GEOCHEMICAL ASSESSMENT OF MINE WATERS
WITHIN ABANDONED LEAD-ZINC MINES,
PICHER FIELD, NORTHEAST OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Study Objective

This study is a geochemical assessment of the water located in the mine workings, particularly the water located with the mine stopes of the Oklahoma portion of the Picher field. This was accomplished by determining the spatial and temporal variations in the quality of the mine water and the equilibrium of aqueous minerals in the mine water.

Study Area Location

The study area is the Oklahoma portion of the Picher Mine field located in Ottawa County in the far northeast corner of Oklahoma. The study area location and extent of the underground mine workings in the Oklahoma portion of the Picher field are shown on Figure 1. All mine water sampling locations were located in T29N-R23E and T28N-R23E-07 IM. Emphasis has been placed on the geochemistry of the water located within the mine stopes.

Scope of Study

Numerous studies including Playton et al (1980), Hittman (1981), OWRB

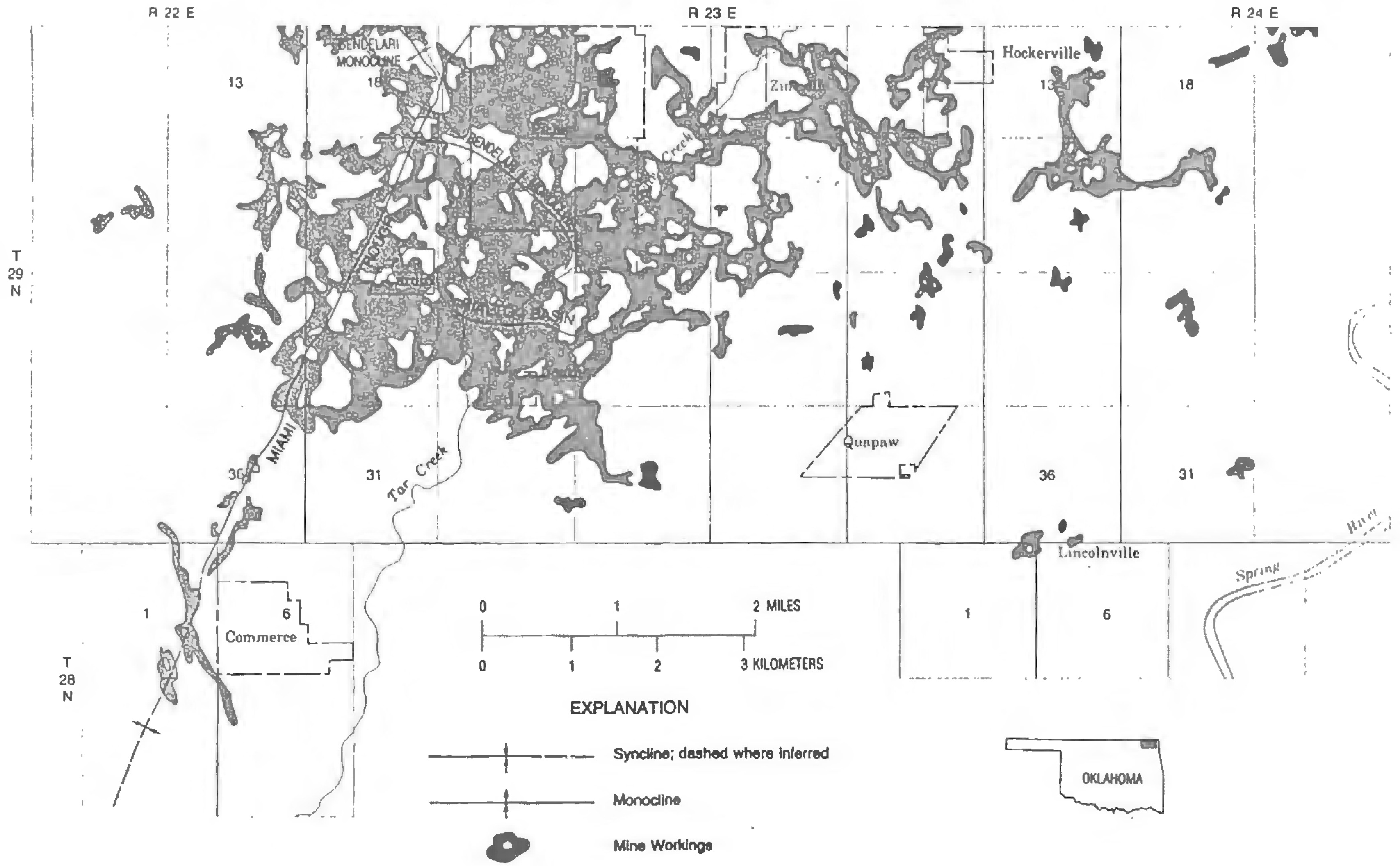


Figure 1. Oklahoma Portion of the Picher Field (Luza 1986)

(1983), Luza (1986), Spruill (1987), Kent et al (1987), and Parkhurst et al (1987) and (1988), have been conducted on the water and sediment quality of Tar Creek in response to the discharge of acid mine water. Few studies have actually addressed the geochemistry of the mine waters prior to discharge. The scope of this study includes the geochemical assessment of the mine water, with emphasis placed on the water located within the mine stopes.

The history, hydrology, hydrogeology, geology, and general water quality of the study area was obtained from Oklahoma Water Resourses Board, Oklahoma Geological Survey, and U.S. Geological Survey publications. Water quality data were obtained from the U.S. Geological Survey data base WATSTOR, Oklahoma State Health Department, and U.S. Geological and Oklahoma Geological Survey publications.

Precipitate identification and mineral speciation calculated using the U.S. Geological Survey geochemical model WATEQ4F aided in the interpretation of the chemical equilibrium of the mine water with respect to various mineral species. Precipitate samples were collected at mine discharge points and mineralogy determined using x-ray diffraction. Water quality data was evaluated using WATEQ4F to determine the chemical equilibrium of the mine water from selected mines and mine discharge points with respect to viable minerals.

CHAPTER II

LITERATURE REVIEW

Acid Production

Acidic conditions commonly associated with acid mine drainage are produced when oxygen and water come in contact with soluble iron sulfide minerals, Figure 2 (Solomons 1988). Sulfuric acid is formed from the oxidation of iron sulfide minerals because pyrite and marcasite contain more sulfur than is needed to form the iron salts, primarily $FeSO_4$ (Nordstrom 1982). Once oxidized in an aqueous environment, these minerals release one mole of ferrous iron and two moles of elemental sulfur or sulfur dioxide. This provides a free sulfur to hydrolyze in the presence of oxygen and form sulfuric acid. Ferrous iron is slowly oxidized to ferric iron by abiotic oxidation or rapidly with the aid of a bacterial catalysis (Noike et al. 1983). Additional acid is produced as ferric salts hydrolyze in the presence of oxygen to form insoluble ferric hydroxide and more sulfuric acid (Trexler et al 1975). This reaction significantly decreases the pH of the water because three moles of sulfuric acid are produced for every two moles of ferric hydroxide produced (Emmons 1940)

The sulfuric acid formed from the dissolution of iron sulfide minerals will rapidly oxidize and dissolve the normally insoluble sulfide minerals, sphalerite and galena, thus liberating trace elements (Emmons 1940). Upon oxidation and dissolution

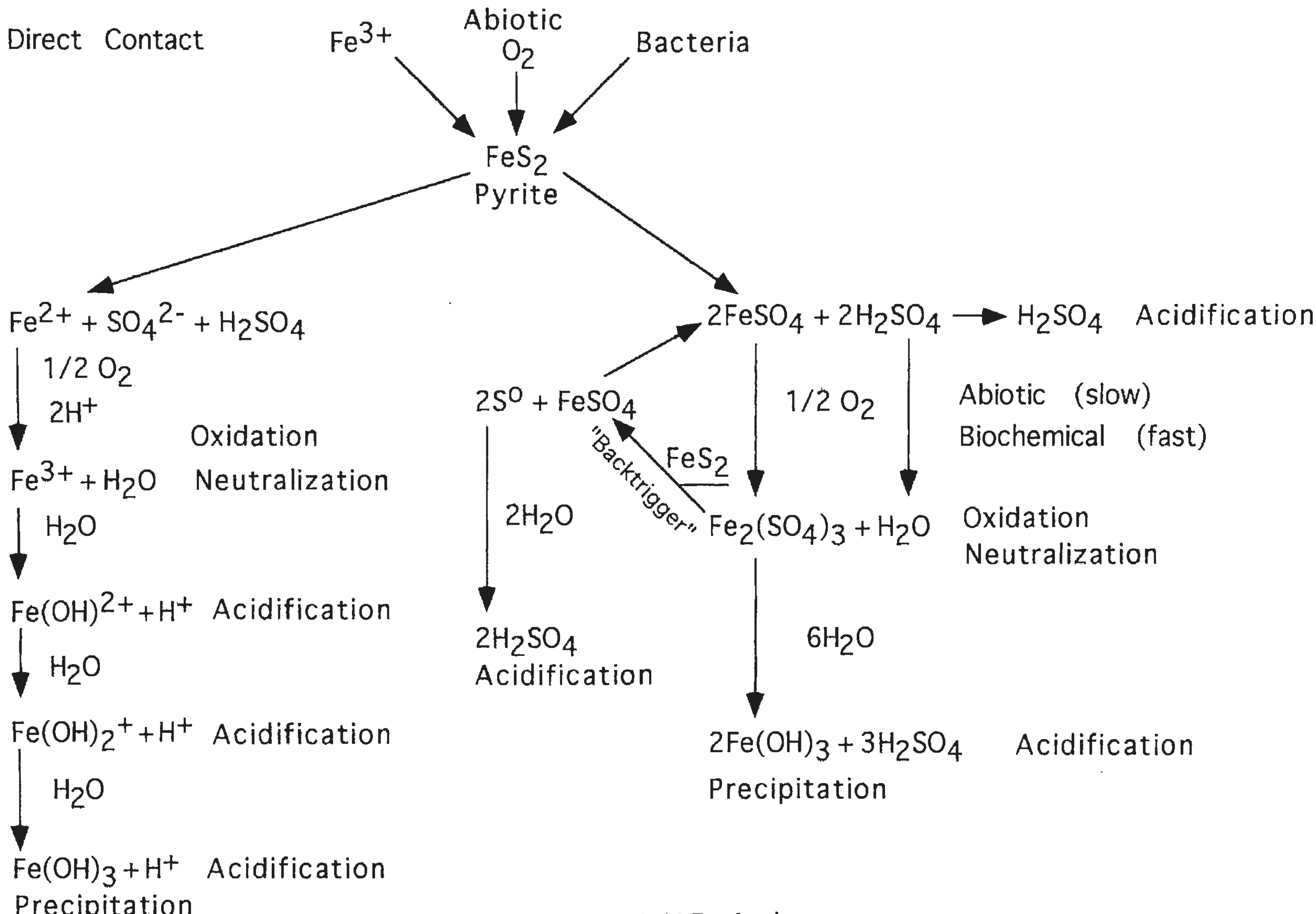


Figure 2. Acid Production

of these minerals, trace elements are released, thus further degrading the water quality, Figure 3.

Acid Neutralization

The acidity resulting from the oxidation of pyrite can be fully neutralized by the dissolution of calcite if the weighted ratio of pyrite to calcite is less than 0.6 (Wai et al. 1981). Calcite (limestone) neutralizes sulfuric acid in the following manner.

$$H_2SO_4 + CaCO_3 = Ca^{2+} + SO_4^{2-} + H_2CO_3$$

As the calcite continues to neutralize the acid, the concentrations of Ca^{2+} and SO_4^{2-} in solution increase until the solution is supersaturated with respect to gypsum. At this point the precipitation of gypsum occurs, controlling the Ca^{2+} and SO_4^{2-} concentrations in solution. At a pH < 6.0, the dominant carbonate species present in solution would be H_2CO_3. Once the water becomes saturated with respect to H_2CO_3, carbonic acid dissociates and releases H_2O and CO_2 gas, as shown below (Blowes and Jambor 1990).

$$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$$

History

Zinc and lead ores, primarily sphalerite, galena, and zinc silicate, were mined in the Picher field from 1891 through 1970. When production ended in 1970, more

FERRIC IRON OXIDATION

Sulfide Minerals:

$$Fe^{3+} + MS + 4H_2O = FeSO_4 + 8H^+ + M^{2+}$$

where M is Zn, Pb, Cu, or Fe.

CHEMICAL OXIDATION

Sphalerite: $ZnS + 2O_2 = ZnSO_4$

releasing -> (Fe, Ag, Ge, Ga, In, Co, Hg, Cu, Cd, Pb)

Galena: $PbS + 2O_2 = PbSO_4$

releasing -> (Ag, Sb, Cu, Fe)

Chalcopyrite: $CuFeS_2 + 4O_2 = FeSO_4 + CuSO_4$

releasing -> (Ni, Ag, Cu)

Marcusite: $2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$

releasing -> (Ni, Co)

Figure 3. Oxidation of Sulfide Minerals and the Release of Associated Trace Metals

than 5.2 million tons of zinc and 1.3 million tons of lead had been produced, Table 1 (McKnight and Fisher 1970). The extensive mining operations left approximately 2,540 acre underlain by mine workings, 481 mine shafts, 2,900 acres covered by mining and/or milling waste, and 14 major tailing ponds (Luza 1986).

The mineralized zones located in the Tri-State District contained eight principal minerals: sphalerite, galena, chalcopyrite, marcasite, pyrite, calcite and dolomite. Minor ores which included enargite, luzonite, wurzite, and barite occurred locally in small quantities (Hagni 1976). Analyses revealed that sphalerite, galena, chalcopyrite, marcasite, and pyrite contained numerous trace elements. These elements include: Fe, Ag, Ge, Ga, In, Co, Hg, Cu, Cd, and Pb in sphalerite, Ag, Sb, Ag, Cu, and Fe in galena, Ni, Ag, and Cu in marcasite, Ni and Co in pyrite, and Ag and Ni in chalcopyrite (Hagni 1976 and E/MJ 1940). The ore bodies were typically disseminated within a brecciated chert and to a lesser extent a brecciated limestone matrix (McKnight and Fisher 1970). Ore deposits containing these minerals are considered stable in an environment located below the water table, mildly alkaline, mildly reducing, and remains constant indefinitely. Once these conditions are altered, through mining activities which exposes the minerals to air and oxygenated water via dewatering and mine shafts, the minerals become unstable and oxidation takes place.

The Boone Formation (Figure 4), where the mineralized zones occurred, was a primary aquifer in Ottawa, County, and produced large quantities of water through fractures and solution openings (Reed 1955). High volume acid resistent pumps were used to dewater the Boone formation during mining operations. In the early 1930's, 43 pump stations, located within Oklahoma and Kansas, discharged more than 13 mgd

TABLE 1

ZINC AND LEAD PRODUCTION FROM THE PICHER FIELD, 1904-1964

Subdistricts included are Lincolnville, Quapaw, Sunnyside, Picher-Cardin, Century, Commerce, Miami, and Melrose in Oklahoma; Baxter Springs-Blue Mound, Treece, and Melrose in Kansas. Figures for 1904-06 from A. J. Martin (1946, p. 29, 63); those for 1907-31 based on tables published in annual volumes of Mineral Resources of the United States; those for 1932-64 based on unpublished statistical charts furnished by U.S. Bur. Mines]

Year	Lead concentrates (galena)		Zinc concentrates (sphalerite)		Recoverable metal content [1]			
					Lead		Zinc	
	Short tons	Value [2]	Short tons	Value [2]	Short tons	Value [2]	Short tons	Value [2]
1904	150	$8,250	633	$21,245	112	$9,789	317	$32,841
1905	566	34,450	2,670	103,480	422	40,174	1,354	159,772
1906	669	51,299	3,242	124,528	498	56,374	1,624	201,051
1907	647	43,644	[3] 3,159	120,071	500	53,000	1,495	176,410
1908	2,234	118,253	[3] 10,033	249,674	1,726	144,984	4,404	413,976
1909	4,300	223,131	[3] 16,622	569,200	3,319	285,434	7,685	827,820
1910	3,634	187,861	13,976	447,043	2,798	246,224	6,305	680,940
1911	3,177	170,729	[3] 10,642	330,186	2,416	212,608	4,963	565,782
1912	4,257	231,678	[3] 11,881	484,429	3,286	295,740	5,627	776,526
1913	7,807	402,927	24,097	766,200	6,039	531,432	11,649	1,303,568
1914	9,402	443,543	[3] 28,367	926,778	7,329	571,662	13,990	1,426,980
1915	9,058	494,524	28,280	1,901,490	6,934	651,796	14,191	3,519,368
1916	15,206	1,275,761	54,932	4,109,565	11,777	1,625,226	28,498	7,637,464
1917	33,770	3,401,926	171,726	11,611,675	26,624	4,685,824	92,339	18,837,156
1918	77,487	6,889,080	341,175	17,321,065	60,924	9,016,752	183,434	33,384,988
1919	81,290	5,524,106	413,418	17,892,434	63,427	7,357,532	219,792	32,089,632
1920	101,285	9,560,901	502,134	22,610,299	79,755	12,760,800	270,610	43,838,820
1921	74,580	3,949,045	278,331	6,344,770	59,977	5,397,930	149,623	14,962,300
1922	108,510	8,240,542	482,970	16,528,301	85,628	9,419,080	260,119	29,653,566
1923	107,496	10,255,061	633,035	25,656,673	84,045	11,766,300	332,224	45,182,464
1924	113,363	12,142,523	690,809	28,502,120	88,074	14,091,840	361,073	46,939,490
1925	130,410	15,324,698	749,254	38,303,908	100,838	17,545,812	387,002	58,824,304
1926	124,361	13,226,619	744,028	34,567,144	95,832	15,333,120	382,683	57,402,450
1927	99,524	8,689,985	591,447	22,945,385	76,404	9,626,904	303,298	38,822,144
1928	87,238	7,054,366	527,495	19,355,536	67,406	7,819,096	271,116	33,076,152
1929	91,087	7,687,831	562,371	22,091,618	69,699	8,782,074	290,375	38,329,500
1930	45,492	2,994,261	394,459	12,044,167	34,291	3,429,100	204,363	19,618,848
1931	24,565	1,115,883	218,689	5,119,691	18,990	1,405,260	115,569	8,783,244
1932	21,130	765,715	167,725	3,066,363	16,461	987,660	89,686	5,381,160
1933	30,820	1,378,300	248,933	6,507,023	23,643	1,749,582	131,761	11,067,924
1934	30,222	1,183,580	276,887	7,527,784	23,250	1,720,500	146,900	12,547,400
1935	44,715	1,894,278	344,027	9,916,502	34,035	2,722,800	182,300	16,042,400
1936	48,545	2,498,168	391,383	12,291,640	36,778	3,383,576	206,974	20,697,400
1937	59,906	4,181,830	403,783	16,752,621	45,799	5,404,282	214,080	27,830,400
1938	47,461	2,467,059	335,927	10,340,762	36,200	3,330,400	182,463	17,533,728
1939	53,654	3,163,728	379,435	13,075,004	41,396	3,891,224	206,598	21,486,192
1940	43,290	2,561,072	400,647	16,874,966	33,131	3,313,100	217,028	27,346,528
1941	51,301	3,452,758	429,660	21,569,025	39,391	4,490,574	233,173	34,975,950
1942	41,942	4,141,239	369,043	25,585,281	32,146	4,307,564	198,931	37,001,166
1943	38,536	4,652,150	310,980	30,836,571	28,851	4,327,650	166,850	36,039,600
1944	29,952	3,532,942	275,220	27,906,030	22,817	3,650,720	148,125	33,772,500
1945	25,813	3,209,989	206,580	22,402,691	19,043	3,275,396	111,486	25,641,780
1946	25,880	4,213,144	206,764	23,790,583	19,800	4,316,400	111,558	27,220,152
1947	27,805	5,299,841	164,574	17,586,767	21,104	6,077,952	88,634	21,449,428
1948	32,392	7,482,361	143,429	12,539,196	24,294	8,697,252	76,409	20,324,794
1949	38,785	7,249,558	134,513	10,382,456	28,767	9,090,372	71,895	17,829,960
1950	39,073	5,993,270	137,275	12,792,548	29,910	8,075,700	73,701	20,931,084
1951	34,468	7,282,897	152,853	18,944,275	25,474	8,814,004	82,333	29,969,212
1952	28,010	5,643,233	148,488	17,363,541	20,887	6,725,614	80,229	26,636,028
1953	16,608	2,579,916	90,541	6,594,882	12,649	3,314,038	48,917	11,250,910
1954	24,394	4,110,406	123,340	8,104,829	18,237	4,996,938	62,281	13,452,696
1955	26,917	4,721,589	129,978	9,977,920	19,624	5,847,952	69,154	17,011,884
1956	28,101	5,180,293	106,135	9,173,252	19,985	6,275,290	56,180	15,393,320
1957	15,901	2,922,323	56,891	4,599,858	11,440	3,271,840	30,810	7,147,920
1958	7,041	931,441	18,001	1,093,365	4,991	1,167,894	9,688	1,976,352
1959	1,607	211,244	4,061	282,285	1,082	248,860	2,066	475,180
1960	3,098	283,818	8,877	657,838	1,717	401,778	4,449	1,147,842
1961	3,243	352,243	10,666	716,541	2,429	500,374	5,594	1,286,620
1962	4,800	480,412	25,564	1,771,466	3,680	677,120	13,956	3,209,880
1963	5,719	604,378	30,762	2,270,865	4,219	911,304	16,753	3,853,190
1964	5,333	733,391	31,228	2,731,701	3,966	1,039,092	16,824	4,576,128
Total	2,298,117	225,101,443	13,774,945	697,075,106	1,766,266	270,166,669	7,282,668	1,109,973,264

[1] Allowance has been made for smelting losses of both lead and zinc.

[2] In comparing the values of metal and concentrates it should be borne in mind that the value given for the metal is calculated from the average price for all grades, whereas the value given for the concentrates is that actually received by the producers.

[3] Includes a small quantity of silicate and carbonate.

(McKnight and Fisher 1970)

System	Series	Group formation or member		Thick-ness (feet)	Beds
PENNSYLVANIAN	Des Moines	Krebs Group	Bluejacket Sandstone Member (of Boggy Fm.)	15-60	
			Savannah Shale Doneley Limestone Mem.	120	
			McAlester Shale Warner Sandstone Mem.	30	
			Hartshorne Formation	0-50	Un
	Morrow		Hale Formation	0-83+	Un
MISSISSIPPIAN	Chester		Fayetteville Shale	0-70	
			Batesville Sandstone	0-70	
			Hindsville Limestone	0-85	Un
	Meramec		Quapaw Limestone	0-31	
		Boone Formation	Moccasin Bend Member	0-140	B-H
			Baxter Springs Member	0-116	J-L
			Short Creek Oolite Mem.		Dis
	Osage		Joplin Member	0-100	M
			Grand Falls Chert Member	25-95	N-Q
			Reeds Spring Member	70-105	R
			St. Joe Limestone Member	10-32	
MISSISSIPPIAN AND DEVONIAN	Kinderhook and Upper Devonian		Chattanooga Shale	0-50	Un
ORDOVICIAN	Lower Ordovician		Cotter Limestone	143-183	
			Jefferson City Dolomite	220-340	
			Roubidoux Formation	142-190	
		Van Buren Formation	Gasconade Dolomite Gunter Sandstone	240-300	
CAMBRIAN	Upper Cambrian		Eminence Dolomite	137-157	
			Davis Formation	110-120	
			Bonneterre Dolomite	45-75	
			Lamotte Sandstone	12-50	
PRECAMBRIAN			Granite		

Figure 4. Stratigraphy of the Picher Field
(Modified from McKnight 1970)

to insure the mines kept free of water. By 1948, 27.8 mgd of groundwater was discharged from all sources within the Boone Formation in Ottawa, County (Reed 1955).

The dewatering of the Boone Formation and mining operations provided an avenue for oxygenated air to come in contact with the exposed sulfide minerals. Although the Boone Formation was continuously being dewatered with pumps, the walls of the mine stopes contained numerous seeps (McKnight et al 1970). The abiotic oxidation of marcasite and pyrite readily occurs in the presents of oxygen and moisture. Abiotic oxidation of iron sulfide minerals occurs slowly, but initiates the production of sulfuric acid. Once oxygenated water in the mines become strongly acidic, ferric iron rapidly oxidizes more iron sulfide minerals, thus accelerating the process several orders of magnitude (Karlson et al. 1987). Under these conditions, exposed sulfide minerals were readily oxidized.

$$MS_x \rightarrow M^{2+} + S_x^o + 2e^-$$

Where M is a divalent metal. As a result of the oxidation and dissolution of many principal minerals, the water forming the seeps and contained within the mine sumps were strongly acidic, highly mineralized, and over saturated with respect to numerous secondary minerals (McKnight and Fisher 1970). Many secondary minerals such as gypsum, smithsonite, anglesite, and greenockite formed as coatings on the surface of weathered principal minerals and mine stopes (McKnight and Fisher 1970). Other secondary minerals such as goslarite, melanterite, and copiapite formed as efflorescence upon the dehydration of mine waters. A list of the primary and secondary minerals observed within the mine stopes is provided on Table 2.

By the late 1960's most of the ore within the Picher Field had been removed. The depletion of ore and the decline in the lead and zinc market lead to the closing of all major mining operations and the associated dewatering of the Boone Formation (McKnight and Fisher 1970). Once the dewatering of the mines ended in the late 1960's, the cone of depression resulting from over 50 years of pumping began to recover, rapidly flooding the mines. Natural recharge to the dewatered portion of the Boone Formation occurred through fractures and solution openings, flooding the mine workings with good quality groundwater. The flooding of the mine workings were accelerated by poor quality surface water artificially recharging the Boone Formation via abandoned boreholes, mine shafts, and collapse features, Figure 5 (Playton et al 1980 and Luza 1986). Playton (1980) estimated that the water within the Blue Goose Mine rose on an average of 2.6 feet per month between September 1975 and February 1980.

By November 1979, mine water began to discharge continuously at the Commerce Spring, elevation 790 feet MSL, and intermittently soon after at OWRB 4S, approximate elevation 799 feet MSL (Playton et al. 1980). By October 1983 most of the mine workings had filled with approximately 54,925 acre-feet of water in the Oklahoma portion of the Picher mine field (Luza 1986). Parkhurst (1985) calculated that the water within the mine workings had a 22 year resident time, and discharged an estimated 3,400 acre-feet/year.

The water within the mines was moderately acidic and contain a high

TABLE 2

OBSEVRED MINERALS IN THE PICHER FIELD

Major Minerals:

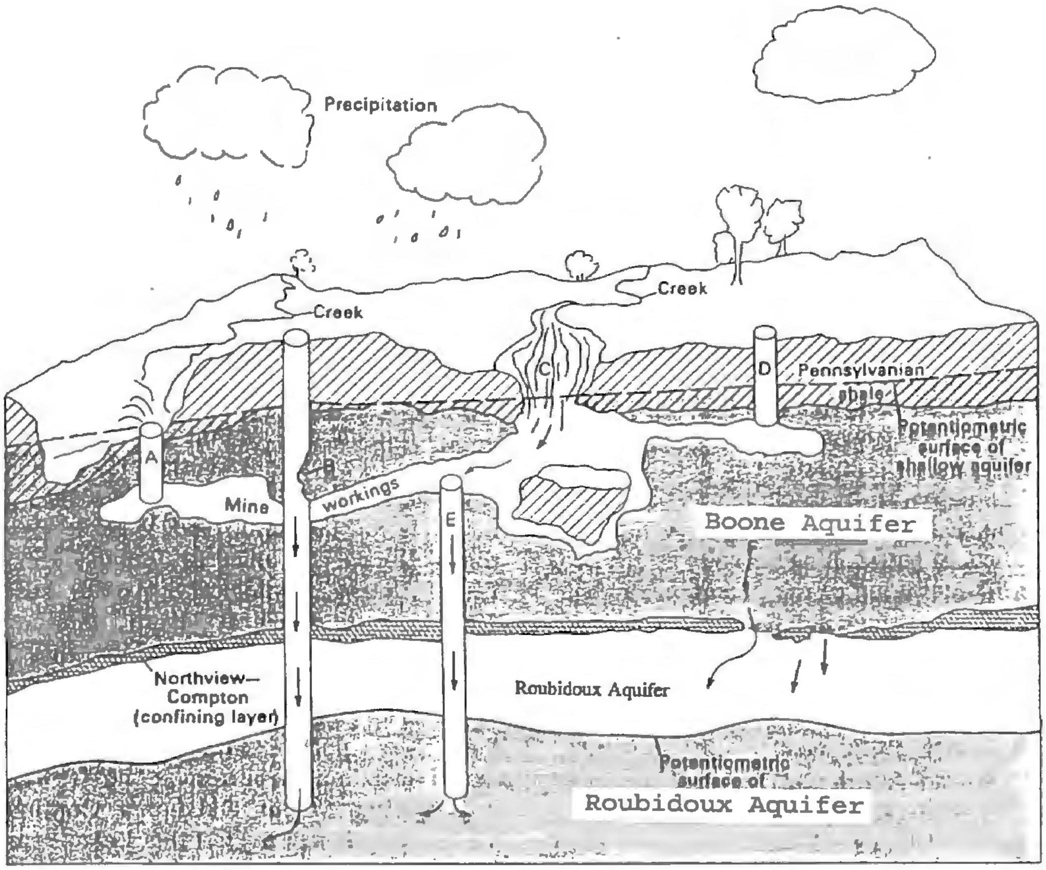
Sulfates	Carbonates	Silicate
sphalerite	calcite	chert
galena	dolomite	
chalcopyrite		
marcasite		
pyrite		

Minor Minerals:

- Native Elements
  - Sulfur
- Sulfides
  - bornite
  - wurtzite
  - greenockite
  - millerite
  - covellite
- Sulfosalts
  - enargite
  - luzonite
- Sulfates
  - barite
  - anglesite
  - gypsum
  - starkeyite
  - chalcanthite
  - melanterite
  - epsomite
  - goslarite
  - linarite
  - jarosite
  - plumpojarosite
  - aluminite
  - copiapite
  - caledonite
  - szomolnokite
  - carphosiderite
- Carbonates
  - smithsonite
  - arogonite
  - cerussite
  - hydrozincite
  - aurichalcite
  - malachite
  - azurite
  - leadhillite
- Oxides
  - goethite
  - hemaitite
  - cuprite
  - pyrolusite

Silicates	Arsenates	Phosphates
hemimorphite	picropharmacolite	vivianite
allophane	mimetite	apatite
chrysocolla		pyromorphite
kaolinite		wavellite
glauconite		diadochite

(Wolf 1976)



EXPLANATION

A DRILL HOLE DISCHARGING TO CREEK—Bed below potentiometric surface
B CORRODED CASING
C WATER RECHARGING SHALLOW AQUIFER THROUGH COLLAPSE ON STREAMBED—Bed above potentiometric surface
D DRILL HOLE ALLOWING RECHARGE TO SHALLOW AQUIFER
E OPEN ABANDONED WELL
F LEAKAGE FROM SHALLOW AQUIFER THROUGH BREAK IN CONFINING LAYER

Figure 5. Mine Hydraulics (Spruill 1987)

concentration of sulfate, trace metals, and TDS. Concentrations of some trace metals such as zinc and iron can range from a few hundred ug/l near the surface to a few hundred thousand ug/l at the base of the mine shaft. Because of the high concentrations of metals, specifically cadmium and lead, the water within the mine stopes is considered unusable for domestic supply, irrigation, and industrial cooling without treatment (Playton 1980).

As early as April 1976 it was reported by Playton and Davis (1977) that the mine water was stratified, Figures 6 through 9. With increasing depth, pH and dissolved oxygen decreased whereas, temperature, specific conductance, sulfate, most trace metals, and TDS increased (Playton 1980 and OWRB 1983). The highest specific conductance value and concentrations of sulfate, iron, manganese, zinc, and the lowest pH occur in the lower portions of the mine shafts (Spruill 1987).

All of the mine shafts sampled display some degree of thermal stratification. Under normal circumstances, the condition of cooler water overlying warmer water would cause an unstable thermal stratification because of differences in density. In the mine shafts, the thermal density difference is over shadowed by a substantial increase in TDS with depth which causes the lower warmer water to have a higher density than the overlying cooler water (Playton 1980).

Based on bi-monthly sampling conducted between April 1976 and June 1977, Playton and others (1980) concluded that a significant linear correlation existed between specific conductance and hardness, calcium, magnesium, sulfate, lithium, and dissolved solids. Aluminum, nickel, and zinc possessed a significant linear correlation with pH when transformed to natural or Napierian logarithms. Sulfate correlates with

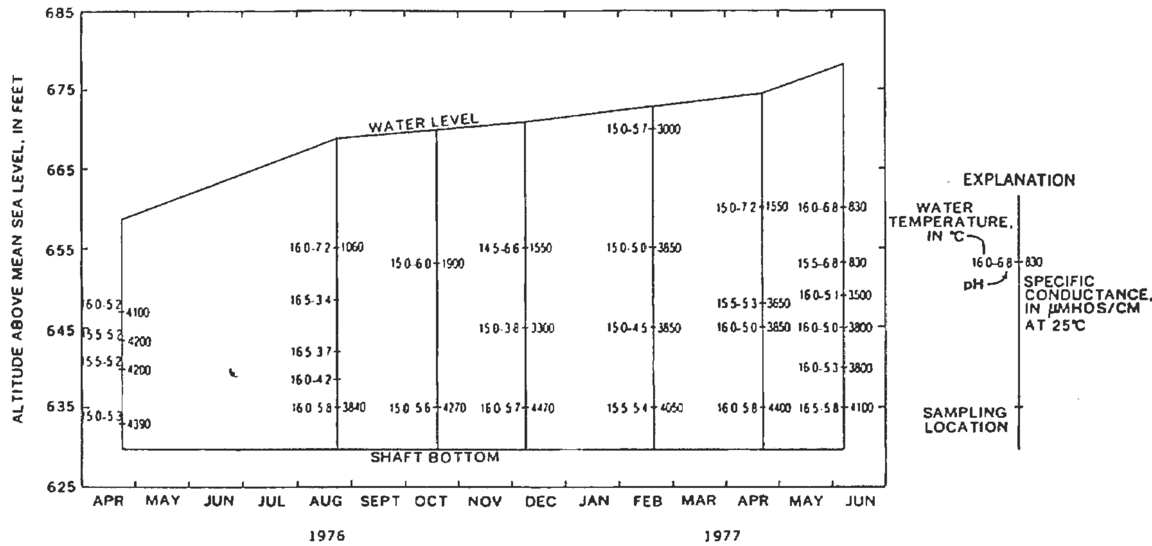


Figure 6. Rise in Water Level Between April 1976
and June 1977, Birthday Mine

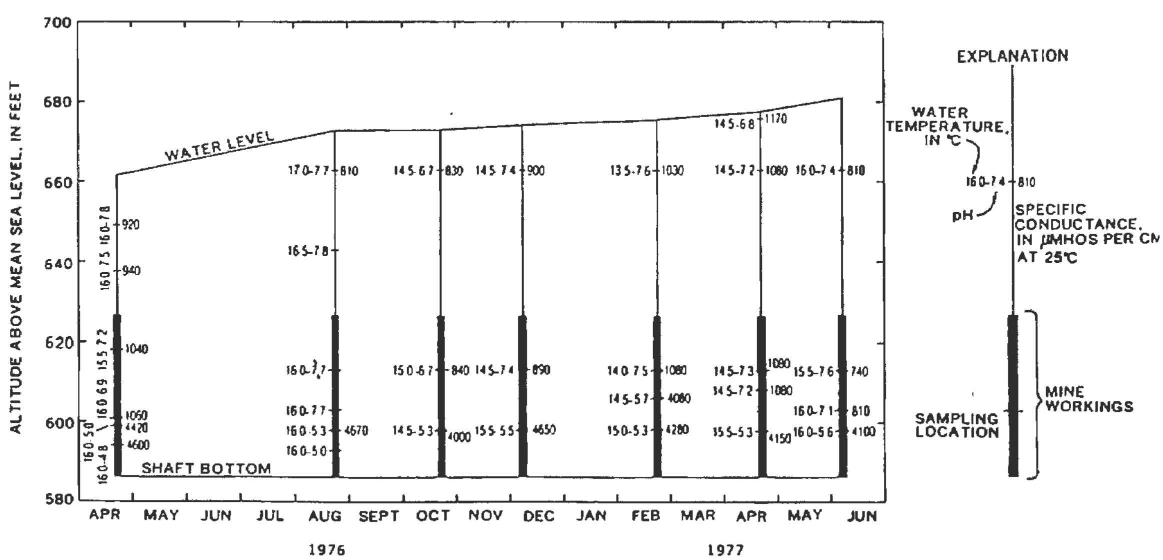


Figure 7. Rise in Water Level Between April 1976
and June 1977, Consolidated No.2-Pl Mine

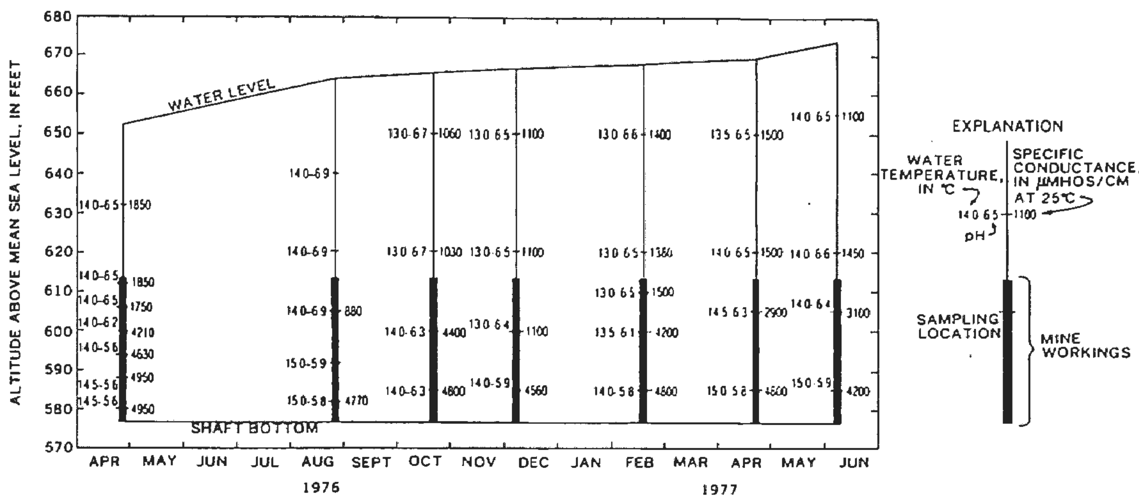


Figure 8. Rise in Water Level Between April 1976 and June 1977, Lucky Bill Air Shaft

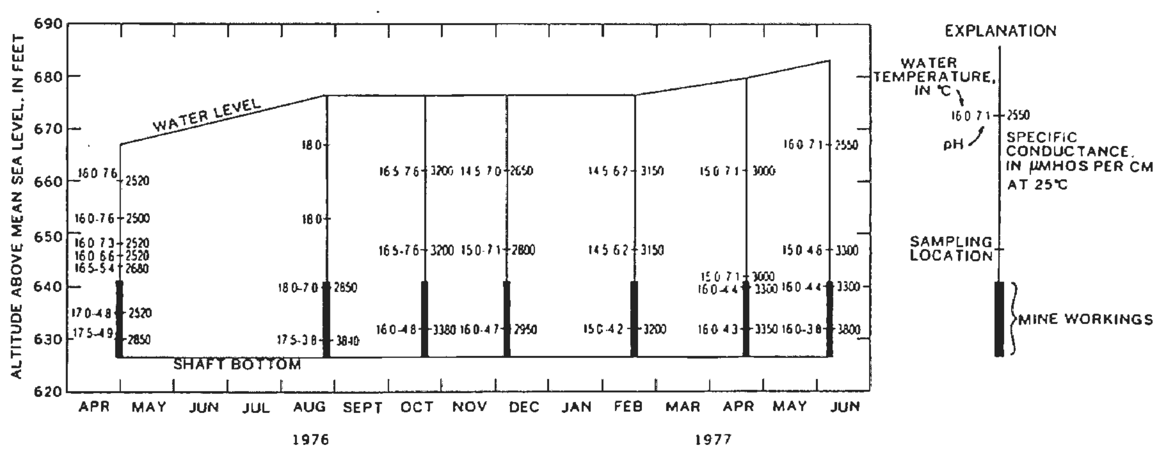


Figure 9. Rise in Water Level Between April 1976 and June 1977, New Chicago Mine

iron, manganese, and zinc concentrations.

No significant seasonal fluctuation or aerial trends in water quality were observed between April 1976 and June 1977 (Playton 1980 and OWRB 1983). Minor fluctuations in water quality within any given mine may occur as the result of dilution and/or circulation caused by inflowing surface water (OWRB I.3 1983).

During the 1982 sampling event, an anomaly was observed at the Admiralty No.4 mine shaft. The Admiralty No.4 mine is located at a lower surface elevation and geographically down gradient from the other mines. Sampling revealed that the mine water was not stratified to the degree as in the other mines. Water sampled at the surface of the shaft was significantly lower in dissolved oxygen and higher in iron and sulfate than what was characterized by the other mines. Flocs, an aggregate of amorphous colloidal particals, of red ferric hydroxide were also observed at the surface of the Admiralty No.4 shaft indicating the upward movement of water (OWRB 1983). The low dissolved oxygen and high Fe and sulfate concentrations throughout the entire water column, ferric hydroxide flocs on the surface of the water, and the geographic location of the Admiralty No.4 mine were all evidence of the upward movement of water within the mine shaft, indicative of a groundwater discharge area.

The mine stopes generally occurred in brecciated zones composed primarily of siliceous chert, essentially devoid of limestone, thus having very little buffering capacity (Spruill 1987). The limestone and dolomite that were present in the host rock and the carbonate strata, that were intersected by the vertical mine shaft, reacted with the acid mine water during the flooding period. In the natural neutralization process, calcium carbonate removes the H^+ from the water, which raises the pH and increases the hardness (Hittman 1981 and OWRB 1983). Hittman (1981) speculated that the limestone may eventually loose its neutralizing capacity as precipitates, primarily gypsum, coat the limestone. This significantly hinders or even prevents the reaction from taking place. Parkhurst (1985), using the computer program PHREEQE, concluded that calcite and dolomite were undersaturated within the mine water and gypsum was nearly saturated.

The highly mineralized acidic water found within the mine workings was restricted to the mining areas. The migration of mine water, either down gradient to the west or downward into the Roubidoux, resulted in dilution from mixing with higher pH water and dispersion (Hittman 1981). As the migrating mine water moves father away from the mining area and is neutralized, the heavy metal concentration will decline because of dispersion, adsorption, and precipitation as hydroxides (Hittman 1981).

Water discharged from the mines, in conjunction with surface runoff from tailing piles and tailing ponds, were the major contributors to the degradation of the water quality in Tar Creek (OWRB 1983). A notable decrease in pH has been observed in Tar Creek down stream from mine discharge points. This has been attributed to a second stage of acid production which occurs when ferric sulfate is hydrolyzed to form ferric hydroxide (Kent et al. 1987). When the water discharged from the mine workings came in contact with the atmosphere, the remaining ferrous iron in solution oxidizes to ferric iron. Because only minute amounts of ferric iron exist in solution at a $pH > 3$, ferric iron and ferric sulfate are rapidly hydrolyzed to form ferric hydroxide (Hem 1962 and Nordstrom 1979). The reactions proceeds as shown below.

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

$$Fe^{3+} + H_2O = Fe(OH)^{2+} + H^+$$

$$Fe(OH)^{2+} + H_2O = Fe(OH)_2^+ + H^+$$

$$Fe(OH)_2^+ + H_2O = Fe(OH)_3 + H^+$$

or

$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3 + 3H_2SO_4$$

ferric sulfate   water   ferric hydroxide   sulfuric acid

This reaction produces three moles of sulfuric acid from each mole of ferric sulfate. This is responsible for significantly reducing the pH of the water in Tar Creek, whose water remains acidic until it travels down stream and encounters a larger body of water with a sufficient buffering capacity to neutralize the water (Kent et al. 1987). A detailed literature review was conducted to evaluate past studies in the Tri-State mining district, mineral equilibria, aqueous geochemistry associated with ore deposits, and acid mine drainage.

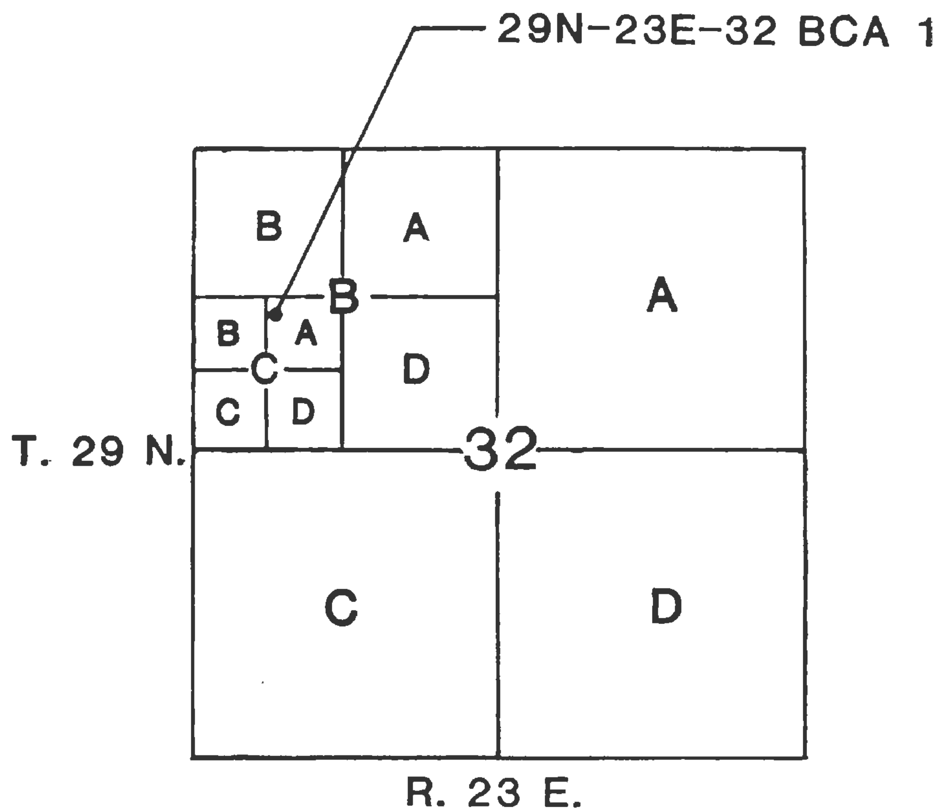
CHAPTER III

METHODOLOGY

Water quality analyses obtained from the U.S. Geological Survey data base WATSTOR were evaluated to determine spatial (both vertical and aerial) and temporal variations in water quality. Geochemical computer simulations using WATEQ4F were conducted to evaluate the equilibrium of aqueous minerals commonly associated with acid mine drainage. Finally, precipitates were collected and analyzed to aid in determining the aqueous mineral equilibrium of the mine water and to validate the geochemical modeling.

Sample Location Numbering System

Point sample locations were identified and labeled using the same methodology as used by the United State Geological Survey (USGS). The standard method of site numbering used by the USGS incorporates the Public Land Survey (PLS) system of township, range, section, and the quarter section of the location usually down to three subdivisions. It is arranged in descending order starting with the township and finishing with the smallest quarter division. If more than one sampling site is located within the same quarter, 10 acres, then a numerical designator is assigned to each site starting with the number one.


29N-23E-32 BCA 1
B
A
B
B
A
C
C
D
D
A
T. 29 N.
32
C
D
R. 23 E.

Sample Location and Description

In response to the increasing demand for water in the Miami-Picher area, the water located within the mine stopes was investigated as an alternative water supply. The USGS in cooperation with the OGS was contacted to provide the water quality data to determine if the water was suitable for public supply, industrial cooling, or irrigation (Playton 1977).

Between April 1976 and June 1977, water samples (Table 3) were collected at seven mines, six in Oklahoma, (Birthday, Consolidated No.2-PL, Lavrion, Lucky Bill, New Chicago, and Skelton) and one in Kansas (Lucky Jew), Figure 10. All seven mines were sampled in April 1976. Birthday, Consolidated No.2-PL, Lucky Bill, New Chicago were sampled in April 1976, August 1976, October 1976, December 1976, February 1977, April 1977, and June 1977. Skelton and Lucky Jew were sampled in April 1976, October 1976, and June 1977. Lavrion was only sampled in April 1976 because it was plugged in July 1976 (Playton 1980). These mines were chosen based on safety, accessibility and aerial distribution (Playton 1980).

Field measurements of pH, specific conductance, and water temperature were collected at multiple depths to determine optimal levels to collect water samples for detailed physical and chemical analyses. During the sampling process, water levels were recorded for the mine being sampled and the Blue Goose mine. All of the samples collected between April 1976 and June 1977 were analyzed by the USGS Central Laboratory in Salt Lake City, Utah (Playton 1980). Details of sampling methods and laboratory procedures are outlined in Playton (1977) and Playton (1980).

TABLE 3

MINE SAMPLE DATA, 1976-1977

Name of mine (site location)	Land-surface altitude at mine shaft (ft)[1]	Depth to water (ft)[2]							Sampling depths (ft)[2]						
		Apr 1976	Aug 1976	Oct 1976	Dec 1976	Feb 1977	Apr 1977	June 1977	Apr 1976	Aug 1976	Oct 1976	Dec 1976	Feb 1977	Apr 1977	June 1977
Lucky Jew	845	183	—	171	--	--	--	164	200		200				180
(35S-23E-3ADD1)									205		220				200
									211		260				210
									222						
									230	--	298	--	--	--	220
									259						240
									287						260
									298						280
															298
Lucky Bill	810	158	146	144	143	142	140	136	178	170	160	160	160	160	155
(air shaft)									198	190	190	190	190	190	190
(29N-23E-30AAA1)									204	205	210	210	200	205	205
									210	218	225	225	210	225	225
									216	228			225		
									222						
									230						
Lavrion	810	144	—	—	—	—	—	—	150						
(29N-23E-29CDD1)									160						
									170	--	--	--	--	--	--
									182						
									191						
Skelton	825	159	--	148	--	--	--	140	165	--	160	--	--	--	150
(29N-23E-28CCB1)															165
New Chicago	825	160	150	151	150	150	147	144	167	160	165	165	165	165	160
(29N-23E-28CAB1)									174	174	180	180	180	185	180
									179	187	198	195	195	187	187
									183	197				195	195
									192						
									197						
Birthday	815	156	146	145	144	142	141	137	168	160	162	160	145	155	155
(20N-23E-28BBB1)									172	167	180	170	160	167	162
									175	173		180	170	170	166
									182	177			180	180	170
										180					175
															180
Consolidated No. 2	830	166	155	155	153	152	150	146	179	165	165	165	165	152	165
(29N-23E-16DDB1)									191	185	215	215	215	165	215
									210	215	230	230	222	215	225
									227	225			230	220	230
									229	230				230	
									234	235					

1 - Estimated to nearest 5 ft above mean sea level from 7½-minute topographic maps.

2 - Measured from land surface.

