

1025

ABANDONED MINE LANDS SITE CHARACTERIZATION

Katherine Mine, Mill, and Tailings Site,
Mohave County, Arizona



Prepared for:

Lake Mead National
Recreation Area,
National Park Service

by:

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LAME-1025

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EXECUTIVE SUMMARY

The Katherine Mine, mill, and tailings in Mohave County, Arizona were investigated by the U.S. Bureau of Mines (USBM) at the request of the National Park Service (NPS) in order to identify and characterize chemical and physical hazards. The site includes a large tailings impoundment covering over 20 acres, with some underground workings extending to the surface. The mine was operated from 1914 to 1941, and the mill was operated from 1914 to 1941. The site is located in the Lake Mead National Recreation Area, which is a part of the National Park System. The site is a potential source of contamination to the surrounding environment, and the NPS is concerned about the potential for contamination of the Lake Mead water supply. The USBM was requested to conduct an investigation of the site to identify and characterize chemical and physical hazards.

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EXECUTIVE SUMMARY

The Katherine Mine, mill, and tailings in Mohave County, Arizona were investigated by the U.S. Bureau of Mines (USBM) at the request of the National Park Service (NPS) in order to identify and characterize chemical and physical hazards. The site includes a large tailings impoundment covering over 26 ac, extensive underground workings, sloughing surface openings, and ruins of a cyanide mill. The investigation was originally undertaken because of concern about potential risks, especially to visitors, associated with the presence of cyanide and heavy metals in the mill tailings. Stormwater runoff into Lake Mohave and windblown contamination of the surrounding environment were additional concerns. As characterization work progressed, the NPS also requested that the USBM investigation be further broadened to include physical hazards associated with near-surface underground workings. Development and application of integrated, multidisciplinary site characterization methodologies were also goals of the USBM study.

Katherine Mine site is about six miles north of Bullhead City, Arizona and one-half mile east of Lake Mohave on land administered by the NPS Lake Mead National Recreation Area (LAME). The average elevation of the site is 820 ft. The small community of Katherine is situated at the east end of the Mine site, and well water serving the community is pumped from the 900-ft-deep main shaft. The water table is 300 ft deep. Despite its remote desert location, public visitation to the site by residents of the local community and LAME recreational users is frequent. The NPS also leads interpretive tours to the historically significant Katherine Mine and mill.

Gold was discovered in 1900 on a small outcrop of Precambrian granite which protrudes through Quaternary alluvium. Gold and silver ore occurs in a quartz vein system which strikes northeast and dips steeply northwest. Development of the Katherine (a.k.a. Catherine) Mine began in 1903, and production was intermittent through about 1930. The Katherine mill was built in 1925 and processed Katherine Mine ore and ores from other mines in the Union Pass-Katherine Mining District until 1943. Katherine Mine workings extend 1,700 ft along strike with six developed levels and a maximum depth of over 900 ft. Mining was primarily by shrinkage stope methods. Ore was crushed and pulverized, and cyanide and lime were added to a slurry to leach the precious metals which were then recovered using a zinc precipitate. Records and estimates show that 880,000 tons of ore were processed by the mill and placed into the tailings impoundment.

Field investigations were conducted in two 10-day seasons in 1993 and 1994. Techniques employed included: 1) a site survey and mapping of significant features; 2) collection of geochemical, mineralogic, geotechnical, and hydrologic samples; and 3) seismic refraction, electromagnetic ground conductivity, and magnetic gradient geophysical surveys. A total of 179 geochemical samples were collected including 119 samples from auger holes and channels through the tailings, 8 samples of mill and chemical residues, 36 samples of soil, 6 samples of rock and dumps, and 10 samples of stream sediments. Geochemical samples were selectively submitted for one or more of the following elements or compounds: antimony, arsenic, beryllium, cadmium, copper,

gold, lead, mercury, silver, zinc, cyanide, and a suite of oxides. Geotechnical procedures included determination of bulk density and analyses for particle size distribution, liquid limit, and direct shear. In addition, six samples of water collected from Lake Mohave were analyzed for a suite of metals including cyanide, cadmium, lead, and mercury.

The following conclusions were reached as a result of the USBM investigation:

- ◆ Based on the USBM survey, it is calculated that the original impoundment contained 587,000 yd³ of tailings at an average dry bulk density of 89 lb/ft³.
- ◆ The material is uniform silt and fine sand, has a liquid limit of 11.4 % and a Universal Soil Classification of ML, and the tailings are partially cemented with lime.
- ◆ Extensive erosion of the tailings, primarily by piping, tunneling, and toppling, is attributed to stormwater runoff.
- ◆ An estimated 49,000 yd³ of Katherine tailings have been eroded by stormwater runoff and transported down Katherine Wash into Lake Mohave.
- ◆ Stability analyses show a minimum factor of safety of 2.3 when dry, but it may be considerably weaker with loss of cementation or when saturated.
- ◆ The tailings present a chronic falling and caving hazard to the public, and unless radical stabilization techniques are applied public access should be restricted. This can be accomplished by 1) closure of the Katherine community road through the tailings, 2) reopening of the south boundary trail, and 3) placement of fences to limit public access.
- ◆ Concentrations of the heavy metals and cyanide in the tailings fall below maximum acceptable contaminant levels used as a standard for the investigation; however, unexpectedly high concentrations of beryllium, averaging 57 ppm, were detected in select samples analyzed. Assessment of risk depends on the form of beryllium, the determination of which is underway.
- ◆ Unless stabilized, the tailings will continue to be subject to erosion by stormwater runoff.
- ◆ No adverse impacts on Lake Mohave are expected due to chemical composition of the tailings, and tests of Lake Mohave water revealed that no metals or compounds analyzed exceeded Environmental Protection Agency drinking water standards.
- ◆ The consequences of periodic deposition of large volumes of fine-grained sediments onto the lake bottom are unknown.
- ◆ The presence of heavy metals in soils north of the impoundment is probably due to windblown transport of tailings material. However, concentrations of the elements analyzed are below acceptable contamination levels.
- ◆ High concentrations of total cyanide, greater than 40 ppm, and anomalous concentrations of beryllium, lead, and zinc were detected in several samples of residues from the Katherine mill ruins, especially within the tank foundations. Lead and zinc are at clean-up levels while cyanide is considered only moderate contaminations. Selective removal of mill residues is recommended if public visitation to the site continues.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ac	acre
ft	foot
ft ³	cubic foot
>	greater than
<	less than
gal	gallon
gpm	gallon per minute
Hz	hertz
in	inch
kHz	kilohertz
kg	kilogram
lb	pound
lb/ft ³	pound per cubic foot
Mb	megabyte
m	meter
mi	mile
mi ²	square mile
mg	milligram
mg/kg	milligram per kilogram
mg/l	milligram per liter
mg/m ³	milligram per cubic meter
ml	milliliter
mm	millimeter
mS/m	millisiemen per meter
oz	ounce
pH	hydrogen ion content
ppb	part per billion
ppm	part per million
ppt	part per thousand
%	percent
st/d	short ton per day
V	volt
yd	yard
yd ³	cubic yard

Reference to specific products and software does not imply endorsement by the U.S. Bureau of Mines.

CHEMICAL ABBREVIATIONS USED IN THIS REPORT

Ag	silver
Au	gold
As	arsenic
Be	beryllium
Be ₃ Al ₂ (SiO ₃) ₆	beryl
Be ₂ SiO ₄	phenakite
BeO	beryllium content
Cd	cadmium
Cu	copper
CN _F	free cyanide
HCN ⁻	hydrogen cyanide ion
CN ⁻	free cyanide ion
Fe	iron
H	hydrogen
Hg	mercury
Pb	lead
Sb	antimony
Zn	zinc
Ca ²⁺	calcium ion
CaCO ₃	calcium carbonate
CaO	calcium oxide content
CuSO ₄	copper sulfate
NaCN	sodium cyanide
Pb ²⁺	lead ion
PbS	lead sulfide (galena)
Zn ²⁺	zinc ion
ZnSO ₄	zinc sulfate

Reference to specific products and software does not imply endorsement by the U.S. Bureau of Mines.

ABANDONED MINE LANDS SITE CHARACTERIZATION:

KATHERINE MINE, MILL, AND TAILINGS SITE,

MOHAVE COUNTY, ARIZONA

By Stephen R. Iverson¹, Samuel W. McNary², Phillip R. Moyle³,
J. Mitchell Linne⁴, and Jody Fay³

ABSTRACT

The U.S. Bureau of Mines (USBM) investigated the Katherine Mine, mill, and tailings to characterize chemical and physical hazards and to research, develop, and apply new characterization technologies.

Extensive geochemical sampling was conducted of the tailings, millsite, surrounding soils, and stream sediments to determine the presence and transport of heavy metals, and cyanide. Lake water, down-gradient from the site was also sampled. A geotechnical investigation of the steeply sloped tailings was conducted to determine stability. Seismic refraction, vertical-gradient magnetic, and electromagnetic surveys were conducted on the tailings to determine physical extent and metals contamination of the tailings and on the surface over the underground mine workings to determine the location of near surface stopes.

Geochemical investigation of the tailings indicate cyanide and heavy metals exist on-site but in concentrations within or below maximum acceptable levels. Mill site soil and residue exceed clean-up levels for lead and zinc and is moderately contaminated with cyanide. Water and wind transport of site material have not effectively caused a degradation of the surrounding environment. Geotechnical analysis indicates a factor of safety of greater than 2.3 for circular slope failure of the tailings. Toppling failure of the tailings is more likely, especially after storm events. Geophysical surveys found two suspected drum burial sites in the tailings and outlined an area over the mine workings that has a potential for subsidence.

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INTRODUCTION

The National Park Service (NPS) has expressed a concern that cyanide and heavy metals are potentially being released from the Katherine tailings site located within the Lake Mead National Recreation Area (LAME). The transport mechanisms involved are 1) water from Katherine wash which bisects the tailings which are upstream and in close proximity to a heavily-used beach on Lake Mohave and 2) windblown contamination. Direct contact by on-site visitors is also possible. Cyanide was used in the milling process to recover gold and silver. Assessor metals associated with the ore are present in the tailings.

The Katherine site characterization is a cooperative project between the NPS and the USBM. The purpose of the study was to develop procedures and methodology for characterizing inactive and abandoned mine lands (IAML). From this data NPS will develop a management plan for the Katherine Mine, mill, and tailings site.

The scope of the characterization of chemical hazards is limited to heavy metals and cyanide. Potential organic contaminants that are related to most industrial sites (fuel oil, gasoline, etc.) were not evaluated though no such contamination is suspected. USBM also investigated physical hazards including suspected subsidence phenomena associated with the underground mine workings.

The most detailed operational description of the Katherine Mine and mill is from Dimmick and Ireland (1927), who

visited the site during the peak of its operation. An excellent geologic description of the area is given by Longwell (1963). Ore deposit geology is described by Schrader (1909) and Lausen (1915). A compilation of mining history and geology of the Katherine Mine area was concurrently being prepared by Hobbs (personal communication, 1992 and 1993) but was not formally completed. The State of Arizona Department of Environmental Quality monitors ground water pumped from the mine shaft, sampling monthly. The tailings were evaluated for the NPS by Eutectic+Castolin Institute (Womack, 1978) for cyanide and sampled by Harding Lawson Associates (1980) for precious metals. Two tailings samples were taken by NPS personnel and analyzed by the Reno Research Center (RRC) in April 1992, with the purpose of identifying cyanide and metal constituents. A pre-field literature search was conducted by the Intermountain Field Operations Center, USBM.

Following agreement for a cooperative IAML site characterization of the Katherine Mine and tailings, a preliminary site reconnaissance was conducted in November, 1992 by personnel from the NPS and personnel from the USBM Western Field Operations Center (WFOC). During the preliminary site inspection, six channel samples of the tailings were taken at surface exposures along the wash. Samples were later analyzed for cyanide, lead, zinc, antimony, arsenic, cadmium, copper, mercury, iron, gold, and silver. Total cyanide up to 9.481 ppm was detected.

KATHERINE MINE AND MILL SITE DESCRIPTION

The Katherine Mine, mill site, and tailings are located in sections 5 and 6, T. 21 N., R. 21 W., Gila and Salt River Meridian, in Mohave County, Arizona. It is about six miles north of Laughlin, Nevada and Bullhead City, Arizona. Arizona State Highway 68 lies about three miles south of the Katherine site. Figure 1 shows the general location of the site. The site is also shown on the Davis Dam 7.5 minute U.S. Geological Survey (USGS) Quadrangle map.

The site is situated on alluvium between the Black Mountains to the east and Lake Mohave to the west (figure 2). The land slopes 200 ft/mile from the base of the Black Mountains to Lake Mohave and is dissected to depths of 100 ft by ephemeral streams (Bentley, 1969). The crest of the Black Mountains is about 5000 ft and Lake Mohave normal pool elevation is 644 ft. The climate is arid with hot summers and mild winters. Vegetation includes creosote-bush, grasses, cactus, and other desert flora. Salt cedar occurs along the shoreline of Lake Mohave. The mill tailings on the site has naturally revegetated with creosote-bush at intervals consistent with the surrounding soils (figure 3). Grasses occur on the tailings locally under the shading creosote-bush.

Site features include a large dewatered tailings impoundment, mill foundations, steel tanks from the mill, mine workings, a new pumping station and water storage tank for the adjacent housing development, and associated access roads.

The Katherine tailings and mill site are on Federal land within the LAME. A private easement exists for access to water rights in Katherine Mine main shaft.

Public exposure to the Katherine site is frequent. Members of Katherine community frequently drive, cycle, and walk down Katherine wash and through the tailings to reach Cabinside Road and Lake Mohave. Tourists frequent the site due to its historical significance or nuisance appeal, and the NPS leads the public on interpretive tours of the Mine and mill. The public also frequents the site to carve graffiti into the tailings. Both adults and children were observed playing in the crevasses and on the high walls of the tailings during the USBM investigation.

GEOLOGY

Local geology of the Katherine Mine area consists of Precambrian granite and nearby Tertiary andesite and rhyolite flows which are overlain by Quaternary alluvium. The older Quaternary alluvium is weakly to moderately cemented clay, sand, and gravel deposited by the Colorado River and locally derived fan gravel consisting of volcanic and granitic fragments (Bentley, 1979). The younger Holocene alluvium is unconsolidated sand and gravel found in stream channels and flood plains.

An outcrop of granite adjacent to the Katherine mill site is the only natural exposure in the vicinity of the mine, mill,

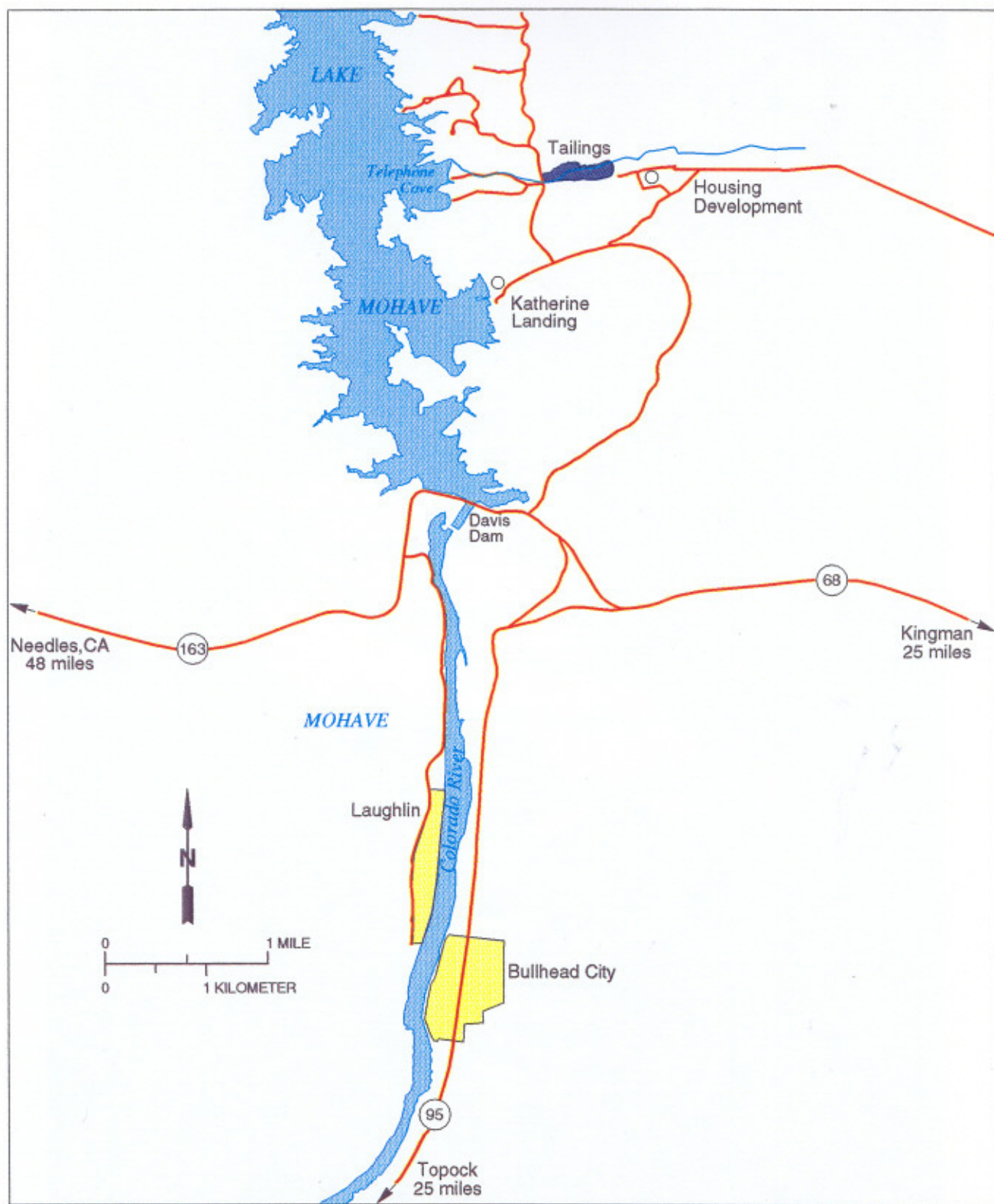


Figure 1. General location of the Katherine mine, mill, and tailings



Figure 2.--Aerial view of the Katherine Mine, mill, and tailings



Figure 3.--Katherine tailings showing vegetation

and tailings area (figure 4). Granite is also exposed in small surface-mine disturbances and in the inaccessible underground mine workings.

The Katherine Mine follows an irregular system of veins in a fracture zone over 260 ft wide that trends N55E and dips 80 to 90 degrees NW (Dimmick and Ireland, 1927). The veins occur within a fracture zone and are composed of greenish-yellow quartz, calcite and fine-grained gold/silver electrum. The veins are offset by thrust faults that trend north and dip to the west.

HYDROLOGY

The mean annual precipitation is less than 8 inches and the mean annual pan evaporation is 130 inches (Overstreet, 1970).

Ephemeral streams transect the Katherine tailings and vicinity and flow west into Lake Mohave (figure 5). The annual flow of these streams ranges from none to several times the volume of the mean annual flow which is two ac-ft/mi² of area drained (Bentley, 1979). The ephemeral stream which transects the Katherine tailings is mentioned by Bentley (1979) as an unnamed wash. It has a drainage area of 13 sq mi, and a mean annual flow of about 25 ac-ft. On average, about one stream flow event per year occurs.

Davis dam was constructed on the Colorado River in 1950 forming the Lake Mohave reservoir. The dam is sited on impermeable granite and no significant groundwater flow occurs under or around the dam and prevents any groundwater

flow southward (Bentley, 1979).

The groundwater table at the site is at 645 ft elevation or 295 ft below the main shaft collar of the Katherine Mine and at about the same, and is related to, the elevation of Lake Mohave (Bentley, 1979). The regional movement of groundwater is westward from the mountains to the lake. Only a small amount of precipitation collected in stream channels infiltrates to the groundwater reservoir.

Because no lateral groundwater flow occurs southward and precipitation only nominally charges the groundwater supply, the rate of groundwater flow westward must be very low.

MINING HISTORY

Like many other mining districts and mines in the western U.S., the Union Pass-Katherine Mining District and the Katherine Mine experienced a long and cyclic history. The following history is compiled from several literature sources in order to provide the most accurate record (Hobbs, 1992 and 1993).

The mid-1800's were the period of prospecting and mine discovery of the Katherine-Union Pass area. The Pyramid and Golden Cycle Mines, both in Arizona near the Telephone Cove area, the Homestake Mine, across the river in Nevada, and the Sheeptrails Mine in the Union Pass area, were the more important discoveries. The Pyramid Mine is the oldest in the area, however, the Sheeptrails Mine is the oldest recorded location.



Figure 4.--Millsite area showing Katherine vein exposed on knob

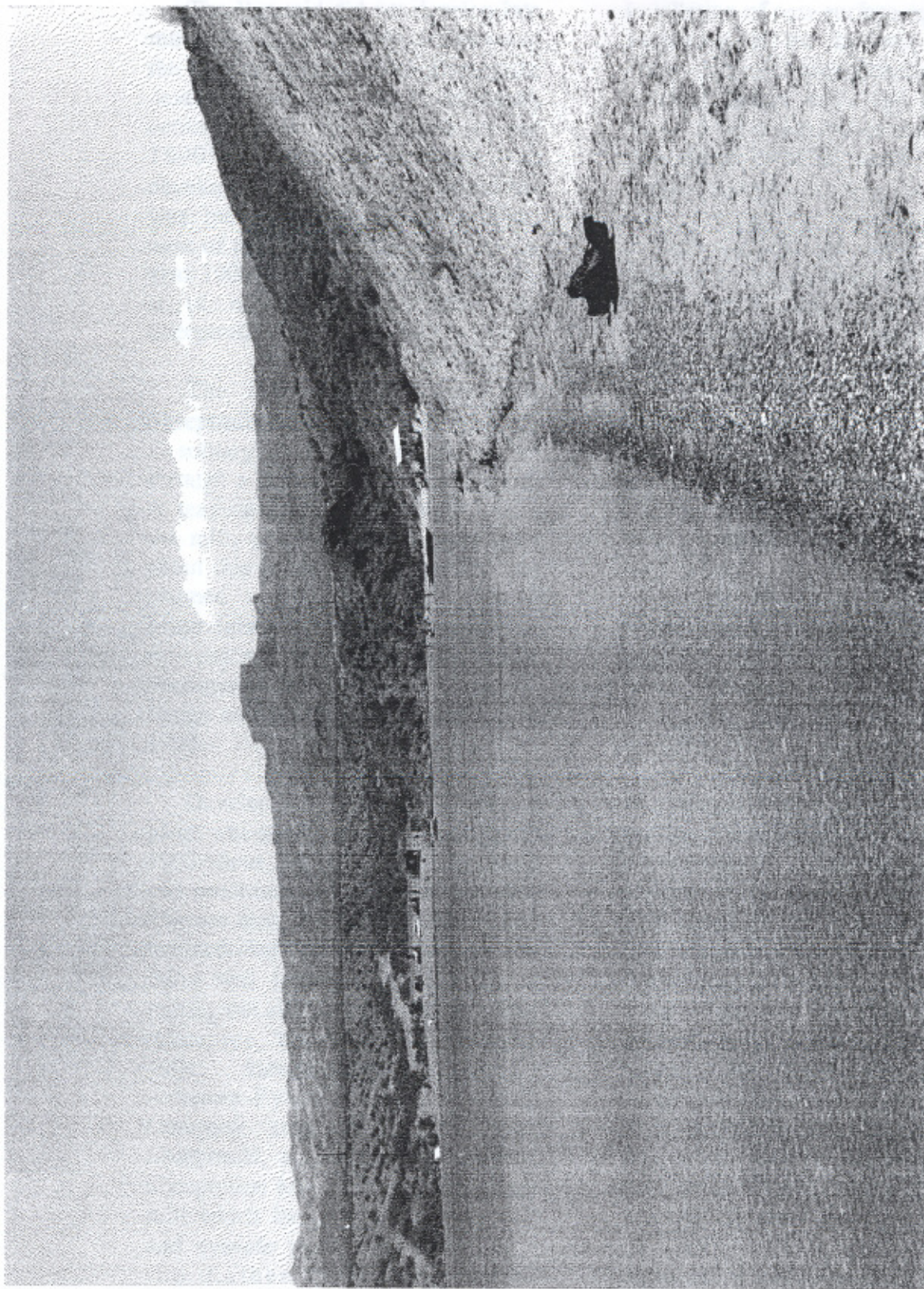


Figure 5.--South Telephone cove looking east towards Katherine tailings

The Pyramid did not develop into much of a mine and little is known of the Golden Cycle. The Homestake developed into a major operation, continuing up to sometime in the 1890's. The Sheeptrails was developed and a mill to treat the ore was built near the Colorado river, west of the Pyramid Mine. Up to the year 1900, possibly 14,000 to 15,000 st of ore was hauled from the Sheeptrails Mine to the mill.

The ore haul road from the Sheeptrails Mine to the mill passed by a solitary granite knob protruding through a somewhat flat gravel plain. A teamster, who was hauling ore to the mill, panned some samples from about this outcrop. The outcrop was claimed and became the Catherine Mine (also known as and hereafter referred to as the Katherine Mine). Presumably, the teamster was S.C. Baggs and the time was September, 1900.

Development of the Katherine Mine was started by Baggs and up to 1903 about 2000 st of ore was mined and processed at the Sheeptrails mill. The ore came from the surface and an inclined shaft about 60 ft deep. The mine was leased in 1903. After mining out an unknown amount of the richer ore, the mine was closed in 1904. Subsequently, in 1904 the Arizona-Pyramid Gold Mining Company acquired the Katherine, Sheeptrails, and Boulevard (adjoined Sheeptrails) Mines and the Sheeptrails mill which included a 20 stamp mill and cyanide plant. Development at the Katherine Mine included

installation of new surface equipment, deepening of the inclined shaft to about 225 ft, and driving several hundred feet of drifts and crosscuts. About 5000 st was mined underground plus about 2000 st mined from the surface outcrop.

Late in 1906 or early 1907 the Katherine was closed. The reasons cited were the unprofitability of the operation due to the inefficient mill and the high cost of wagon haulage 1.5 mi to the mill. This was in spite of the ore grade at about \$12/st or about 0.6 oz/st gold (gold was valued at \$20.67 per troy ounce). The Sheeptrails continued operations even with a 7 mile haul.

For the next 10 to 15 years, it was rather quiet in the District; some prospecting was going on and a few mines operated intermittently. The Sheeptrails mill burned in 1918.

In 1915, the United Eastern Mine was discovered and produced over \$15 million through 1924. This discovery caused the "First Oatman Boom" and a flood of stock promotion ventures. These endeavors were characterized by the staking of numerous claims and the subsequent sinking of shafts with little reason and even less chance of success. In 1923, of the 85 properties listed by the USGS of the Oatman Mining District, only 13 were active. This "Boom" reached the Union Pass-Katherine Mining District shortly thereafter. Following the lead established at Oatman, numerous claims were staked, mostly surrounding and or adjacent to the

Katherine, Sheeptrails, and other older existing mines. Shafts were sunk with the same little reason and probable even less chance of success than they were at Oatman. Most of these "Boomers" included Katherine in their name, such as Katherine Extension (connects at 200 ft level with Katherine Mine), Katherine Treasure Vault, Katherine Illinois, Katherine Mohawk, Katherine Revenue, Katherine Midway, etc. None of the newcomers had recorded production of mineral resources, and all activity had faded out by the onset of the "Great Depression" in 1929.

The "Boom" also saw the promotion of the Katherine and TriState Townsites. The former was about two miles east of the Katherine Mine and the latter was across the river from the present Katherine Landing. Today, little can be found of the Katherine Townsite; the TriState Townsite now lies under the waters of Lake Mohave.

In 1919, the original company, now known as the Katherine Gold Mining Company, began further development of the Katherine Mine. This included sinking of a new vertical shaft to 950 ft and opening of the 500 and 600 levels from a winze sunk from the 400 level. A 150 st/d cyanide mill, costing \$95,000, was completed in June 1925 (Dimmick and Ireland, 1927). It was later enlarged to 260 st/d.

The mill started up in June 1925 and ran more or less continuously through 1927. The mine operated all

of 1928; however, the mill ran only 7 months. While the 1928 output of the Katherine mill was much less than that in 1927, it was almost equal to the entire output of the Oatman District. The year 1929 saw the mine work only 5 months and the mill operate only in July and August. Unexpectedly, the ore did not extend much below the 300 ft level.

In December 1929 the Katherine Gold Mining Company was declared bankrupt, \$560,000 in debt. The company was placed under the management of a trustee in bankruptcy.

The mill operated again for a very short period in 1930 and 1931, treating a small amount of tailings and rich ore. During 1932 the mill treated a small amount of ore from some area mines. This marked the separation of the Katherine mill and Katherine Mine operations.

During 1933 the price of gold rose from the fixed price of \$20.67 to an average price of \$25.57 per troy ounce. On January 31, 1934, the price was fixed at \$35.00 per troy ounce. Many old mines subsequently re-opened.

The Gold Standard Mining Company acquired the Katherine mill and the mine water rights, starting up on September 13, 1933. In September 1934, the mill and the mine was heavily damaged by fire. The mill was back in operation by November 1934. It processed ores from the surrounding area mines, running

continuously until April 15, 1943, when it was closed by the War Production Board Closure Order L-208.

The Gold Standard Mining Company acquired title to the Katherine Mine in 1935. After mine rehabilitation and repair of the fire damage of 1934, the Katherine Mine produced from 1937 to 1940.

MINE DEVELOPMENT

Several mine features exist at the surface. A large open cut in the granite outcrop is where initial production occurred. Ore was drawn from the main shaft. It is now sealed and used as a water source. An open shaft to the northeast of the main shaft is developed to below the current water table. A capped shaft farther to the northeast in the wash may or may not intersect the main workings.

The underground workings include six levels which were accessible primarily by the main shaft, and a winze developing the vein system 1700 ft along strike and 900 ft along dip. Four veins or zones have been developed varying in width from 9 to 60 ft. Ore production occurred between the 400 level and the surface (Gardner, 1936).

Shrinkage stoping was the mining method usually practiced. The largest stopes extended 700 ft along strike, were 40 to 50 ft wide, and had a vertical height of 200 ft (Dimmick and Ireland, 1927). Large voids remained after shrinkage stopes were completed. Cut-and-fill stopes were used where walls were weak

(Gardener, 1936). Stopes were filled with waste material from the footwall as mining progressed upward.

MILLING METHOD

The Katherine mill was built in 1925 and had a capacity of only 150 st/d (figure 6). The ore was initially ground to 80 pct minus 200 mesh; however, it was found that a coarser grind would give satisfactory results so the mill throughput was stepped up to a capacity of 260 st/day (Dimmick and Ireland, 1927).

