainage.

Water quality variations were caused by a "flush-dilute-degrade cycle", common to the pool and fracture sites in 1988 data. The steps include:

1) Water with oxidation products are flushed from fractures during early spring recharge; conductance values increase.
2) Continued spring recharge dilutes oxidation products; conductance diminishes.
3) Baseflow period permits concentration of oxidation products; greatest conductance occurs during mid-winter.

Pool water quality similarly varied with time at monitored sites. Water quality variability increases with greater overhead disturbance and with greater proportion of direct surface recharge.

Temporal Variations of Water Quality

Homestake Level

Oxidation products were flushed from fracture 15 into pool 13 (Figure 10) in early March, 1987 (Figures 18, and 19). The pool water quality improved in late spring when better quality fracture flow diluted the pool's poor water quality. Fracture flow receded to its base flow by April, 1987. Pool depths decrease and water quality declines in fracture discharge and the pooled water.

Fracture discharge at site 8 enters site 7 (Figure 10). These sites had the greatest water quality variation (Figures 20 and 21) likely due to better-quality tributary waters that merge with poor quality water at sites 7 and 8. The flushing-dilution-degrading cycle is present but at a smaller scale.

A small recharge event in late November, 1986 decreased the pool water conductance at site 7. The lowest conductance reading for this site was in early May, the peak recharge period. Conductance generally increased through the remainder of 1987 and until March of 1988 when flushing of the fractures again occurred.

Site 1, greatly influenced by mining in the upper country, had the second highest conductance values and metal load of study area sites. Conductance ranged from 4,600 to 13,000 micromhos/cm (Figure 22) and zinc concentration ranged from 1,100 to 3,200 mg/l. Zinc concentration for

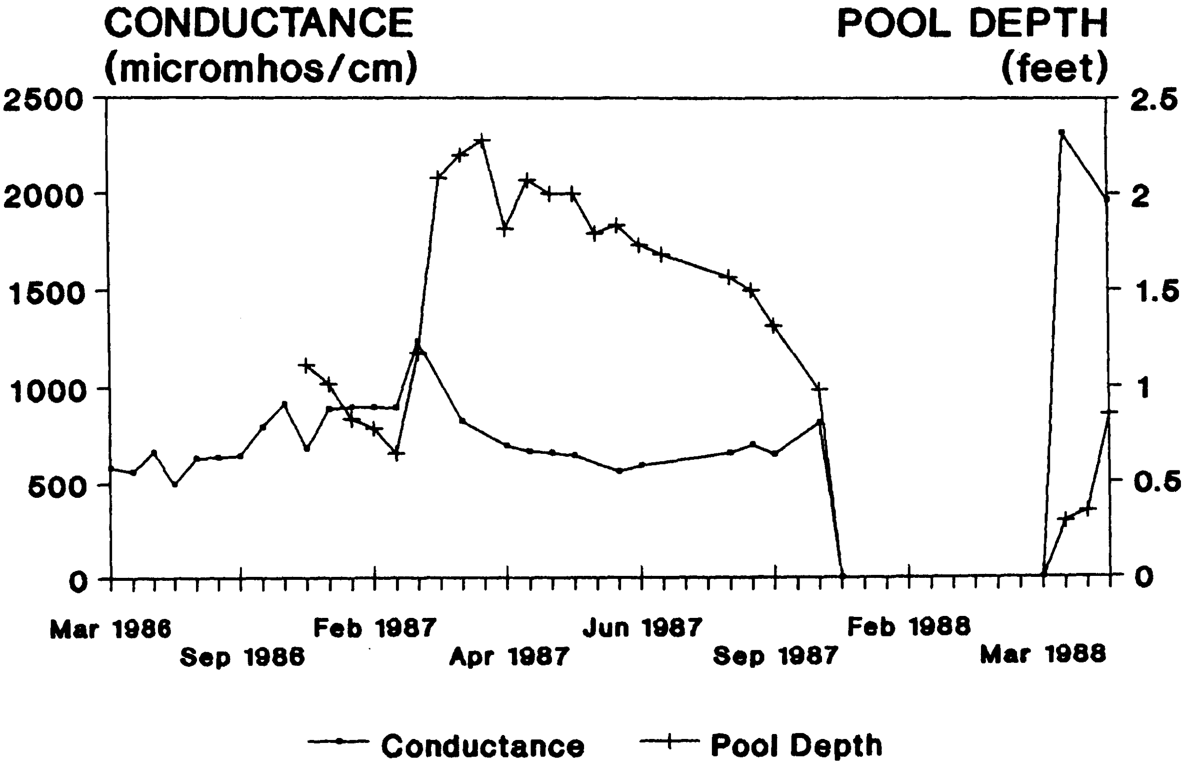


Figure 18. Site 13 conductance and pool depth with time.

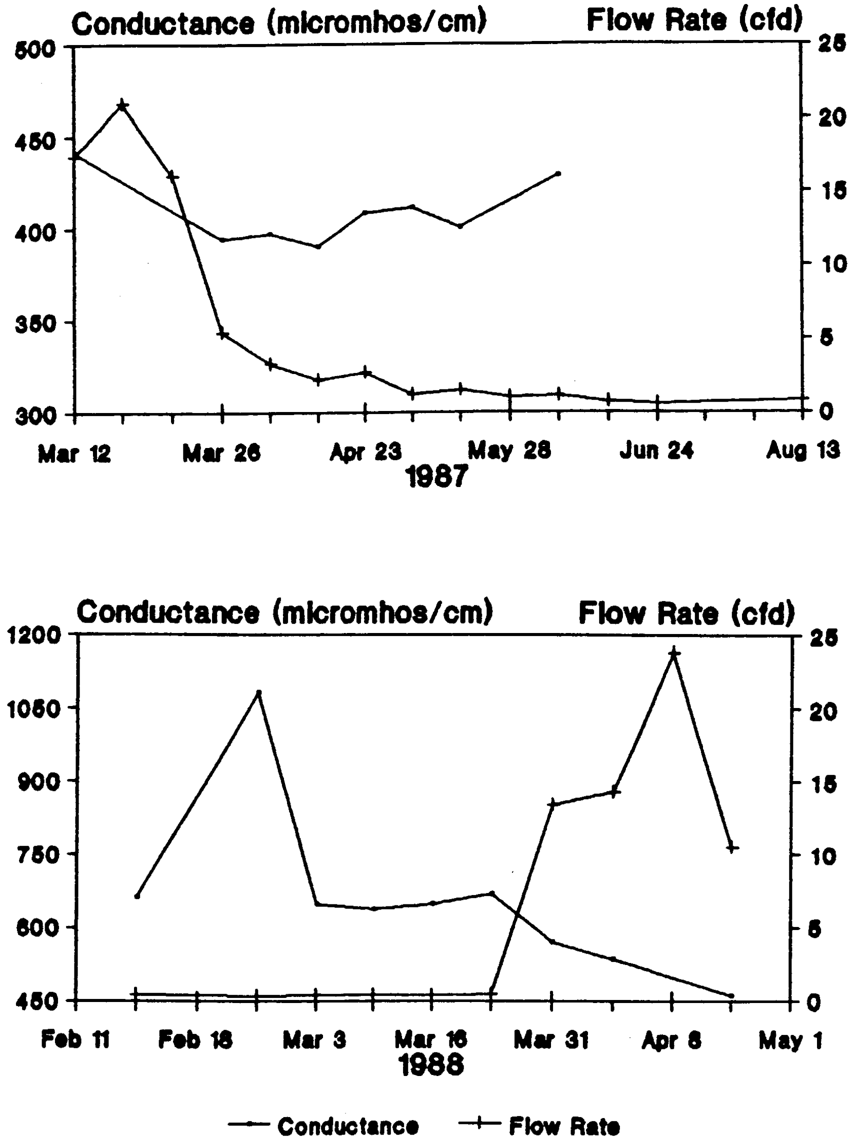


Figure 19. Site 15 conductance and flow for 1987 and 1988.

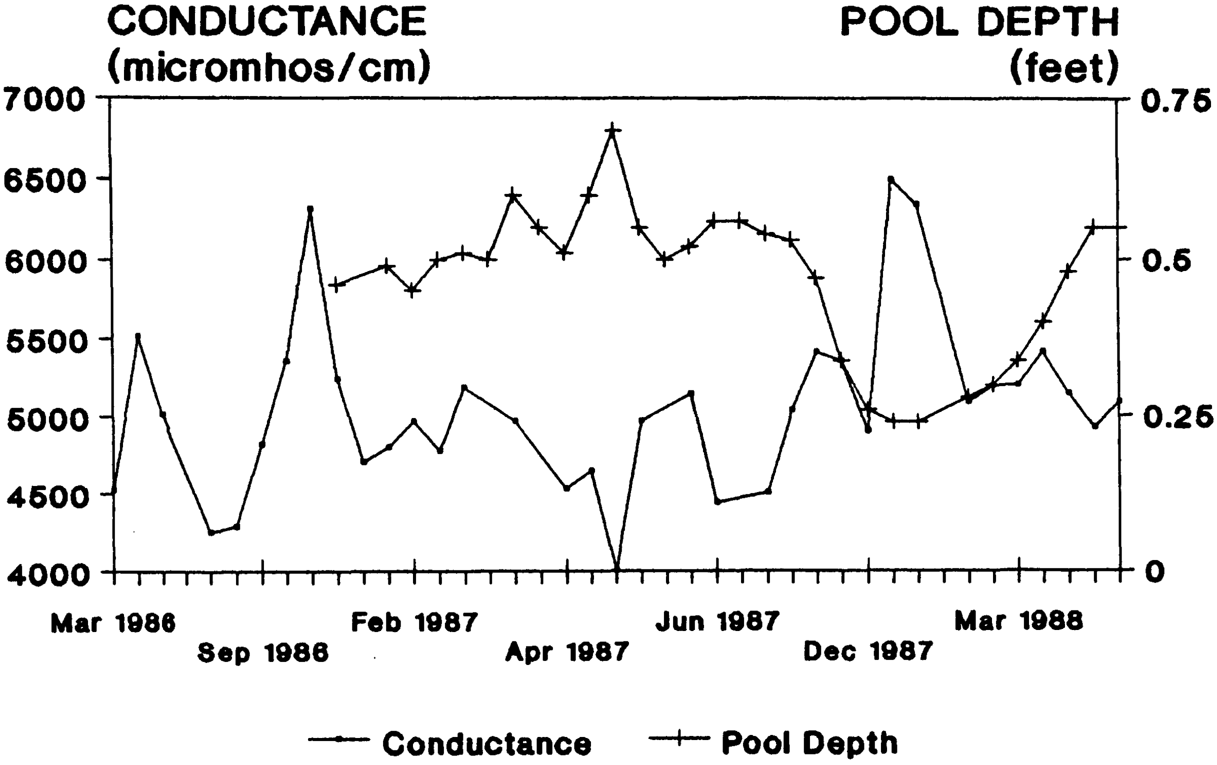


Figure 20. Site 7 conductance and pool depth with time.

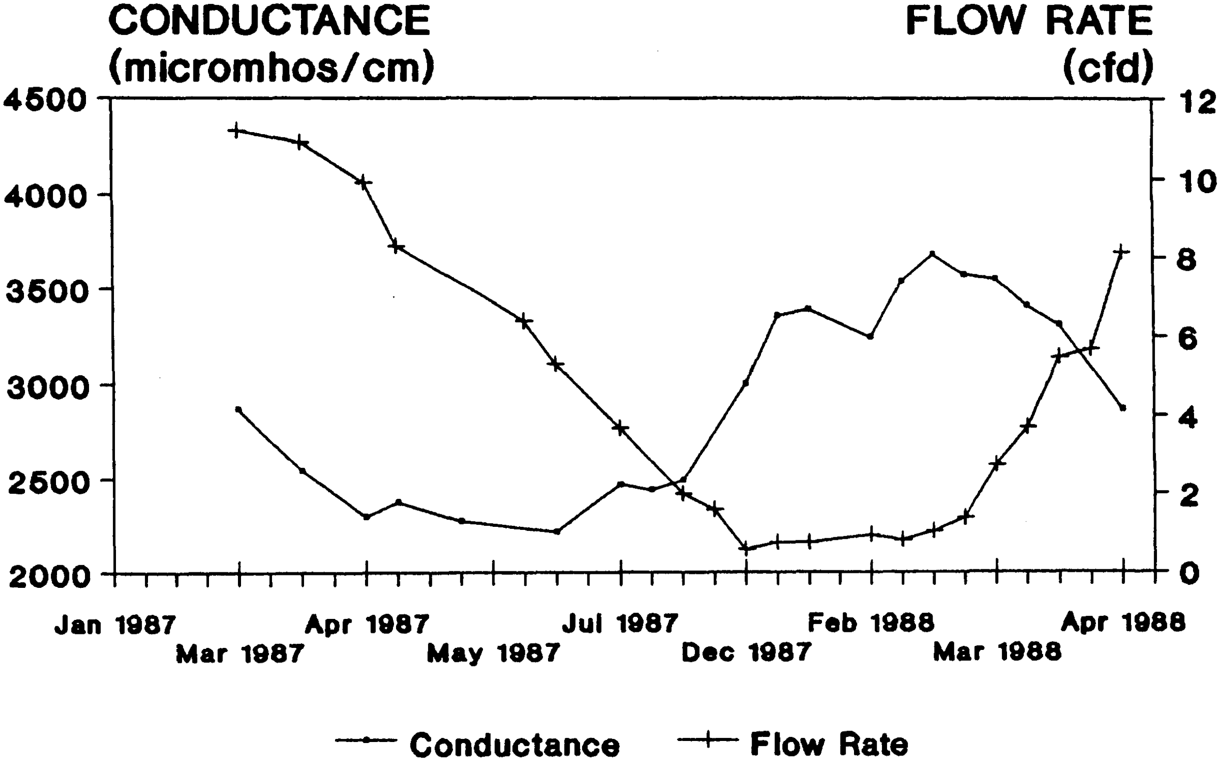


Figure 21. Site 8 conductance and flow with time,

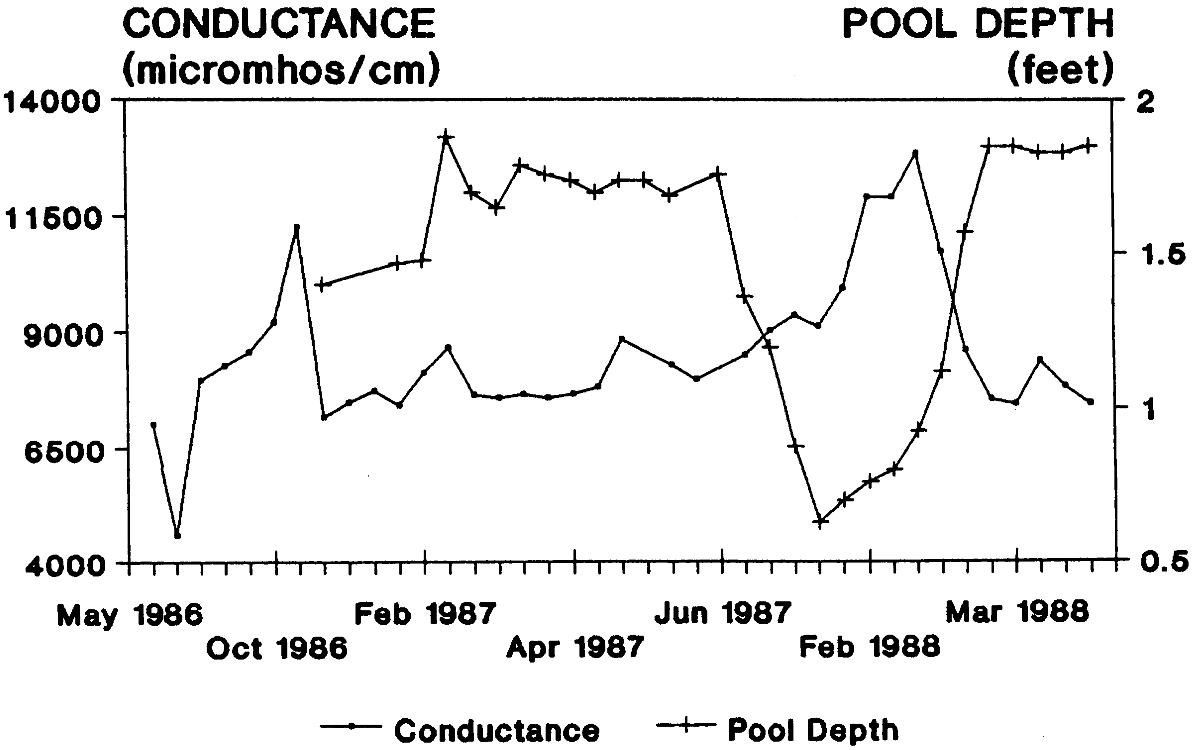


Figure 22. Site 1 conductance and pool depth with time.

the flow period of March through June, 1987 ranged from approximately 2,900 to 4,000 mg/l.

Two smaller-scale events during February, 1987 and May, 1987 probably resulted from poor quality water flushed from above levels, downward to site 1. These events produced highest conductance values at peak flow and lowest conductance values at the low flow. Riley (1985) measured similar flushing responses at his 5 level sites.

Fracture discharge at site 2 entering site 1 (Figure 10) is among the most highly degraded of the study group. Conductance values at site 2 ranged from 10,600 to 20,000 micromhos/cm for March through June, 1987. Conductance values and metal concentrations are not available for late fall and winter because the low flow rates made collection of the necessary sample volume impossible. Consequently, conductance versus pool depth are plotted on two separate graphs (Figure 23).

The dilution and early degradation phases of site 2 were monitored from March, 1987 through July, 1987. The flushing and early dilution phases were monitored from February, 1988 through late April, 1988. Conductance and metal load, unmeasurable during low flow from August, 1987 to February, 1988 were assumed to have increased in this time period. Precipitation of ferric hydroxides on the monitor tarp increased significantly during this period.

Cherry 4 Flume

Site 16 (Figure 11) data indicate pool water conductance decreased while discharge decreased (Figure 24). This response is common to drainage ditch locations on lower levels. Pool water quality and discharge characteristics are similar to the pools in the Homestake workings after June, 1987. From mid June to late October; water quality

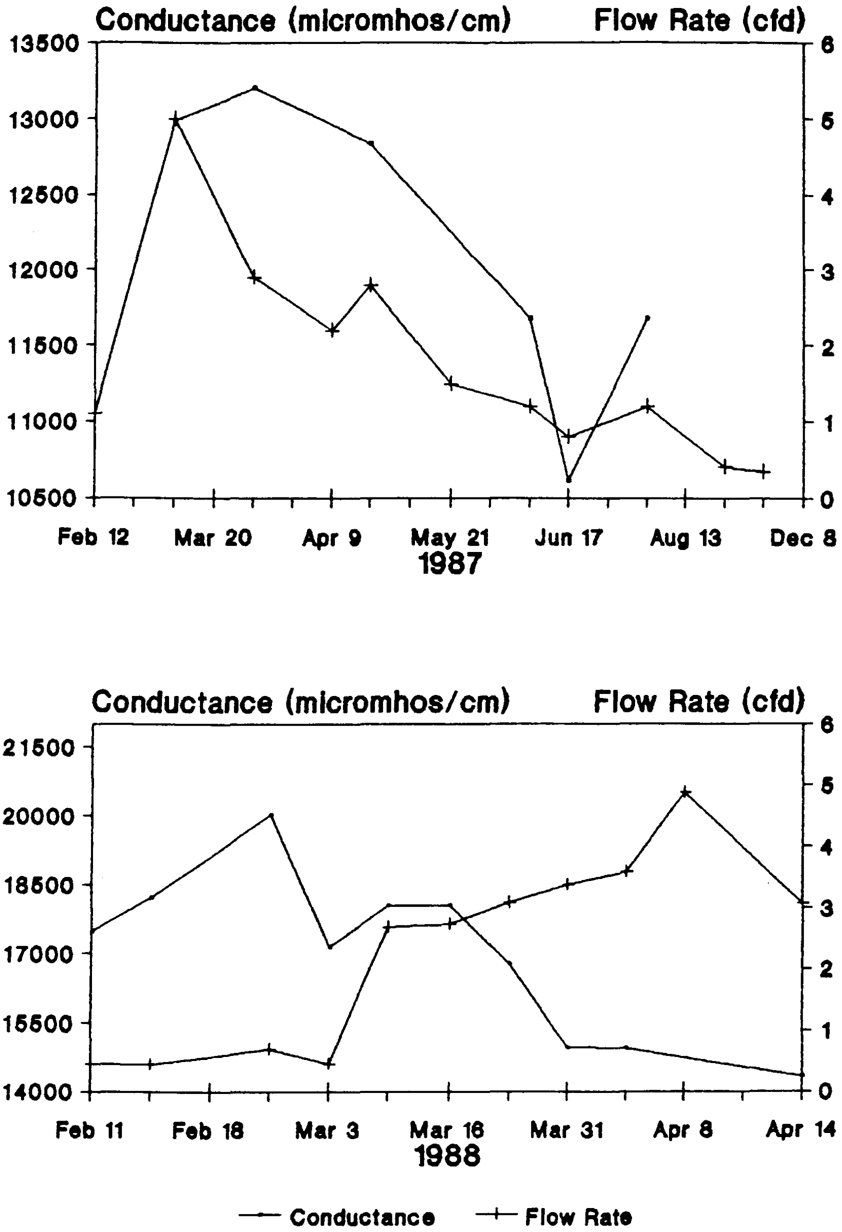


Figure 23. Site 2 conductance and flow (in cubic feet per day) for 1987 and 1988.