(Playton et al 1980)

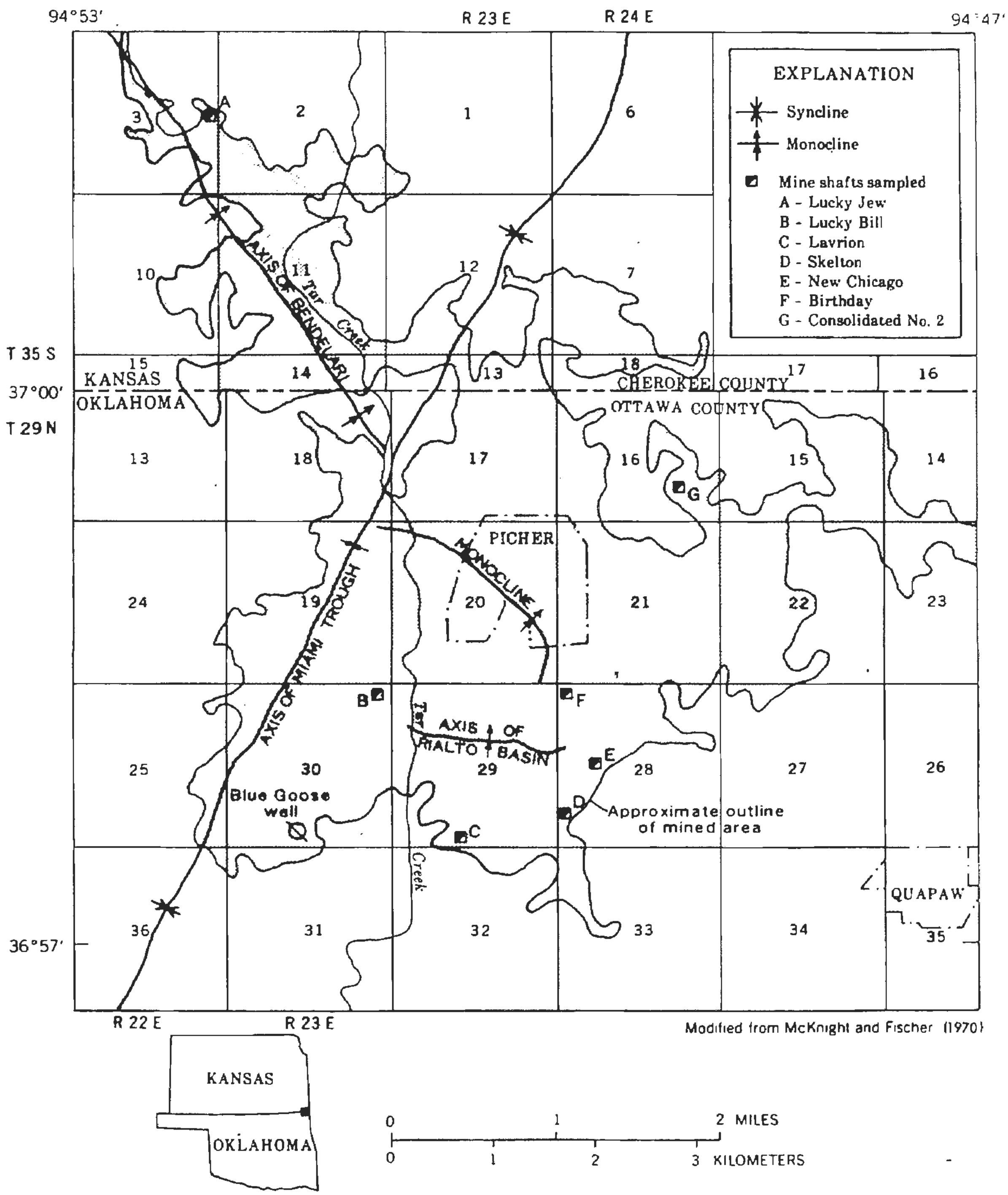


Figure 10. Mine Sample Location Map for 1976-1977
(Playton 1980)

The Oklahoma Water Resources Board conducted a two part investigation of the mine water located within the Picher Field mining district. The first part of the investigation, in conjunction with the Tar Creek Task Force, implemented a monitoring program to determine the chemical quality of the water within the mine stopes (OWRB 1983). The second part of the investigation, in accordance with the Tar Creek Superfund Work Plan, Element I, Task I.3, was to identify the presence of a temporal trend in water quality (OWRB 1983).

Between August 1980 and May 1982 four mines , Admiralty No.4, Consolidated No.2-S, Kenoyer, and Lawyer (New Chicago No.2), were sampled at multiple depths, Figure 11. The Lawyer Shaft collapsed in June 1981, therefore Admiralty No.4 was sampled in its place from July 1981 to May 1982 (OWRB 1983). Admiralty No.4 was sampled in June 1981 and May 1982. Consolidated No.2-S was sampled eight time from August 1980 to May 1982. In May 1981 and June 1982 Consolidated No.2-S was sampled at 20 foot intervals from 0-240 feet below land surface. Kenoyer was sampled nine time from October 1980 to May 1982. In May 1981 and June 1982 Kenoyer was sampled at 20 foot intervals from 0-260 feet below land surface. Lawyer (New Chicago No.2) was sampled seven time from August 1980 to July 1981. In May 1981 and June 1982 Lawyer was sampled at 20 foot intervals from 0-160 feet below land surface. August 1980 and May 1982 sample locations are shown in Figure 11.

In December 1981, water samples were collected from the Farmington Shaft at 2-10 foot intervals from 70 to 270 feet below land surface. Although this sample site was not mentioned in the OWRB report, the OWRB was the only known organization

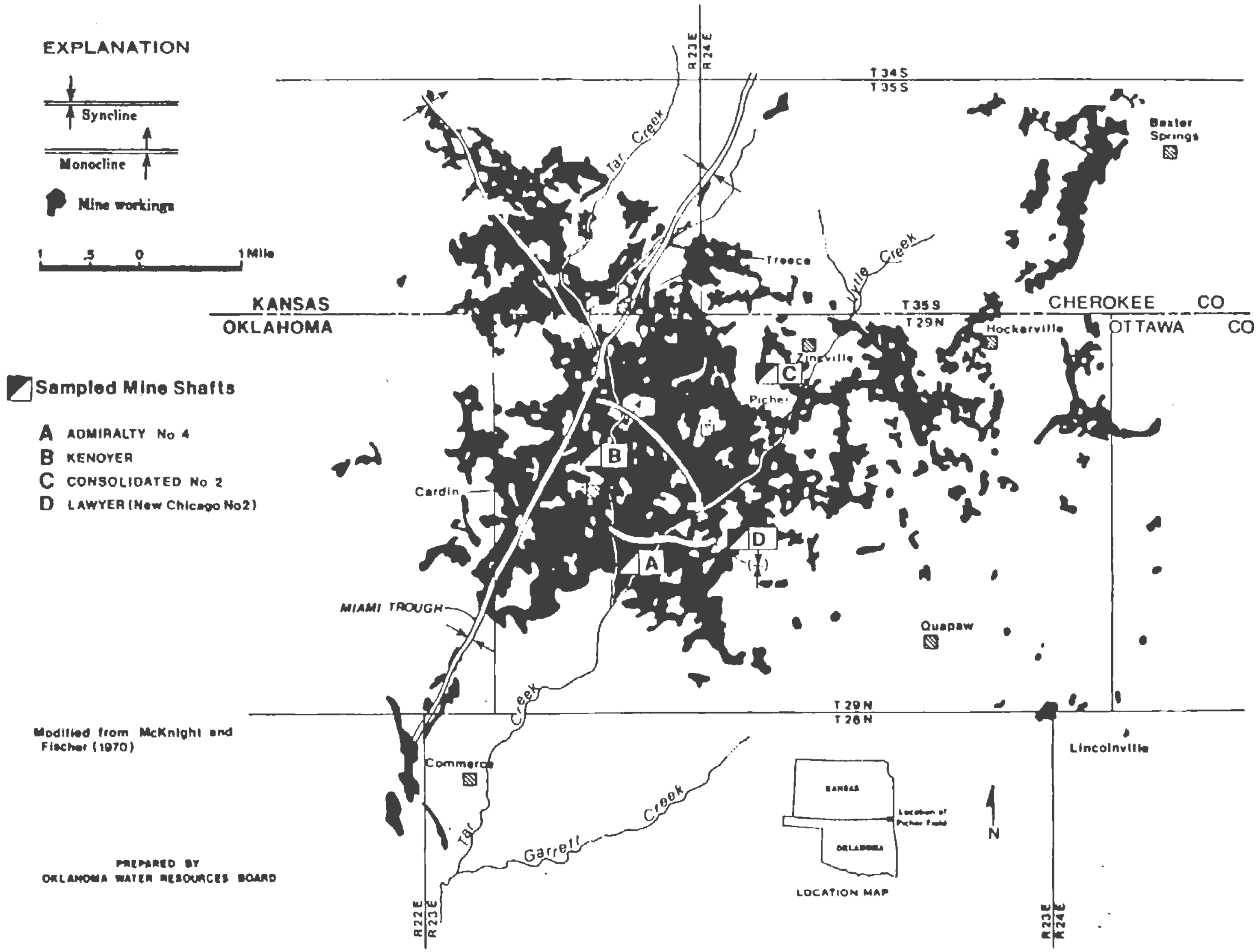


Figure 11. Mine Sample Location Map for 1980-1985
(OWRB 1983)

sampling at this time. For this reason, analyses were included with the OWRB sampling data.

Field measurements of pH, specific conductance, dissolved oxygen, and temperature were aquired with a model 4041 digital Hydrolab at the time the samples were collected (OWRB 1983). Further details of sampling methods and laboratory procedures are discussed in OWRB 1983 Task I.3. Water samples were submitted to the State Environmental Laboratory of the Oklahoma State Department of Health for chemical analysis.

Because acid mine water continued to intermittently discharge into Tar Creek, the USGS undertook the task of determining the chemical evolution of the mine water and its effect on surface water chemistry, primarily Tar Creek (Parkhurst 1987). A detailed study was conducted on the mobilization and fate of heavy metals within and discharging from the mines, but the results of the full study were never published (Ragone 1988 and Oral communication with Parkhurst 1991).

Between November 1983 and February 1986 water samples were collected from abandoned mines, mine-water discharge points, and from selected surface-water locations. During this study 169 water samples were collected at 49 different locations (Parkhurst 1987). Of these, the water samples collected from six mines in Oklahoma, were used in this study. They are the Admiralty, Consolidated No.2-S, Farmington, Gordon, Kenoyer, and Lucky Syndicate mines. Water samples were collect at Admiralty, Consolidated No.2-S, Farmington, Kenoyer, and Lucky Syndicate mines on November 1983, March 1984, and June 1985, Figure 11. Gordon mine was sampled only on November 1983. Spring discharge and surface location sampled during this period include Air Shaft Pipe at OWRB 4, Borehole discharge at OWRB 4S, Weir at OWRB 4, and Commerce Spring at OWRB 14.

Field measurements of pH, specific conductance, dissolved oxygen, temperature, and redox potential were recorded at the time of sampling. Immediately upon obtaining the sample, alkalinity was determined from end-point titration (Parkhurst 1987). Water samples were collected at a single depth in all of the mine except Farmington Shaft were it was sampled at three intervals. Water samples were analyzed for major ions, trace metals, and nutrients at three laboratories, the Central Laboratory of the Water Resources Division in Arvada, Colorado, and the U.S. Geological Survey laboratories in Denver, Colorado and Reston, Virginia (Parkhurst 1987).

Water Quality Data

Water quality data used in this paper were obtained from the USGS WATSTOR data base. Refined data and sample location information and descriptions were derived from USGS, OGS, and OWRB publications.

Vertical, aerial, and temporal variations in mine water quality were determined from water quality analyses collected from selected mines between April 1976 and June 1985. During this time frame, samples of mine water were collected from April 1976 through June 1977 and from November 1983 through June 1985. Sparse intermediate mine water quality data were randomly collected from October 1980 though May 1982.

Vertical Variations

Vertical variations in water quality were determined from water analyses collected from selected mines between April 1976 and June 1981. Water samples were collected at 2 to 20 foot intervals and analyzed for temperature in °C, pH, dissolved oxygen (DO) in mg/l, and specific conductance (SC). These four physical parameters were plotted on X-Y plots to visually display numerical fluctuations with depth. Vertical water quality data and vertical plots are shown in Appendix A.

During the first sampling period, vertical variations in mine water quality were determined from samples collected at Birthday, Consolidated No.2-Pl., Lucky Bill, and New Chicago mines. Water samples were collect from these mines at variable depths on seven separate occasions between April 1976 and June 1977, as shown on Table 3.

Between August 1980 and December 1981, vertical variations in water quality were determine from limited water analyses data collected at Consolidated No.2-S, Farmington, Kenoyer, and Lawyer mines. Water samples were collected at Consolidated No. 2-S mine on May 11, 1981 and June 11, 1981 at 20 foot intervals from 0 to 240 feet below the static water level. Farmington shaft was sampled on December 1, 1981 from 70 to 270 feet below the static water level at 2 to 20 foot intervals. The Kenoyer shaft was sampled on May 11, 1981 and on June 11, 1981. Water samples were collected at 20 foot intervals from 0 to 200 feet below the static water level on May 11, 1981 and from 0 to 260 feet below static water level on June 11, 1981. Water samples were collected within the Lawyer Mine at variable intervals from 0 to 210 feet below the static water level on August 19, 1980 and at 20 foot intervals from 0 to 160 on May 12, 1981.

Vertical variations in aqueous mineral equilibrium within the mine water were evaluated using WATEQ4F. The saturation index (SI) of selected minerals were calculated with WATEQ4F to evaluate the variation in mineral saturation with depth during the period when the mines were initially flooding, Appendix D. Water quality data was collect from the Consolidated No.2-Pl mine in April 1976 at 191, 227, 229, and 234 feet down from the shaft opening and from the Farmington mine in June 1985 at 140, 176 and 194 feet below the surface of the water.

Spatial Variations

Spatial variations in mine water quality were determined from water samples collected with in the mine stopes in April 1976, June 1977, June 1981, July 1981, November 1983, and June 1985. The data used to evaluate variations in mine water quality are tabulated in Appendix B.

During the first sampling period, water analyses from samples collected in the mine stopes of five mines, Consolidated No.2-Pl, Lucky Bill, Lavrion, New Chicago, and Birthday, in April 1976, and from four mines, Consolidated No.2-S, Lucky Bill, New Chicago, and Birthday, in June 1977, were selected to evaluate spatial variations in water quality.

Samples of mine water collected in June and July of 1981 were analyzed for physical properties, SO_4, and a few selected trace metals. Admiralty No.4, Consolidated No.2-S, and Kenoyer mines were all sampled at 200 feet below water surface, in June 1981, whereas, Consolidated No.2-S, Kenoyer, and Lawyer mines were sampled at 180, 180, and 200 feet, respectively, in July 1981.

During the second sampling period, water samples collected within the mine stopes of Admiralty No.4, Consolidated No.2-S, Farmington, Gordon, Kenoyer, and Lucky Syndicate, in November 1983, Admiralty No.4, Consolidated No.2-S, Farmington, Kenoyer, and Lucky Syndicate mines, in March 1984, and Consolidated No.2-S, Farmington, Kenoyer, and Lucky Syndicated mines, in June 1985, were chosen to evaluate spacial changes in mine water quality.

TEMPORAL VARIATIONS

Mine-water quality data used to evaluate temporal variations in the mine water was compiled from April 1976 through June 1985. This includes quarterly sampling of four mines, Birthday, Consolidated No.2-Pl, Lucky Bill, and New Chicago from April 1976 through June 1977 and annual sampling of Admiralty No.4, Consolidated No.2-S, Kenoyer, and Lucky Syndicate mines from November 1983 though June 1985. Limited intermediate data was collected for Admiralty No.4, Consolidated No.2-S, Kenoyer, Lawyer (New Chicago No.2), and Lucky Syndicate mines from 1980 through 1982. These mines were sporadically sampled between 1980 and 1982 with variable and incomplete analyses.

Analyses from water samples collected near the base of the mine shafts, typically adjacent to the mine workings, were chosen to relay trends in water quality. Water quality data from these eight mines were plotted on X-Y graphs to visually display variations within the mine water over time. Selected constituents included temperature, pH, DO, SC, alkalinity, CO_2, Ca, SO_4, Al, Cd, Fe, Pb, Ni, and Zn.

Precipitate Collection

Precipitates were collected at two mine water discharge locations, OWRB 4S and OWRB 14. The first reported point where mine water discharge was observed was the Commerce Spring, Figure 12, located on Mayers Property at 28N-23E-07 BDD. This location, designated site OWRB 14 by the Oklahoma Water Resources Board, has a surface elevation of 790 feet MSL. Mine water has been discharging continuously from this location since November 1979. In June 1982, the USGS determined that the Commerce Spring was 123 feet deep using a caliber-log. The spring is thought to be an exploration hole connected to Cactus mine workings by solution openings (Hittman 1982). A weir was installed approximately 100 yards down stream to the southeast of the Commerce Spring at 28N-23E-07 CAA to measure the combined discharge from OWRB sites 13 and 14.

The second point of discharge, designated OWRB 4S by the Oklahoma Water Resources Board, is located at 29N-23E-29 CDC. It consists of the combined discharge from an opening created from a decayed tap root and a borehole which intersects Lavrion mine workings, Figure 12. These two discharge points have a surface elevation of 799 feet above MSL (OWRB 1983). Discharge from OWRB 4S occurs intermittently, controlled by the fluctuation of the mine water levels which are dictated by precipitation. Approximately 30 feet to the east of the borehole discharge is a steel stand pipe which is believed to be an air vent for the Lavrion mine. The combined discharge from these points is funnelled through a weir located approximately 100 feet to the west of the discharge points.

Precipitates were collected at OWRB 14, OWRB 4S, and associated weirs on

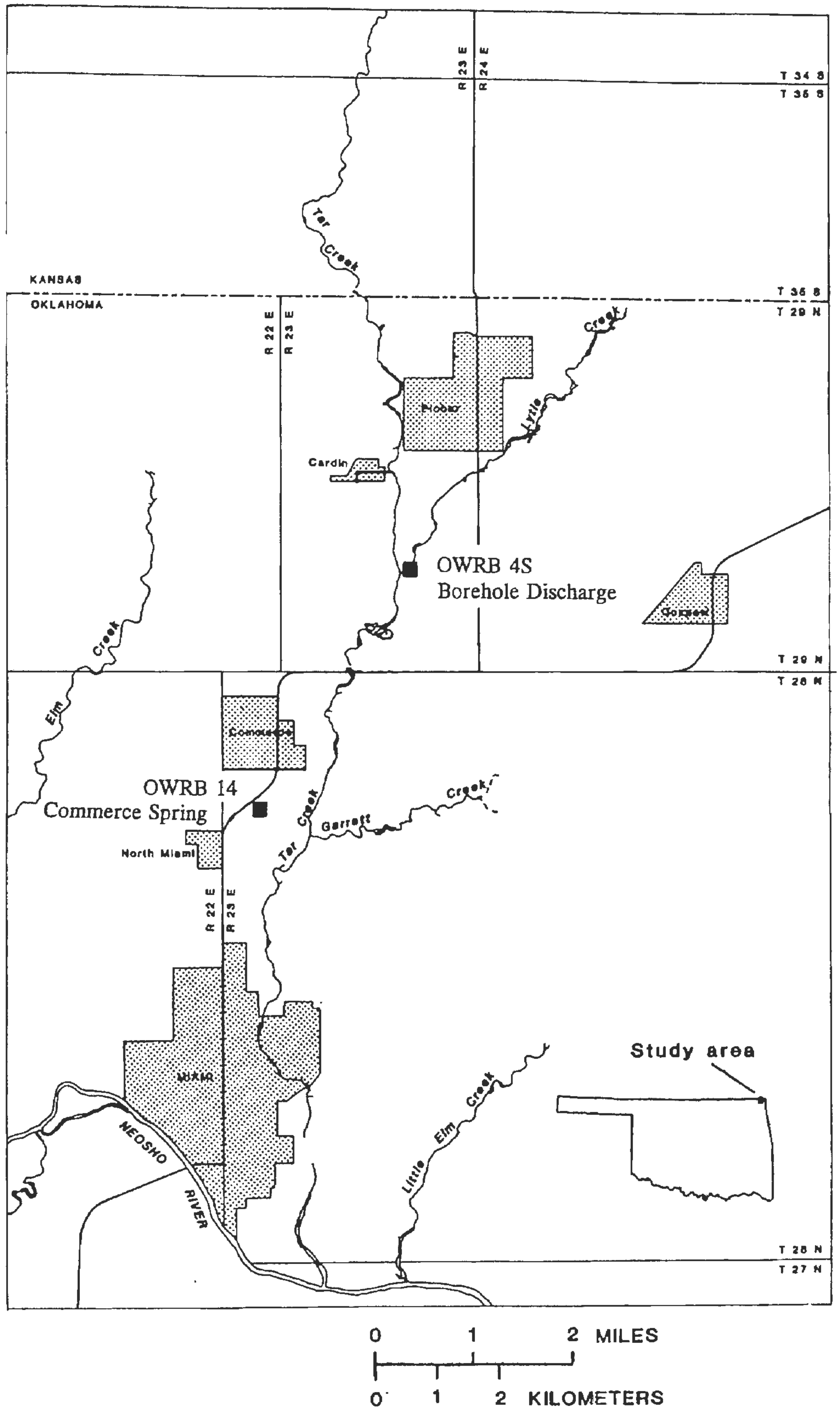


Figure 12. Mine Discharge Location OWRB 14 and OWRB 4S (Parkhurst et al 1988)

April 17, 1992 and on December 4, 1992. The mineralogy of the precipitates were determined using x-ray diffraction with copper radiation.

Geochemical Modeling

The computer program WATEQ4F was used to calculate the equilibrium-speciation distribution of major and trace element species within the mine stopes. Water quality data used in the WATEQ4F calculations for selected mines came from the U.S. Geological Survey Data base WATSTOR QW. Each analysis contained the physical properties, major anions and cations, and most of the trace metals As, B, Ba, Cd, Cu, Fe, Pb, Mn, Ni, Sr, Zn, Al, Se, and Li. The chemical data used in the calculations are tabulated in Appendix E.

Redox Determination

Field determined reduction-oxidation potentials were entered in the WATEQ4F runs as Eh. In analyses where the redox potentials were not determined, an initial WATEQ4F run was used to calculate the Eh and pe from the $NO_3^{=}/NH_4^{+}$ couple. The saturation indexes for selected aqueous minerals were calculated using the newly calculated Eh value, during a second computer run.

Saturation Index

In this study, the degree of saturation of aqueous minerals within the mine water was represented by the saturation index (SI), where the SI is the log of the ionic activity product of the mine water divided by the solubility product of the respective mineral. A zero SI indicates the water was at equilibrium with respect to the mineral phase; positive values indicate oversaturation, and negative values indicate undersaturation. Geochemical equilibrium calculations derived from WATEQ4F simulations do not conclusively prove the presence or absences of aqueous minerals, but rather provides an indication of the tendency for the reaction to occur.

The results of the WATEQ4F calculated saturation indexes for minerals commonly associated with acid mine drainage were used to evaluate the degree of saturation of minerals likely to precipitate in the Picher field. Selected aqueous minerals evaluated using WATEQ4F simulations are provided in Table 4.

Mineral Species

Typically gibbsite and kaolinite were thought to control the Al concentration in an acidic aqueous environment. In the Al_2O_3-SO_3-H_2O system, the stability of the aluminum mineral is dependant on the pH and sulfate activity of the solution, Table A. Nordstrom (1982) noted that gibbsite and kaolinite were not stable in acid sulfate water, thus in the pH range of 4-6 alunite, basaluminite, and diaspore are the likely precipitates. In the alunite/gibbsite stability range, pH 4-12, basaluminite is the most kenetically favored Al mineral to precipitate in an acid sulfate environment.

Iron concentrations in acidic mine water were primarily controlled by the precipitation of ferric oxyhydroxide minerals. WATEQ4F typically evaluates the equilibrium controls on iron concentration by the solubility of ferrous and ferric minerals. The most common of these minerals are ferric hydroxide, goethite, hematite, jarosite, $Fe_3(OH)_8$, siderite, melanterite, and greenalite. Ferric hydroxide

TABLE 4

SELECTED PRECIPITATES ASSOCIATED WITH ACID MINE DRAINAGE

CALCITE	$CaCO_3$
DOLOMITE	$CaMg(CO_3)_2$
GYPSUM	$CaSO_4 * H_2O$
QUARTZ	SiO_2
CHALCEDONY	SiO_2
ALUMINUM HYDROXIDE	$Al(OH)_3$
BAUXITE	
BOEHMITE	AlOOH
DIASPORE	AlOOH
GIBBSITE	$Al(OH)_3$
ALLOPHANE	$Al_2SiO_5 * nH_2O$
JURBANITE	$Al(OH)SO_4$
BASALUMINITE	$Al(OH)_{10}SO_4$
ALUNITE	$KAl_3(SO_4)_2(OH)_6$
KAOLINITE	$Al_2Si_2O_5(OH)_4$
BARITE	$BaSO_4$
FERRIHYDRITE	$Fe_{4-5}(O,OH)_{12}$
FERRIC HYDROXIDE	$Fe(OH)_3$
FERROSOFERRIC HYDROXIDE	$Fe_3(OH)_8$
GOETHITE	FeOOH
HEMATITE	Fe_2O_3
SIDERITE	$FeCO_3$
MELANTERITE	$FeSO_4*7H_2O$
GREENALITE	$Fe_3Si_2O_5(OH)_4$
JAROSITE Na	$NaFe_3(SO_4)_2(OH)_6$
JAROSITE K	$KFe_3(SO_4)_2(OH)_6$
JAROSITE H	$HFe_3(SO_4)_2(OH)_6$
PYROLUSITE	MnO_2
RHODOCHOSITE	$MnCO_3$
MnHPO4	$MnHPO_4$
CUPROUSFERRITE	$CuFe_2O_4$
SMITHSONITE	$ZnCO_3$
ZnSiO3	$ZnSiO_3$
OTAVITE	$CdCO_3$
CERRUSITE	$PbCO_3$
ANGLESITE	$PbSO_4$
PLUMBOGUMMITE	$PbAl_3(OH)_7P_2O_7$

forms from the hydrolysis of ferric iron. Both ferric hydroxide and goethite are common precipitates associated with acid mine drainage under a wide range of pH, whereas jarosite and melanterite are the dominant ferric iron precipitates under extremely acidic conditions, Table 5. Ferrosoferric hydroxide, $Fe_3(OH)_8$, is a dominant ferrous iron species associated with reducing soils, but comprises only a small percentages in acid sulfate waters (Ball 1979). Hematite rarely forms from direct precipitation but from the dehydration of goethite and ferric hydroxide. Under the given Eh, pH, and sulfate activity, the most likely iron minerals to control the iron concentration by precipitation are ferric hydroxide, goethite, and under high alkalinities and low Eh, siderite.

The activities for copper ferrites, calculated by WATEQ4F, which include cuprousferrite and cupricferrite, typically run several orders of magnitude oversaturated with respect to equilibrium constants, but are not known to control the copper or iron concentrations in natural water (Ball 1979).

WATEQ4F Runs

Six sets of WATEQ4F computer runs were conducted to evaluate the speciation and equilibrium of aqueous minerals within the mine stopes. Water quality data and WATEQ4F calculated SI values are tabulated in Appendix E.

The first set of runs was conducted to determine the saturation index of plausible aqueous minerals during the initial phases of the mine flooding. Water quality data collected in April 1976 from the lower portions of Birthday, Consolidated No.2-Pl., Lucky Bill, and New Chicago mines, represented the water quality within

TABLE 5

IRON AND ALUMINUM PRECIPITATE STABILITY FIELDS

ALUMINUM MINERAL	FORMULA	pH RANGE	SOURCE[1]
Alungen	$KAl_3(SO_4)_2(OH)_6$	< 0	1982
Jurbanite	$Al(OH)SO_4$	0-4	1982
Alunite	$KAl_3(SO_4)_2(OH)_6$	3-7	1982
Basaluminite	$Al(OH)_{10}SO_4$	> 4	1982
Gibbsite	$Al(OH)_3$	> 6	1982
Kaolinite	$Al_2Si_2O_5(OH)_4$	> 6	1982
IRON MINERALS			
Melanterite	$FeSO_4*7H_2O$	0-1.5	1982
dehydration			
Rozenite	$FeSO_4*4H_2O$	0-1.5	1982
Szomolnokite	$FeSO_4*H_2O$	0-1.5	1982
dehydration/oxidation			
Copiapite	$Fe^{2+}Fe^{3+}(SO_4)_6(OH)_2*2OH_2O$	0-1.5	1982
Jarosite	$KFe_3(SO_4)_2(OH)_6$	1.5-2.5	1979
Ferrihydrite	$Fe_{4-5}(O,OH)_{12}$	2-5	1970
Ferric Hydroxide	$Fe(OH)_3$	> 2.5	1970
Goethite	FeOOH	> 2.5	1979
dehydration			
Hematite	Fe_2O_3	----	1970
Lepidocrosite	FeO*OH	4-7	1970

(Precipitates associated with acid sulfate waters)

Note[1]:

1982 - Nordstrom 1982
1979 - Nordstrom 1979
1970 - Langmuir 1970

the mine stopes during the initial phases of flooding.

The second set of runs was conducted to evaluate the saturation index of plausible aqueous minerals within the mine stopes after the mines had flooded and the water stabilized. Water quality data, collected in June 1985 from the lower portions of Admiralty No.4, Consolidated No.2-S, Farmington, and Kenoyer mine shafts, were used to represent the water within the mine stopes.

The third set of runs was conducted to evaluate the variation in the SI of selected minerals with depth during the period when the mines were flooding. Water quality data were collect in April 1976 at 191, 227, 229, and 234 feet down from the shaft opening of the Consolidated No.2-Pl mine. During the sampling event, the water level within the mine shaft was at an elevation of 662 feet MSL, approximately 167 feet down from the shaft opening.

The fourth set of runs was conducted to evaluation vertical variations in the SI of selected minerals commonly found in an acid mine environment after the mines had flooded and stabilized. Water quality data collected in June 1985 at 140, 176, and 194 feet below the static water level in the Farmington mine shaft was used in the runs.

The fifth set of runs was conducted to determine temporal variations in the SI of selected minerals. Water quality data collected from the lower portions of the Consolidated No.2-Pl mine shaft, from April 1976 to June 1977, and Consolidated No.2-S mine shaft, from October 1983 to June 1985, were used in the WATEQ4F runs.

The sixth set of runs was conducted to evaluate the SI of selected minerals within the springs and to provide a WATEQ4F simulation to correlate with collected precipitates. Water quality data, collected in June 1985 at the discharge points for the OWRB 4S Borehole Discharge and Commerce Spring, were used in the WATEQ4F runs. The calculated saturation indexes are tabulated in Appendix D.

CHAPTER IV

DISCUSSION

Variations in Mine Water Quality

The water within the mine workings was evaluated for spatial and temporal variations in water quality. Spatial variations in water quality were further separated into vertical and spatial components. Emphasis was placed on the mine water quality data obtained during the first and second sampling periods.

Spatial Variations

In April 1976, the mines were in the initial stages of flooding. Water levels within the mines were low but rapidly rising. Stratification of the mine water was only observed within mines that contained water levels that extended well above the mine stopes, such as Consolidated No.2-Pl. and Lucky Bill, Figure 13.

By June 1977, the water levels within the mines had risen approximately 20 feet. All of the mines sampled displayed some degree of stratification. The temperature, pH, and specific conductance of the mine water remained relatively constant for the first few tens of feet below the surface. At the approximate depth where the water column intersected the middle to lower portions of the mine stopes, an abrupt change in water quality occured. Within a 5 foot interval, most of the water

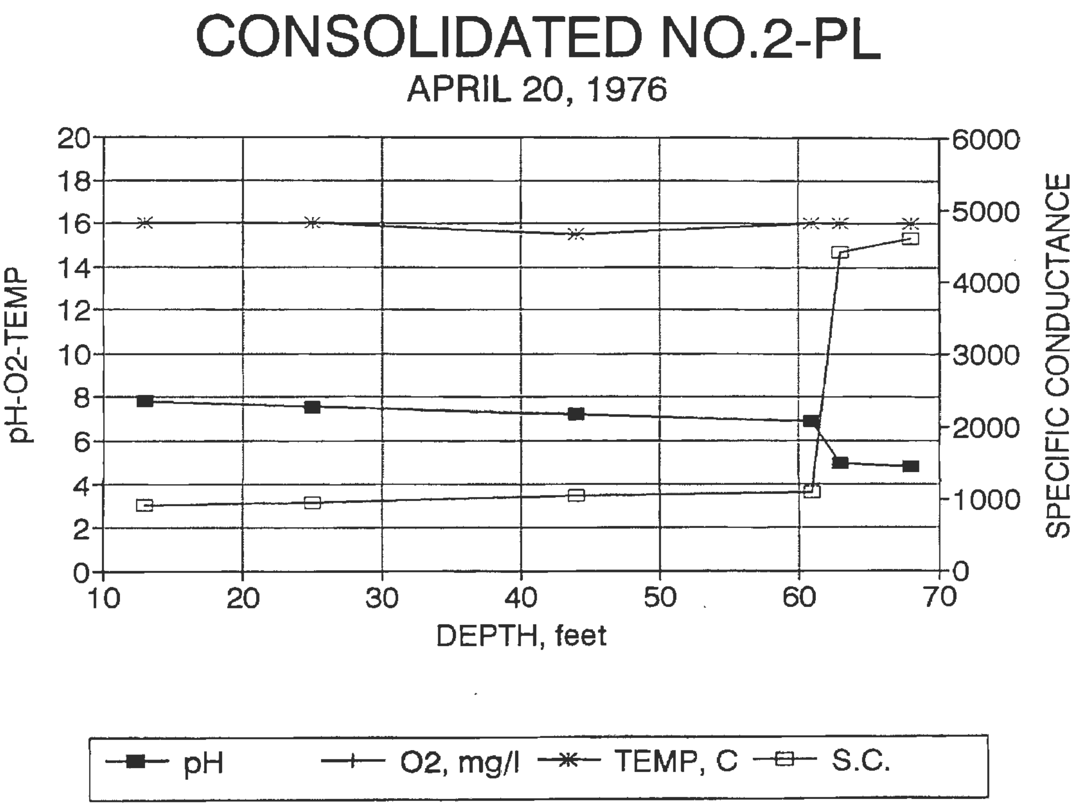


Figure 13. Vertical Variations in Water Quality
Consolidated No.2-PL, April 20, 1976

within the mines exhibited a sharp increase in temperature, specific conductance, sulfate and most metal concentrations, and a decrease in the pH and alkalinity.

The upper portions of the water within the Consolidated No.2-PL mine shaft were saturated with respect to allophane, oversaturated with respect to diaspore, $ZnSiO_3$, and otavite, became undersaturated with respect to otavite with increasing depth. Bicarbonate concentration were low throughout the entire water column, decreasing with depth resulting in the absence of carbonate mineral (aragonite, calcite, dolomite, siderite rhodocrosite, otavite, and cerrusite) in the lower portions of the shaft. The water in the upper portion of the mine shafts were undersaturated with respect to the sulfate minerals gypsum, alunite, basaluminite, jurbanite, and jarosite becoming oversaturated with depth in response to increasing sulfate concentrations.

The entire water column within the shaft was saturated with respect to barite and quartz. Dissolved Al and Fe concentrations within the mine water increased four orders of magnitude with increasing depth. The water within the mine shafts were oversaturated with respect to kaolinite, boehmite, diaspore, gibbsite, goethite, and ferric hydroxide, and maintained the same level of oversaturation throughout the entire water column, Figure 14.

During first sampling period, the mines were in the initial stages of flooding. The water levels within the mines were rapidly rising as the mines received natural recharge in the lower portion from the Boone aquifer and rapid artificial inflow of surface water via open mine shafts, collapse features, and abandoned exploration holes.

The water located within the mine stopes was characterized by moderate to

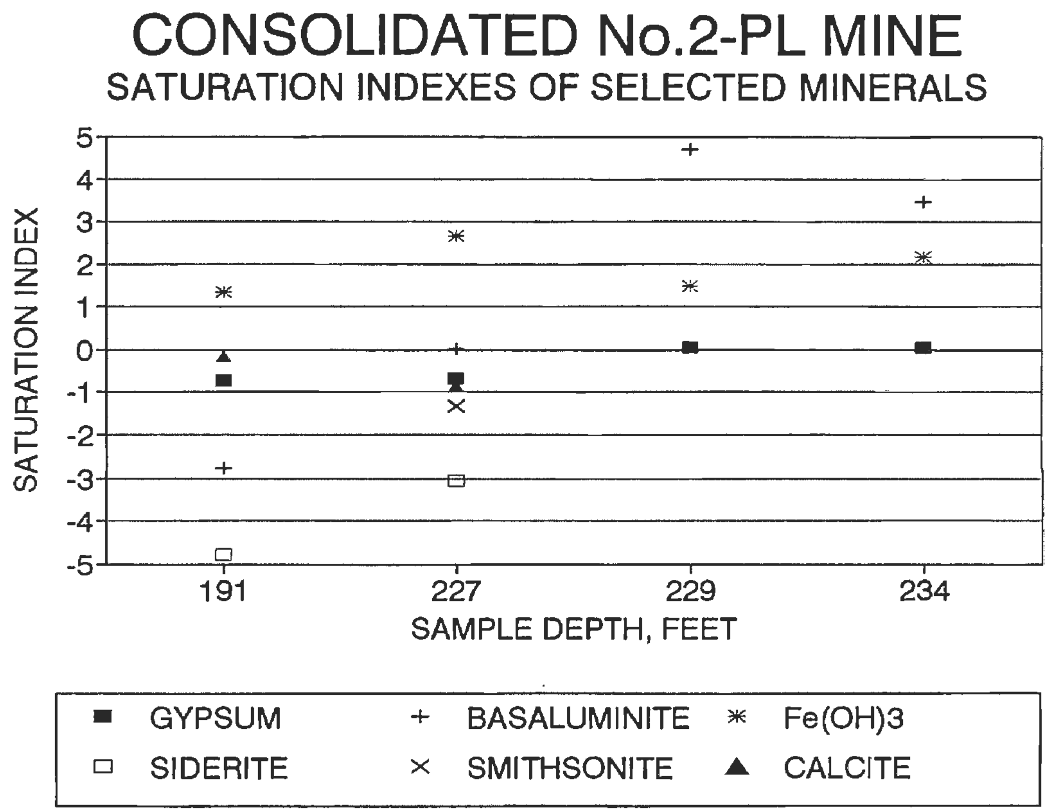


Figure 14. Saturation Indexes for Selected Minerals
Consolidated No.2-PL April 20, 1976

low pH, 3.8-5.9, and low but variable alkalinities, generally < 5 mg/l ($CaCO_3$), never exceeding 37 mg/l ($CaCO_3$). Fluctuations in the alkalinity in the mine water follow the same trends observed in elevated concentrations of dissolved CO_2. As expected from the low bicarbonate concentrations, all of the mines were undersaturated with respect to carbonate minerals. High but variable calcium and sulfate concentrations generally averaged 500 mg/l and 3000 mg/l, respectively, were controlled by the precipitation of gypsum, Figure 15. The water located within the mine stopes was oversaturated with respect to barite, alunite, and basaluminite in relation to the high sulfate and Al concentration. Trace metal concentration were high with Zn > Fe > Al > Ni > Cd > Pb.

During the initial stage of the mines flooding, Zn concentration were high and relatively stable. High Zn and SiO_2 concentrations in the waters resulted in oversaturation with respect to $ZnSiO_3$ and quartz. Iron concentrations were high and generally increased with time. Aluminum concentration varied one to two orders of magnitude, whereas Ni, Cd, and Pb concentrations were relatively stable. The water within the mine stopes were oversaturated with respect to diaspore, kaolinite, ferric hydroxide, goethite, and jarosite, saturated with respect to boehmite and gibbsite, and near saturation with respect to allophane, jurbanite, and ferrosoferric hydroxide. This is the result of the high Al and Fe concentrations in the mine water.

No discernable aerial variations in water quality were observed for the first sampling period. The water quality within the mine stopes appeared to be primarily governed by the rapid inflow of oxygenated surface waters, especially after periods of heavy rain fall, and additional contact with ore bodies resulting from increasing water

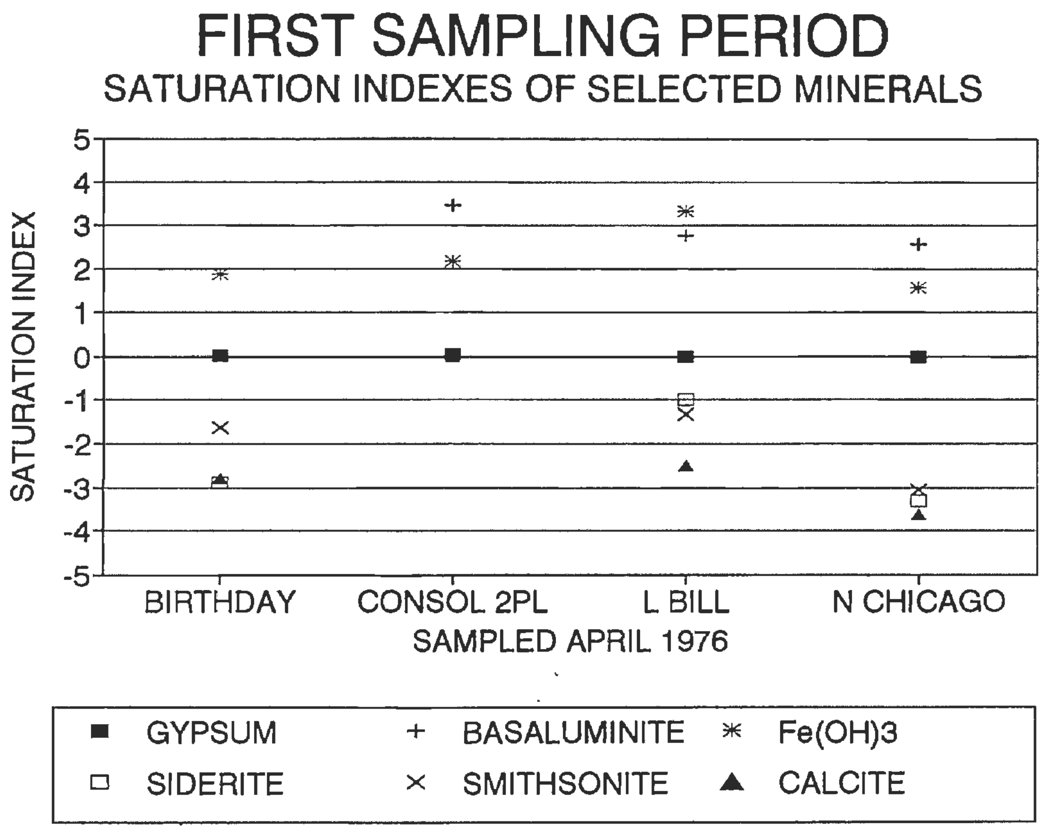


Figure 15. Saturation Indexes for Selected Minerals
Spatial - April 1976

levels.

By the second sampling period, November 1983 through June 1985, the mine workings had completely filled with water. Most of the surface inflow points had been remediated by stream diversion structures and plugging abandoned exploration holes. This restricting the inflow of oxygenated surface water to periods of intense precipitation and consequent flooding. The increased depth of water within the mines and the remediation of surface inflow points resulted in the water within the mine stopes reducing to a transitional environment.

The water within the mine shafts continued to be stratified, during the second sampling period, Figure 16. Temperature, sulfate and most trace metal concentrations increased, whereas pH decreased with depth. The water in the Farmington mine shaft was separated into three zones defined by variations in the reduction-oxidation potential of the water. The upper and lower portions of the shaft were classified as oxidizing-transitional zones while the middle interval was a transitional-reducing zone.

The upper most zone, located at 140 feet below the water surface, was characterized by a high calcium concentrations, moderate alkalinity, lower sulfate and trace metal concentrations, and a higher Eh.

The middle zone was characterized by an abrupt drop in the Eh of the mine water. Maximum concentrations of alkalinity and calcium were observed in this interval. Most trace metal concentrations remained the same, although Zn and sulfate concentrations doubled, whereas Fe, Ni, and Co increased by a order of magnitude. This is most likely the result of marcasite and pyrite dissolving.

The lower most zone was characterized by a 60 % increase in the Eh and a 50

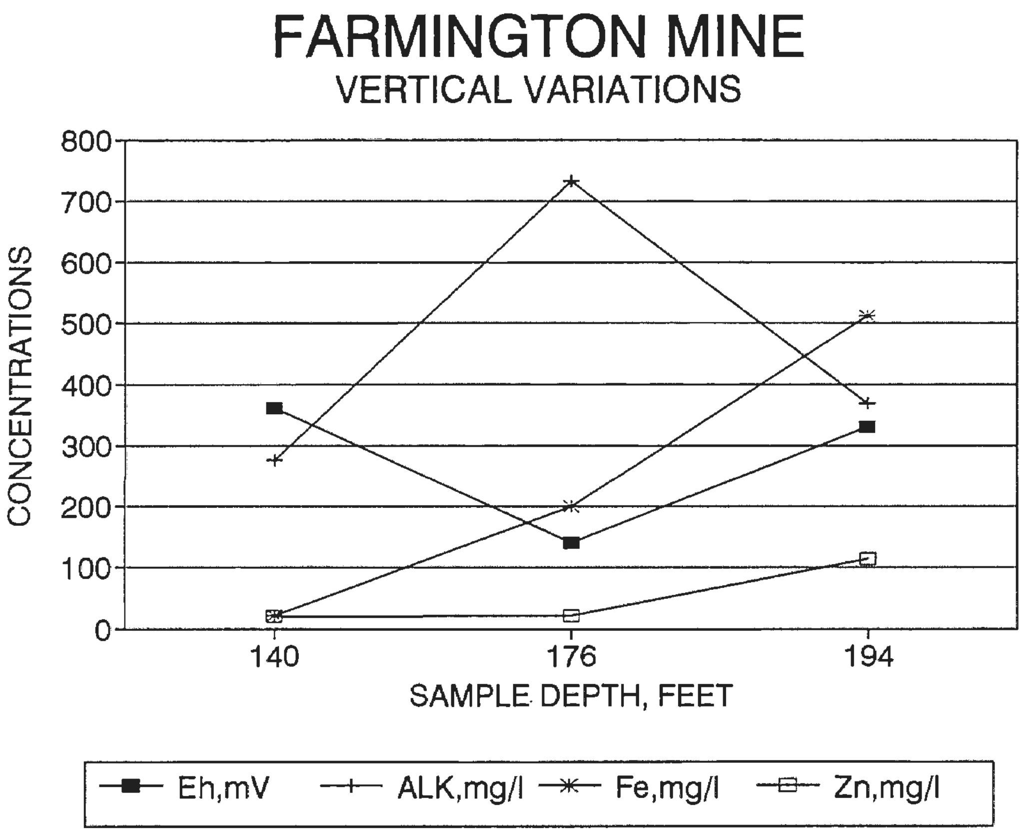


Figure 16. Vertical Variations in Water Quality
Farmington, June 12, 1985

% decrease in alkalinity. Calcium concentrations decreased but remained high, whereas Mg, Fe, Co, and sulfate concentrations increased. Zinc, Cd, and Pb concentrations increased by an order of magnitude reflecting an increase in the dissolution of sphalerite and galena under higher Eh and lower pH conditions.

The entire column of water was oversaturated with respect to quartz, barite, diaspore, allophane, goethite, and $ZnSiO_3$. The water was oversaturated with respect to ferric hydroxide and jarosite in the upper and lower portions of the mines and undersaturated in the middle portion, reflecting the changes in ferric iron with respect to variation in Eh.

The alkalinity within the mine water was moderately high, inversely following the same trend as the redox potential. Despite the increase in alkalinity, the water remains under saturated with respect to the most carbonate minerals. The high alkalinity resulted in the water becoming saturated with respect to siderite in the upper and low portions of the mine and oversaturated in the middle portion, a result of high ferrous iron concentrations reflecting the low Eh.

Sulfate concentrations in the mine water doubled, whereas Al, Zn, and Fe concentrations increase by an order of magnitude between the upper and lower sampling portions. As the sulfate concentrations increased with depth, the water within the mines became saturated with respect to gypsum and oversaturated with respect to alunite and basaluminite, Figure 17.

The Eh of the water within an individual mine shaft is related to the circulation pattern within the mine. Most mines exhibit a downward migration of water as indicated by a decrease in the Eh and increase in TDS. The water located in

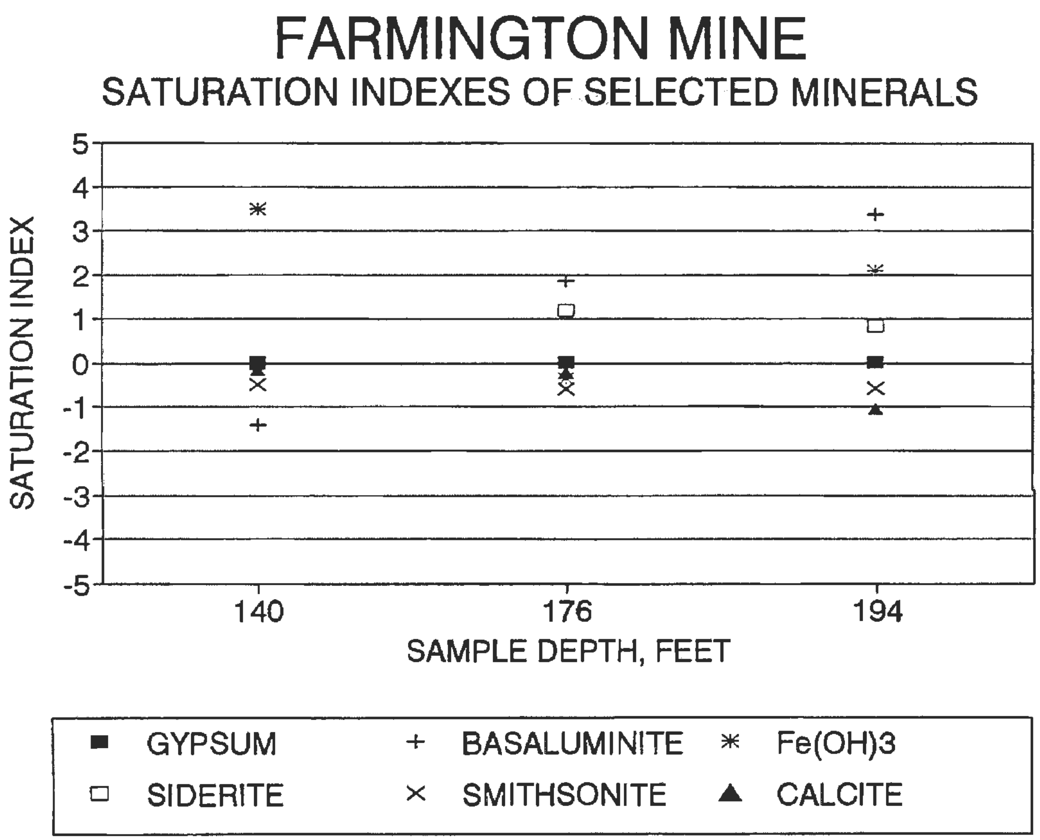


Figure 17. Saturation Indexes for Selected Minerals
Farmington, June 12, 1985

the upper portions of the mines possessed a high Eh from surface contact with the air and periodic inflow of oxygenated surface water during flood events. The decrease in the Eh within the middle zone most likely reflected a relatively stagnant layer of water which lies above the upper level of the mine stopes. Water circulating through the mine stopes increases the Eh of the water within the lower levels of the mine, as observed in the Farmington mine. The downward migration of water within the mine shafts can also be seen by the increase in the TDS with depth. The water in the upper portion of the mine shaft possesses the lowest TDS, while the water with the highest TDS is found in the mine stopes. Inflowing surface water and groundwater from the Boone formation is relatively low in TDS (Reed 1955). As the combined water enters into the mine workings and comes in contact with soluble ores, small portions of the minerals dissolve, increasing the dissolved solids concentration of the water. As the water continues to migrate downward, the TDS of the water increases with increasing residence time and increasing contact with additional ore. A few mines, located in the southern most portions of the Picher mine field, display little vertical variations in water quality, indicating an upward migration of water, a discharging mine.

During the second sampling period, the water within the mine stopes was characterized by a moderate and stable pH, 5.6 to 6.2. The mines had completely filled with water and stabilized, resulting in maximum contact between the mine water and the limestone strata in the overburden. This resulted in a moderate to high alkalinity. Although the bicarbonate concentrations within the mine stopes had increased by one to two orders of magnitude since April 1976, the waters remained undersaturated with respect to most carbonate minerals, with the exception of siderite.

High calcium and sulfate concentrations continue to exist with concentration averaging > 500 mg/l and 2700 mg/l, respectively, primarily controlled by the precipitation of gypsum, Figure 18. Trace metal concentrations remained high with Fe > Zn > Ni > Al > Pb > Cd. Iron, Zn, and Al concentrations were stable, displaying a slight but steady decrease in concentration with time. Nickel concentrations remained constant or decreased slightly with time. Cadmium and Pb concentrations decreased in the Admiralty and Kenoyer mines, increased in the Consolidated No.2-S mine, and were stable in the Farmington mine. High sulfate, Al, and Fe concentrations resulted in the mine water becoming oversaturated with respect to barite, basaluminite, alunite, and jarosite, and saturated with respect to allophane, whereas high Al, and Fe concentrations resulted in the mine water becoming oversaturated with respect to diaspore, kaolinite, ferric hydroxide, and goethite. The mine water was oversaturated with respect to $ZnSiO_3$ and quartz, because of high Zn and SiO_2 concentration.

No spatial trends in water quality were observed within the Picher mine field during the second sampling period. Variations in water quality appear to be more of a function of depth rather than spatial location.