The ore was hoisted from the main shaft of the Katherine Mine, and/or hauled from other mines using trucks, and stored in a 75-st-capacity bin. Primary crushing was done by a 12 by 24 in jaw crusher to minus 3 in. and secondary crushing was done by a 3 ft cone crusher to minus 5/8 in. Based on tailings sieve analysis, the crushed ore was ground to about 80 pct minus 140 mesh by two 6 ft by 6 ft ball mills operating in series. Following a non-standard thickener to recover mill solutions, the ore slurry was fed to the cyanide plant. Three agitation tanks operating in series mixed the ore slurry with cyanide and lime causing gold and silver to leach into solution. Standard countercurrent decantation (CCD) cyanide leaching practice was followed (Gardener, 1936) (see cover picture). Following agitation, the slurry was fed into the CCD circuit of five thickeners to remove the pregnant solution from the barren tailings. Water was added to the thickened, barren tailings to support pumping to the tailings impoundment.

Gold and silver were recovered using zinc precipitation. The solution was first



Figure 6.--Aerial view of the Katherine Mine and mill when in operation

clarified and deoxygenated. Using zinc dust, the gold and silver were precipitated and filtered. Finally, the precipitate was fed into a furnace and bullion was produced.

TAILINGS DEPOSITION

The configuration of the tailings indicates that the impoundment was constructed in three distinct lifts. The outwash and thinning of tailings westward may have been caused by uncontrolled release during initial operations or from post-closure erosion due to stormwater runoff.

The tailings were probably deposited using an upstream construction method and spigotting. The tailings were hydraulically transported to the disposal site from the mill by pipeline and then spigotted from single or multiple points along the dike crest. Typically, the coarsest fraction settles near the discharge point while the finer fraction settles progressively outward toward the pond. The iron pipeline and spigots were supported by a wood fence. Remnants of these fences were found on the face of the dams.

MILL PRODUCTION

A total of 880,000 st of ore was processed and disposed at the Katherine site from 1924 through 1943 based on actual reported annual production and estimates. Production during 1924 through 1931 were reported in dollar figures only. Since gold and silver were produced, and average ore grade was not reported, only an estimate of short tons produced is possible. Recorded and estimated production for the Katherine

Mine by period is listed in table 1.

TAILINGS AREA AND VOLUME

A land survey of the Katherine mill and tailings area was conducted to establish topographic control points for locating site features on a map (figure 7). NPS personnel assisted by establishing several survey control points on the tailings forming a baseline and transects. From these control points the tailings and other features were surveyed using a theodolite and an electronic measuring device providing an accuracy of 0.1 ft.

The survey data made possible an accurate calculation of the area and volume of the tailings. A total of 587,000 yd³ of tailings were disposed covering 26.4 ac. Thickness ranges from only inches thick on the west end to over 40 ft thick on the east end. The average thickness over the 26.4 ac is 13.8 ft. The Katherine Wash has bisected the tailings and a calculated 49,000 yd³ of tailings has washed into Lake Mohave leaving 538,000 yd³ of tailings on-site. Using a specific density of 89 lbs/ft³ and the calculated volume, 705,000 st of tailings were disposed on-site. This is less than what recorded production and estimated production indicates. The initial production years may have been overestimated.

PHYSICAL HAZARDS

Physical hazards were found at the site. These hazards were determined primarily by simple evaluation based on the possibility someone could fall into or from a feature or that a feature could fail and fall on someone.

Table 1.--Recorded production of the Katherine Mill for the years 1924 to 1943

Period	Production (st)	Primary Mine Source(s) ¹
1924-1931	350,000 est.	Katherine
1933	5,894	Roadside, Arabian, Tyro
1934	39,000 est.	Roadside, Arabian, Frisco
1935	70,000 est.	Tyro, Portland
1936	73,759	Portland ²
1937	23,319	None ³
1938	36,715	Katherine ⁴
1939	59,871	Tyro, Katherine ⁵
1940	76,100	Tyro, custom ore ⁶
1941	81,992	Tyro ⁷
1942	77,089	Tyro, 510 st custom
1943	30,398 est.	Tyro

- (1) Secondary or minimal contributors to mill feed for that year are footnoted.
- (2) Minnie, Philadelphia, Arabian, Frisco, Tyro, Roadside
- (3) Tyro, Arabian, Philadelphia, Katherine, Frisco, Pyramid
- (4) Arabian (7,659 st), Philadelphia (2741 st), Frisco, Tyro
- (5) Frisco, Philadelphia, Burt, Minnie, Escondido
- (6) Katherine, Pyramid, Minnie, Philadelphia
- (7) Buellard, Burt, King of Secret Pass, Minnie, Philadelphia, Sheep Trail



Figure 7.--Scientist surveying Katherine tailings

Two shafts of which one is capped with cement (east shaft) and the other (middle shaft) is fenced with barbed wire are falling hazards. The capped shaft has since been re-capped using PUF (Polyurathane foam) technology. NPS accomplished this by constructing a light-duty form several feet below the collar and then combining two chemical components resulting in a rigid plastic foam that fills the shaft from the form to the collar. The fencing at the other shaft is not adequate and only discourages entry (figure 8). A person could slip under the fence and into the shaft from the eroding upper end.

The tailings present falling hazards due to the internal piping and crevasse erosion that has progressed since deposition ceased in 1943 (figure 9). Piping is a sub-surface pipe-shaped void resulting from erosion. It was observed

that some crevasses are as deep as the tailings are thick, so may be as much as 30 ft to 40 ft deep. Piping is not always visually predictable at the surface. Failure of a near surface piping feature is a strong possibility. The vertical tailings wall exposed in Katherine Wash ranges in height from 3 to 31 ft (figure 10). The cemented nature of the tailings can give a false sense of security at the upper edge of these highwalls. At the base of the tailings highwall, tourists carve names and pictures (figure 11). The tailings are subject to failure by toppling and comprise a serious threat to the public (figure 12). The tailings are accessible from all sides.

The large open cut above the mill foundation on the knob is a falling hazard. The top of the open cut is accessible north of the interpretation pathway which is adjacent to the mill foundations.

GEOCHEMICAL SAMPLING

INTRODUCTION

No uniform and consistent, national or international, guidelines have been established for determining the action levels or maximum allowable concentrations of metals and nonmetals in soils and sediments. The Environmental Protection Agency (EPA) and various states have established soil clean up guidelines, and numerous studies have been done on the toxicity of metals and nonmetals to plants and animals. Published guidelines have a wide range of allowable concentrations, as seen in table 2. Neither do any consistent guidelines exist for determining the maximum allowable concentration of various metals

and nonmetals in mill tailings and mine waste. Background information on the behavior and effects of heavy metals and cyanide is discussed in appendix E.

Studies are currently being conducted by various state and federal agencies to determine allowable concentrations and to establish reasonable guidelines for soil cleanup. Unfortunately such standards are not easy to determine, particularly since the metals and nonmetals of concern occur in minerals which are not easily weathered and decomposed into their constituent elements under conditions normally found in the surface or near-surface environment. These elements would not be bioavailable to plants and animals,



Figure 8.-- Open shaft between main shaft and east shaft

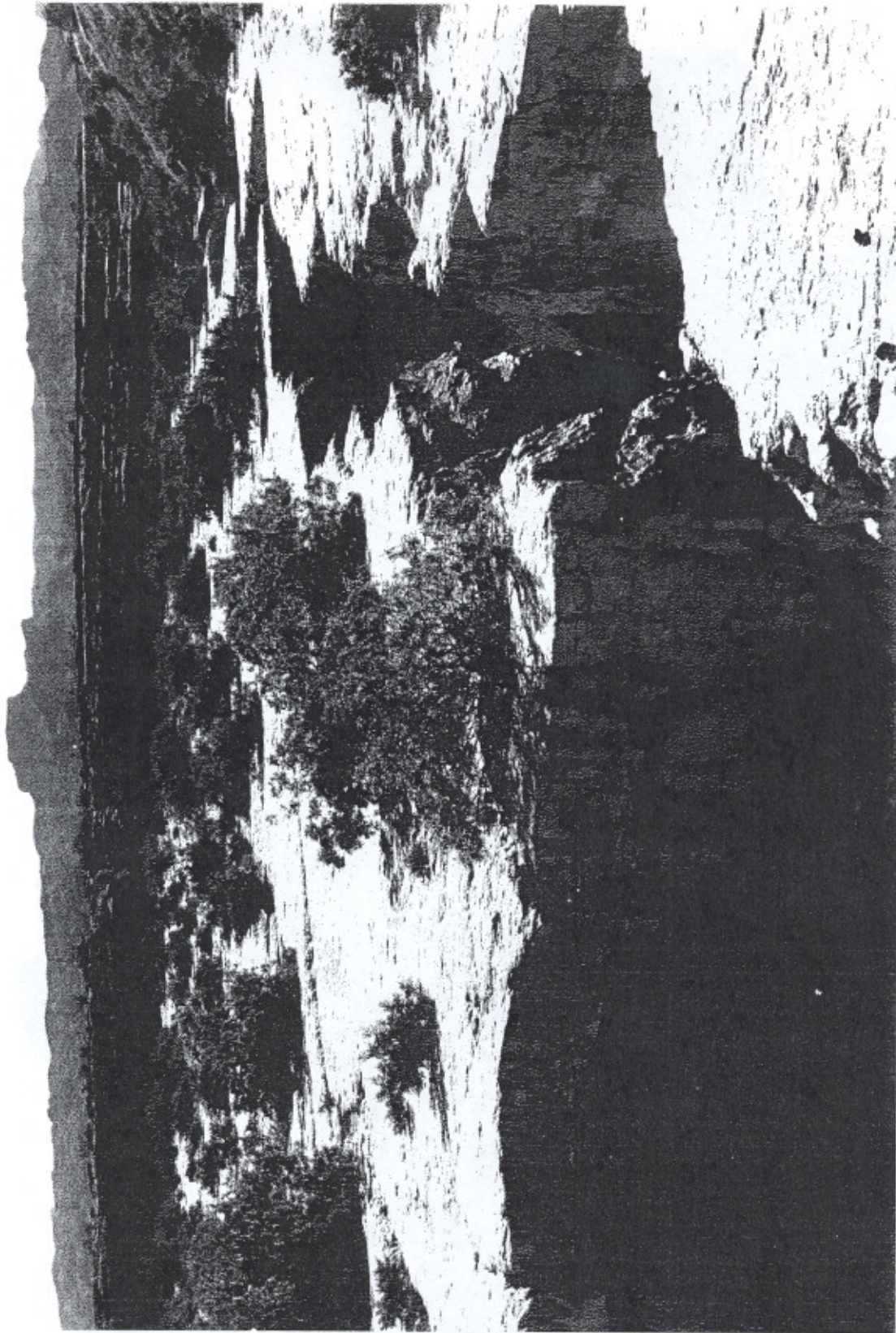


Figure 9.--Erosion in the Katherine tailings showing crevasse



Figure 10.--Highwalls eroded into tailings from Katherine Wash

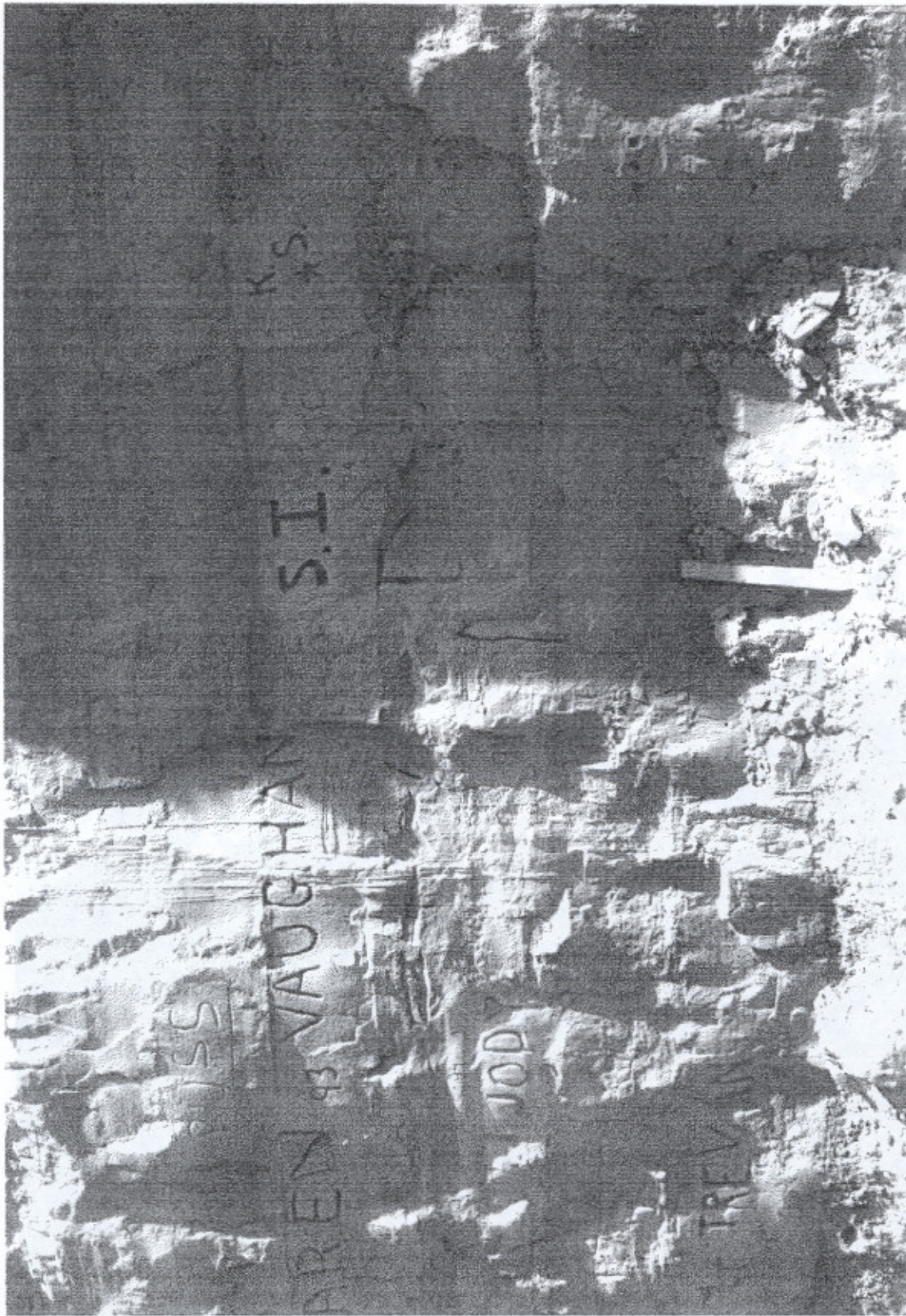


Figure 11.--Typical carvings into Katherine tailings



Figure 12--Slope failure of tailings due to undercutting by Katherine Wash

Table 2. Comparison of elemental concentrations in Katherine mill tailings and soils with proposed maximum contaminant levels (All concentration data are given in ppm)

Element	Concentration ranges			Mean concentration of elements in tailings	Mean concentration of elements in surface soils	Proposed maximum acceptable concentrations in agricultural soils ^a	Soil toxicity reference concentrations ^b	EPA proposed RCRA standards (1992)	State of Washington cleanup levels ^c
	Tailings	Surface soil	Subsurface soil						
Au	0.133-0.728	0.055-0.354	0.003-0.143	0.344	0.201	NR	NR	NR	NR
Ag	2.2-111.1	0.5-6.5	<0.1-0.2	15.2	2.7	2	8	400	NR
As	1-10	2-19	3-15	6.8	6.8	10-50	40	20	20
Cu	10-79	12-24	10-18	30.8	17.6	50-140	60	NR	NR
Pb	20-151	22-40	18-31	55.3	32.3	50-100	1000	250	500
Zn	58-290	37-65	22-43	112.5	48.6	200-400	500	NR	1000
Hg	0.021-0.898	<0.002-0.032	<0.002-0.241	0.158	0.013	1-5	5	1	20
Be	7.9-84.4	1.85-19.2	0.76-1.26	56.7	8.05	< 10	NR	NR	NR
Cd	<1	ND	<1	< 1	< 1	1-15	20	40	2
Sb	<0.5-10	ND	ND	< 0.5	< 0.5	5-10	NR	30	NR
CN-T	1.15-48.66	ND	ND	7.09	ND	NR	NR	NR	NR
CN-W	<1.0-2.32	ND	ND	< 1.0	ND	NR	NR	NR	NR
CN-F	<1.0-2.14 ^d	ND	ND	< 1.0	ND	NR	NR	NR	NR

^aKabata-Pendias, A., and Pendias, H., 1992, Trace Elements in Soils and Plants, 2nd ed., p. 14.

^bU.S. Environmental Protection Agency, 1992, Record of Decision--Bunker Hill Mining and Metallurgical Complex, Shoshone, County, Idaho, table 6-4.

^cMarten, B.M. and McPhee, J.T., 1991, MTCA Handbook--Key Provisions of the Washington State Superfund, p. 153.

^dCN-F (free cyanide) was detected in only 5 out of 36 samples analyzed for CN. According to standard laboratory practice, analysis for CN-F is not done unless the CN-W (weak-acid dissociable cyanide) is >1 ppm.

ND-not analyzed; NR-not reported

even though their total concentration in soil or sediment may be high.

Complete characterization of any site thus requires that mineralogical studies be done to determine the particular minerals species in which the elements of concern occur. These studies would include determining, not only the mineral species, but also numerous other characteristics of the minerals that might determine their bioavailability. The studies would include percentage of each mineral present; grain size and shape; degree of rounding; alteration products; degree of oxidation of the sulfide minerals; specific location of the heavy metals, such as Cu, Cd, Pb, Zn, and Be within their mineral hosts; evidence of rinding or encapsulation of the heavy metals by secondary reaction products; and any relationship between grain size and heavy metals.

METHODOLOGY

During the 1993 and 1994 field seasons, samples of mill tailings, background soils, stream sediments, rock, waste dump, and residue and mixed soils and tailings in the vicinity of the mill site, were taken for chemical and mineralogical analysis. All sample sites are plotted on figure 13 (in pocket), and a complete listing of sample analyses from the contract laboratory are included in tables A-2 and A-3.

Ninety-five tailings samples were collected from 17 hand-drilled auger holes in the mill tailings impoundment (figure 14). Fifteen tailings samples were also collected from two channel sample locations in the main wash (figure 15).

Nine tailings samples were taken from other locations near the main impoundment.

Twenty-five background soil samples were collected from the ridge that forms the north side of the Katherine wash, and 11 soil locations were sampled south of the tailings impoundment. Three stream sediment samples were taken from the wash west of the highway, and seven were taken from a wash south of the tailings impoundment (figure 13).

Four rock samples and two waste dump samples were collected from near the mine site. Eight samples of chemical residue and mixed soil/tailings/spillage material were collected at the mill site where the tanks once stood (figure 13).

Since the site lies in a known alkalic granitic province containing elevated Be concentrations the decision was made to analyze all samples collected during the 1994 field season for Be.

Detailed descriptions of the sampling methodology for each sample type are given in appendix A. Brief descriptions of the sample preparation and analytical procedures are also presented in appendix A.

DATA INTERPRETATION

Concentrations of Cd, Sb, and Hg in all samples collected at the Katherine Mine and mill site are at or below the detection limits for these elements and below any of the maximum acceptable concentrations (table 2). The maximum concentrations found for As, Cu, Pb, and Zn fall in the low range for maximum

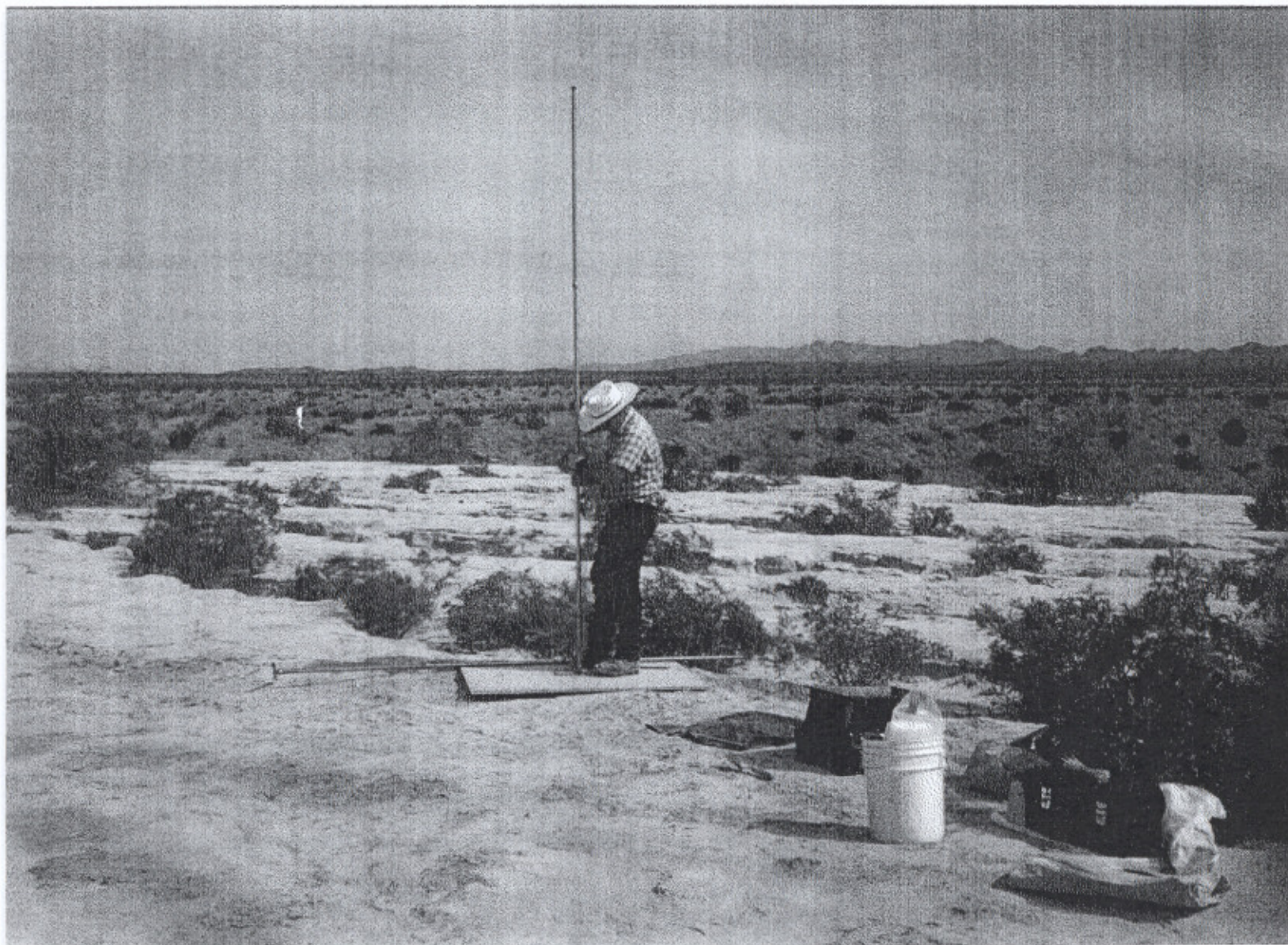


Figure 14.--Scientist hand auger sampling Katherine tailings



Figure 15.--Scientist channel sampling Katherine tailings

acceptable contaminant levels for all samples taken (table 2).

Tailings

Results of whole rock analysis (major oxide analysis) seven tailings samples are given in table 3. They show that about 64 to 82 percent of the tailings material consists of SiO_2 , while Al_2O_3 , Fe_2O_3 , CaO , and K_2O are the other major components. The major oxide composition of the tailings material closely reflects that of the rock samples also analyzed, which were collected from the altered host rock and vein material exposed at the surface in the vicinity of the shafts. This correspondence would be expected; however, part of the CaO content may be the result of the addition of lime to the pulp during the milling process.

Thirty-six tailings samples were analyzed for both total and weak-acid-dissociable cyanide (CN-T and CN-W, respectively) (Table A-2 and A-3). Table A-4 is a summary of cyanide concentrations in the tailings. Five tailings samples contained CN-W concentrations >1 ppm, and were subsequently analyzed for free cyanide (CN-F). The highest CN-F concentration was 2.14 ppm. CN-F tends to decompose rapidly upon exposure to sunlight. The five samples that contained CN-F were at depth in the tailings. The additional compounds included in CN-T that are not CN-W or CN-F are less toxic, more stable, and very insoluble. The following is a list of cyanide ions ordered in increasing stability and related to analysis type:

<u>Analysis</u>	<u>Associated ions</u>
CN-F	HCN^- , CN^- .
CN-W	CN-F ions and Na^+ , K^+ , Ca^{+2} , Mg^{+2} , Zn , Cd , Ag , Cu , Ni .
CN-T	CN-W ions and Fe , Co , Au , Pt , Hg .

Three samples (KMT 17-1, 17-2, and 17-3) of tailings from the debris area at the NE corner of the tailings impoundment contained low levels (<4 ppm) of CN-T and undetectable CN-W (Table A-4). Metals content was in the low range but does exceed agricultural standards for most metals and exceeds EPA RCRA standards for lead (Table 2).

Two auger holes (AH 18 and 19) explored a buried barrel site at the southwest area in the tailings. No debris was intercepted and no unusual metals levels were found (Table A-3).

The average (mean) concentrations of As, Cu, Pb, Zn, and Hg in the mill tailings from the large impoundment are within or below any of the maximum acceptable concentrations proposed by various state or federal agencies (table 2).

Au and Ag, which are not considered hazardous, are generally present in low concentrations in the tailings. Gold tends to be highest at depth in the easternmost level. This can probably be attributed to loss of gold during the milling process early in the history of the mine and mill.

Table 3.--Major oxide composition (in weight percent) of rock and mill tailings samples from the Katherine Mine and mill sites

Oxide	Sample Number											
	KMR-1	KMR-2	KMR-3	KMR-4	T2A-1	T2A-2	T2A-3	T2A-4	T2A-5	T2A-6	T2A-7	BC-1
SiO ₂	59.20	85.30	56.80	82.80	69.80	64.40	77.80	81.70	80.90	79.40	81.50	1.45
TiO ₂	.662	.013	.237	.043	.337	.146	.206	.229	.237	.253	.169	.009
Al ₂ O ₃	12.51	4.55	5.96	4.19	5.72	3.67	5.49	5.49	4.79	5.16	4.37	.230
Fe ₂ O ₃	4.95	.61	1.91	.64	2.75	1.61	2.05	1.97	1.95	2.05	2.00	.59
MgO	1.02	.08	1.28	.15	.57	.35	.44	.61	.62	.63	.18	NIL
MnO	.070	.015	.028	.036	.057	.062	.088	.050	.043	.052	.057	.012
CaO	2.15	1.43	12.24	4.07	7.16	10.51	4.89	1.85	1.99	2.22	2.76	53.03
Na ₂ O	2.50	.31	.67	.38	.62	.41	.60	.73	.58	.51	.32	.06
BaO	.105	.007	.044	.014	.050	.025	.027	.020	.020	.021	.021	.003
K ₂ O	4.73	4.04	3.49	3.49	2.73	2.27	3.49	3.14	2.60	2.89	2.51	.100
P ₂ O ₅	.317	.038	.104	.062	.162	.115	.126	.147	.138	.143	.106	.046
LOI	1.20	0.00	12.40	3.08	6.40	9.08	4.08	2.04	2.20	2.40	2.92	42.52
GOI	NIL	2.40	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
TOTAL	89.41	98.79	95.16	98.96	96.36	92.65	99.29	97.98	96.07	95.73	96.91	98.05

Of the 13 tailing samples assayed for beryllium from auger hole samples on the main tailings impoundment, all contained elevated Be concentrations (table 4). These concentrations exceeded the normal background content for Be in alkalic rocks by a factor of four to five. The high concentration of Be in the tailings (57 ppm) is the result of Be minerals naturally present in the ore but not recovered in the mill.

Mineral speciation studies are currently being done on several tailings samples from the Katherine tailings. The results of these studies should provide information on the occurrence and form of the Be. The results of the mineralogical studies will help determine if the Be occurs in a form that could represent a contamination threat, or if it is tied up in insoluble or relatively insoluble minerals, such as beryl.

Chemical analyses of the surface 1 in. layer of the tailing impoundment, as shown in table 5, do not show a definite enrichment for any of the elements of concern, except for copper (figures A-1 through A-8).

During sampling of the tailings material, two Bureau geologists developed a skin rash, which may have been due solely to a combination of fine, irritating dust particles, sweat, and sun screen; however, because lime (CaO) was added the slurry during milling, enough of it may remain in the tailings to cause skin irritation.

Soil

Samples of the soil/tailings (KMS-33,

34, and 38) were collected from within the foundations where the thickener tanks once stood, and samples KMS-35, 36, and 37 were collected from the material deposited on the remains of the floors of the tanks. All these samples showed anomalous concentrations of Au, Ag, Be, Pb, and Zn (table 6). These samples undoubtedly represent the sludge that accumulated below and within the tanks during the periods of mill operation. The highest concentrations of CN-T (>40 ppm) were detected in samples of these soils though CN-W was not detected (KMS-33, 35, 36, and 37). The U.S. Fish and Wildlife Service (FWS) has reported that in relating to human health, complex cyanide cleanup level in soil is above 100 ppm with moderate contamination above 50 ppm (Eisler, 1991). Free cyanide cleanup level in soil is also above 100 ppm with moderate contamination above 10 ppm. Sample KMSR-1, collected from a rectangular opening that may have been the base of a chimney in the mill, contained anomalous Au, Ag, Be, Cu, Pb, and Zn concentrations.

In referring back to proposed standards mentioned in table 2, soil samples at the mill site exceed standards for the following elements; Ag, Cu, Pb, Zn, Be, and Sb exceed the proposed agricultural standard, Ag, Cu, Pb, and Zn exceed the soil toxicity reference concentration, Pb, Zn, and Sb exceed EPA proposed RCRA standard, and Pb and Zn exceed State of Washington cleanup levels.

As shown in figures A-1, A-2, A-4, A-5, A-6, and A-8, the concentrations of Au, Ag, Cu, Pb, Zn, and Be are higher in soil samples collected at the surface along

Table 4.-- Descriptive statistics for tailings samples from auger holes

(The concentrations for all elements are given in ppm)

Descriptive statistic	Au	Ag	As	Cu	Pb	Zn	Hg	Be
Number of samples	77*	81	81	81	81	81	81	13
Maximum concentration	0.728	111.1	10	79	151	290	0.898	84.4
Minimum concentration	0.133	2.2	1	10	20	58	0.021	7.9
Mean concentration	0.344	15.2	6.8	30.8	55.3	112.5	0.158	56.7
Median concentration	0.316	8.5	7	28	42	106	0.106	64.5
Standard deviation	133.7	17.4	3.3	10.1	28.7	44.9	157.8	20.4

*Does not include four outliers (1.117, 2.934, 4.248, and 7.911 ppm)

Table 5.--Chemical analysis of minus-200-mesh fraction of samples collected from the surface (top 1 in) of Katherine mill tailings impoundment^a
(all data given in ppm)

Element	Sample Number											
	T1-1A	T2-1A	T3-1A	T4-1A	T5-1A	T6-1A	T7-1A	T8-1A	T9-1A	T10-1A	T11-1A	T12-1A
As	6	4	5	5	5	7	5	5	5	6	4	4
Cu	306	187	291	187	213	283	221	166	355	203	184	148
Pb	47	23	17	18	29	22	26	22	20	28	20	22
Zn	143	111	128	118	121	136	111	101	126	109	90	80
Hg	0.243	0.122	0.109	0.082	0.082	0.126	0.151	0.136	0.182	0.111	0.131	0.102

^aSurface samples were collected at auger holes KMT1 - KMT12, for a total of 12 samples.