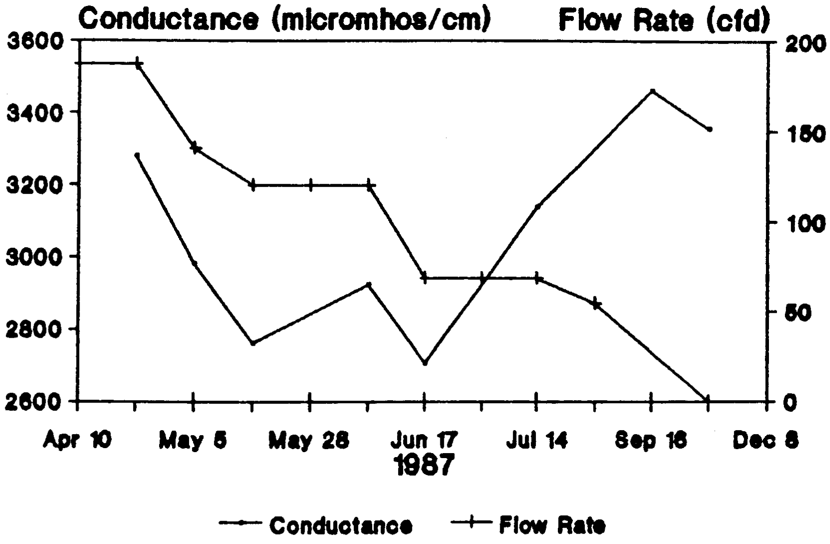


Figure 24. Site 16 conductance and flow for 1987.

deteriorates, channel flow ceases, and the pool drained to lower levels through fractures.

Reed 5 Level Workings

Pools on the Cherry 4 and Homestake levels likely drain downward to sites 22 and 24 (Figure 12) on the Reed 5 level. Water from these sites then drains to lower workings.

Flushing responses for sites 22 and 24 (Figures 25 and 26) are similar to those observed by Riley (1985). Metal concentrations generally decrease with time through late 1986. Poor quality water arrived in January, 1987. Metal concentration and flow peaked in early April, 1987. Metal concentrations and flow then decreased with time until the next seasonal recharge in mid March 1988.

Sites 22 and 24 monitored early flushing in 1987, similar to the responses at Homestake 4 level pool sites the same year. Metal concentration peaks occur early on the rising limb of the recharge hydrograph and likely are caused by a late winter thaw. During the 1988 recharge, only site 22 displayed flushing responses characteristic of pools. Riley (1985) reports similar flushing responses for 1983 through 1985.

Homestake Contribution to Mine Drainage Metal Loading

Metal loading is used to describe water quality deterioration associated with seasonal flushing (Riley, 1985). Metal load of a water sample is metal concentration multiplied by flow rate. Flow is measured with flumes and water chemistry is sampled at the flumes.

Metal loading was difficult to determine in the Homestake workings because flow from pools were only available for sites 12, 18, and 19.

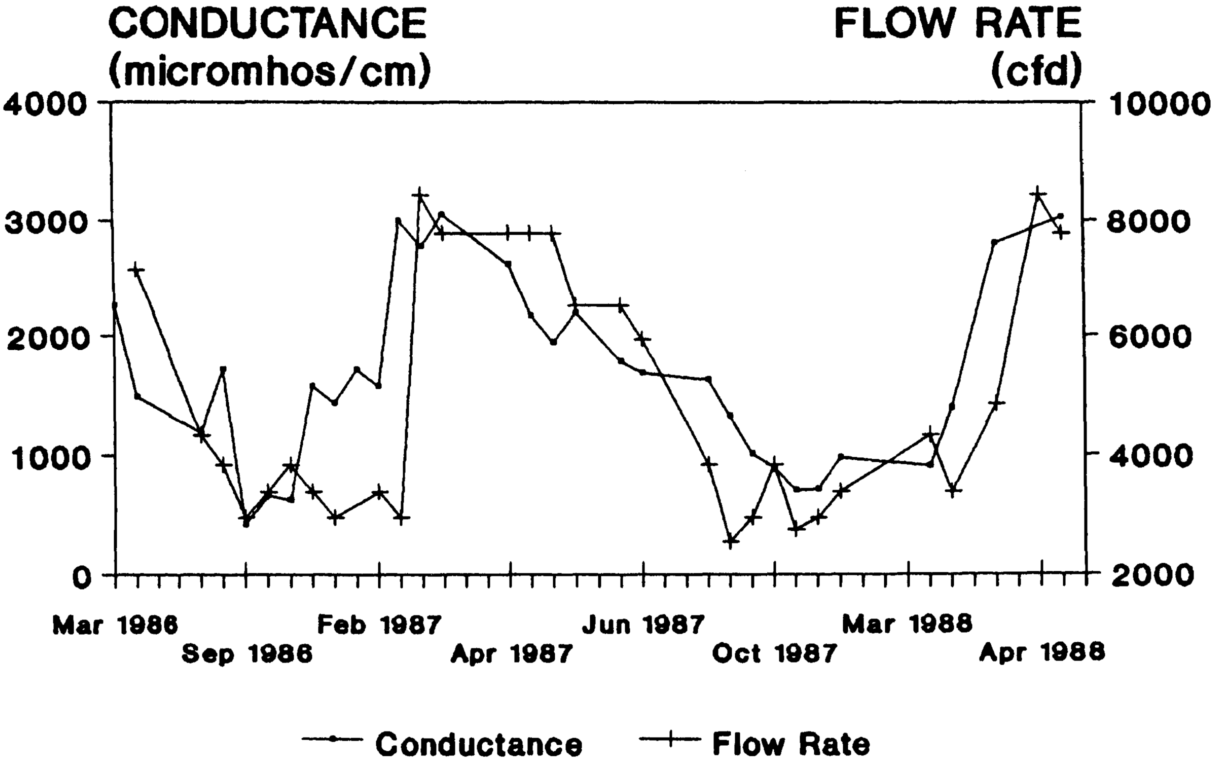


Figure 25. Site 22 conductance and flow with time.

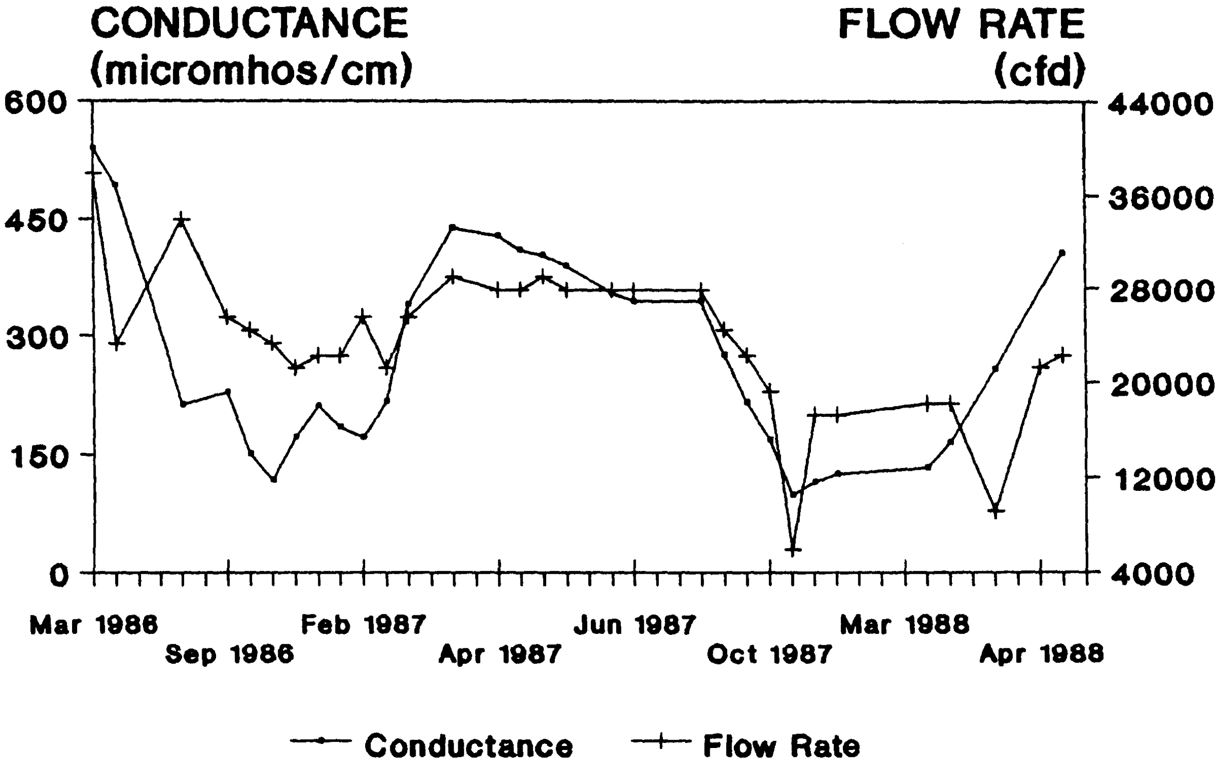


Figure 26. Site 23 conductance and flow with time.

Other flow from the Homestake pools were indirectly calculated by increases and decreases in pool volumes with time, using the methods described in Chapter 3.

Zinc load contributed by the Homestake level to mine drainage is calculated from zinc concentrations and estimated mean daily flow rates. Mean daily flow rates are calculated using 3 methods.

1) Mean daily flow rate determined from totaling the biweekly changes in individual pool volumes for the 200-day flow recession period of 1987.
2) Mean daily flow rate determined by the difference of the total maximum volume and the total minimum volume divided by the 200-day recession period of 1987.
3) Mean daily zinc load determined by totalling mean daily zinc load at sites 16, 18, and 19 on the Cherry 4 level; these sites are known Homestake level discharge points.

Methods 1 and 3 have an estimation error of 30 percent. Method 2 has an estimation error of 10 percent. The load values obtained are presented in Table 13. Table 14 includes flow figures, length of flow period, and mean zinc concentration values used in method 2.

Table 13. Summation of metal load calculations for the Homestake workings.

	Method 1	Method 2	Method 3
Zinc load (lbs/day)	3.2	2.0	3.8
Estimated Error	+/- 30%	+/- 10%	+/- 30%

Table 14. Method 2 load calculation values.

Site	Mean Zinc Concentration (mg/l)	Length of Flow Period (days)	Flow Rates Max. Min. (ft^3/day)	Mean Flow Rate (ft^3/day)	Zinc Load (*)
19[1]	1,625	50	36.5	0.45	.13
16	331	100	61	4.5	.06
18[2]	290	180	193	3.0	1.84

[1] Zinc concentration is the site 6 mean zinc value.
[2] Zinc concentration is the site 9 mean zinc value.
(*) pounds of zinc per day of recharge flow.

Zinc load values determined by the methods are within the estimation error and indicate that the Homestake level likely contributes 2 to 4 pounds of zinc per day during the 200 days of drainage that followed the 1987 recharge event. Methods 1 and 2 likely would yield values similar to the method 3 value if additional fracture discharges to the Cherry 4 level, the northwest end of scram 2x (Figure 11), were monitored. Using a Kellogg Tunnel mean load value of 2,100 pounds of zinc/day and a mean discharge flow rate of 3.4 c.f.s. reported by Riley (1985), the estimated Homestake load of 2 to 4 pounds of zinc/day accounts for 0.2 to 0.5 percent of the mean Kellogg Tunnel load. The 50 c.f.d. mean daily discharge rate (as measured on the Cherry 4 level) of the Homestake accounts for 0.02 percent of the Kellogg Tunnel mean discharge rate. The comparison serves to illustrate the concept proposed by Riley (1985) that relatively large metal load contributions derive from very small flows.

The location of this source of metal load and the mean zinc concentration are of greater significance than the actual volume of zinc being contributed. This zinc load contribution is occurring near the top of a flow path through the Flood-Stanly ore body to the Kellogg Tunnel discharge point. The Homestake workings are situated 80 feet to 120 feet below the ground surface; the pooled water has a mean zinc concentration of 1,280 mg/l. This value is greater than 10 times the mean zinc concentration reported by Riley (1985) for the Kellogg Tunnel discharge (116 mg/l). These values illustrate that significant production of acid drainage is already occurring in the very near surface workings over the Flood-Stanly ore body.

CHAPTER 6

MINE AIR AEROSOL AND ITS RELATIONSHIP TO ACIDIC MINE WATER

Introduction

The mined-out openings of the upper country are used as the air exhaust system for the Bunker Hill Mine. The exhaust air is 100 percent saturated with respect to water. The purpose of this portion of the study is to discuss the relationships which exist between this vapor in the mine exhaust air and the pools of poor quality water in the Homestake workings. The monitor network included evaporation pans, water quality collected from the evaporation pans, vapor water quality.

Site Locations and Descriptions

The aerosol sites (Figure 27) are located within the Homestake workings to represent a range of visible air velocities and eddies, pool water quality, and locations with respect to the exhaust discharge into the workings. Siting information is presented in Table 15.

Sites E_1 and E_5 are air intake control sites. Site E_1 is located 5 feet off the floor, 45 feet inside the portal to the Homestake workings. The site is sampled by a water pan only. Site E_5 is a vapor plate located next to a 50 foot diameter hole which opens down to the Cherry 4 workings. Most of the moist air enters the Homestake workings through this hole.

Sites E_2, E_3, and E_4 contain both pans and plates and are the main data collection points. These sites are located near pooled water of poor quality. The sections of drift they occupy also vary greatly with respect to air flow velocities and distance to air intake locations.

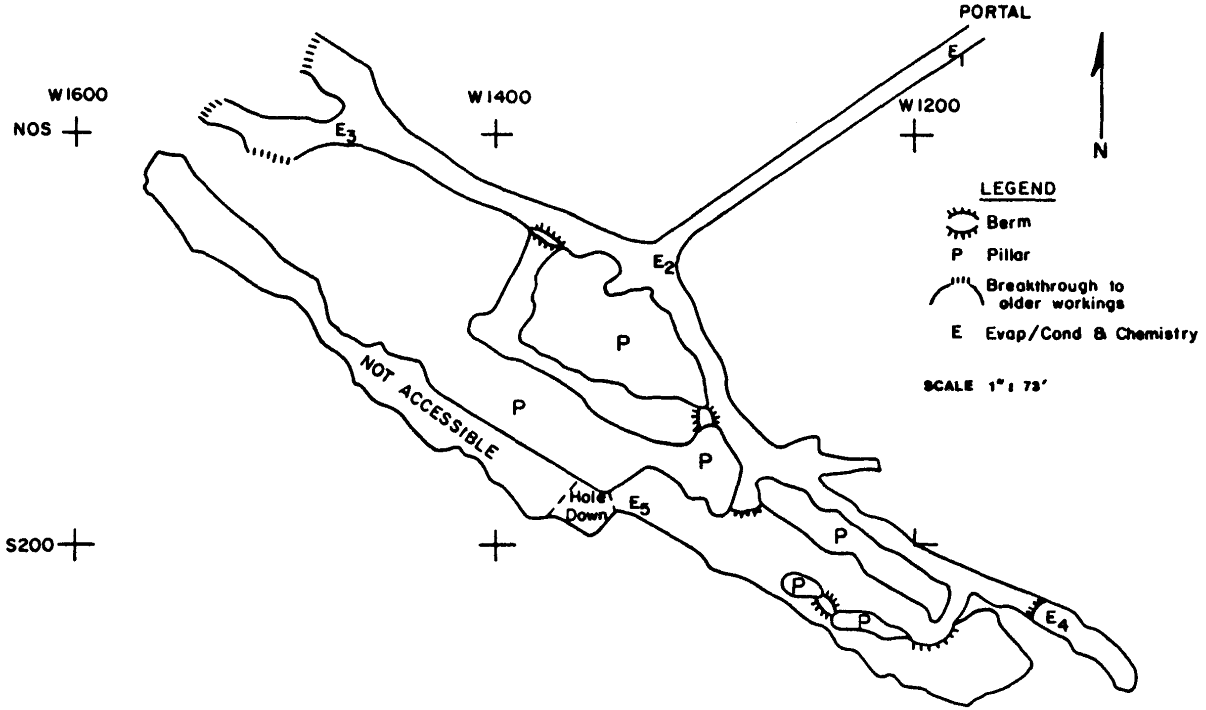


Figure 27. Vapor collection sites, Homestake workings.

Table 15. Characteristics of the aerosol collecting sites.

Criteria	E_1	E_2	E_3	E_4	E_5
Pan Number	1	2A / 2B	3A / 3B	4A / 4B	none
Prominent feature or nearest pool	Site 6 and portal	Site 6 air source convergence	Sites 1 and 3, very low quality pools	Site 13, fair quality pool water	no pool major major source of exhaust air into workings
Visible aerosol	no	yes	no	yes	yes
Type and velocity of air flow seen	fast and bidirectional	variable	low, eddies	moderate velocity, variable in in direction	fast, directional in pulses
Aerosol collection plate number	none	plate 2	none	plate 4	plate 5
Pool longevity	4-5 months	4-5 months	Site 1, permanent; Site 3, 6-7 months	10-12 months	none

Data Presentation

Table 16 is a compilation of the data collected at sites E_2, E_3, and E_4 from March, 1987 through April, 1988. Site E_1 is not included because the site showed no changes in water chemistry over the study period. This is most likely a function of the pan's close proximity to air flow from the portal, 45 feet away.

Table 16. Values of acidic water indicators for aerosol sampling sites.

Site	pH			Zinc Concentration (mg/liter)			Conductance (micromhos/cm)		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
E_2	6.6	3.7	5.6	4.4	1.1	2.2	162	35	64
E_{3A}	4.2	2.3	3.1	232	18.7	83.8	2009	114	778
E_{4A}	6.0	2.5	3.6	50.2	3.4	23.0	1408	49	499

NOTE: Conductance is temperature corrected to 25^0 C.
$_A$ indicates the short erm pan data.

Site E_1 water characteristics varied only slightly around the normal pH and conductance of the tap water used to fill the pans. Conductance ranged between 35-40 micromhos/cm while pH ranged between 5.6 and 6.0. Conductance rose to approximately 90 micromhos/cm when a metal staff gauge had to be used to measure pan water depth. Thereafter conductance ranged between 85-95 micromhos/cm. Site E_5 did not exist long enough for the data collected to produce any trends. Vapor data is listed in Appendix C.

The most probable mechanism for exchange of metals and acid from the pools to the mine atmosphere is by diffusion. Metal ions and H_2SO_4

migrate from poor quality pool water to higher quality water droplets along a concentration gradient. Temporal variations of pan conductance therefore are compared to the depth measurements of the nearest upwind pool. This comparison for sites E_2, E_3, and E_4 are presented in Figures 28, 29, and 30.

Temporal and Spatial Variations of the Vapor Water Quality

A relationship exists between the conductance values of the vapor water and the depth of the pools in the Homestake workings. Figures 28 through 30 demonstrate the relationship of pan conductance with the nearest, upwind pool depth. All three figures indicate a coincident increase in pan conductance with increasing pool depth.

Pans 2 and 3 (Figures 28 and 29) respond more immediately than pan 4. Pans 2 and 3 were at the pool surface level and adjacent to the pool edge when the pool was at maximum stage level. Pan 4 (Figure 30) has a similar response after a two week lag period. This lag may be the result of the pan position. At the highest water level pan 4 is approximately 2 feet above and 4 feet away from the water surface.

Water quality of the nearest upwind pool affects the aerosol water quality. The nearest upwind pool is the likely source of conductance because: 1) the metal migration away is by air movement and 2) air velocities are too low to allow long residence times and long travel paths of the metal ions and the acid molecules (Slinn and others, 1978). Table 17 is a comparison of the mean conductance of the pans and the mean conductance of the nearest upwind pool. Conductance of pans 3 and 4 indicate that the magnitude of the conductance found in the pan water is a function of the water quality of the nearest up-airstream pool.