The Lucky Syndicate mine was an anomaly during the second sampling period. Calcium and sulfate concentrations in the mine water were consistent with the rest of the mine field, but the alkalinity was approximately three times higher, Figure 19. The saturation with respect to gypsum remains as the most probable control on the concentrations of calcium and sulfate, whereas the increase in the alkalinity has had little effect on the degree of saturation with respect to most carbonate minerals

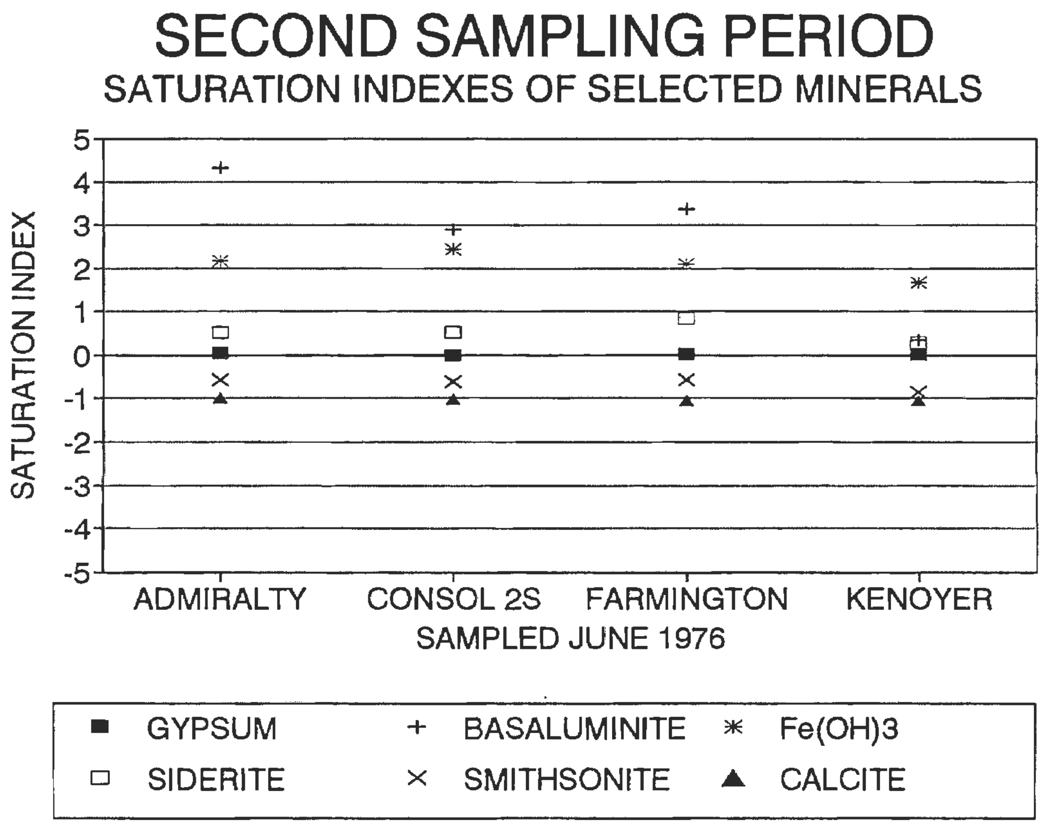


Figure 18. Saturation Indexes for Selected Minerals
Spatial, June 1985

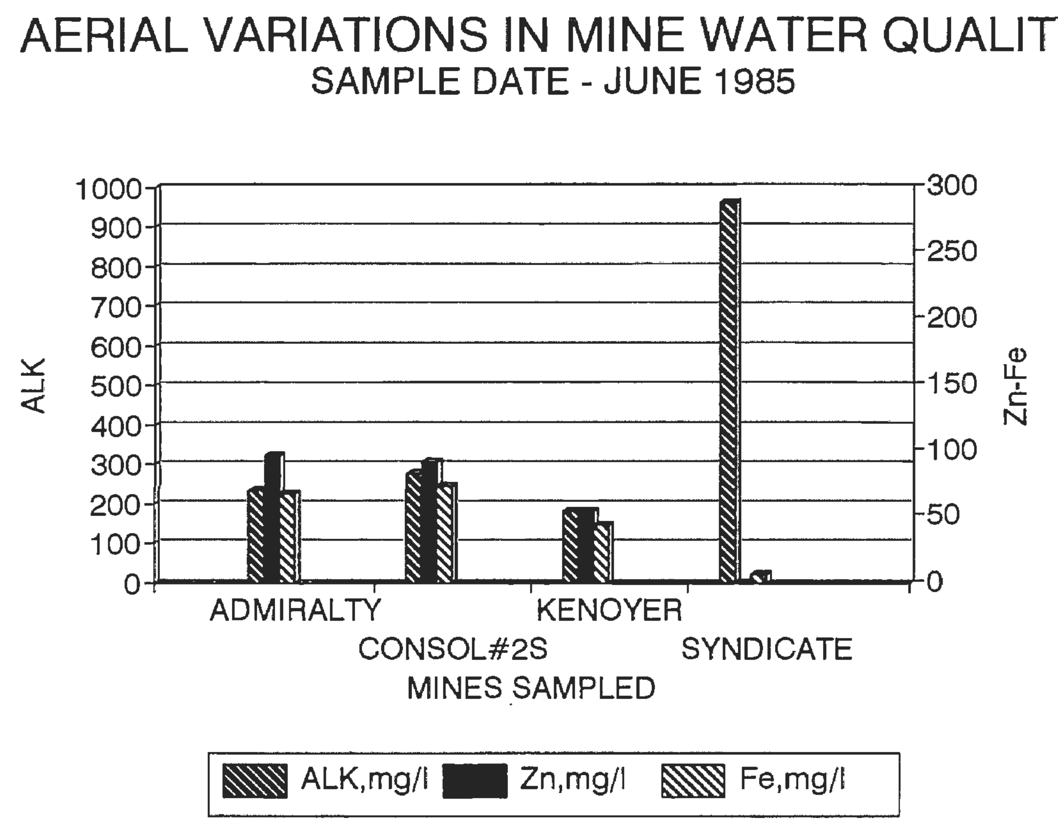


Figure 19. Aerial Variations in Water Quality
June 11, 1985

because of a substantially lower trace metal concentrations.

Trace metal concentrations in the water located within the mine stopes were generally lower than observed average from rest of the mines. Iron, Ni, and Al concentrations were an order of magnitude lower, whereas Zn concentration were two orders of magnitude lower. The water within the mine stopes was determined to be oversaturated with respect to ferric hydroxide, goethite, and diaspore, and saturated with respect to siderite and alunite. Although the mine water was determined to be oversaturated with respect to several iron precipitates, the decrease in the concentrations of Ni and Cd coinciding with the decrease in the Fe and Zn indicate that a reduction in the amount of marcasite and sphalerite dissociating was responsible for the lower concentrations.

The abnormally high alkalinity and low trace metal concentrations appear to be related to the substantially shallower mine depth and lower water column in the Lucky Syndicate mine. The Lucky syndicate mine shaft contained approximately 80 feet of water during the second sampling period. This was approximately half the depth measured in the other mines. The Alkalinity of mine water located within the Farmington mine decreased and the trace metal concentrations increased with depth.

Limited water quality data were collected during an intermediate sampling period, from August 1980 to December 1981, by the OWRB. During this time frame, the mines were almost filled, but were still receiving large quantities of oxygenated surface water, especially during periods of high precipitation. Large variations in water quality were noted during this period and the water within the mines were stratified, Figure 20.

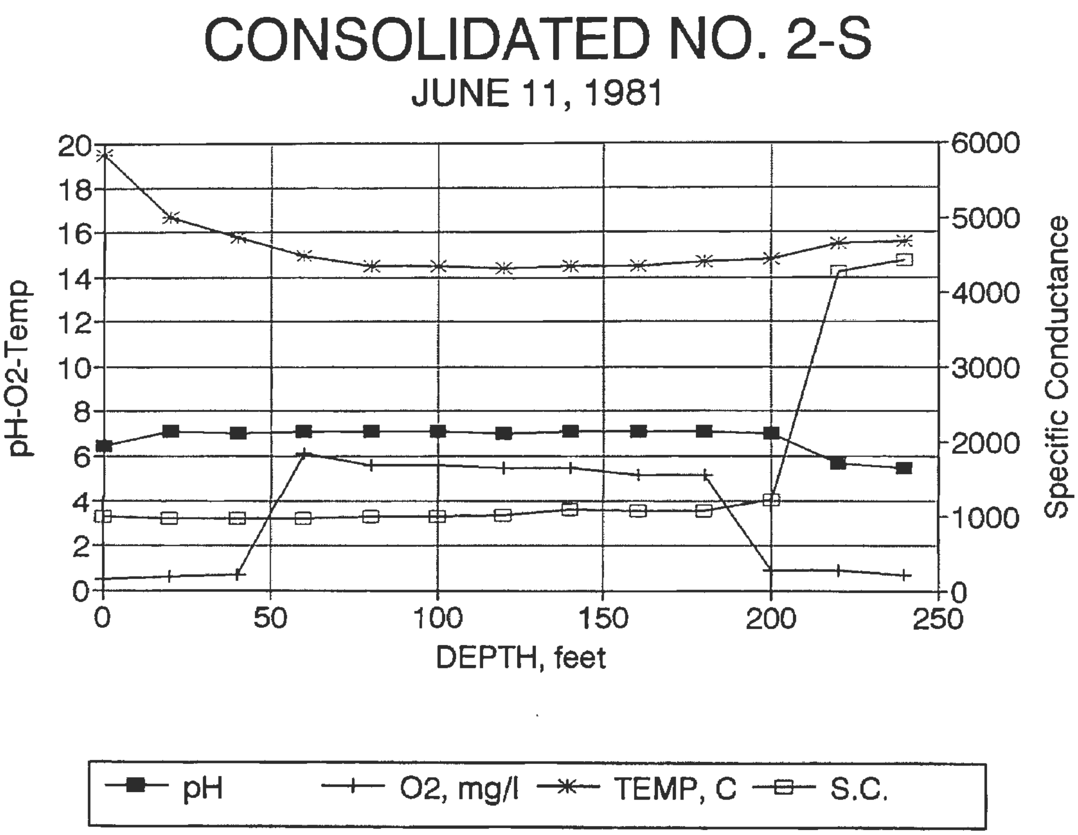


Figure 20. Vertical Variations in Water Quality
Consolidated No.2-S, June 11, 1981

Water temperatures generally remained relatively constant for in the upper 100 to 150 feet of water then began to increase with increasing depth. During the hot summer and early fall months high air temperatures warmed the mine water near the surface. This resulted in high surface water temperatures with decreasing water temperature with depth in the upper 70 feet. The water in the upper portions of the mines were characterized by a neutral pH and low to moderate alkalinity and sulfate concentrations. Dissolved oxygen, pH, and specific conductance generally remained relatively constant from 10 feet below the water surface down to the upper level of the mine stopes. At this interval, the upper to middle portion of the mine stopes, an abrupt increase in specific conductance, sulfate, and most trace metal concentrations were observed in relation to a abrupt decrease in the pH and dissolved oxygen levels in the mine water. A few tens of feet below this point the pH, dissolved oxygen, temperature, and specific conductance of the mine water generally remained relatively constant with increasing depth.

The water within the mine stopes between October 1980 and July 1981, were characterized by widely fluctuating pH, alkalinity, and, trace metal concentrations. The pH of the mine water was variable ranging from moderately acidic (pH 4.7) to neutral (pH 7). The alkalinity of the mine water as moderately low, generally < 200 mg/l. Trace metal concentrations were variable generally with Fe > Zn > Ni > Al > Pb > Cd, but commonly reversed to Ni < Al, and Pb < Cd between sampled dates. Iron and Zn concentrations were high but have been recorded decreasing by two orders of magnitude during a single sample date. Wide variations in the water quality were most likely caused by frequent inflows of large volumes of oxygenate surface water and acid mine water from adjacent tailing piles during periods of high precipitation.

Temporal Variations

Temporal variations in water quality were observed between the first and second sampling periods. From April 1976 to June 1985, the pH of the water within the mine stopes was relatively stable, increasing slightly with time. The alkalinity of the mine water increased approximately two orders of magnitude between June 1977 and November 1983, in relation to increased contact with limestone in the overburden during flooding, Figure 21. Although the alkalinity of the mine water increased, most carbonate minerals remained undersaturated but decrease in the degree of undersaturation, with the exception of siderite. As the alkalinity of the mine water increased, the carbonate minerals calcite, rhodocrosite, smithsonite, otavite, and cerrusite, remained undersaturated but decreased in the degree of undersaturation.

Calcium and sulfate concentration were high averaging 500 mg/l and 3000 mg/l. A direct correlation was observed between calcium and sulfate concentrations, most likely controlled by the precipitation of gypsum, Figures 21 and 23. In relation to the high sulfate, Al, and Fe concentrations in the mine water, the water was determined to be oversaturated with respect to barite, alunite, basaluminite, and jarosite.

Trace metal concentrations in the water located within the mine stopes were high and variable where Zn > Fe > Al > Ni > Cd > Pb during the initial stages of the mines filling and Fe > Zn > Ni > Al > Pb > Cd after the mines had filled,

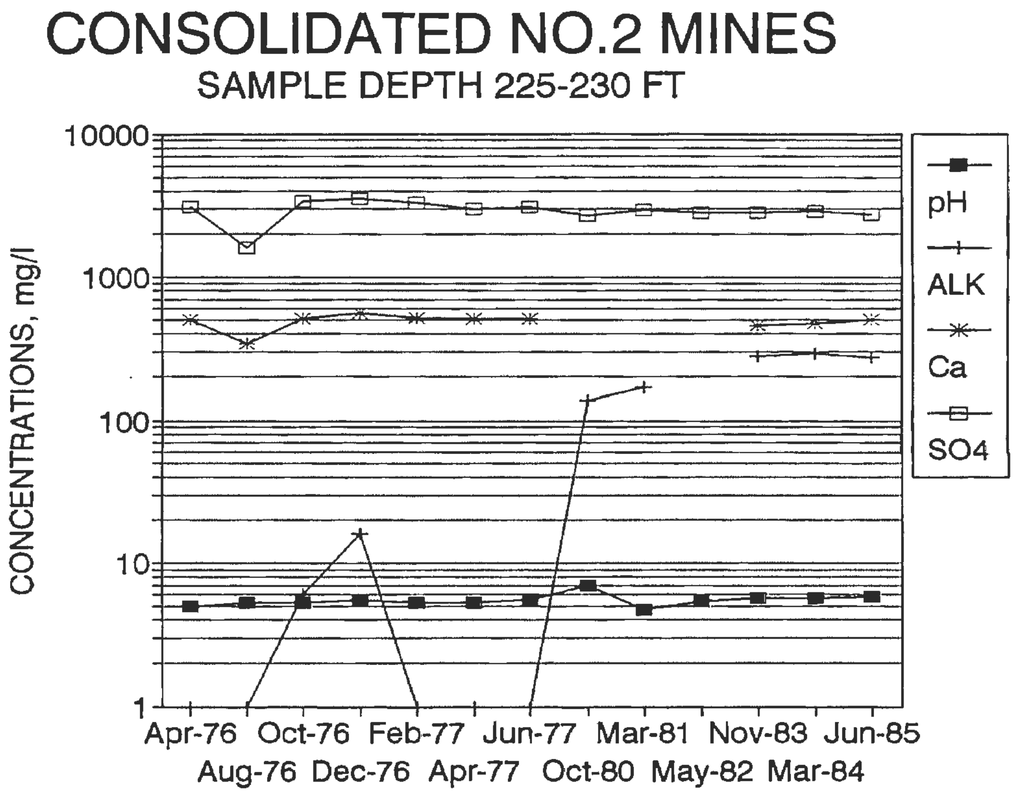


Figure 21. Temporal Variations in Chemical Parameters, Consolidated No.2 Mines

Figure 22. Iron concentrations were high and generally increased with time, whereas Ni concentration remained relatively the stable. The high Fe concentrations resulted in the water being oversaturated with respect to ferric hydroxide and goethite during both sampling periods and saturated with respect to siderite during the second sampling period, Figure 23. During periods of low redox potential, the saturation index of ferric iron precipitates declined in response to the low ferric/ferrous iron ratio. In March 1984, the redox potential of the mine water reduced into a transitional environment resulting in the reduction in the degree of saturation of the ferric iron minerals. Zinc concentration were the highest during the initial stages of the mine filling, exhibiting an one half to one third reduction in concentration after the mine had filled. Despite the reduction the Zn concentrations, the mine water remained saturated with respect to $ZnSiO_3$. Aluminum, Pb, and Cd concentrations were high and fluctuated significantly over time, decreasing by an order of magnitude after the mines had filled. The water within the mine stopes remained oversaturated with respect to diaspore despite the substantial reduction in average Al concentration. During periods of extremely low Al concentrations, as in June 1977, all Al minerals were undersaturated.

Minerals containing phosphorus, $MnHPO_4$ and plumbogummite, increased in the degree of saturation with time in response to the increase in phosphate concentrations. Cuprousferrite and cupricferrite maintained a high level of oversaturation throughout the sampling period.

Variations in the quality of the water located within the mine stopes were primarily related to the increase in the depth of water in the mine shafts and the

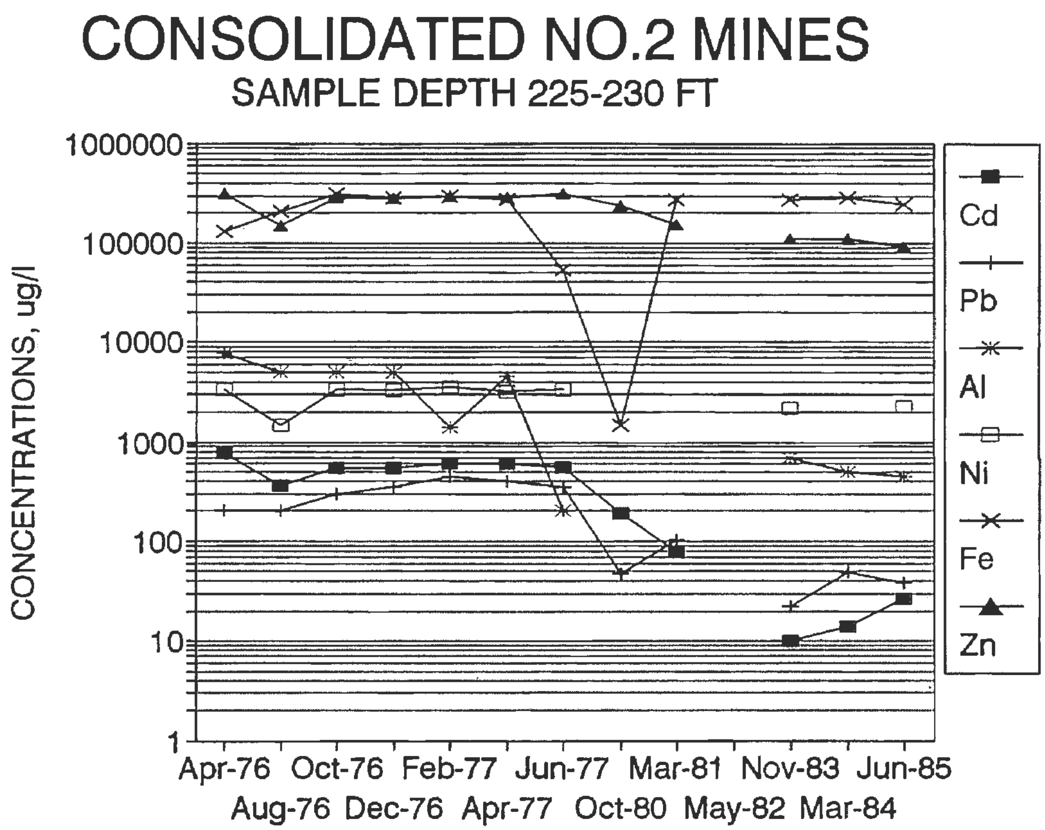


Figure 22. Temporal Variations in Trace Metal Concentrations, Consolidated No.2 Mines

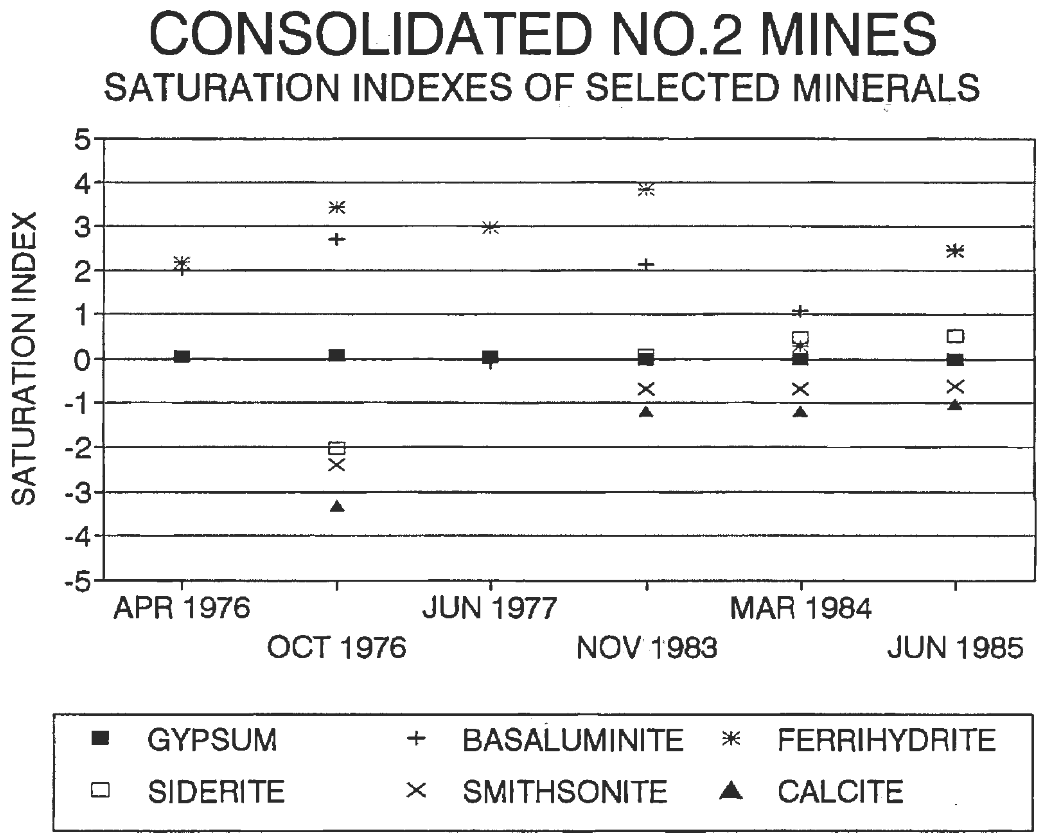


Figure 23. Saturation Indexes for Selected Minerals
Consolidated No.2 Mines

inflow of surface water. The moderately acidic water located within the mine stopes was produced by a combination of the oxidation of marcasite and pyrite and the dissociation of carbonate minerals. During the initial stages of the mines filling, the water was primarily in contact with brecciated chert zones with little buffering capacity. As oxygenated surface water discharged into the mines, marcasite and pyrite were rapidly oxidized producing sulfuric acid. The acid produced was then neutralized by the carbonate gangue minerals calcite and dolomite. The limited amount of carbonate minerals and accelerated acid production during periods of high surface water discharge resulted in variable but moderately acidic conditions with a very low alkalinity, generally < 5 mg/l, never exceeding 37 mg/l.

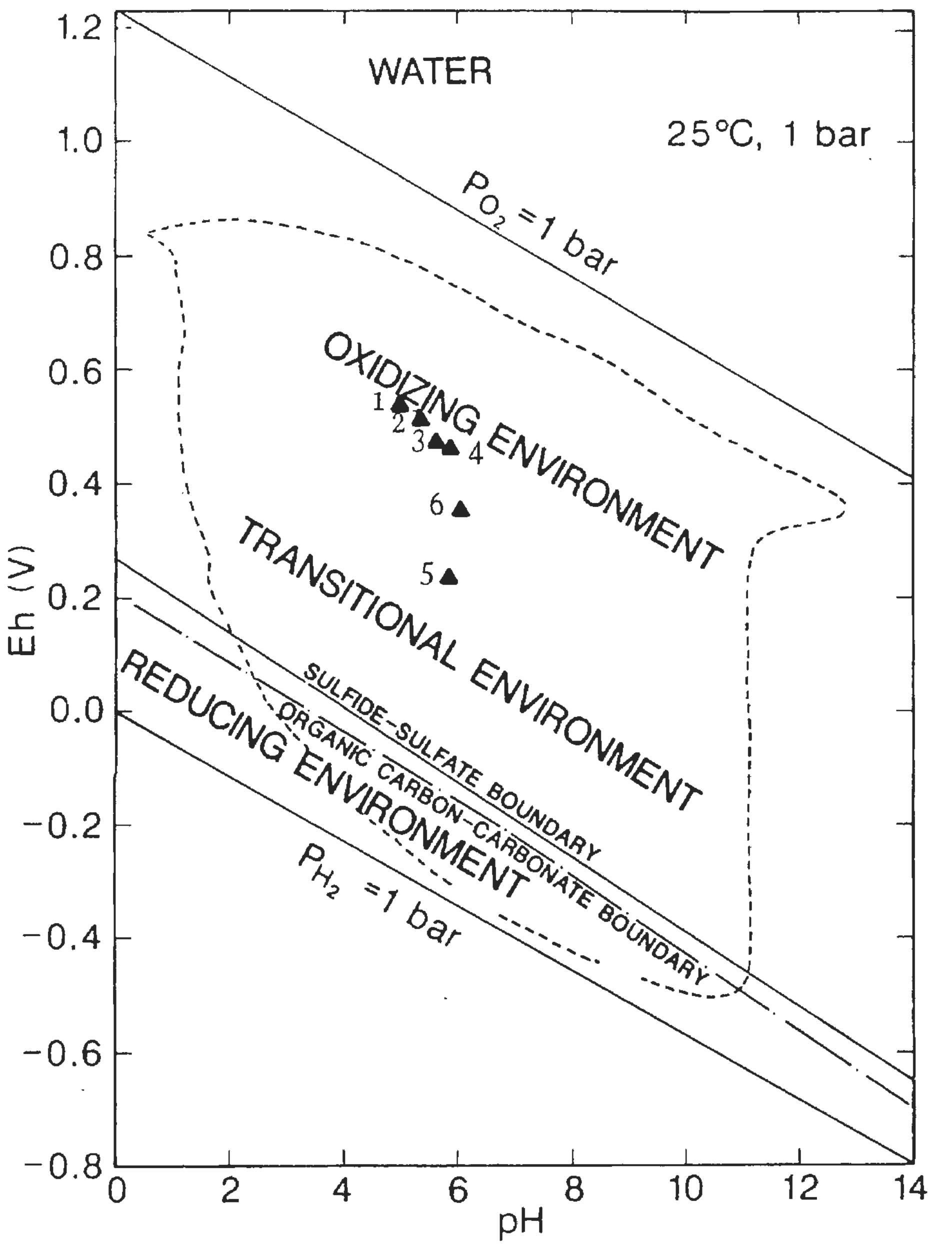
A strong correlation was observed between the alkalinity and the CO_2 concentration in the mine water. Under acidic conditions, carbonic acid is a by product of the neutralization reaction. If sufficient quantities of carbonate minerals react with the acid, the water will become oversaturated with respect to carbonic acid and dissociate releasing water and CO_2. This reaction is responsible for the large volume of CO_2 gas which is expelled from the Commerce Spring.

As the water in the mine workings continued to rise, it came in contact with the limestone located in the Boone formation and overlying strata. The combination of the increased contact with additional limestone and the remediation of surface inflow points, by stream diversion and plugging of abandoned exploration holes, allowed the pH of the water within the mine stopes to stabilize at a moderately acidic pH. At the same time the alkalinity increased by two orders of magnitude by November 1983.

The oxidation of sulfide minerals and the neutralization of sulfuric acid by calcite and dolomite released large quantities of calcium and sulfate into the mine water. A strong correlation was observed between the calcium and sulfate concentrations in the water located within the mine stopes. Calcium and sulfate concentrations were variable and generally maintained around 500 mg/l and 3000 mg/l, respectively, by the precipitation of gypsum. This was supported by WATEQ4F calculated that the water located within the mine stopes was saturated with respect to gypsum and by the precipitation of crystalline gypsum at OWRB 4S. The high sulfate concentrations in the mine water would most likely impede the dissolution of barite nodules located in the Boone formation.

Temporal variations observed in the Eh of the water located within the mine stopes was related to the rise in the water levels in the mine shafts and the reduction in the inflow of surface water. The Eh of the water located within the mine stopes decreased over time, reverting back toward the reducing conditions which existed prior to the mining operations. During the initial stages of flooding, the water located within the mine stopes was in an oxidizing environment, Figure 24. As the water within the mine shafts rose approximately 20 feet between April 1976 and June 1977, the Eh of the water located within the mine stopes steadily decreased.

By the second sampling period, the mines had completely filled and the inflow of oxygenated water was restricted from entering the mines, occurring only during periods of high precipitation and associated flooding. The Eh of the water located within the mine stopes fluctuated and continued to decrease. The drop in the Eh resulted in the mine water reducing to a transitional environment.



(Modified from Brookins 1988)

Figure 24. Oxidation-Reduction Environments of Water within the Consolidated No.2 Mine Stopes: *1* April 20, 1976; *2* October 19, 1976; *3* June 7, 1977; *4* November 30, 1983; *5* March 22, 1984; *6* June 7, 1985.

Aqueous Mineral Equilibrium

High Fe and Ni concentrations in the water located within the mine stopes primarily came from the oxidation and dissolution of marcasite and pyrite. Iron concentrations increased with time whereas Ni concentrations remained relatively stable. This would indicate a constant rate in the dissolution of marcasite and pyrite. The increase in the dissolved iron concentrations in the mine water was related the decrease in the Eh of the water, Figure 25. Although iron can exist in two oxidation state, in natural waters, ferrous iron is found in solution through most of the Eh range under neutral to strongly acidic conditions, whereas ferric iron occurs only in high Eh and strongly acidic conditions, $pH < 5$. Dissolved iron concentrations in the mine waters were controlled by the oxidation of ferrous iron to ferric iron and the hydrolysis of ferric iron to ferric hydroxide. Under the Eh-pH conditions of the mine water, the dissolved ferric iron concentrations were controlled by the precipitation of amorphous ferric hydroxide and amorphous goethite.

During the initial stages of the mine filling when oxygenated surface water and air were in contact with the ore located in the mine stopes, Fe concentrations were relatively low rapidly increasing with time, whereas Ni concentrations remained relatively stable. Under these high oxygenated acidic conditions, a large percentage of the ferrous iron would oxidize to ferric iron and precipitate out of solution as amorphous ferric hydroxide, thus significantly reducing the Fe concentration in the mine water. In contrast, the mine water was undersaturated with respect to Ni minerals, therefor the Ni remained in solution.

As the water levels within the mine shafts increased, the Eh of the water

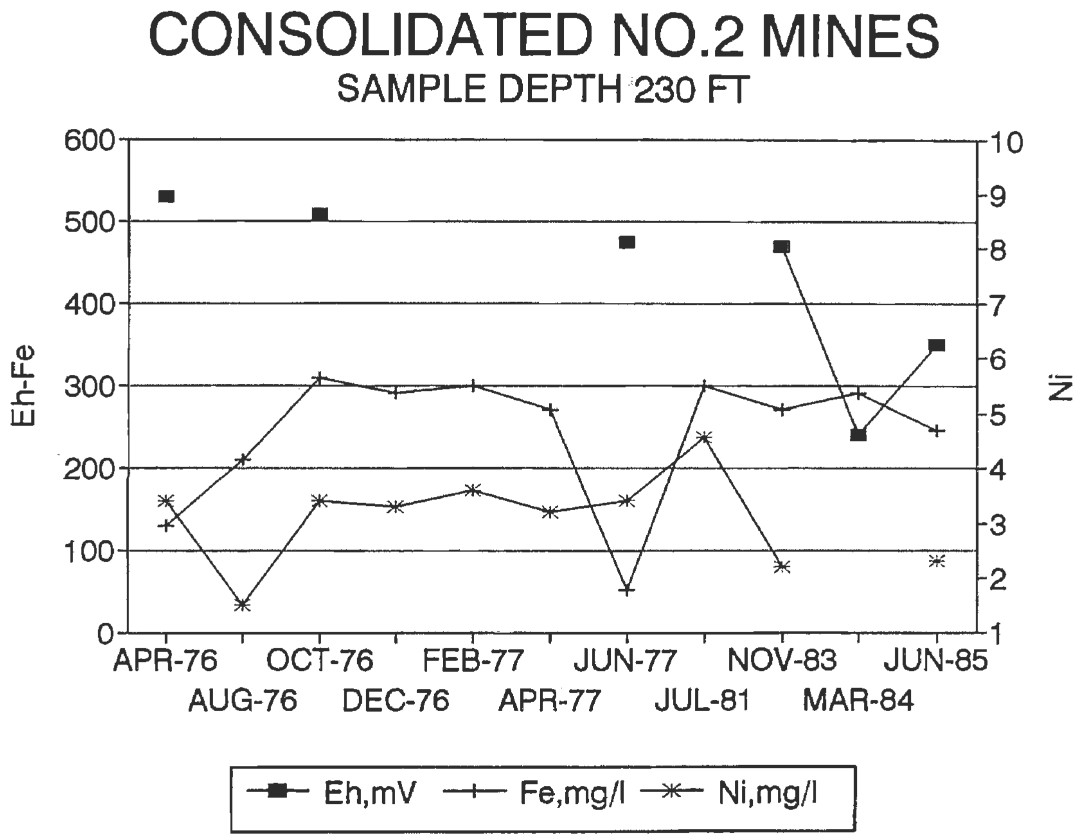


Figure 25. Temporal Variations in Fe Concentrations vs. Eh
Consolidated NO.2 Mines

within the mine stopes decreased. By November 1983, most of the mines had completely flooded and the water levels within the mine shafts were at equilibrium with Tar Creek. Most of the surface inflow points had been remediated, by stream diversion structures and plugging abandoned exploration holes, restricting the inflow of oxygenated surface water to periods of high precipitation. The low Eh of the mine water during the 1983-85 sampling period would provide a more stable environment for ferrous iron. With less ferrous iron oxidizing to ferric iron and consequentially precipitating out of solution as ferric hydroxide, more iron would remain in solution. By this reasoning, the same amount of marcasite and pyrite dissociated during both sampling periods, but under the lower Eh conditions more dissolved iron remained in solution.

A substantial decrease in the Zn, Cd and Pb concentrations in the water located within the mine stopes was observed between the first and second sampling periods. The drop in concentrations correlates with a decrease in the Eh of the mine water, Figure 26. High Zn and Cd concentrations come from the dissolution of sphalerite and high Pb concentrations come from the dissolution of galena. Under neutral pH and reducing conditions, which existed prior to the mine activity, sphalerite and galena are stable. In the oxidizing environment which existed during the initial stages of the mine filling, sphalerite and galena were readily dissolved, releasing high concentrations of Zn, Cd, and Pb, as observed in the first sampling period. As the Eh of the water located within the mine stopes continued to decrease, the sulfide minerals became more stable. By the second sampling period, the water located within the mine stopes had reduced to a transitional environment. Under the

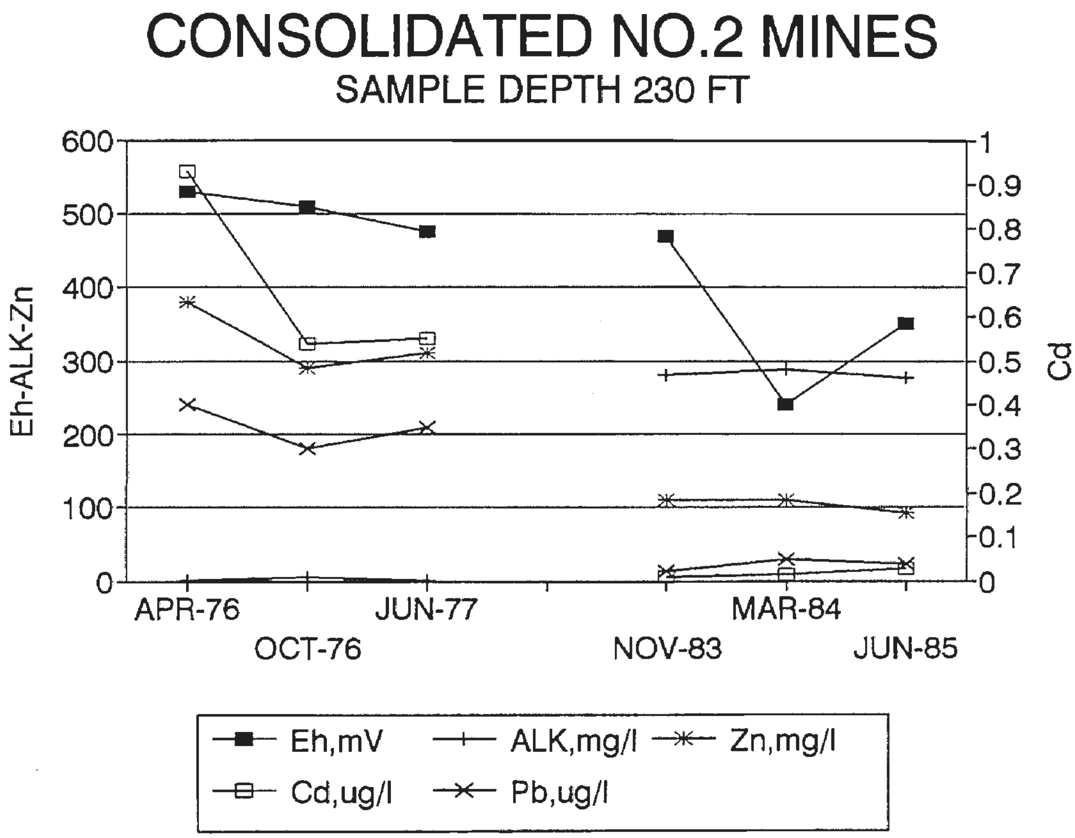


Figure 26. Temporal Variations in Zn and Pb Concentrations vs. Eh, Consolidated No.2 Mines

observed Eh-pH conditions, the oxidation and dissolution of sphalerite and galena decreased, as shown by the lower Zn, Cd, and Pb concentrations recorded during the second sampling period. The reduction in the dissolution of sphalerite as the primary factor responsible for the decrease in Zn concentrations was supported by a similar decrease in Cd concentrations. Since the primary source of Zn and Cd was the dissolution of sphalerite, if the decrease in Zn concentrations were related to precipitation, then Cd would not follow the same decline in concentrations. WATEQ4F calculation indicate that the mine water was oversaturated with respect to $ZnSiO_3$ and quartz resulting from the high Zn and SiO_2 concentrations.

Despite the reduction in the Al concentrations in the mine water, the water located within the mine stopes remained oversaturated with respect to diaspore, kaolinite, basaluminite, and alunite during both sampling periods. The aluminum concentrations in the acid sulfate water found in the mine stopes were controlled by the precipitation of amorphous basaluminite. The Al and sulfate concentrations in the mine water were the lowest near the surface of the mine shafts, increasing with in concentration depth. Under low sulfate concentrations, the aluminum concentrations would be controlled by the precipitation of bauxite, primarily diaspore, and kaolinite.

Precipitate Description and Analysis

Precipitates were collected at two mine water discharge points to determine aqueous mineral equilibrium and to validate WATEQ4F runs. Precipitates were collection at OWRB 14 and OWRB 4S on April 17, 1992 and on December 4, 1992.

A list and description of the mine discharge sampling locations are provided in Table 6.

Mine water was discharging from the Commerce Spring (OWRB 14) at the time of sampling during both sampling events, Figure 27.a. Large quantities of CO_2 gas were released into the atmosphere upon discharge. Water discharged from the spring was clear and appeared to be free of suspended colloidal particles. The area surrounding the spring and adjacent creek were coated with a pale yellow-brown precipitate with red amorphous flocs of iron precipitate coating the surface of the water.

A pale yellow-brown precipitate coating was observed adhering to the plant material surrounding the spring and bottom accumulations at the spring overflow connecting the spring with the creek. The precipitates have a low density and produce a high irregular background reading during x-ray diffraction. From this it was concluded the precipitates consists of amorphous iron.

On April 17, 1992, precipitates were collected from the weir located downstream from the Commerce spring. Water within the creek was stained red from the colloidal iron particles suspended in the water. The metal weir was coated with a thick layer of dense dark red iron precipitate. A thick sediment deposit of dark red iron precipitates was located both upstream and downstream adjacent to the weir, Figure 27.b.

During both sampling events, water was discharging from both the borehole and the taproot. The taproot discharge comprised the minimal amount of the combined discharge. Water discharging from the taproot was clear, free from

TABLE 6

PRECIPITATE COLLECTION LOCATIONS AND DESCRIPTIONS

FIGURE	LOCATION	DESCRIPTION
27.a	28N-23E-07 BDD	COMMERCE SPRING, excessive CO_2 discharged, red-brown (iron) flocs on water
	(OWRB 14)	
27.b	28N-23E-07 BDD	WEIR EAST OF COMMERCE SPRING, heavy layered (iron) precipitates on weir and vegetation
	WEIR	
28.a	29N-23E-29 CDC	TAPROOT DISCHARGE, pale yellow-tan precipitates on sediment and stump
	(OWRB 4S)	
28.a	29N-23E-29 CDC	TAPROOT DISCHARGE, white crystals on vegetation extending out of the water.
	(OWRB 4S)	
28.b	29N-23E-29 CDC	TAPROOT DISCHARGE, thick yellow-brown layered precipitate on sediment.
	(OWRB 4S)	
29.a	29N-23E-29 CDC	BOREHOLE DISCHARGE, minor CO_2 discharge, yellow precipitates on tree roots within borehole
	(OWRB 4S)	
29.b	29N-23E-29 CDC	BOREHOLE WEIR, heavy (iron) precipitate on weir and vegetation
	(OWRB 4S)	
30.a	29N-23E-29 CDC	CREEK AT OWRB 4S, bottom coated with yellow-brown precipitate, red iron flocs on water surface
	(OWRB 4S)	
30.b	29N-23E-29 CDC	AIR SHAFT PIPE, white, red, and black crystal precipitate inside pipe. (not discharging)
	(OWRB 4S)	

Figure 27. OWRB 14, a) Commerce Spring, b) Commerce Spring Weir

noticeable suspended colloidal particles with no noticeable release of CO_2 gas bubbles. The remnant stump which overlies the taproot discharge point was coated with precipitates, Figure 28. Portions of the stump which are exposed to air were coated with white to pale yellow-brown precipitates, some in small crystal form. Below the water surface, all surfaces are coated with a pale yellow-brown precipitate with sediment accumulations of precipitates covering the bottom. The ground lying between the taproot and the borehole was coated with a dense yellow-brown to brown layered precipitate, Figure 28.b. Small vegetation extending above the water level was coated with a white to yellow-tan crystalline precipitate.

The borehole discharge comprised the majority of the combined discharge. Water discharging form the borehole was clear, free of any noticeable suspended colloidal particles, Figure 29.a. Small amounts of CO_2 gas bubbles were observed rising from the borehole discharge. Large quantities of a foamy material, possibly iron flocculent, covered the water surface around the borehole extending tens of feet downstream, Figure 30.a. All vegetation beneath the water surface possessed a thick coating of a yellow-brown precipitate. The floor of the discharge stream was covered with a sediment deposit of the same yellow-brown precipitate.

On April 17, 1992 precipitates were collected at the weir located approximately 100 feet to the west downstream from the borehole discharge. The weir consisted of a metal plate with a broad flat box-shaped notch cut out of it to allow water to pass through it uniformly. The weir was encrusted with a reddish iron precipitate. The stream bottom up and downstream of the weir were covered in a deep layer, over one foot thick, of precipitates, Figure 29.b. The precipitates were deep

Figure 28. OWRB 4S, a) Taproot Discharge Point, b) OWRB 4S Taproot Discharge, Encrusted Ground

Figure 29. OWRB 4S, a) Borehole Discharge, b) OWRB 4S, Weir

red in color fine to coarse grained and dense, probably containing a large portion of heavy metals.

During both sampling events, the water within the air stand pipe was approximately one foot from the top of the pipe. The steel air shaft stand pipe was coated on the inside with a dense crystalline precipitate. The precipitate was white towards the top grading to yellow, red, brown, then black at and just below the water surface. On December 4, 1992 the outside of the air stand pipe was coated with a dense yellow-brown encrusted layer of precipitate with a powdery yellow surface, Figure 30.b.

The CO_2 gas which was observed accompanying the mine water discharge at both springs came from the dissolution of limestone. Calcite (limestone) reacts with the sulfuric acid in the mine water to neutralize it in the following manner.

$$H_2SO_4 + CaCO_3 = Ca^{2+} + SO_4^{2-} + H_2CO_3$$

As the calcite continues to neutralize the acid, the concentrations of Ca^{2+} and SO_4^{2-} in solution increase until the solution is supersaturated with respect to gypsum. At this point the precipitation of gypsum occurs, controlling the Ca^{2+} and SO_4^{2-} concentrations in solution. At a pH < 6.0, the dominant carbonate species present in solution would be H_2CO_3. Once the water becomes saturated with respect to H_2CO_3, carbonic acid dissociates releasing H_2O and CO_2 gas, as shown below.

$$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$$

Figure 30. OWRB 4S, a) Creek Draining OWRB 4S Discharge
b) Standpipe Discharge

The extremely high volume of CO_2 gas discharged at the Commerce Spring reflexes the longer residence time and the increased contact with limestone.

The mineralogy of the precipitates were determined using x-ray diffraction with copper radiation. X-ray diffraction of the precipitates revealed that the crystalline precipitates found within the air stand pipe and on material extending above the water surface in the vicinity of the taproot and the borehole at OWRB 4S were gypsum. No peaks were recorded from the remaining samples, but a high irregular background indicated that the precipitates were amorphous or poorly crystalline. Although it has been determined that secondary iron fluorescence can cause a high background reading, field observations and documented literature pertaining to acid mine drainage and related precipitates indicated that the remaining precipitates were most likely amorphous iron and aluminum minerals, primarily amorphous varieties of ferric hydroxide, goethite, and basaluminite.

Chemical analysis of iron precipitates collected near the mine discharge point revealed that they contained high concentrations of Fe and Al (Parkhurst and others 1988). WATEQ4F runs calculated that the water discharging from OWRB 4S and OWRB 14 were oversaturated with respect to gypsum, ferric hydroxide, goethite, and basaluminite, Figure 31. Based on the above data the red flocs are amorphous ferric hydroxide, the yellow-brown precipitates are amorphous goethite and basaluminite, and the dense red precipitate found at the weirs is a poorly crystalline hematite.

Iron Precipitate Dehydration Series

Large quantities of iron precipitates have been observed deposited at the mine

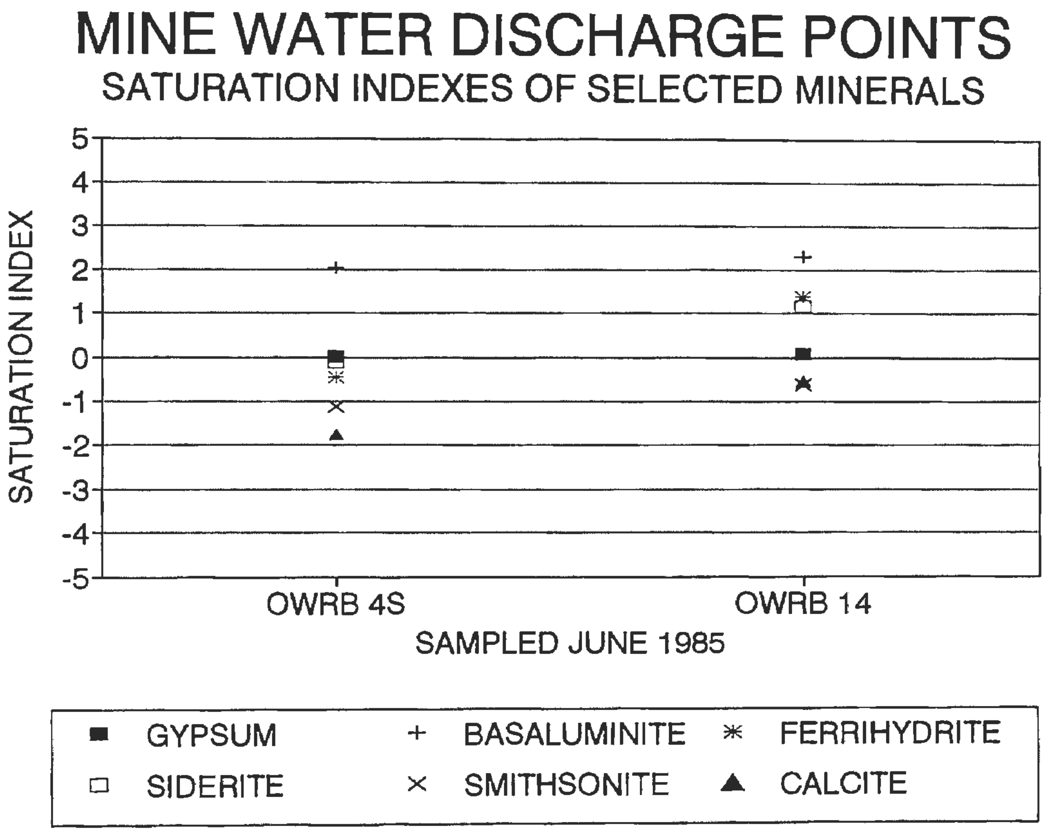


Figure 31. Saturation Indexes of Selected Minerals
OWRB 4S and OWRB 14, June 1985

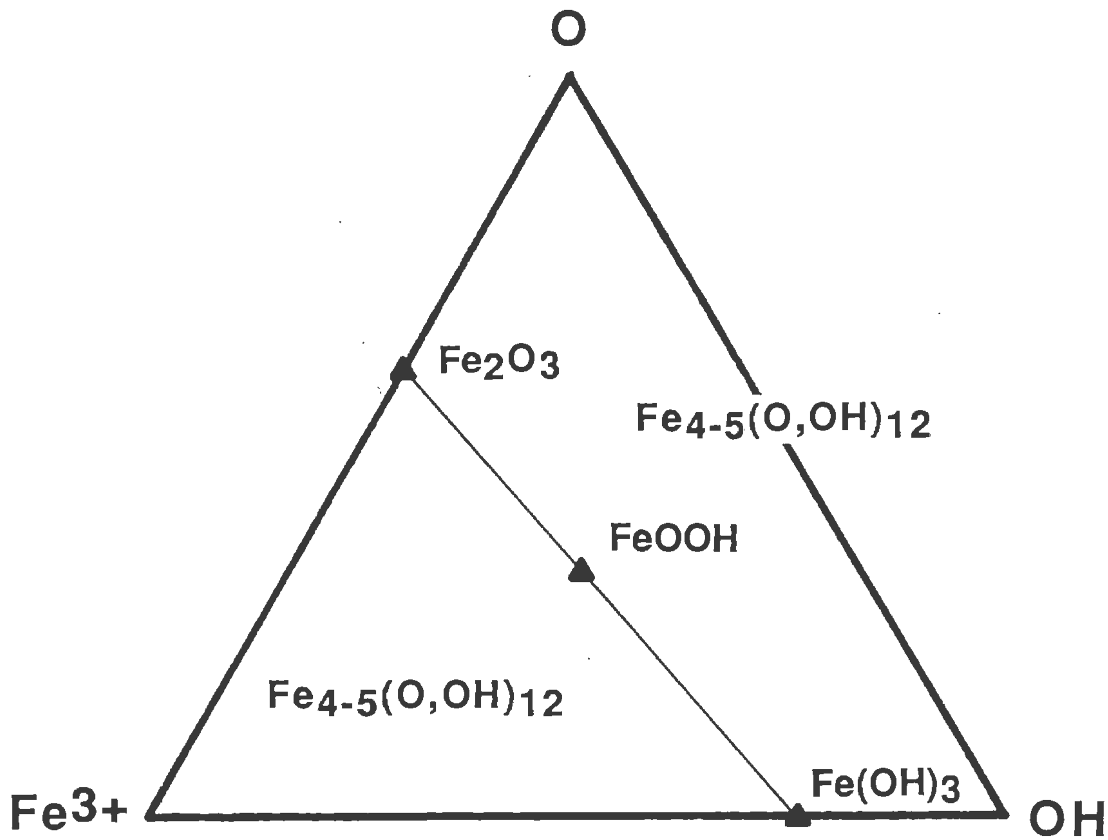
water discharge locations, continuing long distances down stream. Upon deposition, ferric iron minerals ferric hydroxide, goethite, and hematite form a dehydration series in relation to the Eh of the water, Figure 32. Ferric hydroxide is typically the first ferric mineral to precipitate from solution resulting from the hydrolysis of ferric iron. Upon deposition, typically near the mine water discharge points, ferric hydroxide would dehydrate to form the more stable mineral goethite. Further down stream in a more stable oxidizing environment, goethite formed from either direct precipitation or from the dehydration of ferric hydroxide dehydrates to form the more thermodynamically stable mineral hematite.