Table 6.--Chemical analysis of special samples collected from soils, residue,
and tails at mill site
(All data given in ppm)

Element	Sample Number							
	KMS-33	KMS-34	KMS-35	KMS-36	KMS-37	KMS-38	KMSR-1	KMBC-1*
Au	2.86	1.88	22.36	24.24	3.40	6.34	39.69	ND
Ag	21.7	19.8	188.6	213.9	41.5	172.1	150.9	ND
As	3	< 0.5	8	5	3	4	6	<50
Cu	51	37	49	131	38	57	132	<10
Pb	135	92	267	167	945	180	254	1300
Zn	290	182	1850	675	346	585	446	16
Hg	< 0.002	0.011	0.004	0.004	0.057	0.023	0.323	ND
Be	20.6	35.7	25.6	40.5	35.3	57.2	12.8	ND
Cd	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 5
Sb	ND	ND	ND	ND	ND	ND	ND	360

*Concentrations for KMBC-1 were determined by ICAP 26-element scan.

ND-not analyzed

the soil line north of the tailings than they are at a depth of 5 to 8 in. This increase in concentration may be due to addition of windblown material from the tailings and/or the addition of elements due to natural weathering of mineralized rock in a desert environment.

Natural weathering is supported by the following observations:

(1) Desert soils tend to be very thin and to have poorly developed profiles. Trace element composition typically tends to correspond to the underlying parent material. Natural weathering and winnowing by the wind would tend to concentrate the heavier minerals at the surface, where most of the weathering takes place. Little or no movement of minerals downward into the soil takes place in the desert environment.

(2) Heavy minerals, such as Au- and Ag-bearing minerals, would not be subject to wind transport and deposition under normal conditions. Au and Ag are very mobile and could be related to the Katherine Mine deposit or a mineralized extension as a geochemical signature.

(3) The higher surface concentrations of the above elements tend to decrease and approach those of the subsurface samples at the east end of the soil line, this may indicate that mineralized vein material lies beneath the ridge north of the tailings and the west end of the soil line.

Windblown contamination is equally supported and includes these observations:

(1) Beryllium was elevated in the surface soil layer on the ridge north of the

tailings impoundment (table 7); however, the concentration was lower at a depth of 6 in. The elevated Be concentrations only in the surface soils indicates windblown contamination from the tailings. Subsurface concentrations of Be are similar to background for the granite country rock.

(2) Beryllium concentrations drop off gradually to the east away from the tailings. This and the drop in surface concentrations of other metals east of the tailings indicates soils closer to the tailings may contain windblown contamination.

(3) Leaching of metals from surface tailings contamination into the subsoils is possible even in a desert environment.

Stream Sediment

Metal concentrations are low in seven stream sediment samples collected from dry washes south of the tailings impoundment and three samples located down stream from the tailings (figure 13) (Table A-2 and A-3).

Vein and Intrusive Rock

Chemical analysis and examination of samples collected from vein material that crops out near the main shaft and an outcrop east of the middle shaft indicate that the beryllium is associated with mineralized quartz veins (Figure 13). Beryllium concentrations are 28.2 and 54.1 ppm, respectively. As suspected, gold concentrations in the vein are high at 2824 ppb and 2694 ppb, respectively. In most hydrothermal ore deposits, beryllium content is less than 1 ppm. In beryl-rich pegmatites Be concentrations can reach

Table 7.--Descriptive statistics for soil samples collected on ridge
north of Katherine mill tailings
(The concentrations for all elements are given in ppm)

A. Surface Samples

Element	Number of Samples	Maximum Conc.	Minimum Conc.	Mean Conc.	Median Conc.	Standard Deviation
Au	21	0.354	0.055	0.201	0.178	90.22
Ag	21	6.5	0.5	2.7	2.2	0.91
As	21	19	2	6.8	6	4.86
Cu	21	24	12	17.6	17	3.05
Pb	21	40	22	32.3	33	4.04
Zn	21	65	37	48.6	49	5.94
Hg	21	0.032	<0.002	0.013	0.010	7.83
Be	21	19.2	1.85	8.05	6.72	5.55

B. Samples collected at depth of 5 in to 8 in

Element	Number of Samples	Maximum Conc.	Minimum Conc.	Mean Conc.	Median Conc.	Standard Deviation
Au	21	0.143	0.003	0.026	0.021	30.1
Ag	21	0.2	<0.1	0.1	0.1	33.2
As	21	15	3	7.9	7	3.06
Cu	21	18	10	13.7	13	2.03
Pb	21	31	18	24.6	26	3.43
Zn	21	43	22	28.8	28	5.00
Hg	21	0.241	<0.002	0.070	0.046	63.79
Be	21	1.26	0.76	0.99	1.01	140.12

200 ppm (Griffitts, 1973, p. 89). Intrusive rock adjacent to the vein contains about 3 ppm Be.

Results of whole rock analysis (major oxide analysis) of four rock samples are

given in table 3. Samples were collected from the altered host rock and vein material exposed at the surface in the vicinity of the shafts. The major oxide composition of the rock closely reflects that of the tailings samples.

HYDROLOGIC INVESTIGATION

INTRODUCTION

Lake Mohave is downstream from the Katherine mill tailings. During storm events, tailings are exposed to water and erosion from Katherine wash and are carried into Lake Mohave. Lake Mohave was sampled to determine if heavy metals or cyanide were present as a contaminant from the mill tailings.

Water is also present in the mine workings at the same elevation as Lake Mohave. Based on the site description, groundwater movement from the mine and under the tailings westward towards Lake Mohave is low.

METHODOLOGY

Lake Mohave is a reservoir and represents the Colorado river flowing south. Katherine wash flows west and into Lake Mohave at Telephone cove. Sampling sites were selected upgradient, down gradient and at the confluence of Katherine wash (figure 16). A comparison of metals and cyanide concentrations of the three sites could determine if Katherine wash is a potential transport source. The upgradient sample represents background, while the down gradient and confluence sites represent potential contamination.

Water sampling was conducted in 1993 to look for indications of metals and cyanide contamination. Samples were analyzed at WFOC. Water sampling was conducted in 1994 to confirm 1993 results. Samples were taken at similar but not exactly the same locations. The background sample site in 1994 is further north than the location in 1993. Sample locations for both years are shown in figure 17.

A suite of elements were analyzed in 1994 which included cyanide, arsenic, and selected heavy metals potentially transported from the mill tailings to the lake. Due to weather limitations during our site visits, storm water runoff from the tailings area was not available to sample.

Groundwater in the mine shaft was not sampled (figure 18) because the owner restricted access. Groundwater at the mine is monitored monthly by the Arizona Department of Environmental Quality (ADEQ). Analyses from the monthly samples are shown in appendix B. Water is sampled by ADEQ from the main shaft well site or at locations along the water supply route to the housing development.



Figure 16.--Scientist water sampling at north Telephone cove in Lake Mohave

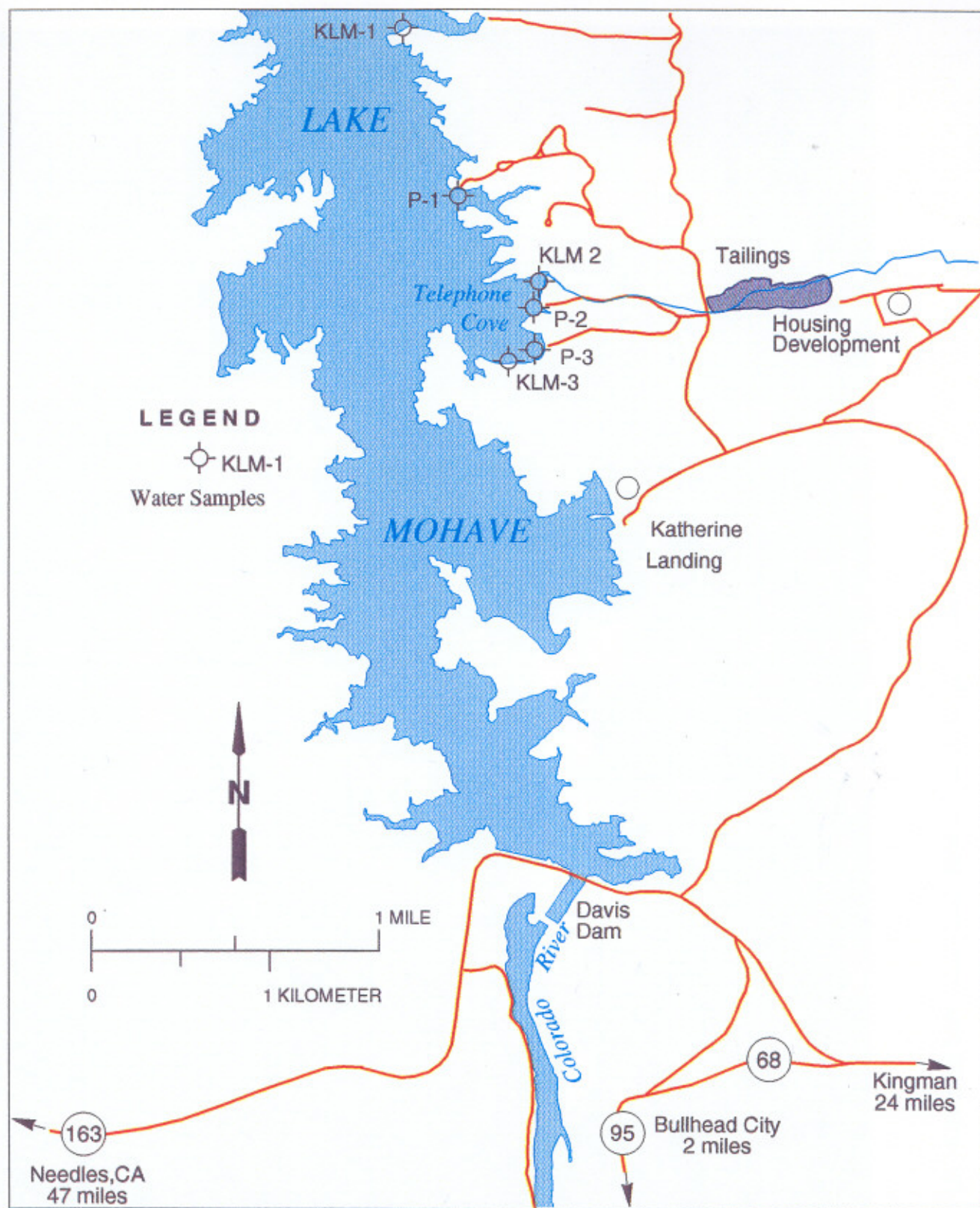


Figure 17. Location of water samples taken from Lake Mohave

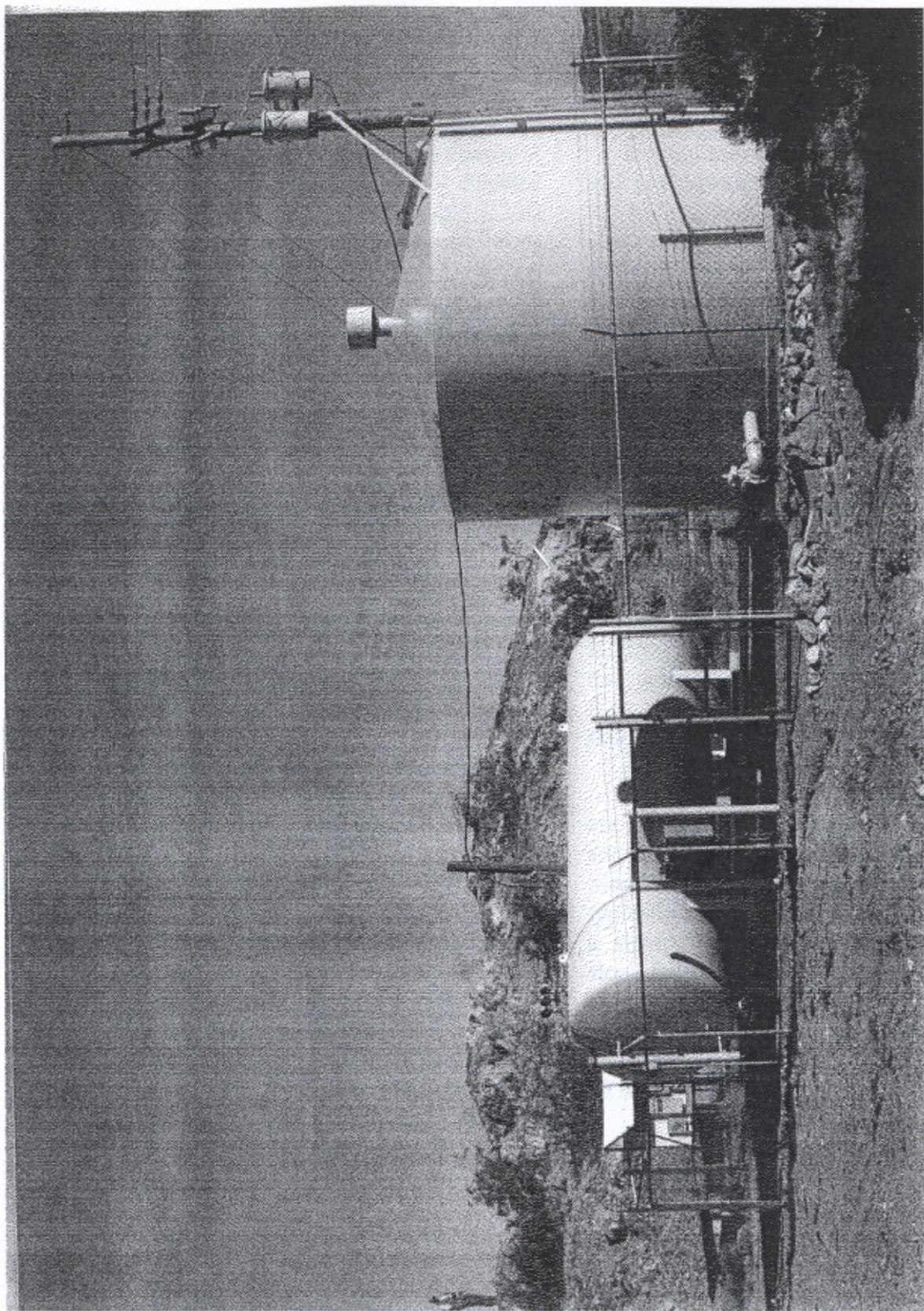


Figure 18.--Katherine Mine main shaft showing water supply system

DATA INTERPRETATION

Analyses from sampling Lake Mohave in 1993 indicate moderate levels of cadmium, lead, and mercury as shown in table 8. These metals were not detected in samples taken in 1994 (table 8); all elements analyzed were near or below detection limits (figure A-2).

Analyses from water samples taken at the main shaft by ADEQ are used to determine drinking water quality. In reviewing this data from 1988 to present, it is found that samples are not being

analyzed for cyanide or beryllium, two potential hazards associated with the mine and mill site.

It is unlikely that surface water quality and groundwater is being degraded by the mill tailings. EPA Drinking water standards were not exceeded for metals analyzed in our 1994 water samples. ADEQ approves the use of groundwater at the site for drinking. The site has low precipitation and net evaporation which lessens the possibility for surface and groundwater degradation.

GEOTECHNICAL INVESTIGATION OF KATHERINE TAILINGS

INTRODUCTION

The configuration of the tailings pile (steep slope faces and steep narrow eroded gullies) present a potential physical hazard so the Bureau conducted a geotechnical survey of the site. Studies included particle size distribution and soil classification, bulk density, and slope stability analysis (Appendix C).

SOIL CLASSIFICATION

Particle size distribution of the tailings material was determined using U.S. Standard sieves (Appendix C). One Liquid Limit analysis was performed for soil classification purposes. This yielded a Liquid Limit of 11.4%. The material is a non-plastic uniform silt and fine sand with a Universal Soil Classification of ML.

SLOPE STABILITY ANALYSIS

Eroded highwalls and erosional piping

have created very steep slopes on some margins of the tailings. This presents the potential for a physical hazard from slope failure. The Bureau sampled and tested the tailings material to determine the factor of safety (FOS) against slope failure.

The tailings from the Katherine mill are fine-grained, partially cemented silt and sand. This resembles a soil material. Slope failure in this type of material will typically be a circular failure resembling a slump. The factor of safety against slope failure of this type can be estimated using stability charts or can be calculated by various methods including some included in computer codes such as STABL.

The factor of safety against failure is defined as the ratio of the forces resisting failure (material strength) to those tending to induce failure (gravity, hydrostatic uplift). A factor of safety of 1 indicates a condition of limiting equilibrium at which

Table 8. Selected surface water sample analyses near Katherine Wash outlet

SAMPLE NUMBER ₁	Location	FREE CYANIDE (mg/l)	TOTAL CYANIDE (mg/l)	LEAD (mg/l)	MERCURY (mg/l)	CADMIUM (mg/l)
P-1	Cabin site	0.002	NA	0.022	.00246	.002
P-2	Telephone Cove (north)	0.002	NA	.030	.00193	.004
P-3	Telephone Cove (south)	0.001	NA	.040	.00370	.024
KLM-1	Telephone Cove (north)	NA	< .01	.002	< .0002	< .002
KLM-2	Telephone Cove (south)	NA	< .01	.002	< .0002	< .002
KLM-3	One mile north of Telephone Cove	NA	< .01	< .001	< .0002	< .002

(1) P samples were taken in 1993 as an initial screening, KLM samples were taken in 1994 for confirmation.

NA Not Analyzed

See Appendix B for a complete listing of analyses.

failure is imminent. Factors of safety equal to 2 are often used for protection of human safety in civil engineering.

Methodology

Direct shear analysis was conducted on samples 2 inches in diameter and approximately 2 inches tall which were cut from blocks of material taken from three sites. All cores were cut horizontally into the block so that shear testing would represent material, rather than bedding-plane, strength. Shear tests were performed on at least four samples from each block at normal loads of 10, 20, 50, and 80 pounds. The peak strength (psi) was noted and plotted versus normal pressure (psi). A straight line was fit by linear regression and the phi angle and cohesion were noted. The results from this testing indicate a material with an internal friction angle of about 30 degrees and a cohesion value of about 20 psi, representing a material with high internal strength. Although no samples contain an appreciable amount of clay, all exhibited a cohesion of about 20 psi. This is attributed to cementation by lime present in the tails.

Data Interpretation

Stability analysis using stability charts with composited experimental data indicates a factor of safety against failure due to strength of about 2.3. This analysis assumes a vertical slope face, face height of 40 feet and a specific weight of 89 pounds per cubic foot.

Stability analysis using the STABL code was performed on several configurations (figure 19) assuming the

same specific weight. Factor of safety (FOS) determinations for each profile are as follows:

<u>Profile</u>	<u>Minimum FOS</u>
1	12.1
2	10.8
3	8.4
4	5.1

Note that the factor of safety ranges from 5.1 to 12.1 in these calculations, which is significantly higher than that obtained by use of stability charts with composite strength data.

All the above analyses assume the material remains dry. When wet, the material will be significantly weaker due to loss of cementation and if saturated, the effective stress in the material is reduced, further reducing strength. Although this area is usually very arid, extended periods of rain do occur. A more detailed analysis of potential failure when wet is needed because of the possibility of a lowered FOS during these prolonged storm events. A preliminary analysis assuming saturation but no loss in cementation indicates a minimal decrease in the factor of safety.

ADDITIONAL OBSERVATIONS

A characteristic of the tailings is the existence of many horizontal surfaces resembling bedding planes. These surfaces appear to have much lower strength than the material itself and could serve as preferential failure planes. Soil failure due to loss of strength occurs on a circular path from the top of the slope to near the toe. Except near the toe, this path crosses the bedding planes rather

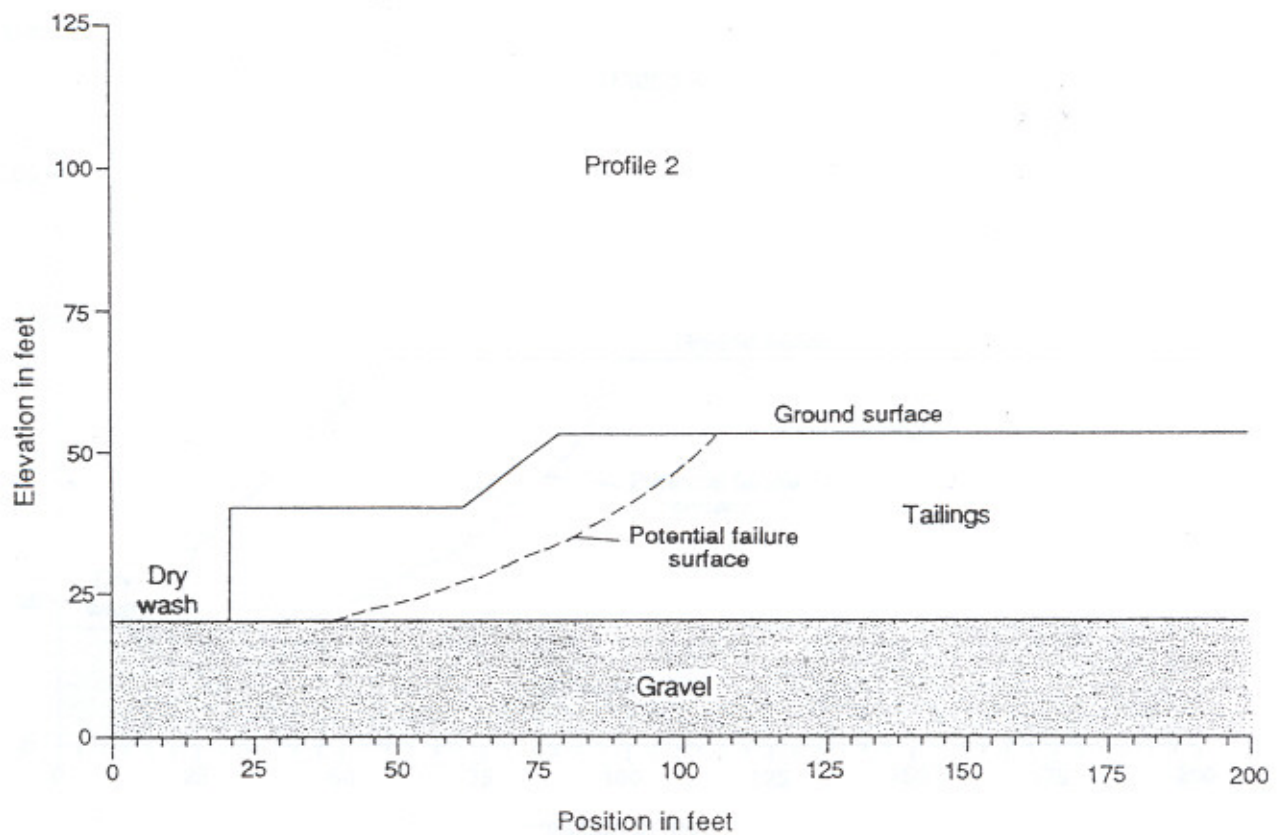
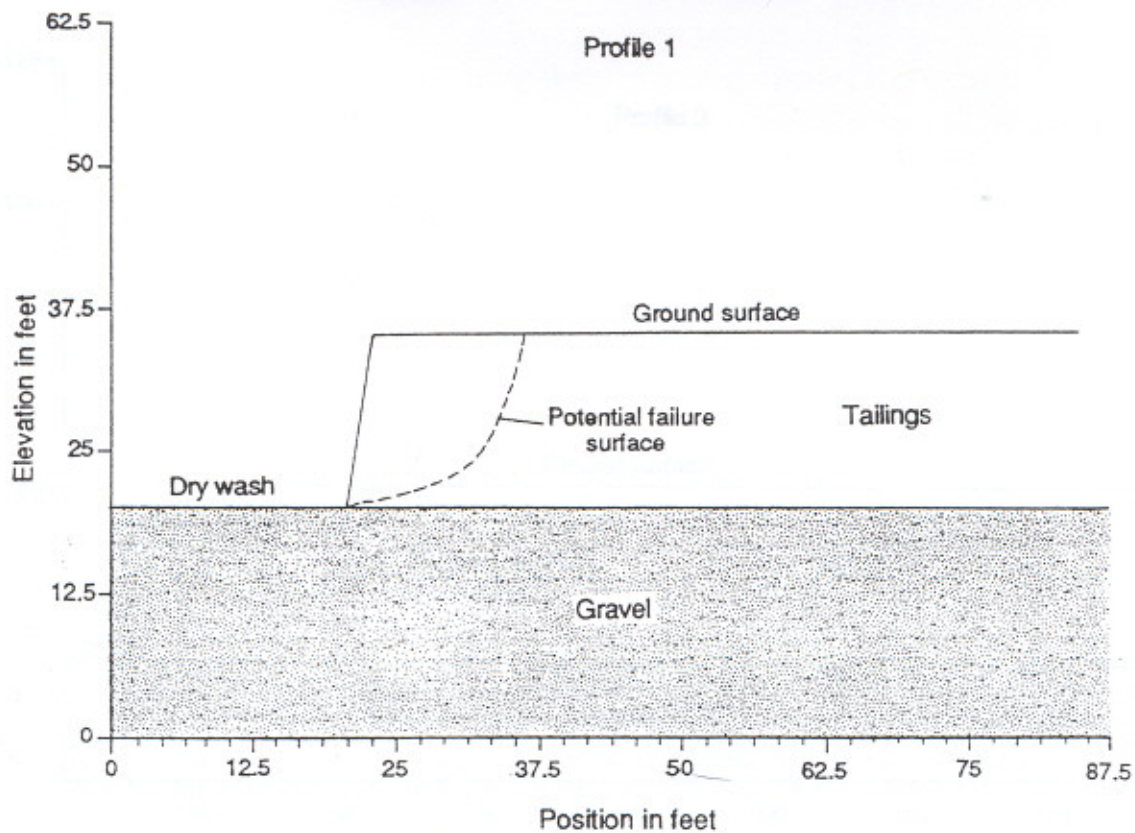


Figure 19A.-Slope stability profiles

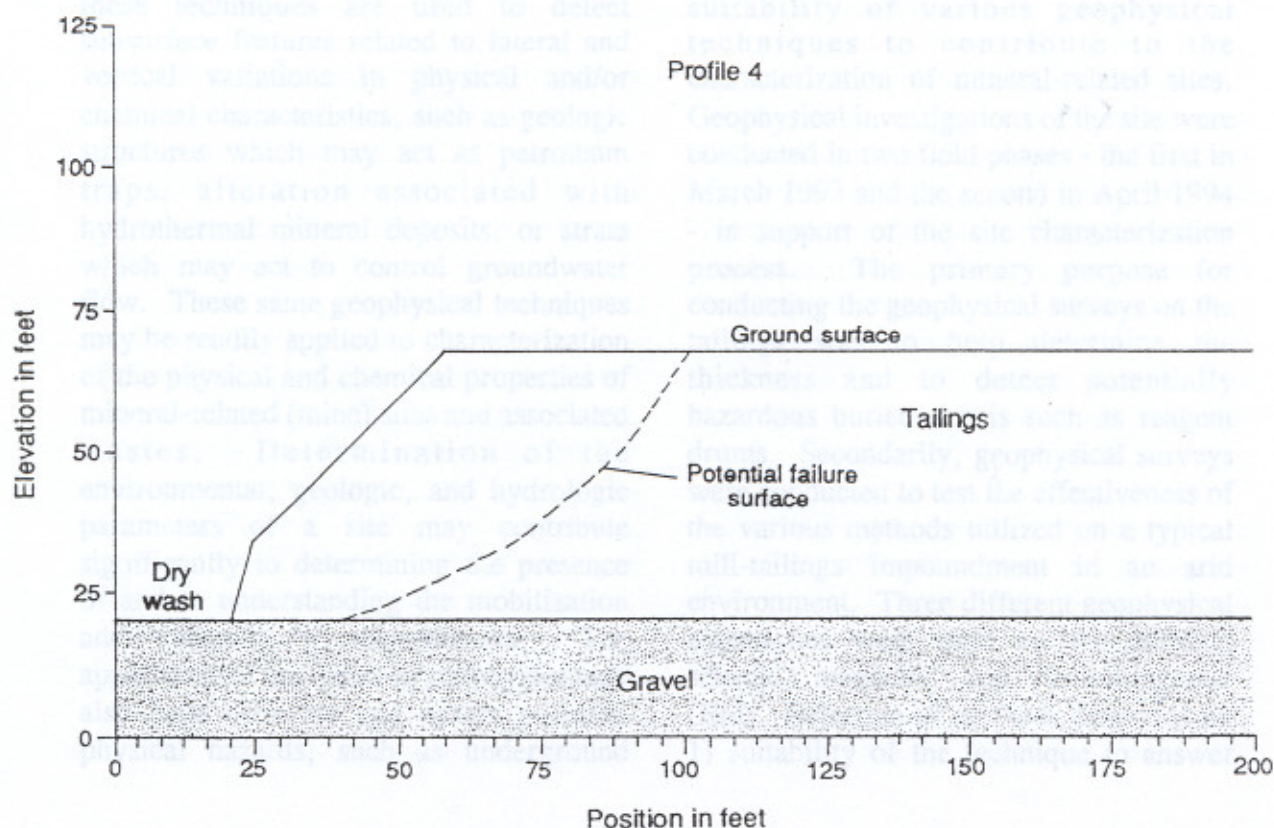
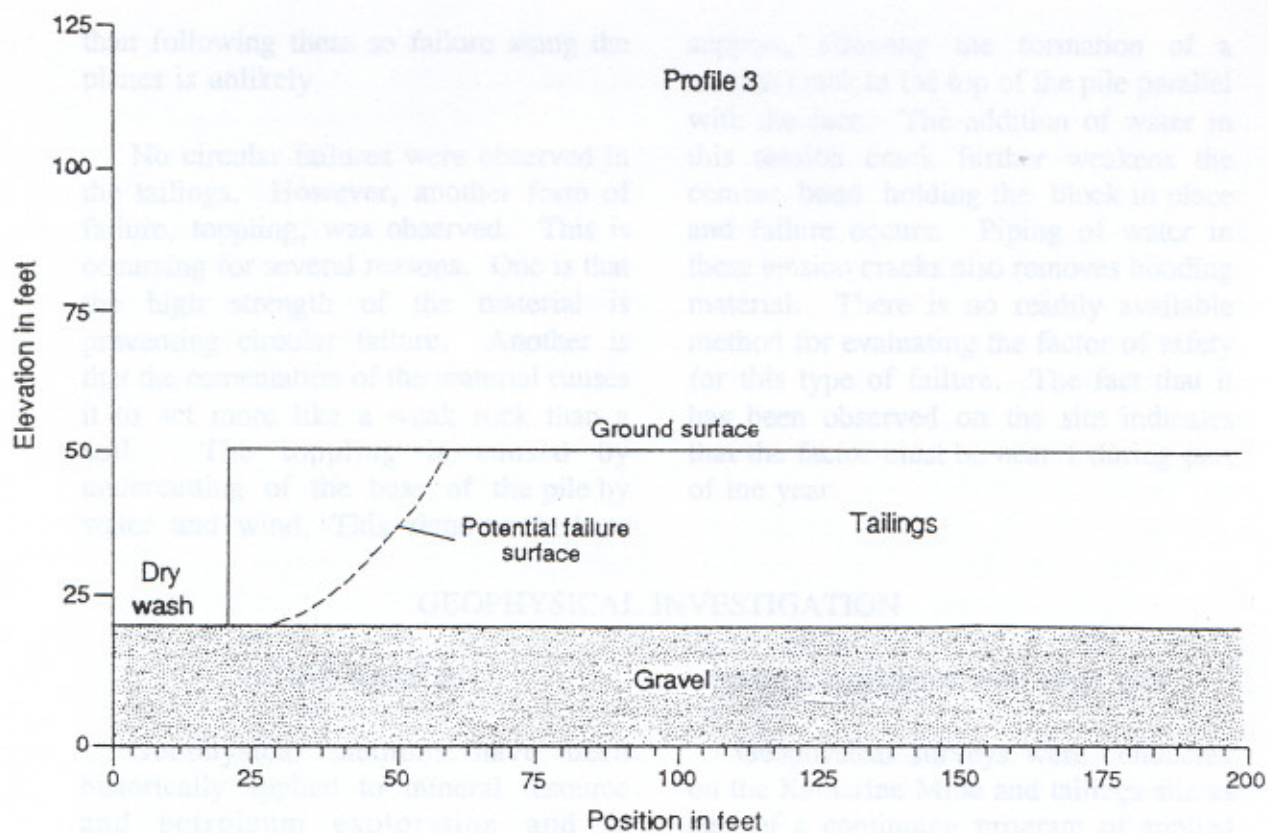


Figure 19B.- Slope stability profiles

than following them so failure along the planes is unlikely.