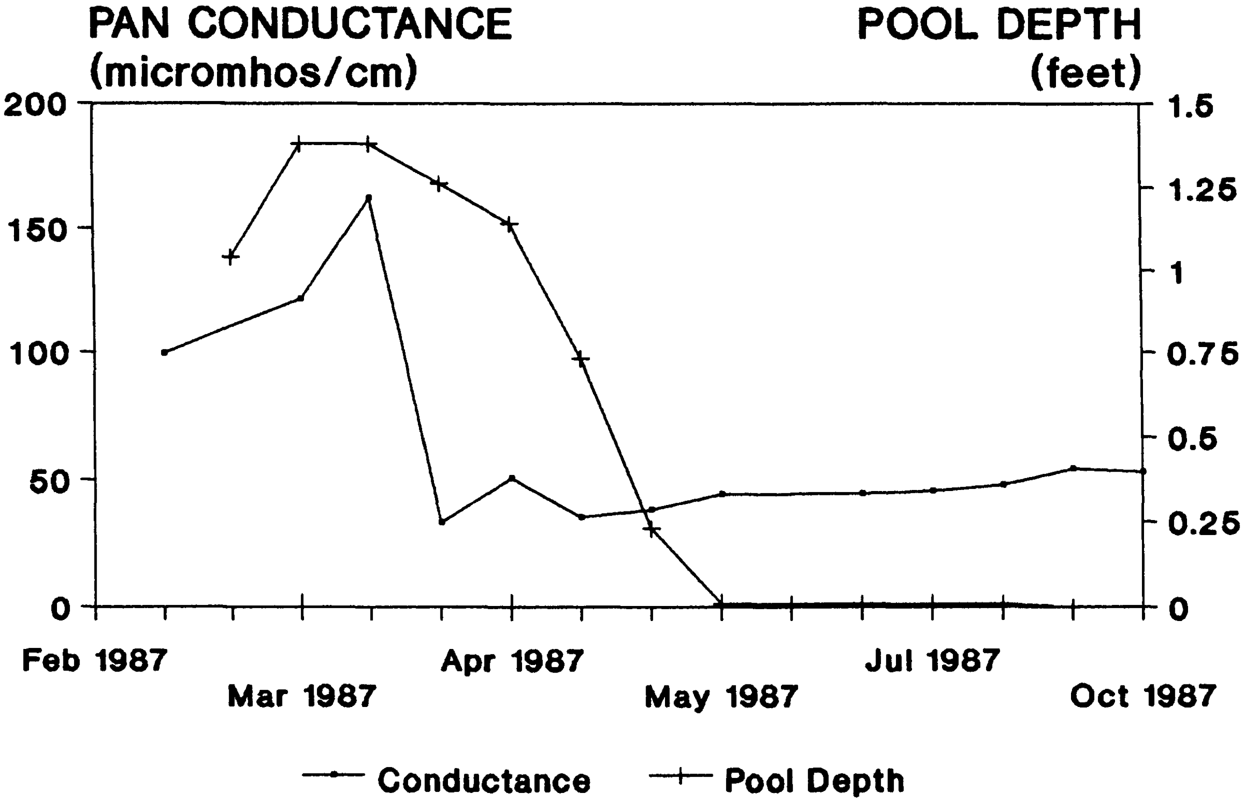


Figure 28. Pan 2 conductance vs. the pool depth of site 6.

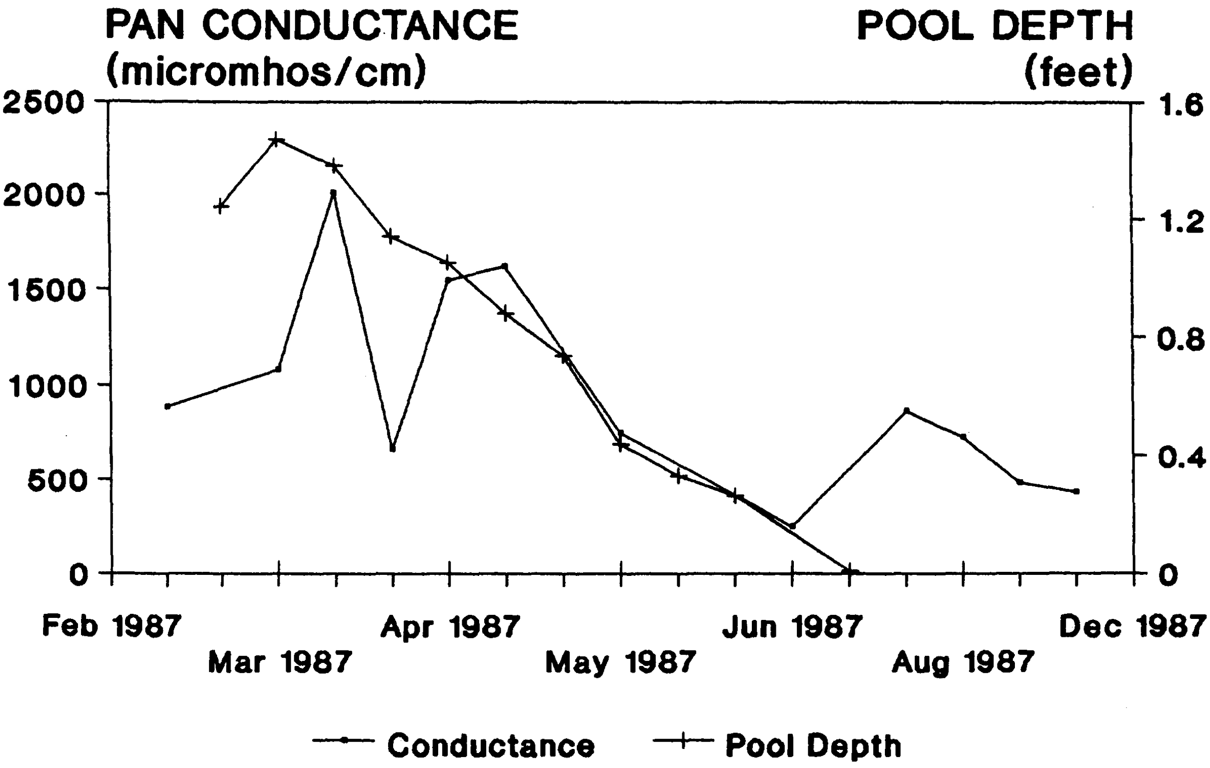


Figure 29. Pan 3 conductance vs. the pool depth of site 3.

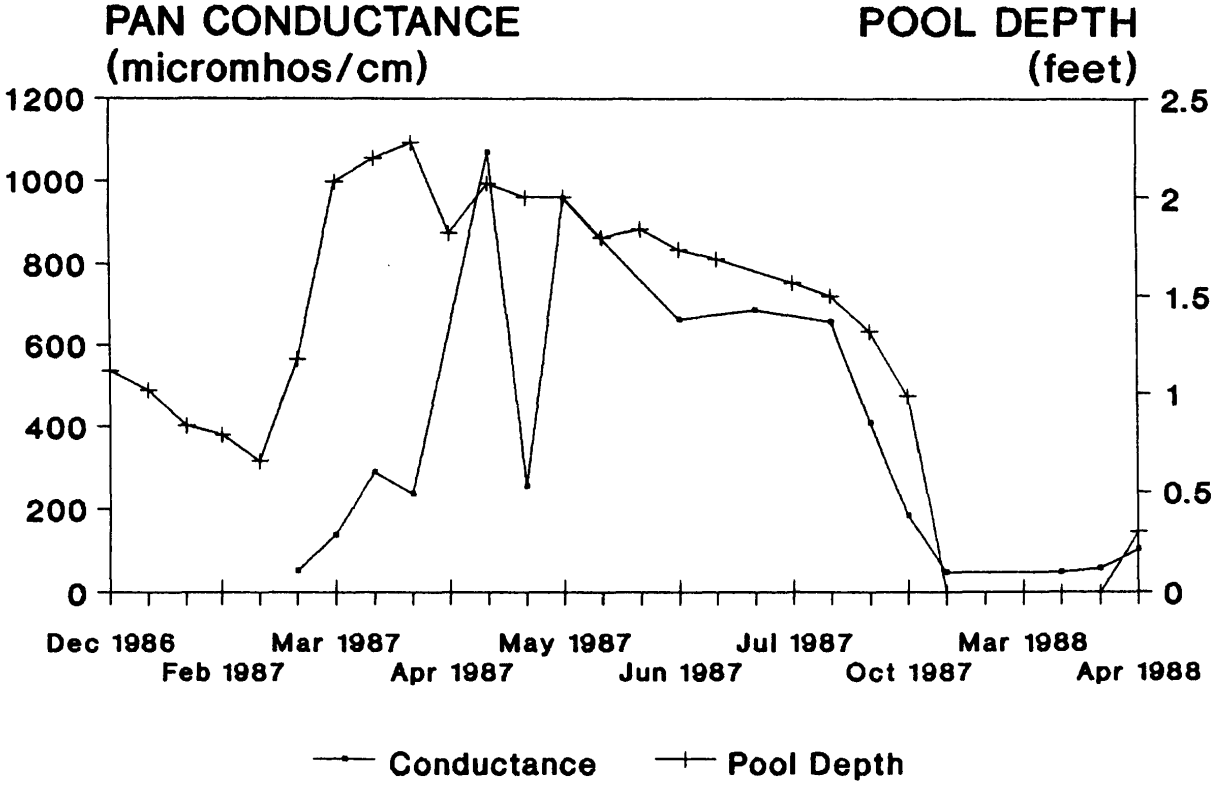


Figure 30. Pan 4 conductance vs. the pool depth of site 13.

Table 17. Comparison of mean pan water conductance with the mean water conductance of the nearest pool.

Pan Site	Pan Conductance	Pool Conductance
E_2	100	6130 (Site 6)
E_{3A}	1600	8500 (Site 3)
E_{4A}	624	775 (Site 13)

NOTE: Conductance is measured in micromhos/cm and corrected to 25^0 C.
$_A$ indicates the short term pan data.

Site 6 (Figure 10) had high conductance values, yet pan 2 had relatively less than expected water conductance compared to pans 3 and 4. Factors unique to this pan site include inflow of drier high quality air from the portal, variable air flow direction and variable air flow velocities.

Drier inflow or higher air flow velocities might reduce the rate of diffusion from the pool to the air. Variable air velocities and variable flow direction would cause variable metal transport direction and residence times (Slinn and others, 1978) which would result in metal transport away from the pans if no pool exists upwind of the pan.

The water conductance of pan 2 does suggest a local influence. Figure 28 indicates water conductance of pan 2 increases and decreases as the pool at site 6 fills and drains. The constant nature of the pan 2 water conductance demonstrated after March, 1987 is important. This flat response is coincidental with the decrease of the pool at site 6 to the size of a puddle. The conductance levels found in pan 2 during this period reflect the natural conductance of the tap water used to fill the pans. The conductance of the pan water was independent of poor quality puddles and pools that exist nearby but are downwind from the pan site.

Metals are being transported by the vapor in the water saturated, mine exhaust air. The data suggest that the vapor water quality is a function of pool water quality, pool longevity, and distance of an aerosol collection site from a pool. More quantitative conclusions cannot be drawn from the data collected because of major short-comings in the experimental design of both the sampling devices and the sampling program. Improvements in the sampling devices and sampling program would include:

1) sufficient controls to determine background levels in the aerosol prior to entrance to a pool area,
2) sufficient numbers of sampling devices at each site to define the spatial variability of the vapor chemistry at each site (Miller et al., 1987),
3) sample collection on a more frequent basis to collect samples whose chemistry may better represent real time vapor chemistry,
4) better sample site standardization with regards to installation as well as surrounding water quality, air velocity, pool proximity and height above the pooled water surface.

For these reasons this study should be viewed as a preliminary survey only. However the general subject area merits future consideration.

CHAPTER 7

RECLAMATION ALTERNATIVES

Introduction

This chapter proposes multiple procedures to abate acid mine drainage at the Bunker Hill Mine. Conclusions include those of Hunt (1984), Erikson (1985), Hampton (1985), and Riley (1985) and this study.

Correlation of the Studies

Hampton (1985) recommends surface sealing to prevent recharge to the upper country. Hunt (1984) concentrated his efforts on defining areas where significant recharge might occur. Hunt concludes that the most significant recharge sources to the mine were the West Milo Creek drainage and the intersection of the South Creek of Milo Creek with the Cate Fault. Erikson (1985) proposes that the north-northwest trending faults, such as the Cate Fault, form the primary flow paths in the upper country of the Bunker Hill Mine.

Hunt's and Erikson's conclusions are supported by recharge to the Homestake workings during 1988. The first fractures to begin flowing were at either end of the workings. Flowing fractures then appeared progressively towards the center of the workings. These two wetting fronts advanced at different rates of speed and entered the workings at different times. Sites 2 and 15 are 500 to 700 feet from the intersection of major recharge features and the Cate Fault. The arrival of peak flow at these sites is separated by two to three weeks.

Riley (1985) uses water chemistry to delineate areas of significant pyrite oxidation in the upper country. Riley discusses the possible improvements of mine discharge water quality resulting from decreasing flow and/or reducing zinc concentrations from targeted areas. Riley concludes that the water quality of mine discharge can be improved by first identifying specific flow paths. One scenario discussed by Riley is the improvement of water quality at the Kellogg Tunnel portal by decreasing of 30 percent to 50 percent of the metal load and flow volume from the upper country.

A decrease in flow occurred in 1987-1988 because precipitation was 30 percent less than normal. This recharge reduction limited pooling in the Homestake workings; peak flows on the Reed 5 level workings were approximately 30 percent less than those peak flow rates recorded since 1983. Peak zinc concentrations at sites 22 and 24 also decreased 40 to 50 percent. Similar reductions of zinc concentration and flow rate likely occurred at the Kellogg Tunnel portal although data were not collected. These data indicate the recharge reduction is a viable alternative.

The most likely recharge to the Reed 5 level is from the Buckeye, Cate and Sullivan Faults where they intersect the surface between the Guy subsidence basin and the south fork of Milo Creek. This area of approximately 50 acres should be a primary target of any reclamation effort.

Reclamation Alternatives

The complex faults and structures in saturated and unsaturated zones underlying the Bunker Hill Mine make it difficult to successfully seal off recharge. Acid mine drainage abatement would require both short and long term mine sealing plans. Short term alternatives are effective for less than 20 years. Long term alternatives are effective for greater than 20 years.

Short Term Alternatives

Short term alternatives include two approaches with different objectives. Approach one is to mine the remaining ore body in the upper country by insitu leaching. Use of this alternative would require the least amount of attention to the problem. Pyrite oxidation and mobilization of the oxidation products would continue with recharge. Researchers from the Metallurgy Department at the University of Idaho are conducting studies to determine methods to extract metals from the acidic water and/or precipitated sludge (Williams and others, 1988). This alternative assumes a demand for the metals recovered and the availability of an operator who is interested in producing them.

Approach two includes:

1) surface diversion of the branches of Milo Creek past the 50 acre area where the acid producing ore body outcrops,
2) surface and/or subsurface grouting of fractures,
3) removal of berms that impound pools in the underground workings,
4) limited backfilling of drifts to prevent new pools from forming as drift ceilings continue to collapse.

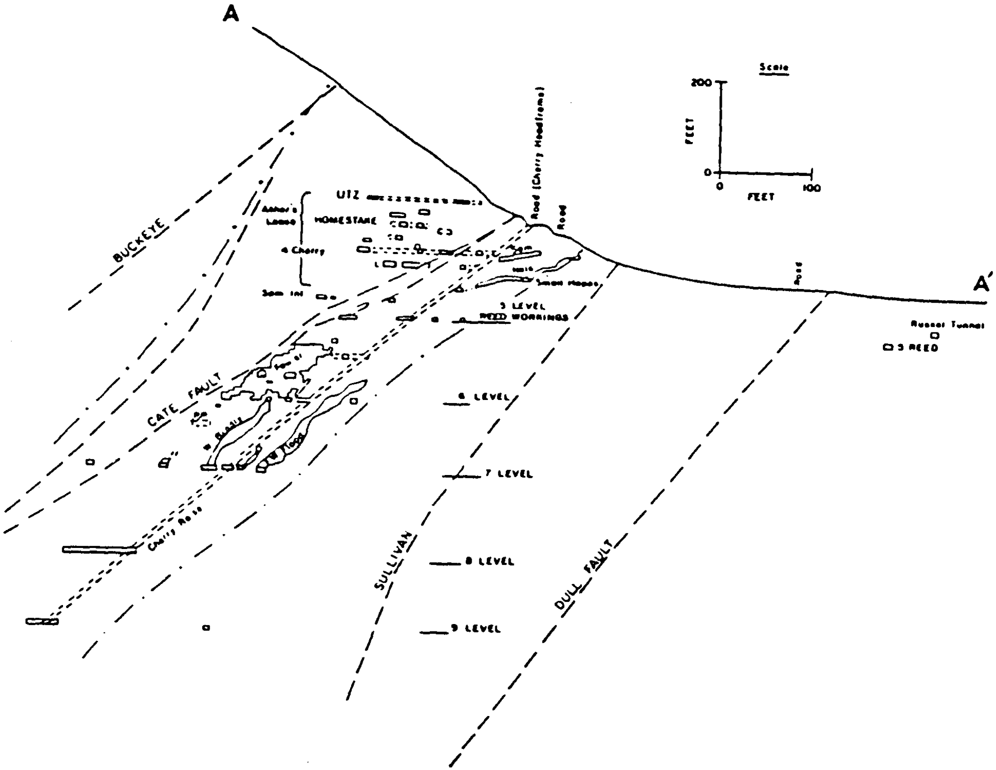
Reclamation would take place in the near-surface drifts in and around the Homestake and Cherry 4 workings. This work would decrease acid production and movement of acid water. Both approach 1 and approach 2 do not deal with continued subsidence in the Guy Cave area and the caving areas in the Asher lease ground (Dupuit, 1988).

Long Term Alternatives

Subsidence continues in the Guy Cave area (Figure 5) and portions of the Asher Lease ground (Figure 31) below the Homestake workings. The Guy Cave area is comprised of 1000 feet of strike length of the Cate Fault and areas on the 3, 4, and 5 levels of the upper country (Schwab, 1952). Block cave mining was completed in the mid-1950's. In the late 1970's more mining by block caving techniques occurred on the eastern edge of mine from the Utz workings to at least the Reed 5 level. The cross section shown in Figure 31 illustrates the disturbance of the near surface area of the Flood-Stanly ore body. Many areas in these upper workings such as the Homestake and Asher's lease are progressively caving upward. Stabilization of these upper country stopes is a critical step of any long term program of acid water reduction by recharge reduction.

One long term alternative would be to stabilize subsidence by backfilling old stopes. Backfilling of the open workings might be accomplished through sand filling techniques or by grouting if access to the workings is possible. Limited access may prevent successful backfilling operations.

A second alternative is to design an open pit mine of limited width and depth. Open pit mining would remove the pyrite bearing rock and ore from the acid producing environment. Economic minerals recovered would be sold to defray some of the pit construction costs. A small open pit mine would provide access to open stopes for backfilling and grouting as well as permitting the removal of oxidized rock, ore, and potential acid producing material from the oxidizing environment. The open pit may also expose new pyrite to oxidation which in turn would produce acid



—·—·— DENOTES THE APPROXIMATE LOCATION OF THE FLOOD-STANLY ORE BODY

Figure 31. The 1000 N.W. cross-section through the Bunker Hill Mine "upper country" in the vicinity of the Homestake workings.

by-products at land surface. Prior planning and drilling could define these areas, to prevent their exposure.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The general objective of this research was to study role of flushing poor quality pools in the near-surface workings with respect to the production of acid in the upper country. The following conclusions may be stated:

1) Pooling of the water in the Homestake workings plays a role in the production of acid drainage within the mine. The pools provide small, yet chemically significant volumes of poor quality water which degrades much better quality recharge.
2) The Homestake workings discharged 2 to 4 lbs/day of zinc during the 1987 spring recharge. This zinc load amounted to 0.2 percent of the projected Kellogg Tunnel load of 2,100 lbs/day. The Homestake workings discharged 50 cubic feet per day during this same period; 0.02 percent of the projected mean Kellogg Tunnel discharge of 3.4 cubic feet per second.
3) Oxidation products are commonly flushed from the fractures on the rising limb of the recharge hydrograph in the near-surface environment. The following peak flow then dilutes the degraded water in the pools. Pool water quality then deteriorates till the next recharge event.
4) Pool water quality degrades with time and the molal concentration of iron. The iron ion concentration increases a) when the pool is nearer to the ore zone, b) with mining

disturbance, and c) when Acidophilic iron-oxidizing bacteria are present.