Sorption Processes

Ferric hydroxide has a highly adsorptive nature and is capable of adsorbing and coprecipitating a large quantity of a variety trace elements. Adsorption and coprecipitation with ferric hydroxide were the primary control of the trace elements Zn, Pb, Ni, Mn, Cd, and Cd in the mine waters. This is supported with analyses of stream sediments collected in 1985 which detected high concentrations of Fe, Al, Zn, Pb, Ni, Mn, Co, and Cd associated with iron precipitates (Parkhurst 1988).

Summary

The water within the mine shafts was stratified during the study period, April 1976 and June 1985. The temperature of the mine water increases with depth except during the warmer summer and fall months when surface water was heated above that of the groundwater, specifically the water in reserve within the mine stopes, then the



DEHYDRATION

$Fe(OH)_3$ -> $FeOOH + H_2O$
Ferric Hydroxide Goethite

$2FeOOH$ -> $Fe_2O_3 + H_2O$
Goethite Hematite

$Fe_{4-5}(O,OH)_{12}$ -> $4FeOOH$
Ferrihydrite Goethite

$2Fe_{4-5}(O,OH)_{12}$ -> $5Fe_2O_3 + 5H_2O$
Ferrihydrite Hematite

Figure 32. Dehydration Series of Ferric Oxyhydroxide Precipitates

thermal gradient was reversed. Typically, the specific conductance increased and the pH decreased with depth. Dissolved oxygen concentrations were typically the highest within the upper few feet of the water column, decreasing gradually with depth. An abrupt change in water quality occurred within the mine shafts in the vicinity of the middle to lower portions of the mine stopes. This zone was characterized by an abrupt increase in SC, SO_4 and most trace metal concentrations, and a decrease in pH and DO, Appendix B. In most cases the mine water was stratified with cooler water possessing a low TDS overlying a warmer but denser water because of its substantially higher TDS content. The boundary which separates these waters within any given mine generally remains fairly constant in the vicinity of the upper to middle portions of the mine stope, but commonly varies 5 to 20 feet.

Water analyses used to evaluate the water quality within the mine stopes were collected during two primary sampling events. The first sampling event occurred from April 1976 through June 1977. During this sampling period, the mines were in the initial stages of flooding. They received rapid inflow of surface water via open mine shafts, collapse features, and abandoned exploration holes. The water levels within the mines rose approximately 20 feet during this period. The water within the mine stopes was characterized by a moderate but variable pH, 3.8-5.9, and a low alkalinity, generally less than 5 mg/l. Trace metal concentrations were high with Zn > Fe > Al > Ni > Cd > Pb. The mine water contained high concentrations of Ca and SO_4 averaging 500 mg/l and 3000 mg/l, respectively. The water in the mine stopes possessed a high redox potential classifying it as an oxidizing environment. The water quality between individual mines was variable, displaying no discernable spatial trends, Appendix C. Vertical sampling of the mines indicated that the water within the mines was stratified and the boundary between the stratified units occurred near the upper portions of the mine stopes.

The second sampling period occurred from November 1983 through June 1985. During this period the mines had completely filled and the trace element concentrations began to stabilize. The inflow of surface water into the mine workings was restricted by stream diversion structures and plugging abandoned exploration holes, occurring only during periods of intense precipitation and associated flooding. The water within the mine stopes was characterized by a moderated pH, 5.6-6.2, and a moderated to locally high alkalinity, generally between 200-300 mg/l. Trace metal concentration remained high with Fe > Zn > Ni > Al > Pb > Cd. Calcium concentrations remained high, averaging over 500 mg/l, whereas sulfate concentrations averaged around 2700 mg/l. A reduction in the redox potential of the water within the mine stopes reduced the water to a transitional environment. No definable spatial trends were observed and the water remained stratified. Variations in the water quality appear to be more of a function of depth than location.

The pH of the water within the mine stopes was relatively stable, increasing slightly over time. A direct correlation was observed between Ca and SO_4 concentrations. Average concentrations of Ca and SO_4 were maintained around 500 mg/l and 3000 mg/l, respectively, by the precipitation of gypsum. This was supported by WATEQ4F calculated the water within the mine stopes was saturated with respect to gypsum and the precipitation of crystalline gypsum at OWRB 4S. The alkalinity of the mine water increased by two orders of magnitude between 1977 and 1985, reflecting the contact with additional limestone present in the overburden strata after the mines had filled. Iron concentration remained high increasing by a factor of two in some mines, whereas Zn concentration decreased by half to one third between the first and second sampling periods. Aluminum, Cd, and Pb concentrations decreased by an order of magnitude, whereas Ni concentrations remained the same.

The decrease in dissolved Zn and Pb concentrations are related to the drop in the Eh of the mine water. Zinc, Cd, and Pb concentrations all display the same trend in decreasing concentrations over time corresponding to the decrease in the Eh of the mine water. Zinc, Cd, and Pb concentrations in the mine water come from the dissolution of sphalerite and galena which are stable under reducing conditions. During the first sampling period, the mine water was in an oxidizing environment. Under these conditions, sphalerite and galena would readily dissolve. This was confirmed by the high Zn and Pb concentrations in the water. By the second sampling period, the decrease in the Eh in the mine stopes reduced the mine water to a transitional environment. Under these conditions, sphalerite and galena are more stable. The oxidation and dissolution of these minerals would be retarded as reflected by lower concentrations of Zn and Pb in the mine water. The reduction in the amount of sphalerite dissolving was verified by the decrease in Cd concentration corresponding to the decrease in Zn concentrations over time.

The increase in the Fe concentrations were also related to the drop in the Eh of the mine water. Iron and Ni concentrations in the mine water came from the dissolution of marcasite and pyrite. In acid sulfate waters with $pH > 5$, iron will primarily exist in solution as ferrous iron and ferrous sulfate. In an oxidizing environment, which existed during the first sampling period, the ferrous iron species would oxidize to ferric iron and precipitate out of solution as ferric hydroxide, thus reducing the total dissolved Fe concentration in the mine water. In the second sampling period, when the Eh of the water decreased, less ferrous iron was oxidized and precipitated out of solution. This would increase the total dissolved iron concentration in the mine water while dissociating the same amount of iron sulfide minerals, confirmed by the relatively constant concentrations of Ni vs increasing Fe concentrations in the mine water.

WATEQ4F runs and precipitate analyses indicate that concentrations of Ca, SO_4, Al, and Fe in solution were controlled by the precipitation reactions. Calcium and sulfate concentrations in the mine water were controlled by the precipitation of gypsum. Basaluminite was the dominant Al precipitate found in the acid sulfate water located in the mine stopes, whereas diaspore and kaolinite would be the dominant precipitate in neutral low sulfate water commonly found near the surface of the mine shafts.

Iron concentrations in the mine water were controlled by the oxidation of ferrous iron to ferric iron and the precipitation of ferric hydroxide, which is dependent on the Eh-pH of the water. Ferric ion concentrations in the mine water were also controlled by the precipitation of amorphous goethite. As the alkalinity of the water within the mine stopes increased during the second sampling period, the water became oversaturated with respect to siderite, and other carbonate minerals, such as smithsonite and calcite, approached saturation.

Large quantities of amorphous ferric hydroxide, goethite, and basaluminite and smaller quantities of crystalline gypsum were observed deposited surrounding the mine water discharge points. Upon deposition, ferric oxyhydroxide minerals go through a transformation preferentially dissolving transforming into more thermodynamically stable minerals. Ferric hydroxide and amorphous goethite are precipitated at the entrances of mine discharge points. Upon transportation down stream and deposited in a stable aerobic environment, ferric hydroxide is transformed into goethite. Goethite over time will then be transformed into hematite. This process was observed at OWRB 4S and OWRB 14, as one proceeds down stream from the discharge points.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study is a geochemical assessment of the water located within the mine stopes of the Oklahoma portion of the Picher mine field. This was accomplished by evaluating water quality analyses for vertical, spatial, and temporal variations in water quality, determining the equilibrium of aqueous minerals in solution using the geochemical computer program WATEQ4F, and precipitate collection and analyses to validate the computer runs.

Acidic conditions associated with the water located in the mine stopes was the result of the oxidation and dissolution of iron sulfide minerals, marcasite and pyrite. Under the acidic and oxidizing conditions, the less soluble sulfide ore and gangue minerals, primarily sphalerite, galena, marcasite, and pyrite, were readily dissociated and contributed to the high concentration of trace metals found in the mine water. The high concentrations of Zn and Cd in the mine water came from the dissociation of sphalerite, Pb from galena, Ni from marcasite and pyrite, and Co primarily from pyrite and to a lesser extent from sphalerite.

The moderate acidity of the water in the mine stopes, pH 5-6, reflects the buffering capacity of the calcite and dolomite gangue minerals associated with the ores and limestone in the overburden formations. In the upper portions of the mine shafts near the surface, the pH of the mine water increases because of carbonate dissolution and dilution from inflowing surface water and groundwater. Carbonate neutralization of the mine water is responsible for the extremely high volume of CO_2 gas discharged at the Commerce Spring.

Vertical Variations

Vertical variations in water quality were observed within all of the mines sampled at multiple depths. The water within the mines was stratified during the April 1976 through June 1985 sampling periods. An abrupt change in water quality was observed in the mine water near the vicinity of the upper limit of the mine stopes. Temperature, specific conductance, sulfate, and most trace metal concentrations increased with depth, whereas Eh, pH, dissolved oxygen, and alkalinity decreased.

Spatial Variations

No discernable spatial trends in water quality were observed within the mines sampled between April 1976 and June 1985. Variations in mine water quality appear to be more of a function of depth rather than spatial location. Water samples collected within the mines at during the same sampling period and at similar depths displayed similar water quality.

During the initial stages of water filling the mines, April 1976 through June 1977, the water within the mine stopes was characterized by a moderate pH ranging from 3.8 to 5.9 and a low alkalinity, generally < 5 mg/l. Trace metal concentrations were high with Zn > Fe > Al > Ni > Cd > Pb. Calcium and sulfate concentrations were high averaging slightly more than 500 mg/l of Ca and 3000 mg/l SO_4. The water within the mines possessed a high Eh which indicated that the water was in an oxidizing environment, resulting from rapid inflow of surface water.

By November 1983, most of the mines had completely filled with water and fluctuations in trace element concentrations began to stabilize. Once the mines had filled, November 1983 through June 1985, the water in the mine stopes was characterized by a moderate pH, ranging from 5.6 to 6.2, and a moderate to high alkalinity ranging from 200 to 1000 mg/l as $CaCO_3$. Trace metal concentrations remained high with Fe > Zn > Ni > Al > Pb > Cd. Average calcium concentrations remained high, 500 mg/l, while average sulfate concentrations decreased slightly to 2700 mg/l. The Eh of the water within the mine stopes had decreased, which indicated that the water had reduced to a transitional environment. This resulted from the increased depth of water in the mine shafts and the restriction of surface water from entering the mine workings, occurring only during periods of intense precipitation and associated flooding.

Temporal Variations

Temporal variations in water quality were observed in water samples collected from within the mine stopes between April 1976 and June 1985. The pH of the mine water remained relatively constant or increased slightly during this period. A direct correlation was observed between Ca and SO_4 concentrations, corresponding to the precipitation of gypsum, which controlled the concentrations of these ions in solution.

This was supported by WATEQ4F runs which indicated that the mine water was saturated with respect to gypsum. Small crystals of gypsum, observed at OWRB 4S, indicated that the water was saturated with respect to gypsum, verifying the WATEQ4F runs. A substantial increase in alkalinity occurred between June 1977 and November 1983 which reflects the additional contact of the water with limestone in the overburden as the mines filled.

A notable change in trace metal concentrations was observed between June 1977 and November 1983. Iron concentrations in the mine water remained stable or increased by a factor of two, whereas Zn concentrations decreased by a factor of two to three. Aluminum, Cd, and Pb concentrations decreased by an order of magnitude, while Ni concentrations remained stable.

The decrease in Zn, Cd, and Pb concentrations were related to the decreasing solubility of the sulfide minerals because of the decrease in the Eh of the water. Under lower Eh conditions, the less soluble sulfide minerals, sphalerite and galena, are more stable. The decrease in Eh and increase in pH reduced the rate of oxidation and dissolution of these minerals, reducing the Zn, Cd, and Pb in solution.

Iron concentrations have increased while Ni concentrations remained the same over time. Stable concentrations of Ni in the mine water indicate a relatively constant rate and amount of marcasite and pyrite dissolving over time. As the Eh of the mine water decreased, a larger percentage of the iron would remain in solution as ferrous iron, thus increasing the dissolved iron concentration while dissociating the same amount of iron sulfate minerals.

Aqueous Mineral Equilibrium

The equilibrium of aqueous minerals commonly associated with acid mine drainage were calculated with WATEQ4F. WATEQ4F runs in conjunction with observed precipitates were used to determine the controls of certain elements in solution.

The water within the mine stopes was oversaturated with respect to gypsum which resulted in the precipitation of gypsum and played a major roll in the control of calcium and sulfate concentrations in solution. Iron concentrations in the mine water are controlled by the oxidation of ferrous iron to ferric iron and by the precipitation of amorphous ferric hydroxide and goethite. Aluminum concentrations are controlled by the precipitation of amorphous basaluminite in the acid sulfate waters found in the mine stopes and by the precipitation of bauxite, primarily diaspore, and kaolinite in the neutral and low sulfate water found near the surface of the mine shafts.

Precipitates

Precipitates were collected at the two primary mine water discharge points, OWRB 4S and OWRB 14, to validate the WATEQ4F runs. Small crystals of gypsum, observed at OWRB 4S, indicated that the water was saturated or oversaturated with respect to gypsum, verifying the WATEQ4F runs. At the two major mine water discharge points, OWRB 4S and OWRB 14, large quantities of amorphous ferric hydroxide flocs were observed on the surface of the water. Amorphous goethite and basaluminite covered the vegetation and walls of the discharge outlets. Thick deposits of unconsolidated poorly crystalline hematite were found adjacent to both weirs, located a few hundred feet down stream from the discharge points.

Upon deposition, ferric oxyhydroxide precipitates form a dehydration series, $Fe(OH)_3$-FeOOH-Fe_2O_3, preferentially dissolving to transform into a more thermodynamically stable mineral. Amorphous ferric hydroxide and goethite formed from direct precipitation at the mine discharge points. Amorphous ferric hydroxide continues to precipitate after discharge from the mines resulting from the oxidation of ferrous iron to ferric iron and the hydrolysis of ferric iron. Upon deposition in a stable aerobic environment ferric hydroxide preferentially dissolves to form goethite, goethite then preferentially dissolves to form hematite. This process, at OWRB 4S and OWRB 14, occurs at the discharge points and continues downstream to the respective weirs.

Future Outlook

Without more recent water quality data, one can only speculate on the evolution of the water within the mine stopes over time. Past water quality data indicates that the water within the mine stopes is reverting back to the reducing conditions which occurred before the mining operations existed. Zinc, Cd, and Pb concentrations in the mine water seem to be decreasing with time in relation to a decrease in the Eh of the water and the concentrations will continue to decrease as the water in the mines reverts back to reducing conditions.

Iron concentrations in the mine water will most likely remain high or increase with time. Marcasite and pyrite will continue to be oxidized even if the water within the mines revert back to reducing conditions. The oxidation of iron sulfide minerals can occur abiotically under very low dissolved oxygen concentration and biochemically even under anaerobic conditions. As the Eh of the mine water decreases a larger percentage of the dissolved iron will remain in solution as ferrous iron with only a small percentage oxidizing to ferric iron and precipitating.

The pH of the water within the mine stopes has remained relatively stable during the last three years of sampling, November 1983 through June 1985. This would indicate that the oxidation of marcasite and pyrite had reached equilibrium with the dissolution of limestone. The water within the mine stopes will remain slightly acidic with a moderate alkalinity until the one is exhausted or restricted from reacting with the acidic mine water by a precipitate coating.

Recommendations

To verify the evolution of the water within the mine stopes, water samples would need to be collected within the Admiralty No.4, Consolidated No.2-S, Farmington, and Kenoyer mines at the same intervals as were collected from November 1983 through June 1985. The water quality analyses would need to include the same parameters as June 1985 analyses in addition to specific conductance, dissolved oxygen, ammonia, nitrate, and nitrite concentrations. Analyzing for ammonia, nitrate, and nitrite is essential for determining the accuracy of the Eh calculated from the $NH_4^+/NO_3^=$ and $NO_3^=/NO_2$ couples using WATEQ4F as compared to field determined redox potentials. Water analyses containing Fe and Ni are needed to evaluate the dissociation of marcasite and pyrite, Zn and Cd for the dissociation of sphalerite, and Pb for the dissociation of galena. The Eh and pH of the necessary to determine the trace metal speciation with respect to the measured trace metal concentrations.

Vertical sampling of the mine shafts at 20 foot intervals should include depth, temperature, pH, Eh, specific conductance, dissolved oxygen, alkalinity, Zn, and Fe concentrations. These parameters would be necessary to define the circulation within the shaft and characterize changes in the water quality with depth.

Water quality data collected after the mines had been flooded for an extended period of time is needed to determine the stability and evolution of the water within the mine stopes. Ideally, water samples should be collected quarterly for at least two years to verify seasonal or annual trends in water quality. Unfortunately, detailed analysis of water samples are costly but without them one can only speculate on the present quality of the water within the mine stopes. Post flooding mine water quality data is essential to determine the effectiveness of the EPA no action decision on remediation of Tar Creek which receives acid mine drainage from the Picher mine field.

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APPENDIXES

APPENDIX A

MINE WATER QUALITY ANALYSES

April 1976 to June 1977 Data

Novermber 1983 to June 1985 Data

SAMPLE PARAMETERS AND UNITS

SAMPLING DEPTH (FEET)
TEMPERATURE, WATER (DEG. C)
TURBIDITY (NTU)
OXIDATION REDUCTION POTENTIAL (MILLIVOLTS)
SPECIFIC CONDUCTANCE, MICROSIEMENS PER CENTIMETERAT 25 DEGREES CENTIGRADE
OXYGEN, DISSOLVED (MG/L)
PH (STANDARD UNITS)
CARBON DIOXIDE, DISSOLVED (MG/L AS CO2)
ALKALINITY, WATER, WHOLE, FIELD, FET, (MG/L AS CACO3)
ACIDITY, TOTAL (MG/L AS CACO3)
BICARBONATE, WATER, WHOLE, FIELD, FET, (MG/L AS HCO3)
CARBONATE, WATER, WHOLE, FIELD, FET, (MG/L AS CO3)
NITROGEN, AMMONIA, WATER, DISSOLVED, (MG/L AS N)
NITROGEN, NITRITE, DISSOLVED (MG/L AS N)
NITROGEN, NITRATE, DISSOLVED (MG/L AS N)
NITROGEN, NITRITE PLUS NITRATE, WATER, DISSOLVED, (MG/L AS N)
CARBON, ORGANIC, TOTAL (MG/L AS C)
HARDNESS, TOTAL (MG/L AS CACO3)
HARDNESS, NONCARBONATE, WATER, WHOLE, FIELD, FET,(MG/L AS CACO3)
CALCIUM, WATER, DISSOLVED, (MG/L AS CA)
MAGNESIUM, WATER, DISSOLVED, (MG/L AS MG)
SODIUM, WATER, DISSOLVED, (MG/L AS NA)
SODIUM ADSORPTION RATIO
SODIUM, PERCENT
POTASSIUM, WATER, DISSOLVED, (MG/L AS K)
CHLORIDE, WATER, DISSOLVED, (MG/L AS CL)
SULFATE, WATER, DISSOLVED, (MG/L AS S04)
FLUORIDE, WATER, DISSOLVED, (MG/L AS F)
SILICA, DISSOLVED (MG/L AS SIO2)
ARSENIC, WATER, DISSOLVED, (UG/L)
ARSENIC, TOTAL (UG/L AS AS)
BARIUM, WATER, DISSOLVED, (UG/L)
BARIUM, TOTAL (UG/L AS BA)
BERYLLIUM, WATER, DISSOLVED, (UG/L)
BORON, WATER, DISSOLVED, (UG/L)
BORON, TOTAL (UG/L AS B)
CADMIUM, WATER, DISSOLVED, (UG/L)
CADMIUM, TOTAL (UG/L AS CD)
CHROMIUM, WATER, DISSOLVED, (UG/L)
CHROMIUM, TOTAL (UG/L AS CR)
COBALT, DISSOLVED (UG/L AS CO)
COBALT, TOTAL (UG/L AS CO)
COPPER, WATER, DISSOLVED, (UG/L)
COPPER, TOTAL RECOVERABLE (UG/L AS CU)
IRON, TOTAL (UG/L AS FE)
IRON, WATER, DISSOLVED, (UG/L)
LEAD, WATER, DISSOLVED, (UG/L)
LEAD, TOTAL (UG/L AS PB)
MANGANESE, TOTAL (UG/L AS MN)
MANGANESE, WATER, DISSOLVED, (UG/L)
MOLYBDENUM, WATER, DISSOLVED, (UG/L)
MOLYBDENUM, TOTAL (UG/L AS MO)
NICKEL, WATER, DISSOLVED, (UG/L)
NICKEL, TOTAL (UG/L AS NI)
STROTIUM, WATER, DISSLOVED (UG/L)
VANADIUM, WATER, DISSOLVED, (UG/L)
ZINC, WATER, DISSOLVED, (UG/L)
ZINC, TOTAL (UG/L AS ZN)
ALUMINUM, TOTAL (UG/L AS AL)
ALUMINUM, WATER, DISSOLVED, (UG/L)
LITHIUM, DISSOLVED (UG/L AS LI)
SELENIUM, WATER, DISSOLVED, (UG/L)
SELENIUM, TOTAL (UG/L AS SE)

SAMPLE PARAMETERS AND UNITS, cont'

METHYLENE BLUE ACTIVE SUBSTANCE (MG/L)
SOLIDS, RESIDUE AT 110 DEG. C, SUSPENDED TOTAL, (MG/L)
SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)
SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)
SOLIDS, DISSOLVED (TONS PER ACRE-FOOT)
ACIDITY, WATER, WHOLE, TOTAL, (MG/L AS H)
NITROGEN, AMMONIA, DISSOLVED (MG/L AS NH4)
NITROGEN, NITRATE, DISSOLVED (MG/L AS NO3)
NITROGEN, NITRITE, DISSOLVED (MG/L AS NO2)
MERCURY, WATER, DISSOLVED, (UG/L)
MERCURY, TOTAL RECOVERABLE (UG/L AS HG)
C13/C12 RATIO BOT.MAT

29N-23E-28 BBB 1 BIRTHDAY MINE SHAFT

SAMPLE DATE	23APR76	23APR76	19OCT76	19OCT76	08JUN77	08JUN77	08JUN77
SAMPLING DEPTH	168.0000	182.0000	162.0000	180.0000	155.0000	170.0000	180.0000
TEMP. C)	16.0000	15.0000	15.0000	15.0000	16.0000	16.0000	16.5000
TURBIDITY (NTU)	79.9999	71.9999	24.0000	160.0000	7.9000	110.0000	400.0000
S C	4099.9900	4389.9900	1900.0000	3799.9900	830.0000	3800.0000	4100.0000
PH	5.2000	5.3000	6.0000	5.6000	6.8000	5.0000	5.8000
CO2	81.0000	192.0000	82.0000	181.0000	24.0000	0.0000	99.0000
ALKALINITY	7.0000	20.0000	42.0000	37.0000	77.0000	1.0000	32.0000
ACIDITY	843.9990	893.9990	------	------	10.0000	1090.0000	943.0000
HCO3	8.0000	24.0000	51.0000	45.0000	94.0000	0.0000	39.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AMMONIA, N	0.3500	0.3300	0.1900	0.1700	0.1400	0.5100	0.0300
NITRITE, N	0.0100	0.0100	0.0100	0.0100	0.0400	0.0100	0.0100
NITRATE, N	0.0100	0.0300	0.0100	0.0100	0.3600	0.0600	0.0500
NO2+NO3, N	0.0100	0.0300	0.0100	0.0200	0.4000	0.0700	0.0600
TOC, C	0.0000	0.0000	4.2000	5.4000	2.4000	4.6000	5.1000
HARDNESS, TOTAL	2200.0000	2200.0000	890.0000	2100.0000	410.0000	2200.0000	2500.0000
HARDNESS,NONCO3	2200.0000	2200.0000	850.0000	2100.0000	330.0000	2200.0000	2400.0000
Ca	489.9990	489.9990	250.0000	490.0000	120.0000	500.0000	540.0000
Mg	230.0000	240.0000	64.0000	220.0000	27.0000	230.0000	270.0000
Na	51.9999	52.9999	40.0000	47.0000	19.0000	63.0000	44.0000
Na ADSORP RATIO	0.5000	0.5000	0.6000	0.4000	0.4000	0.6000	0.4000
Na %	5.0000	5.0000	9.0000	5.0000	9.0000	6.0000	4.0000
K	2.7000	2.6000	4.9000	4.1000	3.7000	5.0000	3.5000
Cl	6.7000	6.8000	4.7000	7.3000	2.3000	6.9000	7.2000
SO4	3000.0000	3000.0000	1000.0000	3100.0000	360.0000	3200.0000	3200.0000
F	8.1000	7.2000	1.8000	2.5000	0.6000	8.6000	0.4000
SiO2	11.0000	11.0000	6.4000	12.0000	6.8000	14.0000	9.4000
As	1.0000	2.0000	1.0000	1.0000	1.0000	3.0000	6.0000
As, TOTAL	2.0000	2.0000	1.0000	1.0000	1.0000	3.0000	6.0000
Ba	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	200.0000
Ba, TOTAL	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
B	200.0000	200.0000	110.0000	160.0000	70.0000	180.0000	200.0000
B, TOTAL	220.0000	240.0000	150.0000	220.0000	110.0000	260.0000	250.0000
Cd	899.9990	899.9990	8.0000	60.0000	55.0000	180.0000	20.0000
Cd, TOTAL	879.9990	899.9990	130.0000	100.0000	60.0000	260.0000	80.0000
Cr	20.0000	20.0000	0.0000	0.0000	20.0000	20.0000	20.0000
Cr, TOTAL	20.0000	20.0000	20.0000	20.0000	0.0000	20.0000	20.0000
Co	549.9990	579.9990	74.0000	71.0000	9.0000	700.0000	800.0000
Co, TOTAL	579.9990	599.9990	150.0000	600.0000	100.0000	650.0000	800.0000
Cu	36.0000	59.9999	2.0000	2.0000	8.0000	90.0000	4.0000
Cu, TOTAL	49.9999	49.9999	20.0000	20.0000	20.0000	70.0000	20.0000
Fe, TOTAL	110000.0000	110000.0000	15000.0000	150000.0000	710.0000	240000.0000	230000.0000
Fe	110000.0000	9999.9800	13000.0000	110000.0000	90.0000	220000.0000	230000.0000
Pb	78.9999	92.9999	51.0000	13.0000	7.0000	40.0000	17.0000
Pb, TOTAL	300.0000	300.0000	200.0000	200.0000	200.0000	200.0000	300.0000

BIRTHDAY MINE SHAFT, cont'

Mn, TOTAL	5499.9900	5499.9900	1300.0000	9000.0000	180.0000	5000.0000	13000.0000
Mn	5599.9900	5499.9900	930.0000	9000.0000	190.0000	5200.0000	13000.0000
Mo	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mo, TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Ni	3300.0000	3499.9900	500.0000	2500.0000	50.0000	3500.0000	3000.0000
Ni, TOTAL	3699.9900	3899.9900	500.0000	2500.0000	50.0000	3000.0000	2800.0000
V	39.0000	36.0000	0.8000	49.0000	0.0000	130.0000	50.0000
Zn	489999.0000	489999.0000	65000.0000	360000.0000	6700.0000	340000.0000	400000.0000
Zn, TOTAL	469999.0000	489999.0000	65000.0000	370000.0000	6400.0000	340000.0000	410000.0000
Al, TOTAL	9099.9800	8799.9800	980.0000	4000.0000	70.0000	6200.0000	100.0000
Al	8599.9800	8899.9800	600.0000	3200.0000	50.0000	2900.0000	100.0000
Li	250.0000	250.0000	50.0000	150.0000	20.0000	200.0000	140.0000
Se	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Se, TOTAL	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000
METHYLENE BLUE	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000	0.1000
TSS AT 110 ^{0}C	138.0000	134.0000	29.0000	165.0000	4.0000	84.0000	156.0000
TDS AT 180 ^{0}C	5149.9900	5199.9900	1590.0000	4620.0000	630.0000	4960.0000	5340.0000
SUM OF CONST	4439.9900	4360.0000	1480.0000	4390.0000	595.0000	4620.0000	4760.0000
SOLIDS	7.0000	7.0700	2.1600	6.2800	0.8600	6.7500	7.2600
ACIDITY	17.0000	18.0000	------	------	0.2000	22.0000	19.0000
NH4	0.4500	0.4300	0.2400	0.2200	0.1800	0.6600	0.0400
NO3	0.0400	0.1300	0.0400	0.0400	1.6000	0.2700	0.2200
NO2	0.0000	0.0000	0.0000	0.0300	0.1300	0.0300	0.0300
Hg	0.7000	1.0000	0.5000	0.5000	0.5000	0.5000	0.5000
Hg, TOTAL	0.9000	0.9000	0.5000	0.5000	0.5000	0.5000	0.5000

29N-23E-28 BBB 1 BIRTHDAY MINE SHAFT

SAMPLE DATE	25AUG76	25AUG76	07DEC76	07DEC76	18FEB77	18FEB77	21APR77	21FEB77
SAMPLING DEPTH	160.0000	180.0000	160.0000	180.0000	160.0000	180.0000	155.0000	170.0000
TEMP. C)	16.0000	16.0000	14.5000	16.0000	15.0000	15.5000	15.0000	16.0000
TURBIDITY (NTU)	0.8000	140.0000	9.8000	130.0000	55.0000	80.0000	2.1000	33.0000
S C	1060.0000	3839.9900	1550.0000	4000.0000	3850.0000	4050.0000	1550.0000	3850.0000
PH	7.2000	5.8000	6.6000	5.7000	5.0000	5.4000	7.2000	5.0000
CO2	11.0000	2.5000	45.0000	0.0000	0.0000	0.0000	8.5000	0.0000
ALKALINITY	88.0000	1.0000	92.0000	1.0000	1.0000	1.0000	69.0000	1.0000
ACIDITY	10.0000	646.0000	20.0000	894.0000	993.0000	993.0000	10.0000	447.0000
HCO3	107.0000	1.0000	112.0000	0.0000	0.0000	0.0000	84.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HARDNESS, TOTAL	540.0000	1600.0000	830.0000	2400.0000	1900.0000	2100.0000	730.0000	2000.0000
HARDNESS,NONCO3	460.0000	1600.0000	740.0000	2400.0000	1900.0000	2100.0000	660.0000	2000.0000
Ca	160.0000	420.0000	230.0000	540.0000	480.0000	490.0000	200.0000	470.0000
Mg	35.0000	130.0000	62.0000	260.0000	180.0000	210.0000	55.0000	190.0000
Na	29.0000	40.0000	63.0000	46.0000	54.0000	51.0000	59.0000	61.0000
Na ADSORP RATIO	0.5000	0.4000	1.0000	0.4000	0.5000	0.5000	1.0000	0.6000
Na %	10.0000	5.0000	14.0000	4.0000	6.0000	5.0000	15.0000	6.0000
K	3.7000	3.8000	6.3000	3.0000	4.2000	3.8000	4.6000	4.6000
Cl	3.2000	9.1000	5.5000	6.9000	7.4000	6.8000	3.4000	6.4000
SO4	520.0000	2100.0000	870.0000	3500.0000	2900.0000	3200.0000	760.0000	2700.0000
F	0.4000	2.9000	0.5000	1.1000	8.6000	6.5000	1.1000	7.6000
SiO2	6.8000	10.0000	7.8000	12.0000	13.0000	13.0000	4.9000	13.0000
B	90.0000	240.0000	140.0000	170.0000	150.0000	160.0000	90.0000	150.0000
B, TOTAL	110.0000	130.0000	190.0000	230.0000	240.0000	220.0000	120.0000	230.0000
Cd	60.0000	230.0000	2.0000	60.0000	360.0000	370.0000	140.0000	300.0000
Cd, TOTAL	60.0000	270.0000	20.0000	160.0000	350.0000	360.0000	130.0000	280.0000
Fe, TOTAL	240.0000	110000.0000	2000.0000	160000.0000	190000.0000	210000.0000	280.0000	190000.0000
Fe	210.0000	89000.0000	710.0000	83000.0000	180000.0000	200000.0000	140.0000	170000.0000
Pb	12.0000	40.0000	2.0000	67.0000	300.0000	300.0000	50.0000	200.0000
Pb, TOTAL	200.0000	300.0000	200.0000	300.0000	300.0000	300.0000	200.0000	300.0000
Mn, TOTAL	70.0000	12000.0000	1800.0000	11000.0000	5200.0000	7400.0000	300.0000	5000.0000
Mn	70.0000	7400.0000	1500.0000	10000.0000	5000.0000	7000.0000	300.0000	4400.0000
Ni	50.0000	1800.0000	150.0000	2900.0000	3100.0000	3200.0000	97.0000	2900.0000
Ni, TOTAL	50.0000	2000.0000	500.0000	8000.0000	2900.0000	3000.0000	200.0000	2900.0000
V	0.4000	------	0.0000	45.0000	110.0000	100.0000	0.0000	50.0000
Zn	9400.0000	260000.0000	4400.0000	390000.0000	340000.0000	380000.0000	8300.0000	270000.0000
Zn, TOTAL	9200.0000	340000.0000	54000.0000	390000.0000	340000.0000	390000.0000	8400.0000	310000.0000
Al, TOTAL	60.0000	4000.0000	60.0000	4000.0000	13000.0000	8900.0000	180.0000	11000.0000
Al	40.0000	4000.0000	100.0000	2000.0000	13000.0000	7900.0000	20.0000	11000.0000
Li	20.0000	120.0000	40.0000	160.0000	160.0000	160.0000	30.0000	160.0000
TSS AT 110 oC	0.0000	156.0000	3.0000	149.0000	115.0000	216.0000	9.0000	70.0000
TDS AT 180 oC	864.0000	------	1390.0000	5000.0000	4570.0000	4860.0000	1260.0000	4300.0000
SUM OF CONST	821.0000	3090.0000	1310.0000	4880.0000	4210.0000	4600.0000	1140.0000	3920.0000
SOLIDS	1.1800	4.2000	1.8900	6.8000	6.2200	6.6100	1.7100	5.8500
ACIDITY	0.2000	13.0000	0.4000	18.0000	20.0000	20.0000	0.2000	9.0000

29N-23E-16 DDB 1 CONSOLIDATED #2 - PL

SAMPLE DATE	20APR76	21APR76	21APR76	21APR76	19OCT76	19OCT76	07JUN77	07JUN77
SAMPLING DEPTH	191.0000	227.0000	229.0000	234.0000	165.0000	230.0000	165.0000	230.0000
TEMP. C)	16.0000	16.0000	16.0000	16.0000	14.5000	14.5000	16.0000	16.0000
TURBIDITY (NTU)	3.0000	5.0000	88.0000	72.0000	------	130.0000	0.7000	200.0000
S C	940.0000	1080.0000	4420.0000	4600.0000	830.0000	3999.9900	810.0000	4100.0000
PH	7.5500	6.9000	5.0000	4.8000	6.7000	5.3000	7.4000	5.6000
CO2	2.9000	11.0000	0.0000	0.0000	24.0000	56.0000	5.0000	0.0000
ALKALINITY	53.0000	47.0000	1.0000	1.0000	62.0000	6.0000	64.0000	1.0000
ACIDITY	10.0000	10.0000	894.0000	1140.0000	------	------	0.0000	1090.0000
HCO3	64.0000	57.0000	0.0000	0.0000	76.0000	7.0000	78.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AMMONIA, N	0.0200	0.0100	0.2800	0.2800	0.0100	0.2700	0.0100	0.2700
NITRITE, N	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
NITRATE, N	0.2600	0.2400	0.0000	0.0100	0.2200	0.4200	0.2100	0.0200
NO2+NO3, N	0.2600	0.2400	0.0100	0.0100	0.2200	0.4200	0.2100	0.0300
TOC, C	5.4000	4.7000	4.7000	4.8000	1.7000	0.9000	0.7000	1.0000
HARDNESS, TOTAL	520.0000	550.0000	2200.0000	2300.0000	480.0000	2200.0000	440.0000	2200.0000
HARDNESS,NONCO3	470.0000	510.0000	2200.0000	2300.0000	420.0000	2200.0000	380.0000	2200.0000
Ca	170.0000	180.0000	500.0000	520.0000	160.0000	510.0000	150.0000	510.0000
Mg	24.0000	25.0000	240.0000	240.0000	20.0000	230.0000	16.0000	220.0000
Na	10.0000	11.0000	80.0000	8.0000	8.9000	81.0000	7.1000	80.0000
Na ADSORP RATIO	0.2000	0.2000	0.7000	0.1000	0.2000	0.7000	0.1000	0.7000
Na %	4.0000	4.0000	7.0000	1.0000	4.0000	7.0000	3.0000	7.0000
K	1.7000	1.8000	2.2000	2.2000	2.0000	4.1000	1.4000	3.8000
Cl	2.1000	1.7000	6.2000	6.8000	1.1000	7.0000	1.1000	5.9000
SO4	460.0000	520.0000	3100.0000	3200.0000	440.0000	3400.0000	370.0000	3100.0000
F	0.3000	0.4000	1.9000	1.6000	0.7000	2.4000	0.4000	1.8000
SiO2	10.0000	9.8000	8.4000	9.8000	11.0000	7.7000	12.0000	8.4000
As	1.0000	1.0000	2.0000	1.0000	1.0000	10.0000	1.0000	6.0000
As, TOTAL	1.0000	1.0000	3.0000	2.0000	1.0000	10.0000	1.0000	5.0000
Ba	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	200.0000
Ba, TOTAL	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	200.0000
B	30.0000	100.0000	150.0000	120.0000	40.0000	170.0000	30.0000	170.0000
B, TOTAL	60.0000	170.000	180.0000	190.0000	70.0000	240.0000	60.0000	280.0000
Cd	90.0000	100.0000	780.0000	930.0000	80.0000	540.0000	80.0000	550.0000
Cd, TOTAL	80.0000	100.0000	780.0000	950.0000	90.0000	570.0000	70.0000	530.0000
Cr	0.0000	0.0000	20.0000	30.0000	0.0000	20.0000	20.0000	30.0000
Cr, TOTAL	20.0000	20.0000	30.0000	40.0000	20.0000	20.0000	20.0000	20.0000
Co	0.0000	3.0000	53.0000	56.0000	4.0000	61.0000	2.0000	800.0000
Co, TOTAL	100.0000	100.0000	800.0000	850.0000	100.0000	750.0000	100.0000	750.0000
Cu	4.0000	7.0000	70.0000	100.0000	3.0000	33.0000	2.0000	13.0000
Cu, TOTAL	20.0000	20.0000	60.0000	100.0000	20.0000	30.0000	20.0000	30.0000
Fe, TOTAL	650.0000	800.0000	250000.0000	510000.0000	140.0000	300000.0000	300.0000	350000.0000
Fe	10.0000	670.0000	130000.0000	130000.0000	40.0000	310000.0000	70.0000	53000.0000
Pb	2.0000	2.0000	200.0000	400.0000	3.0000	300.0000	0.0000	350.0000
Pb, TOTAL	200.0000	200.0000	300.0000	500.0000	200.0000	300.0000	0.0000	400.0000

CONSOLIDATED No.2 - PL, cont'

Mn, TOTAL	100.0000	80.0000	5800.0000	6600.0000	40.0000	5500.0000	160.0000	5400.0000
Mn	80.0000	80.0000	5700.0000	5900.0000	30.0000	5400.0000	160.0000	5600.0000
Mo	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mo, TOTAL	3.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Ni	3.0000	32.0000	3400.0000	47.0000	39.0000	3400.0000	14.0000	3400.0000
Ni, TOTAL	50.0000	50.0000	3300.0000	3800.0000	50.0000	3500.0000	50.0000	3500.0000
V	0.1000	0.1000	150.0000	150.0000	1.0000	130.0000	0.0000	160.0000
Zn	3200.0000	3999.9900	310000.0000	380000.0000	3900.0000	290000.0000	2100.0000	310000.0000
Zn, TOTAL	3000.0000	4899.9900	280000.0000	360000.0000	3900.0000	290000.0000	2100.0000	310000.0000
Al, TOTAL	90.0000	90.0000	7300.0000	12000.0000	150.0000	10000.0000	60.0000	200.0000
Al	10.0000	20.0000	7700.0000	10000.0000	100.0000	5000.0000	20.0000	200.0000
Li	30.0000	40.0000	210.0000	220.0000	30.0000	200.0000	20.0000	300.0000
Se	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Se, TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
METHYLENE BLUE	0.1000	0.0000	0.1000	0.1000	0.0000	0.0000	0.0000	0.0000
TSS AT 110 oC	4.0000	3.0000	106.0000	36.0000	12.0000	186.0000	0.0000	114.0000
TDS AT 180 oC	795.0000	841.0000	5160.0000	5380.0000	722.0000	5160.0000	622.0000	5100.0000
SUM OF CONST	715.0000	784.0000	4420.0000	4540.0000	686.0000	4860.0000	600.0000	4330.0000
SOLIDS	1.0800	1.1400	7.0200	7.3200	0.9800	7.0200	0.8500	6.9400
ACIDITY	0.2000	0.2000	18.0000	23.0000	------	------	0.1000	22.0000
NH4	0.0300	0.0000	0.3600	0.3600	0.0000	0.3500	0.0000	0.3500
NO3	1.2000	1.1000	0.0000	0.0400	0.9700	1.9000	0.9300	0.0900
NO2	0.0000	0.0000	0.0300	0.0000	0.0000	0.0000	0.0000	0.0300
Hg	0.7000	0.5000	0.5000	0.6000	0.5000	0.5000	0.5000	0.5000
Hg, TOTAL	0.8000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

29N-23E-16 DDB 1 CONSOLIDATED #2 - PL

SAMPLE DATE	25AUG76	25AUG76	07DEC76	07DEC76	02FEB77	02FEB77	04APR77	04APR77
SAMPLING DEPTH	165.0000	230.0000	165.0000	230.0000	165.0000	230.0000	165.0000	230.0000
TEMP. C)	17.0000	16.0000	14.5000	15.5000	13.5000	15.0000	14.5000	15.5000
TURBIDITY (NTU)	1.0000	140.0000	1.1000	45.0000	1.0000	160.0000	1.0000	70.0000
S C	809.9990	4669.9900	900.0000	4649.9900	1030.0000	4280.0000	1080.0000	4150.0000
PH	7.7000	5.3000	7.4000	5.5000	7.6000	5.3000	7.2000	5.3000
CO2	2.6000	8.0000	4.5000	101.0000	2.3000	0.0000	5.6000	0.0000
ALKALINITY	66.0000	1.0000	58.0000	16.0000	47.0000	1.0000	45.0000	1.0000
ACIDITY	5.0000	894.0000	5.0000	993.0000	5.0000	1040.0000	5.0000	546.0000
HCO3	81.0000	1.0000	71.0000	20.0000	57.0000	0.0000	55.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HARDNESS, TOTAL	440.0000	1300.0000	520.0000	2400.0000	570.0000	2200.0000	570.0000	2200.0000
HARDNESS,NONCO3	370.0000	1300.0000	460.0000	2400.0000	520.0000	2200.0000	520.0000	2200.0000
Ca	150.0000	340.0000	170.0000	560.0000	180.0000	520.0000	180.0000	510.0000
Mg	16.0000	100.0000	23.0000	240.0000	29.0000	230.0000	29.0000	230.0000
Na	7.1000	43.0000	9.7000	77.0000	12.0000	81.0000	12.0000	77.0000
Na ADSORP RATIO	0.1000	0.5000	0.2000	0.7000	0.2000	0.7000	0.2000	0.7000
Na %	3.0000	7.0000	4.0000	7.0000	4.0000	7.0000	4.0000	7.0000
K	1.6000	3.4000	1.9000	3.9000	2.1000	3.6000	2.1000	3.4000
Cl	0.5000	9.1000	1.3000	7.0000	3.1000	6.8000	1.8000	6.3000
SO4	360.0000	1600.0000	490.0000	3500.0000	510.0000	3300.0000	500.0000	3000.0000
F	0.4000	1.7000	0.3000	1.9000	0.5000	3.5000	0.6000	1.5000
SiO2	11.0000	11.0000	12.0000	9.2000	13.0000	8.0000	12.0000	8.8000
B	40.0000	100.0000	60.0000	190.0000	40.0000	170.0000	30.0000	140.0000
B, TOTAL	120.0000	90.0000	60.0000	240.0000	70.0000	270.0000	50.0000	240.0000
Cd	110.0000	360.0000	70.0000	540.0000	65.0000	600.0000	75.0000	610.0000
Cd, TOTAL	110.0000	620.0000	90.0000	540.0000	60.0000	580.0000	70.0000	580.0000
Fe, TOTAL	120.0000	290000.0000	70.0000	300000.0000	120.0000	310000.0000	480.0000	280000.0000
Fe	80.0000	210000.0000	40.0000	290000.0000	10.0000	300000.0000	40.0000	270000.0000
Pb	10.0000	200.0000	3.0000	350.0000	2.0000	450.0000	50.0000	400.0000
Pb, TOTAL	200.0000	400.0000	200.0000	300.0000	200.0000	400.0000	200.0000	400.0000
Mn, TOTAL	90.0000	6000.0000	50.0000	6000.0000	60.0000	5600.0000	100.0000	5600.0000
Mn	100.0000	4200.0000	40.0000	50.0000	60.0000	5500.0000	100.0000	5100.0000
Ni	10.0000	1500.0000	37.0000	3300.0000	36.0000	3600.0000	55.0000	3200.0000
Ni, TOTAL	50.0000	3500.0000	900.0000	6000.0000	50.0000	3400.0000	50.0000	3200.0000
V	0.5000	------	0.0000	60.0000	0.0000	200.0000	0.0000	110.0000
Zn	2200.0000	150000.0000	3500.0000	280000.0000	3300.0000	300000.0000	4200.0000	291999.0000
Zn, TOTAL	2200.0000	300000.0000	30000.0000	280000.0000	3300.0000	300000.0000	------	------
Al, TOTAL	60.0000	15000.0000	40.0000	10000.0000	40.0000	4500.0000	40.0000	4500.0000
Al	30.0000	5000.0000	100.0000	5000.0000	100.0000	1400.0000	10.0000	4500.0000
Li	20.0000	120.0000	30.0000	190.0000	40.0000	200.0000	40.0000	190.0000
TSS AT 110 oC	------	93.0000	0.0000	74.0000	0.0000	93.0000	2.0000	73.0000
TDS AT 180 oC	648.0000	------	768.0000	5090.0000	838.0000	5180.0000	845.0000	4970.0000
SUM OF CONST	589.0000	2500.0000	747.0000	5010.0000	781.0000	4790.0000	769.0000	4420.0000
SOLIDS	0.8800	3.4000	1.0400	6.9200	1.1400	7.0400	1.1500	6.7600
ACIDITY	0.1000	18.0000	0.1000	20.0000	0.1000	21.0000	0.1000	11.0000

29N-23E-29 CDD 1 LAVRION

SAMPLE DATE	28APR76	28APR76	28APR76
SAMPLING DEPTH	160.0000	182.0000	191.0000
TEMP. C)	14.5000	15.0000	15.0000
TURBIDITY (NTU)	37.0000	10.0000	12.0000
S C	3419.9900	3680.0000	3899.9900
PH	4.8000	3.9200	4.7000
CO2	0.0000	0.0000	0.0000
ALKALINITY	1.0000	1.0000	1.0000
ACIDITY	843.9990	1140.0000	993.0000
HCO3	0.0000	0.0000	0.0000
CO3	0.0000	0.0000	0.0000
AMMONIA, N	0.3400	0.4900	0.4500
NITRITE, N	0.0100	0.0100	0.0100
NITRATE, N	0.0000	0.0000	0.0400
NO2+NO3, N	0.1000	0.1000	0.0400
TOC, C	1.8000	1.4000	1.6000
HARDNESS, TOTAL	1700.0000	1800.0000	1800.0000
HARDNESS,NONCO3	1700.0000	1800.0000	1800.0000
Ca	469.9990	510.0000	520.0000
Mg	120.0000	130.0000	120.0000
Na	44.9999	55.0000	53.0000
Na ADSORP RATIO	0.5000	0.6000	0.5000
Na %	6.0000	6.0000	6.0000
K	4.0000	4.5000	4.3000
Cl	7.2000	8.0000	7.8000
SO4	2500.0000	2900.0000	2700.0000
F	9.8000	15.0000	14.0000
SiO2	13.0000	17.0000	16.0000
As	1.0000	1.0000	1.0000
As, TOTAL	1.0000	1.0000	1.0000
Ba	100.0000	100.0000	100.0000
Ba, TOTAL	100.0000	100.0000	100.0000
B	120.0000	150.0000	140.0000
B, TOTAL	130.0000	400.0000	280.0000
Cd	20.0000	13.0000	13.0000
Cd, TOTAL	979.9980	860.0000	830.0000
Cr	30.0000	60.0000	60.0000
Cr, TOTAL	20.0000	60.0000	70.0000
Co	36.0000	45.0000	44.0000
Co, TOTAL	399.9990	600.0000	650.0000
Cu	140.0000	160.0000	120.0000
Cu, TOTAL	130.0000	130.0000	130.0000
Fe, TOTAL	66999.8000	140000.0000	160000.0000
Fe	75999.8000	130000.0000	130000.0000
Pb	20.0000	16.0000	10.0000
Pb, TOTAL	300.0000	300.0000	200.0000

LAVRION, cont'

Mn, TOTAL	4799.9900	7800.0000	8400.0000
Mn	4399.9900	6500.0000	6300.0000
Mo	1.0000	1.0000	1.0000
Mo, TOTAL	1.0000	1.0000	1.0000
Ni	2300.0000	3400.0000	3100.0000
Ni, TOTAL	2000.0000	3800.0000	4000.0000
V	22.0000	60.0000	39.0000
Zn	389999.0000	420000.0000	430000.0000
Zn, TOTAL	339999.0000	420000.0000	439999.0000
Al, TOTAL	11000.0000	26000.0000	280000.0000
Al	14000.0000	29000.0000	26000.0000
Li	140.0000	200.0000	200.0000
Se	1.0000	1.0000	1.0000
Se, TOTAL	1.0000	1.0000	1.0000
METHYLENE BLUE	0.0000	0.0000	0.0000
TSS AT 110 oC	16.0000	4.0000	0.0000
TDS AT 180 oC	4079.9900	4650.0000	4360.0000
SUM OF CONST	3670.0000	4250.0000	4050.0000
SOLIDS	5.5500	6.3200	5.9300
ACIDITY	17.0000	23.0000	20.0000
NH4	0.4400	0.6300	0.5800
NO3	0.0000	0.0000	0.1800
NO2	0.0000	0.0000	0.0000
Hg	0.5000	0.5000	0.5000
Hg, TOTAL	0.5000	0.5000	0.5000