No circular failures were observed in the tailings. However, another form of failure, toppling, was observed. This is occurring for several reasons. One is that the high strength of the material is preventing circular failure. Another is that the cementation of the material causes it to act more like a weak rock than a soil. The toppling is caused by undercutting of the base of the pile by water and wind. This removes the base

support, allowing the formation of a tension crack in the top of the pile parallel with the face. The addition of water in this tension crack further weakens the cement bond holding the block in place and failure occurs. Piping of water in these tension cracks also removes bonding material. There is no readily available method for evaluating the factor of safety for this type of failure. The fact that it has been observed on the site indicates that the factor must be near 1 during part of the year.

GEOPHYSICAL INVESTIGATION

INTRODUCTION

Geophysical methods have been historically applied to mineral resource and petroleum exploration and to engineering investigations. Generally, these techniques are used to detect subsurface features related to lateral and vertical variations in physical and/or chemical characteristics, such as geologic structures which may act as petroleum traps, alteration associated with hydrothermal mineral deposits, or strata which may act to control groundwater flow. These same geophysical techniques may be readily applied to characterization of the physical and chemical properties of mineral-related (mine) sites and associated wastes. Determination of the environmental, geologic, and hydrologic parameters of a site may contribute significantly to determining the presence of and to understanding the mobilization and transport of contaminants. The application of engineering geophysics may also help delineate and assess potential physical hazards, such as underground

workings, associated with mine sites.

Geophysical surveys were conducted on the Katherine Mine and tailings site as part of a continuing program of applied research by the USBM to investigate the suitability of various geophysical techniques to contribute to the characterization of mineral-related sites. Geophysical investigations of the site were conducted in two field phases - the first in March 1993 and the second in April 1994 - in support of the site characterization process. The primary purpose for conducting the geophysical surveys on the tailings was to help determine the thickness and to detect potentially hazardous buried debris such as reagent drums. Secondly, geophysical surveys were conducted to test the effectiveness of the various methods utilized on a typical mill-tailings impoundment in an arid environment. Three different geophysical approaches were used on the tailings; seismic, magnetic, and electromagnetic (EM). Selection of methods depended on 1) suitability of the technique to answer

specific questions about the site, 2) the complementary nature of the methods, 3) availability of instruments, and 4) physical or environmental conditions present at the site. At the request of the NPS, an additional abbreviated geophysical investigation was also conducted over the underground workings in order to verify the location and extent of workings and possible areas of subsidence.

The locations of seismic refraction surveys are shown on figures 20 and 21 (in pocket), magnetic gradient surveys are shown on figure 22 (in pocket), and electromagnetic surveys are shown on figure 23 (in pocket). A brief description of each geophysical method, instrument, field procedure, and data processing procedure, as well as graphical presentations and supporting data for the tailings and subsidence geophysical investigations, are presented in Appendix D.

A review of preliminary findings of the subject geophysical site investigation was presented at the NPS "Abandoned Mineral Lands Series Workshop on Underground Mine Closures and Issues" held November 15 to 17, 1994 in Laughlin, NV. In addition to specific literature cited in the ensuing text, the following references were frequently consulted in support of survey planning, field operations, data processing, and data interpretation: Breiner, 1973; McNeill, 1980a,b; Milson, 1989; Mooney, 1980; Redpath, 1973; Sheriff, 1991; Telford and others, 1980; Van Blaricom, 1992; and Ward, 1990.

METHODOLOGY

Seismic refraction surveys (figure 24) using a 12-channel Geometrics SmartSeis S12 seismograph were conducted on selected transects on the tailings and nearby alluvium to determine depth to bedrock, thickness of alluvium, depth to base of the tailings and, possibly, to reveal internal tailings stratigraphy. Tailings surveys consisted of fourteen seismic refraction spreads each 110 ft long, and one 220-ft-long spread was conducted along the floor of the large crevasse cut through the tailings by Katherine Wash (figures 20 and D-1 to D-10). Each refraction line on the tailings utilized 12 geophones placed at 10-ft intervals for a total length of 1,540 ft, whereas the spread in the wash used a 20-ft geophone interval. In addition, four seismic refraction spreads were conducted at the east shaft in order to determine depth to bedrock and the competency of earth materials near the shaft and underlying the adjacent housing development. Only two of the seismic refraction surveys contain useable data [figures 20, 21, and D-11 (SR-2000) and D-12 (SR-3000)]. Respectively, 20-ft and 15-ft geophone intervals were utilized on these two lines. Multiple hammer stations, including a mid-point, were employed on all seismic refraction spreads, and only minimal filtering was used.

Gradient magnetometry surveys (figure 25) using a Geometrics Memory-Mag G-856 AGX gradient magnetometer system

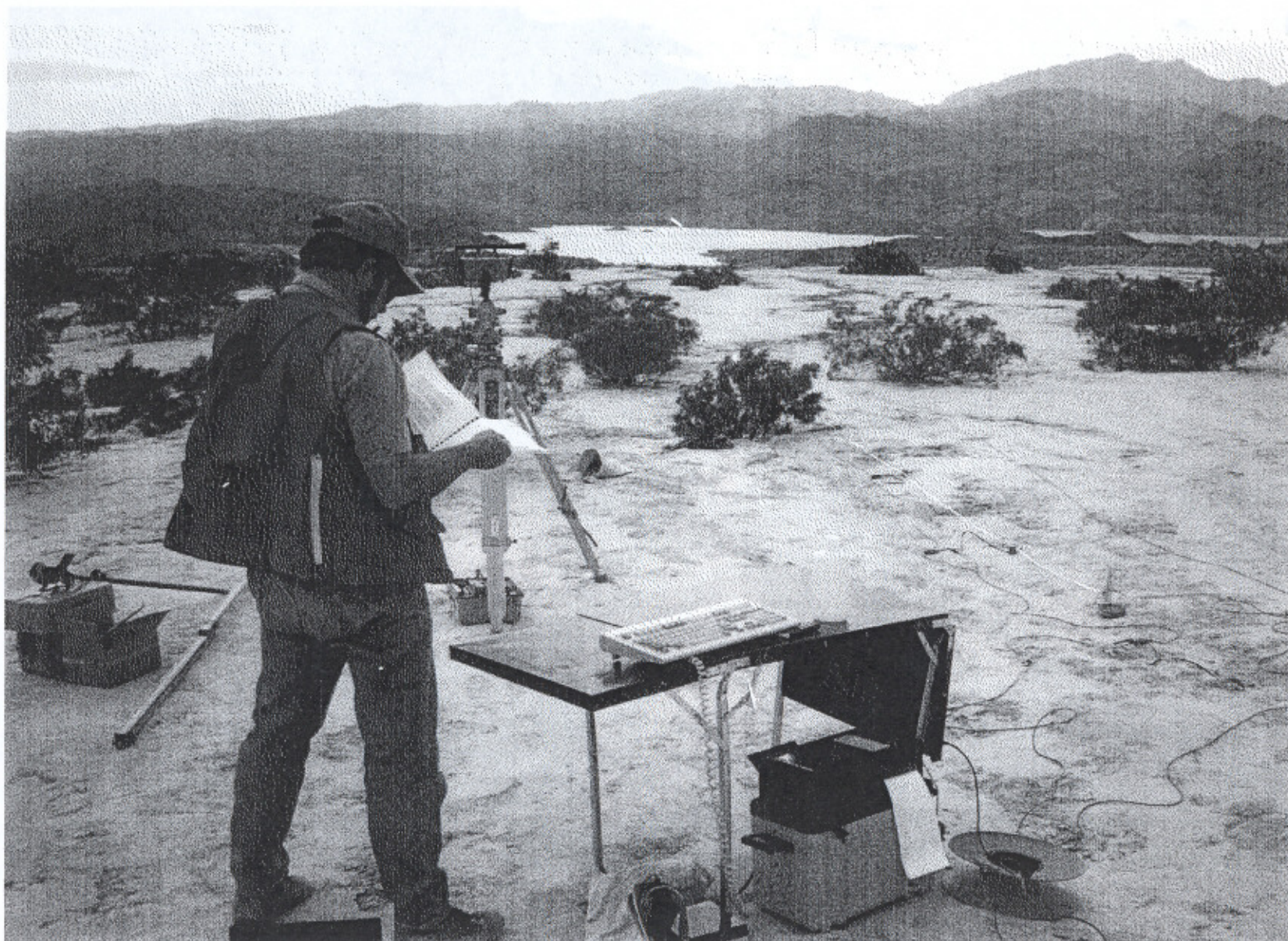


Figure 24.--Scientist conducts seismic refraction survey on the Katherine tailings with a SmartSeis S-12 seismograph and 12-geophone spread.



Figure 25.--Scientist prepares to conduct magnetic gradient survey at the Katherine Mine site with a Geometrics G-856 AGX gradient magnetometer system

were conducted using a 10-ft station interval on 11 transects (GM-test to GM-500) across the tailings to detect buried objects of environmental concern, such as drums or pipelines, which could also cause difficulty with interpreting EM ground-conductivity data. Careful field notes were taken to correlate anomalies to identifiable objects. GM-test was intentionally run over an area with known surface and buried debris on the northeast lobe of the tailings to test the effectiveness of the method to detect the metallic debris. The 4,190 ft of magnetic gradient transects conducted on the tailings are shown on figure 22, magnetic profiles are presented in figures D-13 to D-23, and data are listed in table D-1. A 100 ft by 200 ft magnetic gradient survey utilizing a grid of six transects and 5-ft station intervals for a total of 970 ft of line was conducted over the south end of the level C berm in order to delineate the extent of buried drums used to reinforce the impoundment. Three-dimensional perspectives of the drum burial site surface and of the magnetic gradient are presented in figures D-24 and D-25, and data are listed in table D-2. An additional 11 magnetic gradient transects (T-1 to T-11) were positioned approximately perpendicular to Katherine Mine underground workings in an attempt to detect voids and cultural objects associated with the underground workings. Transects ranged from 300 ft to 400 ft for a total length of 4,135 ft of survey line at a 5-ft station interval. Locations of transects T-1 to T-11 are shown on figure 22, magnetic gradient profiles are presented in figures D-26 to D-36, and data are listed in table D-3. To

assist with the magnetic data interpretation, seven rock samples collected from various locations on the Katherine Mine site were submitted to Pittsburgh Research Center for magnetic susceptibility tests. Ten readings were taken from each specimen and an average value calculated (table D-4).

EM induction surveys using a Geonics EM-31 ground-conductivity system (figure 26) were employed in both vertical- and horizontal-dipole configuration to determine areal distribution of apparent ground conductivity associated with tailings character, such as moisture, or buried metallic debris. Five transects ranging in length from 150 ft to 300 ft at a 10-ft station interval were conducted on the upper tailings, including a 300 ft test line over the northeastern lobe of the tailings to test the effectiveness of the method to detect metallic debris. Locations of the 1,250 ft of EM-31 transects are shown on figure 23, EM-31 profiles are presented in figures D-37 to D-41, and data are listed in table D-5.

Three very low frequency electromagnetic (VLF-EM) surveys (T-2, T-5, and T-11) using a Geonics EM-16¹ VLF-EM receiver (figure 27) were conducted at a 10-ft station interval across the projected location of underground workings and mineralized zone to supplement interpretation of the magnetic gradient data. Locations of the 1,250 ft of EM-16 transects are shown on figure 22, EM-16 profiles are presented in figures D-42 to D-44, and data are listed in table D-6.



Figure 26.--Scientist conducts electromagnetic survey on the Katherine tailings with a Geonics EM-31 ground-conductivity system

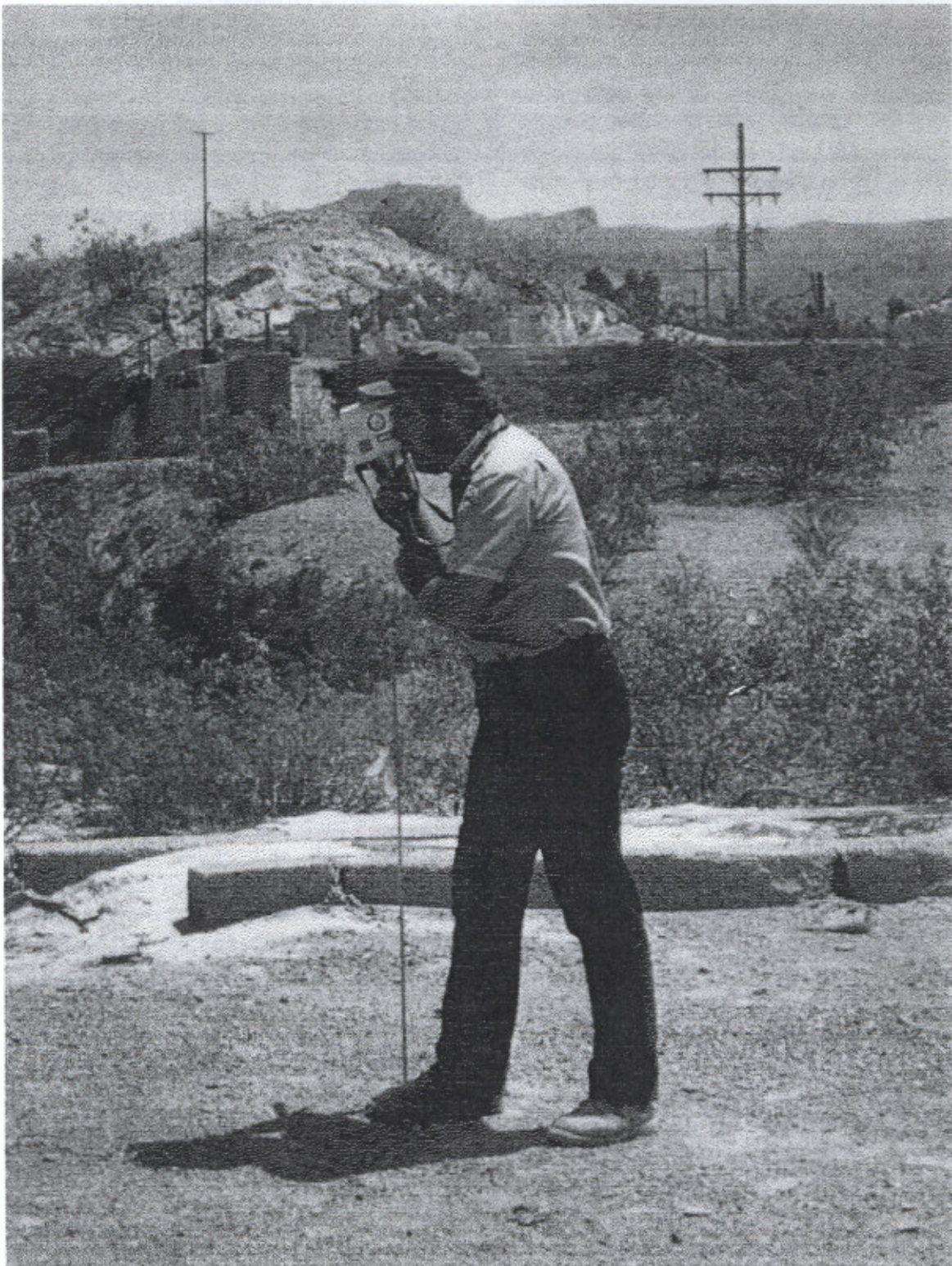


Figure 27.--Scientist conducts VLF electromagnetic survey over the Katherine Mine underground workings with a Geonics EM-16 VLF-EM receiver

DATA INTERPRETATION

Tailings Investigation

Seismic refraction investigations reveal that the tailings exhibit homogeneous lateral seismic velocity of about 1,150 ft/s; tailings velocity ranges from 1,058 ft/s to 1,223 ft/s (figures 20 and D-1 through D-9). A typical seismic stratigraphic model of the tailings is shown in figure 28 (in pocket), a composite of Line SR-B1-3. Study of first arrival time-distance plots used to prepare the seismic models shows a modest increase in tailings velocity with depth, probably related to a corresponding increase in bulk density; however, data indicate little or no internal tailings stratigraphy. Tailings depths interpreted from seismic refraction surveys ranged from about 40 ft on level A to less than 6 ft for level D. Comparison of measured augerhole depths of the tailings to seismically-interpreted depths showed a strong correlation, especially in the thicker sections (figure 28). Orthogonal seismic arrays also showed good correlation, suggesting the method is reliable and accurate. This despite 2 ft to 5 ft of relief in the base of the tailings revealed in examination of the high wall in the Katherine Wash cut.

Velocity of the underlying gravel of Katherine Wash averages about 4,000 ft/s. Interpretation of time-distance plots of all 17 seismic refraction spreads shows that a shallow sand and gravel layer, averaging about 1,450 ft/s and typically less than 10-ft thick, overlies the higher-velocity gravel layer. The shallow gravel, not generally "visible" under the tailings profiles, probably represents recently deposited,

unconsolidated alluvium. Lines SR-7000, SR-2000, and SR-3000 (figures D-10 to D-12) are interpreted as exhibiting varying sand and gravel strata and increasing seismic velocity with depth. Seismic velocities determined for the tailings, sand, and gravel to a depth of up to 80 ft are typical of velocities associated with dry alluvium.

Seismic velocities ranging from 13,760 ft/s to 19,460 ft/s were encountered in only three seismic spreads, Lines SR-A2, SR-2000, and SR-3000 (figures D-2, D-11, and D-12), typical of gneiss to granodiorite bedrock (Lankston, 1990, table 1). The wide range of bedrock seismic velocities is probably due to variations in characteristics such as massive to fractured to altered or mineralized. No seismic refraction surveys west of SR-A2 are interpreted as bedrock seismic velocities; therefore, the basement is probably at least 100 ft deep under SR-7000.

Katherine tailings typically exhibited a very low response on the magnetic gradient surveys (figure 22, D-13 to D-23), especially thick sections of tailings. Typical responses are observed on the GM-test profile to known debris and drums encountered along the transect. Figure 29 presents a composite magnetic gradient transect through the tailings east to west axis. The highest magnitude anomaly is interpreted to be in response to an 8-ft-diameter steel tank at the east end of the axis profile. "Rusted" pipelines observed on the tailings exhibited moderate anomalies ranging up to 15 gammas/ft, and similar anomalies near the south edge of levels A, B, and C (GM-103, GM-203, and GM-303; figure 22)

are interpreted to be associated with a tailings pipeline distribution system. Magnetic gradient response over major crevasses cutting the tailings is modest to variable; only marginally consistent enough to be considered for predicting voids. A variable magnetic response is observed over the west end of the axis profile [figures 29 (in pocket) and D-23] where it runs directly over Katherine Wash; the heterogeneous variety of rock types observed in the wash is interpreted to be the cause of the variable response.

The magnetic gradient grid conducted over the south end of the level C berm successfully delineated the location and extent of buried drums partially exposed on the tailings slope which may have been used to reinforce the impoundment or to support the discharge pipes.

Figure D-25 clearly shows a high-magnitude anomaly over the known drum burial site and also demonstrates a normalization of response outside the known burial area. Progressive oxidation of the steel drums will ultimately contribute to destabilization of the impoundment.

Electromagnetic surveys (figures D-37 to D-41) using an EM-31 exhibited predictable response to steel objects observed on the tailings, especially drums and a pipeline on the 300-ft test transect and the 8-ft-diameter tank on the 099 transect. Relatively low EM values, 5 mS/m to 10 mS/m, are encountered off the east end of the tailings, but unexpectedly high EM values, 20 mS/m to 35 mS/m, are common over the middle of tailings level A. In addition, vertical dipole readings are typically 5 mS/m

higher than the horizontal dipole on the 100, 101, and 103 Transects (figures D-39 to D-41). These relationships are interpreted to be caused by the presence of moisture in the center of the thicker tailings.

Field examination of the Katherine site revealed an old dump area with miscellaneous buried debris, including drums, machine parts, and gloves at the northeast corner of the tailings and adjacent to the Katherine Community road (figure 23). A random electromagnetic ground conductivity survey conducted over the site revealed several small areas interpreted to contain buried metallic debris. The boundaries of the burial areas were surveyed and illustrated on figures 23 and 30 (in pocket).

Mine Workings Investigation

Dimmick and Ireland (1927) provides the only known documentation of the Katherine mine underground workings; the map is probably incomplete as it was prepared approximately 15 years before the mine finally ceased operation. An enlarged plan map prepared from Dimmick's map is presented in figures 15, 20, 22, and 23, and an idealized cross-section of the underground workings (figure 31, in pocket) prepared from Dimmick's cross-sections and seismic refraction surveys (figures D-1 to D-12) is projected to the surveyed east-west axis line. Location and orientation of the underground workings map was assisted by detailed transit surveys of surface workings, such as the main shaft, and related features. Site safety concerns of the NPS were confirmed by field examination of shaft collars and ground

surfaces above major stopes which revealed evidence of sloughing and subsidence, especially localized above level 1. Interpretation of geophysical surveys was focused on confirming the location of and assessing the condition of the workings.

Magnetic gradient profiles T-1 to T-11 (D-26 to D-36) exhibit responses caused by variations in ground surface, Katherine Mine underground workings, and various cultural features. The effectiveness of magnetometry alone is limited to areas with little cultural noise. An overhead powerline, underground pipeline, various metal debris, and fences surrounding open shafts contribute to an abundance of noise. Therefore, it is difficult to differentiate magnetic anomalies associated with the underground workings from the extensive noise that is present over the transects. Filtering out the noise associated with these eleven profiles would perhaps allow hidden magnetic low signatures to be revealed. Anomalies suggesting voids (magnetic lows) are apparent on magnetic gradient transects T-2, T-3, T-6, T-7, T-8, T-9, T-10, and T-11. Transects T-7 through T-11 exhibit small anomalies directly above level 2 underground workings which were used to make minor adjustments to the plan-view map; however, the signatures lack consistency and may not be considered uniquely diagnostic of underground workings. Absence of a unique signature of low anomaly voids may depend on the depth and size of underground workings as well as cultural material left in the workings.

The three VLF-EM surveys (figures 23, and D-42 to D-44) were conducted in an attempt to delineate the altered and

mineralized rock through which most of the underground workings pass. Profiles T-2, T-5, and T-11 exhibit phase cross-overs over the suspected workings. However, the responses may also be associated with cultural noise and are not considered to be conclusive evidence of a mineralized zone.

The seismic refraction lines SR-2000 and SR-3000 (figures 20, D-11, and D-12) clearly demonstrate bedrock with a seismic velocity of 13,760 ft/s to 17,840 ft/s, at a depth of 100 ft below the east shaft collar. Bedrock seismic velocity is within the range (11,500 ft/s to 20,000 ft/s) reported by Lankston (1990, table 1) for gneiss to granodiorite. With the exception of the top few feet (5 ft to 10 ft) of recent alluvial wash material, the gravels which overly bedrock are probably well consolidated, as indicated by a seismic velocity of 3,700 ft/s to 3,800 ft/s. Based on the projection of Dimmick and Ireland (1927) of the mine site and underground workings, level 1 workings are approximately 100 ft below the surface, level 2 workings are approximately 200 ft below the surface, and the ore-bearing vein is estimated to dip approximately 85 degrees. It is evident that level 1 was not developed as far as the east shaft because bedrock was detected at that depth by seismic refraction; therefore, the east shaft area is considered to be stable with respect to subsidence potential.

In summary, levels 1 and 2 may be too deep to detect a distinct void anomaly by the magnetic gradient method. This may be due in part to the low magnetic susceptibility of the host rocks (table D-4). Without the underground workings'

map, delineation of underground workings only by following magnetic gradient profile anomalies suggesting apparent voids would be difficult and unreliable. Gradient magnetometry may still prove to be a useful tool for void detection, especially when it is used in coordination

with other techniques and in the absence of cultural noise. Further geophysical investigations, utilizing resistivity, micro-gravity, or acoustic tomography, or a more detailed magnetic gradient grid may improve the detection and definition of abandoned underground mine workings.

CONCLUSIONS

CHEMICAL HAZARDS

Elevated concentrations of metals and cyanide occur in samples from the surface soils and processing residues in the vicinity of the mill site. Cyanide occurs mainly as very insoluble and stable compounds. Select sampling of what may be a buried barrel and debris dump at the northeast corner of the tailings impoundment where the road emerges from the deep wash showed the material to have elevated metal concentrations.

Steel drums, pipelines, and similar metallic debris were readily detected on the tailings by magnetic gradient test transects; a buried pipeline probably lies along the south boundary of the tailings. Two burial sites containing drums and associated debris were evaluated by magnetic gradient and electromagnetic methods. Drums used possibly to reinforce the tailings impoundment were determined by gradient magnetometry to be confined to a small area and pose no immediate hazard; however, their deterioration by oxidation will contribute to local destabilization of the impoundment. No other significant buried objects, such as drums or pipelines, were detected in the impoundment by selective magnetic gradient and electromagnetic ground-conductivity surveys beyond debris visible on the surface or known to be

present. EM surveys over the upper tailings impoundment indicate detectable moisture is present in the thicker tailings. An area of miscellaneous partially buried debris, including drums, machine parts, and gloves, was delineated at the northeast corner of the tailings site (figures 21 and 30) by electromagnetic ground conductivity.

Suggested Remediation Measures

The dump area at the northeast corner of the tailings impoundment receives heavy visitor traffic, and should be cleaned up for visual reasons. CN-W and CN-F were not detected, and metals concentrations are below clean-up levels. Because this dump occupies a small area, it could be remediated by hauling it off-site to a proper disposal area.

The millsite area also receives high visitor traffic. CN-T is near moderate contamination level; CN-W and CN-F were not detected. Most metal concentrations were below clean-up levels, although lead and zinc concentrations are at clean-up levels. The soils at the millsite should be removed and disposed including the material on the bottoms of the remains of the thickener and agitation tanks. The suggested clean-up areas are indicated on figure 33.

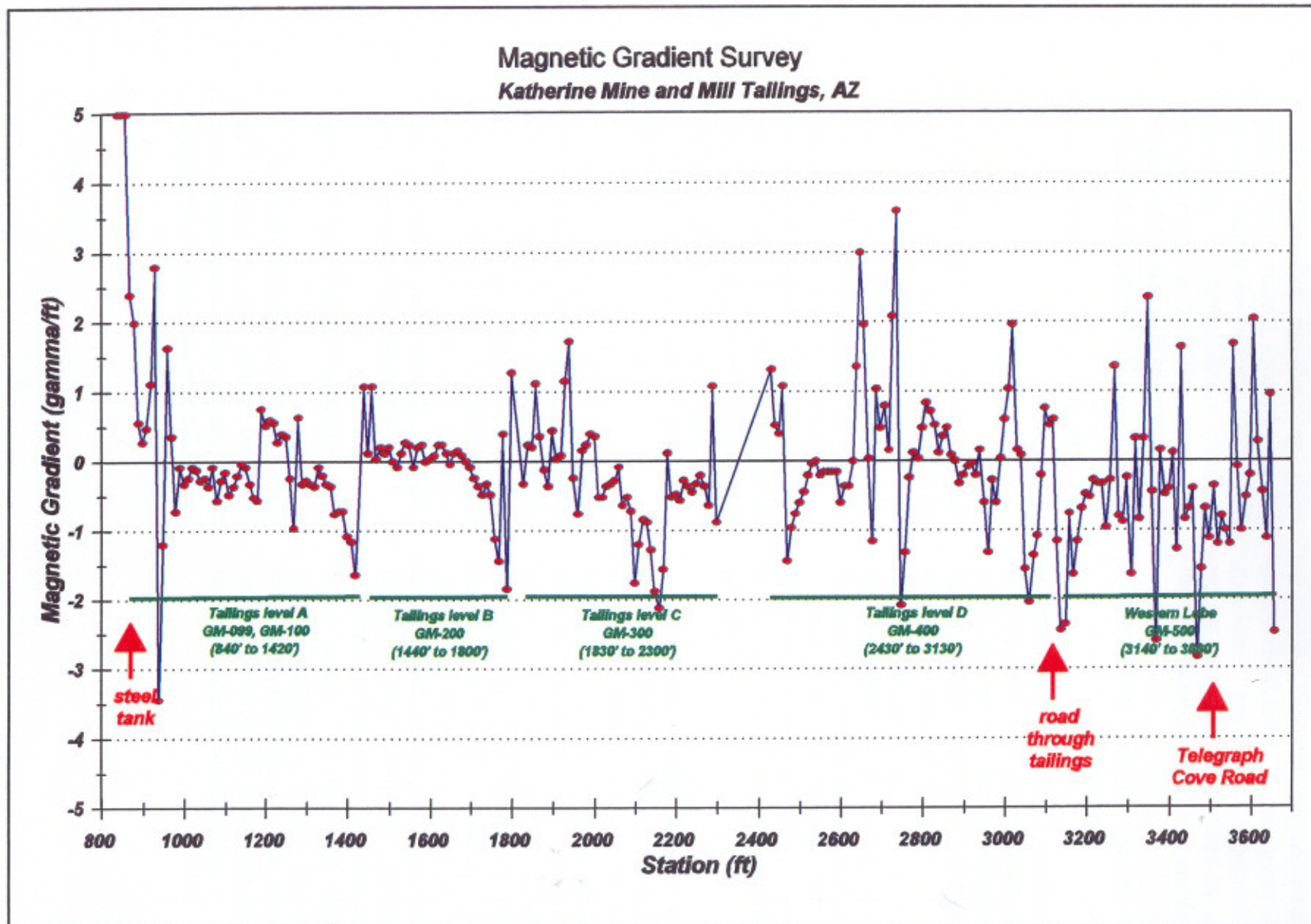


Figure 30. Vertical magnetic gradient transect, mine and mill tailings.