5) The intersection of the Cate Fault with the South Fork of Milo Creek and the intersection of the Buckeye Fault, the Guy Subsidence feature, and the Utz workings are the two important sources of recharge to the Homestake workings.

6) The vapor in the mine exhaust air becomes acidic because of interaction with pools of poor water quality in the Homestake workings. This poor quality vapor acts as a transport media for acid and metals found in the pools.

Recommendations

Recommendations resulting from this research are:

1) Initiate a small scale subsurface grouting program in the Homestake, Utz, and Cherry 4 workings to test the feasibility of sealing the Cate and Buckeye Faults, along with their associated structural fold fabrics, from surface recharge by the South Fork of Milo Creek and the Guy subsidence area,

2) Initiate a geotechnical survey using geophysical techniques to delineate the extent of unmapped, caved mine openings in the upper country, along the Cate and Buckeye Faults,

3) Trace flow paths through inaccessible areas between the Homestake and Reed 5 level workings by placing tracers in the Homestake pools.

4) Consider the development of a limited open pit mine in the area to remove pyrite and remaining ore from the subsiding, oxidizing environment of the upper country.

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APPENDIX A

PYRITE OXIDATION AND THE ROLE OF IRON IN THE NEAR-SURFACE ENVIRONMENT

Pyrite Oxidation and the Role of Iron in the Underground Environment

Pyrite (FeS_2) oxidation has long been recognized as a producer of acid mine drainage. Regardless of this fact, Lowson (1982) writes that iron sulfide oxidation is less understood than the chemistry of many of today's new compounds. This section is presents a brief overview of the likely oxidation mechanisms. The role that the dissociated iron ion (Fe(II),Fe(III)) plays in the near surface mine water environment also is discussed. The reader is referred to Lowson (1982) for an in-depth review of aqueous pyrite oxidation.

Pyrite oxidation occurs when oxygen and water are in contact with pyrite. This oxidation process, in unsaturated conditions, may be characterized by the following reactions (Stumm and Morgan,1970):

$$FeS_2(s) + 7/2O_2 + H_2O <=> Fe^{2+} + 2SO_4^{2-} + 2H^+$$
$$Fe^{2+} + 1/4O_2 + H^+ <=> Fe^{3+} + 1/2\ H_2O$$
$$Fe^{3+} + 3H_2O <=> Fe(OH)_3(s) + 3H^+$$
$$FeS_2(s) + 14Fe^{3+} + 8H_2O <=> 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

A model of these stoichiometric equations that describes pyrite oxidation in natural mine waters, is presented in Figure 32. This model is a schematic configuration which does not represent the actual mechanistic steps involved. A number of reactions are illustrated in Figure 32 (Stumm and Morgan, 1970). The initiation of the oxidation process is accomplished through either oxidation of pyrite by molecular oxygen (Rl) or dissolution of pyrite (R2) with the subsequent oxidation of the sulfide (R3). The end result is the same, production of Fe(II) and sulfate. Reaction 1 (Rl) is the most probable beginning step in the unsaturated conditions of the mine environment.

Singer and Stumm (1970) consider the fourth reaction (R4) to be the rate-determining step for acid water production. Oxidation of Fe(II) to

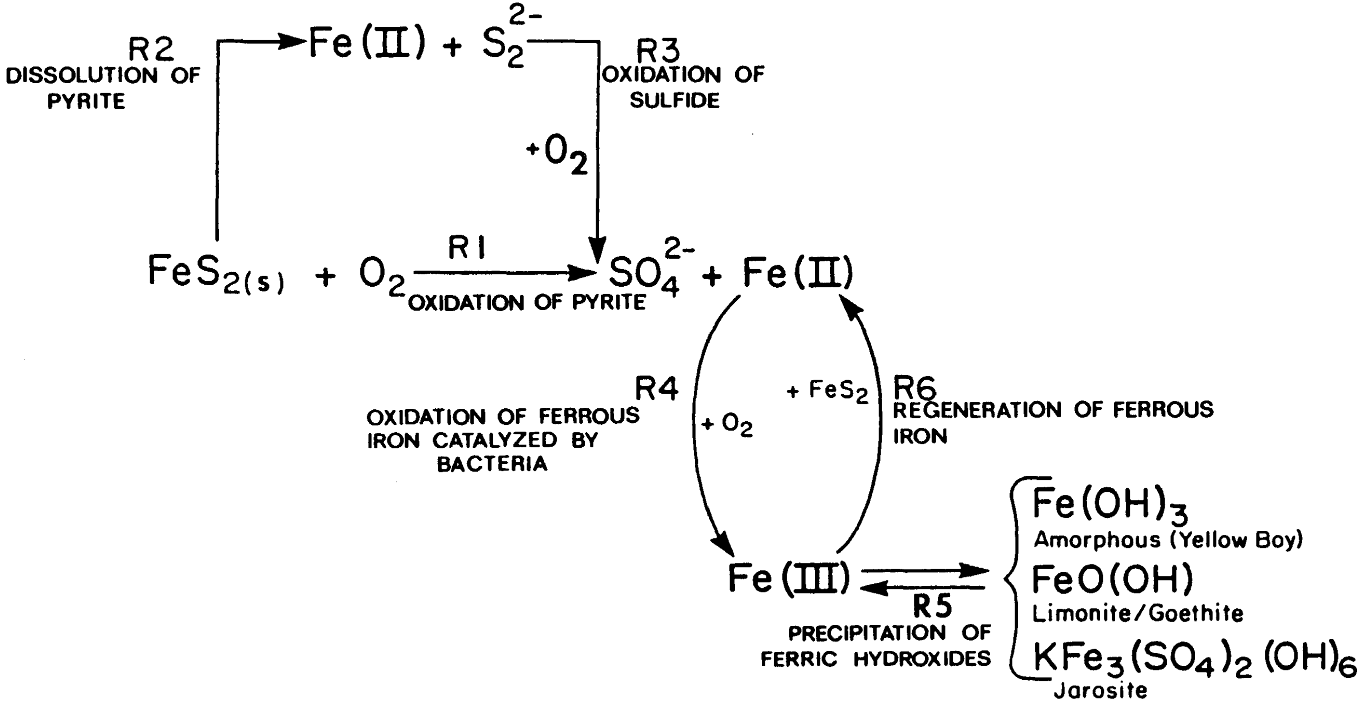

Figure 32. A schematic representation of pyrite oxidation in the unsaturated mine environment (Stumm and Morgan, 1970, p. 541).

Fe(III) is a very slow reaction unless catalyzed by bacteria of the genus Thiobaccilus. The oxidation rate is increased 5 to 6 orders of magnitude under the influence of these bacteria. This catalytic action is the key factor in the production of acid mine drainage (Nordstrom, 1979).

Reaction six (R6) is the reduction of Fe(III) by pyrite to Fe(II). This is a spontaneous reaction resulting in the production of 16 moles of H+ for every mole of pyrite oxidized. Reaction 6 regenerates Fe(II) for microbial oxidation to Fe(III). The role of molecular oxygen becomes secondary at this point in the oxidation process and Fe(III) becomes the primary oxidant of pyrite. The emergence of Fe(III) as the primary oxidant is of importance in the saturated conditions which ore and pyrite bearing rock exist when covered by pooled water.

Fe(III), in the saturated environment of the pools, might play another role as well. Marcy (1979) demonstrates that oxidation of sphalerite and galena by Fe(III) is spontaneous, though secondary to molecular oxygen. As with pyrite in the saturated environment of the pond, the Fe(III) ion probably plays a more significant role than molecular oxygen due to the effectiveness of water as a barrier to molecular oxygen diffusion. The major factors controlling the rate of the oxidation reaction are (Marcy, 1979):

1) rate of diffusion of the primary oxidizer to the surface of the metal,
2) presence of the primary oxidizer,
3) surface area of the metal crystal,
4) presence of microbial catalysts.

The precipitation of ferric hydroxide (R5) is another reaction indicated by Figure 12. Ferric hydroxide precipitates serve as a reservoir of soluble Fe(III) should the regeneration of Fe(III) by reaction 4 be stopped (Stumm and Morgan, 1970). The ferric hydroxide most commonly produced by reaction 5 is an amorphous form commonly called yellow boy.

This ferric hydroxide precipitate can take other forms. The crystalline form of the precipitate and its thermodynamic stability is a function of the Fe(II) molarity. Fe(II) molarities in the magnitude of ten to the minus two permit crystallization of insoluble goethite within a few hours, while precipitates in waters with ten to the minus six Fe(II) molarities may require thousands of years to crystallize (Langmuir and Whittemore, 1971). The precipitates play one other important role in the pond environment. Acid is released as the precipitate forms. Three moles of H+ are produced for every mole of precipitate formed. This production of acidity seems to buffer the natural system around a pH range of 2.5 to 3.5.

APPENDIX B

BASIC DATA FOR UNDERGROUND SAMPLING SITES, BUNKER HILL MINE "UPPER COUNTRY"

SITE: 1 (Pool 2R)
LOCATION: Homestake Workings N 03 W 1500
PERIOD OF RECORD: 5/20/86 4/14/88
AVERAGE ZINC CONCENTRATION: 1820 mg/l
NUMBER OF SAMPLES: 40

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and volume are reported as feet and cubic feet, respectively.
'.' indicate missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE
5/20/86	69	54.54	118.00	1129.00	112.40	1498.00	2222.00	216.30	2.41	.	2.50	.	.	.
6/10/86	90	68.25	129.80	1358.00	135.90	1694.00	2516.00	264.30	2.74	.	2.20	7024.90	19.50	.
6/25/86	105	66.93	134.40	1415.00	145.20	1792.00	2649.00	272.70	2.74	.	2.30	4600.00	25.00	.
7/21/86	131	76.01	144.40	1485.00	145.00	1675.00	2900.00	292.90	2.57	.	2.00	7961.60	18.50	.
8/21/86	162	77.56	159.70	1577.00	160.60	1658.00	2988.00	249.20	2.76	.	.	8277.40	22.00	.
9/19/86	191	95.08	182.60	2174.00	188.80	1982.00	3985.00	313.20	2.87	.	1.90	8574.10	21.50	.
10/11/86	213	98.90	203.00	2250.00	199.00	1840.00	3870.00	450.60	3.17	110.50	2.20	9200.70	21.00	.
11/20/86	253	128.10	269.80	3166.00	249.70	2520.00	5067.00	721.10	5.55	112.80	2.10	11257.10	18.00	.
12/22/86	285	62.50	145.00	1650.00	143.00	1540.00	2670.00	340.00	5.31	80.90	2.00	7176.50	20.00	1.40
1/14/87	308	73.30	165.00	2060.00	155.00	2050.00	4430.00	363.00	4.96	87.60	.	7482.60	13.00	.
1/29/87	323	76.10	165.00	2400.00	162.00	2200.00	3930.00	536.00	5.05	81.60	2.40	7728.60	20.00	.
2/12/87	337	69.70	194.00	2140.00	155.00	1840.00	3790.00	1520.00	4.79	83.60	2.40	7433.80	20.50	1.47
2/26/87	351	86.90	212.00	2030.00	172.00	1930.00	3940.00	1800.00	5.50	89.70	2.20	8120.80	17.50	1.48
3/12/87	365	71.60	187.00	1740.00	156.00	1710.00	3580.00	1560.00	5.08	85.70	2.40	8659.50	21.00	1.88
3/20/87	373	.	.	.	.	.	.	.	.	.	2.40	7640.70	22.00	1.70
3/26/87	379	62.30	136.00	1440.00	135.00	1540.00	2670.00	1410.00	4.30	79.00	2.20	7577.10	21.00	1.65
4/02/87	386	.	.	.	.	.	.	.	.	.	2.30	7652.40	20.50	1.79
4/09/87	393	61.50	135.00	1100.00	116.00	1960.00	2860.00	1870.00	3.90	79.50	2.50	7577.00	21.00	1.76
4/23/87	407	63.90	146.00	1490.00	127.00	1880.00	3000.00	1850.00	3.99	86.00	2.60	7652.40	20.50	1.74
5/05/87	419	65.10	150.00	1470.00	133.00	1930.00	2830.00	1910.00	3.79	88.00	2.70	7793.50	21.00	1.70
5/21/87	435	62.20	137.00	1560.00	132.00	2010.00	3160.00	2010.00	104.00	82.90	2.60	8832.60	20.00	1.74
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	1.74
6/04/87	449	64.80	134.00	1570.00	135.00	1890.00	2990.00	1980.00	40.50	82.60	.	8277.40	22.00	1.69
6/17/87	462	73.50	165.00	1880.00	174.00	2320.00	3400.00	2170.00	47.30	94.00	2.80	7959.10	22.00	.
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	1.76
7/14/87	489	73.60	170.00	1980.00	175.00	2490.00	3580.00	2310.00	3.94	91.80	.	8489.70	22.00	1.36
8/13/87	519	73.90	160.00	1900.00	161.00	2290.00	3810.00	2620.00	4.45	94.40	.	9020.30	22.00	1.20
9/16/87	553	98.40	219.60	2252.00	187.40	2674.00	4321.00	.	.	99.70	2.30	9338.60	22.00	0.88

Site 1 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE
10/21/87	589	109.40	237.50	2276.00	215.10	2699.00	3943.00	.	.	44.00	2.10	9110.00	21.50	0.63
12/08/87	687	.	.	.	.	.	.	.	.	.	2.20	9900.00	.	0.70
2/11/88	701	.	.	.	.	.	.	.	.	.	2.30	11906.70	21.00	0.76
2/18/88	709	.	.	.	.	.	.	.	.	.	2.20	11906.70	21.00	0.80
2/25/88	715	.	.	.	.	.	.	.	.	.	2.20	12861.20	21.50	0.93
3/03/88	722	.	.	.	.	.	.	.	.	.	2.30	10717.70	21.50	1.12
3/10/88	729	.	.	.	.	.	.	.	.	.	2.30	8595.80	22.00	1.57
3/16/88	735	.	.	.	.	.	.	.	.	.	2.30	7534.60	22.00	1.85
3/25/88	744	.	.	.	.	.	.	.	.	.	2.40	7428.50	22.00	1.85
3/31/88	750	.	.	.	.	.	.	.	.	.	2.40	8359.80	21.50	1.83
4/07/88	757	.	.	.	.	.	.	.	.	.	2.40	7793.50	21.00	1.83
4/14/88	764	.	.	.	.	.	.	.	.	.	2.60	7428.50	22.00	1.85

SITE: 2 (Pool 2R Fracture Discharge)
LOCATION: Homestake Workings N 07 W 1482
PERIOD OF RECORD: 2/12/87 4/14/88
AVERAGE ZINC CONCENTRATION: 3424 mg/l
NUMBER OF SAMPLES: 24

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicate missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	QCUFTD
02/12/87	337	87.80	174.00	3970.00	155.00	6060.00	6690.00	5760.00	4.08	44.20	.	.	.	1.10
03/12/87	365	66.80	154.00	3360.00	109.00	4900.00	6000.00	4340.00	12.20	84.50	2.80	12989.20	21.00	5.00
03/26/87	379	71.20	167.00	3540.00	150.00	2070.00	6390.00	5140.00	9.78	102.20	2.60	13205.70	21.00	2.90
04/09/87	393	75.10	170.00	3360.00	152.00	5600.00	6040.00	5700.00	6.97	82.50	.	.	.	2.20
04/23/87	407	.	.	.	.	.	.	.	.	.	2.70	12840.60	22.00	2.80
05/21/87	435	67.90	151.00	2890.00	135.00	4320.00	5250.00	4760.00	177.00	71.30	.	.	.	1.50
06/04/87	449	.	.	.	.	.	.	.	.	.	.	11673.30	22.00	1.20
06/17/87	462	.	.	.	.	.	.	.	.	.	3.10	10612.10	22.00	0.80
07/14/87	489	.	.	.	.	.	.	.	.	.	.	11673.30	22.00	1.20
09/16/87	553	.	.	.	.	.	.	.	.	.	.	.	.	0.40
10/21/87	589	.	.	.	.	.	.	.	.	.	.	.	.	0.34
02/11/88	701	.	.	.	.	.	.	.	.	.	2.50	17490.00	22.00	0.45
02/17/88	708	.	.	.	.	.	.	.	.	.	2.60	18220.00	21.50	0.44
02/25/88	715	.	.	.	.	.	.	.	.	.	2.70	20025.00	21.00	0.70
03/03/88	722	.	.	.	.	.	.	.	.	.	2.70	17148.30	21.50	0.45
03/10/88	729	.	.	.	.	.	.	.	.	.	2.80	18040.50	22.00	2.68
03/16/88	735	.	.	.	.	.	.	.	.	.	2.60	18040.50	22.00	2.73
03/25/88	744	.	.	.	.	.	.	.	.	.	2.70	16767.10	22.00	3.08
03/31/88	750	.	.	.	.	.	.	.	.	.	2.70	14963.00	22.00	3.37
04/07/88	757	.	.	.	.	.	.	.	.	.	2.80	14937.60	21.00	3.58
04/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	4.88
04/14/88	764	.	.	.	.	.	.	.	.	.	2.80	14326.30	22.00	3.07

SITE: 3 (Pool 1r)
LOCATION: Homestake Workings S 12 W 1430
PERIOD OF RECORD: 5/20/86 4/14/88
AVERAGE ZINC CONCENTRATION: 2637 mg/l
NUMBER OF SAMPLES: 24

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage is reported as feet of depth.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE
5/20/86	69	29.63	97.31	1553.00	63.00	1210.00	2278.00	278.40	2.96	.	2.40	.	.	.
6/10/86	90	33.92	108.70	1463.00	73.73	1075.00	2333.00	182.80	2.34	.	2.30	5162.80	19.50	.
8/21/86	162	44.21	134.80	1746.00	92.11	1232.00	2421.00	226.50	1.43	.	.	6323.40	21.50	.
11/20/86	253	137.80	282.80	5359.00	269.00	9656.00	10717.00	25.04	4.15	42.52	2.00	16009.60	17.50	.
12/22/86	285	64.00	139.00	1720.00	138.00	1760.00	2910.00	225.00	3.83	68.40	1.80	7247.90	19.50	0.68
1/14/87	308	90.20	179.00	2840.00	192.00	3500.00	5020.00	236.00	4.23	65.40	.	9055.20	12.00	0.21
1/29/87	323	114.00	230.00	3860.00	237.00	6640.00	8230.00	175.00	4.21	57.60	1.90	11261.60	20.00	0.16
2/12/87	337	120.00	216.00	3890.00	281.00	6590.00	8020.00	6360.00	3.53	55.00	1.90	13249.00	20.00	0.16
2/26/87	351	131.00	240.00	3870.00	.	6240.00	7930.00	6250.00	3.74	53.20	1.80	14341.10	16.00	.
3/12/87	365	38.50	90.30	1150.00	90.30	1200.00	2020.00	1400.00	3.18	49.90	2.60	5953.40	21.00	1.24
3/20/87	373	.	.	.	.	.	.	.	.	.	2.50	7728.60	20.00	1.47
3/26/87	379	52.20	115.00	1590.00	103.00	2550.00	3130.00	2390.00	4.43	55.30	2.30	7949.40	20.00	1.38
4/02/87	386	.	.	.	.	.	.	.	.	.	2.20	8745.60	20.50	1.14
4/09/87	393	59.20	143.00	2240.00	124.00	3500.00	3970.00	3210.00	4.78	57.60	2.40	9838.80	20.50	1.05
4/23/87	407	71.00	162.00	2370.00	124.00	3610.00	4540.00	3370.00	4.55	66.80	2.40	10283.10	21.00	0.88
5/05/87	419	74.90	171.00	2380.00	146.00	3670.00	4300.00	3890.00	5.24	58.00	2.70	10932.60	21.00	0.74
5/21/87	435	70.80	171.00	3080.00	145.00	4760.00	5670.00	5130.00	182.00	41.30	2.40	12989.20	21.00	0.44
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	0.33
6/04/87	449	74.10	166.00	3080.00	154.00	5730.00	5780.00	5040.00	68.40	31.50	.	13397.10	21.50	0.26
3/16/88	735	.	.	.	.	.	.	.	.	.	2.20	7322.20	22.00	0.62
3/25/88	744	.	.	.	.	.	.	.	.	.	2.20	6897.80	22.00	0.78
3/31/88	750	.	.	.	.	.	.	.	.	.	2.60	4816.80	21.00	1.22
4/07/88	757	.	.	.	.	.	.	.	.	.	2.60	5033.30	21.00	1.24
4/14/88	764	.	.	.	.	.	.	.	.	.	2.70	5306.00	22.00	1.47