29N-23E-30 AAA 1 LUCKY BILL AIR SHAFT

SAMPLE DATE	22APR76	22APR76	22APR76	20OCT76	20OCT76	07JUN77	07JUN77
SAMPLING DEPTH	178.0000	210.0000	222.0000	190.0000	225.0000	155.0000	225.0000
TEMP. C)	14.0000	14.0000	14.5000	13.0000	14.0000	14.0000	15.0000
TURBIDITY (NTU)	2.1000	180.0000	100.0000	1.4000	3.3000	0.3000	220.0000
S C	1850.0000	4210.0000	4950.0000	1030.0000	4800.0000	1100.0000	4200.0000
PH	6.5000	6.1500	5.6000	6.7000	6.3000	6.5000	5.9000
CO2	190.0000	67.0000	100.0000	69.0000	8.8000	152.0000	12.0000
ALKALINITY	308.0000	48.0000	21.0000	177.0000	9.0000	250.0000	5.0000
ACIDITY	129.0000	546.0000	1090.0000	------	------	79.0000	1190.0000
HCO3	375.0000	59.0000	25.0000	216.0000	11.0000	300.0000	6.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AMMONIA, N	0.0300	0.3300	0.4900	0.0100	0.5800	0.0100	0.5300
NITRITE, N	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
NITRATE, N	0.1500	0.0100	0.0000	0.1600	0.0300	0.1900	0.0300
NO2+NO3, N	0.1500	0.0200	0.0100	0.1600	0.0300	0.2000	0.0400
TOC, C	4.0000	2.2000	2.9000	3.4000	3.2000	3.2000	1.6000
HARDNESS, TOTAL	910.0000	2100.0000	2200.0000	520.0000	2400.0000	570.0000	2400.0000
HARDNESS,NONCO3	600.0000	2100.0000	2200.0000	340.0000	2400.0000	320.0000	2400.0000
Ca	300.0000	500.0000	480.0000	180.0000	470.0000	190.0000	500.0000
Mg	39.0000	210.0000	250.0000	16.0000	290.0000	23.0000	280.0000
Na	57.0000	68.0000	87.0000	19.0000	92.0000	26.0000	86.0000
Na ADSORP RATIO	0.8000	0.6000	0.8000	0.4000	0.8000	0.5000	0.8000
Na %	12.0000	7.0000	8.0000	7.0000	8.0000	9.0000	7.0000
K	8.5000	4.5000	6.0000	4.5000	8.2000	4.7000	6.2000
Cl	10.0000	13.0000	16.0000	4.0000	23.0000	4.5000	15.0000
SO4	810.0000	2800.0000	3000.0000	380.0000	3500.0000	420.0000	3400.0000
F	0.3000	5.0000	9.2000	0.7000	7.5000	0.2000	7.9000
SiO2	19.0000	8.1000	7.6000	11.0000	7.8000	19.0000	10.0000
As	1.0000	2.0000	7.0000	1.0000	11.0000	1.0000	11.0000
As, TOTAL	14.0000	2.0000	8.0000	1.0000	13.0000	1.0000	8.0000
Ba	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	600.0000
Ba, TOTAL	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	600.0000
B	180.0000	180.0000	220.0000	100.0000	220.0000	150.0000	210.0000
B, TOTAL	180.0000	240.0000	250.0000	120.0000	290.0000	160.0000	310.0000
Cd	9.0000	420.0000	490.0000	12.0000	330.0000	8.0000	350.0000
Cd, TOTAL	180.0000	400.0000	460.0000	80.0000	350.0000	110.0000	300.0000
Cr	0.0000	20.0000	20.0000	0.0000	20.0000	0.0000	20.0000
Cr, TOTAL	0.0000	20.0000	20.0000	0.0000	20.0000	20.0000	20.0000
Co	2.0000	52.9999	42.9999	2.0000	43.0000	0.0000	800.0000
Co, TOTAL	100.0000	599.9990	849.9990	100.0000	850.0000	100.0000	800.0000
Cu	20.0000	4.0000	13.0000	11.0000	7.0000	8.0000	8.0000
Cu, TOTAL	30.0000	20.0000	30.0000	20.0000	20.0000	20.0000	20.0000
Fe, TOTAL	350.0000	160000.0000	290000.0000	80.0000	370000.0000	180.0000	320000.0000
Fe	290.0000	150000.0000	270000.0000	20.0000	240000.0000	20.0000	310000.0000
Pb	250.0000	69.0000	400.0000	150.0000	350.0000	99.0000	250.0000
Pb, TOTAL	450.0000	300.0000	500.0000	200.0000	300.0000	200.0000	300.0000

LUCKY BILL AIR SHAFT, cont'

Mn, TOTAL	80.0000	4800.0000	6100.0000	30.0000	6000.0000	10.0000	5800.0000
Mn	60.0000	5000.0000	5700.0000	30.0000	6000.0000	20.0000	6200.0000
Mo	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mo, TOTAL	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000
Ni	47.0000	3000.0000	4200.0000	24.0000	5000.0000	20.0000	4500.0000
Ni, TOTAL	200.0000	4000.0000	5400.0000	50.0000	5000.0000	50.0000	4500.0000
V	0.0000	21.0000	130.0000	0.7000	120.0000	0.0000	150.0000
Zn	68000.0000	280000.0000	490000.0000	25000.0000	440000.0000	39000.0000	440000.0000
Zn, TOTAL	68000.0000	350000.0000	480000.0000	46000.0000	440000.0000	39000.0000	440000.0000
Al, TOTAL	60.0000	2000.0000	5500.0000	40.0000	10000.0000	30.0000	5500.0000
Al	10.0000	2000.0000	5700.0000	100.0000	5000.0000	20.0000	5500.0000
Li	69.9999	160.0000	210.0000	30.0000	220.0000	40.0000	210.0000
Se	3.0000	1.0000	1.0000	2.0000	1.0000	3.0000	1.0000
Se, TOTAL	3.0000	1.0000	1.0000	2.0000	1.0000	3.0000	1.0000
METHYLENE BLUE	0.1000	0.2000	0.8000	0.1000	0.0000	0.1000	0.1000
TSS AT 110 oC	3.0000	209.0000	174.0000	12.0000	15.0000	0.0000	156.0000
TDS AT 180 oC	1580.0000	4380.0000	5470.0000	830.0000	5920.0000	910.0000	5650.0000
SUM OF CONST	1500.0000	4090.0000	4670.0000	748.0000	5100.0000	877.0000	5100.0000
SOLIDS	2.1500	5.9600	7.4400	1.1300	8.0500	1.2400	7.6800
ACIDITY	2.6000	11.0000	22.0000	------	------	1.6000	24.0000
NH4	0.0400	0.4300	0.6300	0.0100	0.7500	0.0000	0.6800
NO3	0.6600	0.0400	0.0000	0.7100	0.1300	0.8400	0.1300
NO2	0.0000	0.0300	0.0300	0.0000	0.0000	0.0300	0.0300
Hg	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
Hg, TOTAL	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

29N-23E-30 AAA 1 LUCKY BILL AIR SHAFT

SAMPLE DATE	26AUG76	26AUG76	07DEC76	07DEC76	17FEB77	17FEB77	21APR77	21APR77
SAMPLING DEPTH	205.0000	228.0000	190.0000	225.0000	190.0000	225.0000	190.0000	225.0000
TEMP. C)	14.0000	15.0000	13.0000	14.0000	13.0000	14.0000	14.0000	15.0000
TURBIDITY (NTU)	1.0000	160.0000	1.6000	140.0000	1.7000	180.0000	0.9000	160.0000
S C	879.9990	4769.9900	1100.0000	4559.9900	1380.0000	4800.0000	1500.0000	4800.0000
PH	6.9000	5.8000	6.5000	5.9000	6.5000	5.8000	6.5000	5.8000
CO2	50.0000	2.5000	146.0000	70.0000	157.0000	0.0000	162.0000	0.0000
ALKALINITY	202.0000	1.0000	237.0000	29.0000	254.0000	1.0000	260.0000	1.0000
ACIDITY	25.0000	1240.0000	74.0000	1340.0000	84.0000	1140.0000	99.0000	546.0000
HCO3	246.0000	1.0000	289.0000	35.0000	310.0000	0.0000	320.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HARDNESS, TOTAL	450.0000	2100.0000	580.0000	2300.0000	640.0000	2300.0000	780.0000	2400.0000
HARDNESS,NONCO3	250.0000	2100.0000	340.0000	2300.0000	380.0000	2300.0000	520.0000	2400.0000
Ca	160.0000	490.0000	200.0000	490.0000	220.0000	480.0000	270.0000	520.0000
Mg	13.0000	220.0000	19.0000	260.0000	21.0000	260.0000	26.0000	270.0000
Na	16.0000	90.0000	23.0000	81.0000	29.0000	82.0000	36.0000	85.0000
Na ADSORP RATIO	0.3000	0.8000	0.4000	0.7000	0.5000	0.8000	0.6000	0.8000
Na %	7.0000	8.0000	8.0000	7.0000	9.0000	7.0000	9.0000	7.0000
K	4.0000	9.2000	4.7000	7.0000	5.4000	6.5000	6.2000	6.8000
Cl	3.8000	21.0000	4.6000	20.0000	14.0000	18.0000	6.6000	15.0000
SO4	320.0000	3400.0000	430.0000	3100.0000	510.0000	3300.0000	610.0000	3500.0000
F	0.3000	9.4000	0.1000	6.6000	1.2000	7.4000	0.4000	7.9000
SiO2	19.0000	9.0000	19.0000	8.8000	22.0000	10.0000	19.0000	11.0000
B	100.0000	290.0000	110.0000	240.0000	130.0000	200.0000	130.0000	200.0000
B, TOTAL	110.0000	240.0000	140.0000	310.0000	140.0000	310.0000	250.0000	320.0000
Cd	20.0000	370.0000	13.0000	360.0000	20.0000	340.0000	140.0000	340.0000
Cd, TOTAL	70.0000	380.0000	100.0000	380.0000	110.0000	330.0000	600.0000	310.0000
Fe, TOTAL	380.0000	350000.0000	150.0000	340000.0000	170.0000	320000.0000	240.0000	320000.0000
Fe	370.0000	330000.0000	150.0000	270000.0000	70.0000	300000.0000	60.0000	290000.0000
Pb	90.0000	400.0000	97.0000	200.0000	98.0000	250.0000	150.0000	250.0000
Pb, TOTAL	200.0000	400.0000	200.0000	300.0000	200.0000	300.0000	400.0000	300.0000
Mn, TOTAL	20.0000	6600.0000	50.0000	5300.0000	60.0000	6000.0000	2700.0000	5900.0000
Mn	20.0000	6500.0000	50.0000	5400.0000	50.0000	5500.0000	50.0000	5500.0000
Ni	17.0000	5000.0000	28.0000	4100.0000	31.0000	3900.0000	49.0000	4000.0000
Ni, TOTAL	50.0000	4600.0000	200.0000	6000.0000	50.0000	3900.0000	1800.0000	3900.0000
V	0.5000	------	0.0000	120.0000	0.0000	0.0000	0.0000	110.0000
Zn	20000.0000	450000.0000	27000.0000	420000.0000	35000.0000	410000.0000	49000.0000	411999.0000
Zn, TOTAL	20000.0000	470000.0000	27000.0000	430000.0000	36000.0000	420000.0000	49000.0000	------
Al, TOTAL	40.0000	10000.0000	50.0000	8000.0000	40.0000	4500.0000	20000.0000	5000.0000
Al	20.0000	10000.0000	100.0000	5000.0000	100.0000	4500.0000	100.0000	5000.0000
Li	20.0000	220.0000	30.0000	110.0000	40.0000	200.0000	50.0000	210.0000
TSS AT 110 oC	0.0000	175.0000	0.0000	170.0000	0.0000	183.0000	5.0000	172.0000
TDS AT 180 oC	687.0000	------	904.0000	5370.0000	1030.0000	5230.0000	1200.0000	5520.0000
SUM OF CONST	679.0000	5080.0000	872.0000	4720.0000	1010.0000	4910.0000	1180.0000	5140.0000
SOLIDS	0.9300	6.9100	1.2300	7.3000	1.4000	7.1100	1.6300	7.5100
ACIDITY	0.5000	25.0000	1.5000	27.0000	1.7000	23.0000	2.0000	11.0000

29N-23E-28 CAB 1 NEW CHICAGO

SAMPLE DATE	29APR76	29APR76	29APR76	20OCT76	20OCT76	08JUN77	08JUN77	08JUN77
SAMPLING DEPTH	174.0000	192.0000	197.0000	165.0000	195.0000	160.0000	180.0000	195.0000
TEMP. C)	16.0000	17.0000	17.5000	16.5000	16.0000	16.0000	15.0000	16.0000
TURBIDITY (NTU)	4.6000	10.0000	38.0000	160.0000	75.0000	0.8000	10.0000	39.0000
S C	2500.0000	2520.0000	2850.0000	3200.0000	3200.0000	2550.0000	3300.0000	3800.0000
PH	7.6000	4.8000	4.9000	7.6000	4.8000	7.1000	4.6000	3.8000
CO2	4.6000	228.0000	121.0000	6.8000	127.0000	23.0000	0.0000	0.0000
ALKALINITY	94.0000	7.0000	5.0000	138.0000	4.0000	150.0000	1.0000	1.0000
ACIDITY	40.0000	228.0000	293.0000	------	------	10.0000	596.0000	1140.0000
HCO3	114.0000	9.0000	6.0000	168.0000	5.0000	180.0000	0.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AMMONIA, N	0.0100	0.0200	0.0900	0.0100	0.1500	0.0100	0.2700	0.4800
NITRITE, N	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
NITRATE, N	0.1200	0.0300	0.0100	0.2100	0.0700	0.1800	0.0100	0.0100
NO2+NO3, N	0.1200	0.0300	0.0100	0.2100	0.0700	0.1800	0.0200	0.0200
TOC, C	3.4000	3.6000	3.5000	3.3000	0.8000	3.1000	0.8000	3.2000
HARDNESS, TOTAL	1600.0000	1600.0000	1600.0000	2100.0000	1900.0000	1700.0000	1900.0000	2100.0000
HARDNESS,NONCO3	1500.0000	1600.0000	1600.0000	2000.0000	1800.0000	1600.0000	1900.0000	2100.0000
Ca	430.0000	489.9990	499.9990	490.0000	510.0000	470.0000	530.0000	500.0000
Mg	130.0000	81.9999	85.9999	210.0000	140.0000	130.0000	140.0000	200.0000
Na	29.0000	28.0000	28.0000	140.0000	36.0000	32.0000	38.0000	57.0000
Na ADSORP RATIO	0.3000	0.3000	0.3000	1.3000	0.4000	0.3000	0.4000	0.5000
Na %	4.0000	4.0000	4.0000	13.0000	4.0000	4.0000	4.0000	6.0000
K	2.9000	1.9000	1.6000	4.3000	3.1000	3.2000	3.5000	4.0000
Cl	4.5000	4.6000	4.8000	7.4000	5.8000	4.8000	5.4000	6.2000
SO4	1800.0000	2000.0000	2100.0000	2300.0000	2300.0000	1600.0000	2400.0000	3000.0000
F	1.0000	2.2000	2.6000	1.9000	5.4000	0.9000	8.3000	1.0000
SiO2	9.3000	11.0000	12.0000	12.0000	14.0000	13.0000	19.0000	19.0000
As	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
As, TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000
Ba	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	200.0000	100.0000
Ba, TOTAL	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
B	130.0000	160.0000	180.0000	70.0000	100.0000	70.0000	150.0000	200.0000
B, TOTAL	330.0000	190.0000	190.0000	100.0000	150.0000	100.0000	210.0000	260.0000
Cd	11.0000	16.0000	130.0000	16.0000	410.0000	12.0000	510.0000	860.0000
Cd, TOTAL	50.0000	350.0000	360.0000	20.0000	430.0000	20.0000	500.0000	850.0000
Cr	20.0000	0.0000	20.0000	20.0000	30.0000	20.0000	60.0000	140.0000
Cr, TOTAL	0.0000	20.0000	20.0000	20.0000	50.0000	20.0000	60.0000	150.0000
Co	88.0000	0.0000	0.0000	8.0000	64.0000	2.0000	400.0000	600.0000
Co, TOTAL	100.0000	200.0000	250.0000	100.0000	350.0000	100.0000	350.0000	600.0000
Cu	2.0000	17.0000	36.0000	3.0000	100.0000	2.0000	130.0000	260.0000
Cu, TOTAL	20.0000	49.9999	49.9999	20.0000	120.0000	20.0000	120.0000	240.0000
Fe, TOTAL	390.0000	2100.0000	18000.0000	490.0000	61000.0000	90.0000	110000.0000	190000.0000
Fe	40.0000	99.9998	20000.0000	30.0000	55000.0000	50.0000	120000.0000	210000.0000
Pb	11.0000	65.9999	120.0000	2.0000	300.0000	4.0000	350.0000	400.0000
Pb, TOTAL	200.0000	200.0000	200.0000	200.0000	300.0000	200.0000	400.0000	400.0000

NEW CHICAGO, cont'

Mn, TOTAL	310.0000	1300.0000	1300.0000	200.0000	2000.0000	220.0000	2800.0000	4200.0000
Mn	310.0000	1100.0000	1400.0000	200.0000	1500.0000	220.0000	3100.0000	4600.0000
Mo	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mo, TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Ni	150.0000	699.9990	999.9980	200.0000	1100.0000	200.0000	1700.0000	2900.0000
Ni, TOTAL	200.0000	799.9990	899.9990	200.0000	1100.0000	50.0000	1600.0000	2600.0000
V	0.5000	0.7000	2.7000	0.1000	24.0000	0.0000	0.0000	17.0000
Zn	16000.0000	99999.8000	120000.0000	6500.0000	130000.0000	7300.0000	190000.0000	340000.0000
Zn, TOTAL	18000.0000	110000.0000	110000.0000	6300.0000	140000.0000	7000.0000	190000.0000	350000.0000
Al, TOTAL	200.0000	3099.9900	3699.9900	130.0000	14000.0000	20.0000	23000.0000	42000.0000
Al	30.0000	110.0000	5399.9900	20.0000	13000.0000	10.0000	24000.0000	42000.0000
Li	50.0000	89.9999	110.0000	70.0000	130.0000	60.0000	190.0000	260.0000
Se	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000
Se, TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000
METHYLENE BLUE	0.4000	0.0000	0.0000	0.0000	0.0000	0.1000	0.0000	0.1000
TSS AT 110 oC	4.0000	5.0000	16.0000	173.0000	90.0000	0.0000	3.0000	2.0000
TDS AT 180 oC	2450.0000	2750.0000	2930.0000	3210.0000	3480.0000	2690.0000	3850.0000	4800.0000
SUM OF CONST	2480.0000	2730.0000	2890.0000	3260.0000	3220.0000	2350.0000	3500.0000	4410.0000
SOLIDS	3.3300	3.7400	3.9800	4.3700	4.7300	3.6600	5.2400	6.5300
ACIDITY	0.8000	4.6000	5.9000	------	------	0.2000	12.0000	23.0000
NH4	0.0100	0.0300	0.1200	0.0000	0.1900	0.0100	0.3500	0.6200
NO3	0.5300	0.1300	0.0400	0.9300	0.3100	0.8000	0.0400	0.0400
NO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0300	0.0300
Hg	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
Hg, TOTAL	0.8000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

29N-23E-28 CAB 1 NEW CHICAGO

SAMPLE DATE	26AUG76	26AUG76	06DEC76	06DEC76	02FEB77	02FEB77	21APR77	21APR77
SAMPLING DEPTH	187.0000	197.0000	165.0000	195.0000	165.0000	195.0000	165.0000	195.0000
TEMP. C)	18.0000	17.5000	14.5000	16.0000	14.5000	15.0000	15.0000	16.0000
TURBIDITY (NTU)	3.8000	11.0000	8.4000	90.0000	8.0000	45.0000	1.3000	0.5000
S C	2850.0000	3839.9900	2650.0000	2950.0000	3150.0000	3200.0000	3000.0000	3350.0000
PH	7.0000	3.8000	7.0000	4.7000	6.2000	4.2000	7.1000	4.3000
CO2	27.0000	0.0000	15.0000	0.0000	24.0000	0.0000	14.0000	0.0000
ALKALINITY	136.0000	1.0000	77.0000	1.0000	20.0000	1.0000	90.0000	1.0000
ACIDITY	20.0000	745.0000	40.0000	407.0000	84.0000	298.0000	35.0000	248.0000
HCO3	166.0000	0.0000	94.0000	0.0000	24.0000	0.0000	110.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HARDNESS, TOTAL	2000.0000	1800.0000	2100.0000	1900.0000	2000.0000	1800.0000	2000.0000	2100.0000
HARDNESS,NONCO3	1900.0000	1800.0000	2000.0000	1900.0000	1900.0000	1800.0000	1900.0000	2100.0000
Ca	520.0000	510.0000	500.0000	510.0000	490.0000	500.0000	490.0000	600.0000
Mg	170.0000	130.0000	200.0000	140.0000	180.0000	140.0000	190.0000	140.0000
Na	34.0000	36.0000	44.0000	36.0000	44.0000	39.0000	45.0000	39.0000
Na ADSORP RATIO	0.3000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
Na %	4.0000	4.0000	4.0000	4.0000	5.0000	4.0000	5.0000	4.0000
K	4.1000	2.8000	3.7000	3.1000	3.4000	3.2000	4.0000	3.2000
Cl	8.8000	8.1000	7.0000	5.6000	7.3000	14.0000	7.3000	72.0000
SO4	1900.0000	2300.0000	2000.0000	2600.0000	2000.0000	2200.0000	1900.0000	2500.0000
F	1.1000	7.2000	1.3000	2.9000	1.9000	3.9000	1.4000	8.0000
SiO2	14.0000	16.0000	12.0000	15.0000	11.0000	14.0000	13.0000	15.0000
B	70.0000	140.0000	80.0000	100.0000	80.0000	130.0000	70.0000	140.0000
B, TOTAL	90.0000	210.0000	120.0000	150.0000	110.0000	140.0000	110.0000	140.0000
Cd	20.0000	630.0000	11.0000	390.0000	8.0000	340.0000	65.0000	560.0000
Cd, TOTAL	50.0000	920.0000	100.0000	400.0000	150.0000	320.0000	60.0000	570.0000
Fe, TOTAL	510.0000	83000.0000	1000.0000	60000.0000	950.0000	42000.0000	350.0000	120000.0000
Fe	80.0000	67000.0000	30.0000	59000.0000	30.0000	41000.0000	60.0000	100000.0000
Pb	14.0000	500.0000	2.0000	250.0000	10.0000	200.0000	200.0000	300.0000
Pb, TOTAL	200.0000	400.0000	200.0000	300.0000	200.0000	200.0000	200.0000	300.0000
Mn, TOTAL	400.0000	3500.0000	440.0000	1700.0000	840.0000	1800.0000	400.0000	2500.0000
Mn	380.0000	2800.0000	420.0000	1900.0000	820.0000	1800.0000	420.0000	2500.0000
Ni	91.0000	1600.0000	500.0000	1200.0000	500.0000	1100.0000	250.0000	1600.0000
Ni, TOTAL	200.0000	1800.0000	900.0000	1200.0000	500.0000	1000.0000	250.0000	1700.0000
V	0.7000	32.0000	0.0000	18.0000	0.0000	22.0000	0.0000	7.0000
Zn	17000.0000	200000.0000	26000.0000	130000.0000	53000.0000	120000.0000	22000.0000	170000.0000
Zn, TOTAL	17000.0000	260000.0000	50000.0000	130000.0000	55000.0000	120000.0000	22000.0000	170000.0000
Al, TOTAL	130.0000	2900.0000	340.0000	12000.0000	1400.0000	9000.0000	140.0000	26000.0000
Al	80.0000	100.0000	10.0000	14000.0000	820.0000	100.0000	100.0000	26000.0000
Li	60.0000	180.0000	80.0000	130.0000	110.0000	130.0000	90.0000	180.0000
TSS AT 110 oC	0.0000	36.0000	1.0000	57.0000	0.0000	25.0000	3.0000	6.0000
TDS AT 180 oC	2990.0000	3670.0000	3170.0000	3410.0000	3090.0000	3330.0000	3060.0000	3630.0000
SUM OF CONST	2750.0000	3300.0000	2840.0000	3530.0000	2810.0000	3080.0000	2730.0000	3680.0000
SOLIDS	4.0700	4.9900	4.3100	4.6400	4.2000	4.5300	4.1600	4.9400
ACIDITY	0.4000	15.0000	0.8000	8.2000	1.7000	6.0000	0.7000	5.0000

29N-23E-28 CCB 1 SKELTON MINE SHAFT

SAMPLE DATE	26APR76	18OCT76	06JUN77
SAMPLING DEPTH	165.0000	160.0000	165.0000
TEMP. C)	16.0000	16.0000	17.0000
TURBIDITY (NTU)	26.0000	23.0000	4.8000
S C	2250.0000	2360.0000	3200.0000
PH	5.7000	5.1000	3.4300
CO2	188.0000	114.0000	0.0000
ALKALINITY	48.0000	7.0000	1.0000
ACIDITY	124.0000	------	695.0000
HCO3	59.0000	9.0000	0.0000
CO3	0.0000	0.0000	0.0000
AMMONIA, N	0.0800	0.1900	0.2600
NITRITE, N	0.0100	0.0100	0.0100
NITRATE, N	0.1100	0.0100	0.0200
NO2+NO3, N	0.1200	0.0100	0.0200
TOC, C	0.9000	0.6000	0.7000
HARDNESS, TOTAL	1300.0000	1300.0000	1600.0000
HARDNESS,NONCO3	1200.0000	1300.0000	1600.0000
Ca	450.0000	440.0000	500.0000
Mg	38.0000	45.0000	88.0000
Na	22.0000	25.0000	33.0000
Na ADSORP RATIO	0.3000	0.3000	0.4000
Na %	4.0000	4.0000	4.0000
K	1.8000	1.6000	1.3000
Cl	4.7000	4.6000	5.0000
SO4	1300.0000	1600.0000	2300.0000
F	1.8000	2.9000	2.3000
SiO2	12.0000	14.0000	18.0000
As	1.0000	1.0000	1.0000
As, TOTAL	1.0000	2.0000	2.0000
Ba	100.0000	100.0000	200.0000
Ba, TOTAL	100.0000	100.0000	100.0000
B	60.0000	70.0000	110.0000
B, TOTAL	1700.0000	100.0000	170.0000
Cd	9.0000	470.0000	1200.0000
Cd, TOTAL	160.0000	490.0000	1100.0000
Cr	0.0000	20.0000	140.0000
Cr, TOTAL	20.0000	20.0000	150.0000
Co	89.0000	49.0000	350.0000
Co, TOTAL	150.0000	200.0000	300.0000
Cu	3.0000	48.0000	220.0000
Cu, TOTAL	20.0000	60.0000	200.0000
Fe, TOTAL	8900.0000	29000.0000	70.0000
Fe	140.0000	28000.0000	60.0000
Pb	2.0000	30.0000	350.0000
Pb, TOTAL	200.0000	200.0000	200.0000

SKELTON MINE SHAFT, cont'

Mn, TOTAL		620.0000	740.0000	1600.0000
Mn		670.0000	760.0000	1600.0000
Mo		1.0000	1.0000	1.0000
Mo, TOTAL		1.0000	1.0000	1.0000
Ni		500.0000	600.0000	1300.0000
Ni, TOTAL		600.0000	650.0000	1100.0000
V		0.0000	1.2000	11.0000
Zn	3	47000.0000	110000.0000	250000.0000
Zn, TOTAL	3	59000.0000	110000.0000	250000.0000
Al, TOTAL		680.0000	6000.0000	26000.0000
Al		540.0000	5500.0000	30000.0000
Li		60.0000	70.0000	140.0000
Se		1.0000	1.0000	1.0000
Se, TOTAL		1.0000	1.0000	1.0000
METHYLENE BLUE		0.0000	0.0000	0.0000
TSS AT 110 oC		11.0000	27.0000	7.0000
TDS AT 180 oC		2120.0000	2400.0000	3480.0000
SUM OF CONST		1910.0000	2280.0000	3250.0000
SOLIDS		2.8800	3.2600	4.7300
ACIDITY		2.5000	------	14.0000
NH4		0.1000	0.2400	0.3300
NO3		0.4900	0.0400	0.0900
NO2		0.0300	0.0000	0.0000
Hg		1.3000	0.8000	0.5000
Hg, TOTAL		0.5000	0.5000	0.5000

29N-23E-29 CBA 1 - ADMIRALTY SHAFT

SAMPLE DATE	29NOV83	23MAR84	11JUN85
SAMPLING DEPTH	150.0000	180.0000	190.0000
TEMP (DEG. C)	19.0000	15.0000	18.0000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX		200.0000	320.0000
S C	4450.0000	4100.0000	
OXYGEN	0.4000	0.2000	
PH	5.8000	5.7000	5.9000
PH, LAB	3.7000	5.5000	2.8000
ALKALINITY	260.0000	260.0000	232.0000
AMMONIA, N	0.5300		0.8900
NITRITE, N	0.0100		
NO2+NO3, N	0.1000		
P	0.0100	0.1250	0.0800
(MG/L AS CA)	570.0000	490.0000	509.0000
(MG/L AS MG)	280.0000	250.0000	193.0000
(MG/L AS NA)	93.0000	89.0000	88.0000
(MG/L AS K)	6.2000	6.5000	5.7000
(MG/L AS CL)	33.0000	28.0000	30.0000
(MG/L AS S04)	3200.0000	3200.0000	2900.0000
(MG/L AS F)	4.5000	6.1000	2.5000
(MG/L AS SIO2)	16.0000	19.0000	15.0000
BARIUM			9.0000
BERYLLIUM			1.0000
CADMIUM	22.0000	14.0000	8.0000
COBALT			322.0000
COPPER	1.0000	1.0000	30.0000
IRON	300000.0000	280000.0000	223600.0000
LEAD	40.0000	28.0000	7.2000
MANGANESE	5300.0000	5300.0000	2584.0000
MOLYBDENUM			20.0000
NICKEL	3500.0000		2900.0000
STRONTIUM			882.0000
VANADIUM			12.0000
ZINC	170000.0000	150000.0000	96920.0000
ALUMINUM	2900.0000	1400.0000	1600.0000
LITHIUM			153.0000
DBLS WL	2.0000	0.0000	0.0000
C13/C12			-8.6000
S C LAB	3930.0000	4090.0000	4020.0000

29N-23E-16 DCA 1 - CONSOLIDATED NO. 2 S

SAMPLE DATE	30NOV83	22MAR84	11JUN85
SAMPLING DEPTH	226.0000	225.0000	228.0000
TEMP (DEG. C)	17.0000	15.4000	17.5000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX		240.0000	350.0000
S C	4050.0000	4080.0000	
OXYGEN		0.1000	
PH	5.7000	5.7000	5.8000
PH, LAB	5.1000	5.3000	2.8000
ALKALINITY	280.0000	288.0000	275.5000
AMMONIA, N	0.4100		0.6800
NITRITE, N	0.0100		
NO2+NO3, N	0.1000		
P	0.0100	0.0220	0.0290
(MG/L AS CA)	460.0000	470.0000	497.0000
(MG/L AS MG)	230.0000	250.0000	203.0000
(MG/L AS NA)	67.0000	73.0000	69.0000
(MG/L AS K)	3.8000	4.2000	3.8000
(MG/L AS CL)	10.0000	9.6000	9.4000
(MG/L AS SO4)	2800.0000	2900.0000	2700.0000
(MG/L AS F)	1.2000	1.7000	0.7000
(MG/L AS SIO2)	8.6000	12.0000	10.0000
BARIUM			12.0000
BERYLLIUM			1.0000
CADMIUM	10.0000	14.0000	27.0000
COBALT			316.0000
COPPER	2.0000	1.0000	30.0000
IRON	270000.0000	290000.0000	245600.0000
LEAD	22.0000	49.0000	38.8000
MANGANESE	4400.0000	4300.0000	3554.0000
MOLYBDENUM			20.0000
NICKEL	2200.0000		2300.0000
STRONTIUM			994.0000
VANADIUM			12.0000
ZINC	110000.0000	110000.0000	91700.0000
ALUMINUM	690.0000	500.0000	450.0000
LITHIUM			161.0000
DBLS WL	26.8000	26.0000	26.0000
C13/C12			-9.4000
S C LAB	3570.0000	3880.0000	4020.0000

29N-23E-14 AAB 1 - FARMINGTON SHAFT

SAMPLE DATE	01DEC83	01DEC83	01DEC83
SAMPLING DEPTH	138.0000	176.0000	192.0000
TEMP (DEG. C)	16.0000	17.5000	18.0000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX			
S C	2800.0000	3950.0000	4650.0000
OXYGEN			
PH	6.4000	6.0000	5.6000
PH, LAB	6.6000	6.1000	5.1000
ALKALINITY	280.0000	680.0000	360.0000
AMMONIA, N	0.3100	0.9500	1.0000
NITRITE, N	0.0100	0.0100	0.0100
NO2+NO3, N	0.1000	0.1000	0.1000
P	0.0200	0.0100	0.0100
(MG/L AS CA)	560.0000	640.0000	500.0000
(MG/L AS MG)	49.0000	210.0000	260.0000
(MG/L AS NA)	52.0000	81.0000	74.0000
(MG/L AS K)	5.6000	9.2000	12.0000
(MG/L AS CL)	7.0000	12.0000	14.0000
(MG/L AS SO4)	1600.0000	2100.0000	3500.0000
(MG/L AS F)	1.7000	2.0000	1.6000
(MG/L AS SIO2)	11.0000	9.6000	9.3000
BARIUM			
BERYLLIUM			
CADMIUM	9.0000	3.0000	29.0000
COBALT			
COPPER	1.0000	1.0000	1.0000
IRON	42000.0000	180000.0000	600000.0000
LEAD	1.0000	1.0000	22.0000
MANGANESE	2700.0000	2400.0000	5200.0000
MOLYBDENUM			
NICKEL	520.0000	2500.0000	1500.0000
STRONTIUM			
VANADIUM			
ZINC	38000.0000	21000.0000	150000.0000
ALUMINUM	70.0000	310.0000	1700.0000
LITHIUM			
DBLS WL	56.5000	56.5000	56.5000
C13/C12			
S C LAB	2510.0000	3350.0000	4230.0000

29N-23E-14 AAB 1 - FARMINGTON SHAFT

SAMPLE DATE	22MAR84	22MAR84	22MAR84
SAMPLING DEPTH	140.0000	176.0000	192.0000
TEMP (DEG. C)	15.4000	15.5000	15.5000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX	190.0000	205.0000	240.0000
S C	2730.0000	3810.0000	4730.0000
OXYGEN	0.2000	0.1000	0.1000
PH	6.40009	6.0000	5.6000
PH, LAB	6.5000	6.2000	5.3000
ALKALINITY	350.0000	720.0000	375.0000
AMMONIA, N			
NITRITE, N			
NO2+NO3, N			
P	0.0050	0.0060	0.0140
(MG/L AS CA)	560.0000	600.0000	450.0000
(MG/L AS MG)	45.0000	190.0000	250.0000
(MG/L AS NA)	51.0000	78.0000	72.0000
(MG/L AS K)	5.7000	9.4000	11.0000
(MG/L AS CL)	4.8000	10.0000	11.0000
(MG/L AS S04)	1600.0000	2200.0000	3700.0000
(MG/L AS F)	1.3000	1.9000	1.0000
(MG/L AS SIO2)	13.0000	15.0000	11.0000
BARIUM			
BERYLLIUM			
CADMIUM	5.0000	2.0000	18.0000
COBALT			
COPPER	1.0000	1.0000	2.0000
IRON	43000.0000	150000.0000	590000.0000
LEAD	1.0000	1.0000	34.0000
MANGANESE	2800.0000	2500.0000	5500.0000
MOLYBDENUM			
NICKEL			
STRONTIUM			
VANADIUM			
ZINC	47000.0000	23000.0000	150000.0000
ALUMINUM	60.0000	350.0000	540.0000
LITHIUM			
DBLS WL	45.5000		
C13/C12			
S C LAB	2690.0000	3470.0000	4490.0000

29N-23E-14 AAB 1 - FARMINGTON SHAFT

SAMPLE DATE	12JUN85	12JUN85	12JUN85
SAMPLING DEPTH	140.0000	176.0000	194.0000
TEMP (DEG. C)	17.0000	17.0000	17.5000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX	360.0000	140.0000	330.0000
S C			
OXYGEN			
PH	6.5000	6.1000	5.7000
PH, LAB	6.8000	6.0000	3.6000
ALKALINITY	277.0000	732.0000	368.0000
AMMONIA, N	0.5500	1.2000	1.5000
NITRITE, N			
NO2+NO3, N			
P	0.0050	0.0140	0.0250
(MG/L AS CA)	564.0000	593.0000	497.0000
(MG/L AS MG)	36.0000	183.0000	206.0000
(MG/L AS NA)	49.0000	84.0000	71.0000
(MG/L AS K)	5.5000	9.9000	14.0000
(MG/L AS CL)	6.1000	6.6000	13.0000
(MG/L AS SO4)	1600.0000	2300.0000	3200.0000
(MG/L AS F)	1.3000	1.0000	0.7000
(MG/L AS SIO2)	13.0000	13.0000	10.0000
BARIUM	14.0000	21.0000	10.0000
BERYLLIUM	1.0000	1.0000	1.0000
CADMIUM	8.0000	3.0000	28.0000
COBALT	70.0000	248.0000	556.0000
COPPER	20.0000	20.0000	30.0000
IRON	22820.0000	199680.0000	512600.0000
LEAD	1.4000	1.8000	23.8000
MANGANESE	2326.0000	1400.0000	1910.0000
MOLYBDENUM	20.0000	20.0000	20.0000
NICKEL	400.0000	3000.0000	2300.0000
STRONTIUM	409.0000	599.0000	455.0000
VANADIUM	12.0000	12.0000	12.0000
ZINC	19906.0000	21660.0000	113420.0000
ALUMINUM	30.0000	270.0000	610.0000
LITHIUM	222.0000	366.0000	291.0000
DBLS WL	47.0000	47.0000	47.0000
C13/C12	-7.6000	-8.4000	
S C LAB	2560.0000	3490.0000	4200.0000

29N-23E-14 AAB 1 - FARMINGTON SHAFT

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29N-23E-14 AAB 1 - FARMINGTON SHAFT

SAMPLE DATE	07DEC81	07DEC81
SAMPLING DEPTH	70.0000	180.0000
TEMP (DEG. C)	14.1000	15.6000
(CODES)	1028.0000	1028.0000
(CODES)	1028.0000	1028.0000
REDOX		
S C	1700.0000	3750.0000
OXYGEN		
PH	5.2000	5.6000
PH, LAB		
ALKALINITY	14.0000	600.0000
AMMONIA, N		
NITRITE, N	0.1000	0.0000
NO2+NO3, N		
P		
(MG/L AS CA)	360.0000	610.0000
(MG/L AS MG)	29.0000	180.0000
(MG/L AS NA)	43.0000	77.0000
(MG/L AS K)	6.0000	9.0000
(MG/L AS CL)	15.0000	8.1000
(MG/L AS S04)	1000.0000	2200.0000
(MG/L AS F)	1.1000	1.8000
(MG/L AS SIO2)	15.0000	6.0000
BARIUM	0.0000	0.0000
BERYLLIUM		
CADMIUM	7.0000	14.0000
COBALT		
COPPER	80.0000	70.0000
IRON	2000.0000	220000.0000
LEAD	0.0000	0.0000
MANGANESE	1200.0000	2700.0000
MOLYBDENUM		
NICKEL		
STRONTIUM		
VANADIUM		
ZINC	4400.0000	30000.0000
ALUMINUM		
LITHIUM		
DBLS WL	68.0000	68.0000
C13/C12		
S C LAB		

29N-23E-18 DBA 1GORDON AIR SHAFT

SAMPLE DATE	30NOV83
SAMPLING DEPTH	170.0000
TEMP (DEG. C)	19.0000
(CODES)	1028.0000
(CODES)	80020.0000
REDOX	
S C	4700.0000
OXYGEN	
PH	5.7000
PH, LAB	3.6000
ALKALINITY	280.0000
AMMONIA, N	0.9000
NITRITE, N	0.0100
NO2+NO3, N	0.1000
P	0.0100
(MG/L AS CA)	690.0000
(MG/L AS MG)	330.0000
(MG/L AS NA)	120.0000
(MG/L AS K)	10.0000
(MG/L AS CL)	35.0000
(MG/L AS SO4)	3000.0000
(MG/L AS F)	5.4000
(MG/L AS SIO2)	18.0000
BARIUM	
BERYLLIUM	
CADMIUM	4.0000
COBALT	
COPPER	1.0000
IRON	390000.0000
LEAD	1.0000
MANGANESE	5600.0000
MOLYBDENUM	
NICKEL	4400.0000
STRONTIUM	
VANADIUM	
ZINC	150000.0000
ALUMINUM	3400.0000
LITHIUM	
DBLS WL	30.0000
C13/C12	
S C LAB	4270.0000

29N-23E-20 CBB 1KENOYER SHAFT

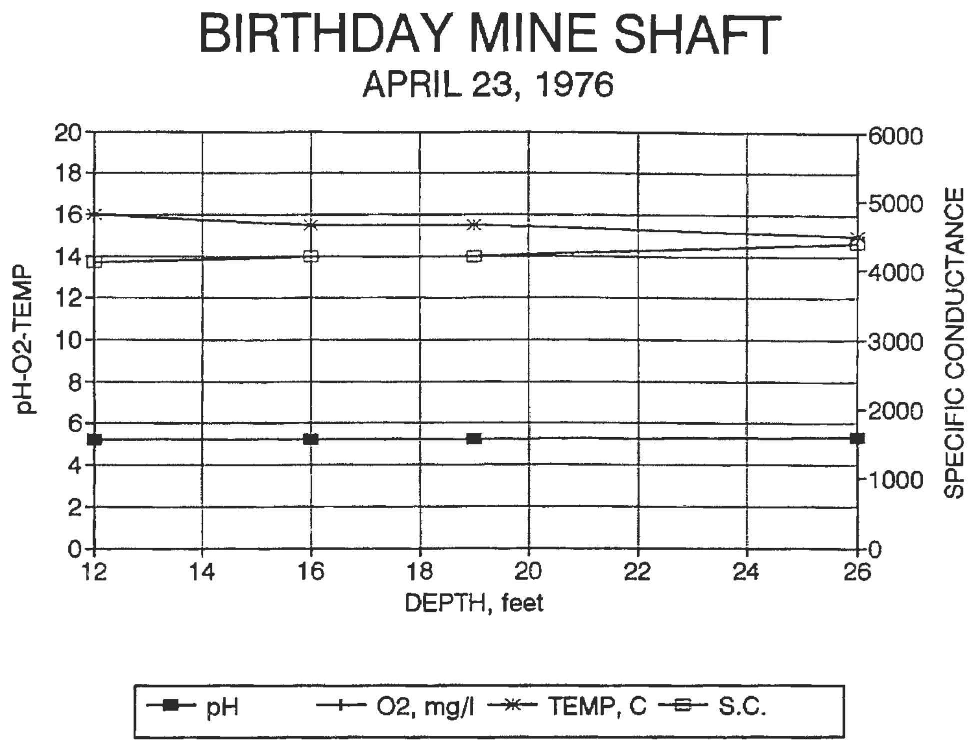
SAMPLE DATE	29NOV83	22MAR84	11JUN85
SAMPLING DEPTH	184.0000	185.0000	182.0000
TEMP (DEG. C)	19.0000	16.1000	18.0000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX		240.0000	300.0000
S C	4000.0000	3600.0000	
OXYGEN		0.3000	
PH	5.6000	5.7000	5.9000
PH, LAB	3.4000	3.6000	3.2000
ALKALINITY	260.0000	202.0000	180.0000
AMMONIA, N	0.5900		0.7300
NITRITE, N	0.0100		
NO2+NO3, N	0.1000		
P	0.0100	0.3510	0.0000
(MG/L AS CA)	500.0000	490.0000	514.0000
(MG/L AS MG)	190.0000	180.0000	134.0000
(MG/L AS NA)	91.0000	82.0000	75.0000
(MG/L AS K)	5.5000	5.5000	5.2000
(MG/L AS CL)	37.0000	33.0000	27.0000
(MG/L AS S04)	2500.0000	2300.0000	2300.0000
(MG/L AS F)	3.1000	4.2000	2.1000
(MG/L AS SIO2)	13.0000	18.0000	13.0000
BARIUM			10.0000
BERYLLIUM			1.0000
CADMIUM	12.0000	6.0000	3.0000
COBALT			171.0000
COPPER	2.0000	2.0000	20.0000
IRON	210000.0000	200000.0000	147260.0000
LEAD	1.0000	21.0000	10.0000
MANGANESE	3800.0000	3800.0000	2728.0000
MOLYBDENUM			20.0000
NICKEL	2500.0000		2000.0000
STRONTIUM			909.0000
VANADIUM			12.0000
ZINC	120000.0000	91000.0000	54760.0000
ALUMINUM	1800.0000	1100.0000	750.0000
LITHIUM			119.0000
DBLS WL	15.0000	15.0000	15.0000
C13/C12			-8.1000
S C LAB	3580.0000	3520.0000	3330.0000

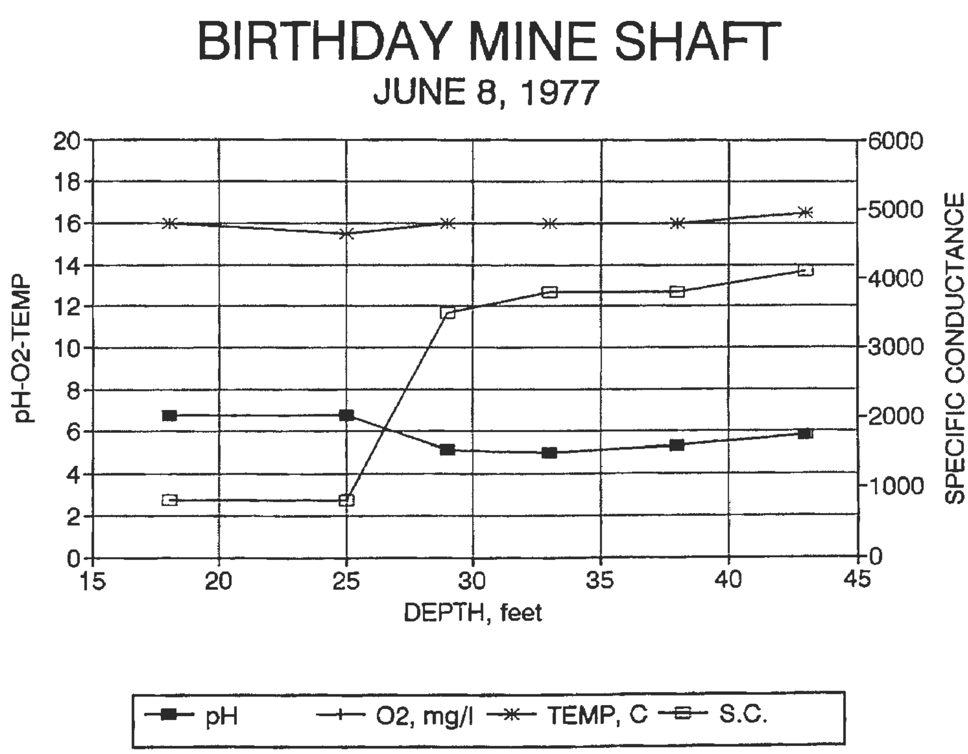
29N-23E-17 BCD 1LUCKY SYNDICATE AIR

SAMPLE DATE	30NOV83	23MAR84	12JUN85
SAMPLING DEPTH	110.0000	110.0000	110.0000
TEMP (DEG. C)	19.0000	17.3000	18.5000
(CODES)	1028.0000	1028.0000	1028.0000
(CODES)	80020.0000	80020.0000	80020.0000
REDOX		230.0000	300.0000
S C	5400.0000	4830.0000	
OXYGEN		0.1000	
PH	6.2000	6.0000	6.1500
PH, LAB	6.6000	6.7000	6.7000
ALKALINITY	1000.0000	870.0000	960.0000
AMMONIA, N	0.8500		1.3000
NITRITE, N	0.0100		
NO2+NO3, N	0.1000		
P	0.0100	0.0050	0.0070
(MG/L AS CA)	540.0000	510.0000	543.0000
(MG/L AS MG)	440.0000	364.0000	413.0000
(MG/L AS NA)	310.0000	340.0000	311.0000
(MG/L AS K)	43.0000	44.0000	45.0000
(MG/L AS CL)	96.0000	85.0000	100.0000
(MG/L AS S04)	2700.0000	2900.0000	3000.0000
(MG/L AS F)	0.9000	0.6000	0.7000
(MG/L AS SIO2)	13.0000	14.0000	14.0000
BARIUM			18.0000
BERYLLIUM			1.0000
CADMIUM	1.0000	1.0000	2.0000
COBALT			200.0000
COPPER	2.0000	1.0000	30.0000
IRON	18000.0000	12000.0000	20480.0000
LEAD	1.0000	1.0000	1.4000
MANGANESE	9700.0000	7800.0000	8158.0000
MOLYBDENUM			20.0000
NICKEL	510.0000		500.0000
STRONTIUM			5348.0000
VANADIUM			12.0000
ZINC	640.0000	480.0000	534.0000
ALUMINUM	10.0000	30.0000	10.0000
LITHIUM			392.0000
DBLS WL	29.0000	28.0000	28.5000
C13/C12			
S C LAB	4950.0000	5060.0000	5310.0000

APPENDIX B

VERTICAL MINE WATER QUALITY DATA


BIRTHDAY MINE SHAFT
APRIL 23, 1976
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
20
18
16
14
12
10
8
6
4
2
0
6000
5000
4000
3000
2000
1000
0
12
14
16
18
20
22
24
26
pH
O2, mg/l
TEMP, C
S.C.

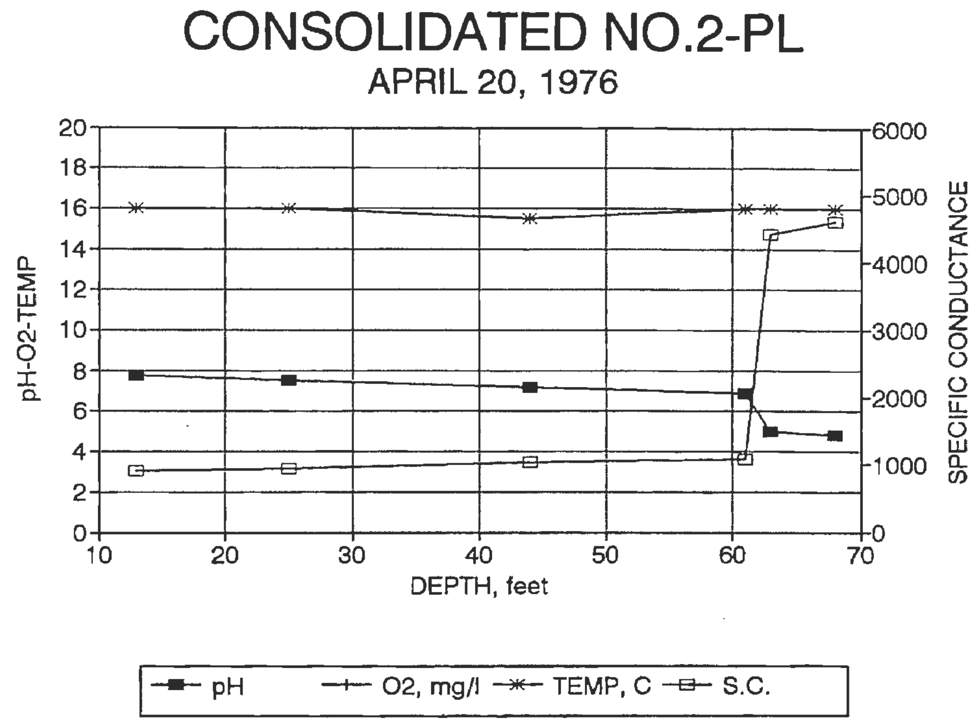

BIRTHDAY MINE SHAFT
JUNE 8, 1977
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
20
18
16
14
12
10
8
6
4
2
0
6000
5000
4000
3000
2000
1000
0
15
20
25
30
35
40
45
pH
O2, mg/l
TEMP, C
S.C.

BIRTHDAY
APRIL 23, 1976

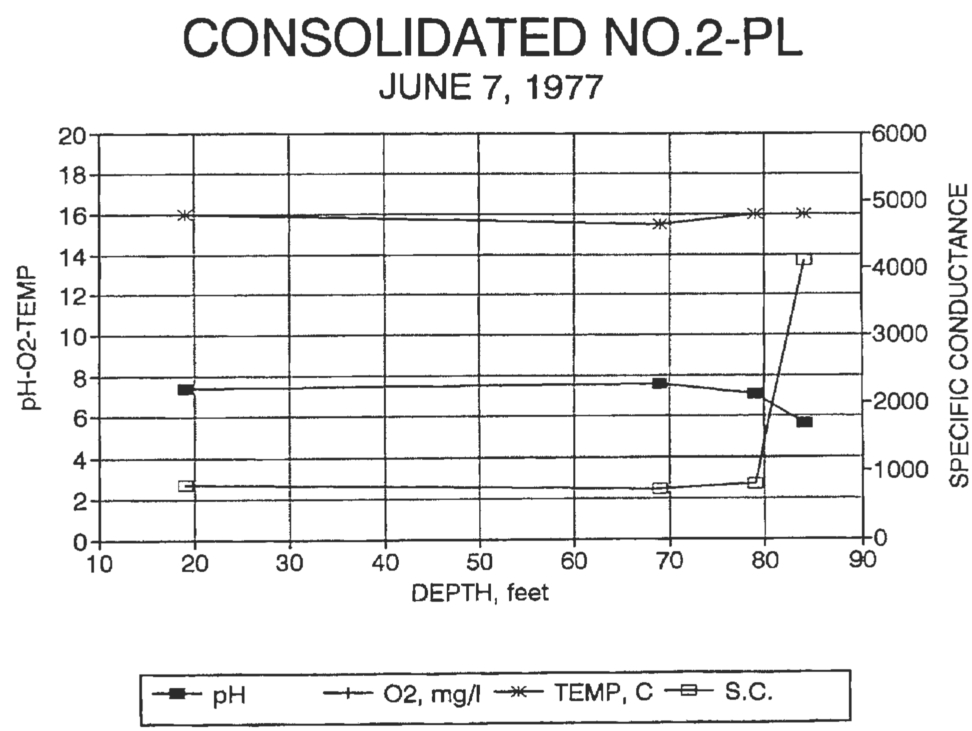
DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
168	16	5.2	81	4100	7	3000	110	490
171.5	15.5	5.2		4200				
175	15.5	5.2		4200				
182	15	5.3	192	4390	20	3000	10	490

BIRTHDAY
JUNE 8, 1977

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
155	16	6.8	24	830	77	360	0.09	6.7
162	15.5	6.8		830				
166	16	5.1		3500				
170	16	5.0	0	3800	1	3200	220	340
175	16	5.3		3800				
180	16.5	5.8	99	4100	32	3200	230	400



CONSOLIDATED NO.2-PL
APRIL 20, 1976
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.