An alternative to removing these materials is to restrict access by closing the road through the tailings. Figure 31 shows an alternate access road, a preferred route to the home sites. The addition of a fence will keep visitors off the tailings (figure 31).

GEOTECHNICAL HAZARDS

Tailings

Seismic refraction surveys reveal compressional velocities of 1,150 ft/s for tailings, 1,450 ft/s to nearly 5,800 ft/s for various alluvial strata, and 13,760 ft/s to over 19,000 ft/s for altered to massive bedrock. A strong correlation is demonstrated between orthogonal seismic spreads and tailings depths determined by augerhole. The seismic refraction method is reliable and accurate for determination of tailings geometry. Bedrock lies at least 100 ft below tailings level D.

Factor of safety analysis of the tailings material indicates that the pile is not in imminent danger of circular failure when dry. Direct shear analysis of saturated tailings material is needed to determine the factor of safety in this condition. Toppling failure has occurred, probably after a large precipitation event.

Suggested Remediation Measures

The most efficient means of preventing slope failure is by cutting back the existing slope faces. The material is not in danger of circular failure but does tend

to topple. This will only occur on high, near-vertical faces. As previously mentioned, an alternative would be to restrict access to the tailings by closing the road through the tailings and fencing.

Underground Workings and Associated Subsidence

Site safety concerns of the NPS were confirmed by field examination of shaft collars and ground surfaces above major stopes which revealed evidence of sloughing and subsidence, especially localized above level 1. Level 1 was not developed as far as the east shaft because the bedrock surface was detected at that depth by seismic refraction; therefore, the east shaft area is considered to be stable with respect to subsidence potential.

A zone of potential subsidence and a safety buffer zone is shown on figure 31. This was determined by the use of underground mine working maps and correlation with magnetic gradient surveys. Delineation of underground workings by interpretation of magnetic gradient anomalies suggesting apparent voids, without the benefit of the underground workings' map, would be difficult and probably unreliable. Gradient magnetometry may still prove to be a useful tool for void detection, especially when it is used in coordination with other techniques in the absence of cultural noise and in rocks with moderate to high magnetic susceptibility.

FURTHER STUDIES

Further geophysical investigations, utilizing seismic reflection, resistivity, micro-gravity, or acoustic tomography, or a more detailed magnetic gradient grid may improve the detection and definition of the Katherine underground mine workings as well as other abandoned mine sites.

Additional study needs to be done to determine the mineral species that are contributing to the high Be content of the tailings material. If the main contributor is beryl, then a problem does not exist because beryl is very resistant to weathering processes. The high Be concentrations would have resulted from total digestion of the sample material and liberation of the Be during analysis.

ACKNOWLEDGEMENTS

The Bureau gratefully thanks all NPS personnel and volunteers for their assistance during our field investigations. The Bureau gives special thanks to Dale Melville, Bob Ajoonian, and Jeanette Costello who assisted in surveying. Also, Bill Burke and Vera Smith who provided the support needed for multi-agency work. A special appreciation is acknowledged to Mr. Bob Hobbs, NPS volunteer and retired USGS and USBM employee who assisted during our November 1992 visit and during our 1993 field season. Bob was so helpful with his knowledge and research on the Katherine Mine and Mill providing the Bureau with detailed mining history for this report.

On-site surveying by NPS personnel greatly facilitated the completion of field

If, however, Be is found to be present in oxide minerals that are more easily weathered, then a Be contamination problem may exist.

Before any additional sampling is done, a thorough literature study should be undertaken to determine the toxic forms and occurrence of Be, as well as the natural occurrence of Be in the geological formations and mineralized areas in southern Nevada and northern Arizona. These studies could be accomplished using existing sample splits collected by and available from the Bureau of Mines in Spokane, Washington.

Further study is suggested in determining the slope failure FOS of the tailings during wet conditions.

geophysical surveys. Karen Cohen, a geophysicist at the USBM Pittsburgh Research Center, conducted magnetic susceptibility measurements on several rock samples from the Katherine site. Ken Hauser, a geophysicist at the USBM Twin Cities Research Center, reviewed and contributed to the interpretation of magnetic gradient surveys conducted to detect underground workings at the Katherine Mine.

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REFERENCES

- Alloway, B. J. (editor), Heavy Metals in Soils, Halsted Press, 1990, 339 pp.
- Bentley, C. B., 1979, Geohydrologic Reconnaissance of Lake Mead National Recreation Area - Mount Davis to Davis Dam, Arizona: U.S. Geological Survey Open File Report 79-691, 34 p.
- Breiner, Sheldon, 1973, Applications manual for portable magnetometers: Geometrics, Sunnyvale, CA 94086.
- Callahan, M. A., Slimak, M. W., et al, 1979, Water-Related Environmental Fate of 129 Priority Pollutants: v. 1, U.S. Environmental Protection Agency, EPA-440/4-79-029a, December.
- Dimmick, R. L. and Ireland, E., 1927, Mining and Milling at the Katherine Gold Mine in Engineering and Mining Journal: v. 123, No. 18, April 30, p. 716-721.
- Eisler, R., 1991, Cyanide Hazards to Fish, Wildlife, and Invertebrates, A Synoptic Review: U.S. Department of Interior, Fish and Wildlife Service Biological Report 85(1.23)-Contaminant Hazard Reviews Report 23, December, 55 p.
- Eutectic + Castolin Institute, 1978, Cyanide safety report on the Katherine tailings - Katherine Mine files: located at Lake Mead National Recreation Area, Katherine Ranger Station, National Park Service.
- Gardner, E. D., 1936, Gold Mining and Milling in the Black Mountains, Western Mohave County, Arizona: U.S. Bureau of Mines Information Circular 6901, September, 59 pp.
- Geometrics, 1984, Model G-856 Proton Precession Magnetometer operator's manual: Geometrics, Sunnyvale, CA 94089.
- Geometrics, 1993, Smartseis S12 Exploration Seismograph operator's manual: Geometrics, Sunnyvale, CA 94089.
- Geonics Limited, 1979, Operating manual for EM16 VLF-EM: Geonics Limited, Mississauga, Ontario, Canada L5T 1C5, 78 p.
- Griffitts, W.R., 1973, Beryllium, in Brobst, D.A., and Pratt, W.P., eds., United States mineral Resources: U.S. Geological Survey Professional Paper 820, p. 85-93.
- Harding and Lawson Associates, 1980, Chemical analysis report of the Katherine tailings - Katherine Mine files: located at Lake Mead National Recreation Area, Katherine Ranger Station, National Park Service.
- Hendrix, J. L. and Nelson, J. H., 1985, Fate of Cyanide Tailings - an Update in Cyanide and the Environment: Volume 1, Proceedings of a Conference, Tucson, Arizona, December 11-14, 1984, p. 265-272.

- Hinkle, M.E., 1988, Geochemical sampling in arid environments by the U.S. Geological Survey: U.S. Geological Survey Circular 997, 26 p.
- Hobbs, R. G., 1992, A Summary of the Major Mines in the Lower Lake Mohave Area, Mohave and Clark Counties, Arizona and Nevada: unpublished report, available at WFOC, Spokane, Washington, 3 p.
- Hobbs, R. G., 1993, The Katherine Mine - A Historical Summary: unpublished report, available at WFOC, Spokane, Washington, 5 p.
- Huiatt, J. L., 1985, Problems and Research Needs in Cyanide and the Environment: ed. by Van Zyl, D., (Proc. Conf. Univ. AZ, Tucson, AZ, Dec. 11-14, 1984.) CO State Univ., Ft. Collins, CO, p. 519-530.
- Ingles, J. C., and Scott, J. S., 1987, State-of-the-art Processes for the Treatment of Solid Mill Effluents: pages unknown; available from Can. Environ. Protection Ser., Ottawa, Ontario, Canada.
- Kabata-Pendias, A., and Pendias, H., 1992, Trace elements in soils and plants (2nd ed.): Boca Raton, Fla., CRC Press Inc., 365 p.
- Lankston, R. W., 1990, High-resolution refraction seismic data acquisition and interpretation, in Ward, S. H., editor, Geotechnical and Environmental Geophysics - Volume I: Review and Tutorial: Society of Exploration Geophysics, Investigations in Geophysics, Volume 5, p. 45-73.
- Lausen, C., 1915, Geology and Ore Deposits of the Oatman and Katherine Districts, Arizona: Arizona Bureau of Mines Bulletin No. 131, 126 pp.
- Longwell, C. R., 1963, Reconnaissance geology between Lake Meak and Davis Dam, Arizona-Nevada: U.S. Geol. Survey Prof. Paper 374-E, 51 p.
- Manahan, S.E., 1990, Environmental Chemistry (4th ed.): Boca Raton, Fla., Lewis Publishers, Inc., 612 p.
- Marten, B.M., and McPhee, J.T., 1991, MTCA Handbook--Key provisions of the Washington State Superfund: Peanut Butter Publishing, Seattle, WA., 172 p.
- McNeill, J. D., 1980a, Electrical conductivity of soils and rocks: Technical Note TN-5, October, 1980, Geonics Limited, Mississauga, Ontario, Canada, 22 p.
- McNeill, J. D., 1980b, Electromagnetic terrain conductivity measurement at low induction numbers: Technical Note TN-6, October, 1980, Geonics Limited, Mississauga, Ontario, Canada, 15 p.
- Milson, John, 1989, Field geophysics: Geological Society of London Handbook, Halsted Press, John Wiley and Sons, Inc., New York, 182 p.
- Mooney, H. M., 1980, Handbook of engineering geophysics - volume I: seismic: Bison Instruments, Inc., Minneapolis, MN 55416.

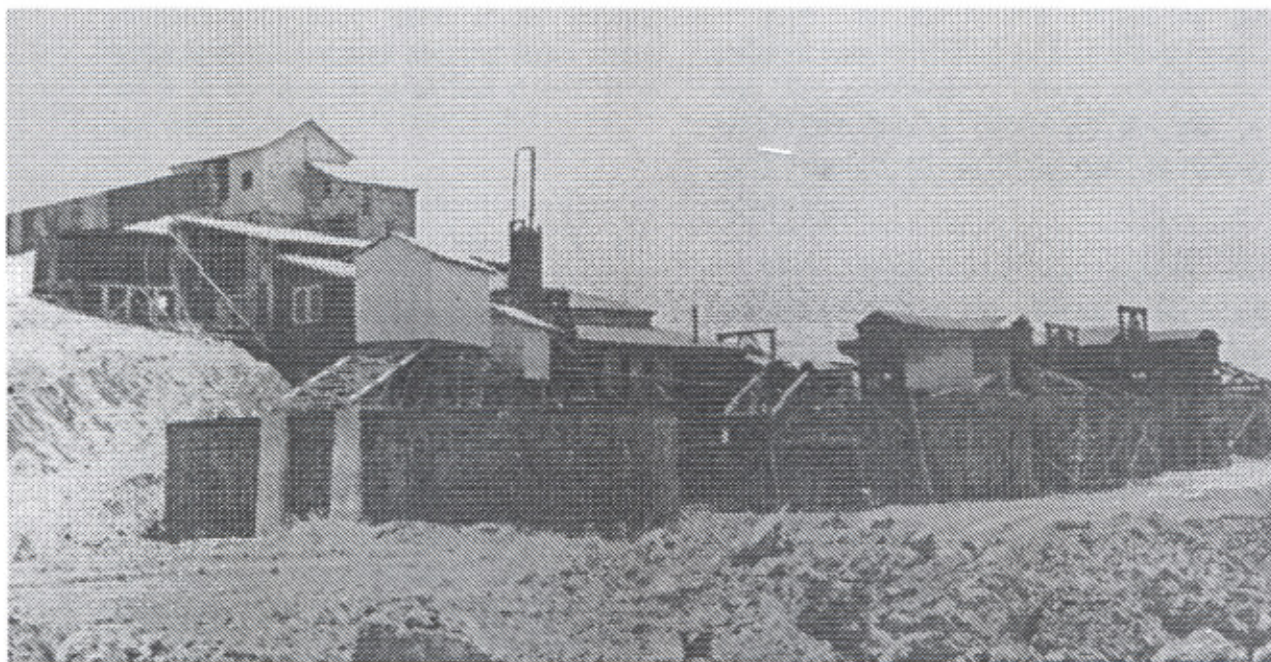
- Mudder, T. I. (ed.), 1989, *The Chemistry, Analysis, Toxicity, and Treatment of Cyanidation Wastewaters*: Pres. at Soc. Min. Eng. AIME Short Course, Las Vegas, NV, Feb. 26, 350 p.; available from SME Meetings Dept., Littleton, CO.
- Olson, F. A., Huiatt, J. L., Kerrigan, J. E., and Potter, G. L. (eds.), 1983, *Proceedings of a Workshop, Cyanide from Mineral Processing*: Utah Mining and Minerals Resources Research Institute, Feb. 2-3, 1982, Salt Lake City, UT, 123 p.
- Overstreet, W. B., 1970, *National Atlas of the United States of America*: U.S. Dept. of the Interior, Geological Survey, Washington, D.C., 417 p.
- Redpath, B. B., 1973, *Seismic refraction exploration for engineering site investigations*: U.S. Army Engineer Waterways Experiment Station, Explosive Excavation Research Laboratory Technical Report E-73-4, N.T.I.S. AD-768 710, 51 p.
- Rimrock Geophysics Inc., 1994, *Seismic refraction analysis programs - SIP shell, SIPIK, SIPIN & SIPEDT, and SIPT2*: Rimrock Geophysics Inc., Lakewood, CO 80228.
- Sheriff, R. E., 1991, *Encyclopedic dictionary of exploration geophysics*, 3rd Edition: Society of Exploration Geophysics, P.O. Box 702740, Tulsa, OK 74170-2740, 376 p.
- Schrader, F. C., 1909, *Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Arizona*: U.S. Geol. Survey Bull. 397, 226 p.
- Siegel, F. R., 1974, *Applied Geochemistry*: John Wiley & Sons, New York, NY, p. 95-96.
- Telford, W. M., Geldart, L. P., Sheriff, R. E., and Keys, D. A., 1980, *Applied geophysics*: Cambridge University Press, New York, 860 p.
- U.S. Department of Health and Human Services, NIOSH Pocket Guide to Chemical Hazards, June 1990.
- U.S. Environmental Protection Agency (EPA), *Treatability Manual*, Vol. III. EPA-600/8-80-042. July 1980, 241 p.
- U.S. Environmental Protection Agency (EPA), Region 10, 1992, *Record of Decision--Bunker Hill mining and metallurgical complex, Shoshone, County, ID*: 300 p.
- Van Blaricom, Richard (Compiler), 1992, *Practical Geophysics II for the exploration geologist*: Northwest Mining Association, 10 N. Post, Suite 414, Spokane, WA 99201-0772, 570 p.
- Van Zyl, D (editor), 1984, *Cyanide and the Environment: 1985, Proceedings of a Conference, Tucson, Arizona, December 11-14, Two Volumes*, 579 p.
- Schrader, F. C., 1909, *Mineral deposits*

Ward, S. H. (Editor), 1990, Geotechnical and environmental geophysics, volumes I-III: Investigations in Geophysics, Volume 5, Society of Exploration Geophysics, P.O. Box 702740, Tulsa, OK 74170-2740.

Warner, L.A., Holser, W.T., Wilmarth, V.R., and Cameron, E.N., 1959, Occurrence of Nonpegmatite beryllium in the United States: U.S. Geological Survey Professional Paper 318, 195 p.

ABANDONED MINE LANDS SITE CHARACTERIZATION

Katherine Mine, Mill, and Tailings Site,
Mohave County, Arizona APPENDIX



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ABANDONED MINE LANDS SITE CHARACTERIZATION APPENDIX:

KATHERINE MINE, MILL AND TAILINGS SITE, MOHAVE COUNTY,

ARIZONA: LAME-1025, TEC A: U.S. BUREAU OF MINE SPOKANE, WA

1995 KATHERINE MINE MINES AND MINERALS

LAME-1025

1995

APPENDIX A.--GEOCHEMICAL DATA

GEOCHEMICAL SAMPLING METHODOLOGY

Preliminary Survey (November, 1992)

Bureau of Mines scientists made a reconnaissance visit to the Katherine Mine area on November 5, 1992. The following characteristics of the tailings were noted:

(1) The tailings impoundment was divided into four main levels having estimated thicknesses ranging from about 40 ft at the east level to less than 2 ft at the west end.

(2) The tailings material consisted of relatively homogeneous fine sand to silt-size material.

(3) The tailings were moderately compacted and have eroded to near vertical walls where exposed in the main wash.

(4) Where complete sections through the tailings were exposed in the main wash, a color change from light brown or gray to reddish or pinkish brown was noted about one third of the way down from the surface.

(5) The tailings were underlain by unconsolidated fine gravel and pebbles at contact with surface of wash.

(6) Erosion had carved deep channels and gullies in the surface of the tailings impoundment, as well as causing subsurface piping.

(7) Little evidence was seen for large accumulations of buried junk in the tailings impoundment.

(8) The material was very dry; however, the surface had a thin crust and showed desiccation cracks.

(9) The surface of the tailings impoundment was sparsely vegetated primarily with creosote bush.

(10) Access to the surface of the tailings was restricted to foot travel only, and the presence of deep gullies and subsurface piping prevented the use of large motorized drilling and sampling equipment.

(11) Remains of old barrels and debris enclosed in the tailings at northeast corner of impoundment suggested possible buried chemical waste.

During the reconnaissance visit, six representative samples were collected from the tailings exposed in the walls of the main wash. All six samples (KM-1 through KM-6) were analyzed for Au, Ag, Sb, As, Cd, Cu, Hg, Fe, Pb, and Zn. Two samples (KM-4 and KM-5) were analyzed for cyanide (total, weak acid dissociable, and free). The analytical results are listed in table A-2.

The analytical results showed that Cd concentrations were below the detection limit and that Sb concentrations were below or slightly above the detection limit. Cu, As, Hg, Pb, and Zn concentrations were also low; however,

Pb and Zn were slightly elevated in samples KM-5 and KM-6. Free cyanide, the form of cyanide that is of concern, was less than 12 ppm in both samples.

April 1993 Field Work

Prior to commencement of USBM field work, the NPS surveyed a base line, approximately 3,000 ft in length and trending E-W, that bisected the long axis of the tailings impoundment. This base line was used to accurately determine the geochemical sample locations.

Auger samples

Fourteen sample sites were located on the tailings impoundment. Beginning with the eastern-most level of the impoundment and progressing westward from the mill site, two sample sites were located on each of the four levels. On each level the sample sites were located 100 ft from the base line, 200 feet apart on a line perpendicular to the base line. Sample distance from one level to the next was 500 ft. On the fourth level (the westernmost level) four additional samples were collected at the locations shown on figure 13. Two sample sites were also located on a small finger of tailings material in a wash west of the paved road.

The samples were collected using a stainless-steel, sand-type bucket auger having a diameter of 3 in. and a length of about 12 in. Forty-five-in.-long extension rods were used to sample at depth. The auger was turned using a 12-in.-long T-handle. A 4-ft-square, 3/4-in.-thick piece of plywood having a 4-in.-diameter hole in the center, was used as a working platform.

Each run of the auger penetrated about 6 in. into the tailings at which point it was withdrawn and emptied. To adjust for material that sloughed from the sides of the hole and would contaminated the sample below, the material that protruded above the top of the bucket auger was discarded. A steel spatula was used to empty the bucket auger into a steel pan. The auger was then cleaned with a brush to remove any loose material. Because the tailings were extremely dry, it was not necessary to wash the auger between each sampling run.

After a 3- to 4-foot interval had been sampled, the material was thoroughly mixed in a steel trough, then passed through a riffle splitter. Half of the sample was discarded; the other half was split again. Half of the second split was double bagged in heavy-duty poly sample bags for analysis; the other half was bagged and saved. The splitter and all pans and tools were cleaned between samples to remove all loose material and reduce cross contamination. The entire process was repeated for each sample interval.

As each hole progressed in depth, extensions were added to the auger assembly. Because of the stress placed on the threads at the connections where the rods joined, as well as the difficulty of handling a long string of extensions, the string was disconnected at every second or third joint as the rods were withdrawn to empty the auger bucket. A specially designed rod holder having a holding slot was used to prevent the rods from falling back down the hole while crescent wrenches were used to disconnect the rods.

After each hole was completed, 1 to 2 ft of bentonite was added to the hole to seal the bottom, then the remainder of the hole was filled with tailings material left over from the sampling. Because of the time required to pull the rod string, empty the auger bucket, and return the rod string to the hole, auger holes nos. 1 through 4 took about 8 hours each to complete.

Channel samples

In addition to the auger samples, channel samples were collected from three sites along the road in the main wash (figure 13). The channels were dug using a standard pick. A stainless-steel trowel was used to collect a sample from each distinct layer or zone exposed in the channel, and the samples were placed in heavy-duty poly bags. Original plans called for channel sampling the high wall on the south side of the wash on the northeast end of the tailings; however, the physical hazards were considered to far outweigh the benefits, especially because the deep end of the tailings impoundment could be sampled at depth using an auger.

Surface samples from tailings impoundment

At the request of the NPS, a sample of the surface material (0 in. to 1 in. deep) was collected at the site of each auger hole on the tailings impoundment. This material was screened and the minus-200 mesh material analyzed. The purpose of these samples was to determine if wind blown tailings material could contain significant concentrations of heavy metals

and thus represent a pollution problem.

Soil samples

Soil samples were collected from five sites on the ridge northeast of the tailings impoundment. The purpose of the samples was to determine background metal concentrations, as well as to detect any evidence of contamination of the soil by windblown tailings material.

At each soil sample location, the surface layer of desert pavement and organic material was scraped away. A soil pick was used to dig a hole 6 in. to 8 in. deep, at which point a stainless steel trowel was used to collect a soil sample, which was placed in a heavy-duty poly bag. Horizon development was not evident, so sampling was done at a constant depth.

Stream sediment samples

Three stream sediment samples were collected from the wash west of the highway (figure 13). The purpose of these samples was to determine if elevated concentrations of elements found in the tailings were present in the stream material.

At each sample locality, sediment and fine sand was collected from several nearby areas in the dry wash using a stainless steel trowel and placed in heavy-duty poly bags. Each stream sediment sample was thus a composite of material from several subsites.

May 1994 Field Work

The results of the 1993 field season were used to plan the 1994 field work. Because this project was originally undertaken as a research project, a few changes were made in the sampling methods to better achieve the desired results and comply with the wishes of the NPS.

Auger samples

On the basis of the results of the 1993, the samples of the tailings impoundment were judged to be sufficient both in quantity and quality, so that only a limited amount of additional sampling needed to be done. Because of the lack of sufficient auger extensions, auger holes nos. 1 and 2 in the easternmost tailings area had been terminated at about 33 ft. To determine the exact depth of the tailings and to obtain material for chemical analysis, another auger hole (KMT2A) was drilled at the same location as auger hole no. 2 (figure 13). The interface of the bottom of the tailings pile and the original surface of the wash was encountered at 38.3 ft. Not only did this hole provide tailings samples for analysis, but it also provided a check on the accuracy of seismic methods, which were being tested as noninvasive tools for depth determination.

Two other auger holes (AH18 and AH19) were dug near what appeared to be an area of buried drums, located on the southwest end of the tailings dam on level 3 (figure 13). No buried drums were found; analyses of samples collected from the two auger holes are listed in table A-3.

Soil samples

Soil was collected from 22 sites on the ridge north and northeast of the tailings impoundment (figure 13). The sites were spaced about 100 ft apart along a 2,000-ft traverse. The purpose was to determine the background concentrations of the target elements in the soil, as well as to determine if samples from the surface had higher concentrations of the elements as a result of contamination from windblown material from the tailings. Therefore, two soil samples were collected at each soil sample site: one from the surface, and one from a depth of 4 in. to 8 in.

At each sample site, the surface material, consisting of desert pavement and weeds, was scraped away and a sample of surface soil collected with a stainless-steel trowel. The material was sieved through a 10-mesh stainless-steel spoon to remove the larger material then placed in a 250 ml, HDPE, wide-mouthed bottle and sealed. The subsurface samples were collected and treated in the same manner.

All the sampling equipment was thoroughly dusted and cleaned after each sample. Because the soil was so dry, a stiff brush could be used to remove most particles of dirt from the screen and trowel. Washing the tools between samples was not considered necessary.

Eleven soil samples were collected along a 1,000-ft-long traverse on the ridge directly south of the east half of the tailings impoundment. Because the surface here had been disturbed by mining activity and was strewn with metal, wood,

glass, and other artifacts, surface samples were considered unreliable and definitely subject to contamination, so they were not collected. Subsurface samples were collected at a depth of 4 in. to 8 in. to determine background concentrations and to find out if the subsurface was contaminated.

Two soil samples (KMS-41 and KMS-42) were collected at a depth of 6 to 8 in. from a ridge about 2,200 ft north of the mill site. The purpose of these samples was to help determine background concentrations for the elements of interest in the soil.

Stream sediment samples

Seven stream sediment samples were collected from the wash south of the tailings impoundment. At each sample location, a composite sample consisting of several scoops of fine material were collected with a stainless-steel trowel and sieved through a 10-mesh stainless steel sieve to remove larger material and debris. The composite sample was then placed in a 250-cc HDPE bottle and sealed tightly. The wash, as well as most of the area south of the tailings, is strewn with abundant metal debris, such as rusty pipe, cans, wire, wood, and assorted trash; therefore, the probability of contamination of samples is high.

Rock samples

Four rock chip samples (KMR-1 -- KMR-4) were taken from outcrops southeast of the mill site near the main shaft. These samples consisted of the intrusive rock, hydrothermally altered rock, and vein material.

KMR-1 was a random chip of reddish-black intrusive rock exposed in cut. The rock contained large phenocrysts of feldspar 3/4 in. in diameter, as well as feldspar phenocrysts < 1/8 in. in diameter that showed slight hydrothermal alteration. Minor amounts of epidote and calcite were present on fractures in rock, which also contained localized gouge zones about 1 in. thick and 1/4-in.-thick quartz veins.

KMR-2 is a chip sample across an 18-ft-wide, hydrothermal vein. The hanging and foot walls of the vein are exposed in the outcrop.

KMR-3 is a 6-ft-long chip sample of altered intrusive rock that forms the hanging wall of the vein.

KMR-4 is a chip sample across a 6-ft-wide zone of greenish-white, quartz vein material.

KMD-1 and KMD-2 were from a waste dump north of the mill site.

Special samples

KMST-1 and KMST-2 are channel samples cut through 26-in.-thick and 18-in.-thick vertical sections of mill tailings in a wash southwest of the mill site. The tailings are mixed with abundant metal debris, glass, and wood.

KMSR-1 consisted of light-brown, fine- to medium-grained, rocky material collected from a 24-in. by 44-in. rectangular, filled-in hole in concrete foundation at upper mill site. Red brick was found at a depth of 7 in. below surface. Hole may be at base of old flue.

KMBC-1 was a sample of a white, moderately indurated material found in a rusty 50-gal barrel about 15 ft northwest of the concrete-capped collar of shaft in wash (figure 13). The material is only moderately indurated and is easily crushed into a white powdery clay, which effervesces in weak hydrochloric acid. Chemical analysis of this sample indicates that it is primarily lime.

Samples KMS-33 through KMS-38 were collected from the area of the mill that contains the remains of the thickener tanks and vats. KMS-33 consisted of fine-grained, gray tails underlying the foundation of a tank. KMS-34 consisted of fine- to medium-grained, reddish-brown material collected from a rectangular opening in floor of tank foundation near what appeared to be a feed pipe.

KMS-35, 36, and 37 were samples of the residue found on the rusted iron bottoms that were all that remained of three large tanks. Material was white to gray and very fine grained to powdery. Solid chunks of the substance showed layering and sedimentary-like flow features that were probably formed as the slurry was agitated in the tanks.

KMS-38 was collected with the auger from the center of a circle of concrete support pillars for a large tank. The material consisted of fine-grained, reddish-brown to gray, sandy soil.

KMS-39 was cut from an approximately 20-in.-long channel near the west end of what may have been a settling pond about 200 ft south of the main shaft. Material consisted of fine- to medium-grained, light-reddish-brown soil.

None of the material appeared to consist of mill tailings.

Water samples

Three water samples (KLM-001, 002, 003) were collected from Lake Mohave and analyzed for priority pollutant list (PPL) metals. The purpose of these samples was to determine if tailings material was contaminating the lake.

SAMPLE ANALYSIS

Introduction

All samples from both the 1993 and 1994 field seasons were analyzed at the same Contract Lab Program (CLP) laboratory, which does analysis and testing under numerous EPA contracts. The laboratory operates under a comprehensive Quality Assurance (QA) plan that provides a unified approach to supplying data that are scientifically sound, legally defensible, and of known and acceptable quality. The QA plan presents objectives, QA policies, organization, resumes, functional activities and specific Quality Assurance/Quality Control (QA/QC) activities for the chemical analysis of environmental samples. Among other issues, the QA plan carefully considers sample receipt, log-in, storage, chain of custody, glassware cleaning, sample preparation, instrument calibration, calculations, data review, and waste disposal. Both internal and independent laboratory audits are conducted to ensure adherence to analytical and QA/QC procedures and to verify that performance meets, or exceeds, state and federal requirements.

Methods of Analysis

Except for minor differences, the analytical methods used by the CLP laboratory are those commonly used throughout the industry and, except for the Jerome mercury analyzer, will not be described here in detail. The interested reader is referred to appropriate laboratory manuals for detailed descriptions.

A thin gold film undergoes a measurable increase in resistance in the presence of mercury vapor. The Jerome Model 301 Gold Film Mercury Detector uses this principle to accurately detect and measure extremely low-level mercury concentrations in solid, liquid, and gaseous matrices. The method was developed and patented by John McNerney, President, Jerome Instrument Corporation.