SITE: 4 (Ore Chute from the Utz Workings)
LOCATION: Homestake Workings S 57 W 1380
PERIOD OF RECORD: 3/12/86 4/14/88
AVERAGE ZINC CONCENTRATION: 2905 mg/l
NUMBER OF SAMPLES: 41

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and volume are reported as feet and cubic feet, respectively.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	VOLUME	STAGE
3/12/86	1	10.45	40.18	1299.00	23.68	1001.00	1806.00	215.90	3.56	.	2.30	4607.80	15.00	.	.
5/20/86	69	19.70	65.31	1328.00	41.43	966.00	1985.00	243.40	2.92	.	2.30	.	.	.	.
6/10/86	90	24.08	74.51	1284.00	51.35	985.20	1951.00	229.70	2.67	.	2.20	5575.30	19.50	.	.
6/25/86	105	26.42	82.83	1467.00	57.75	1132.00	2236.00	271.70	2.89	.	2.20	4590.00	24.00	.	.
7/21/86	131	33.13	104.30	1776.00	70.35	1326.00	2674.00	317.50	2.83	.	2.00	7811.10	18.00	.	.
8/21/86	162	43.81	134.10	2261.00	96.18	1783.00	3577.00	329.90	3.19	.	.	8277.40	22.00	.	.
9/19/86	191	51.13	158.40	2746.00	110.60	2221.00	4443.00	608.00	3.33	.	1.90	8895.70	21.50	.	.
10/11/86	213	55.95	191.70	2734.00	131.40	2263.00	4234.00	535.00	4.10	62.80	2.20	9741.90	21.00	.	.
11/20/86	253	63.24	215.40	3345.00	150.30	3287.00	5131.00	696.10	4.07	63.10	2.20	11486.90	18.00	.	.
12/22/86	285	69.70	241.00	3780.00	175.00	5000.00	6300.00	821.00	3.75	68.00	1.90	12696.90	20.00	.	.
1/14/87	308	80.30	415.00	5280.00	211.00	6270.00	8490.00	1240.00	6.39	79.80	.	12936.10	13.00	47.90	0.57
1/29/87	323	80.10	293.00	4950.00	199.00	6010.00	8400.00	1180.00	6.70	72.20	2.50	15397.90	23.00	35.20	0.50
2/12/87	337	79.50	290.00	3900.00	205.00	5100.00	8090.00	5170.00	6.17	74.20	2.60	16340.40	20.00	38.60	0.52
2/26/87	351	80.00	304.00	4190.00	212.00	4770.00	7930.00	5170.00	5.96	68.90	2.40	15817.40	17.00	23.70	0.43
3/12/87	365	11.30	49.80	2170.00	19.80	2310.00	3830.00	2140.00	6.42	47.40	2.20	8659.50	21.00	495.20	2.55
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	.	2.54
3/26/87	379	22.20	97.90	2650.00	42.60	3040.00	4960.00	2860.00	9.22	63.90	1.90	9850.10	21.00	547.30	.
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	496.80	2.71
4/09/87	393	.	.	2870.00	62.70	2980.00	4890.00	2710.00	7.93	62.00	2.30	9729.50	20.50	592.20	2.69
4/23/87	407	33.90	136.00	2980.00	67.20	3090.00	5340.00	3010.00	7.92	59.90	2.30	9850.10	21.00	592.20	2.71
5/05/87	419	36.30	141.00	2890.00	72.20	2940.00	4890.00	2750.00	7.43	58.00	2.60	9741.90	21.00	592.20	2.68
5/21/87	435	32.60	123.00	2630.00	73.30	2500.00	4470.00	2520.00	149.00	54.90	2.40	9741.90	21.00	592.20	.
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	552.70	.
6/04/87	449	34.50	123.00	2520.00	79.10	2210.00	4300.00	2400.00	61.00	53.20	.	9645.90	21.50	499.60	2.39
6/17/87	462	41.00	148.00	2980.00	91.50	2690.00	4750.00	2620.00	65.70	59.90	2.70	9645.90	21.50	435.00	2.12
6/26/87	470	.	.	.	.	.	.	.	.	.	.	.	.	384.50	.
7/14/87	489	47.00	173.00	3120.00	106.00	2960.00	4930.00	3090.00	6.50	60.00	.	10612.10	22.00	300.50	1.66
8/08/87	507	.	.	.	.	.	.	.	.	.	.	.	.	265.00	.

Site 4 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	VOLUME	STAGE
8/13/87	519	50.70	173.00	3090.00	128.00	2890.00	5320.00	3360.00	7.02	64.40	.	11461.00	22.00	204.00	1.27
9/16/87	553	69.49	245.70	3458.00	160.70	4005.00	6100.00	.	.	69.90	2.30	12522.20	22.00	118.80	0.90
10/21/87	589	71.77	280.90	3843.00	173.10	4636.00	5861.00	.	.	28.00	2.30	13795.70	22.00	62.40	0.64
12/08/87	687	.	.	.	.	.	.	.	.	.	2.20	10400.00	.	.	0.56
2/11/88	701	.	.	.	.	.	.	.	.	.	2.20	18401.30	21.00	.	0.55
2/18/88	708	.	.	.	.	.	.	.	.	.	2.40	17643.60	21.00	.	0.54
2/25/88	715	.	.	.	.	.	.	.	.	.	2.30	17860.10	21.00	.	0.53
3/03/88	722	.	.	.	.	.	.	.	.	.	2.50	16612.40	21.50	.	0.54
3/10/88	729	.	.	.	.	.	.	.	.	.	2.30	16448.70	22.00	.	0.53
3/16/88	735	.	.	.	.	.	.	.	.	.	2.30	16448.70	22.00	.	0.53
3/25/88	744	.	.	.	.	.	.	.	.	.	2.20	16979.30	22.00	.	0.50
3/31/88	750	.	.	.	.	.	.	.	.	.	2.40	17864.20	21.50	.	0.50
4/07/88	757	.	.	.	.	.	.	.	.	.	2.40	17491.20	20.50	.	0.50
4/14/88	764	.	.	.	.	.	.	.	.	.	2.20	14326.30	22.50	.	0.80

SITE: 5 (Utz Ore Chute Drainage)
LOCATION: Homestake Workings, S 66 W 1390
PERIOD OF RECORD: 3/12/87 6/16/87
AVERAGE ZINC CONCENTRATION: 2180 mg/l
NUMBER OF SAMPLES: 11

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	FLOW
3/12/87	365	9.42	50.30	2060.00	16.20	2270.00	3840.00	2310.00	7.39	52.10	2.20	7000.00	21.00	21.50
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	24.60
3/26/87	379	.	.	.	.	.	.	.	.	.	.	.	.	10.60
4/02/87	386	.	.	.	.	.	.	.	.	.	2.00	8000.00	21.00	6.20
4/09/87	393	13.10	76.30	2300.00	27.20	2370.00	3380.00	2310.00	6.45	53.70	2.20	7900.00	21.00	9.60
4/23/87	407	.	.	.	.	.	.	.	.	.	2.10	8000.00	22.00	3.40
5/05/87	419	.	.	.	.	.	.	.	.	.	2.50	7800.00	21.50	1.50
5/21/87	435	.	.	.	.	.	.	.	.	.	.	.	.	0.50
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	0.34
6/03/87	448	.	.	.	.	.	.	.	.	.	.	.	.	0.31
6/16/87	461	.	.	.	.	.	.	.	.	.	.	.	.	0.01

SITE: 6 (Portal Adit Pool)
LOCATION: Homestake Workings S 42 W 1300
PERIOD OF RECORD: 1/29/87 4/14/88
AVERAGE ZINC CONCENTRATION: 1635 mg/l
NUMBER OF SAMPLES: 18

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and volume are reported as feet and cubic feet, respectively.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	VOLUME
1/29/87	323	57.60	109.00	2500.00	207.00	5320.00	5240.00	7.91	2.97	18.70	2.10	10108.40	18.00	.
2/12/87	337	55.90	107.00	2190.00	175.00	4330.00	5010.00	3880.00	3.10	18.80	2.00	9384.70	20.00	.
2/26/87	351	51.60	107.00	2080.00	156.00	4640.00	4450.00	4640.00	4.03	23.30	2.10	10019.10	13.00	2399.00
3/12/87	365	.	.	.	.	.	.	.	.	.	.	.	.	2472.00
3/14/87	367	24.40	48.30	875.00	79.30	1810.00	2010.00	1760.00	2.42	16.90	2.40	5520.40	20.00	.
3/20/87	373	.	.	.	.	.	.	.	.	.	2.40	5412.20	21.00	.
3/26/87	379	28.80	64.80	1100.00	92.40	2080.00	2190.00	1880.00	2.64	20.40	2.10	5575.60	20.00	3989.00
3/30/87	383	.	.	.	.	.	.	.	.	.	.	.	.	3375.00
4/02/87	386	.	.	.	.	.	.	.	.	.	2.10	6072.40	20.00	.
4/06/87	390	.	.	.	.	.	.	.	.	.	.	.	.	2866.00
4/09/87	393	28.40	60.60	1140.00	76.00	1960.00	2140.00	1900.00	2.31	20.20	2.40	4880.00	20.00	.
4/17/87	401	.	.	.	.	.	.	.	.	.	.	.	.	1118.00
4/23/87	407	36.60	87.20	1630.00	97.70	2520.00	3120.00	2260.00	3.18	27.90	2.40	7652.40	20.50	.
4/29/87	413	.	.	.	.	.	.	.	.	.	.	.	.	.
5/05/87	419	36.80	95.60	1530.00	98.50	2440.00	2760.00	2510.00	3.21	28.00	2.60	7793.50	21.00	.
5/21/87	435	33.10	85.50	1580.00	88.20	2230.00	2870.00	2260.00	95.60	28.20	2.50	7685.30	21.00	.
6/04/87	449	35.40	84.20	1630.00	92.30	2090.00	2780.00	2270.00	39.20	27.40	.	7502.40	21.50	.
6/17/87	462	.	.	.	.	.	.	.	.	.	2.70	7395.20	21.50	.
3/16/88	735	.	.	.	.	.	.	.	.	.	2.00	11673.30	22.00	.
3/25/88	744	.	.	.	.	.	.	.	.	.	2.10	11673.30	22.00	.
3/31/88	750	.	.	.	.	.	.	.	.	.	2.30	12898.20	21.00	.
4/07/88	757	.	.	.	.	.	.	.	.	.	2.40	11040.80	20.00	.
4/14/88	764	.	.	.	.	.	.	.	.	.	2.50	9020.30	22.00	.

SITE: 7 (Pool 1L)
LOCATION: Homestake Workings, S 105 W 1307
PERIOD OF RECORD: 03/12/86 04/14/88
AVERAGE ZINC CONCENTRATION: 1234 mg/l
NUMBER OF SAMPLES: 40

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage measurements are reported as feet of pool depth.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE
03/12/86	1	17.20	47.84	1075.00	48.46	1434.00	1825.00	105.40	2.63	.	2.40	4522.47	15.00	.
05/20/86	69	25.23	57.99	935.50	57.81	1192.00	1551.00	72.29	1.63	.	2.30	5518.20	19.00	.
06/10/86	90	29.01	67.05	1015.00	71.28	1400.00	1775.00	66.33	1.53	.	2.30	5017.80	19.50	.
06/25/86	105	.	.	.	.	.	.	.	.	.	.	.	.	.
07/21/86	131	20.79	40.76	864.50	32.22	731.60	1103.00	.	0.73	.	2.10	4250.14	18.00	.
08/21/86	162	22.18	43.32	970.90	33.08	841.90	1196.00	.	0.70	.	.	4287.07	21.50	.
09/19/86	191	26.36	57.79	1331.00	42.80	1016.00	1825.00	.	0.97	.	1.90	4822.95	21.50	.
10/11/86	213	31.01	69.72	1520.00	51.02	1065.00	1798.00	1.00	1.34	18.72	2.20	5358.04	21.00	.
11/20/86	253	34.51	78.27	1728.00	58.93	1156.00	1791.00	4.50	1.33	20.45	2.10	6317.77	18.00	.
12/22/86	285	27.00	64.30	1330.00	52.40	1020.00	1710.00	2.50	1.20	16.00	1.60	5244.38	20.00	0.46
01/14/87	308	26.40	54.00	1440.00	44.40	1170.00	1740.00	0.20	0.94	14.30	.	4705.18	13.00	.
01/29/87	323	25.00	55.40	1380.00	40.10	1080.00	1640.00	0.20	0.91	14.20	2.30	4802.75	20.00	0.49
02/12/87	337	29.00	66.00	1420.00	45.90	1080.00	1790.00	1100.00	1.08	16.60	2.20	4968.36	20.00	0.45
02/26/87	351	25.40	66.30	1060.00	48.50	980.00	1520.00	944.00	0.95	15.70	2.20	4780.37	16.00	0.50
03/12/87	365	24.10	54.70	1440.00	53.50	1340.00	1790.00	1410.00	1.32	12.50	2.40	5189.18	20.00	0.51
03/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	0.50
03/26/87	379	30.10	60.90	1240.00	55.90	1380.00	1850.00	1350.00	2.05	18.70	2.30	4968.36	20.00	0.60
04/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	0.55
04/09/87	393	27.60	53.90	1190.00	40.60	1230.00	1610.00	1160.00	1.18	14.00	2.40	4526.73	20.00	0.51
04/23/87	407	26.80	28.80	1260.00	47.40	1180.00	1720.00	1120.00	1.28	13.90	2.50	4646.11	20.50	0.60
05/05/87	419	25.40	55.60	1060.00	42.70	979.00	1390.00	1030.00	0.96	12.50	2.60	4005.00	21.00	0.70
05/21/87	435	24.50	53.50	1250.00	43.40	1200.00	1620.00	1210.00	64.40	13.20	2.60	4968.36	20.00	0.55
05/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	0.50
06/04/87	449	26.80	54.20	1140.00	46.40	1070.00	1610.00	1230.00	28.40	13.61	.	5144.48	21.50	0.52
06/17/87	462	25.70	55.30	1240.00	42.90	1200.00	1530.00	1120.00	24.70	13.30	2.60	4437.97	21.00	0.56
06/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	0.56
07/14/87	489	25.10	55.60	1150.00	42.50	1150.00	1530.00	1160.00	1.13	13.00	.	4501.42	21.50	0.54

Site 7 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE
08/13/87	519	24.80	54.10	1090.00	43.10	1110.00	1540.00	1240.00	1.37	13.60	.	5037.31	21.50	0.53
09/16/87	553	28.95	66.80	1231.00	48.36	1226.00	1688.00	.	.	15.31	2.30	5412.16	21.00	0.47
10/21/87	589	34.02	81.76	1487.00	56.38	1336.00	1664.00	.	.	8.55	2.20	5358.80	21.50	0.34
12/08/87	687	.	.	.	.	.	.	.	.	.	2.20	4900.00	.	0.26
02/11/88	701	.	.	.	.	.	.	.	.	.	2.30	6494.59	21.00	0.24
02/17/88	708	.	.	.	.	.	.	.	.	.	2.40	6340.58	20.50	0.24
02/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.
02/25/88	715	.	.	.	.	.	.	.	.	.	2.30	5087.43	21.00	0.28
03/03/88	722	.	.	.	.	.	.	.	.	.	2.30	5195.67	21.00	0.30
03/10/88	729	.	.	.	.	.	.	.	.	.	2.20	5199.92	22.00	0.34
03/16/88	735	.	.	.	.	.	.	.	.	.	2.00	5412.16	21.00	0.40
03/25/88	744	.	.	.	.	.	.	.	.	.	2.30	5144.48	21.50	0.48
03/31/88	750	.	.	.	.	.	.	.	.	.	2.30	4925.07	21.00	0.55
04/07/88	757	.	.	.	.	.	.	.	.	.	2.40	5087.43	21.00	0.55

SITE 8 (Pool 1L Fracture Discharge)
LOCATION: Homestake Workings S 114 W 1295
PERIOD OF RECORD: 2/12/87 4/14/88
AVERAGE ZINC CONCENTRATION: 348 mg/l
NUMBER OF SAMPLES: 24

Reported EC measurements are compensated to 25 degrees C.
EC measurements reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	FLOW
02/12/87	337	9.62	16.60	218.00	11.60	552.00	510.00	442.00	0.14	7.22	.	.	.	.
03/12/87	365	16.80	31.62	483.00	23.00	723.00	806.00	747.00	0.30	9.82	2.90	2870.61	20.00	11.20
03/26/87	379	12.90	24.60	368.00	19.10	630.00	632.00	603.00	0.26	9.31	2.70	2545.13	19.00	10.90
04/09/87	393	12.50	25.80	371.00	16.00	627.00	637.00	575.00	0.22	8.55	2.70	2296.49	20.00	9.90
04/23/87	407	.	.	.	.	.	.	.	.	.	2.60	2373.77	20.00	8.30
05/21/87	435	11.70	22.50	298.00	14.80	462.00	546.00	503.00	14.70	8.67	2.80	2273.11	21.00	.
06/04/87	449	.	.	.	.	.	.	.	.	.	.	4492.09	21.00	6.40
06/17/87	462	.	.	.	.	.	.	.	.	.	2.60	2218.99	21.00	5.30
07/14/87	489	.	.	.	.	.	.	.	.	.	.	2465.07	21.50	3.70
08/13/87	519	.	.	.	.	.	.	.	.	.	2.20	2435.47	21.00	.
09/16/87	553	.	.	.	.	.	.	.	.	.	2.50	2489.60	21.00	2.00
10/21/87	589	.	.	.	.	.	.	.	.	.	.	.	.	1.60
12/08/87	687	.	.	.	.	.	.	.	.	.	2.20	3000.00	.	0.60
02/11/88	701	.	.	.	.	.	.	.	.	.	2.30	3355.54	21.00	0.77
02/17/88	708	.	.	.	.	.	.	.	.	.	2.30	3388.93	20.50	0.77
02/25/88	715	.	.	.	.	.	.	.	.	.	2.30	3247.30	21.00	0.97
03/03/88	722	.	.	.	.	.	.	.	.	.	2.30	3536.83	21.50	0.84
03/10/88	729	.	.	.	.	.	.	.	.	.	2.30	3680.27	21.00	1.06
03/16/88	735	.	.	.	.	.	.	.	.	.	2.10	3572.03	21.00	1.39
03/25/88	744	.	.	.	.	.	.	.	.	.	2.20	3547.55	21.50	2.75
03/31/88	750	.	.	.	.	.	.	.	.	.	2.40	3409.66	21.00	3.72
04/07/88	757	.	.	.	.	.	.	.	.	.	2.50	3312.24	20.00	5.48
04/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	5.69
04/14/88	764	.	.	.	.	.	.	.	.	.	2.60	2865.26	22.00	8.13

SITE: 9 (Pool 22)
LOCATION: Homestake Workings S 175 W 1285
PERIOD OF RECORD: 5/20/86 4/14/88
AVERAGE ZINC CONCENTRATION: 331 mg/l
NUMBER OF SAMPLES: 30

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and flow are reported as feet and cubic feet/day respectively.
Depth and volume are reportedasfeet and cubic feet respectively.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW	DEPTH	VOLUME
5/20/86	69	13.22	12.36	73.47	14.95	119.30	216.50	2.62	0.27	.	2.30	163.29	19.00	.	.	.	.
6/10/86	90	14.77	13.52	88.42	14.70	121.60	234.60	2.21	0.30	.	2.10	1744.45	20.00	.	.	.	.
6/25/86	105	13.50	12.83	86.02	14.08	115.50	220.30	2.24	0.26	.	2.00	1699.42	21.00	.	.	.	.
7/21/86	131	14.11	12.51	87.70	14.53	112.70	240.50	1.28	0.28	.	2.00	2024.52	18.50	.	.	.	.
8/21/86	162	15.63	14.20	98.00	15.87	136.40	268.70	2.02	0.33	.	.	2175.69	21.50	.	.	.	.
9/19/86	191	17.21	17.90	124.90	19.40	191.00	368.50	3.70	0.43	.	1.90	2653.02	22.00	.	.	1.10	643.00
10/11/86	213	21.78	25.65	174.10	25.70	234.40	477.10	5.02	0.53	13.85	2.00	2678.35	20.50	.	.	.	.
11/20/86	253	30.32	38.30	218.10	39.73	321.10	566.00	7.90	0.63	16.54	2.00	3019.71	18.50	.	.	.	.
12/22/86	285	44.00	58.00	286.00	66.10	375.00	674.00	9.92	0.74	18.90	1.40	3422.65	20.00	.	.	0.60	195.00
1/14/87	308	37.90	84.70	287.00	95.40	423.00	921.00	16.00	0.74	19.30	.	3766.69	15.00	.	.	.	.
1/29/87	323	91.50	115.00	1110.00	133.00	455.00	1356.00	19.30	1.12	26.50	2.20	4919.41	20.50	.	.	.	.
2/12/87	337	107.00	139.00	921.00	138.00	404.00	1340.00	408.00	1.12	27.30	2.20	4802.75	20.00	.	.	0.30	51.00
2/26/87	351	105.00	138.00	954.00	143.00	436.00	1380.00	431.00	1.07	25.20	2.10	5198.65	16.00	.	.	.	.
3/12/87	365	86.00	99.70	1130.00	109.00	479.00	1490.00	533.00	1.03	25.60	2.20	5299.59	20.00	.	.	0.25	5.00
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	0.01	2.14	1.10	643.00
3/26/87	379	23.70	32.40	362.00	39.90	636.00	959.00	620.00	1.33	17.00	2.20	3798.04	20.00	0.02	9.49	1.10	643.00
3/31/87	384	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.10	643.00
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	0.03	22.70	.	.
4/09/87	393	21.70	32.80	369.00	34.80	640.00	884.00	619.00	1.18	14.10	2.30	3643.47	20.00	0.02	9.49	1.10	643.00
4/23/87	407	21.90	29.80	271.00	31.10	429.00	710.00	414.00	0.94	13.90	2.40	3091.43	20.00	0.04	31.62	1.10	643.00
5/05/87	419	19.60	25.40	213.00	27.50	291.00	489.00	264.00	0.73	13.00	2.60	2814.32	21.00	0.03	15.34	1.10	643.00
5/21/87	435	17.70	21.20	158.00	22.50	227.00	418.00	227.00	9.28	11.30	2.50	2428.98	20.00	0.03	22.70	1.10	643.00
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	0.03	22.70	1.10	643.00
6/04/87	449	15.20	17.10	136.00	20.30	195.00	365.00	198.00	5.72	10.20	.	2381.35	21.00	0.03	22.70	1.10	643.00
6/17/87	462	17.60	19.50	154.00	21.20	214.00	407.00	219.00	5.34	11.50	2.50	2489.59	21.00	0.03	22.70	1.10	643.00
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	0.02	9.49	1.10	643.00
7/14/87	489	20.40	26.30	178.00	25.00	293.00	516.00	294.00	0.67	12.90	.	2893.77	21.50	0.02	9.49	1.10	643.00

Site 9 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW	DEPTH	VOLUME
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.10	643.00
8/13/87	519	19.50	25.00	225.00	26.20	357.00	585.00	357.00	0.85	14.00	.	3395.87	22.00	0.02	5.11	1.10	643.00
9/16/87	553	27.39	37.36	258.70	34.89	435.00	698.60	.	.	18.14	2.20	3788.50	21.00	0.00	0.00	.	.
4/14/88	764	.	.	.	.	.	.	.	.	.	2.20	8277.42	22.00	.	.	.	.