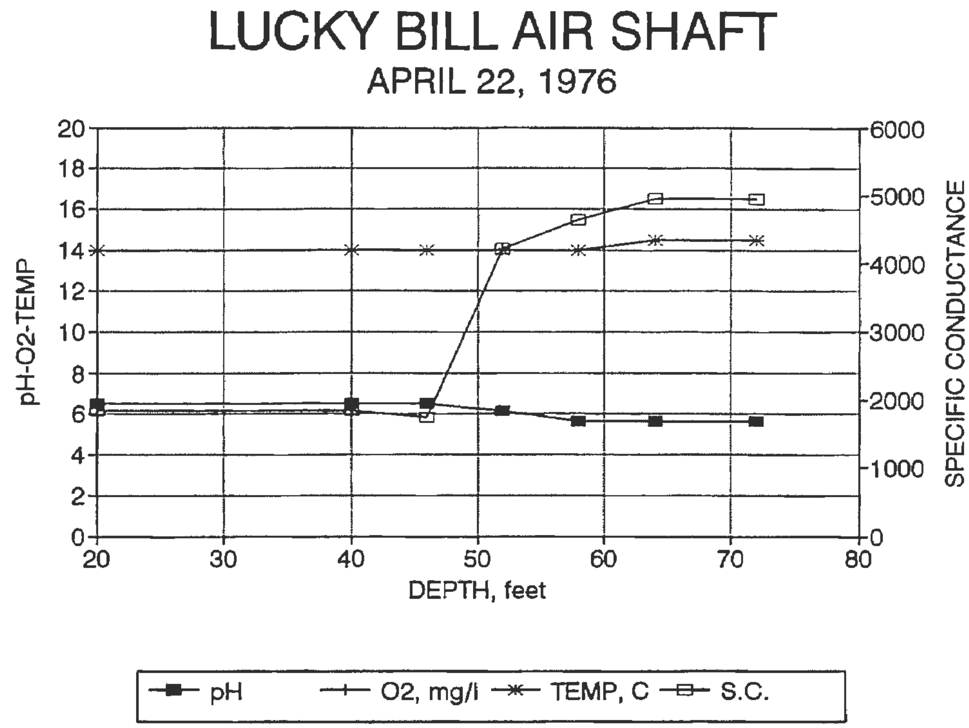
CONSOLIDATED NO.2-PL
JUNE 7, 1977
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

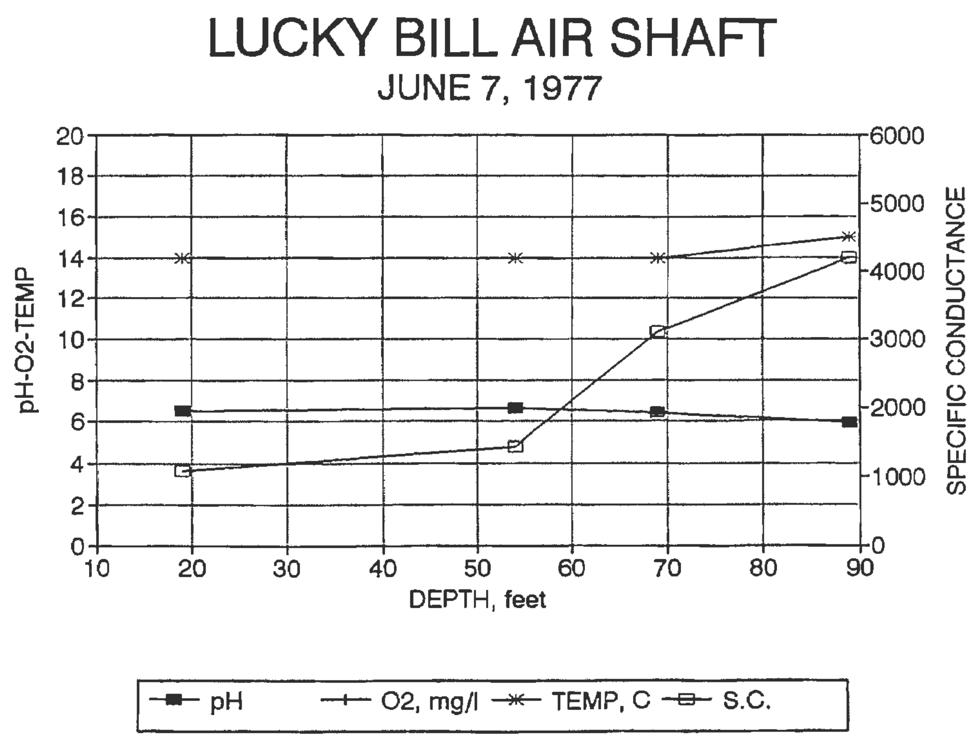
CONSOLIDATED NO.2-PL
APRIL 20, 1976

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
179	16	7.8		920				
191	16	7.55	2.9	940	53	460	0.1	3.2
210	15.5	7.2		1040				
227	16	6.9	11	1080	47	520	0.67	3.4
229	16	5	0	4420	1	3100	130	310
234	16	4.8	0	4600	1	3200	130	380

CONSOLIDATED NO.2-PL
JUNE 7, 1977

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
152	14.5	6.8		1170				
165	14.5	7.2	5.6	1080	45	500	0.05	4.2
215	14.5	7.3		1080				
220	14.5	7.2		1080				
230	15.5	5.3	0	4150	1	3000	270	292


LUCKY BILL AIR SHAFT
APRIL 22, 1976
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

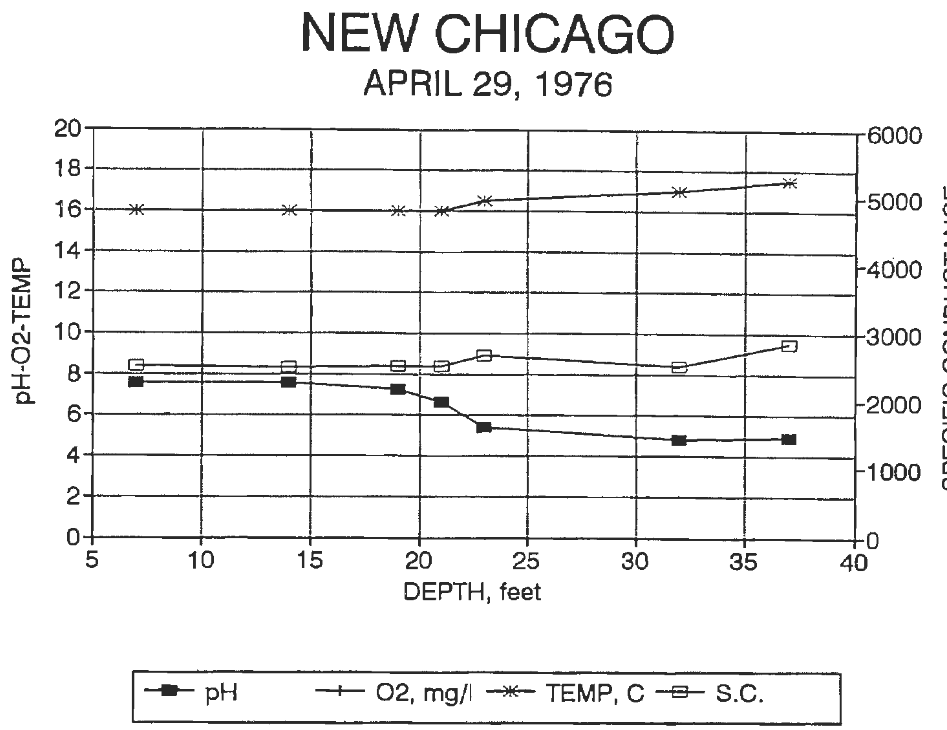

LUCKY BILL AIR SHAFT
JUNE 7, 1977
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

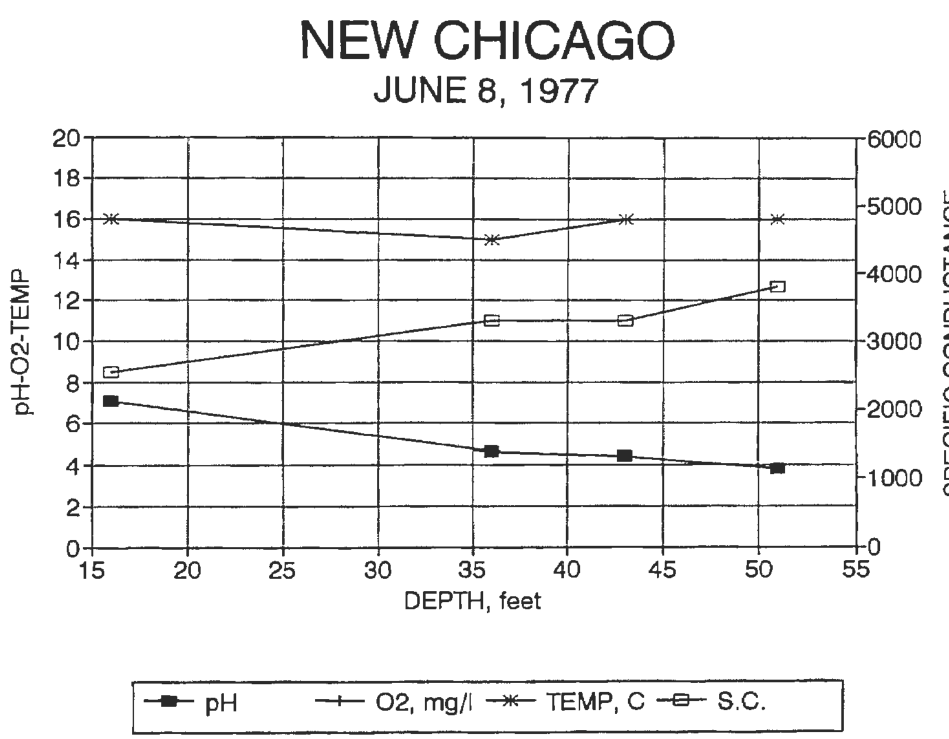
LUCKY BILL
APRIL 22, 1976

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
178	14	6.5	190	1850	308	810	0.29	68
198	14	6.5		1850				
204	14	6.5		1750				
210	14	6.15	67	4210	48	2800	150	280
216	14	5.6		4630				
222	14.5	5.6	100	4950	21	3000	270	490
230	14.5	5.6		4950				

LUCKY BILL
JUNE 7, 1977

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
155	14	6.5	152	1100	250	420	0.02	3.9
190	14	6.6		1450				
205	14	6.4		3100				
225	15	5.9	12	4200	5	3400	310	440


NEW CHICAGO
APRIL 29, 1976
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

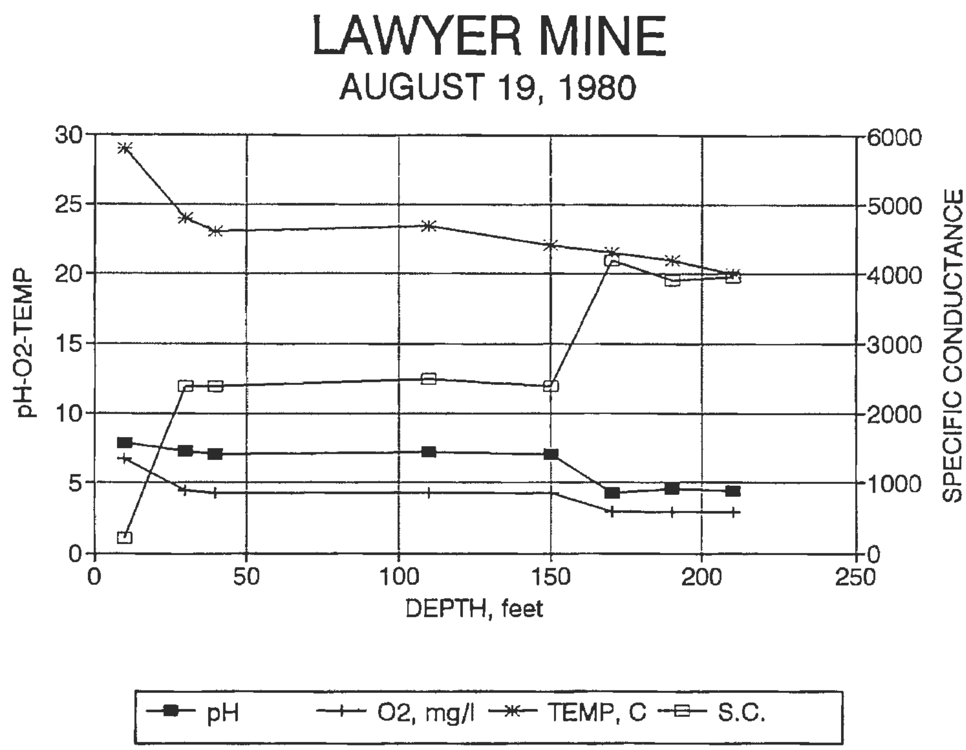

NEW CHICAGO
JUNE 8, 1977
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

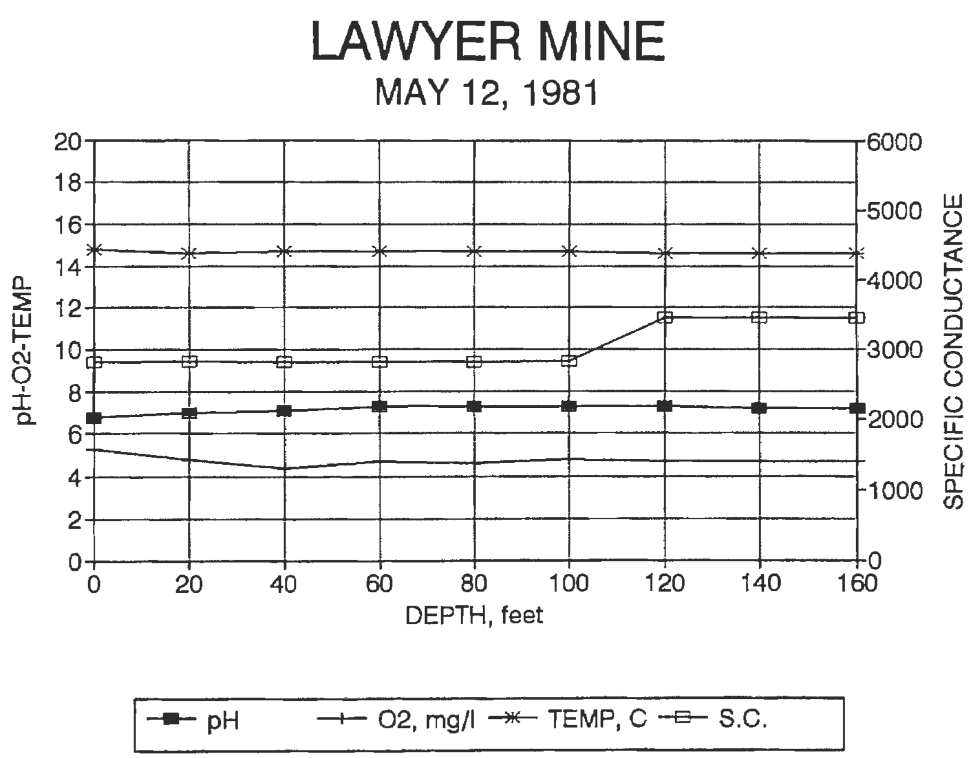
NEW CHICAGO
APRIL 29, 1976

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
167	16	7.6		2520				
174	16	7.6	4.6	2500	94	1800	0.04	16
179	16	7.3		2520				
181	16	6.6		2520				
183	16.5	5.4		2680				
192	17	4.8	228	2520	7	2000	0.1	100
197	17.5	4.9	121	2850	5	2100	20	120

NEW CHICAGO
JUNE 8, 1977

DEPTH,ft	TEMP,^{o}C	pH	CO2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
160	16	7.1	23	2550	150	1600	0.05	7.3
180	15	4.6	0	3300	1	2400	120	190
187	16	4.4		3300				
195	16	3.8	0	3800	1	3000	210	340


LAWYER MINE
AUGUST 19, 1980
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

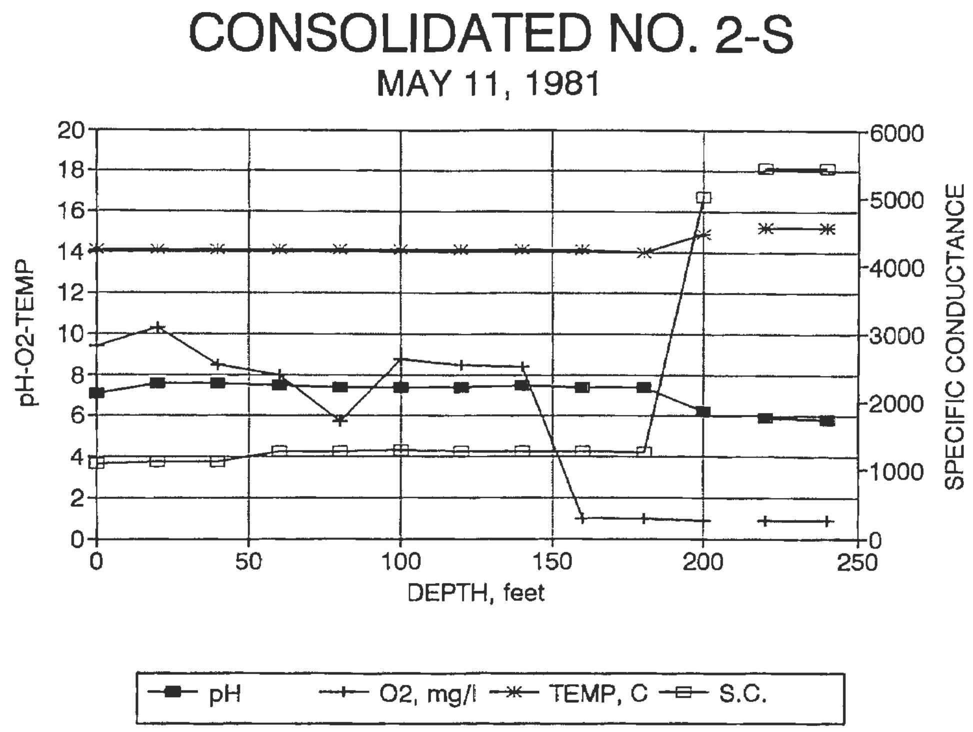

LAWYER MINE
MAY 12, 1981
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

LAWYER
AUGUST 19, 1980

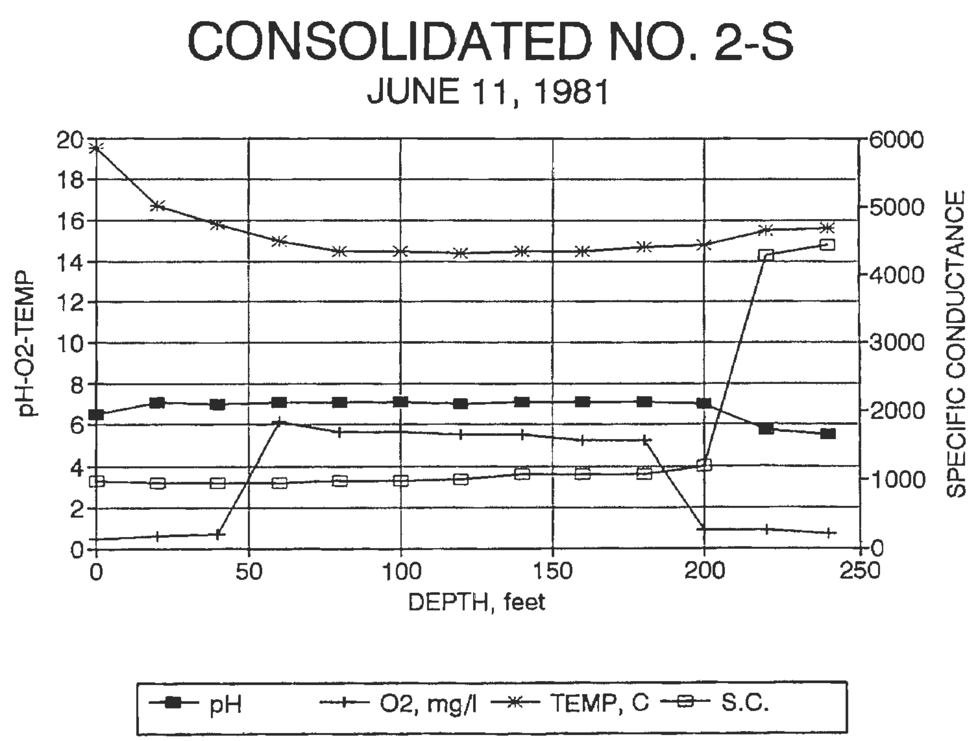
DEPTH,ft	TEMP,°C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
10	29	7.9	6.8	2200	3	1838		
30	24	7.3	4.5	2400	120	4749		
40	23	7.1	4.3	2400	148	1569		
110	23.5	7.2	4.3	2500	154	1569		
150	22	7.1	4.3	2400	148	1614		
170	21.5	4.3	3.0	4200	3	3080		
190	21	4.6	2.9	3900	3	3080		
210	20	4.4	2.9	3950	3	3080		

LAWYER
MAY 12, 1981

DEPTH,ft	TEMP,°C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
0	14.8	6.8	5.3	2820	134	1506	0.8	5.4
20	14.6	7.0	4.8	2830				
40	14.7	7.1	4.4	2820				
60	14.7	7.3	4.7	2820				
80	14.7	7.3	4.6	2820				
100	14.7	7.3	4.8	2830				
120	14.6	7.3	4.7	3460				
140	14.6	7.2	4.7	3460	174	1837	0.2	4.2
160	14.6	7.2	4.7	3460	15	3430	240	40



CONSOLIDATED NO. 2-S
MAY 11, 1981
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.



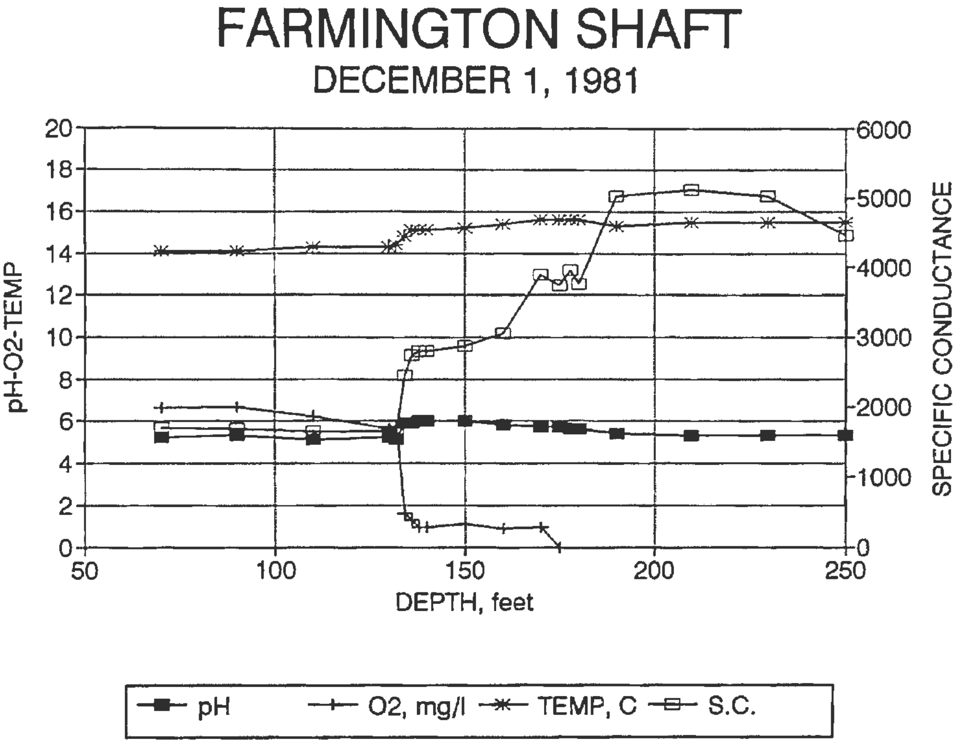
CONSOLIDATED NO. 2-S
JUNE 11, 1981
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
pH
O2, mg/l
TEMP, C
S.C.

CONSOLIDATED No.2-S
MAY 11, 1981

DEPTH,ft	TEMP,°C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
0	14.1	7.1	9.4	1095	64	561	0.52	2.89
20	14.1	7.6	10.3	1129				
40	14.1	7.6	8.5	1120				
60	14.1	7.5	8.0	1271				
80	14.1	7.4	5.7	1274				
100	14.1	7.4	8.8	1286				
120	14.1	7.4	8.5	1272				
140	14.1	7.5	8.4	1271	78	559	0.24	92
180	14.0	7.4	1.0	1269				
200	14.9	6.2	0.9	5010				
210					171	3025	150	51
220	15.2	5.9	0.9	5430				
240	15.2	5.8	0.9	5440				

CONSOLIDATED No.2-S
JUNE 11, 1981

DEPTH,ft	TEMP,°C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
0	19.5	6.5	0.5	986		342	0.1	6.22
20	16.7	7.1	0.6	963				
40	15.8	7.0	0.7	965				
60	15.0	7.1	6.1	965				
80	14.5	7.1	5.6	988				
100	14.5	7.1	5.6	990				
120	14.4	7.0	5.5	1007				
140	14.5	7.1	5.5	1086				
160	14.5	7.1	5.4	1091		492	0.1	5.66
180	14.7	7.1	5.2	1074				
200	14.8	7.0	0.9	1204		2932	400	339
220	15.5	5.7	0.9	4280				
240	15.6	5.5	0.7	4430				

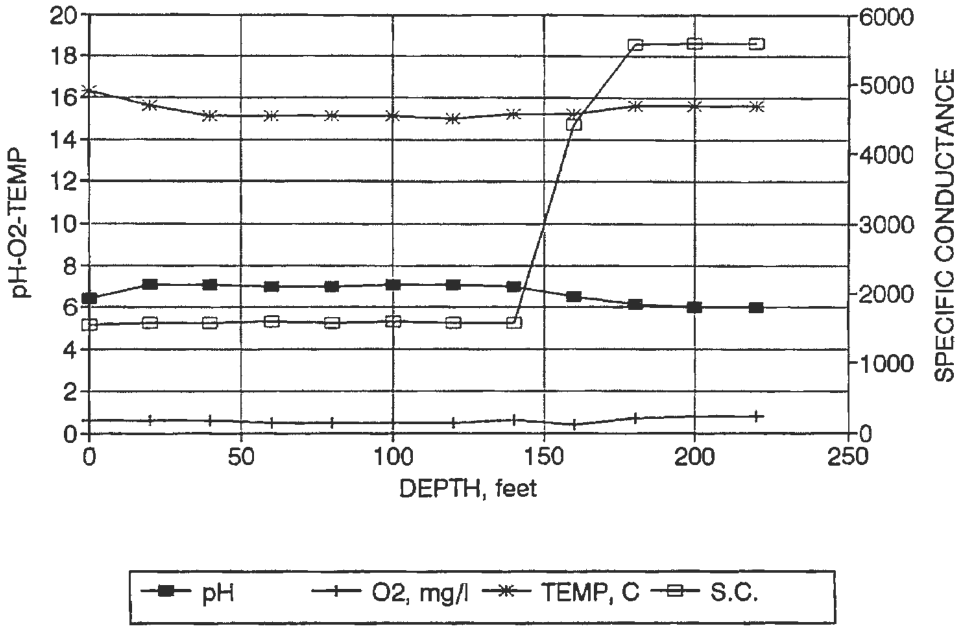

FARMINGTON SHAFT
DECEMBER 1, 1981
pH-O2-TEMP
SPECIFIC CONDUCTANCE
DEPTH, feet
20
18
16
14
12
10
8
6
4
2
0
50
100
150
200
250
6000
5000
4000
3000
2000
1000
0
pH
O2, mg/l
TEMP, C
S.C.

FARMINGTON
DECEMBER 1, 1981

DEPTH,ft	TEMP,^{o}C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
70	14.1	5.2		1700	14	1000	2	4.4
90	14.1	5.3	6.7	1680				
110	14.3	5.1	6.2	1660				
130	14.3	5.2	5.6	1650				
132	14.4	5.1	5.7	1650				
134	14.8	5.9	1.6	2450				
136	15.1	5.9	1.3	2740				
138	15.1	6.0	0.91	2800				
140	15.1	6.0	0.95	2810				
150	15.2	6.0	1.1	2880				
160	15.4	5.8	0.89	3060				
170	15.6	5.7	0.94	3890				
175	15.6	5.7		3740				
178	15.6	5.6		3950				
180	15.6	5.6		3750	600	2200	220	30
190	15.3	5.4		5030				
210	15.5	5.3		5120				
230	15.5	5.3		5020				
250	15.5	5.3		4450				
270	15.6	5.3						

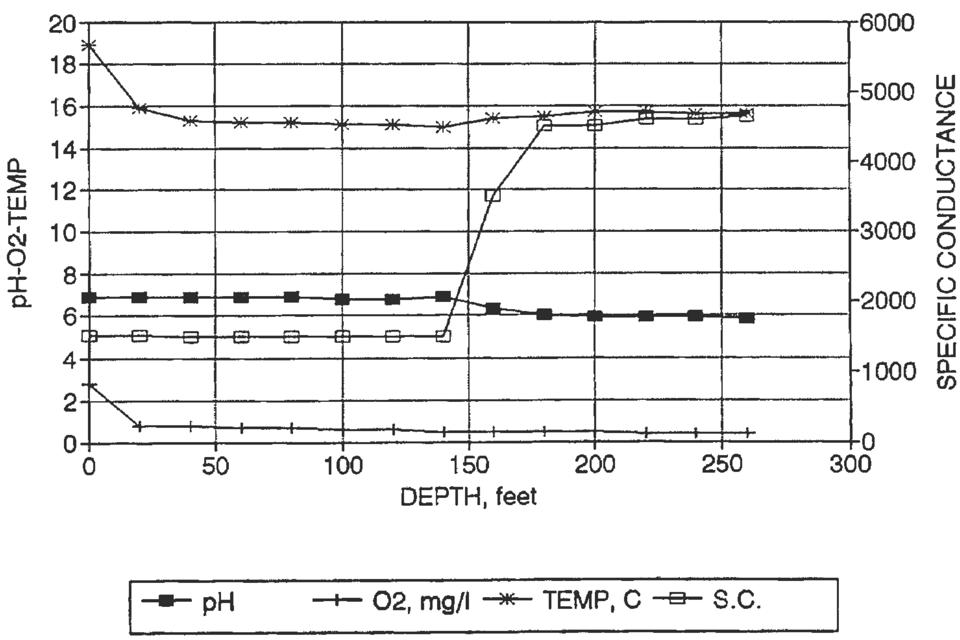
KENOYER SHAFT

MAY 11, 1981



KENOYER SHAFT

JUNE 11, 1981



KENOYER
MAY 11, 1981

DEPTH,ft	TEMP,^{o}C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
0	16.3	6.4	0.6	1549	170	624	0.14	9.6
20	15.6	7.1	0.6	1580				
40	15.1	7.1	0.6	1580				
60	15.1	7.0	0.5	1587				
80	15.1	7.0	0.5	1586				
100	15.1	7.1	0.5	1587				
120	15.0	6.0	0.5	1583				
140	15.2	7.0	0.6	1586	170	640	0.17	7.7
160	15.2	6.5	0.4	4410				
180	15.6	6.1	0.7	5570	175	3119	220	2.34
200	15.6	6.0	0.8	5590				

KENOYER
JUNE 11, 1981

DEPTH,ft	TEMP,^{o}C	pH	O2,mg/l	S.C.,mV	ALK,mg/l	SO4,mg/l	Fe,mg/l	Zn,mg/l
0	18.9	6.9	2.8	1524		613	53	13.27
20	15.9	6.9	0.8	1523				
40	15.3	6.9	0.8	1509				
60	15.2	6.9	0.9	1508				
80	15.2	6.9	0.7	1506				
100	15.1	6.8	0.6	1504	172	630	0.27	13
120	15.1	6.8	0.6	1507				
140	15.0	6.9	0.5	1500				
160	15.4	6.3	0.5	3520				
180	15.5	6.0	0.5	4510				
200	15.7	5.9	0.5	4510	.344	2600	150	190
220	15.7	5.9	0.4	4600				
240	15.6	5.9	0.4	4600				
260	15.6	5.8	0.4	4650				

APPENDIX C

AERIAL MINE WATER QUALITY DATA

AERIAL MINE WATER QUALITY DATA, APRIL 1976

	CONSOLIDATED No.2-PL	LUCKY BILL	LAVRION	NEW CHICAGO	BIRTHDAY	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	229	222	191	197	182	229	182	204.2
TEMP. (^0C)	16	14.5	15	17.5	15	17.5	14.5	15.6
S C (uS)	4420	4950	3899.99	2850	4389.99	4950	2850	4102.0
pH	5	5.6	4.7	4.9	5.3	5.6	4.7	5.1
CO2	0	100	0	121	192	192	0	82.6
ALKALINITY ($CaCO_3$)	1	21	1	5	20	21	1	9.6
HCO3	0	25	0	6	24	25	0	11.0
HARDNESS,TOTAL	2200	2200	1800	1600	2200	2200	1600	2000.0
CALCIUM	500	480	520	499.99	489.99	520	480	498.0
MAGNESIUM	240	250	120	85.99	240	250	85.99	187.2
SODIUM	80	87	53	28	52.99	87	28	60.2
POTASSIUM	2.2	6	4.3	1.6	2.6	6	1.6	3.3
CHLORIDE	6.2	16	7.8	4.8	6.8	16	4.8	8.3
SULFATE	3100	3000	2700	2100	3000	3100	2100	2780.0
FLUORIDE	1.9	9.2	14	2.6	7.2	14	1.9	7.0
SiO2	8.4	7.6	16	12	11	16	7.6	11.0

UNITS: MG/L

TRACE METALS

	CONSOLIDATED No.2-PL	LUCKY BILL	LAVRION	NEW CHICAGO	BIRTHDAY	MAXIMUM	MINIMUM	MEAN
ARSENIC	2	7	1	1	2	7	1	2.6
BARIUM	100	100	100	100	100	100	100	100.0
BORON	150	220	140	180	200	220	140	178.0
CADMIUM	780	490	13	130	899.99	899.99	13	462.6
CHROMIUM	20	20	60	20	20	60	20	28.0
COBALT	53	42.99	44	0	579.99	579.99	0	144.0
COPPER	70	13	120	36	59.99	120	13	59.8
IRON	130000	270000	130000	20000	9999.98	270000	9999.98	112000.0
LEAD	200	400	10	120	92.99	400	10	164.6
MANGANESE	5700	5700	6300	1400	5499.99	6300	1400	4920.0
MOLYBDENUM	1	1	1	1	1	1	1	1.0
NICKEL	3400	4200	3100	999.99	3499.99	4200	999.99	3040.0
VANADIUM	150	130	39	2.7	36	150	2.7	71.5
ZINC	310000	490000	430000	120000	489999	490000	120000	367999.8
ALUMINUM	7700	5700	26000	5399.99	8899.98	26000	5399.99	10740.0
LITHIUM	210	210	200	110	250	250	110	196.0
Eh (WATEQ4F), mV	530	440		524	499	530	440	498.3

UNITS: UG/L

AERIAL MINE WATER QUALITY DATA, JUNE 1977

	CONSOLIDATED NO.2-PL	LUCKY BILL	NEW CHICAGO	BIRTHDAY	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	230	225	195	180	230	180	207.5
TEMP. (^{o}C)	16	15	16	16.5	16.5	15	15.9
S C (uS)	4100	4200	3800	4100	4200	3800	4050.0
pH	5.6	5.9	3.8	5.8	5.9	3.8	5.3
CO2	0	12	0	99	99	0	27.8
ALKALINITY ($CaCO_3$)	1	5	1	32	32	1	9.8
HCO3	0	6	0	39	39	0	11.3
HARDNESS, TOTAL	2200	2400	2100	2500	2500	2100	2300.0
CALCIUM	510	500	500	540	540	500	512.5
MAGNESIUM	220	280	200	270	280	200	242.5
SODIUM	80	86	57	44	86	44	66.8
POTASSIUM	3.8	6.2	4	3.5	6.2	3.5	4.4
CHLORIDE	5.9	15	6.2	7.2	15	5.9	8.6
SULFATE	3100	3400	3000	3200	3400	3000	3175.0
FLUORIDE	1.8	7.9	1	0.4	7.9	0.4	2.8
SiO2	8.4	10	19	9.4	19	8.4	11.7

UNITS: MG/L

TRACE METALS

	CONSOLIDATED NO.2-PL	LUCKY BILL	NEW CHICAGO	BIRTHDAY	MAXIMUM	MINIMUM	MEAN
ARSENIC	6	11	1	6	11	1	6.0
BARIUM	200	600	100	200	600	100	275.0
BORON	170	210	200	200	210	170	195.0
CADMIUM	550	350	860	20	860	20	445.0
CHROMIUM	30	20	140	20	140	20	52.5
COBALT	800	800	600	800	800	600	750.0
COPPER	13	8	260	4	260	4	71.3
IRON	53000	310000	210000	230000	310000	53000	200750.0
LEAD	350	250	400	17	400	17	254.3
MANGANESE	5600	6200	4600	13000	13000	4600	7350.0
MOLYBDENUM	1	1	1	1	1	1	1.0
NICKEL	3400	4500	2900	3000	4500	2900	3450.0
VANADIUM	160	150	17	50	160	17	94.3
ZINC	310000	440000	340000	400000	440000	310000	372500.0
ALUMINUM	200	5500	42000	100	42000	100	11950.0
LITHIUM	300	210	260	140	300	140	227.5

UNITS: UG/L

AERIAL MINE WATER QUALITY DATA, JULY 1981

			CONSOLIDATED			
	LAWYER	KENOYER	No.2-SS	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	180	180	200	200	180	186.7
TEMP (°C)	15.8	15.8	15.6	15.8	15.6	15.7
S C (uS)	3830	3790	3850	3850	3790	3823.3
OXYGEN				ERR	ERR	ERR
pH	4.8	5.8	5	5.8	4.8	5.2
ALKALINITY ($CaCO_3$)				ERR	ERR	ERR
CALCIUM				ERR	ERR	ERR
MAGNESIUM				ERR	ERR	ERR
SODIUM				ERR	ERR	ERR
POTASSIUM				ERR	ERR	ERR
CHLORIDE				ERR	ERR	ERR
SULFATE	3382	2987	2890	3382	2890	3086.3
FLUORIDE				ERR	ERR	ERR
SiO2				ERR	ERR	ERR
UNITS: MG/L						

TRACE METALS

CADMIUM	80	15	73	80	15	56.0
COPPER	10	6	4	10	4	6.7
IRON	350000	230000	300000	350000	230000	293333.3
LEAD	57	41	144	144	41	80.7
MANGANESE	6500	4500	5000	6500	4500	5333.3
NICKEL	6750	4280	4650	6750	4280	5226.7
ZINC	23300	8300	70000	70000	8300	33866.7
ALUMINUM	12900	2000	2000	12900	2000	5633.3
DBLS WL						
UNITS: UG/L						

AERIAL MINE WATER QUALITY DATA, JUNE 1981

	ADMIRALTY CONSOLIDATED					
	KENOYER	No.4	No.2-S	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	200	200	200	200	200	200.0
TEMP (°C)	15.6	14.3	14.8	15.6	14.3	14.9
S C (uS)	4780	5000	1201	5000	1201	3660.3
OXYGEN	0.4	0.4	0.9	0.9	0.4	0.6
pH	5.6	5.5	7	7	5.5	6.0
CO2	1690	1062		1690	1062	1376.0
ALKALINITY ($CaCO_3$)	344	172		344	172	258.0
CALCIUM				ERR	ERR	ERR
MAGNESIUM				ERR	ERR	ERR
SODIUM				ERR	ERR	ERR
POTASSIUM				ERR	ERR	ERR
CHLORIDE				ERR	ERR	ERR
SULFATE	2600	4000	2932	4000	2600	3177.3
FLUORIDE				ERR	ERR	ERR
SiO2				ERR	ERR	ERR
UNITS: MG/L						

TRACE METALS

CADMIUM	1	15	78	78	1	31.3
COPPER				ERR	ERR	ERR
IRON	150000	340000	400000	400000	150000	296666.7
LEAD	50	130		130	50	90.0
MANGANESE			3900	3900	3900	3900.0
NICKEL				ERR	ERR	ERR
ZINC	190000	290000	339000	339000	190000	273000.0
ALUMINUM				ERR	ERR	ERR
DBLS WL			32	32	32	32.0
UNITS: UG/L						

AERIAL MINE WATER QUALITY DATA, NOVEMBER 1983

	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	GORDON	KENOYER	LUCKY SYNDICATE	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	150	226	176	170	184	110	226	110	169.3
TEMP (^{0}C)	19	17	17.5	19	19	19	19	17	18.4
S C (uS)	4450	4050	3950	4700	4000	5400	5400	3950	4425.0
OXYGEN	0.4						0.4	0.4	0.4
pH	5.8	5.7	6	5.7	5.6	6.2	6.2	5.6	5.8
ALKALINITY ($CaCO_3$)	260	280	680	280	260	1000	1000	260	460.0
CALCIUM	570	460	640	690	500	540	690	460	566.7
MAGNESIUM	280	230	210	330	190	440	440	190	280.0
SODIUM	93	67	81	120	91	310	310	67	127.0
POTASSIUM	6.2	3.8	9.2	10	5.5	43	43	3.8	13.0
CHLORIDE	33	10	12	35	37	96	96	10	37.2
SULFATE	3200	2800	2100	3000	2500	2700	3200	2100	2716.7
FLUORIDE	4.5	1.2	2	5.4	3.1	0.9	5.4	0.9	2.9
SiO2	16	8.6	9.6	18	13	13	18	8.6	13.0

UNITS:MG/L

TRACE METALS

	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	GORDON	KENOYER	LUCKY SYNDICATE	MAXIMUM	MINIMUM	MEAN
CADMIUM	22	10	3	4	12	1	22	1	8.7
COPPER	1	2	1	1	2	2	2	1	1.5
IRON	300000	270000	180000	390000	210000	18000	390000	18000	228000.0
LEAD	40	22	1	1	1	1	40	1	11.0
MANGANESE	5300	4400	2400	5600	3800	9700	9700	2400	5200.0
NICKEL	3500	2200	2500	4400	2500	510	4400	510	2601.7
ZINC	170000	110000	21000	150000	120000	640	170000	640	95273.3
ALUMINUM	2900	690	310	3400	1800	10	3400	10	1518.3
DBLS WL	2	26.8	56.5	30	15	29	56.5	2	26.6

UNITS: UG/L

AERIAL MINE WATER QUALITY DATA, MARCH 1984

	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	KENOYER	LUCKY SYNDICATE	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	180	225	176	185	110	225	110	175.2
TEMP (^{o}C)	15	15.4	15.5	16.1	17.3	17.3	15	15.9
S C (uS)	4100	4080	3810	3600	4830	4830	3600	4084.0
OXYGEN	0.2	0.1	0.1	0.3	0.1	0.3	0.1	0.2
pH	5.7	5.7	6	5.7	6	6	5.7	5.8
ALKALINITY ($CaCO_3$)	260	288	720	202	870	870	202	468.0
CALCIUM	490	470	600	490	510	600	470	512.0
MAGNESIUM	250	250	190	180	364	364	180	246.8
SODIUM	89	73	78	82	340	340	73	132.4
POTASSIUM	6.5	4.2	9.4	5.5	44	44	4.2	13.9
CHLORIDE	28	9.6	10	33	85	85	9.6	33.1
SULFATE	3200	2900	2200	2300	2900	3200	2200	2700.0
FLUOIDE	6.1	1.7	1.9	4.2	0.6	6.1	0.6	2.9
SiO2	19	12	15	18	14	19	12	15.6

UNITS: MG/L

TRACE METALS

	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	KENOYER	LUCKY SYNDICATE	MAXIMUM	MINIMUM	MEAN
CADMIUM	14	14	2	6	1	14	1	7.4
COPPER	1	1	1	2	1	2	1	1.2
IRON	280000	290000	150000	200000	12000	290000	12000	186400.0
LEAD	28	49	1	21	1	49	1	20.0
MANGANESE	5300	4300	2500	3800	7800	7800	2500	4740.0
NICKEL						ERR	ERR	ERR
ZINC	150000	110000	23000	91000	480	150000	480	74896.0
ALUMINUM	1400	500	350	1100	30	1400	30	676.0
DBLS WL	0	26		15	28	28	0	17.3

UNITS: UG/L

AERIAL MINE WATER QUALITY DATA, JUNE 1985

	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	KENOYER	LUCKY SYNDICATE	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	190	228	176	182	110	228	110	177.2
TEMP (^{o}C)	18	17.5	17	18	18.5	18.5	17	17.8
REDOX (mV)	320	350	330	300	300	350	300	320
S C (uS)						ERR	ERR	ERR
OXYGEN						ERR	ERR	ERR
pH	5.9	5.8	6.1	5.9	6.15	6.15	5.8	6.0
ALKALINITY ($CaCO_3$)	232	275.5	732	180	960	960	180	475.9
CALCIUM	509	497	593	514	543	593	497	531.2
MAGNESIUM	193	203	183	134	413	413	134	225.2
SODIUM	88	69	84	75	311	311	69	125.4
POTASSIUM	5.7	3.8	9.9	5.2	45	45	3.8	13.9
CHLORIDE	30	9.4	6.6	27	100	100	6.6	34.6
SULFATE	2900	2700	2300	2300	3000	3000	2300	2640.0
FLUORIDE	2.5	0.7	1	2.1	0.7	2.5	0.7	1.4
SiO2	15	10	13	13	14	15	10	13.0

UNITS: MG/L

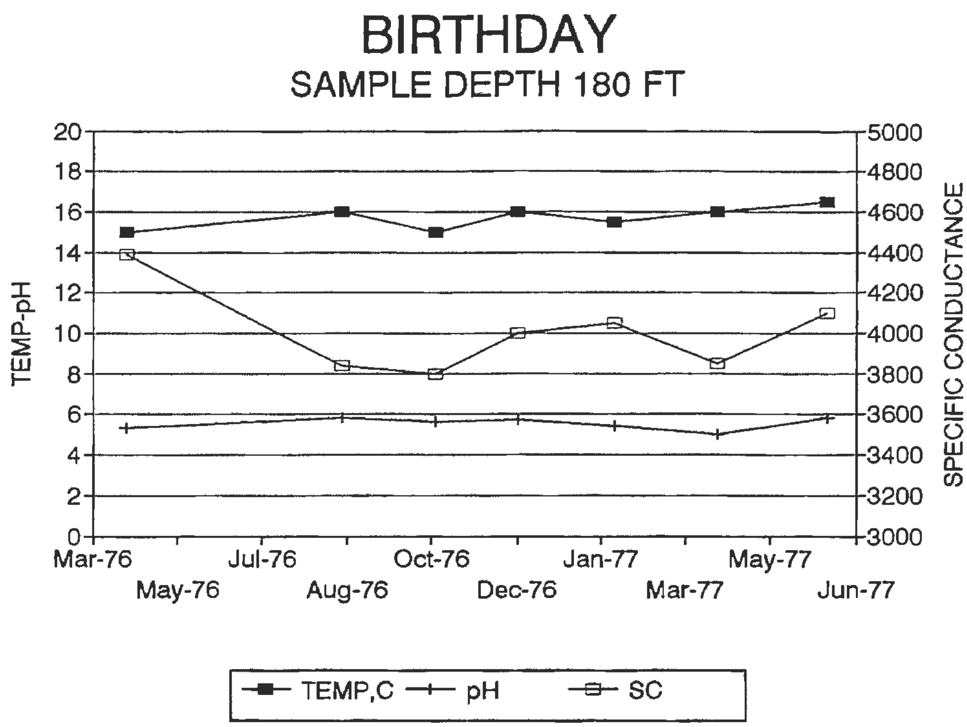
TRACE METALS

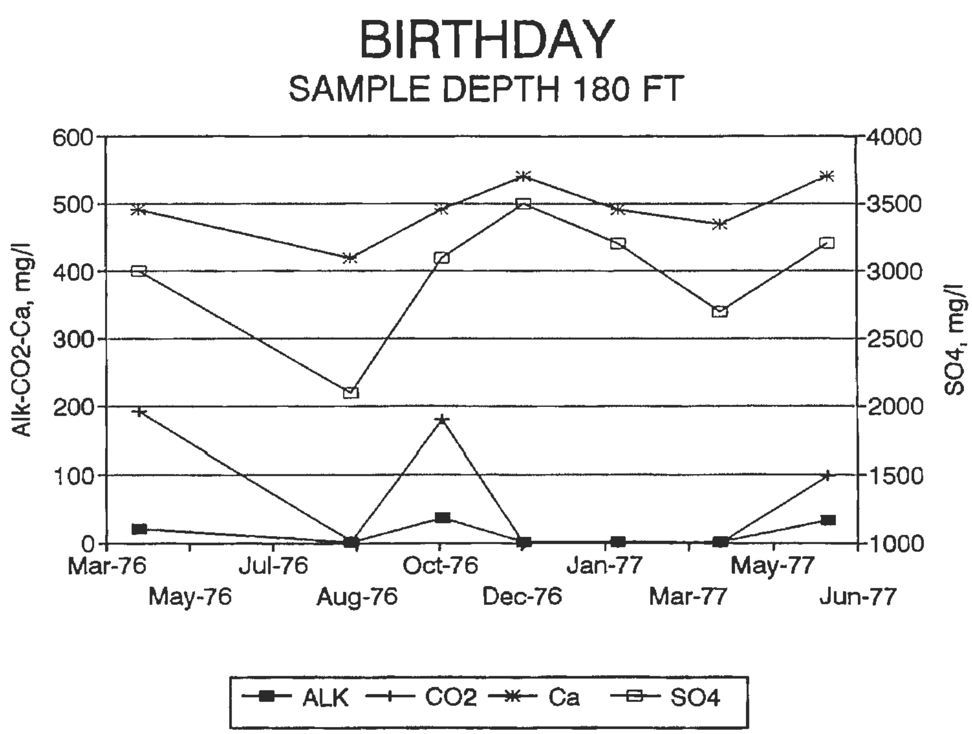
CADMIUM	8	27	3	3	2	27	2	8.6
COPPER	30	30	20	20	30	30	20	26.0
IRON	223600	245600	199680	147260	20480	245600	20480	167324.0
LEAD	7.2	38.8	1.8	10	1.4	38.8	1.4	11.8
MANGANESE	2584	3554	1400	2728	8158	8158	1400	3684.8
NICKEL	2900	2300	3000	2000	500	3000	500	2140.0
ZINC	96920	91700	21660	54760	534	96920	534	53114.8
ALUMINUM	1600	450	270	750	10	1600	10	616.0
DBLS WL	0	26	47	15	28.5	47	0	23.3