During analysis with the Model 301, mercury is first reduced to the elemental state by direct combustion of soils or by chemical oxidation-reduction of liquids. A 100 mg sample is used for analysis. As samples containing elemental mercury are introduced into the instrument, an internal pump draws the mercury across a gold-plated coil (the collector), which is contained in a plug-in module on the panel face. The gold coil collects and pre-concentrates the mercury as it is released from the sample.

The collector is then heated by an electric current for 12 seconds. The heat volatilizes the adsorbed mercury back into the flow system, where it passes over the gold films. Upon adsorption of the mercury vapor, the gold film sensor

increases in resistance. This increase is measured by means of a wheatstone bridge, is amplified electronically, and the results are displayed on the digital meter.

At the end of the day, the gold films are heated to desorb the accumulated mercury from the surfaces.

An auto circuit continually compensates for any drift in the resistance of the films. When mercury adsorbs on the sensor film, the rate of change in resistance of the film overrides the auto zero. The peak reading is displayed for a few seconds before the auto zero circuit begins to re-zero the imbalance in the wheatstone bridge.

SAMPLE PREPARATION

All samples collected for geochemical analysis during both the 1993 and 1994 field seasons, except for those from the near surface 1 in. of the tailings impoundment, were sent to the laboratory for preparation and analysis. Because all samples were to be analyzed for mercury, they were dried in an oven at less than 37°C (100°F) to prevent the volatilization of the mercury. The samples were then crushed, roll crushed, split and pulverized to minus 100 mesh. They were analyzed for total content of those elements of concern by the various techniques and methods listed in table A-1. For most of the analytical techniques between 20 and 100g of sample were used.

The surface samples were sieved to minus 200 mesh at WFOC, and only the minus 200 mesh material was sent to the laboratory analyzed to determine if the metal concentrations of this fraction were

high enough to constitute a health hazard from wind-blown material.

The type of digestion used depends on the specific element to be determined. For flame atomic absorption (FLAA) analyses, samples are digested in an aqua regia matrix (HNO_3 and HCl) and then analyzed by direct aspiration using a Varion AA spectrometer.

SAMPLE ANALYSES

Tables A-2 and A-3 are a complete list of analytical results from the contract laboratory for geochemical and water samples. Sample numbers in this figure match sample numbers used in this report.

North Soil Line

Sample Location In Plot	Sample Number
SUE	KMS-21
SS00E	KMS-30
SS00E	KMS-19
SS00E	KMS-18
SS00E	KMS-17
SS00E	KMS-16
SS00E	KMS-15
SS00E	KMS-14
SS00E	KMS-13
SS00E	KMS-12
SS00E	KMS-11
SS00E	KMS-10
SS00E	KMS-9
SS00E	KMS-8
SS00E	KMS-7
SS00E	KMS-6
SS00E	KMS-5
SS00E	KMS-4
SS00E	KMS-3
SS00E	KMS-2
SS00E	KMS-1



Figure A-1—Comparison of surface and subsurface gold concentrations

North Soil Line

Sample Location in Feet	Sample Number	Au Concentration (ppm)	
		Surface	Subsurface
S0E	KMS-21	0.177	0.029
S100E	KMS-20	.176	.022
S200E	KMS-19	.178	.031
S300E	KMS-18	.322	.021
S400E	KMS-17	.324	.031
S500E	KMS-16	.303	.036
S600E	KMS-15	.293	.143
S700E	KMS-14	.332	.062
S800E	KMS-13	.354	.032
S900E	KMS-12	.276	.021
S1000E	KMS-11	.191	.017
S1100E	KMS-10	.177	.014
S1200E	KMS-9	.142	.003
S1300E	KMS-8	.192	.006
S1400E	KMS-7	.124	.007
S1500E	KMS-6	.126	.003
S1600E	KMS-5	.211	.003
S1700E	KMS-4	.116	.025
S1800E	KMS-3	.105	.031
S1900E	KMS-2	.055	.003
S2000E	KMS-1	.057	.003

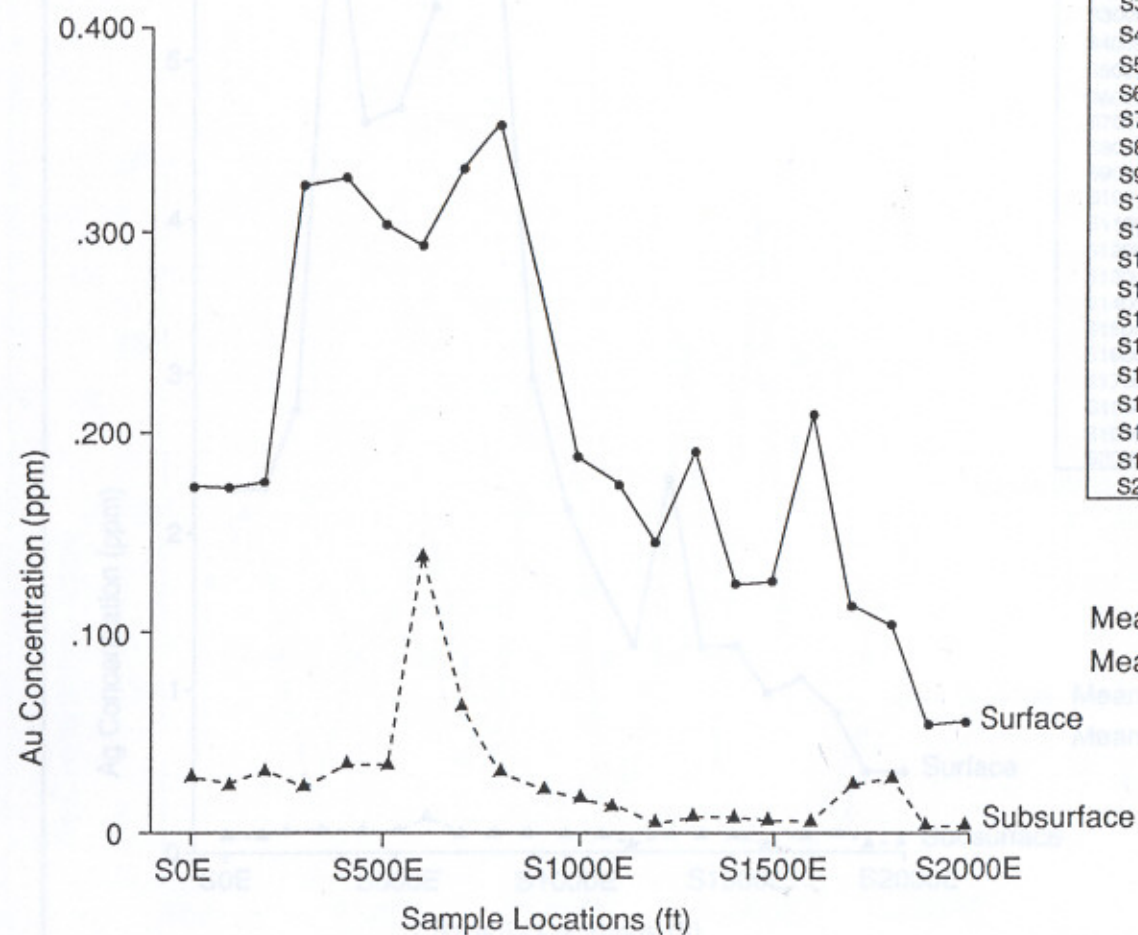


Figure A-1.--Comparison of surface and subsurface gold concentrations

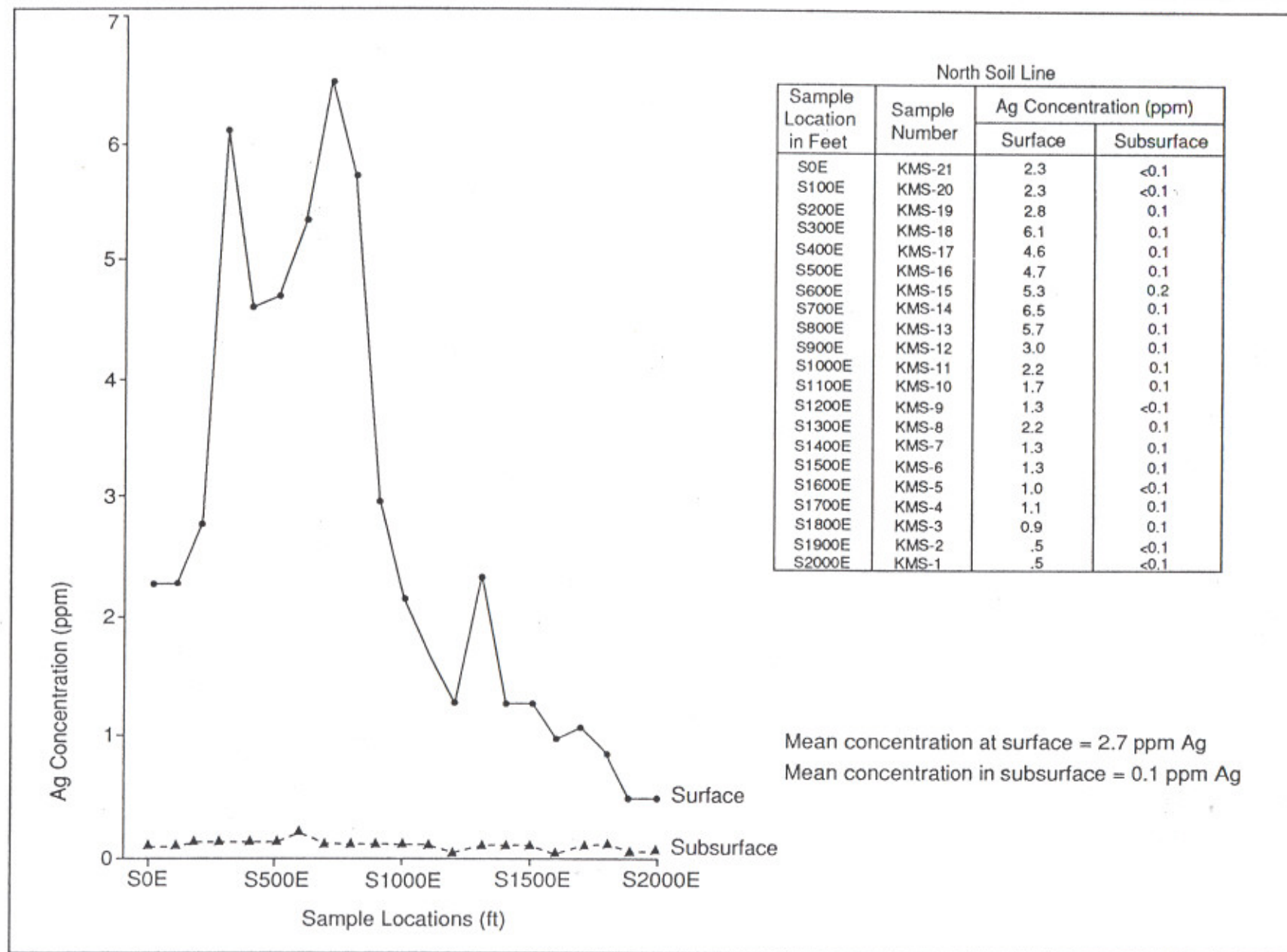


Figure A-2.--Comparison of surface and subsurface silver concentrations

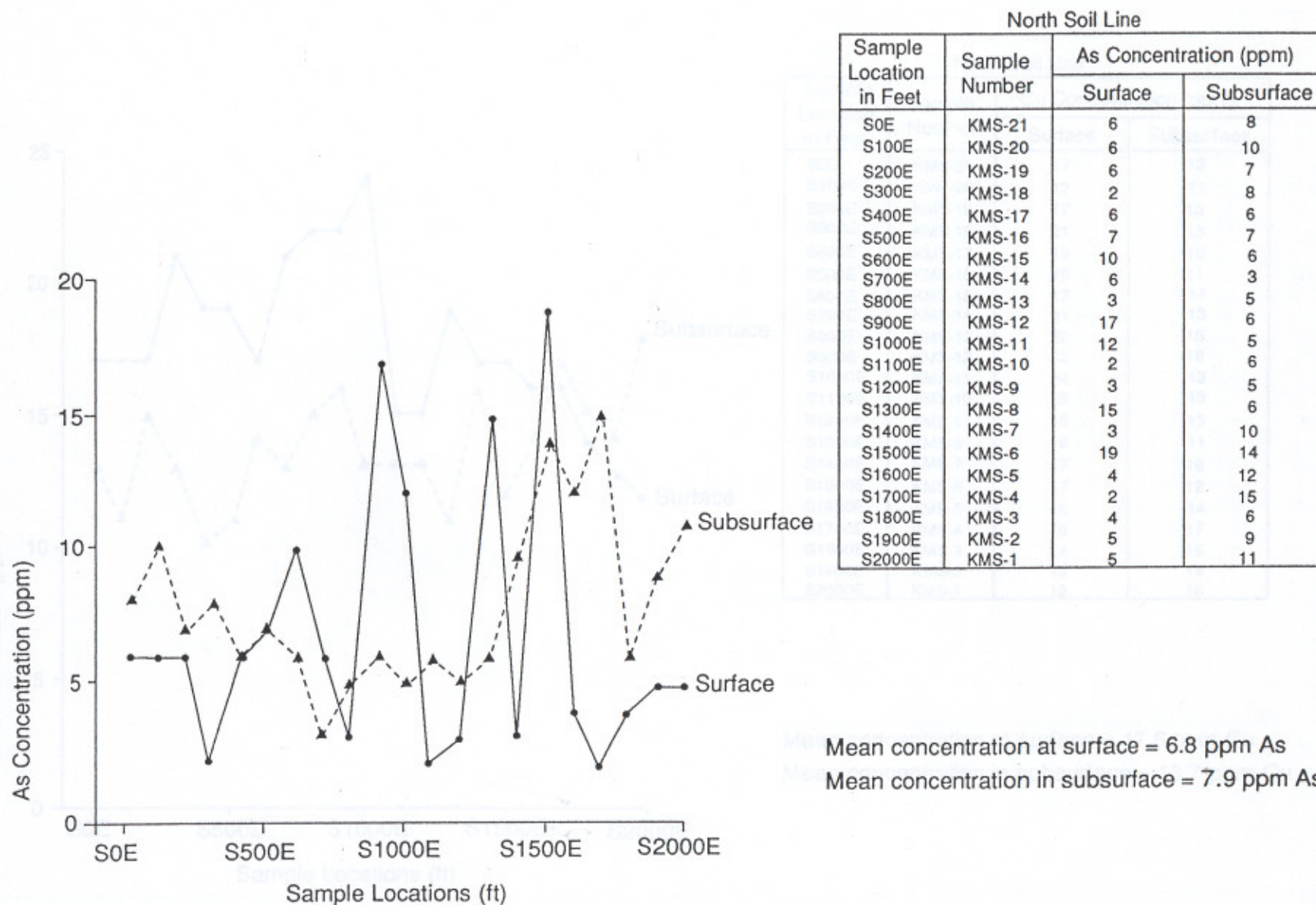
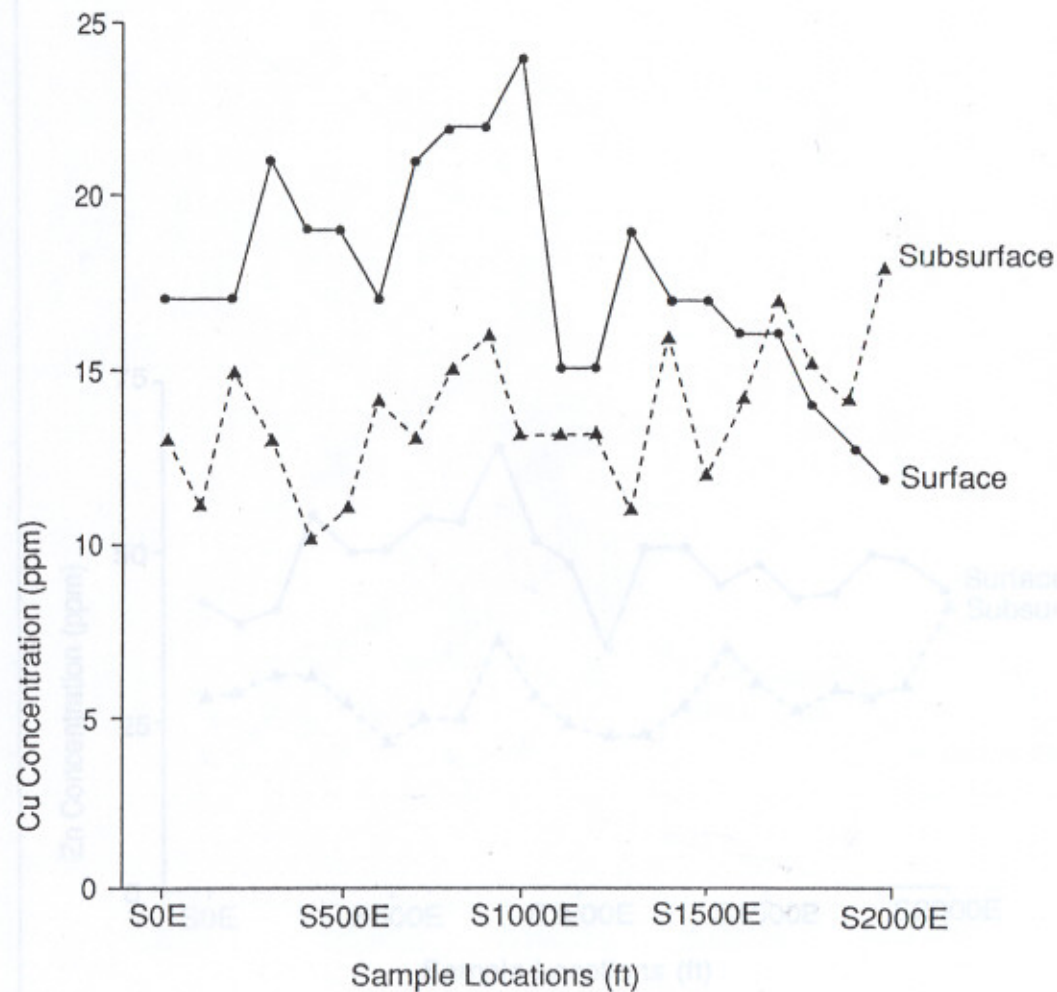


Figure A-3.--Comparison of surface and subsurface arsenic concentrations



North Soil Line			
Sample Location in Feet	Sample Number	Cu Concentration (ppm)	
		Surface	Subsurface
S0E	KMS-21	17	13
S100E	KMS-20	17	11
S200E	KMS-19	17	15
S300E	KMS-18	21	13
S400E	KMS-17	19	10
S500E	KMS-16	19	11
S600E	KMS-15	17	14
S700E	KMS-14	21	13
S800E	KMS-13	22	15
S900E	KMS-12	22	16
S1000E	KMS-11	24	13
S1100E	KMS-10	15	13
S1200E	KMS-9	15	13
S1300E	KMS-8	19	11
S1400E	KMS-7	17	16
S1500E	KMS-6	17	12
S1600E	KMS-5	16	14
S1700E	KMS-4	16	17
S1800E	KMS-3	14	15
S1900E	KMS-2	13	14
S2000E	KMS-1	12	18