SITE: 11 (Ore Car Pool)
LOCATION: Homestake Workings S 165 W 1238
PERIOD OF RECORD: 3/12/86 4/14/88
AVERAGE ZINC CONCENTRATION: 288 mg/l
NUMBER OF SAMPLES: 27

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and volume are reported as feet and cubic feet, respectively.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	VOLUME	STAGE
3/12/86	1	18.30	28.54	246.20	37.58	362.70	606.30	12.25	1.05	.	2.30	2547.70	15.00	.	.
5/20/86	69	15.37	17.85	116.80	22.02	127.30	246.60	7.57	0.43	.	2.30	1700.51	19.00	.	.
6/10/86	90	14.39	14.24	92.83	16.84	114.30	226.00	4.05	0.30	.	2.10	1799.65	20.00	.	.
7/21/86	131	14.00	11.61	80.30	12.70	113.00	225.50	1.36	0.26	.	2.00	1952.77	18.00	.	.
8/21/86	162	13.67	12.51	95.70	13.97	156.10	271.30	2.30	0.35	.	.	2056.62	21.00	.	.
9/19/86	191	14.91	14.97	118.60	15.85	221.70	383.70	2.87	0.45	.	2.10	2489.59	21.00	185.00	0.60
10/11/86	213	20.30	22.70	165.00	21.00	300.00	489.00	2.84	0.63	13.03	2.10	2077.09	20.50	.	.
11/20/86	253	21.49	27.14	212.50	27.26	411.00	584.20	6.69	0.73	15.17	1.90	2104.13	18.50	.	.
12/22/86	285	24.10	32.40	291.00	37.80	412.00	689.00	8.84	0.94	18.40	1.70	3400.57	20.00	.	.
1/14/87	308	31.20	40.70	286.00	52.40	336.00	671.00	16.50	0.93	20.50	.	3327.86	15.00	.	.
1/29/87	323	36.90	45.20	423.00	60.00	238.00	753.00	14.50	0.78	20.00	2.30	3422.65	20.00	99.00	.
2/12/87	337	.	.	.	.	.	.	.	.	.	.	.	.	0.00	.
3/12/87	365	.	.	.	.	.	.	.	.	.	.	.	.	29.00	.
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	78.00	0.42
3/26/87	379	30.00	50.20	1040.00	53.30	2840.00	2860.00	2780.00	4.82	28.90	2.00	8611.83	20.00	.	.
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	185.00	0.60
4/09/87	393	33.10	61.10	775.00	63.70	1390.00	1700.00	1330.00	3.41	26.50	2.30	5189.18	20.00	204.00	0.62
4/23/87	407	29.30	53.50	453.00	65.40	440.00	855.00	417.00	1.70	21.70	2.40	3279.61	20.50	204.00	0.62
5/05/87	419	26.50	47.50	359.00	58.10	344.00	658.00	350.00	1.39	19.00	2.70	3060.97	20.50	204.00	0.61
5/21/87	435	21.20	31.50	241.00	39.30	243.00	509.00	245.00	15.00	14.80	2.50	2716.90	21.00	204.00	0.62
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	.	0.62
6/04/87	449	16.50	21.80	175.00	27.40	211.00	423.00	213.00	8.84	12.40	.	2435.47	21.00	204.00	0.62
6/17/87	462	18.60	23.90	191.00	27.40	223.00	442.00	235.00	5.92	13.30	2.50	2597.84	21.00	204.00	0.62
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.	0.62
7/14/87	489	17.50	22.70	174.00	22.50	319.00	529.00	334.00	0.69	12.30	.	2814.32	21.00	204.00	0.62
8/13/87	519	17.30	21.60	221.00	21.70	401.00	589.00	419.00	0.82	12.70	.	3215.30	21.50	.	0.65
9/16/87	553	20.90	27.15	249.60	25.50	546.50	767.90	.	.	14.56	2.20	3680.30	21.00	.	0.62

SITE: 12 (Flume 4)
LOCATION: Homestake Workings S 222 W 1150
PERIOD OF RECORD: 7/21/86 4/14/88
AVERAGE ZINC CONCENTRATION: 303 mg/l
NUMBER OF SAMPLES: 21

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	FLOW
7/21/86	131	12.22	10.57	89.60	10.91	159.50	256.20	0.83	0.31	.	2.10	2044.66	18.00	.
8/21/86	162	12.99	11.19	110.10	11.97	269.00	367.90	2.21	0.42	.	.	2273.11	21.00	.
9/19/86	191	14.32	13.63	113.80	13.77	371.00	441.10	1.94	0.48	.	2.00	2900.92	21.00	22.70
10/11/86	213	17.31	19.63	216.60	18.22	473.50	611.40	1.58	0.93	21.60	2.00	3233.69	19.50	0.48
11/20/86	253	19.23	25.05	525.70	24.61	962.60	1137.00	6.40	1.92	15.90	2.00	5118.16	18.50	.
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	9.49
3/26/87	379	16.80	23.60	270.00	28.90	456.00	634.00	432.00	1.18	13.90	2.20	3355.96	19.00	100.76
4/09/87	393	17.50	25.30	168.00	28.40	320.00	481.00	327.00	0.71	10.90	2.40	2649.79	20.00	100.76
4/23/87	407	17.20	24.40	188.00	26.70	329.00	510.00	304.00	0.75	11.90	2.40	2627.71	20.00	140.35
5/05/87	419	19.20	29.90	251.00	34.00	311.00	540.00	300.00	0.89	11.00	2.70	2706.08	21.00	68.08
5/21/87	435	18.60	27.20	277.00	29.80	307.00	532.00	309.00	13.40	11.80	2.40	2649.79	20.00	68.08
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	68.08
6/04/87	449	16.70	21.40	232.00	25.80	309.00	535.00	310.00	8.62	10.50	.	2814.32	21.00	68.08
6/17/87	462	16.80	21.60	277.00	23.70	386.00	601.00	383.00	7.51	11.70	2.50	3030.81	21.00	22.70
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.
6/25/87	469	.	.	.	.	.	.	.	.	.	.	.	.	54.28
7/14/87	489	16.50	21.50	223.00	20.80	456.00	627.00	443.00	0.91	11.10	.	3355.54	21.00	42.14
7/19/87	494	.	.	.	.	.	.	.	.	.	.	.	.	22.70
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	.
8/13/87	519	16.60	20.30	384.00	21.60	749.00	951.00	805.00	1.76	13.40	.	4654.46	21.00	15.34
9/16/87	553	20.05	25.65	547.10	26.04	1204.00	1369.00	.	.	14.90	2.10	5412.16	21.00	22.70
10/20/87	588	.	.	.	.	.	.	.	.	.	.	.	.	.
10/21/87	589	22.33	33.78	849.10	34.90	1776.00	1703.00	.	.	7.46	1.90	5412.16	21.00	5.11

SITE: 13 (1B Blue Pool)
LOCATION: Homestake Workings S 237 W 1124
PERIOD OF RECORD: 3/12/86 4/14/88
AVERAGE ZINC CONCENTRATION: 38 mg/l
NUMBER OF SAMPLES: 35

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported in micromhos/cm.
Metal concentrations reported in mg/liter.
'.' indicates missing data.
Stage and volume are reported in feet and cubic feet respectively.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	VOLUME
3/12/86	1	11.94	10.91	36.62	15.70	29.04	86.02	0.37	0.17	.	2.80	585.12	15.00	.	.
5/20/86	69	10.55	7.14	15.84	8.02	23.83	60.95	0.92	0.06	.	2.70	563.08	19.00	.	.
6/10/86	90	11.18	6.65	20.88	8.01	29.84	71.90	1.13	0.08	.	2.30	666.85	20.50	.	.
6/25/86	105	11.34	6.15	12.36	7.87	16.85	55.14	0.72	0.04	.	2.40	495.51	19.00	.	.
7/21/86	131	12.01	6.89	17.30	7.38	22.80	65.60	.	0.05	.	2.40	636.93	18.50	.	.
8/21/86	162	12.07	7.32	19.50	8.80	29.48	71.70	.	0.06	.	.	638.63	21.00	.	.
9/19/86	191	12.62	7.71	20.20	8.84	28.01	75.10	.	0.06	.	2.10	649.46	21.00	.	.
10/11/86	213	14.70	13.70	34.30	12.70	66.60	117.00	0.20	0.11	6.51	2.10	796.16	18.50	.	1208.00
11/20/86	253	13.56	11.30	45.67	11.42	49.45	108.70	0.64	0.19	6.23	2.00	913.89	17.00	.	.
12/22/86	285	14.00	11.50	37.40	12.70	44.10	103.00	0.44	0.19	5.14	2.00	686.96	19.00	1.12	374.00
1/14/87	308	14.70	13.30	36.20	14.40	31.50	97.80	0.47	0.17	5.40	.	889.87	15.00	1.02	301.00
1/29/87	323	15.40	14.50	50.50	14.90	40.80	122.00	40.40	0.24	7.39	2.90	900.93	19.00	0.84	184.00
2/12/87	337	15.40	14.50	50.50	14.90	40.80	122.00	40.40	0.24	7.39	2.80	900.93	19.00	0.79	163.00
2/26/87	351	14.80	16.30	33.50	15.80	39.00	97.70	38.90	0.14	7.53	2.70	896.32	16.00	0.66	108.00
3/12/87	365	20.60	22.90	142.00	26.10	97.50	223.00	85.00	0.67	9.66	2.80	1238.78	19.00	1.18	434.00
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	2.08	1731.00
3/26/87	379	13.20	13.20	61.10	16.50	44.30	111.00	43.40	0.20	8.36	2.90	827.05	18.00	2.20	1941.00
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	2.28	2164.00
4/09/87	393	13.60	13.80	40.20	14.80	37.00	99.10	37.40	0.13	6.91	2.90	698.22	19.00	1.82	1263.00
4/23/87	407	12.00	10.30	30.40	11.70	31.50	82.40	31.60	0.14	7.17	2.90	669.04	19.50	2.07	1627.00
5/05/87	419	12.20	9.91	60.60	11.80	29.90	87.70	30.00	0.08	6.73	3.00	662.45	20.00	2.00	1258.00
5/21/87	435	12.60	9.50	26.50	10.10	34.00	86.60	34.40	0.01	6.90	2.90	649.46	21.00	2.00	1258.00
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	1.80	1208.00
6/04/87	449	11.10	8.50	24.10	9.52	28.00	78.60	28.90	0.04	6.13	.	562.86	21.00	1.84	1257.00
6/17/87	462	13.30	9.88	24.60	10.50	30.30	84.00	30.60	0.94	6.43	2.80	595.34	21.00	1.74	1105.00
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	1.69	.
6/26/87	470	.	.	.	.	.	.	.	.	.	.	.	.	1.84	1257.00

Site 13 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	VOLUME
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	1.57	845.00
7/23/87	498	14.00	12.20	33.50	12.40	53.70	105.00	52.40	0.13	6.18	.	660.28	21.00	1.57	845.00
8/13/87	519	13.90	11.30	36.00	11.90	44.80	101.00	44.40	0.14	6.20	.	703.58	21.00	1.50	760.00
9/16/87	553	15.16	13.39	37.67	12.51	34.58	134.80	.	.	6.19	2.90	655.90	20.50	1.32	568.00
10/21/87	589	15.80	14.16	43.99	13.24	32.48	122.80	.	.	7.11	2.80	819.90	20.50	0.99	278.00
11/26/87	625	.	.	.	.	.	.	.	.	.	.	0.00	.	0.00	0.00
3/31/88	750	.	.	.	.	.	.	.	.	.	.	0.00	.	0.00	.
4/07/88	757	.	.	.	.	.	.	.	.	.	2.70	2318.57	20.00	0.30	.
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	0.35	.
4/14/88	764	.	.	.	.	.	.	.	.	.	2.80	1963.23	22.00	0.86	.

SITE: 14 (2B Blue Pool)
LOCATION: Homestake Workings S 270 W 1103
PERIOD OF RECORD: 10/11/86 4/14/88
AVERAGE ZINC CONCENTRATION: 25 mg/l
NUMBER OF SAMPLES: 28

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported in micromhos/cm.
Metal concentrations are reported in mg/liter.
Stage and volume are reported in feet and cubic feet respectively.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	VOLUME	STAGE
10/11/86	213	.	.	.	.	.	.	.	.	.	.	.	.	405.00	1.60
12/22/86	285	11.90	5.45	5.96	5.74	18.50	43.70	0.20	0.04	4.33	2.30	409.45	18.50	239.00	1.20
1/14/87	308	.	.	.	.	.	.	.	.	.	.	.	.	106.00	0.82
1/29/87	323	12.20	6.62	7.31	7.14	15.60	45.70	0.20	0.01	5.13	3.10	437.89	18.50	80.00	0.75
2/12/87	337	14.50	10.80	15.40	10.10	19.40	65.00	23.20	0.02	6.84	3.00	563.08	19.00	98.00	0.79
2/26/87	351	16.30	15.20	17.30	14.40	35.00	81.80	39.20	0.05	6.77	2.90	621.69	15.00	63.00	0.64
3/12/87	365	19.70	18.20	29.80	21.70	27.20	106.00	25.90	0.10	7.92	3.10	675.70	19.00	120.00	0.89
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	546.00	2.06
3/26/87	379	17.20	22.90	79.30	28.60	27.00	123.00	27.00	0.27	9.59	3.20	792.59	18.00	761.00	2.22
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	819.00	2.28
4/09/87	393	.	.	.	.	.	.	.	.	.	.	.	.	.	1.76
4/10/87	394	.	.	.	.	.	.	.	.	.	.	.	.	513.00	1.93
4/23/87	407	.	.	.	.	.	.	.	.	.	.	.	.	594.00	1.93
5/05/87	419	.	.	.	.	.	.	.	.	.	.	.	.	632.00	2.00
5/21/87	435	20.20	26.20	55.30	25.00	136.00	181.00	135.00	2.83	8.65	3.20	883.26	20.00	618.00	1.96
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	590.00	1.90
6/04/87	449	.	.	.	.	.	.	.	.	.	.	.	.	562.00	1.86
6/17/87	462	.	.	.	.	.	.	.	.	.	.	.	.	487.00	1.74
6/25/87	469	.	.	.	.	.	.	.	.	.	.	.	.	487.00	1.74
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	437.00	1.70
8/13/87	519	11.60	4.83	21.60	5.42	21.10	41.30	21.60	0.02	5.00	3.00	349.11	19.00	410.00	1.65
9/16/87	553	19.48	5.79	6.19	6.37	17.90	52.90	.	.	5.51	3.10	386.40	20.00	379.00	1.49
10/21/87	589	25.00	7.02	8.44	6.80	20.60	59.60	.	.	6.61	3.20	408.50	20.00	247.00	1.18
12/08/87	687	.	.	.	.	.	.	.	.	.	3.10	496.80	20.00	.	.
3/31/88	750	.	.	.	.	.	.	.	.	.	3.30	1298.90	21.00	.	0.14
4/07/88	757	.	.	.	.	.	.	.	.	.	2.90	1821.70	20.00	.	0.40
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	.	0.48
4/14/88	764	.	.	.	.	.	.	.	.	.	2.90	1178.90	21.50	.	0.96

SITE: 15 (Blue Pool Fracture Discharge)
LOCATION: Homestake Workings S 294 W 1105
PERIOD OF RECORD: 2/12/87 4/14/88
AVERAGE ZINC CONCENTRATION: 18 mg/l
NUMBER OF SAMPLES: 26

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow is reported as cubic feet/day.
'.' indicated missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	FLOW
2/12/87	337	14.5	22.1	23.4	28.1	21.3	72.4	21.3	0.0	4.0	.	.	.	.
2/26/87	351	.	.	.	.	.	.	.	.	.	.	.	.	.
3/12/87	365	13.5	14.9	18.5	20.7	54.7	83.2	58.8	0.1	7.4	5.7	441.6	20.0	17.4
3/14/87	367	.	.	.	.	.	.	.	.	.	.	.	.	21.0
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	16.1
3/26/87	379	12.7	13.8	15.7	20.1	53.1	74.6	50.4	0.0	7.1	5.3	394.2	19.0	5.4
4/02/87	386	.	.	.	.	.	.	.	.	.	5.1	397.5	20.0	3.3
4/09/87	393	12.3	14.7	15.1	17.8	58.5	77.8	60.0	0.1	7.1	5.3	390.3	19.5	2.2
4/23/87	407	12.9	17.3	17.0	20.6	58.7	88.6	58.9	0.1	7.5	5.1	408.5	20.0	2.7
5/05/87	419	13.1	16.7	17.7	22.4	42.8	78.7	41.0	0.1	5.9	4.5	411.3	21.0	1.2
5/21/87	435	16.1	24.1	20.0	27.5	27.8	85.2	27.7	2.5	5.6	4.8	400.5	21.0	1.5
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	1.0
6/04/87	449	.	.	.	.	.	.	.	.	.	4.4	428.7	21.5	1.1
6/17/87	462	.	.	.	.	.	.	.	.	.	.	.	.	0.7
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	0.6
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	.
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	.
8/13/87	519	.	.	.	.	.	.	.	.	.	.	.	.	0.8
9/16/87	553	.	.	.	.	.	.	.	.	.	.	.	.	.
10/21/87	589	.	.	.	.	.	.	.	.	.	.	.	.	.
12/08/88	687	.	.	.	.	.	.	.	.	.	.	.	.	.
2/11/88	701	.	.	.	.	.	.	.	.	.	.	.	.	.
2/17/88	708	.	.	.	.	.	.	.	.	.	3.5	662.5	20.0	0.4
2/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.
2/25/88	715	.	.	.	.	.	.	.	.	.	3.6	1082.4	21.0	0.3
3/03/88	722	.	.	.	.	.	.	.	.	.	3.5	649.5	21.0	0.4
3/10/88	729	.	.	.	.	.	.	.	.	.	3.4	638.6	21.0	0.4
3/16/88	735	.	.	.	.	.	.	.	.	.	3.3	649.5	21.0	0.4

SITE: 16 (Cherry 4 Flume)
LOCATION: 4 level, S 120 W 1370
PERIOD OF RECORD: 4/10/87 10/21/87
AVERAGE ZINC CONCENTRATION: 473 mg/l
NUMBER OF SAMPLES: 12

Reported EC measurements are compensated to 25 degrees.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow and stage measurements are reported as feet and cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
04/10/87	394	.	.	.	.	.	.	.	.	.	.	.	.	0.08	187.02
04/23/87	407	29.50	51.50	527.00	53.70	373.00	880.00	358.00	1.36	33.70	2.40	3279.61	20.50	0.08	187.02
05/05/87	419	27.30	44.60	397.00	47.60	265.00	651.00	240.00	1.01	28.00	2.70	2981.02	20.00	0.07	140.35
05/21/87	435	27.40	43.40	345.00	42.50	232.00	601.00	237.00	18.80	28.90	2.60	2760.20	20.00	0.07	119.68
05/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	0.07	119.68
06/04/87	449	28.40	42.30	393.00	45.90	236.00	635.00	241.00	11.00	31.50	.	2922.57	21.00	0.07	119.68
06/17/87	462	30.00	48.90	454.00	49.00	251.00	661.00	255.00	11.30	35.80	2.70	2706.08	21.00	0.05	68.08
06/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	0.05	68.08
07/14/87	489	32.30	59.50	502.00	57.00	293.00	825.00	308.00	1.03	43.90	.	3139.05	21.00	0.05	68.08
08/13/87	519	.	.	.	.	.	.	.	.	.	.	.	.	0.05	54.28
09/16/87	553	40.20	82.90	612.00	79.40	366.00	1016.00	.	.	60.80	2.40	3463.80	21.00	0.00	.
10/21/87	589	32.00	68.90	557.00	67.10	301.00	774.00	.	.	61.00	2.40	3355.50	21.00	.	.