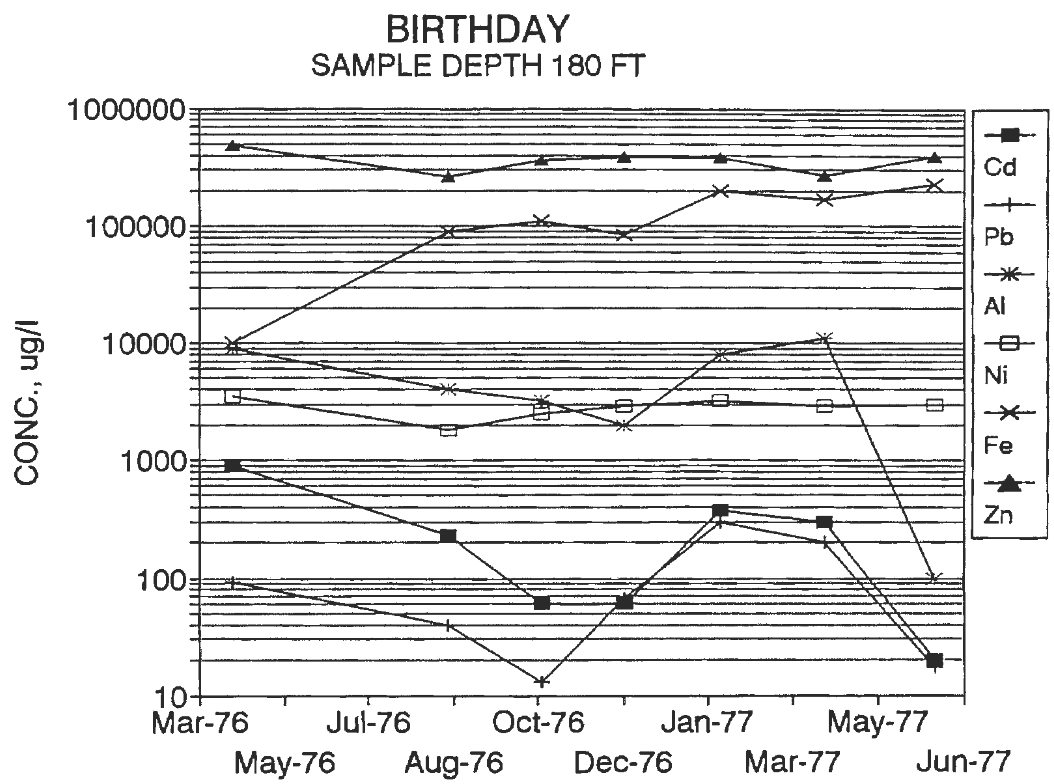
UNITS: UG/L

APPENDIX D

TEMPORAL MINE WATER QUALITY DATA


BIRTHDAY
SAMPLE DEPTH 180 FT
TEMP-pH
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
Mar-76
Jul-76
Oct-76
Jan-77
May-77
May-76
Aug-76
Dec-76
Mar-77
Jun-77
TEMP,C
pH
SC


BIRTHDAY
SAMPLE DEPTH 180 FT
Alk-CO2-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Mar-76
Jul-76
Oct-76
Jan-77
May-77
May-76
Aug-76
Dec-76
Mar-77
Jun-77
ALK
CO2
Ca
SO4


BIRTHDAY
SAMPLE DEPTH 180 FT
CONC., ug/l
1000000
100000
10000
1000
100
10
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, BIRTHDAY

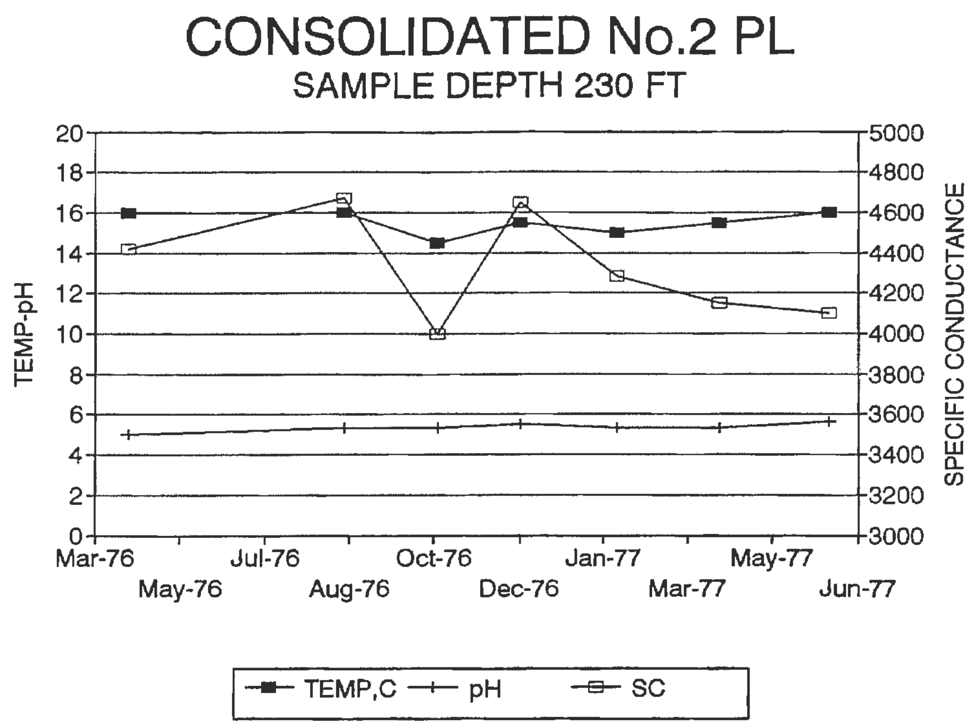
	23APR76	25AUG76	19OCT76	07DEC76	18FEB77	23APR77	08JUN77	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	182	180	180	180	180	170	180	182	170	179
TEMP. (^{O}C)	15	16	15	16	15.5	16	16.5	16.5	15	16
S C (uS)	4389.99	3839.99	3799.99	4000	4050	3850	4100	4389.99	3799.99	4004
pH	5.3	5.8	5.6	5.7	5.4	5	5.8	5.8	5	6
CO2	192	2.5	181	0	0	0	99	192	0	68
ALKALINITY (CaCO3)	20	1	37	1	1	1	32	37	1	13
HCO3	24	1	45	0	0	0	39	45	0	16
HARDNESS, TOTAL	2200	1600	2100	2400	2100	2000	2500	2500	1600	2129
CALCIUM	489.99	420	490	540	490	470	540	540	420	491
MAGNESIUM	240	130	220	260	210	190	270	270	130	217
SODIUM	52.99	40	47	46	51	61	44	61	40	49
POTASSIUM	2.6	3.8	4.1	3	3.8	4.6	3.5	4.6	2.6	4
CHLORIDE	6.8	9.1	7.3	6.9	6.8	6.4	7.2	9.1	6.4	7
SULFATE	3000	2100	3100	3500	3200	2700	3200	3500	2100	2971
FLUORIDE	7.2	2.9	2.5	1.1	6.5	7.6	0.4	7.6	0.4	4
SiO2	11	10	12	12	13	13	9.4	13	9.4	11

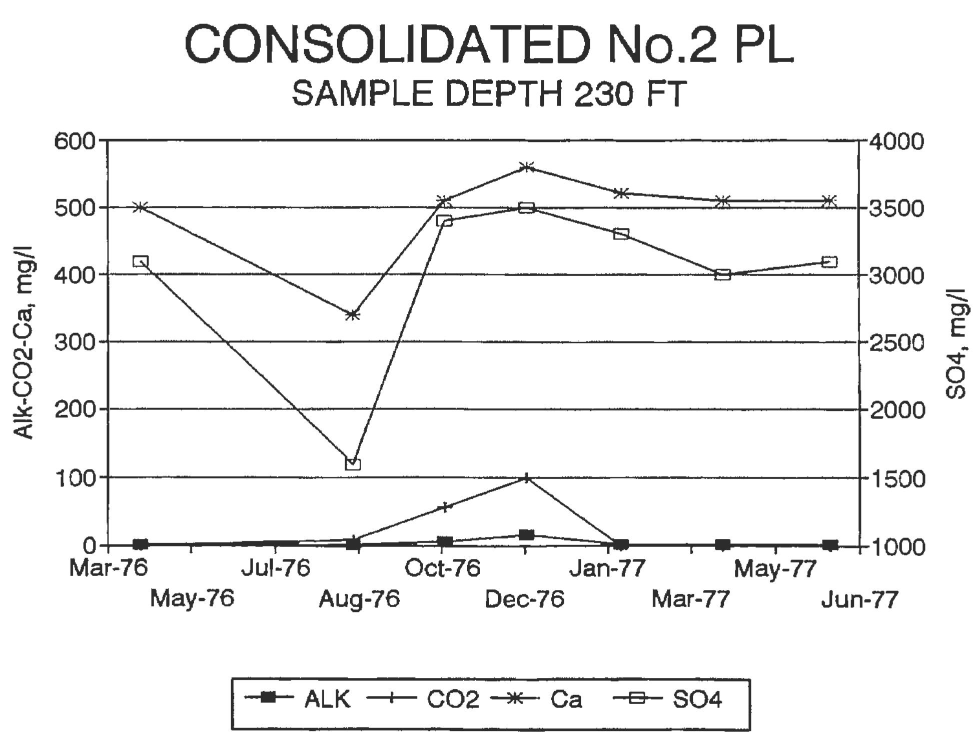
UNITS: MG/L

TRACE METALS

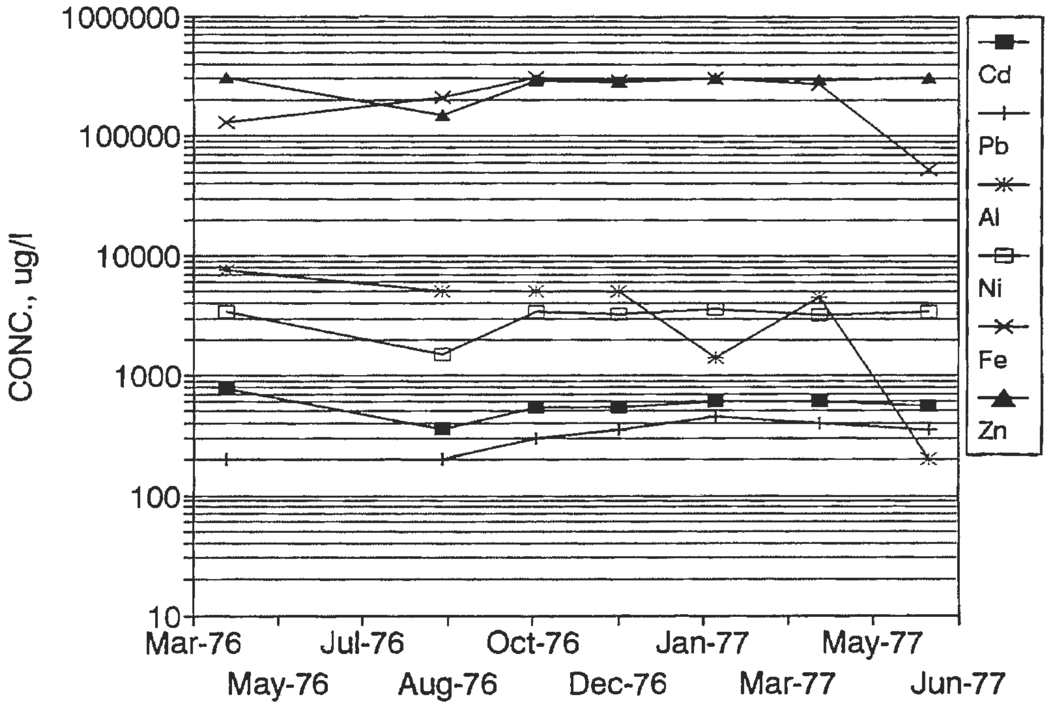
	23APR76	25AUG76	19OCT76	07DEC76	18FEB77	23APR77	08JUN77	MAXIMUM	MINIMUM	MEAN
BORON	200	240	160	170	160	150	200	240	150	183
CADMIUM	899.99	230	60	60	370	300	20	899.99	20	277
IRON	9999.98	89000	110000	83000	200000	170000	230000	230000	9999.98	127429
LEAD	92.99	40	13	67	300	200	17	300	13	104
MANGANESE	5499.99	7400	9000	10000	7000	4400	13000	13000	4400	8043
NICKEL	3499.99	1800	2500	2900	3200	2900	3000	3499.99	1800	2829
VANADIUM	36	----	49	45	100	50	50	100	0	47
ZINC	489999	260000	360000	390000	380000	270000	400000	489999	260000	364286
ALUMINUM	8899.98	4000	3200	2000	7900	11000	100	11000	100	5300
LITHIUM	250	120	150	160	160	160	140	250	120	163

UNITS: UG/L


CONSOLIDATED No.2 PL
SAMPLE DEPTH 230 FT
TEMP-pH
SPECIFIC CONDUCTANCE
0
2
4
6
8
10
12
14
16
18
20
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
TEMP,C
pH
SC


CONSOLIDATED No.2 PL
SAMPLE DEPTH 230 FT
Alk-CO2-Ca, mg/l
SO4, mg/l
0
100
200
300
400
500
600
1000
1500
2000
2500
3000
3500
4000
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
ALK
CO2
Ca
SO4

CONSOLIDATED No.2 PL
SAMPLE DEPTH 230 FT



TEMPORAL MINE WATER QUALITY DATA, CONSOLIDATED No.2-PL

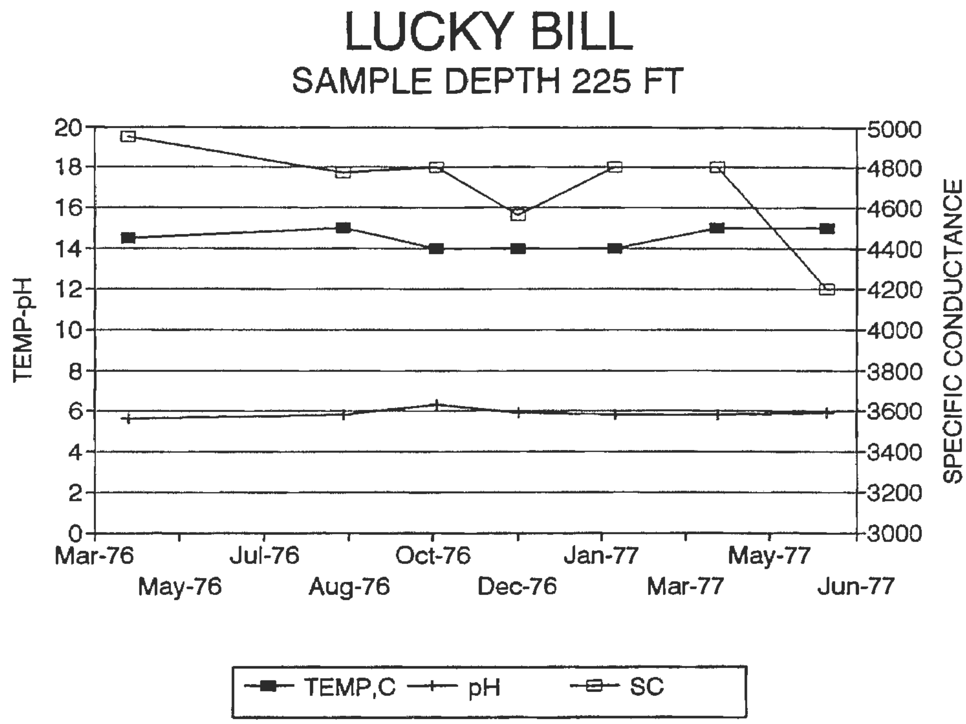
	20APR76	25AUG76	19OCT76	07DEC76	02FEB77	04APR77	07JUN77	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	229	230	230	230	230	230	230	230	229	230
TEMP. (^{o}C)	16	16	14.5	15.5	15	15.5	16	16	14.5	16
S C (uS)	4420	4670	4000	4650	4280	4150	4100	4670	4000	4324
pH	5	5.3	5.3	5.5	5.3	5.3	5.6	5.6	5	5
CO2	0	8	56	101	0	0	0	101	0	24
ALKALINITY (CaCO3)	1	1	6	16	1	1	1	16	1	4
HCO3	0	1	7	20	0	0	0	20	0	4
HARDNESS, TOTAL	2200	1300	2200	2400	2200	2200	2200	2400	1300	2100
CALCIUM	500	340	510	560	520	510	510	560	340	493
MAGNESIUM	240	100	230	240	230	230	220	240	100	213
SODIUM	80	43	81	77	81	77	80	81	43	74
POTASSIUM	2.2	3.4	4.1	3.9	3.6	3.4	3.8	4.1	2.2	3
CHLORIDE	6.2	9.1	7	7	6.8-	6.3	5.9	9.1	5.9	7
SULFATE	3100	1600	3400	3500	3300	3000	3100	3500	1600	3000
FLUORIDE	1.9	1.7	2.4	1.9	3.5	1.5	1.8	3.5	1.5	2
SiO2	8.4	11	7.7	9.2	8	8.8	8.4	11	7.7	9

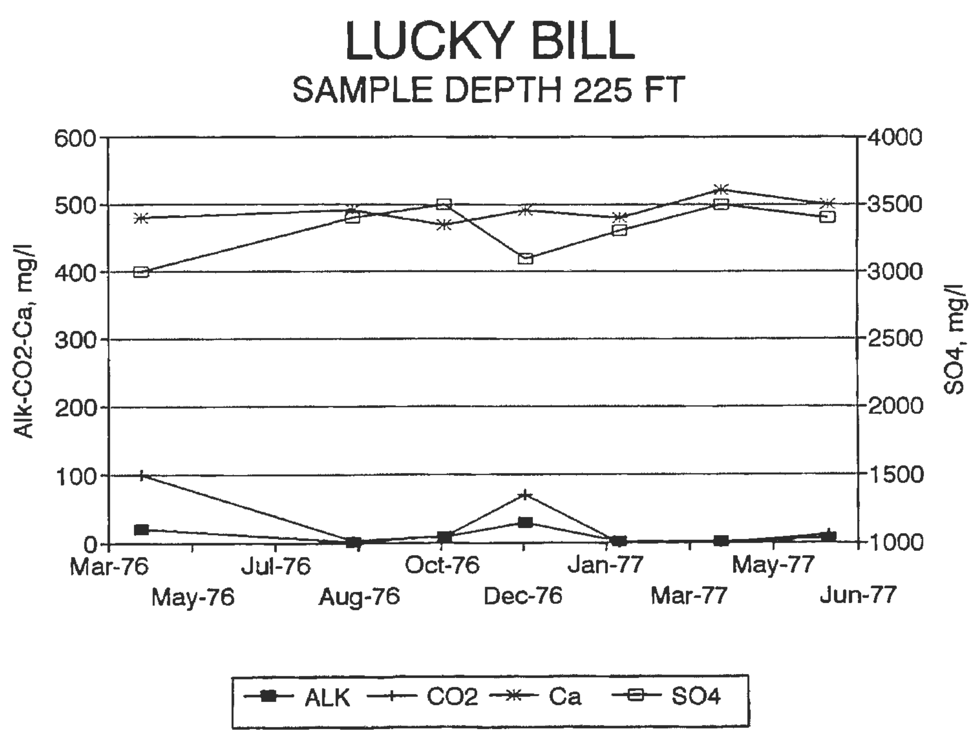
UNITS: MG/L

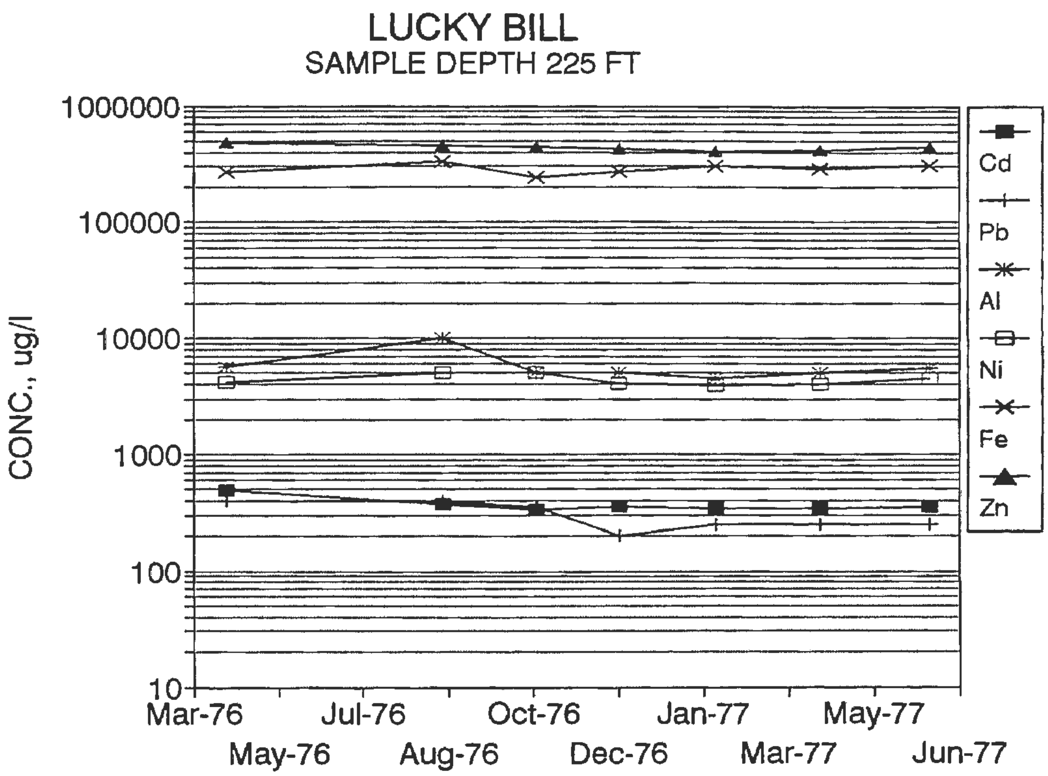
TRACE METALS

	20APR76	25AUG76	19OCT76	07DEC76	02FEB77	04APR77	07JUN77	MAXIMUM	MINIMUM	MEAN
BORON	150	100	170	190	170	140	170	190	100	156
CADMIUM	780	360	540	540	600	610	550	780	360	569
IRON	130000	210000	310000	290000	300000	270000	53000	310000	53000	223286
LEAD	200	200	300	350	450	400	350	450	200	321
MANGANESE	5700	4200	5400	50	5500	5100	5600	5700	50	4507
NICKEL	3400	1500	3400	3300	3600	3200	3400	3600	1500	3114
VANADIUM	150	----	130	60	200	110	160	200	0	116
ZINC	310000	150000	290000	280000	300000	291999	310000	310000	150000	276000
ALUMINUM	7700	5000	5000	5000	1400	4500	200	7700	200	4114
LITHIUM	210	120	200	190	200	190	300	300	120	201
Eh (WATEQ4F), mV	530	----	509	----	----	----	475	530	475	505

UNITS: UG/L


LUCKY BILL
SAMPLE DEPTH 225 FT
TEMP-pH
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
TEMP,C
pH
SC


LUCKY BILL
SAMPLE DEPTH 225 FT
Alk-CO2-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
ALK
CO2
Ca
SO4


LUCKY BILL
SAMPLE DEPTH 225 FT
CONC., ug/l
1000000
100000
10000
1000
100
10
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, LUCKY BILL

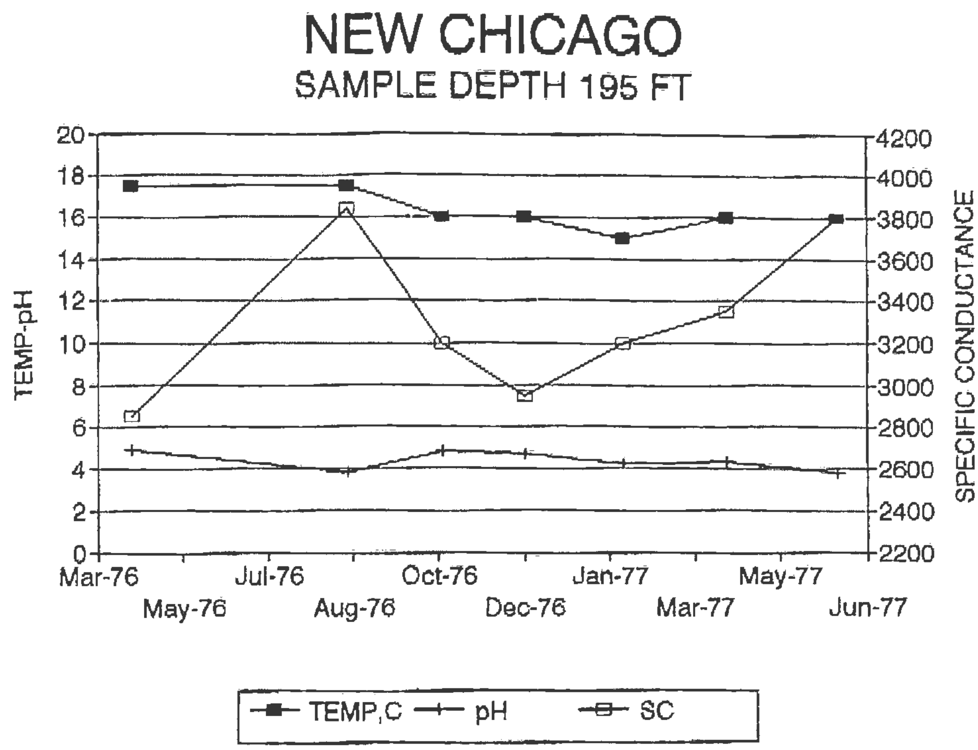
	20APR76	25AUG76	19OCT76	07DEC76	02FEB77	04APR77	07JUN77	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	222	228	225	225	225	225	225	228	222	225
TEMP. (^{o}C)	14.5	15	14	14	14	15	15	15	14	15
S C (uS)	4950	4769.99	4800	4559.99	4800	4800	4200	4950	4200	4697
pH	5.6	5.8	6.3	5.9	5.8	5.8	5.9	6.3	5.6	6
CO2	100	2.5	8.8	70	0	0	12	100	0	28
ALKALINITY (CaCO3)	21	1	9	29	1	1	5	29	1	10
HCO3	25	1	11	35	0	0	6	35	0	11
HARDNESS, TOTAL	2200	2100	2400	2300	2300	2400	2400	2400	2100	2300
CALCIUM	480	490	470	490	480	520	500	520	470	490
MAGNESIUM	250	220	290	260	260	270	280	290	220	261
SODIUM	87	90	92	81	82	85	86	92	81	86
POTASSIUM	6	9.2	8.2	7	6.5	6.8	6.2	9.2	6	7
CHLORIDE	16	21	23	20	18	15	15	23	15	18
SULFATE	3000	3400	3500	3100	3300	3500	3400	3500	3000	3314
FLUORIDE	9.2	9.4	7.5	6.6	7.4	7.9	7.9	9.4	6.6	8
SiO2	7.6	9	7.8	8.8	10	11	10	11	7.6	9

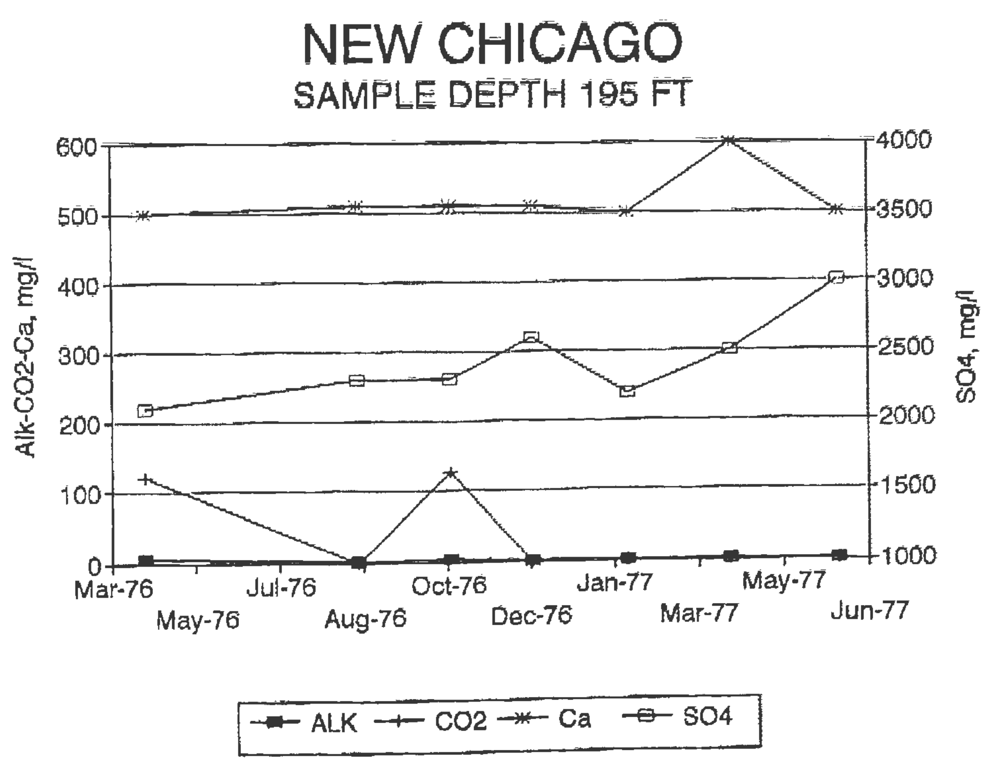
UNITS: MG/L

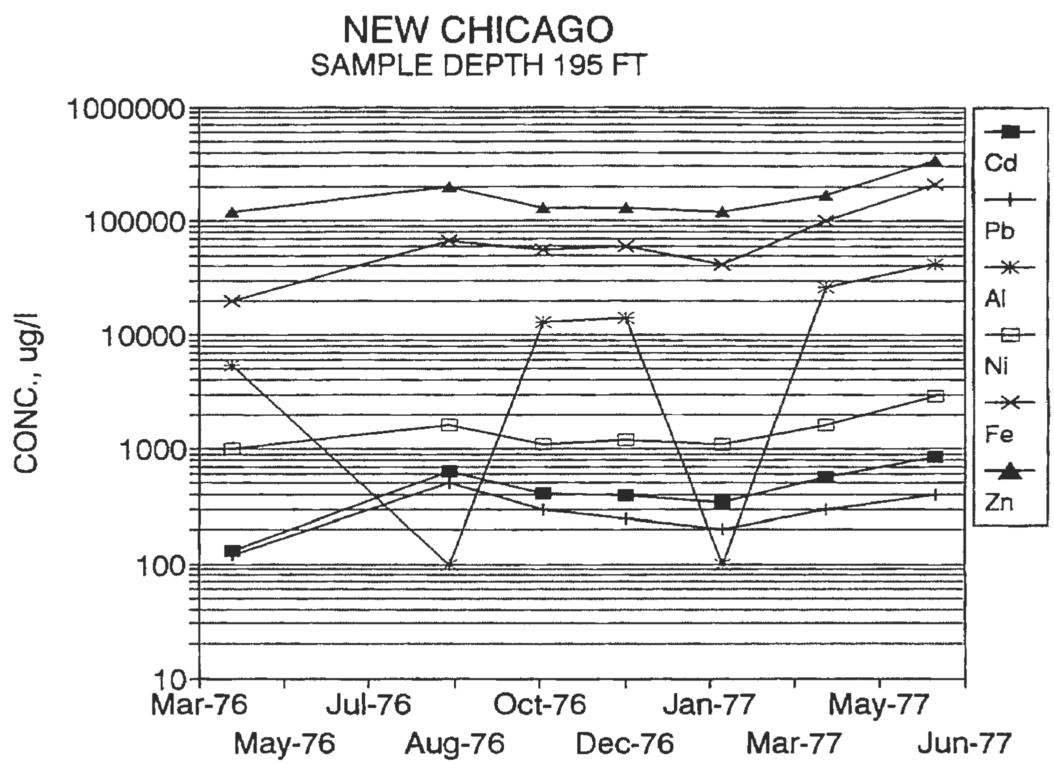
TRACE METALS

	20APR76	25AUG76	19OCT76	07DEC76	02FEB77	04APR77	07JUN77	MAXIMUM	MINIMUM	MEAN
BORON	220	290	220	240	200	200	210	290	200	226
CADMIUM	490	370	330	360	340	340	350	490	330	369
IRON	270000	330000	240000	270000	300000	290000	310000	330000	240000	287143
LEAD	400	400	350	200	250	250	250	400	200	300
MANGANESE	5700	6500	6000	5400	5500	5500	6200	6500	5400	5829
NICKEL	4200	5000	5000	4100	3900	4000	4500	5000	3900	4386
VANADIUM	130	----	120	120	0	110	150	150	0	90
ZINC	490000	450000	440000	420000	410000	411999	440000	490000	410000	437428
ALUMINUM	5700	10000	5000	5000	4500	5000	5500	10000	4500	5814
LITHIUM	210	220	220	110	200	210	210	220	110	197

UNITS: UG/L


NEW CHICAGO
SAMPLE DEPTH 195 FT
TEMP-pH
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
Mar-76
Jul-76
Oct-76
Jan-77
May-77
May-76
Aug-76
Dec-76
Mar-77
Jun-77
TEMP,C
pH
SC


NEW CHICAGO
SAMPLE DEPTH 195 FT
Alk-CO2-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Mar-76
Jul-76
Oct-76
Jan-77
May-77
May-76
Aug-76
Dec-76
Mar-77
Jun-77
ALK
CO2
Ca
SO4



NEW CHICAGO
SAMPLE DEPTH 195 FT
CONC., ug/l
1000000
100000
10000
1000
100
10
Mar-76
May-76
Jul-76
Aug-76
Oct-76
Dec-76
Jan-77
Mar-77
May-77
Jun-77
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, NEW CHICAGO

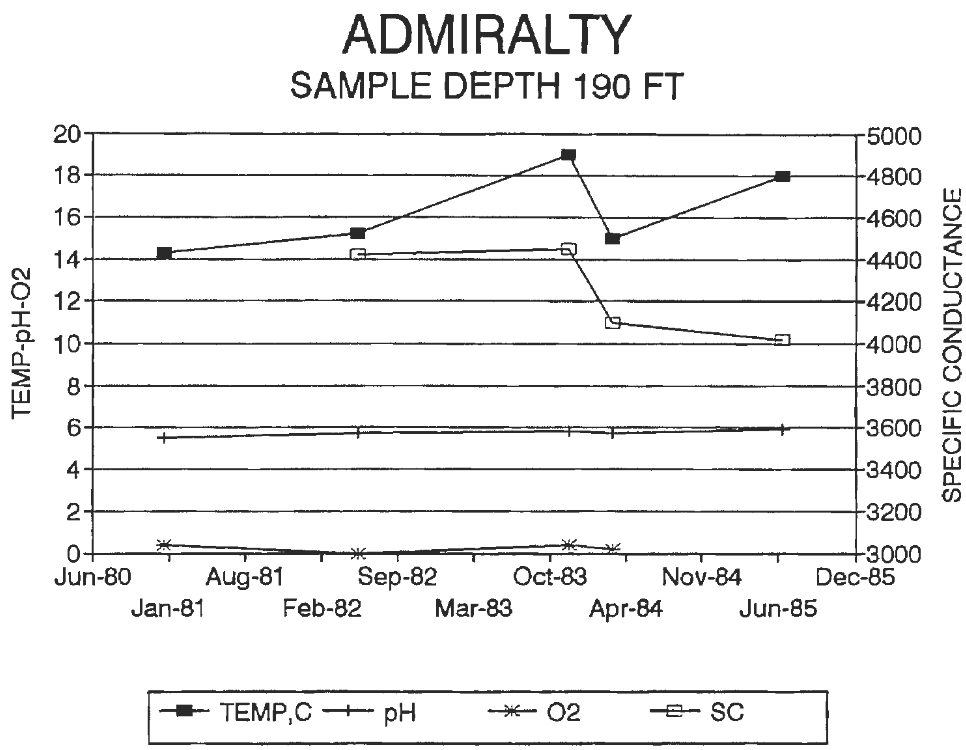
	29APR76	26AUG76	20OCT76	06DEC76	02FEB77	21APR77	08JUN77	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	197	197	195	195	195	195	195	197	195	196
TEMP. (^{o}C)	17.5	17.5	16	16	15	16	16	17.5	15	16
S C (uS)	2850	3839.99	3200	2950	3200	3350	3800	3839.99	2850	3313
pH	4.9	3.8	4.8	4.7	4.2	4.3	3.8	4.9	3.8	4
CO2	121	0	127	0	0	0	0	127	0	35
ALKALINITY (CaCO3)	5	1	4	1	1	1	1	5	1	2
HCO3	6	0	5	0	0	0	0	6	0	2
HARDNESS, TOTAL	1600	1800	1900	1900	1800	2100	2100	2100	1600	1886
CALCIUM	499.99	510	510	510	500	600	500	600	499.99	519
MAGNESIUM	85.99	130	140	140	140	140	200	200	85.99	139
SODIUM	28	36	36	36	39	39	57	57	28	39
POTASSIUM	1.6	2.8	3.1	3.1	3.2	3.2	4	4	1.6	3
CHLORIDE	4.8	8.1	5.8	5.6	14	72	6.2	72	4.8	17
SULFATE	2100	2300	2300	2600	2200	2500	3000	3000	2100	2429
FLUORIDE	2.6	7.2	5.4	2.9	3.9	8	1	8	1	4
SiO2	12	16	14	15	14	15	19	19	12	15

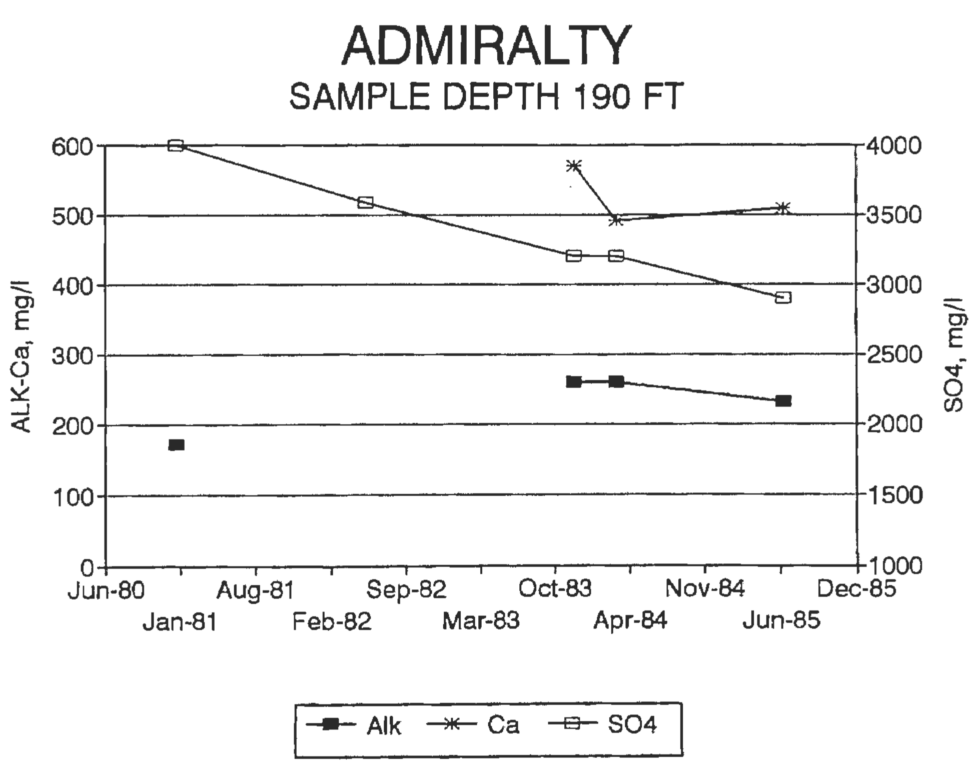
UNITS: MG/L

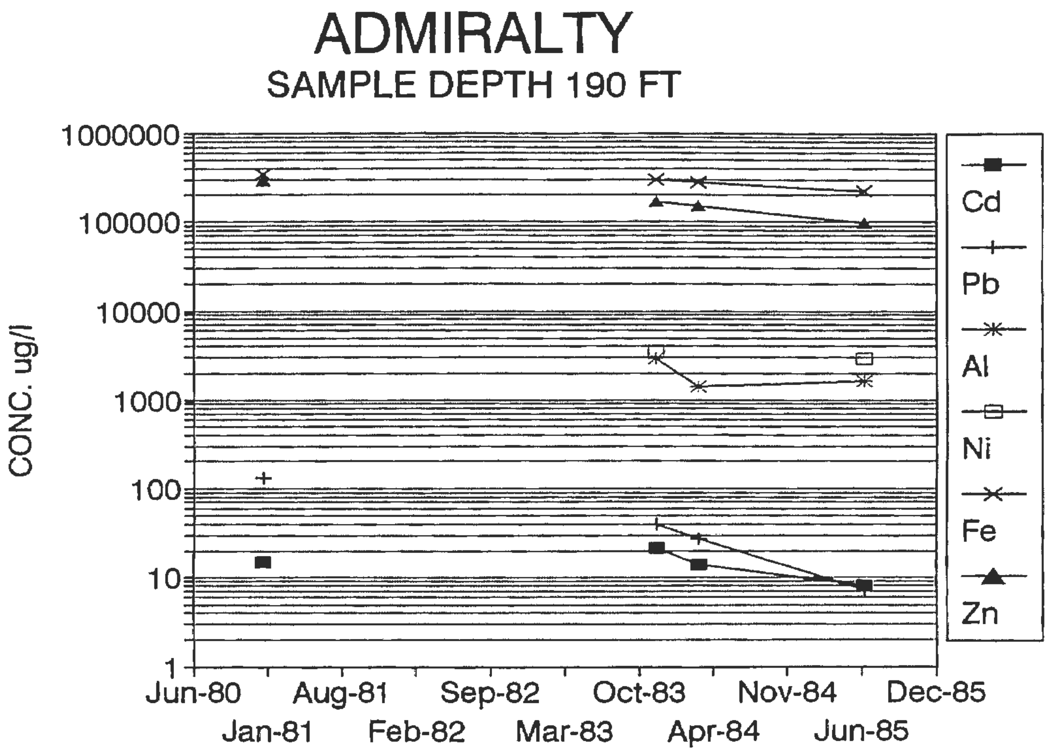
TRACE METALS

	29APR76	26AUG76	20OCT76	06DEC76	02FEB77	21APR77	08JUN77	MAXIMUM	MINIMUM	MEAN
BORON	180	140	100	100	130	140	200	200	100	141
CADMIUM	130	630	410	390	340	560	860	860	130	474
IRON	20000	67000	55000	59000	41000	100000	210000	210000	20000	78857
LEAD	120	500	300	250	200	300	400	500	120	296
MANGANESE	1400	2800	1500	1900	1800	2500	4600	4600	1400	2357
NICKEL	999.99	1600	1100	1200	1100	1600	2900	2900	999.99	1500
VANADIUM	2.7	32	24	18	22	7	17	32	2.7	18
ZINC	120000	200000	130000	130000	120000	170000	340000	340000	120000	172857
ALUMINUM	5399.99	100	13000	14000	100	26000	42000	42000	100	14371
LITHIUM	110	180	130	130	130	180	260	260	110	160

UNITS: UG/L


ADMIRALTY
SAMPLE DEPTH 190 FT
TEMP-pH-O2
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
TEMP,C
pH
O2
SC


ADMIRALTY
SAMPLE DEPTH 190 FT
ALK-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
Alk
Ca
SO4


ADMIRALTY
SAMPLE DEPTH 190 FT
CONC. ug/l
1000000
100000
10000
1000
100
10
1
Jun-80
Jan-81
Aug-81
Feb-82
Sep-82
Mar-83
Oct-83
Apr-84
Nov-84
Jun-85
Dec-85
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, ADMIRALTY No.4

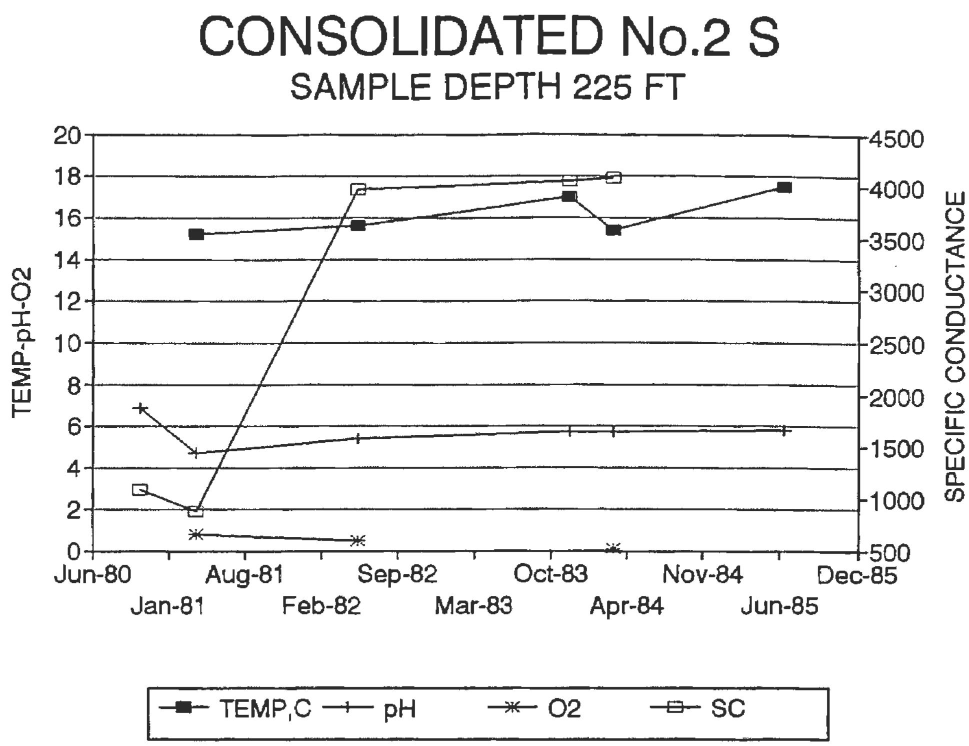
	02JUN81	25MAY82	29NOV83	23MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	200	200	150	180	190	200	150	184.0
TEMP (^{o}C)	14.3	15.2	19	15	18	19	14.3	16.3
REDOX (mV)				200	320	320	200	
S C (uS)		4420	4450	4100	4020	4450	4020	4247.5
OXYGEN	0.4	0	0.4	0.2		0.4	0	0.3
pH	5.5	5.7	5.8	5.7	5.9	5.9	5.5	5.7
ALKALINITY (CaCO3)	172		260	260	232	260	172	231.0
CALCIUM			570	490	509	570	490	523.0
MAGNESIUM			280	250	193	280	193	241.0
SODIUM			93	89	88	93	88	90.0
POTASSIUM			6.2	6.5	5.7	6.5	5.7	6.1
CHLORIDE			33	28	30	33	28	30.3
SULFATE	4000	3587	3200	3200	2900	4000	2900	3377.4
FLUORIDE	7.3	2.73	4.5	6.1	2.5	7.3	2.5	4.6
SiO2			16	19	15	19	15	16.7

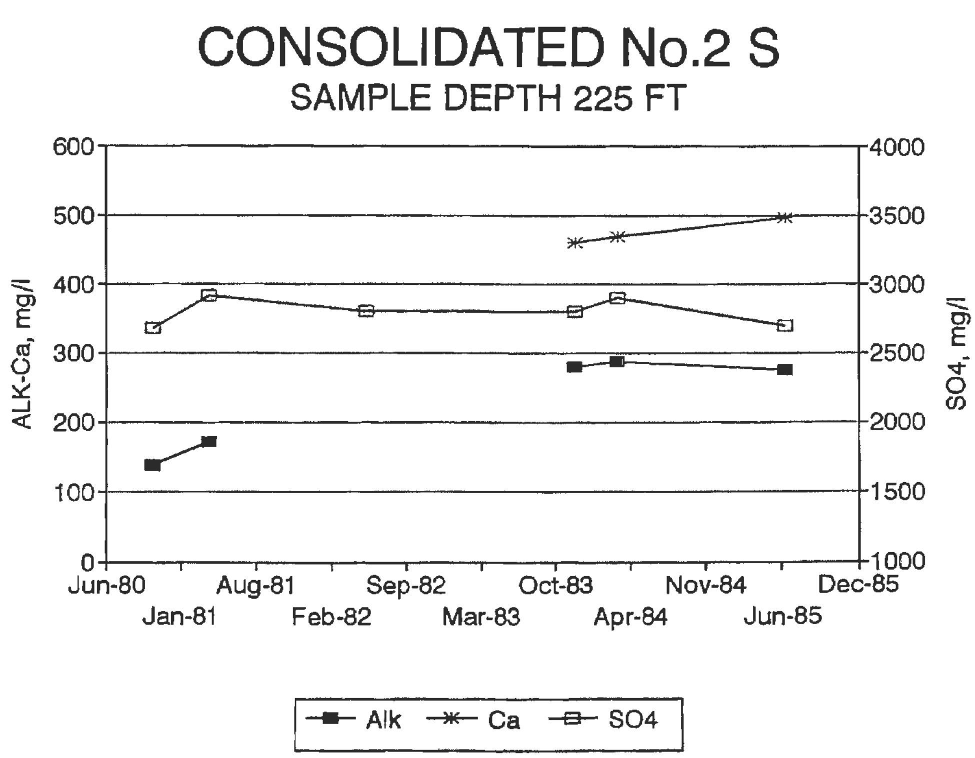
UNITS: MG/L

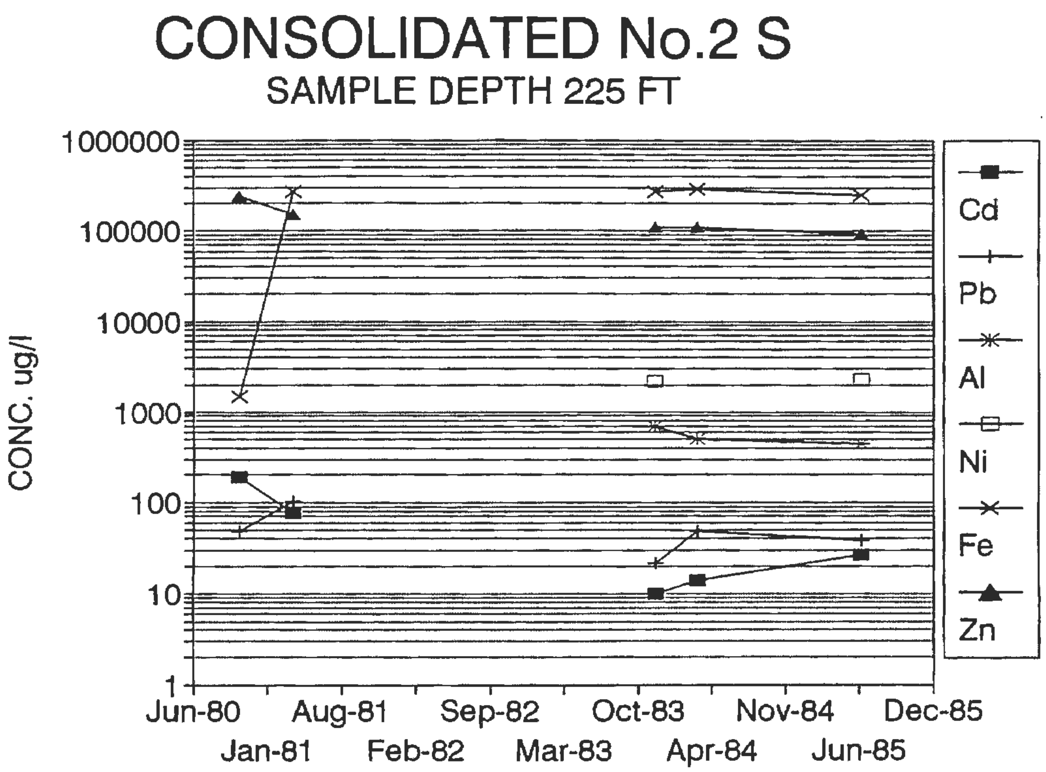
TRACE METALS

	02JUN81	25MAY82	29NOV83	23MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
CADMIUM	15		22	14	8	22	8	14.8
COPPER			1	1	30	30	1	10.7
IRON	340000		300000	280000	223600	340000	223600	285900.0
LEAD	130		40	28	7.2	130	7.2	51.3
MANGANESE			5300	5300	2584	5300	2584	4394.7
NICKEL			3500		2900	3500	2900	3200.0
ZINC	290000		170000	150000	96920	290000	96920	176730.0
ALUMINUM			2900	1400	1600	2900	1400	1966.7
DBLS WL			2	0	0	2	0	0.5

UNITS: UG/L


CONSOLIDATED No.2 S
SAMPLE DEPTH 225 FT
TEMP-pH-O2
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
4500
4000
3500
3000
2500
2000
1500
1000
500
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
TEMP,C
pH
O2
SC


CONSOLIDATED No.2 S
SAMPLE DEPTH 225 FT
ALK-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
Alk
Ca
SO4