Mean concentration at surface = 17.6 ppm Cu

Mean concentration in subsurface = 13.7 ppm Cu

Figure A-4.--Comparison of surface and subsurface copper concentrations

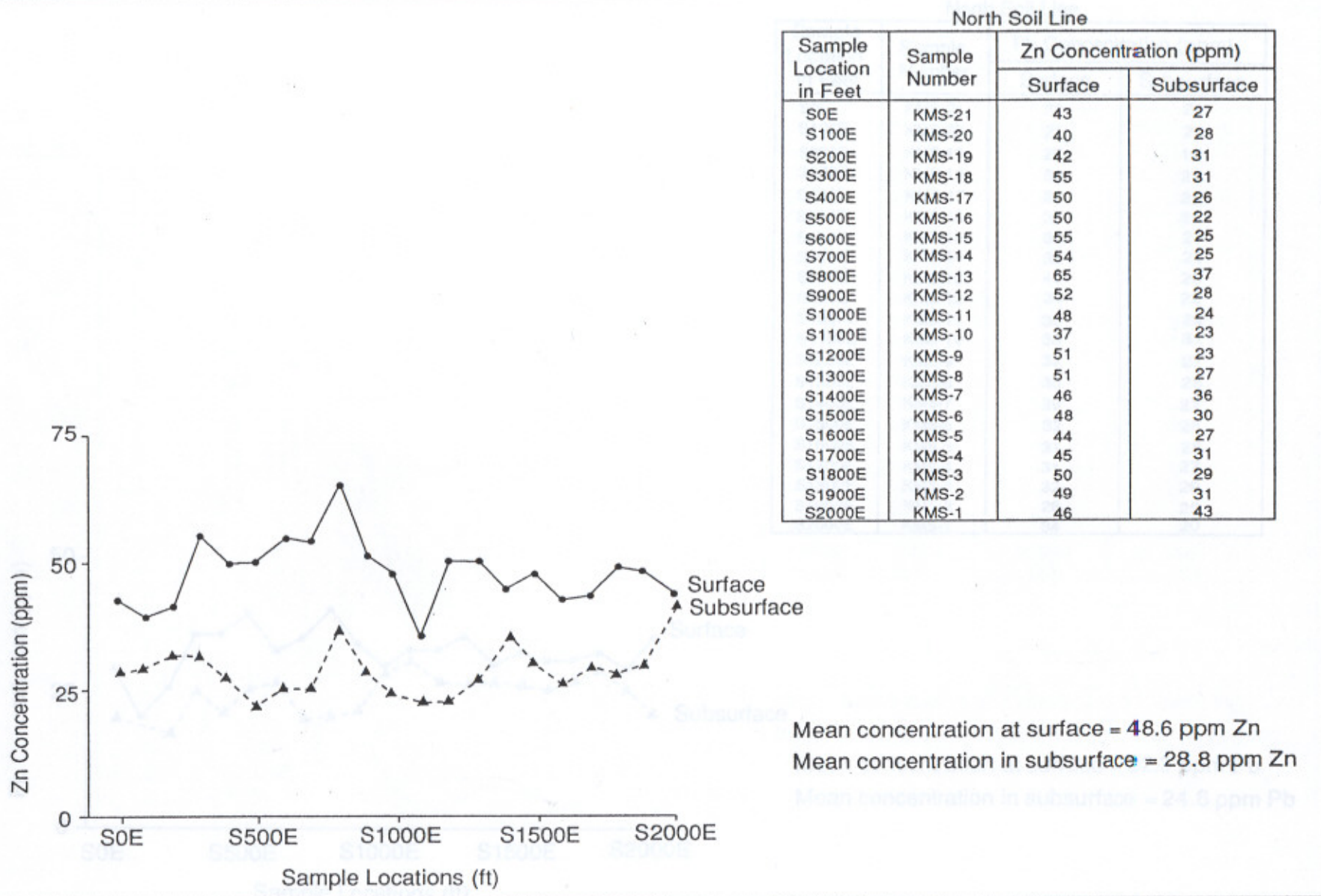


Figure A-5.--Comparison of surface and subsurface zinc concentrations

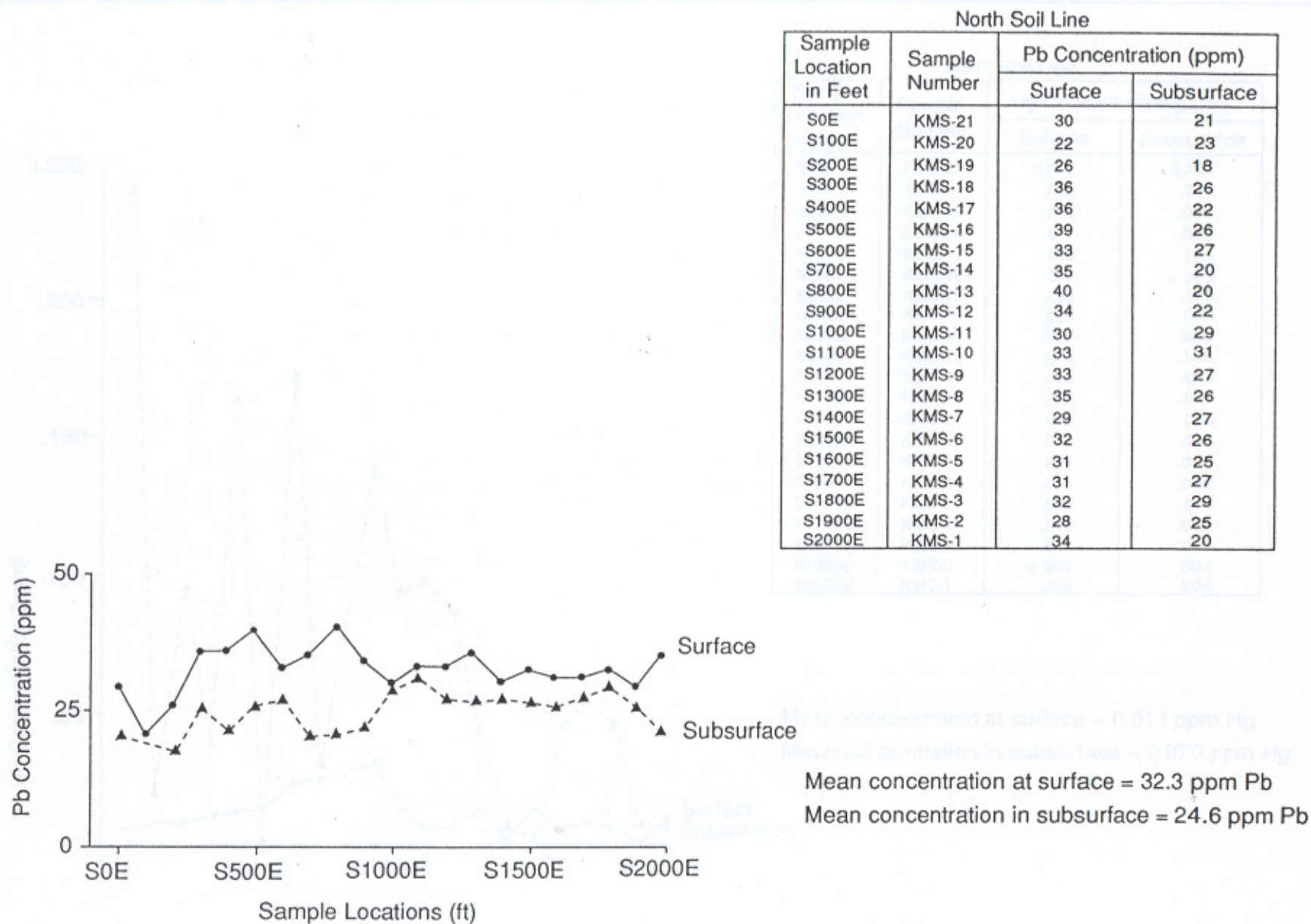


Figure A-6.—Comparison of surface and subsurface lead concentrations

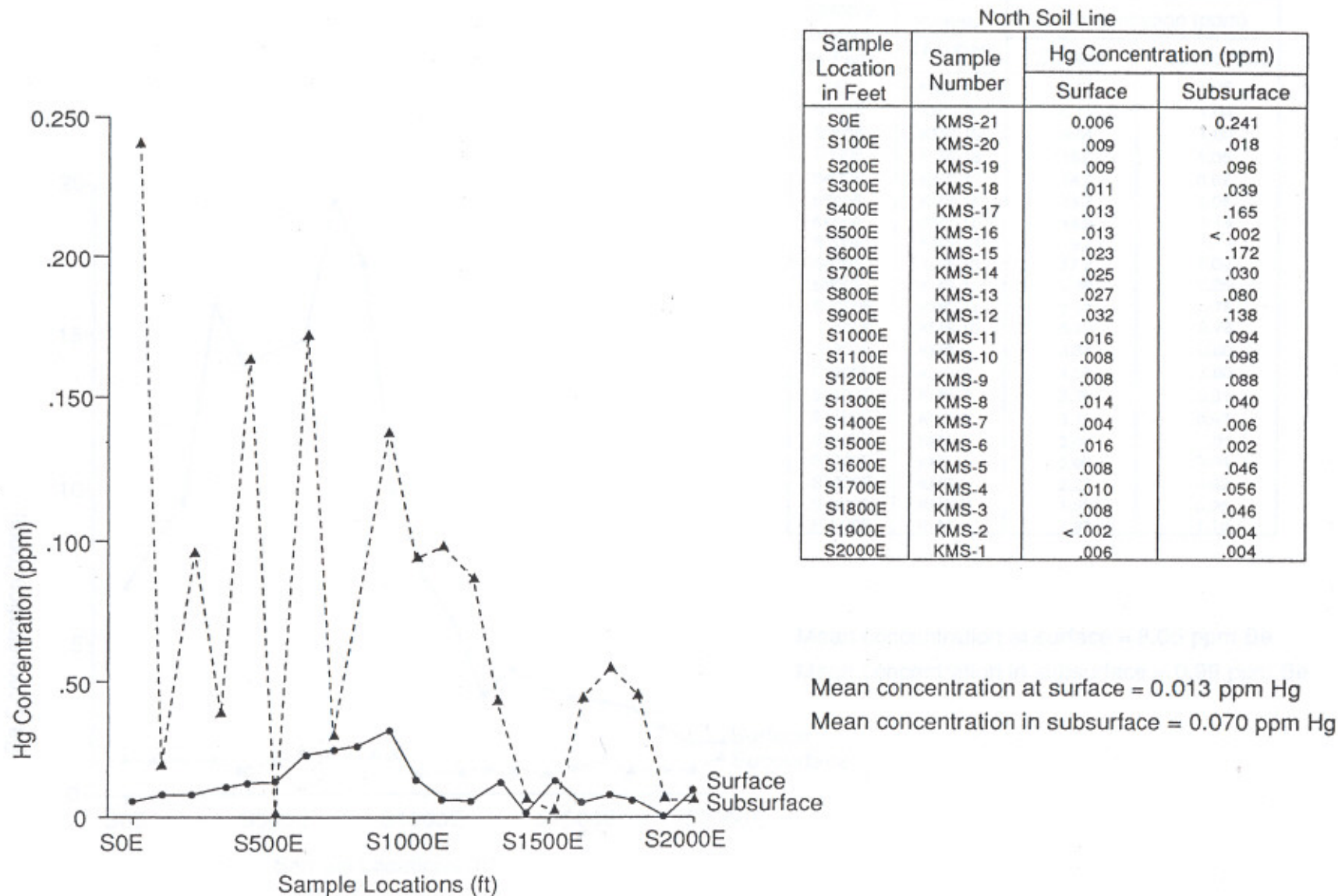


Figure A-7.—Comparison of surface and subsurface mercury concentrations

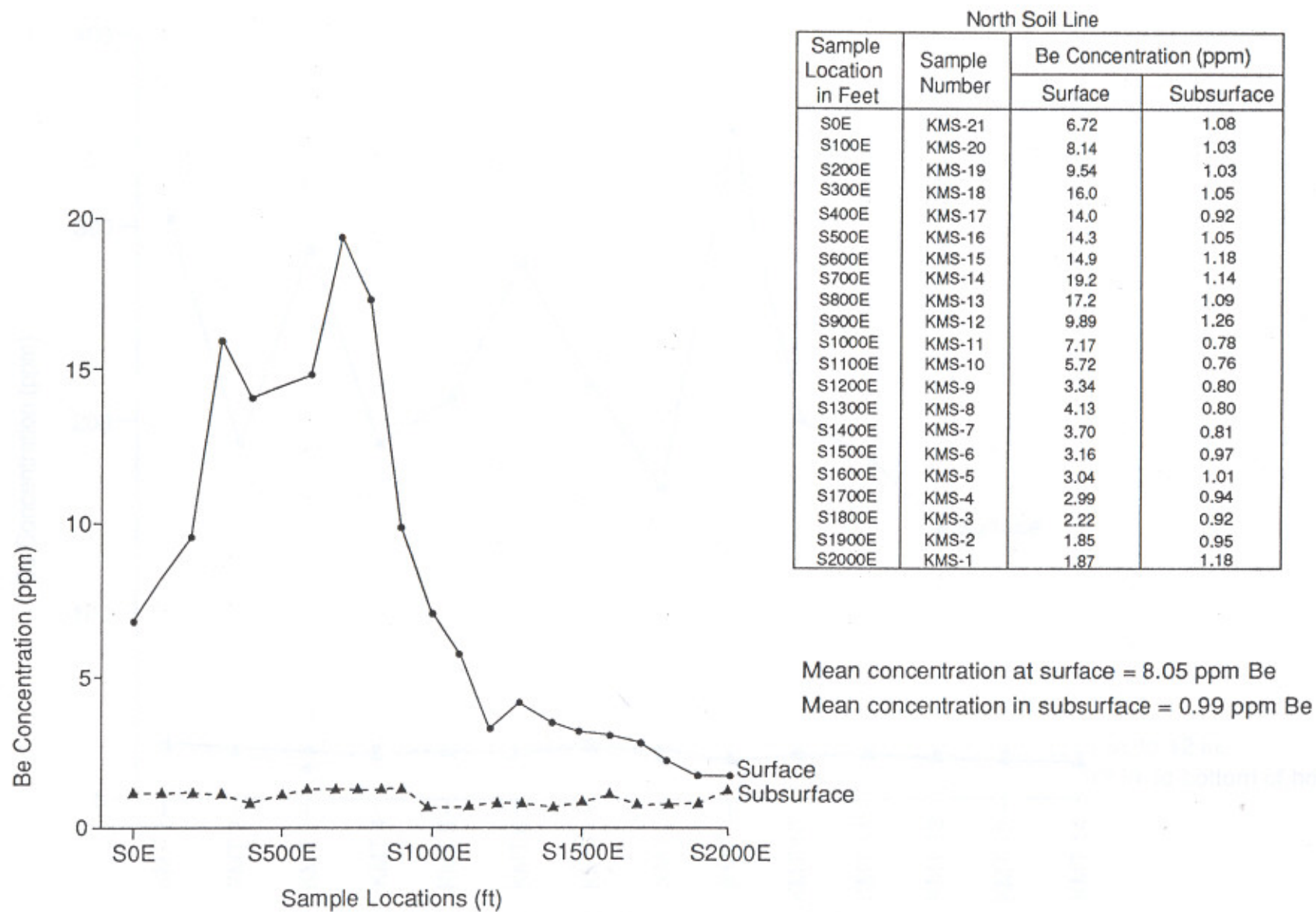


Figure A-8.--Comparison of surface and subsurface beryllium concentrations

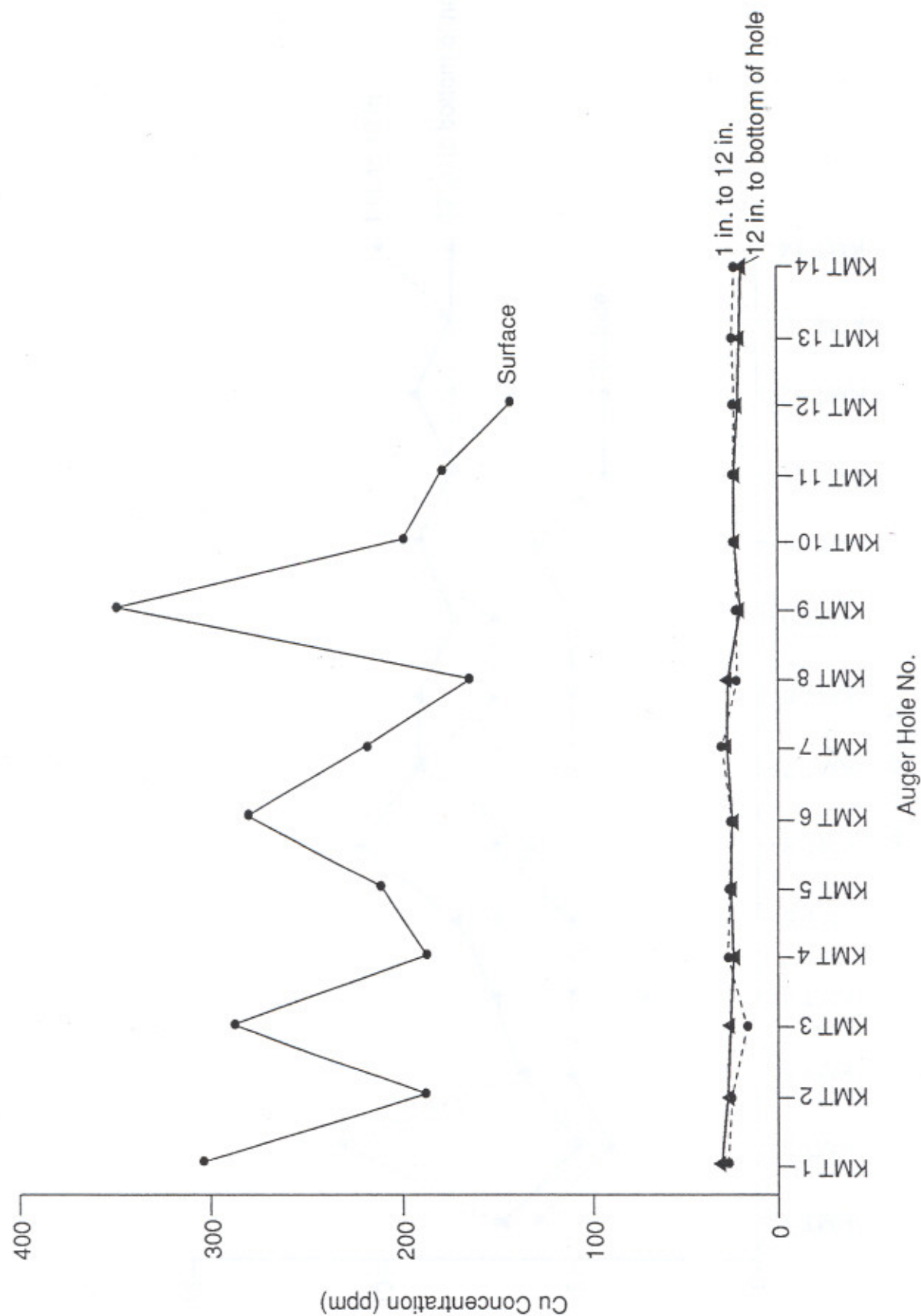


Figure A-9.--Comparison of copper concentrations in auger hole samples

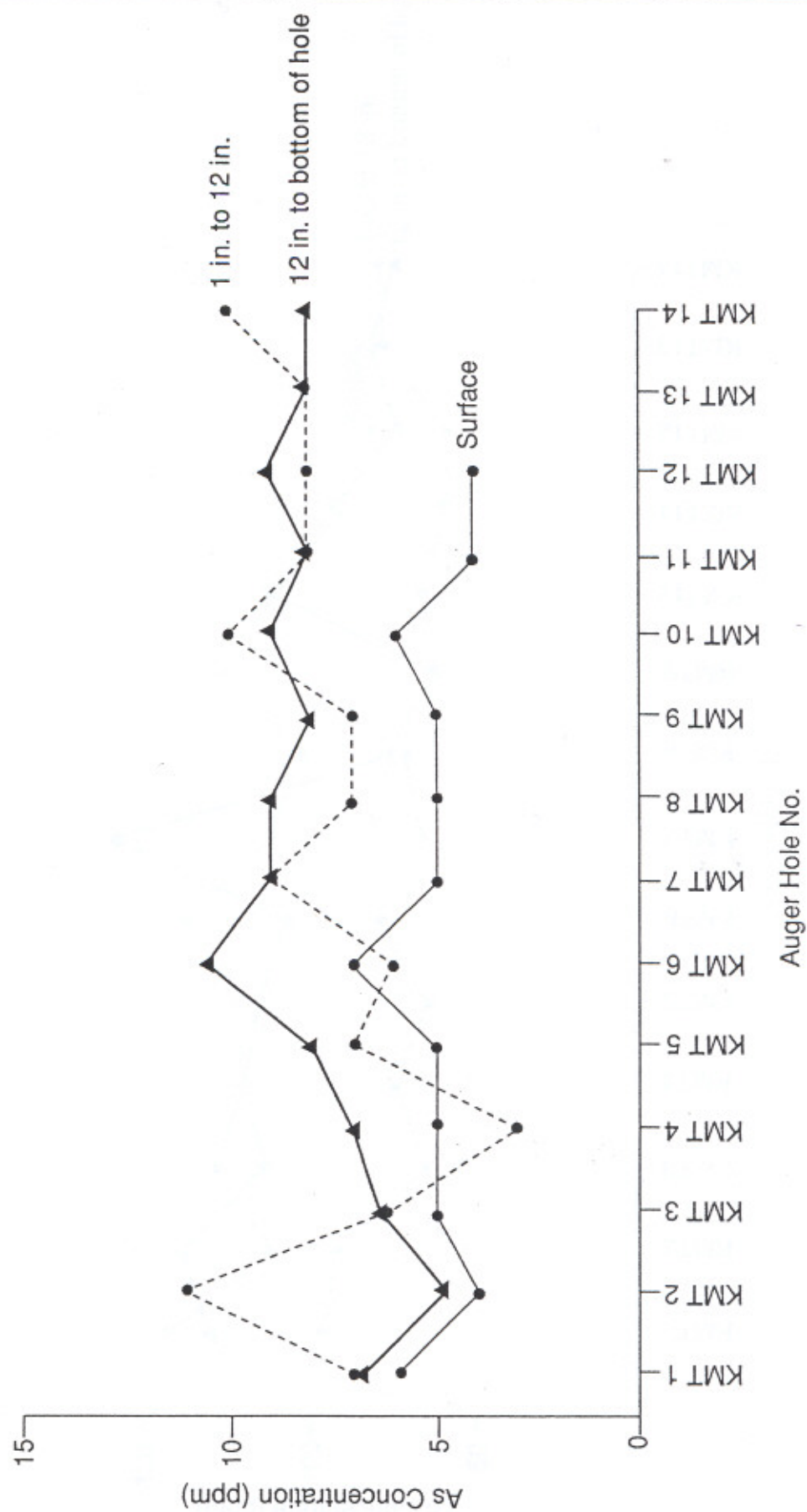


Figure A-10.--Comparison of arsenic concentrations in auger hole samples

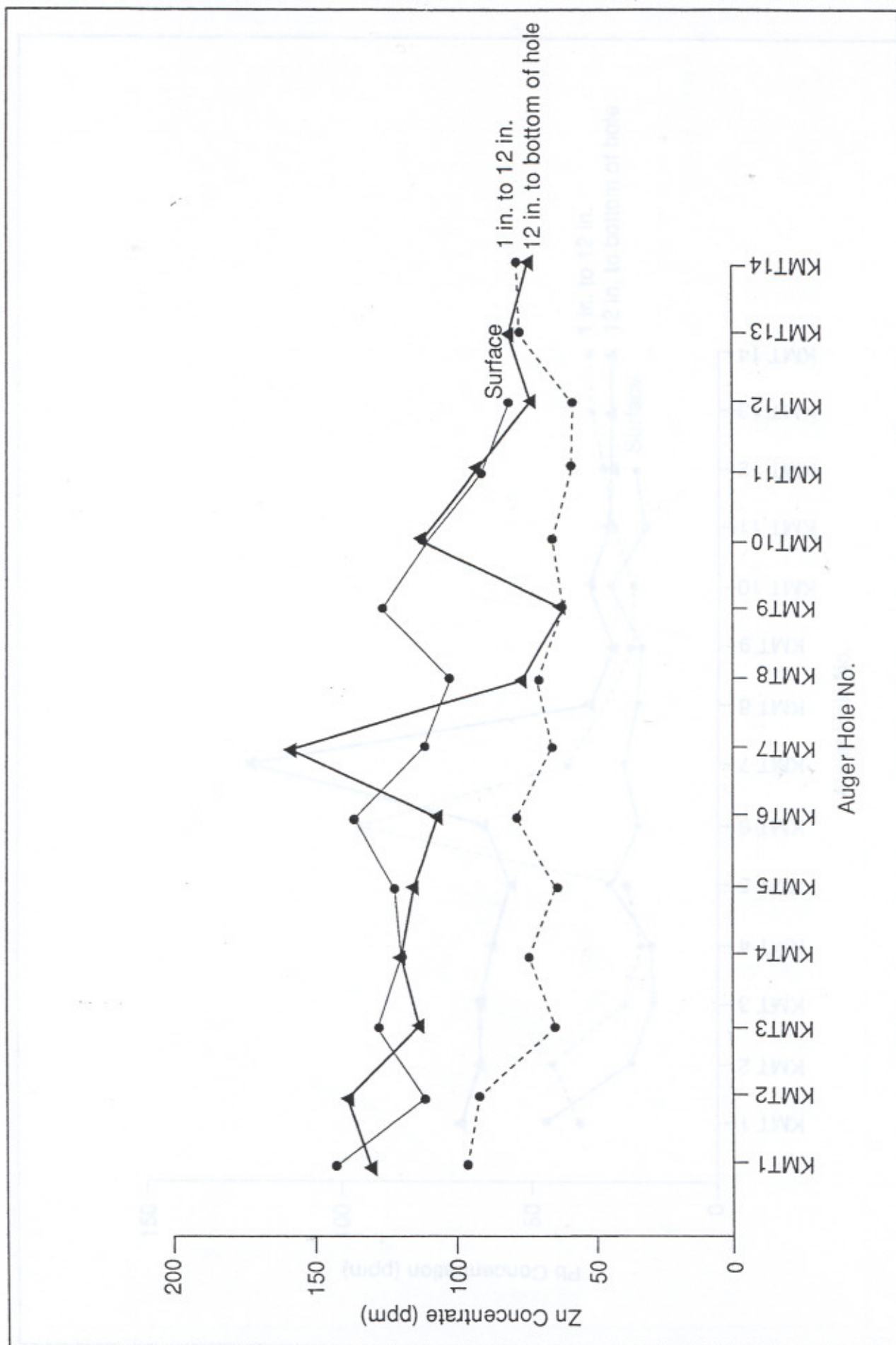


Figure A-11.--Comparison of zinc concentrations in auger hole samples

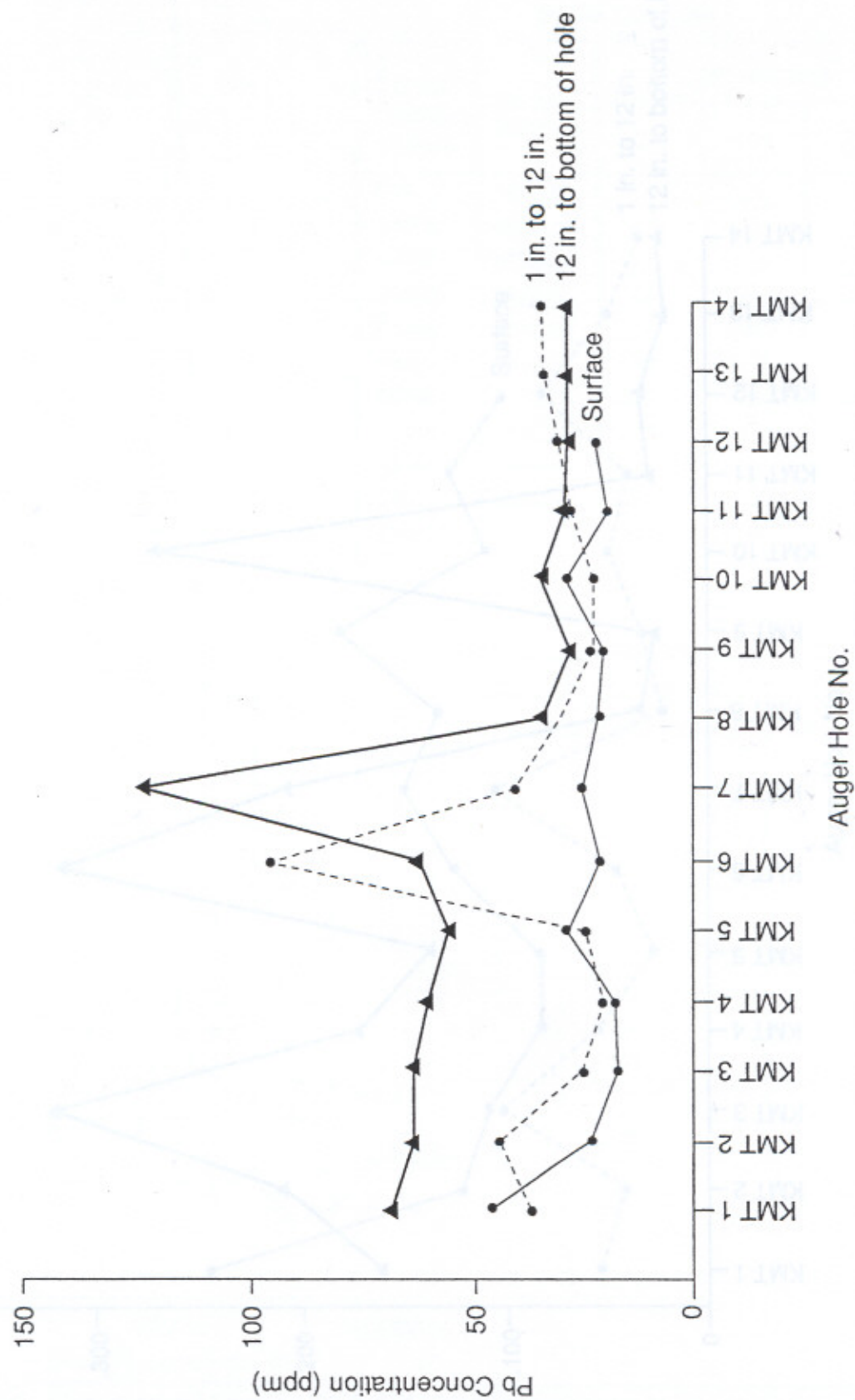


Figure A-12.--Comparison of lead concentrations in auger hole samples

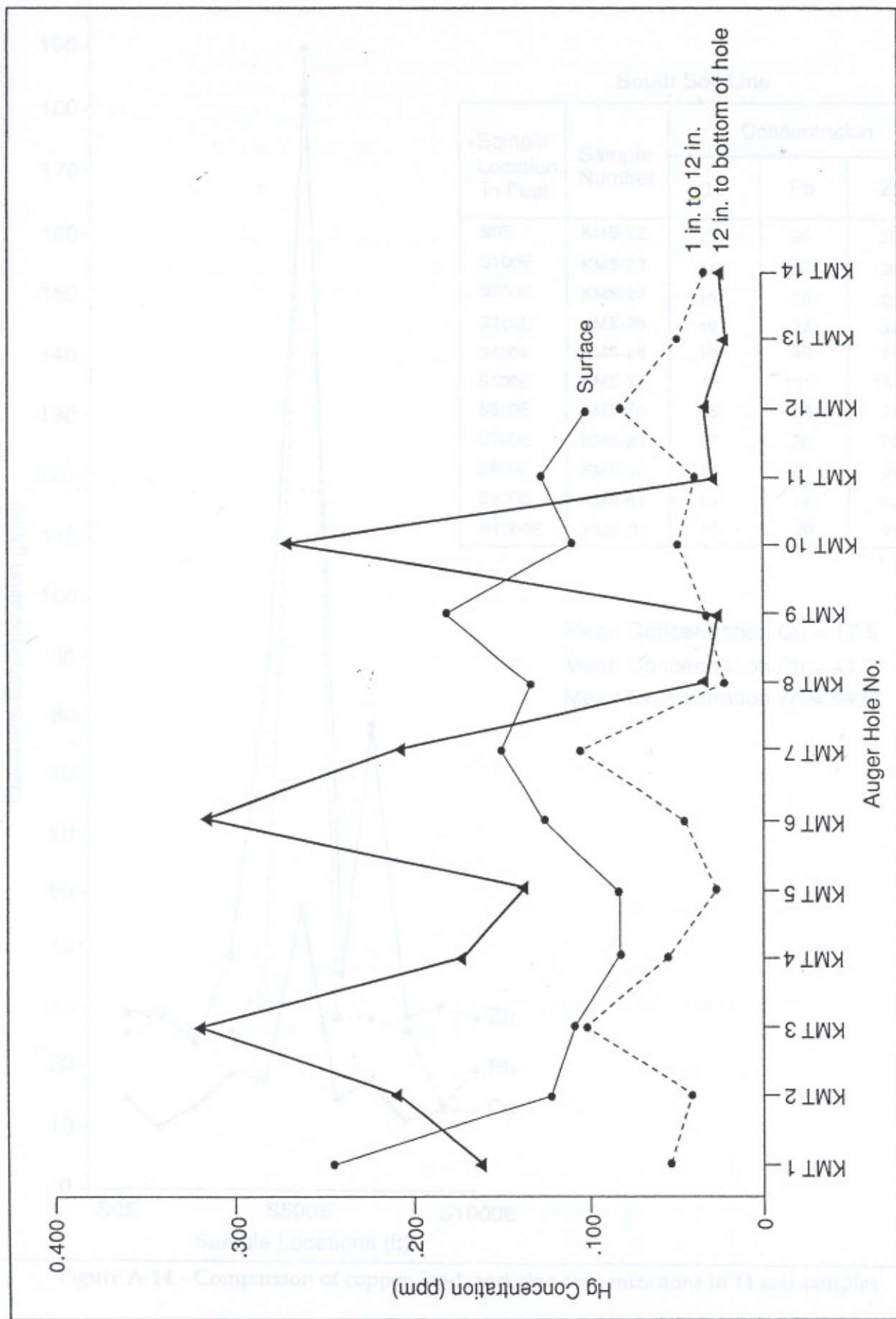


Figure A-13.--Comparison of mercury concentrations in auger hole samples

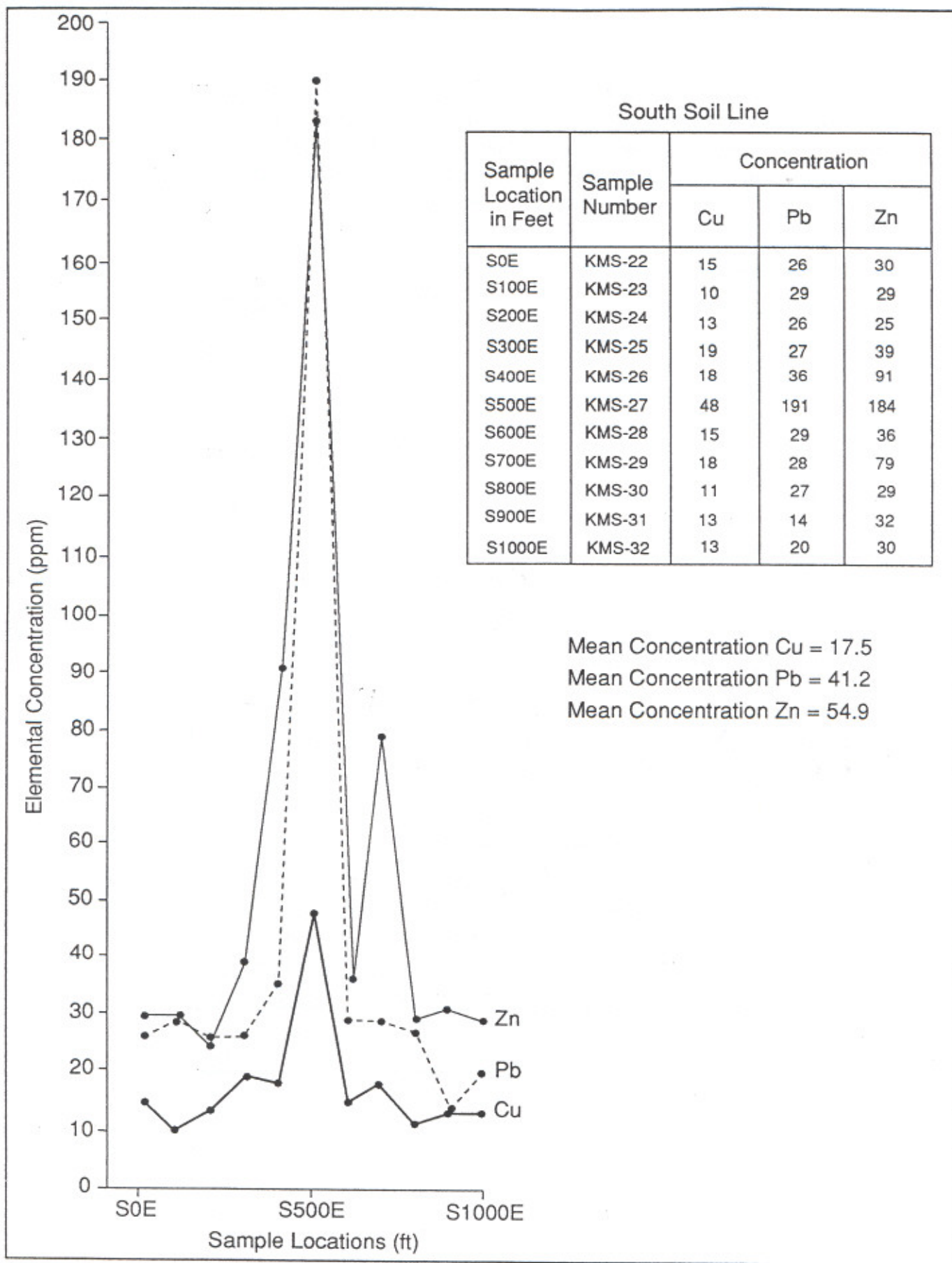


Figure A-14.--Comparison of copper, lead, and zinc concentrations in 11 soil samples

Table A-1.--Techniques used to analyze the Katherine project samples
 (FA+AA--Fire Assay + Atomic Absorption; FA--Fire Assay; ICAP-- Inductively
 Coupled Argon Plasma; GFAA--Graphite Furnace Atomic Absorption; FLAA--Flame
 Atomic Absorption; CVAA--Cold Vapor Atomic Absorption;
 IR--Infrared Spectrophotometer)

Technique	Analyte determined
FA + AA	Au, Ag
FA	Ounces/ton AG in samples having > 25 ppm Ag
ICAP	Be
GFAA	As, Sb
FLAA	Cd, Cu, Pb, Zn
CVAA	Hg in tailings and rocks
Colorimetric	CN-T, CN-WAD
Gravimetric	LOI (loss on ignition), SiO ₂
Jerome method	Hg in soils
Fusion/ICAP	Na ₂ O, CaO, MnO, MgO, Fe(as Fe ₂ O ₃), TiO ₂ , Al ₂ O ₃ , K ₂ O, BaO, P ₂ O ₅
ICAP scan	Sb, Al, As, Ba, Bi, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Si, Na, Sr, Sn, Ti, V, Zn
CaCO ₃ equivalent (titration)	Acid neutralization potential (ANP) of the mill tailings
LECO furnace (Combustion IR)	Acid generation potential (AGP) of the mill tailings

Table A-2. Tailings auger, channel, soil, and stream sediment sample analyses from 1992 and 1993 field season