SITE: 18 (Cherry Four Tarp)
LOCATION: 4 Level, Cherry Workings S 225 W 1260
PERIOD OF RECORD: 3/20/87 10/21/87
AVERAGE ZINC CONCENTRATION: 289 mg/l
NUMBER OF SAMPLES: 13

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measuremnts are reported as cubic feet/day.
'.' indicates missing data.

REMARKS: Tarp measures flow down a manway from the Homestake Workings.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	FLOW
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	140.00
3/26/87	379	.	.	.	.	.	.	.	.	.	.	.	.	193.00
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	.
4/09/87	393	.	.	.	.	.	.	.	.	.	2.30	2925.81	20.00	178.00
4/23/87	407	24.50	35.60	255.00	35.30	218.00	589.00	237.00	0.83	21.00	2.40	2733.01	20.50	192.00
5/05/87	419	23.40	33.20	236.00	33.40	216.00	478.00	207.00	0.71	20.00	2.70	2597.84	21.00	131.00
5/21/87	435	24.40	34.60	300.00	34.20	222.00	495.00	223.00	11.60	22.50	2.40	2428.98	20.00	133.00
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	110.00
6/04/87	449	22.30	30.20	238.00	32.10	198.00	439.00	199.00	6.13	21.10	.	2489.59	21.00	85.00
6/17/87	462	25.30	35.70	247.00	36.00	214.00	503.00	221.00	7.38	25.10	2.60	2597.84	21.00	61.00
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	52.00
7/14/87	489	31.90	47.60	310.00	44.00	282.00	619.00	286.00	0.94	34.10	.	2706.08	21.00	31.00
8/13/87	519	35.90	61.60	441.00	56.30	297.00	733.00	310.00	1.19	47.60	.	3000.95	21.50	13.00
9/16/87	553	.	.	.	.	.	.	.	.	.	2.50	3215.30	21.50	3.00

SITE: 20 (Reed Tunnel Flume)
LOCATION: 5 Level N 725 W 725
PERIOD OF RECORD: 3/13/86 4/14/88
AVERAGE ZINC CONCENTRATION: 2.1 mg/l
NUMBER OF SAMPLES: 21

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicate missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
3/11/86	1	7.52	7.53	4.07	0.91	1.19	23.73	0.20	0.01	.	4.80	161.99	9.00	0.28	11052.76
5/20/86	69	8.02	5.97	0.94	0.24	0.11	14.77	0.83	0.03	.	5.60	78.55	7.00	0.20	5361.61
6/10/86	90	.	.	.	.	.	.	.	.	.	.	.	.	0.15	2888.53
6/25/86	105	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/21/86	131	10.57	6.49	1.60	0.48	0.10	17.50	0.20	0.01	.	5.70	97.64	11.00	.	.
8/21/86	162	10.52	6.14	2.20	0.63	0.80	18.50	0.20	0.01	.	.	.	.	.	.
9/19/86	191	10.95	6.14	2.20	0.61	0.10	20.00	0.20	0.02	.	6.60	63.01	8.00	0.14	2490.33
10/11/86	213	13.10	5.79	1.62	0.55	0.11	16.50	0.20	0.01	3.38	6.60	77.01	8.00	0.08	747.69
11/20/86	253	9.98	5.09	2.54	0.55	0.22	16.73	0.20	0.02	3.39	6.60	63.64	7.50	0.21	5954.60
12/22/86	285	10.80	6.15	1.79	0.67	0.18	20.20	0.20	0.01	2.48	4.40	75.78	4.00	0.14	2490.33
1/14/87	308	10.40	6.00	2.54	0.86	0.53	19.50	0.20	0.04	2.61	4.70	92.76	3.00	0.17	3780.47
1/29/87	323	9.68	5.91	2.03	0.71	0.19	15.20	0.20	0.01	3.09	6.30	106.10	4.00	0.15	2888.53
2/12/87	337	10.50	6.48	2.22	0.71	0.30	16.00	0.47	0.01	4.49	6.10	113.68	4.00	0.14	2490.33
2/26/87	351	10.60	6.45	2.04	0.69	0.56	18.20	0.52	0.01	3.91	5.50	112.86	3.00	0.16	3318.48
3/12/87	365	10.10	6.76	1.52	0.43	0.13	18.30	0.20	0.01	4.26	5.90	116.55	6.00	0.24	7934.78
3/20/87	373	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/26/87	379	9.85	6.40	1.60	0.45	0.11	16.80	0.20	0.01	4.50	5.40	116.84	6.50	0.20	5361.61
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/09/87	393	.	.	.	.	.	.	.	.	.	.	.	.	0.21	5954.60
4/23/87	407	.	.	.	.	.	.	.	.	.	.	.	.	0.22	6580.97
5/05/87	419	.	.	.	.	.	.	.	.	.	.	.	.	0.22	6580.97
5/21/87	435	.	.	.	.	.	.	.	.	.	.	.	.	0.22	6580.97
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/04/87	449	.	.	.	.	.	.	.	.	.	.	.	.	0.22	6580.97
6/17/87	462	.	.	.	.	.	.	.	.	.	.	.	.	0.19	4801.77
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Site 20 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	0.19	4801.77
8/13/87	519	.	.	.	.	.	.	.	.	.	.	.	.	0.17	3780.47
9/16/87	553	.	.	.	.	.	.	.	.	.	.	.	.	0.17	3545.45
10/21/87	589	15.54	6.10	3.22	1.06	0.23	38.36	.	.	3.44	5.00	101.40	7.00	0.16	3318.48
12/08/88	687	.	.	.	.	.	.	.	.	.	3.10	571.30	7.00	0.17	3780.47
2/11/88	701	.	.	.	.	.	.	.	.	.	5.30	110.30	5.50	0.18	4274.81
2/17/88	708	.	.	.	.	.	.	.	.	.	5.30	116.50	6.00	0.18	4274.81
2/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2/25/88	715	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/03/88	722	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/10/88	729	.	.	.	.	.	.	.	.	.	5.00	115.40	6.50	0.19	4801.77
3/16/88	735	.	.	.	.	.	.	.	.	.	4.50	108.10	6.50	0.19	4801.77
3/25/88	744	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/31/88	750	.	.	.	.	.	.	.	.	.	4.70	104.90	6.00	0.20	5361.61
4/07/88	757	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	0.24	7934.78
4/14/88	764	.	.	.	.	.	.	.	.	.	2.90	314.20	7.00	0.22	6580.97

SITE: 21 (West Reed Flume)
LOCATION: 5 Level S 35 W 1070
PERIOD OF RECORD: 3/13/86 4/14/88
AVERAGE ZINC CONCENTRATION: 809 mg/l
NUMBER OF SAMPLES: 33

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
3/12/86	1	71.89	148.20	1565.00	239.10	2241.00	2792.00	40.14	3.61	.	2.40	4126.61	12.00	.	.
5/20/86	69	57.78	126.40	1086.00	168.40	1379.00	1956.00	13.56	2.03	.	2.60	3194.26	9.50	3.30	3110.4
6/10/86	90	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/25/86	105	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/21/86	131	48.26	99.47	687.40	146.10	1037.00	1314.00	2.73	1.00	.	2.50	2760.29	14.00	.	.
8/21/86	162	42.23	81.87	607.90	128.70	929.70	1232.00	2.36	0.77	.	.	3506.32	14.00	2.60	1641.8
9/19/86	191	35.17	67.53	499.20	108.00	714.70	1011.00	1.77	0.62	.	2.60	1966.28	12.00	.	.
10/11/86	213	29.10	59.10	363.00	89.50	505.00	720.00	0.63	0.50	7.41	2.40	1480.46	10.00	.	.
11/20/86	253	25.65	53.43	297.00	77.00	425.20	643.00	1.65	0.41	7.04	2.30	1913.24	11.00	.	.
12/22/86	285	47.00	103.00	803.00	141.00	1430.00	1700.00	7.15	1.43	11.30	2.30	3360.58	8.00	.	.
1/14/87	308	44.50	92.40	821.00	136.00	1390.00	1640.00	4.89	1.31	9.86	2.20	3080.53	8.00	2.05	864.0
1/29/87	323	42.10	90.20	830.00	136.00	1430.00	1660.00	3.25	1.03	9.83	2.70	3674.08	8.50	2.08	915.8
2/12/87	337	44.10	97.30	621.00	130.00	1020.00	1380.00	992.00	0.87	10.70	2.50	3500.60	8.00	2.25	1080.0
2/26/87	351	48.70	134.00	551.00	199.00	1270.00	1530.00	1130.00	0.96	10.50	2.60	3894.64	6.50	2.10	950.4
3/12/87	365	60.30	159.00	907.00	262.00	1870.00	2570.00	2080.00	2.16	17.70	2.40	5541.81	11.00	3.20	2764.8
3/20/87	373	.	.	.	.	.	.	.	.	.	2.40	6069.60	11.00	3.20	2764.8
3/26/87	379	80.40	160.00	1290.00	253.00	2340.00	2790.00	2190.00	3.00	20.00	2.20	6135.58	11.00	2.20	1036.8
4/02/87	386	.	.	.	.	.	.	.	.	.	2.40	5937.65	11.00	2.90	2160.0
4/09/87	393	65.80	139.00	1150.00	205.00	2210.00	2600.00	2126.00	2.24	16.70	2.60	5208.51	10.00	2.90	2160.0
4/23/87	407	66.40	147.00	1160.00	198.00	1870.00	2450.00	1840.00	2.44	17.80	2.50	5343.89	11.00	2.85	2073.6
5/05/87	419	63.00	142.00	1200.00	192.00	1660.00	2100.00	1690.00	2.32	16.00	2.60	4703.32	11.50	2.80	1987.2
5/21/87	435	54.90	118.00	946.00	175.00	1480.00	1950.00	1500.00	56.90	14.50	2.50	4882.07	11.00	2.70	1900.8
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/04/87	449	58.10	118.00	808.00	167.00	1190.00	1820.00	1410.00	24.80	14.80	2.50	4290.89	12.50	2.45	1382.4
6/17/87	462	53.70	109.00	840.00	186.00	1350.00	1590.00	1290.00	21.50	13.30	2.50	4103.14	14.00	2.50	1468.8
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Site 21 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
7/23/87	498	48.30	103.00	687.00	160.00	1120.00	1360.00	1090.00	1.57	11.10	.	3751.46	12.00	2.30	1123.2
8/13/87	519	45.70	91.60	579.00	147.00	937.00	1320.00	1000.00	1.19	10.40	2.90	3656.98	15.00	2.10	950.4
9/16/87	553	52.70	110.00	665.40	171.20	1037.00	1445.00	.	.	10.97	2.60	3797.93	10.50	2.00	777.6
10/21/87	589	39.43	75.15	440.30	110.60	630.40	827.00	.	.	8.39	2.60	2608.30	9.00	1.95	734.0
12/08/88	687	.	.	.	.	.	.	.	.	.	2.50	3430.64	11.00	1.65	475.0
2/11/88	701	.	.	.	.	.	.	.	.	.	2.60	3157.41	9.00	1.75	562.0
2/17/88	708	.	.	.	.	.	.	.	.	.	2.60	3162.79	10.00	1.80	605.0
2/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2/25/88	715	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/03/88	722	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/10/88	729	.	.	.	.	.	.	.	.	.	2.70	2718.52	9.50	2.40	1296.0
3/16/88	735	.	.	.	.	.	.	.	.	.	2.50	3970.31	10.00	2.25	1080.0
3/25/88	744	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/31/88	750	.	.	.	.	.	.	.	.	.	2.40	6056.41	10.00	2.65	1771.0
4/07/88	757	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	3.20	2765.0
4/14/88	764	.	.	.	.	.	.	.	.	.	2.40	7402.28	10.00	3.00	2333.0

SITE: 22 (Becker Weir)
LOCATION: 5 Level S 120 W 975
PERIOD OF RECORD: 3/13/86 4/14/88
AVERAGE ZINC CONCENTRATION: 253 mg/l
NUMBER OF SAMPLES: 31

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
3/12/86	1	37.28	86.22	682.90	96.53	932.40	1182.00	17.34	1.62	.	2.60	2261.06	10.00	.	.
5/20/86	69	24.95	58.51	362.70	57.85	468.00	631.70	5.57	0.70	.	2.80	1484.88	7.50	0.21	7135.96
6/10/86	90	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/25/86	105	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/21/86	131	27.35	58.20	281.70	60.91	370.10	555.70	3.07	0.43	.	2.70	1187.53	11.00	0.16	4326.63
8/21/86	162	21.46	47.36	194.70	51.17	336.90	517.30	0.51	0.29	.	.	1715.32	11.00	0.15	3842.17
9/19/86	191	17.48	40.60	151.90	40.01	199.70	340.90	1.99	0.25	.	2.60	417.22	10.00	0.13	2952.74
10/11/86	213	15.30	36.80	119.00	33.10	159.00	280.00	0.20	0.19	4.89	2.40	659.24	9.50	0.14	3384.11
11/20/86	253	12.17	27.42	84.85	21.96	99.13	184.40	0.53	0.10	4.46	2.30	625.26	9.50	0.15	3842.17
12/22/86	285	21.60	53.00	322.00	52.70	536.00	691.00	2.87	0.54	5.28	2.30	1571.07	7.00	0.14	3384.11
1/14/87	308	19.60	45.20	212.00	42.50	390.00	515.00	1.16	0.45	4.38	2.30	1428.25	7.00	0.13	2952.74
1/29/87	323	19.70	42.50	201.00	45.50	370.00	509.00	1.40	0.35	4.99	2.90	1713.90	7.00	.	.
2/12/87	337	19.30	42.10	163.00	40.30	277.00	388.00	257.00	0.28	5.31	2.80	1571.07	7.00	0.14	3384.11
2/26/87	351	44.40	120.00	440.00	145.00	892.00	1090.00	809.00	0.63	8.98	2.70	2999.32	7.00	0.13	2952.74
3/12/87	365	34.90	87.20	337.00	84.70	571.00	862.00	677.00	0.76	7.70	2.70	2772.89	8.50	0.23	8436.23
3/20/87	373	.	.	.	.	.	.	.	.	.	2.60	3050.18	8.50	0.22	7773.68
3/26/87	379	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/09/87	393	31.10	70.70	424.00	75.70	699.00	933.00	712.00	0.80	7.98	2.80	2618.45	8.00	0.22	7773.68
4/23/87	407	24.00	55.90	286.00	55.80	485.00	691.00	481.00	0.69	7.93	2.80	2170.37	8.00	0.22	7773.68
5/05/87	419	22.60	52.70	264.00	49.40	349.00	554.00	350.00	0.56	7.00	2.90	1941.02	8.50	0.22	7773.68
5/21/87	435	25.30	60.00	300.00	62.50	481.00	654.00	488.00	17.10	7.14	2.70	2196.46	9.00	0.20	6523.25
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/04/87	449	17.40	41.40	204.00	47.00	275.00	457.00	293.00	8.00	5.87	2.70	1784.62	9.00	0.20	6523.25
6/17/87	462	21.00	46.90	222.00	50.60	317.00	481.00	327.00	6.69	6.25	2.70	1682.34	10.00	0.19	5935.75
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Site 22 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
7/23/87	498	20.10	46.10	193.00	47.20	272.00	433.00	271.00	0.39	5.59	.	1625.78	10.50	0.15	3842.17
8/13/87	519	17.20	40.20	166.00	41.10	239.00	353.00	237.00	0.33	4.68	3.40	1319.48	11.00	0.12	2548.37
9/16/87	553	15.16	33.82	112.70	31.01	160.10	268.20	.	.	4.01	3.00	1009.40	10.00	0.13	2952.74
10/21/87	589	13.62	31.80	96.87	27.32	135.90	216.70	.	.	4.86	2.80	901.20	8.50	0.15	3842.17
12/08/87	687	.	.	.	.	.	.	.	.	.	2.90	701.52	8.00	0.13	2747.16
2/11/88	701	.	.	.	.	.	.	.	.	.	2.80	713.85	9.00	0.13	2952.74
2/17/88	708	.	.	.	.	.	.	.	.	.	2.90	980.17	8.00	0.14	3384.11
2/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2/25/88	715	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/03/88	722	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/10/88	729	.	.	.	.	.	.	.	.	.	2.90	910.16	8.00	0.16	4326.63
3/16/88	735	.	.	.	.	.	.	.	.	.	2.60	1386.40	8.50	0.14	3384.11
3/25/88	744	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/31/88	750	.	.	.	.	.	.	.	.	.	2.50	2800.50	8.00	0.17	4837.21
4/07/88	757	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	0.23	8436.23
4/14/88	764	.	.	.	.	.	.	.	.	.	2.50	3022.40	8.50	0.22	7773.68

SITE: 23 (West Motor Flume)
LOCATION: 5 Level S 110 W 970
PERIOD OF RECORD: 3/13/86 4/14/88
AVERAGE ZINC CONCENTRATION: 5.2 mg/l
NUMBER OF SAMPLES: 22