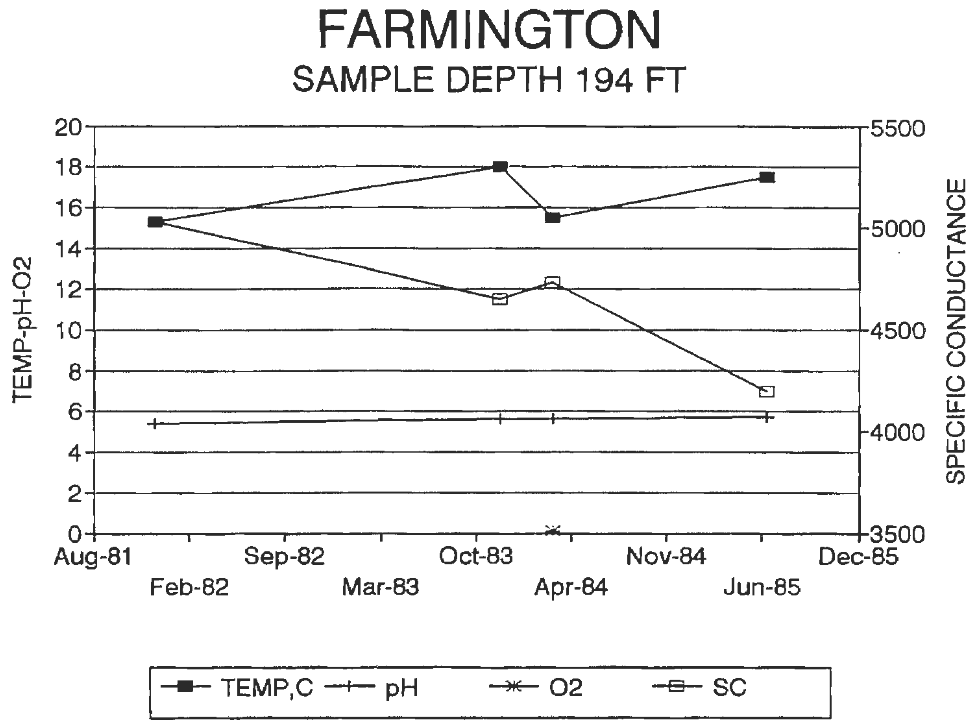

CONSOLIDATED No.2 S
SAMPLE DEPTH 225 FT
CONC. ug/l
1000000
100000
10000
1000
100
10
1
Jun-80
Jan-81
Aug-81
Feb-82
Sep-82
Mar-83
Oct-83
Apr-84
Nov-84
Jun-85
Dec-85
Cd
Pb
Al
Ni
Fe
Zn

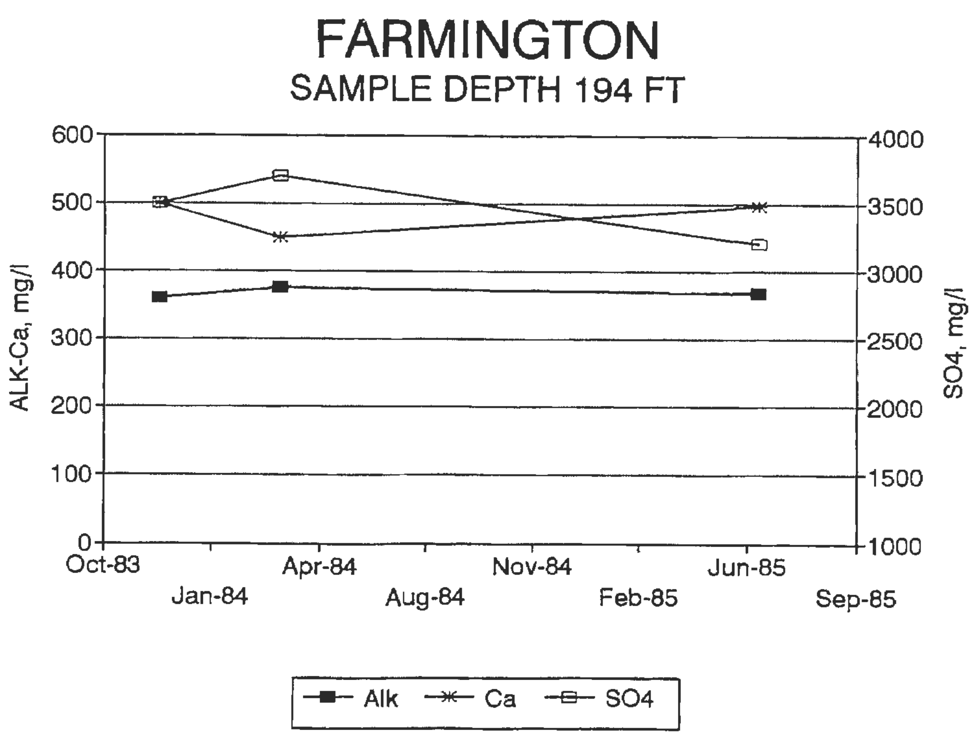
TEMPORAL MINE WATER QUALITY DATA, CONSOLIDATED No.2-S

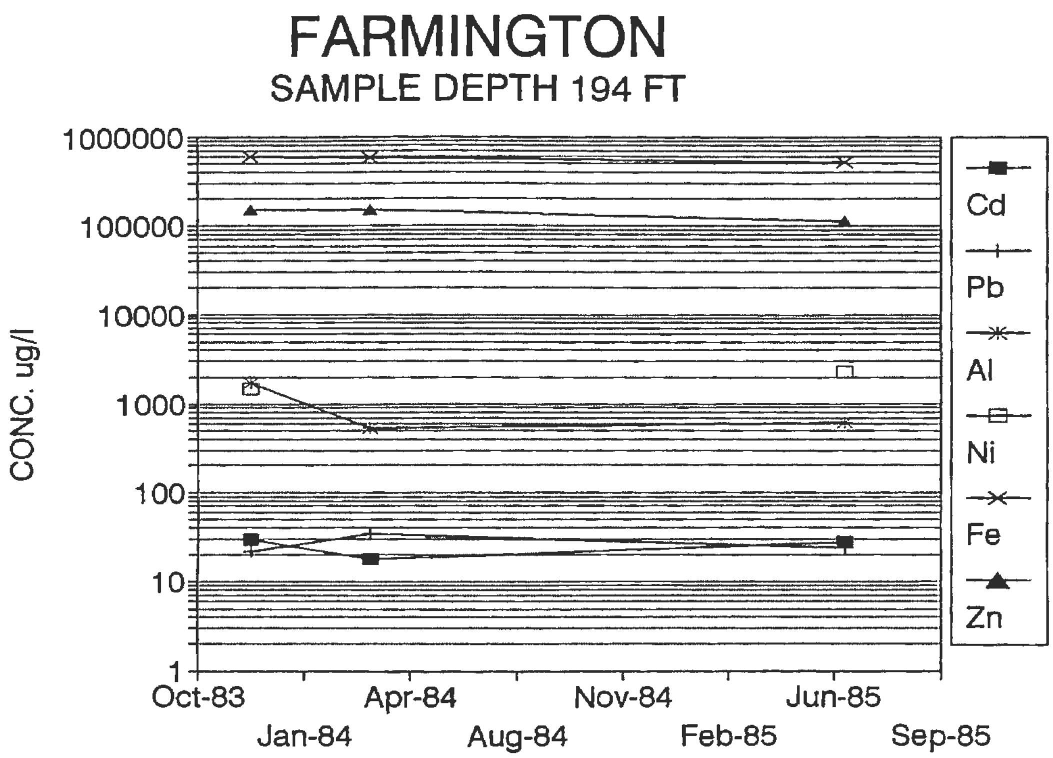
	30OCT80	28MAR81	25MAY82	30NOV83	22MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	234	220	220	226	225	228	234	220	225.5
TEMP (^{0}C)		15.2	15.6	17	15.4	17.5	17.5	15.2	16.1
REDOX (mV)					240	350	350	240	
S C (uS)	1090	880	3970	4050	4080		4080	880	2814.0
OXYGEN		0.8	0.5		0.1		0.8	0.1	0.5
pH	6.9	4.7	5.4	5.7	5.7	5.8	6.9	4.7	5.7
ALKALINITY ($CaCO3$)	138	171		280	288	275.5	288	138	230.5
PHOSPHOROUS				0.01	0.02	0.02	0.02	0.01	0.0
CALCIUM				460	470	497	497	460	475.7
MAGNESIUM				230	250	203	250	203	227.7
SODIUM				67	73	69	73	67	69.7
POTASSIUM				3.8	4.2	3.8	4.2	3.8	3.9
CHLORIDE				10	9.6	9.4	10	9.4	9.7
SULFATE	2685	2915	2804	2800	2900	2700	2915	2685	2800.7
FLUORIDE	1.38	1.65	1.82	1.2	1.7	0.7	1.82	0.7	1.4
SiO2				8.6	12	10	12	8.6	10.2
UNITS: MG/L									

TRACE METALS

	30OCT80	28MAR81	25MAY82	30NOV83	22MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
CADMIUM	190	78		10	14	27	190	10	63.8
COPPER				2	1	30	30	1	11.0
IRON	1500	270000		270000	290000	245600	290000	1500	215420.0
LEAD	48	102		22	49	38.8	102	22	52.0
MANGANESE	5350			4400	4300	3554	5350	3554	4401.0
NICKEL				2200		2300	2300	2200	2250.0
ZINC	241000	152000		110000	110000	91700	241000	91700	140940.0
ALUMINUM				690	500	450	690	450	546.7
DBLS WL				26.8	26	26	26.8	26	26.3
Eh (WATEQ4F) mV				470					
UNITS: UG/L									


FARMINGTON
SAMPLE DEPTH 194 FT
TEMP-pH-O2
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
5500
5000
4500
4000
3500
Aug-81
Feb-82
Sep-82
Mar-83
Oct-83
Apr-84
Nov-84
Jun-85
Dec-85
TEMP,C
pH
O2
SC


FARMINGTON
SAMPLE DEPTH 194 FT
ALK-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Oct-83
Jan-84
Apr-84
Aug-84
Nov-84
Feb-85
Jun-85
Sep-85
Alk
Ca
SO4


FARMINGTON
SAMPLE DEPTH 194 FT
CONC. ug/l
1000000
100000
10000
1000
100
10
1
Oct-83
Jan-84
Apr-84
Aug-84
Nov-84
Feb-85
Jun-85
Sep-85
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, FARMINGTON

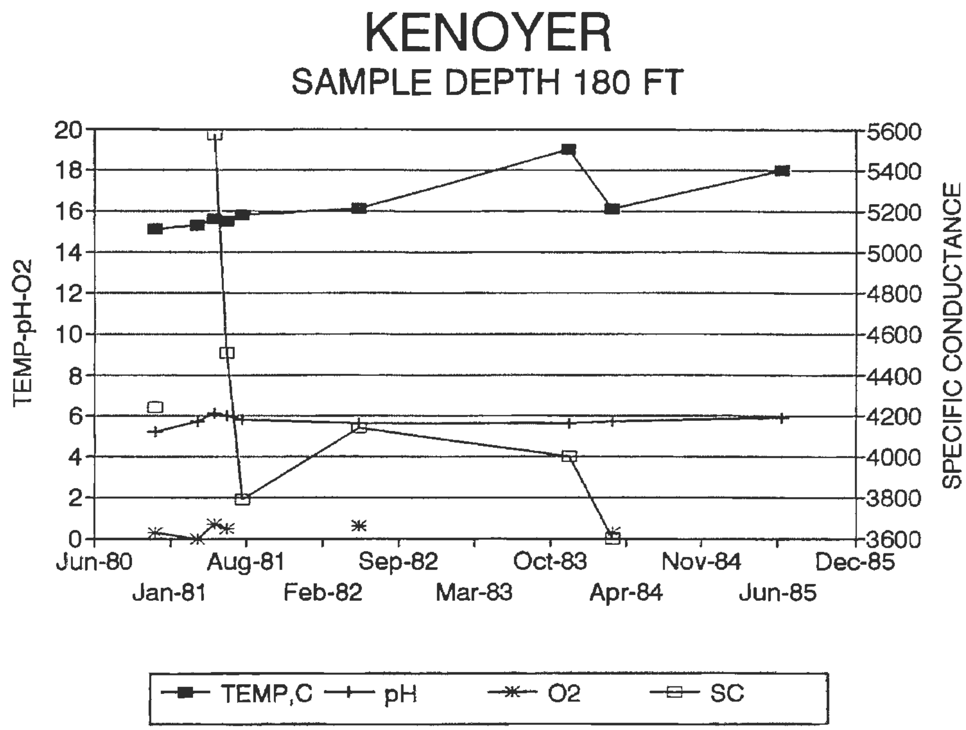
	07DEC81	01DEC83	22MAR84	12JUN85	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	190	192	192	194	194	190	192.0
TEMP (^{o}C)	15.3	18	15.5	17.5	18	15.3	16.6
REDOX (mV)			240	330	330	240	
S C (uS)	5030	4650	4730	4200	5030	4200	4652.5
OXYGEN			0.1		0.1	0.1	0.1
pH	5.4	5.6	5.6	5.7	5.7	5.4	5.6
ALKALINITY (CaCO3)		360	375	368	375	360	367.7
PHOSPHORUS		0.01	0.01	0.02	0.02	0.01	0.0
CALCIUM		500	450	497	500	450	482.3
MAGNESIUM		260	250	206	260	206	238.7
SODIUM		74	72	71	74	71	72.3
POTASSIUM		12	11	14	14	11	12.3
CHLORIDE		14	11	13	14	11	12.7
SULFATE		3500	3700	3200	3700	3200	3466.7
FLUORIDE		1.6	1	0.7	1.6	0.7	1.1
SiO2		9.3	11	10	11	9.3	10.1

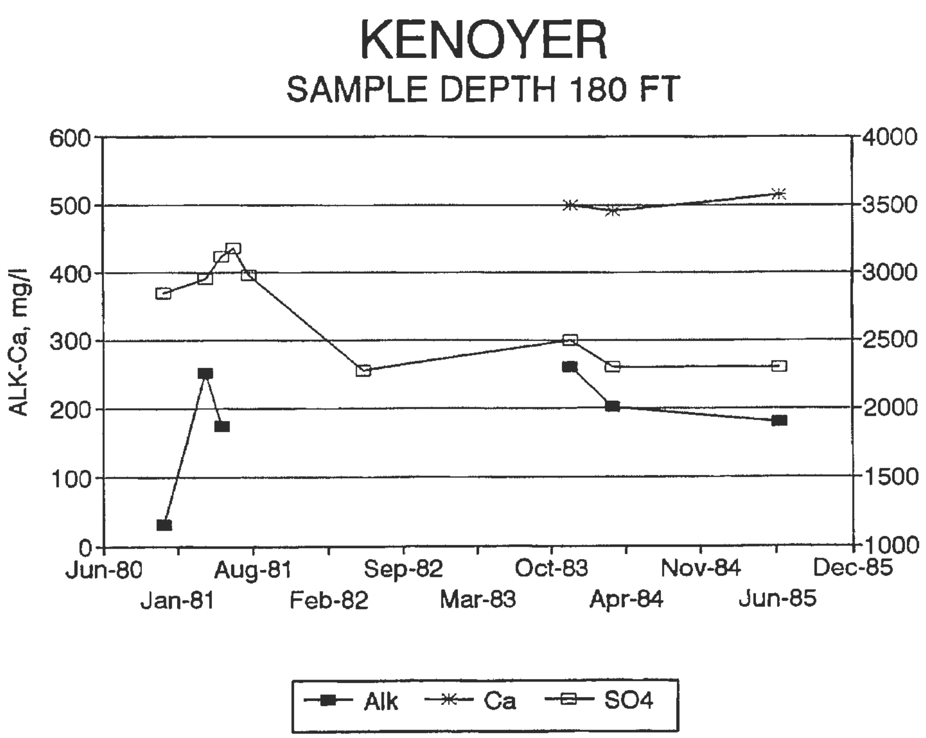
UNITS: MG/L

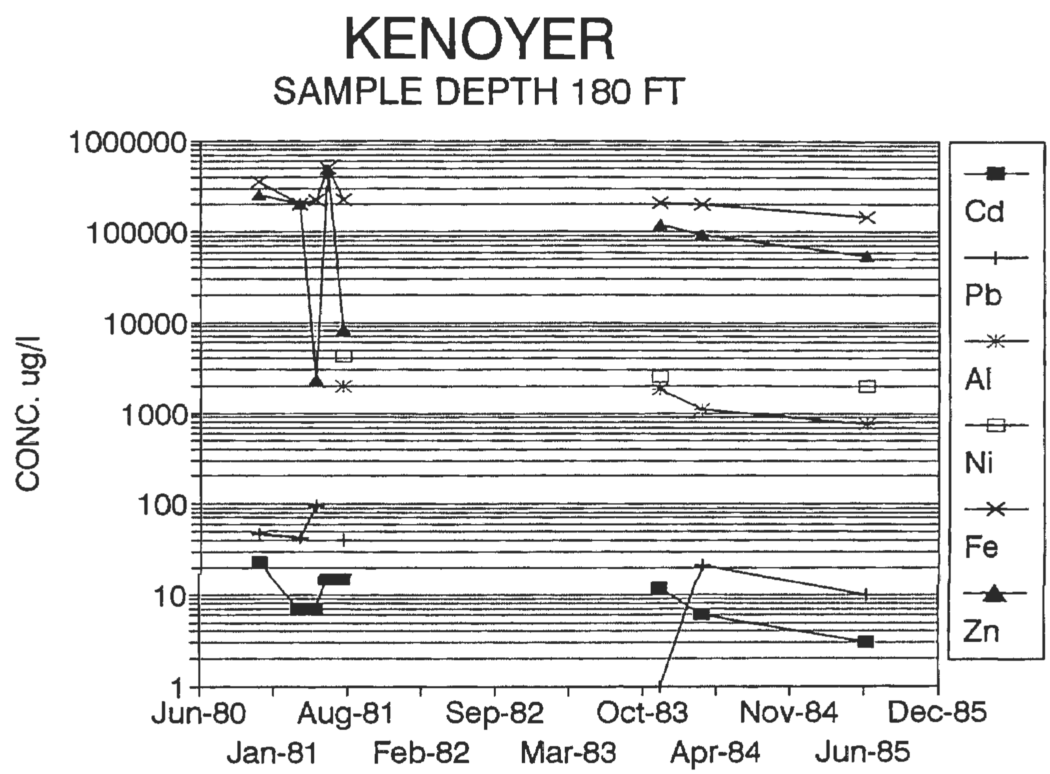
TRACE METALS

CADMIUM		29	18	28	29	18	25.0
COPPER		1	2	30	30	1	11.0
IRON		600000	590000	512600	600000	512600	567533.3
LEAD		22	34	23.8	34	22	26.6
MANGANESE		5200	5500	1910	5500	1910	4203.3
NICKEL		1500		2300	2300	1500	1900.0
ZINC		150000	150000	113420	150000	113420	137806.7
ALUMINUM		1700	540	610	1700	540	950.0
DBLS WL	68	56.5	45.5	47	68	45.5	54.3

UNITS: UG/L


KENOYER
SAMPLE DEPTH 180 FT
TEMP-pH-O2
SPECIFIC CONDUCTANCE
20
18
16
14
12
10
8
6
4
2
0
5600
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
TEMP,C
pH
O2
SC


KENOYER
SAMPLE DEPTH 180 FT
ALK-Ca, mg/l
SO4, mg/l
600
500
400
300
200
100
0
4000
3500
3000
2500
2000
1500
1000
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-81
Feb-82
Mar-83
Apr-84
Jun-85
Alk
Ca
SO4


KENOYER
SAMPLE DEPTH 180 FT
CONC. ug/l
1000000
100000
10000
1000
100
10
1
Jun-80
Jan-81
Aug-81
Feb-82
Sep-82
Mar-83
Oct-83
Apr-84
Nov-84
Jun-85
Dec-85
Cd
Pb
Al
Ni
Fe
Zn

TEMPORAL MINE WATER QUALITY DATA, KENOYER

	04DEC80	27MAR81	11MAY81	11JUN81	22JUL81	25MAY82	29NOV83	22MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
SAMPLE DEPTH (FT)	180	180	180	180	190	180	184	185	182	190	180	182.3
TEMP (^{o}C)	15.1	15.3	15.6	15.5	15.8	16.1	19	16.1	18	19	15.1	16.3
REDOX (mV)								240	300	300	240	
S C (uS)	4240		5570	4510	3790	4140	4000	3600		5570	3600	4264.3
OXYGEN	0.3	0	0.7	0.5		0.6		0.3		0.7	0	0.4
pH	5.2	5.7	6.1	6	5.8	5.6	5.6	5.7	5.9	6.1	5.2	5.7
ALKALINITY ($CaCO_3$)	31	252	175				260	202	180	260	31	183.3
PHOSPHORUS							0.01	0.35	0	0.35	0	0.1
CALCIUM							500	490	514	514	490	501.3
MAGNESIUM							190	180	134	190	134	168.0
SODIUM							91	82	75	91	75	82.7
POTASSIUM							5.5	5.5	5.2	5.5	5.2	5.4
CHLORIDE							37	33	27	37	27	32.3
SULFATE	2847	2954	3119	3182	2987	2283	2500	2300	2300	3182	2283	2719.1
FLUORIDE	0.25	5.3	5.44	5.69	6.68	3.01	3.1	4.2	2.1	6.68	0.25	4.0
SiO_2							13	18	13	18	13	14.7

UNITS: MG/L

TRACE METALS

	04DEC80	27MAR81	11MAY81	11JUN81	22JUL81	25MAY82	29NOV83	22MAR84	11JUN85	MAXIMUM	MINIMUM	MEAN
CADMIUM	23	7	7	15	15		12	6	3	23	3	11.0
COPPER					6		2	2	20	20	2	7.5
IRON	350000	200000	220000	500000	230000		210000	200000	147260	500000	147260	257157.5
LEAD	47	43	96		41		1	21	10	96	1	37.0
MANGANESE				5100	4500		3800	3800	2728	5100	2728	3985.6
NICKEL					4280		2500		2000	4280	2000	2926.7
ZINC	257000	204000	2340	492000	8300		120000	91000	54760	492000	2340	153675.0
ALUMINUM					2000		1800	1100	750	2000	750	1412.5
DBLS WL							15	15	15	15	15	15.0

UNITS: UG/L

APPENDIX E

WATEQ4F SIMULATION DATA

WATEQ4F SPATIAL SIMULATION DATA, APRIL 1976

PARAMETER	BIRTHDAY	CONSOLIDATED NO.2-PL	LUCKY BILL	NEW CHICAGO
SAMPLE DEPTH	182.0000	234.0000	222.0000	197.0000
TEMP. (oC)	15.0000	16.0000	14.5000	17.5000
S.C. (uS)	4389.9900	4600.0000	4950.0000	2850.0000
pH	5.3000	4.8000	5.6000	4.9000
CO2	192.0000	0.0000	100.0000	121.0000
ALKALINITY	20.0000	1.0000	21.0000	5.0000
HCO3	24.0000	0.0000	25.0000	6.0000
CO3	0.0000	0.0000	0.0000	0.0000
TOC, C	0.0000	4.8000	2.9000	3.5000
CALCIUM	489.9990	520.0000	480.0000	499.9990
MAGNESIUM	240.0000	240.0000	250.0000	85.9999
SODIUM	52.9999	8.0000	87.0000	28.0000
POTASSIUM	2.6000	2.2000	6.0000	1.6000
CHLORIDE	6.8000	6.8000	16.0000	4.8000
SULFATE	3000.0000	3200.0000	3000.0000	2100.0000
FLUORIDE	7.2000	1.6000	9.2000	2.6000
SiO2	11.0000	9.8000	7.6000	12.0000
ARSENIC	0.0020	0.0010	0.0070	0.0010
BARIUM	0.1000	0.1000	0.1000	0.1000
BORON	0.2000	0.1200	0.2200	0.1800
CADMIUM	0.9000	0.9300	0.4900	0.1300
CHROMIUM	0.0200	0.0300	0.0200	0.0200
COBALT	0.5800	0.0560	0.0430	0.0000
COPPER	0.0600	0.1000	0.0130	0.0360
IRON	10.0000	130.0000	270.0000	20.0000
LEAD	0.0930	0.4000	0.4000	0.1200
MANGANESE	5.5000	5.9000	5.7000	1.4000
MOLYBDENUM	0.0010	0.0010	0.0010	0.0010
NICKEL	3.5000	0.0470	4.2000	1.0000
VANADIUM	0.0360	0.1500	0.1300	0.0027
ZINC	489.9990	380.0000	490.0000	120.0000
ALUMINUM	8.9000	10.0000	5.7000	5.4000
LITHIUM	0.2500	0.2200	0.2100	0.1100
SELENIUM	0.0010	0.0010	0.0010	0.0010
TDS AT 180 oC	5149.9900	5380.0000	5470.0000	2930.0000
NH4	0.4300	0.3600	0.6300	0.1200
NO3	0.1300	0.0400	0.0000	0.0400
NO2	0.0000	0.0000	0.0300	0.0000
MERCURY	0.0010	0.0006	0.0005	0.0005
Eh (WATEQ4F)	0.4990	0.5300	0.4400	0.5240
pe (WATEQ4F)	8.7280	9.2380	7.7090	9.0800

* UNITS IN MG/L

WATEQ4F SI FOR SELECTED MINERALS, APRIL 1976

	BIRTHDAY	CONSOLIDATED NO.2-PL	LUCKY BILL	NEW CHICAGO
CALCITE	-2.796	----	-2.497	-3.634
DOLOMITE	-5.726	----	-5.108	-7.828
GYPSUM	0.01	0.048	-0.017	0
QUARTZ	0.437	0.371	0.286	0.431
CHALCEDONY	-0.086	-0.148	-0.24	-0.82
Al(OH)3	-0.936	-1.557	-1.435	-1.598
BAUXITE				
BOEHMITE	0.842	0.224	0.341	0.187
DIASPORE	2.636	2.009	2.14	1.958
GIBBSITE	0.808	0.172	0.316	0.109
ALLOPHANE(F)	0.219	-0.271	0.011	-0.26
AlOHSO4	0.683	1.014	-0.401	0.573
Al(OH)10SO4	5.226	3.47	2.759	2.572
ALUNITE	6.087	5.617	4.048	4.767
BARITE	1.094	1.086	1.09	1.043
FERRIHYDRITE	1.885	2.173	3.333	1.572
FE3(OH)8	-0.634	0.194	4.44	-1.595
GOETHITE	5.908	6.234	7.337	5.69
HEMATITE	16.777	17.434	19.632	16.353
SIDERITE	-2.885	----	-1.006	-3.29
GREENALITE	-10.157	-9.501	-3.938	-11.096
JAROSITE Na	7.751	9.441	11.314	7.859
JAROSITE K	9.924	12.349	13.641	10.069
JAROSITE H	5.616	8.679	8.64	6.513
PYROLUSITE	-8.678	-9.496	-9.57	-9.752
RHODOCHROSITE	-2.945	----	-2.623	-4.384
MnHPO4	----	----	----	----
CUPROUSFERRITE	8.216	7.734	10.311	7.017
CUPRICFERRITE	10.654	10.558	13.435	9.318
SMITHSONITE	-1.619	----	-1.312	-3.049
ZnSiO3	0.706	-0.421	1.128	-0.495
OTAVITE	-0.811	----	-0.763	-2.491
CERRUSITE	-2.705	----	-1.749	-3.458
ANGLESITE	-1.483	-0.833	-0.86	-1.378
PLUMBOGUMMITE	----	----	----	----
KAOLINITE	2.792	1.403	1.498	1.419

WATEQ4F SPATIAL SIMULATION DATA, JUNE 1985

PARAMETER	ADMIRALTY	CONSOLIDATED NO.2-S	FARMINGTON	KENOYER
SAMPLE DEPTH	190.0000	228.0000	194.0000	182.0000
TEMP (DEG. C)	18.0000	17.5000	17.5000	18.0000
REDOX	320.0000	350.0000	330.0000	300.0000
S C				
OXYGEN				
PH	5.9000	5.8000	5.7000	5.9000
ALKALINITY	232.0000	275.5000	368.0000	180.0000
*HCO3	283.0000	335.5000	449.0000	219.6000
AMMONIA, N	0.8900	0.6800	1.5000	0.7300
*NH4	1.1440	0.8740	1.9280	0.9380
NITRITE, N				
NO2+NO3, N				
PHOSPHROUS	0.0800	0.0290	0.0250	0.0000
*PO4	0.2453	0.0889	0.0767	0.0000
CALCIUM	509.0000	497.0000	497.0000	514.0000
MAGNESIUM	193.0000	203.0000	206.0000	134.0000
SODIUM	88.0000	69.0000	71.0000	75.0000
POTASIUM	5.7000	3.8000	14.0000	5.2000
CHLORIDE	30.0000	9.4000	13.0000	27.0000
SULFATE	2900.0000	2700.0000	3200.0000	2300.0000
FLUORIDE	2.5000	0.7000	0.7000	2.1000
SiO2	15.0000	10.0000	10.0000	13.0000
BARIUM	0.0090	0.0120	0.0100	0.0100
BERYLLIUM	0.0010	0.0010	0.0010	0.0010
CADMIUM	0.0080	0.0270	0.0280	0.0030
COBALT	0.3220	0.3160	0.5560	0.1710
COPPER	0.0300	0.0300	0.0300	0.0200
IRON	223.6000	245.6000	512.6000	147.2600
LEAD	0.0072	0.0388	0.0238	0.0100
MANGANESE	2.5840	3.5540	1.9100	2.7280
MOLYBDENUM	0.0200	0.0200	0.0200	0.0200
NICKEL	2.9000	2.3000	2.3000	2.0000
STRONTIUM	0.8820	0.9940	0.4550	0.9090
VANADIUM	0.0120	0.0120	0.0120	0.0120
ZINC	96.9200	91.7000	113.4200	54.7600
ALUMINUM	1.6000	0.4500	0.6100	0.7500
LITHIUM	0.1530	0.1610	0.2910	0.1190
DBLS WL	0.00	26.00	47.00	15.00

* UNITS IN MG/L

WATEQ4F SI FOR SELECTED MINERALS, JUNE 1985

	ADMIRALTY NO. 4	CONSOLIDATED NO.2-S	FARMINGTON	KENOYER
CALCITE	-1.014	-1.041	-1.049	-1.066
DOLOMITE	-2.234	-2.264	-2.273	-2.504
GYPSUM	0.028	0.000	0.014	0.001
QUARTZ	0.523	0.355	0.357	0.459
CHALCEDONY	0.012	-0.158	-0.156	-0.052
Al(OH)3	-0.648	-1.078	-1.019	-1.627
BAUXITE				
BOEHMITE	1.139	0.707	0.766	0.159
DIASPORE	2.905	2.478	2.538	1.926
GIBBSITE	1.052	0.629	0.688	0.073
ALLOPHANE(F)	0.529	0.2	0.201	-0.044
AlOHSO4	-0.429	-0.656	-0.352	-1.481
Al(OH)10SO4	4.313	2.904	3.387	0.323
ALUNITE	5.281	4.092	5.218	2.168
BARITE	0.007	0.128	0.060	0.032
FERRIHYDRITE	2.167	2.435	2.086	1.681
FE3(OH)8	2.723	3.109	2.51	1.609
GOETHITE	6.304	6.553	6.204	5.817
HEMATITE	17.583	18.078	17.381	16.609
SIDERITE	0.519	0.534	0.854	0.281
GREENALITE	-1.509	-2.309	-2.011	-2.059
JAROSITE Na	7.342	8.228	7.577	5.675
JAROSITE K	9.597	10.42	10.321	7.962
JAROSITE H	4.536	5.602	5.045	2.931
PYROLUSITE	-12.575	-11.835	-13.229	-13.203
RHODOCROSITE	-1.508	-1.389	-1.668	-1.542
MnHPO4	0.229	-0.325	-0.847	----
CUPROUSFERRITE	11.81	11.428	11.26	11.557
CUPRICFERRITE	12.202	12.474	11.511	11.117
SMITHSONITE	-0.580	-0.630	-0.563	-0.871
ZnSiO3	1.418	1.003	0.850	1.162
OTAVITE	-1.15	-0.635	-0.647	-1.614
CERRUSITE	-2.314	-1.608	-1.864	-2.193
ANGLESITE	-2.82	-2.12	-2.354	-2.673
PLUMBOGUMMITE	2.679	1.006	0.664	----
KAOLINITE	3.499	2.308	2.431	1.412

WATEQ4F VERTICAL SIMULATION DATA,
CONSOLIDATED NO.2-PL

PARAMETER	APRIL 20-21, 1976			
SAMPLE DEPTH	191.0000	227.0000	229.0000	234.0000
TEMP. (oC)	16.0000	16.0000	16.0000	16.0000
S C	940.0000	1080.0000	4420.0000	4600.0000
PH	7.5500	6.9000	5.0000	4.8000
CO2	2.9000	11.0000	0.0000	0.0000
ALKALINITY	53.0000	47.0000	1.0000	1.0000
HCO3	64.0000	57.0000	0.0000	0.0000
CO3	0.0000	0.0000	0.0000	0.0000
TOC, C	5.4000	4.7000	4.7000	4.8000
HARDNESS, T	520.0000	550.0000	2200.0000	2300.0000
CALCIUM	170.0000	180.0000	500.0000	520.0000
MAGNESIUM	24.0000	25.0000	240.0000	240.0000
SODIUM	10.0000	11.0000	80.0000	8.0000
POTASSIUM	1.7000	1.8000	2.2000	2.2000
CHLORIDE	2.1000	1.7000	6.2000	6.8000
SULFATE	460.0000	520.0000	3100.0000	3200.0000
FLUORIDE	0.3000	0.4000	1.9000	1.6000
SiO2	10.0000	9.8000	8.4000	9.8000
ARSENIC	0.0010	0.0010	0.0020	0.0010
BARIUM	0.1000	0.1000	0.1000	0.1000
BORON	0.0300	0.1000	0.1500	0.1200
CADMIUM	0.0900	0.1000	0.7800	0.9300
CHROMIUM	0.0000	0.0000	0.0200	0.0300
COBALT	0.0000	0.0030	0.0530	0.0560
COPPER	0.0040	0.0070	0.0700	0.1000
IRON	0.0100	0.6700	130.0000	130.0000
LEAD	0.0020	0.0020	0.2000	0.4000
MANGANESE	0.0800	0.0800	5.7000	5.9000
MOLYBDENUM	0.0010	0.0010	0.0010	0.0010
NICKEL	0.0030	0.0320	3.4000	0.0470
VANADIUM	0.0001	0.0001	0.1500	0.1500
ZINC	3.2000	4.0000	310.0000	380.0000
ALUMINUM	0.0100	0.0200	7.7000	10.0000
LITHIUM	0.0300	0.0400	0.2100	0.2200
SELENIUM	0.0010	0.0010	0.0010	0.0010
TDS AT 180 oC	795.0000	841.0000	5160.0000	5380.0000
Hg	0.0007	0.0005	0.0005	0.0006
*NH4	0.0260	0.0130	0.3600	0.3600
*NO3	1.1500	1.0600	0.0000	0.0440
*NO2	0.0000	0.0000	0.0330	0.0000
Eh (WATEQ4F)	0.3510	0.4000	0.4500	0.5300
pe (WATEQ4F)	6.1160	6.9670		9.2380

* CALCULATED FROM N

WATEQ4F SI FOR SELECTED MINERALS,
CONSOLIDATED NO.2-PL, APRIL 1976

SAMPLE DEPTH	191	227	229	234
CALCITE	-0.174	-0.859	----	----
DOLOMITE	-1.024	-2.4	----	----
GYPSUM	-0.725	-0.669	0.028	0.048
QUARTZ	0.37	0.362	0.304	0.371
CHALCEDONY	-0.15	-0.157	-0.216	-0.148
Al(OH)3	-1.602	-1.239	-1.151	-1.557
BAUXITE				
BOEHMITE	0.179	0.542	0.629	0.224
DIASPORE	1.964	2.326	2.414	2.009
GIBBSITE	0.127	0.49	0.577	0.172
ALLOPHANE(F)	0.428	0.507	-0.079	-0.271
AlOHSO4	-5.097	-3.388	1.013	1.014
Al(OH)10SO4	-2.776	0.022	4.686	3.47
ALUNITE	-3.948	-0.796	6.221	5.617
BARITE	0.892	0.915	1.084	1.086
FERRIHYDRITE	1.345	2.654	1.48	2.173
FE3(OH)8	-1.922	1.803	-0.691	0.194
GOETHITE	5.406	6.715	5.541	6.234
HEMATITE	15.776	18.396	16.048	17.434
SIDERITE	-4.764	-3.054	----	----
GREENALITE	-10.88	-7.579	-8.131	-9.501
JAROSITE Na	-2.277	3.733	7.749	9.441
JAROSITE K	0.432	6.425	9.657	12.349
JAROSITE H	-5.939	0.681	5.786	8.679
PYROLUSITE	-6.333	-7.238	-11.497	-9.496
RHODOCHROSITE	-1.705	-2.414	----	----
MnHPO4	----	----	----	----
CUPROUSFERRITE	10.432	11.307	8.483	7.734
CUPRICFERRITE	12.057	14.446	9.419	10.558
SMITHSONITE	-0.742	-1.313	----	----
ZnSiO3	3.254	2.071	-0.172	-0.421
OTAVITE	1.273	0.648	----	----
CERRUSITE	-2.1	-2.305	----	----
ANGLESITE	-4.225	-3.689	-1.136	-0.833
PLUMBOGUMMITE	----	----	----	----
KAOLINITE	1.31	2.021	2.08	1.403

WATEQ4F VERTICAL SIMULATION DATA,
FARMINGTOM SHAFT

PARAMETER	JUNE 12, 1985		
SAMPLING DEPTH	140.0000	176.0000	194.0000
TEMP (DEG. C)	17.0000	17.0000	17.5000
REDOX	360.0000	140.0000	330.0000
S C			
OXYGEN			
PH	6.5000	6.1000	5.7000
ALKALINITY	277.0000	732.0000	368.0000
*HCO3	337.9400	893.0400	448.9600
AMMONIA, N	0.5500	1.2000	1.5000
*NH4	0.7100	1.5400	1.9300
NITRITE, N			
NO2+NO3, N			
PHOSPHATE	0.0050	0.0140	0.0250
*PO4	0.0150	0.0430	0.0770
CALCIUM	564.0000	593.0000	497.0000
MAGNESIUM	36.0000	183.0000	206.0000
SODIUM	49.0000	84.0000	71.0000
POTASSIUM	5.5000	9.9000	14.0000
CHLORIDE	6.1000	6.6000	13.0000
SULFATE	1600.0000	2300.0000	3200.0000
FLUORIDE	1.3000	1.0000	0.7000
SiO2	13.0000	13.0000	10.0000
BARIUM	0.0140	0.0210	0.0100
BERYLLIUM	0.0010	0.0010	0.0010
CADMIUM	0.0080	0.0030	0.0280
COBALT	0.0700	0.2480	0.5560
COPPER	0.0200	0.0200	0.0300
IRON	22.8200	199.6800	512.6000
LEAD	0.0014	0.0018	0.0238
MANGANESE	2.3260	1.4000	1.9100
MOLYBDENUM	0.0200	0.0200	0.0200
NICKEL	0.4000	3.0000	2.3000
STRONTIUM	0.4090	0.5990	0.4550
VANADIUM	0.0120	0.0120	0.0120
ZINC	19.9060	21.6600	113.4200
ALUMINUM	0.0300	0.2700	0.6100
LITHIUM	0.2220	0.3660	0.2910
DBLS WL	47.0000	47.0000	47.0000
S C LAB	2560.0000	3490.0000	4200.0000

* UNITS IN MG/L

WATEQ4F SI FOR SELECTED MINERALS,
FARMINGTON, JUNE 1985

SAMPLE DEPTH	140	176	194
CALCITE	-0.182	-0.221	-1.049
DOLOMITE	-1.363	-0.755	-2.273
GYPSUM	-0.012	0.019	0.014
QUARTZ	0.473	0.477	0.357
CHALCEDONY	-0.042	-0.038	-0.156
Al(OH)3	-1.807	-1.205	-1.019
BAUXITE			
BOEHMITE	-0.024	0.579	0.766
DIASPORE	1.752	2.354	2.538
GIBBSITE	-0.093	0.509	0.688
ALLOPHANE(F)	0.019	0.29	0.201
AlOHSO4	-2.899	-1.419	-0.352
Al(OH)10SO4	-1.416	1.87	3.387
ALUNITE	-0.273	3.127	5.218
BARITE	0.161	0.35	0.06
FERRIHYDRITE	3.479	-0.373	2.086
FE3(OH)8	5.369	-1.964	2.509
GOETHITE	7.577	3.726	6.204
HEMATITE	20.125	12.423	17.381
SIDERITE	0.023	1.2	0.854
GREENALITE	-1.572	-0.454	-2.011
JAROSITE Na	8.78	-1.199	7.577
JAROSITE K	11.291	1.331	10.321
JAROSITE H	5.561	-4.237	5.045
PYROLUSITE	-8.841	-18.381	-13.229
RHODOCHROSITE	-0.772	-1.062	-1.668
MnHPO4	0.19	-0.138	-0.262
CUPROUSFERRITE	12.697	12.02	11.26
CUPRICFERRITE	15.628	6.879	11.511
SMITHSONITE	-0.5	-0.6	-0.563
ZnSiO3	1.902	1	0.85
OTAVITE	-0.355	-0.914	-0.647
CERRUSITE	-2.487	-2.52	-1.864
ANGLESITE	-3.877	-3.839	-2.369
PLUMBOGUMMITE	-2.852	-0.348	1.82
KAOLINITE	1.092	2.305	2.431

WATEQ4F TEMPORAL SIMULATION DATA,
CONSOLIDATED NO.2-PL

PARAMETER	21APR76	19OCT76	07JUN77
SAMPLING DEPTH	234.0000	230.0000	230.0000
TEMP. (oC)	16.0000	14.5000	16.0000
S C	4600.0000	3999.9900	4100.0000
PH	4.8000	5.3000	5.6000
CO2	0.0000	56.0000	0.0000
ALKALINITY	1.0000	6.0000	1.0000
HCO3	0.0000	7.0000	0.0000
CO3	0.0000	0.0000	0.0000
TOC, C	4.8000	0.9000	1.0000
HARDNESS, TOTAL	2300.0000	2200.0000	2200.0000
CALCIUM	520.0000	510.0000	510.0000
MAGNESIUM	240.0000	230.0000	220.0000
SODIUM	8.0000	81.0000	80.0000
POTASSIUM	2.2000	4.1000	3.8000
CHLORIDE	6.8000	7.0000	5.9000
SULFATE	3200.0000	3400.0000	3100.0000
FLUORIDE	1.6000	2.4000	1.8000
SiO2	9.8000	7.7000	8.4000
ARSENIC	0.0010	0.0100	0.0060
BARIUM	0.1000	0.1000	0.2000
BORON	0.1200	0.1700	0.1700
CADMIUM	0.9300	0.5400	0.5500
CHROMIUM	0.0300	0.0200	0.0300
COBALT	0.0560	0.0610	0.8000
COPPER	0.1000	0.0330	0.0130
IRON	130.0000	310.0000	53.0000
LEAD	0.4000	0.3000	0.3500
MANGANESE	5.9000	5.4000	5.6000
MOLYBDENUM	0.0010	0.0010	0.0010
NICKEL	0.0470	3.4000	3.4000
VANADIUM	0.1500	0.1300	0.1600
ZINC	380.0000	290.0000	310.0000
ALUMINUM	10.0000	5.0000	0.2000
LITHIUM	0.2200	0.2000	0.3000
SELENIUM	0.0010	0.0010	0.0010
TDS AT 180 oC	5380.0000	5160.0000	5100.0000
NH4	0.3600	0.3500	0.3500
NO3	0.0400	1.9000	0.0900
NO2	0.0000	0.0000	0.0300
MERCURY	0.0006	0.0005	0.0005
Eh (WATEQ4F)	0.5300	0.5090	0.4750
pe (WATEQ4F)	9.2380	8.9180	8.2830

* UNITS IN MG/L

WATEQ4F TEMPORAL SIMULATION DATA,
CONSOLIDATED NO.2-S

PARAMETER	30NOV83	22MAR84	11JUN85
SAMPLING DEPTH	226.0000	225.0000	228.0000
TEMP (DEG. C)	17.0000	15.4000	17.5000
REDOX		0.2400	0.3500
S C	4050.0000	4080.0000	
OXYGEN		0.1000	
PH	5.7000	5.7000	5.8000
ALKALINITY	280.0000	288.0000	275.5000
*HCO3-	341.6000	351.4000	336.1000
AMMONIA, N	0.4100		0.6800
*NH4	0.5300		0.8700
NITRITE, N	0.0100		
*NO2	0.0330		
NO2+NO3, N	0.1000		
*NO3	0.4000		
PHOSPHORUS	0.0100	0.0220	0.0290
*PO4	0.0330	0.0670	0.0890
CALCIUM	460.0000	470.0000	497.0000
MAGNESIUM	230.0000	250.0000	203.0000
SODIUM	67.0000	73.0000	69.0000
POTASSIUM	3.8000	4.2000	3.8000
CHLORIDE	10.0000	9.6000	9.4000
SULFATE	2800.0000	2900.0000	2700.0000
FLUORIDE	1.2000	1.7000	0.7000
SiO2	8.6000	12.0000	10.0000
BARIUM			0.0120
BERYLLIUM			0.0010
CADMIUM	0.0100	0.0140	0.0270
COBALT			0.3160
COPPER	0.0020	0.0010	0.0300
IRON	270.0000	290.0000	245.6000
LEAD	0.0220	0.0490	0.0380
MANGANESE	4.4000	4.3000	3.5540
MOLYBDENUM			0.0200
NICKEL	2.2000		2.3000
STRONTIUM			0.9940
VANADIUM			0.0120
ZINC	110.0000	110.0000	91.7000
ALUMINUM	0.6900	0.5000	0.4500
LITHIUM			0.1610
DBLS WL	26.8000	26.0000	26.0000
Eh (WATEQ4F)	0.4700		
pe (WATEQ4F)	8.1560		

WATEQ4F SI FOR SELECTED MINERALS
CONSOLIDATED No.2 MINES

	CONSOLIDATED NO.2-PL			CONSOLIDATED NO.2-S		
SAMPLE DATE	APR 1976	OCT 1976	JUN 1977	NOV 1983	MAR 1984	JUN 1985
SAMPLE DEPTH	234	230	230	226	225	228
CALCITE	----	-3.319		-1.187	-1.189	-1.041
DOLOMITE	----	-2.813		-2.474	-2.472	-2.264
GYPSUM	0.048	0.064	0.05	-0.016	-0.013	0
QUARTZ	0.371	0.292	0.304	0.298	0.469	0.355
CHALCEDONY	-0.148	-0.234	-0.216	-0.217	-0.053	-0.158
Al(OH)3	-1.557	-0.873	-3.665	-1.444	-2.477	-1.078
BAUXITE						
BOEHMITE	0.224	0.903	-1.885	0.34	-0.698	0.707
DIASPORE	2.009	2.702	-0.1	2.115	1.092	2.478
GIBBSITE	0.172	0.879	-1.937	0.27	-0.74	0.629
ALLOPHANE(F)	-0.271	0.187	-1.178	-0.037	-0.453	0.2
AlOHSO4	1.014	0.851	-2.683	-0.757	-1.681	-0.656
Al(OH)10SO4	3.47	5.697	-6.553	1.815	-1.852	2.904
ALUNITE	5.617	6.644	-2.847	3.391	0.45	4.092
BARITE	1.086	1.124	1.393	----	----	0.128
FERRIHYDRITE	2.173	3.449	2.992	3.848	0.279	2.435
FE3(OH)8	0.194	3.882	2.809	5.367	-1.328	3.109
GOETHITE	6.234	7.453	7.053	7.947	4.317	6.553
HEMATITE	17.434	19.865	19.072	20.865	13.597	18.078
SIDERITE	----	-2.012	----	0.059	0.474	0.534
GREENALITE	-9.501	-6.302	-6.703	-4.145	-2.523	-2.309
JAROSITE Na	9.441	12.709	10.521	12.764	1.922	8.228
JAROSITE K	12.349	14.901	12.667	14.975	4.159	10.42
JAROSITE H	8.679	10.37	7.958	10.227	-0.731	5.602
PYROLUSITE	-9.496	-8.406	-8.237	-8.033	-16.215	-11.835
RHODOCHROSITE	----	-3.491	----	-1.408	-1.431	-1.389
MnHPO4	----	----	----	-0.12	0.152	0.323
CUPROUSFERRITE	7.734	9.304	9.423	9.462	9.535	11.428
CUPRICFERRITE	10.558	13.453	12.907	13.873	6.266	12.474
SMITHSONITE	----	-2.398	----	-0.669	-0.693	-0.63
ZnSiO3	-0.421	0.261	1.021	0.78	0.851	1.003
OTAVITE	----	-1.586	----	-1.182	-1.043	-0.635
CERRUSITE	----	-2.739	----	-1.949	-1.588	-1.608
ANGLESITE	-0.833	-0.947	-0.887	-2.337	-1.991	-2.12
PLUMBOGUMMITE	----	----	----	0.42	-1.659	2.303
KAOLINITE	1.403	2.635	-2.949	1.468	-0.233	2.308

WATEQ4F SPRING SIMULATION DATA

	OWRB 4S BOREHOLE	COMMERCE SPRING	STAND PIPE OWRB.4**
SAMPLE DATE	04JUN85	10JUN85	19JUN84
SAMPLING DEPTH	0.0000	0.0000	0.0000
TEMP (DEG. C)	15.5000	18.0000	15.0000
REDOX (mV)	250.0000	260.0000	370.0000
S C	3850.0000*	3970.0000*	4470.0000
OXYGEN			
PH	5.4000	5.9000	4.5000
ALKALINITY	160.0000	560.0000	13.0000
*HCO3	195.2000	683.2000	15.8600
AMMONIA, N	0.8800	1.3000	0.0000
*NH4	1.1300	1.6700	
NITRITE, N			
NO2+NO3, N			
PHOSPHOROUS	0.0760	0.0650	>1.0000
*PO4	0.2330	0.1990	3.0000
CALCIUM	472.0000	610.0000	480.0000
MAGNESIUM	205.0000	143.0000	120.0000
SODIUM	71.0000	120.0000	54.0000
POTASSIUM	5.7000	15.0000	14.0000
CHLORIDE	28.0000	46.0000	8.1000
SULFATE	3000.0000	2800.0000	2800.0000
FLUORIDE	5.3000	1.4000	15.0000
SiO2	17.0000	12.0000	39.0000
BARIUM	0.0070	0.0210	0.0000
BERYLLIUM	0.0010	0.0010	0.0000
CADMIUM	0.0420	0.0040	0.0780
COBALT	0.4100	0.2380	0.0000
COPPER	0.0200	0.0200	<0.0010
IRON	276.2000	392.2000	300.0000
LEAD	0.0452	0.0005	0.0790
MANGANESE	2.8860	4.0900	5.0000
MOLYBDENUM	0.0200	0.0200	0.0000
NICKEL	3.1000	1.3000	0.0000
STRONTIUM	0.5000	1.7120	0.0000
VANADIUM	0.0012	0.0120	0.0000
ZINC	149.5800	38.8400	180.0000
ALUMINUM	4.2000	0.6200	16.0000
LITHIUM	0.1850	0.2840	0.0000
DBLS WL	0.00	0.00	0.00

* LAB SC
** USGS OPEN FILE REPORT 87-453 TABLE 1.
UNITS IN MG/L

WATEQ4F SI FOR SELECTED MINERALS,
SPRING DATA, JUNE 1985

	OWRB 4S BOREHOLE	COMMERCE SPRING	STAND PIPE OWRB 4
SAMPLE DATE	04JUN85	10JUN85	19JUN84
SAMPLE DEPTH	SURFACE	SURFACE	SURFACE
CALCITE	-1.751	-0.544	INVALID
DOLOMITE	-3.681	-1.505	DATA
GYPSUM	0.007	0.072	
QUARTZ	0.619	0.428	
CHALCEDONY	0.097	-0.083	
Al(OH)3	-1.527	-1.24	
BAUXITE			
BOEHMITE	0.252	0.547	
DIASPORE	2.042	2.313	
GIBBSITE	0.209	0.46	
ALLOPHANE(F)	0.044	0.157	
AlOHSO4	-0.115	-1.055	
Al(OH)10SO4	2.541	1.91	
ALUNITE	4.369	3.855	
BARITE	-0.059	0.358	
FERRIHYDRITE	-0.473	1.381	
FE3(OH)8	-3.459	1.403	
GOETHITE	3.569	5.518	
HEMATITE	12.101	16.011	
SIDERITE	-0.111	1.163	
GREENALITE	-4.103	-0.943	
JAROSITE Na	0.609	5.047	
JAROSITE K	2.989	7.588	
JAROSITE H	-1.726	2.108	
MELANTERITE	-2.412	-2.321	
PYROLUSITE	-17.229	-14.461	
RHODOCHROSITE	-2.165	-0.925	
MnHPO4	0.262	0.711	
CUPROUSFERRITE	9.71	11.687	
CUPRICFERRITE	5.572	10.255	
SMITHSONITE	-1.1	-0.641	
ZnSiO3	0.557	0.87	
OTAVITE	-1.116	-1.108	
CERRUSITE	-2.086	-3.278	
ANGLESITE	-1.907	-4.209	
PLUMBOGUMMITE	2.4	0.129	
KAOLINITE	1.965	2.123	

VITA 2

Mark Logan Finney

Candidate for the Degree of

Masters of Science

Thesis: GEOCHEMICAL ASSESSMENT OF MINE WATER WITHIN ABANDONED LEAD-ZINC MINES, PICHER FIELD, NORTHEAST OKLAHOMA

Major Field: Geology

Biographical:

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