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Flow measurements are reported as cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
3/12/86	1	.	.	.	.	.	.	.	.	.	.	.	.	0.36	4745.60
5/20/86	69	5.86	11.22	4.96	2.27	0.06	22.49	1.01	0.03	.	5.40	104.26	7.00	0.30	3206.65
6/10/86	90	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/25/86	105	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/21/86	131	5.29	10.50	3.10	1.49	0.90	21.00	.	0.01	.	5.80	93.35	9.00	0.22	1646.07
8/21/86	162	5.16	11.17	2.60	1.38	0.70	21.70	.	0.02	.	.	145.14	11.00	.	.
9/19/86	191	4.95	10.32	2.00	1.17	.	19.30	.	0.02	.	7.10	53.01	9.50	0.20	1341.08
10/11/86	213	.	.	.	.	.	.	.	.	.	6.50	83.19	8.50	0.19	1201.05
11/20/86	253	5.30	10.01	4.29	1.34	0.04	18.20	0.20	0.02	3.35	6.40	89.23	9.00	0.21	1489.40
12/22/86	285	5.49	11.60	5.16	1.68	0.03	22.80	0.20	0.03	2.22	4.80	128.54	7.00	0.19	1201.05
1/14/87	308	.	.	.	.	.	.	.	.	.	5.00	121.40	7.00	0.17	945.60
1/29/87	323	4.78	9.86	2.95	1.26	0.03	17.50	0.20	0.01	2.76	6.20	129.97	7.00	0.16	830.04
2/12/87	337	5.21	11.40	4.04	1.27	0.04	20.90	0.25	0.01	4.20	5.90	123.22	8.00	0.17	945.60
2/26/87	351	6.79	14.20	4.12	1.58	0.10	22.80	0.20	0.03	3.71	6.00	144.25	6.50	0.19	1201.05
3/12/87	365	10.40	19.00	13.20	3.24	0.03	45.90	0.20	0.07	5.29	5.40	226.27	7.50	0.26	2357.40
3/20/87	373	.	.	.	.	.	.	.	.	.	5.30	228.52	7.00	0.26	2357.40
3/26/87	379	8.55	16.70	13.80	10.26	0.17	36.70	0.20	0.02	4.61	5.00	213.54	7.50	0.22	1646.07
4/02/87	386	.	.	.	.	.	.	.	.	.	.	.	.	0.21	1489.40
4/09/87	393	.	.	.	.	.	.	.	.	.	.	.	.	0.28	2764.59
4/23/87	407	.	.	.	.	.	.	.	.	.	.	.	.	0.29	2981.24
5/05/87	419	.	.	.	.	.	.	.	.	.	.	.	.	0.29	2871.82
5/21/87	435	.	.	.	.	.	.	.	.	.	.	.	.	0.28	2764.59
5/28/87	442	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6/04/87	449	.	.	.	.	.	.	.	.	.	.	.	.	0.28	2764.59
6/17/87	462	.	.	.	.	.	.	.	.	.	.	.	.	0.24	1984.70
6/24/87	468	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7/14/87	489	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Site 23 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
7/23/87	498	.	.	.	.	.	.	.	.	.	.	.	.	0.23	1811.15
8/13/87	519	.	.	.	.	.	.	.	.	.	.	.	.	0.23	1811.15
9/16/87	553	.	.	.	.	.	.	.	.	.	.	.	.	0.24	1984.70
10/21/87	589	4.22	8.46	1.75	1.08	0.03	27.81	.	.	3.12	5.60	71.40	9.00	0.22	1646.07
12/08/87	687	.	.	.	.	.	.	.	.	.	5.30	71.38	9.00	0.34	4196.82
2/11/88	701	.	.	.	.	.	.	.	.	.	5.00	113.13	7.50	0.21	1489.40
2/17/88	708	.	.	.	.	.	.	.	.	.	4.90	131.90	10.00	0.22	1646.07
2/18/88	709	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2/25/88	715	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/03/88	722	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/10/88	729	.	.	.	.	.	.	.	.	.	5.00	166.37	8.50	0.26	2357.40
3/16/88	735	.	.	.	.	.	.	.	.	.	4.60	169.70	7.50	0.22	1646.07
3/25/88	744	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3/31/88	750	.	.	.	.	.	.	.	.	.	4.90	202.23	7.50	0.35	4466.70
4/07/88	757	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	0.34	4196.82
4/14/88	764	.	.	.	.	.	.	.	.	.	4.00	196.57	7.50	0.29	2981.24

SITE: 24 (Williams Weir)
LOCATION: 5 level, S 280 W 800
PERIOD OF RECORD: 3/12/86 4/14/88
AVERAGE ZINC CONCENTRATION: 27 mg/l
NUMBER OF SAMPLES: 31

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
Stage and flow measurements are reported as feet and cubic feet/day.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
03/12/86	1	14.59	22.61	100.30	20.94	30.60	137.50	3.62	0.34	.	3.20	539.09	8.00	0.52	37845.58
05/20/86	69	11.04	12.70	44.49	11.91	8.80	65.49	1.65	0.09	.	3.30	492.75	7.00	0.40	23353.90
07/21/86	131	10.58	10.30	28.70	8.72	5.70	52.80	0.26	0.05	.	3.60	212.78	9.00	0.49	33925.78
09/19/86	191	9.32	6.18	14.60	5.47	5.40	34.80	0.40	0.03	.	3.30	228.76	8.50	0.42	25547.46
10/11/86	213	8.55	5.59	12.32	4.66	5.94	27.24	0.20	0.01	3.75	3.60	151.01	9.00	0.41	24439.44
11/20/86	253	8.64	4.99	10.21	3.99	5.27	23.90	0.20	0.02	4.35	3.20	117.85	8.50	0.40	23353.90
12/22/86	285	8.75	5.97	10.20	4.55	0.00	28.60	0.20	0.04	3.13	3.40	171.39	7.00	0.38	21250.58
01/14/87	308	8.77	5.33	11.00	4.43	4.87	28.30	0.20	0.05	2.78	3.10	211.38	7.00	0.39	22290.92
01/29/87	323	9.02	5.17	9.39	3.91	4.34	13.60	0.20	0.02	3.48	3.90	183.84	7.50	0.39	22290.92
02/12/87	337	9.49	4.69	8.54	3.37	3.63	21.50	4.08	0.01	4.61	3.80	171.39	7.00	0.42	25547.46
02/26/87	351	9.40	10.50	11.50	6.51	4.35	35.40	4.45	0.03	4.05	3.90	217.09	7.00	0.38	21250.58
03/12/87	365	12.20	15.30	19.00	12.10	5.07	58.20	4.52	0.04	4.75	3.70	339.40	7.50	0.42	25547.46
03/26/87	379	12.00	15.70	37.60	12.10	9.18	65.90	8.72	0.09	4.21	3.20	438.39	7.50	0.45	29005.48
04/09/87	393	11.20	14.30	48.60	11.80	9.89	70.80	9.94	0.12	3.88	3.50	428.47	7.00	0.44	27830.56
04/23/87	407	11.40	13.40	44.70	10.50	9.04	71.20	8.73	0.16	4.51	3.30	410.11	7.50	0.44	27830.56
05/05/87	419	10.80	11.10	42.60	9.60	7.70	67.90	7.35	.	4.50	3.50	403.04	7.50	0.45	29005.48
05/21/87	435	10.90	11.00	38.90	8.94	8.59	64.70	8.59	0.98	4.47	3.20	389.27	8.00	0.44	27830.56
06/04/87	449	9.53	9.07	33.00	7.73	9.47	54.20	9.45	0.01	4.30	3.20	353.41	9.50	0.44	27830.56
06/17/87	462	10.60	9.06	31.00	7.63	6.70	50.20	7.04	2.61	4.14	3.40	343.20	9.00	0.44	27830.56
07/23/87	498	10.00	8.44	26.70	7.18	3.06	49.50	3.19	0.04	4.23	.	343.20	9.00	0.44	27830.56
08/13/87	519	9.91	6.84	19.70	5.84	3.33	35.10	3.59	0.03	3.82	3.90	274.56	9.00	0.41	24439.44
09/16/87	553	12.44	6.14	14.02	5.16	4.63	37.70	.	.	3.06	3.70	215.34	10.00	0.39	22290.92
10/21/87	589	22.76	5.63	11.13	4.14	4.48	42.79	.	.	4.50	3.80	168.00	8.00	0.36	19238.25
12/08/87	687	.	.	.	.	.	.	.	.	.	5.20	98.00	8.00	0.19	5935.75
02/11/88	701	.	.	.	.	.	.	.	.	.	5.30	114.60	7.50	0.34	17317.70
02/17/88	708	.	.	.	.	.	.	.	.	.	5.30	124.40	7.50	0.34	17317.70
03/10/88	729	.	.	.	.	.	.	.	.	.	5.20	133.00	8.00	0.35	18266.45
03/16/88	735	.	.	.	.	.	.	.	.	.	4.60	165.20	8.00	0.35	18266.45

Site 24 continued.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP	STAGE	FLOW
03/31/88	750	.	.	.	.	.	.	.	.	.	3.30	256.50	7.50	0.24	9123.42
04/08/88	758	.	.	.	.	.	.	.	.	.	.	.	.	0.38	21250.58
04/14/88	764	.	.	.	.	.	.	.	.	.	2.90	406.10	8.00	0.39	22290.92

APPENDIX C

BASIC DATA FOR AIR VAPOR SAMPLING SITES, HOMESTAKE WORKINGS

SITE: Pan Sample Site 2
LOCATION Homestake Workings S 62 W 1385
PERIOD OF RECORD: 2/26/86 10/21/87
AVERAGE ZINC CONCENTRATION: 2.23 mg/l
NUMBER OF SAMPLES: 15

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
2/26/87	351	1.18	3.60	23.40	4.73	4.86	46.90	5.20	0.05	3.13	.	621.45	16.00
3/12/87	365	0.34	0.71	4.38	0.91	2.61	8.83	2.90	0.01	10.57	3.70	99.37	20.00
3/20/87	373	.	.	.	.	.	.	.	.	.	6.60	121.45	20.00
3/26/87	379	0.09	0.22	2.81	0.64	1.39	5.82	1.04	0.01	30.10	5.60	162.34	13.00
4/02/87	386	.	.	.	.	.	.	.	.	.	5.20	33.12	20.00
4/09/87	393	0.49	0.23	2.53	0.51	0.76	2.50	0.81	0.01	8.07	5.70	50.68	19.00
4/23/87	407	2.09	0.83	1.70	0.38	0.38	6.09	0.44	0.03	10.40	5.90	34.98	20.50
5/05/87	419	3.60	0.80	1.06	0.22	0.63	2.74	0.59	0.01	4.76	5.90	38.00	25.00
5/21/87	435	3.72	1.25	2.00	0.40	1.27	4.54	1.32	0.01	4.12	5.80	44.16	20.00
6/04/87	449	3.89	1.18	1.70	0.37	0.90	3.94	0.94	0.01	3.95	.	.	.
6/17/87	462	5.48	1.59	1.40	0.26	0.77	1.92	0.71	0.21	4.24	.	44.38	21.00
7/14/87	489	5.39	1.55	2.11	0.41	0.35	4.69	0.44	0.16	4.15	.	45.46	21.00
8/13/87	519	6.42	1.88	2.51	0.53	0.23	4.34	0.26	0.02	4.40	6.30	47.75	22.00
9/16/87	553	13.52	1.83	2.62	0.58	0.11	11.70	.	.	4.27	6.10	54.12	21.00
10/21/87	589	7.91	1.48	1.98	0.38	0.31	17.58	.	.	4.02	6.40	53.00	21.00

SITE: Pan Sample Site 3A
LOCTION: 2R/1R Pool Area N 05 W 1500
PERIOD OF RECORD: 2/26/87 4/07/88
AVERAGE ZINC CONCENTRATION: 84 mg/l
NUMBER OF SAMPLES: 20

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

REMARKS: Site monitors the vapor metal concentrations at the sites 1 and 3 connection point.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
2/26/87	351	15.60	20.50	225.00	18.90	247.00	481.00	243.00	0.25	5.60	.	13249.00	20.00
3/11/87	364	2.49	5.39	87.80	4.82	119.00	171.00	124.00	0.24	1.93	3.70	883.30	20.00
3/20/87	373	.	.	.	.	.	.	.	.	.	3.30	1082.40	21.00
3/26/87	379	7.46	14.60	232.00	15.30	245.00	403.00	239.00	0.57	33.40	2.30	2009.40	20.00
4/02/87	386	.	.	.	.	.	.	.	.	.	3.40	662.40	20.00
4/09/87	393	5.45	9.95	146.00	9.50	219.00	286.00	229.00	0.32	11.60	2.70	1545.70	20.00
4/23/87	407	7.58	12.30	172.00	10.40	218.00	348.00	222.00	0.41	14.30	2.70	1623.60	21.00
5/21/87	435	5.35	4.45	46.70	3.28	25.70	85.10	25.00	3.14	4.95	2.80	746.90	21.00
6/04/87	449	4.55	2.29	19.00	1.35	17.90	35.70	18.30	0.38	4.06	.	.	.
6/17/87	462	5.93	2.74	18.70	1.38	20.40	35.00	21.30	0.94	4.33	.	245.40	21.50
7/14/87	489	7.70	6.72	73.10	5.33	192.00	153.00	194.00	0.15	4.95	.	859.60	22.00
8/13/87	519	8.05	5.08	59.30	3.65	32.90	88.80	33.90	0.06	4.58	2.80	725.00	22.50
9/16/87	553	8.87	3.93	31.40	2.59	34.80	68.30	.	.	4.97	2.90	477.50	22.00
10/21/87	589	9.89	4.72	36.30	2.90	58.70	84.90	.	.	4.48	3.30	424.50	22.00
2/25/88	715	.	.	.	.	.	.	.	.	.	2.40	2273.10	21.00
3/16/88	735	.	.	.	.	.	.	.	.	.	2.30	2543.70	21.00
3/25/88	744	.	.	.	.	.	.	.	.	.	4.10	151.50	21.00
3/31/88	750	.	.	.	.	.	.	.	.	.	3.50	292.30	21.00
4/07/88	757	.	.	.	.	.	.	.	.	.	3.00	601.30	20.50

SITE: Pan Sample Site 4A
LOCATION: Blue Pool Berm S 240 W 1130
PERIOD OF RECORD: 2/26/87 4/05/88
AVERAGE ZINC CONCENTRATION: 23.0 mg/l
NUMBER OF SAMPLES: 19

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
2/26/87	351	11.20	20.70	1630.00	13.30	1570.00	2350.00	1300.00	5.84	13.20	.	2756.85	18.00
3/12/87	365	0.13	0.22	3.45	0.03	0.46	3.73	0.38	0.02	10.67	4.10	51.96	21.00
3/20/87	373	.	.	.	.	.	.	.	.	.	6.00	135.14	19.00
3/26/87	379	0.31	0.10	23.60	0.12	2.52	32.50	2.29	0.08	29.00	3.40	289.47	18.00
4/02/87	386	.	.	.	.	.	.	.	.	.	3.10	236.49	19.00
4/23/87	407	2.27	0.90	50.20	0.35	43.90	114.00	46.70	0.26	10.50	2.70	1069.85	19.00
5/05/87	419	3.79	0.97	21.80	0.16	11.30	49.90	11.10	0.10	5.14	3.50	254.37	21.00
5/21/87	435	.	.	.	.	.	.	.	.	.	2.80	957.24	19.00
6/04/87	449	4.11	1.35	32.60	0.29	14.60	58.20	14.40	0.38	4.11	.	.	.
6/17/87	462	5.69	1.57	23.70	0.12	13.00	58.80	13.30	0.13	4.33	.	662.45	20.00
7/14/87	489	5.29	1.42	21.60	0.14	9.01	54.60	9.16	0.58	4.60	.	684.53	20.00
8/13/87	519	6.66	1.91	25.70	0.18	7.38	53.10	7.24	0.09	4.70	2.60	655.92	20.50
9/16/87	553	7.91	2.62	15.80	0.15	2.16	44.60	.	.	4.65	2.90	408.51	20.00
10/20/87	588	16.03	1.74	11.60	0.08	0.80	39.80	.	.	4.50	2.80	182.20	20.00
2/25/88	715	.	.	.	.	.	.	.	.	.	2.60	1282.33	19.50
3/16/88	735	.	.	.	.	.	.	.	.	.	2.50	1407.70	19.00
3/25/88	744	.	.	.	.	.	.	.	.	.	5.30	49.19	20.50
3/31/88	750	.	.	.	.	.	.	.	.	.	5.00	57.98	19.50
4/05/88	755	.	.	.	.	.	.	.	.	.	4.00	101.36	19.00

SITE: Air Vapor Plate Sample Site 2
LOCATION: Homestake Workings
PERIOD OF RECORD: 3/26/87 3/3/88
AVERAGE ZINC CONCENTRATION 463 mg/l
NUMBER OF SAMPLES: 12

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

REMARKS: Plate 2 is located in the vicinity of pan sampler 2.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
3/26/87	379	84.70	249.00	1920.00	247.00	933.00	2000.00	946.40	0.52	7.06	.	.	.
4/09/87	393	13.40	23.00	146.00	21.20	48.70	165.00	49.80	0.03	0.63	.	.	.
4/23/87	407	25.00	77.50	426.00	60.20	51.40	457.00	54.60	0.17	1.81	.	.	.
5/05/87	419	15.80	53.60	225.00	39.60	18.20	243.00	16.90	0.05	0.73	.	.	.
5/21/87	435	19.40	196.00	1320.00	177.00	385.00	1330.00	378.00	46.80	2.79	.	.	.
6/04/87	449	34.60	117.00	966.00	100.00	188.00	917.00	191.00	24.60	5.86	.	.	.
7/23/87	498	1.89	2.74	29.00	2.56	1.27	32.20	1.42	0.02	1.28	.	.	.
7/23/87	498	1.47	2.28	24.90	2.13	0.22	29.00	0.31	0.02	1.39	.	.	.
8/13/87	519	0.66	1.37	19.10	1.44	0.45	50.20	19.10	0.02	0.10	.	.	.
9/16/87	553	1.13	1.62	9.31	1.36	0.41	20.30	.	.	0.10	.	.	.
10/20/87	588	0.50	1.08	11.50	1.56	0.19	25.90	.	.	.	.	.	.
3/03/88	722	.	.	.	.	.	.	.	.	.	3.10	344.89	22.00

SITE: Air Vapor Plate Sampler 3
LOCATION: Homestake Workings S 210 W 1320
PERIOD OF RECORD: 7/23/87 3/03/88
AVERAGE ZINC CONCENTRATION: 17.6 mg/l
NUMBER OF SAMPLES: 8

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

REMARKS: Plate 3 monitors air vapor quality at the mine air exhaust inflow point to the Homestake Workings.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
7/23/87	498	5.31	4.60	46.80	4.84	6.03	51.20	5.88	0.24	1.03	.	.	.
7/23/87	498	5.54	4.65	48.90	4.79	5.45	50.10	5.68	0.06	0.99	.	.	.
8/13/87	519	1.00	0.43	3.00	0.72	0.27	8.68	0.28	0.02	0.17	.	.	.
9/16/87	553	0.68	0.10	2.30	0.58	0.29	19.48	.	.	0.09	.	.	.
9/16/87	553	2.00	0.89	2.10	0.53	0.25	16.30	.	.	0.54	.	.	.
10/20/87	588	0.96	0.53	2.55	0.57	0.45	24.26	.	.	0.09	.	.	.
12/08/87	687	.	.	.	.	.	.	.	.	.	3.60	93.39	22.00
3/03/88	722	.	.	.	.	.	.	.	.	.	3.40	114.61	22.00

SITE: Air Vapor Plate Sampler 4
LOCATION: Homestake Workings S 237 W 1124
PERIOD OF RECORD: 3/26/87 3/25/88
AVERAGE ZINC CONCENTRATION: 1224 mg/l
NUMBER OF SAMPLES: 17

Reported EC measurements are compensated to 25 degrees C.
EC measurements are reported as micromhos/cm.
Metal concentrations are reported as mg/liter.
'.' indicates missing data.

REMARKS: Plate 4 monitors the air vapor metal concentrations in the vicinity of sites 12 to 14.

DATE	DAY	CALCIUM	MAGNESIUM	ZINC	MANGANESE	IRON	SULFUR	ALUMINUM	CADMIUM	SILICA	PH	CCOND	TEMP
3/26/87	379	7.57	12.20	2380.00	8.64	1560.00	2690.00	1480.00	9.95	8.34	2.20	.	.
4/23/87	407	8.12	13.20	5580.00	8.38	2270.00	5270.00	2240.00	23.00	9.13	1.90	12200.00	21.00
5/05/87	419	3.57	6.41	1110.00	4.10	635.00	1150.00	627.00	4.26	4.33	.	.	.
5/21/87	435	4.06	6.54	1820.00	4.53	676.00	1680.00	731.00	86.70	4.23	.	.	.
6/04/87	449	3.90	5.81	2040.00	4.33	703.00	1886.00	773.00	57.40	4.81	.	.	.
6/17/87	462	1.93	3.81	597.00	2.46	305.00	609.00	326.00	15.20	2.88	.	.	.
6/17/87	462	1.86	3.36	480.00	2.09	264.00	497.00	275.00	11.90	2.82	.	.	.
7/23/87	498	1.98	4.67	596.00	2.61	330.00	633.00	328.00	2.36	2.38	.	.	.
7/23/87	498	2.03	4.37	686.00	2.66	309.00	608.00	324.00	2.27	2.61	.	.	.
8/13/87	519	1.92	3.13	401.00	1.95	215.00	419.00	210.00	1.63	1.73	.	.	.
9/16/87	553	2.12	4.41	481.00	2.76	295.00	521.00	.	.	2.10	.	.	.
9/16/87	553	2.12	4.14	384.00	2.47	267.00	526.00	.	.	2.07	.	.	.
10/20/87	588	3.27	1.91	298.00	1.38	142.00	305.00	.	.	0.58	.	.	.
10/20/87	588	18.16	2.63	290.00	1.33	135.00	288.00	.	.	2.36	.	.	.
2/11/88	701	.	.	.	.	.	.	.	.	.	2.50	2627.70	20.00
3/03/88	722	.	.	.	.	.	.	.	.	.	2.60	1822.00	21.50
3/25/88	744	.	.	.	.	.	.	.	.	.	2.40	1907.70	21.50