Sample no.	As	Hg	Pb	CN-T	CN-W	CN-F	ANP	AGP	Au	Ag	Ag	Zn	Cu	Cd	Sb
units:	ppm	ppb	ppm	ppm	ppm	ppm	ppt	ppt	ppb	ppm	oz/t	ppm	ppm	ppm	ppm
method:	GFAA	CVAA	FLAA	COLOR	COLOR	ISE	TITRA	LECO	FA+AA	FA+AA	FA	FLAA	FLAA	FLAA	GFAA
KMT1-1	7	53	38	1.86	<1	N/R	N/R	N/R	398	5.3	N/A	96	26	1	N/R
KMT1-2	6	78	27	N/R	N/R	N/R	N/R	N/R	315	4.7	N/A	81	33	33	N/R
KMT1-3	8	274	91	N/R	N/R	N/R	N/R	N/R	316	14	N/A	113	29	N/R	N/R
KMT1-4	9	185	85	N/R	N/R	N/R	N/R	N/R	360	24	N/A	123	36	N/R	N/R
KMT1-5	20	222	74	9.5	1.97	1.48	N/R	N/R	690	>25	1.00	110	23	<1	N/R
KMT1-6	8	175	33	N/R	N/R	N/R	N/R	N/R	354	13	N/A	94	23	N/R	N/R
KMT1-7	4	236	62	N/R	N/R	N/R	N/R	N/R	356	19	N/A	149	32	N/R	N/R
KMT1-8	2	117	89	N/R	N/R	N/R	N/R	N/R	467	17	N/A	160	36	N/R	N/R
KMT1-9	2	90	74	N/R	N/R	N/R	N/R	N/R	728	16	N/A	167	37	N/R	N/R
KMT1-10	2	80	87	6.29	<1	N/R	N/R	N/R	1117	>25	.7	170	35	1	N/R
KMT2-1	11	40	44	1.92	<1	N/R	N/R	N/R	334	4.3	N/A	91	24	<1	N/R
KMT2-2	7	71	41	N/R	N/R	N/R	N/R	N/R	189	3.7	N/A	84	21	N/R	N/R
KMT2-3	9	435	52	N/R	N/R	N/R	N/R	N/R	515	21	N/A	114	22	N/R	N/R
KMT2-4	9	466	42	N/R	N/R	N/R	N/R	N/R	486	>25	.78	120	19	N/R	N/R
KMT2-5	8	340	62	3.72	<1	N/R	N/R	N/R	280	17	N/A	153	23	<1	N/R
KMT2-6	3	211	58	N/R	N/R	N/R	N/R	N/R	316	15	N/A	147	32	N/R	N/R
KMT2-7	2	145	81	N/R	N/R	N/R	N/R	N/R	312	15	N/A	146	44	N/R	N/R
KMT2-8	1	87	73	N/R	N/R	N/R	N/R	N/R	373	15	N/A	150	27	N/R	N/R
KMT2-9	2	71	81	N/R	N/R	N/R	N/R	N/R	417	14	N/A	151	24	N/R	N/R
KMT2-10	2	60	86	2.38	<1	N/R	N/R	N/R	428	15	N/A	165	26	<1	N/R
KMT3-1	6	101	25	1.15	<1	N/R	N/R	N/R	341	3.7	N/A	64	18	<1	N/R
KMT3-2	9	349	40	N/R	N/R	N/R	N/R	N/R	575	5.8	N/A	81	25	N/R	N/R
KMT3-3	6	699	36	N/R	N/R	N/R	N/R	N/R	510	11	N/A	74	25	N/R	N/R
KMT3-4	6	158	38	N/R	N/R	N/R	N/R	N/R	258	17	N/A	91	28	N/R	N/R
KMT3-5	9	140	75	3.96	2.32	2.14	N/R	N/R	272	>25	.73	122	26	<1	N/R
KMT3-6	9	246	65	N/R	N/R	N/R	N/R	N/R	429	>25	.94	127	24	N/R	N/R
KMT3-7	7	219	145	N/R	N/R	N/R	N/R	N/R	442	23	N/A	113	22	N/R	N/R
KMT3-8	6	106	69	N/R	N/R	N/R	N/R	N/R	295	15	N/A	141	39	N/R	N/R
KMT3-9	3	107	78	N/R	N/R	N/R	N/R	N/R	378	23	N/A	148	44	N/R	N/R
KMT3-10	2	279	70	4.1	1.13	1.13	N/R	N/R	667	>25	2.80	160	42	1	N/R
KMT3-11	7	898	25	N/R	N/R	N/R	N/R	N/R	7911	>25	1.34	65	10	N/R	N/R
KMT4-1	3	57	20	1.6	<1	N/R	N/R	N/R	347	4.3	N/A	73	24	<1	N/R
KMT4-2	9	120	38	N/R	N/R	N/R	N/R	N/R	406	3.5	N/A	77	27	N/R	N/R
KMT4-3	8	160	25	N/R	N/R	N/R	N/R	N/R	306	3.4	N/A	66	25	N/R	N/R
KMT4-4	13	229	74	N/R	N/R	N/R	N/R	N/R	268	8.5	N/A	82	25	N/R	N/R
KMT4-5	9	126	83	3.55	1.3	1.13	N/R	N/R	219	18	N/A	123	27	<1	N/R
KMT4-6	6	213	65	N/R	N/R	N/R	N/R	N/R	266	>25	1.03	126	21	N/R	N/R
KMT4-7	7	210	73	N/R	N/R	N/R	N/R	N/R	407	>25	.79	132	21	N/R	N/R
KMT4-8	3	188	61	N/R	N/R	N/R	N/R	N/R	236	17	N/A	173	36	N/R	N/R
KMT4-9	1	131	68	4.37	<1	N/R	N/R	N/R	356	>25	.9	176	37	<1	N/R
KMT5-1	7	26	26	1.39	<1	N/R	N/R	N/R	288	7	N/A	64	29	<1	N/R
KMT5-2	5	42	25	N/R	N/R	N/R	N/R	N/R	332	3.7	N/A	77	28	N/R	N/R
KMT5-3	11	42	53	N/R	N/R	N/R	N/R	N/R	205	3.3	N/A	84	26	N/R	N/R
KMT5-4	10	175	51	N/R	N/R	N/R	N/R	N/R	294	>25	.74	107	24	N/R	N/R
KMT5-5	6	298	93	44.6	<1	N/R	N/R	N/R	284	>25	.98	194	45	<1	N/R
KMT6-1	6	43	97	1.2	<1	N/R	N/R	N/R	708	6.2	N/A	79	29	<1	N/R
KMT6-2	7	112	25	N/R	N/R	N/R	N/R	N/R	279	5.4	N/A	75	27	N/R	N/R
KMT6-3	12	663	73	N/R	N/R	N/R	N/R	N/R	224	6.8	N/A	81	23	N/R	N/R
KMT6-4	15	203	82	N/R	N/R	N/R	N/R	N/R	252	19	N/A	113	26	N/R	N/R
KMT6-5	8	298	71	30.68	<1	N/R	N/R	N/R	343	23	N/A	157	33	<1	N/R
KMT7-1	9	108	40	1.99	<1	N/R	N/R	N/R	294	5.5	N/A	66	34	<1	N/R
KMT7-2	11	151	151	N/R	N/R	N/R	N/R	N/R	287	>25	.74	95	28	N/R	N/R
KMT7-3	7	269	97	N/R	N/R	N/R	N/R	N/R	333	>25	1.11	219	36	N/R	N/R
KMT8-1	7	24	30	3.34	<1	N/R	N/R	N/R	212	7.3	N/A	70	26	1	N/R
KMT8-2	10	34	40	N/R	N/R	N/R	N/R	N/R	272	3.4	N/A	75	27	N/R	N/R
KMT8-3	8	32	28	N/R	N/R	N/R	N/R	N/R	294	3.1	N/A	77	29	N/R	N/R
KMT9-1	7	33	23	1.82	1.15	0.56	N/R	N/R	353	4.9	N/A	61	29	<1	N/R
KMT9-2	8	29	28	N/R	N/R	N/R	N/R	N/R	637	3.8	N/A	62	24	N/R	N/R
KMT10-1	10	52	24	2.28	<1	N/R	N/R	N/R	400	3.4	N/A	65	27	<1	N/R
KMT10-2	9	272	35	N/R	N/R	N/R	N/R	N/R	336	14	N/A	111	28	N/R	N/R

Table A-2. Tailings auger, channel, soil, and stream sediment sample analyses from 1992 and 1993 field season-continued

Sample no.	As	Hg	Pb	CN-T	CN-W	CN-F	ANP	AGP	Au	Ag	Ag	Zn	Cu	Cd	Sb
units:	ppm	ppb	ppm	ppm	ppm	ppm	ppt	ppt	ppb	ppm	oz/t	ppm	ppm	ppm	ppm
method:	GFAA	CVAA	FLAA	COLOR	COLOR	ISE	TITRA	LECO	FA+AA	FA+AA	FA	FLAA	FLAA	FLAA	GFAA
KMT11-1	8	40	28	1.21	<1	N/R	N/R	N/R	249	4.5	N/A	58	29	<1	N/R
KMT11-2	8	32	29	N/R	N/R	N/R	N/R	N/R	467	3.1	N/A	91	30	N/R	N/R
KMT12-1	8	82	30	2.21	<1	N/R	N/R	N/R	305	7.2	N/A	58	29	<1	N/R
KMT12-2	9	37	28	N/R	N/R	N/R	N/R	N/R	456	3.6	N/A	73	29	N/R	N/R
KMT13-1	8	49	33	1.48	<1	N/R	N/R	N/R	197	4.6	N/A	77	31	<1	N/R
KMT13-2	8	21	29	N/R	N/R	N/R	N/R	N/R	173	2.2	N/A	80	26	N/R	N/R
KMT14-1	10	33	35	1.57	<1	N/R	N/R	N/R	193	4	N/A	78	32	<1	N/R
KMT14-2	8	27	30	N/R	N/R	N/R	N/R	N/R	274	2.4	N/A	74	24	N/R	N/R
KMT15-1	9	40	33	1.63	<1	N/R	N/R	N/R	321	4.8	N/A	75	28	<1	N/R
KMT15-2	8	21	31	N/R	N/R	N/R	N/R	N/R	478	4.2	N/A	67	22	N/R	N/R
KMT15-3	11	17	32	N/R	N/R	N/R	N/R	N/R	584	12	N/A	79	23	N/R	N/R
KMT15-4	7	19	33	N/R	N/R	N/R	N/R	N/R	254	4	N/A	79	26	N/R	N/R
KMT15-5	10	111	49	1.69	<1	N/R	N/R	N/R	208	15	N/A	57	17	1	N/R
KMT1-5A	N/R	N/R	N/R	N/R	N/R	N/R	183	<.3	N/R	N/R	N/A	N/R	N/R	N/R	N/R
KMT2-5A	N/R	N/R	N/R	N/R	N/R	N/R	40.2	<.3	N/R	N/R	N/A	N/R	N/R	N/R	N/R
KMT3-5A	N/R	N/R	N/R	N/R	N/R	N/R	148	<.3	N/R	N/R	N/A	N/R	N/R	N/R	N/R
KMT4-5A	N/R	N/R	N/R	N/R	N/R	N/R	188	<.3	N/R	N/R	N/A	N/R	N/R	N/R	N/R
KMT1-1A	8	69	52	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	81	27	<1	<.5
KMT2-1A	11	42	30	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	74	23	<1	<.5
KMT3-1A	8	18	22	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	77	27	<1	<.5
KMT4-1A	14	13	21	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	71	28	<1	<.5
KMT5-1A	7	11	29	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	75	29	<1	<.5
KMT6-1A	8	23	26	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	80	26	<1	<.5
KMT7-1A	8	23	29	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	63	28	<1	<.5
KMT8-1A	5	33	27	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	60	23	<1	<.5
KMT9-1A	7	31	25	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	65	38	<1	<.5
KMT10-1A	6	35	28	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	70	22	<1	<.5
KMT11-1A	5	22	25	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	45	23	<1	<.5
KMT12-1A	6	31	24	N/R	N/R	N/R	N/R	N/R	N/A	N/A	N/A	51	22	<1	<.5
KMT17-1	13	29	27	2.33	<1	<1	N/R	N/R	987	3.6	N/A	73	30	<1	<.5
KMT17-2	19	78	330	3.55	<1	<1	N/R	N/R	221	3.1	N/A	324	318	<1	10
KMT17-3	11	67	25	1.23	<1	<1	N/R	N/R	41	0.2	N/A	79	19	<1	<.5
KM-1	15	59	26	N/A	N/A	N/A	N/A	N/A	225	4.6	N/A	86	25	<1	<.5
KM-2	5	60	3	N/A	N/A	N/A	N/A	N/A	24	0.6	N/A	36	6	<1	0.8
KM-3	15	121	16	N/A	N/A	N/A	N/A	N/A	14	0.2	N/A	65	13	<1	<.5
KM-4	6	47	30	1.419	0.744	0.15	N/A	N/A	305	3.5	N/A	76	22	<1	<.5
KM-5	7	187	92	9.481	0.789	0.32	N/A	N/A	260	>25	1.14	168	23	<1	0.9
KM-6	6	88	50	N/A	N/A	N/A	N/A	N/A	248	18	N/A	105	24	<1	0.8
KMT-1S	24	106	21	N/A	N/A	N/A	N/A	N/A	50	0.6	N/A	18	16	<1	<.5
KMT-2S	9	115	25	N/A	N/A	N/A	N/A	N/A	71	0.3	N/A	17	19	<1	<.5
KMT-3S	21	139	22	N/A	N/A	N/A	N/A	N/A	180	0.4	N/A	24	18	<1	<.5
KMT-4S	22	54	20	N/A	N/A	N/A	N/A	N/A	300	2.7	N/A	27	18	<1	<.5
KMT-5S	14	59	23	N/A	N/A	N/A	N/A	N/A	171	3.9	N/A	22	17	<1	<.5
KMT-1SS	6	25	22	N/A	N/A	N/A	N/A	N/A	263	3.6	N/A	51	25	<1	<.5
KMT-2SS	7	34	23	N/A	N/A	N/A	N/A	N/A	203	2.5	N/A	44	21	<1	<.5
KMT-3SS	6	32	24	N/A	N/A	N/A	N/A	N/A	224	2.8	N/A	37	21	<1	<.5
KMT16-1	4	24	21	N/A	N/A	N/A	N/A	N/A	364	3	N/A	76	27	<1	1
KMT16-2	5	24	20	N/A	N/A	N/A	N/A	N/A	232	5.1	N/A	74	23	<1	<.5
KMT16-3	3	25	17	N/A	N/A	N/A	N/A	N/A	362	5.8	N/A	80	20	<1	<.5
KMT16-4	6	33	26	N/A	N/A	N/A	N/A	N/A	200	5	N/A	78	21	<1	0.6
KMT16-5	9	42	44	N/A	N/A	N/A	N/A	N/A	235	4.1	N/A	153	26	<1	<.5
KMT16-6	15	69	562	N/A	N/A	N/A	N/A	N/A	675	6.8	N/A	1990	92	2	3
KMT16-7	3	33	9	N/A	N/A	N/A	N/A	N/A	7	0.1	N/A	37	6	<1	<.5
KMT16-8	3	37	7	N/A	N/A	N/A	N/A	N/A	<5	0.1	N/A	44	9	<1	0.5
KMT16-9	5	35	9	N/A	N/A	N/A	N/A	N/A	<5	0.1	N/A	45	6	<1	<.5
KMT16-10	5	47	28	N/A	N/A	N/A	N/A	N/A	487	6.2	N/A	505	29	4	<.5
KMT-16-11	14	46	409	N/A	N/A	N/A	N/A	N/A	906	6.5	N/A	2110	122	2	2

N/R not requested for analysis

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season

Element	Units	Method	KLM-001	KLM-002	KLM-003	AH19-1	AH19-2	AH19-3	AH19-4	AH19-5	AH19-6	AH18-1	AH18-2	AH18-3
Au	ppb	FA+AA	N/R	N/R	N/R	221	293	253	196	170	133	148	373	230
Ag	ppm	FA+AA	N/R	N/R	N/R	5.1	5.9	4.1	2.8	4.6	6.3	4.4	6.6	4.1
As	ppm	GFAA	N/R	N/R	N/R	3	9	3	4	2	4	7	6	5
Be	ppm	ICP	N/R	N/R	N/R	64.5	67.8	68.6	64.6	66.3	57.1	56.6	64.5	74.2
Cu	ppm	FLAA	N/R	N/R	N/R	64	38	37	37	36	32	41	40	45
Pb	ppm	FLAA	N/R	N/R	N/R	34	56	35	36	35	34	35	41	40
Zn	ppm	FLAA	N/R	N/R	N/R	110	106	90	92	103	101	122	116	117
Cd	ppm	FLAA	N/R	N/R	N/R	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	59	54	61	73	65	51	40	60	77
Hg	ppb	Jerome	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	<.01	<.01	<.01	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	<.004	<.004	<.004	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	<.001	<.001	<.001	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	<.002	<.002	<.002	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	<.005	<.005	<.005	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	<.002	<.002	<.002	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	<.019	<.019	<.019	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	<.022	<.022	<.022	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	.002	.003	<.002	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	.002	.002	.003	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	.002	.002	<.001	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	.002	.002	.002	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	<.001	<.001	<.001	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	<.0002	<.0002	<.0002	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	AH18-4	KMR-1	KMR-2	KMR-3	KMR-4	KMD-1	KMD-2	KMS-1	KMS-1A	KMS-2	KMS-2A	KMS-3
Au	ppb	FA+AA	202	84	2824	205	2694	1065	63	<5	57	<5	55	31
Ag	ppm	FA+AA	5.8	1.0	18.1	1.6	13.9	17.3	2.5	<.1	.5	<.1	.5	.1
As	ppm	GFAA	7	5	<.5	3	<.5	3	11	11	5	9	5	6
Be	ppm	ICP	84.4	2.87	28.2	3.02	54.1	3.81	3.74	1.18	1.87	.95	1.85	.92
Cu	ppm	FLAA	32	20	19	26	13	70	25	18	12	14	13	15
Pb	ppm	FLAA	115	36	87	32	42	64	27	20	34	25	28	29
Zn	ppm	FLAA	121	112	69	39	43	119	92	43	46	31	49	29
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	78	<10	15	16	68	73	42	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	N/R	N/R	N/R	N/R	N/R	N/R	N/R	4	6	4	<2	46
Na2O	pct	ICP	N/R	2.52	.31	.67	.38	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	1.2	.001	12.4	3.08	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	2.15	1.43	12.24	4.07	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	.070	.015	.028	.036	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	1.02	.08	1.28	.15	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	.317	.038	.104	.062	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	4.95	.61	1.91	.64	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	.662	.013	.237	.043	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	12.51	4.55	5.96	4.19	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	4.73	4.04	3.49	3.49	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	.105	.007	.044	.014	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	59.2	85.3	56.8	82.8	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMS-3A	KMS-4	KMS-4A	KMS-5	KMS-5A	KMS-6	KMS-6A	KMS-7	KMS-7A	KMS-8	KMS-8A	KMS-9
Au	ppb	FA+AA	105	25	116	<5	121	<5	126	7	124	6	192	<5
Ag	ppm	FA+AA	.9	.1	1.1	<.1	1.0	.1	1.3	.1	1.3	.1	2.2	<.1
As	ppm	GFAA	4	15	2	12	4	14	19	10	3	6	15	5
Be	ppm	ICP	2.22	.94	2.99	1.01	3.04	.97	3.16	.81	3.70	.80	4.13	.80
Cu	ppm	FLAA	14	17	16	14	16	12	17	16	17	11	19	13
Pb	ppm	FLAA	32	27	31	25	31	26	32	27	29	26	35	27
Zn	ppm	FLAA	50	31	45	27	44	30	48	36	46	27	51	23
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	8	56	10	46	8	2	16	6	4	40	14	88
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMS-9A	KMS-10	KMS-10A	KMS-11	KMS-11A	KMS-12	KMS-12A	KMS-13	KMS-13A	KMS-14	KMS-14A	KMS-15
Au	ppb	FA+AA	142	14	177	17	191	21	276	32	354	62	332	143
Ag	ppm	FA+AA	1.3	.1	1.7	.1	2.2	.1	3.0	.1	5.7	.1	6.5	.2
As	ppm	GFAA	3	6	2	5	12	6	17	5	3	3	6	6
Be	ppm	ICP	3.34	.76	5.72	.78	7.17	1.26	9.89	1.09	17.2	1.14	19.2	1.18
Cu	ppm	FLAA	15	13	15	13	24	16	22	15	22	13	21	14
Pb	ppm	FLAA	33	31	33	29	30	22	34	20	40	20	35	27
Zn	ppm	FLAA	51	23	37	24	48	28	52	37	65	25	54	25
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	8	98	8	94	16	138	32	80	27	30	25	172
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMS-15A	KMS-16	KMS-16A	KMS-17	KMS-17A	KMS-18	KMS-18A	KMS-19	KMS-19A	KMS-20	KMS-20A	KMS-21
Au	ppb	FA+AA	293	36	303	31	324	21	322	31	178	22	176	29
Ag	ppm	FA+AA	5.3	.1	4.7	.1	4.6	.1	6.1	.1	2.8	<.1	2.3	<.1
As	ppm	GFAA	10	7	7	6	6	8	2	7	6	10	6	8
Be	ppm	ICP	14.9	1.05	14.3	.92	14.0	1.05	16.0	1.03	9.54	1.03	8.14	1.08
Cu	ppm	FLAA	17	11	19	10	19	13	21	15	17	11	17	13
Pb	ppm	FLAA	33	26	39	22	36	26	36	18	26	23	22	21
Zn	ppm	FLAA	55	22	50	26	50	31	55	31	42	28	40	27
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	23	<2	13	165	13	39	11	96	9	18	9	241
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	315.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMS-21A	KMS-22	KMS-23	KMS-24	KMS-25	KMS-26	KMS-27	KMS-28	KMS-29	KMS-30	KMS-31	KMS-32
Au	ppb	FA+AA	177	21	50	114	53	411	2087	56	231	450	150	599
Ag	ppm	FA+AA	2.3	.1	.5	.1	.6	1.8	13.6	.4	1.4	1.4	.1	.6
As	ppm	GFAA	6	19	11	7	26	6	3	8	6	7	3	6
Be	ppm	ICP	6.72	1.22	2.84	1.14	1.88	2.63	14.1	1.43	6.63	1.41	1.53	1.23
Cu	ppm	FLAA	17	15	10	13	19	18	48	15	18	11	13	13
Pb	ppm	FLAA	30	26	29	26	27	36	191	29	28	27	14	20
Zn	ppm	FLAA	43	30	29	25	39	91	184	36	79	29	32	30
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	6	149	<2	59	9	303	294	18	11	52	149	80
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMS-40	KMS-41	KMS-33	KMS-34	KMS-35	KMS-36	KMS-37	KMS-38	KMS-39	KMSS-1	KMSS-2	KMSS-3
Au	ppb	FA+AA	<5	<5	2862	1881	22356	24237	3402	6336	39	466	151	280
Ag	ppm	FA+AA	<.1	.1	21.7	19.8	5.5 oz/t	6.24 oz/t	1.21 oz/t	5.02 oz/t	1.4	15.0	3.1	14.9
As	ppm	GFAA	8	2	3	<.5	8	5	3	4	9	3	3	3
Be	ppm	ICP	1.06	1.12	20.6	35.7	25.6	40.5	35.3	57.2	1.76	16.5	11.8	16.1
Cu	ppm	FLAA	12	13	51	37	49	131	38	57	20	35	17	41
Pb	ppm	FLAA	12	15	135	92	267	167	945	180	27	93	47	128
Zn	ppm	FLAA	23	27	290	182	1850	675	346	585	72	158	66	139
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	57	41	46
Hg	ppb	Jerome	<2	16	<2	11	4	4	57	23	22	N/R	N/R	N/R
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	42.44	26.92	76.30	66.68	62.42	2.03	.637	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses from 1994 field season-continued

Element	Units	Method	KMSS-4	KMSS-5	KMSS-6	KMSS-7	KMT2A-8	KMT2A-9	KMT2A-10	KMST-1	KMST-2	KMSR-1	KMT2A-1	KMT2A-2
Au	ppb	FA+AA	190	136	210	135	676	2934	4248	255	549	39690	N/R	N/R
Ag	ppm	FA+AA	7.6	6.0	3.7	5.6	.78 oz/t	3.24 oz/t	10.6	17.0	.85 oz/t	4.4 oz/t	N/R	N/R
As	ppm	GFAA	6	7	3	14	1	1	7	1	4	6	N/R	N/R
Be	ppm	ICP	11.9	10.6	10.8	10.0	28.4	32.3	7.86	15.4	13.6	12.8	N/R	N/R
Cu	ppm	FLAA	28	24	24	23	65	79	25	49	46	132	N/R	N/R
Pb	ppm	FLAA	58	58	70	51	73	128	35	77	72	254	N/R	N/R
Zn	ppm	FLAA	112	84	193	125	290	269	159	223	243	446	N/R	N/R
Cd	ppm	FLAA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	N/R	N/R
Hg	ppb	CVAA	52	77	93	55	79	229	440	34	57	323	N/R	N/R
Hg	ppb	Jerome	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.62	.41
LOI	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	6.40	9.08
CaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	7.16	10.51
MnO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.057	.062
MgO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.57	.35
P2O5	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.162	.115
Fe2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	2.75	1.61
TiO2	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.337	.146
Al2O3	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	5.72	3.67
K2O	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	2.73	2.27
BaO	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	.050	.025
SiO2	pct	Grav	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	69.8	64.4
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
CN	ppm	335.2	N/R	N/R	N/R	N/R	2.14	28.4	48.66	2.15	14.42	11.46	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tl	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-3. Water, tailings auger, soils, stream sediment, and rock sample analyses for 1994 field season-continued

Element	Units	Method	KMT2A-3	KMT2A-4	KMT2A-5	KMT2A-6	KMT2A-7	KMBC-1	PC-525	PC-526	PC-527	PC-528	PC-529
Au	ppb	FA+AA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	ppm	FA+AA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	ppm	GFAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	ppm	ICP	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	ppm	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	ppm	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	ppm	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	ppm	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	CVAA	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	ppb	Jerome	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Na2O	pct	ICP	.60	.73	.58	.51	.32	.06	N/R	N/R	N/R	N/R	N/R
LOI	pct	Grav	4.08	2.04	2.2	2.4	2.92	42.52	N/R	N/R	N/R	N/R	N/R
CaO	pct	ICP	4.89	1.85	1.99	2.22	2.76	53.03	N/R	N/R	N/R	N/R	N/R
MnO	pct	ICP	.088	.050	.043	.052	.057	.012	N/R	N/R	N/R	N/R	N/R
MgO	pct	ICP	.44	.61	.62	.63	.18	N/R	N/R	N/R	N/R	N/R	N/R
P2O5	pct	ICP	.126	.147	.138	.143	.106	.046	N/R	N/R	N/R	N/R	N/R
Fe2O3	pct	ICP	2.05	1.97	1.95	2.05	2.00	.59	N/R	N/R	N/R	N/R	N/R
TiO2	pct	ICP	.206	.229	.237	.253	.169	.009	N/R	N/R	N/R	N/R	N/R
Al2O3	pct	ICP	5.49	5.49	4.79	5.16	4.37	.23	N/R	N/R	N/R	N/R	N/R
K2O	pct	ICP	3.49	3.14	2.60	2.89	2.51	.10	N/R	N/R	N/R	N/R	N/R
BaO	pct	ICP	.027	.020	.020	.021	.021	.003	N/R	N/R	N/R	N/R	N/R
SiO2	pct	Grav	77.8	81.7	80.9	79.4	81.5	1.45	N/R	N/R	N/R	N/R	N/R
Al	pct	ICP	N/R	N/R	N/R	N/R	N/R	.14	N/R	N/R	N/R	N/R	N/R
Sb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	360	N/R	N/R	N/R	N/R	N/R
As	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 50	N/R	N/R	N/R	N/R	N/R
Ba	ppm	ICP	N/R	N/R	N/R	N/R	N/R	22	N/R	N/R	N/R	N/R	N/R
Bi	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 50	N/R	N/R	N/R	N/R	N/R
Cd	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 5	N/R	N/R	N/R	N/R	N/R
Ca	pct	ICP	N/R	N/R	N/R	N/R	N/R	36	N/R	N/R	N/R	N/R	N/R
Cr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 25	N/R	N/R	N/R	N/R	N/R
Co	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 10	N/R	N/R	N/R	N/R	N/R
Cu	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 10	N/R	N/R	N/R	N/R	N/R
Fe	pct	ICP	N/R	N/R	N/R	N/R	N/R	0.38	N/R	N/R	N/R	N/R	N/R
Pb	ppm	ICP	N/R	N/R	N/R	N/R	N/R	1300	N/R	N/R	N/R	N/R	N/R
Mg	pct	ICP	N/R	N/R	N/R	N/R	N/R	0.12	N/R	N/R	N/R	N/R	N/R
Mn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	79	N/R	N/R	N/R	N/R	N/R
Mo	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 10	N/R	N/R	N/R	N/R	N/R
Ni	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 25	N/R	N/R	N/R	N/R	N/R
P	ppm	ICP	N/R	N/R	N/R	N/R	N/R	170	N/R	N/R	N/R	N/R	N/R
K	pct	ICP	N/R	N/R	N/R	N/R	N/R	< 0.1	N/R	N/R	N/R	N/R	N/R
Si	pct	ICP	N/R	N/R	N/R	N/R	N/R	1.6	N/R	N/R	N/R	N/R	N/R
Na	pct	ICP	N/R	N/R	N/R	N/R	N/R	0.14	N/R	N/R	N/R	N/R	N/R
Sr	ppm	ICP	N/R	N/R	N/R	N/R	N/R	91	N/R	N/R	N/R	N/R	N/R
Sn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 75	N/R	N/R	N/R	N/R	N/R
Ti	ppm	ICP	N/R	N/R	N/R	N/R	N/R	40	N/R	N/R	N/R	N/R	N/R
V	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 5	N/R	N/R	N/R	N/R	N/R
Zn	ppm	ICP	N/R	N/R	N/R	N/R	N/R	16	N/R	N/R	N/R	N/R	N/R
Se	ppm	ICP	N/R	N/R	N/R	N/R	N/R	< 50	N/R	N/R	N/R	N/R	N/R
Pb	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	.99	N/R	1.07	1.12	1.19
Zn	pct	FLAA	N/R	N/R	N/R	N/R	N/R	N/R	2.56	2.98	2.43	2.53	2.50
CN	ppm	335.2	N/R	N/R	N/R	N/R	N/R	< .5	N/R	N/R	N/R	N/R	N/R
CN	mg/l	335.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ag	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Be	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cd	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cr	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Cu	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ni	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Sb	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Zn	mg/l	200.7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
As	mg/l	206.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Pb	mg/l	239.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Se	mg/l	270.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Ti	mg/l	279.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Hg	mg/l	245.2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Table A-4. Cyanide concentrations in samples from the tailings and millsite

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KM-4	Tailings	South wall of tailings impoundment exposed in deep wash along road	1.419	0.15	0.744
KM-5	Tailings	Pinkish zone below KM-4	9.481	0.32	0.789
KMT1-1	Tailings	Auger hole KMT1; interval: 0 to 1 ft	1.86	<1.0	<1.0
KMT1-5	Tailings	Auger hole KMT1; interval: 13 to 17 ft	9.50	1.97	1.48
KMT1-10	Tailings	Auger hole KMT1; interval: 30 to 33 ft	6.29	<1.0	NA
KMT2-1	Tailings	Auger hole KMT2; interval: 0 to 1 ft	1.92	<1.0	NA
KMT2-5	Tailings	Auger hole KMT2; interval: 13 to 17 ft	3.72	<1.0	NA
KMT2-10	Tailings	Auger hole KMT2; interval: 30 to 33 ft	2.38	<1.0	NA
KMT2A-8	Tailings	Auger hole KMT2A; interval: 35 to 37 ft	2.14	<1.0	NA
KMT2A-9	Tailings	Auger hole KMT2A; interval: 37 to 38 ft	28.40	<1.0	NA

Table A-4. Cyanide concentrations in samples from the tailings and millsite-continued

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KMT2A1-10	Tailings mixed with fine gravel	Auger hole KMT2A; interval: 38 to 38.3 ft (contact with wash gravel)	48.66	<1.0	NA
KMT3-1	Tailings	Auger hole KMT3; interval: 0 to 1 ft	1.15	<1.0	NA
KMT3-5	Tailings	Auger hole KMT3; interval: 13 to 17 ft	3.96	2.32	2.14
KMT3-10	Tailings	Auger hole KMT3; interval: 30 to 32 ft	4.10	1.13	1.13
KMT4-1	Tailings	Auger hole KMT4; interval: 0 to 1 ft	1.60	<1.0	NA
KMT4-5	Tailings	Auger hole KMT4; interval: 13 to 17 ft	3.55	1.31	1.13
KMT4-9	Tailings	Auger hole KMT4; interval: 27 to 29 ft	4.37	<1.0	NA
KMT5-1	Tailings	Auger hole KMT5; interval: 0 to 1 ft	1.39	<1.0	NA
KMT5-5	Tailings	Auger hole KMT5; interval: 13 to 15 ft	44.60	<1.0	NA
KMT6-1	Tailings	Auger hole KMT6; interval: 0 to 1 ft	1.20	<1.0	NA

Table A-4. Cyanide concentrations in samples from the tailings and millsite-continued

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KMT6-5	Tailings	Auger hole KMT6; interval: 13 to 16 ft	30.68	<1.0	NA
KMT7-1	Tailings	Auger hole KMT7; interval: 0 to 1 ft	1.99	<1.0	NA
KMT8-1	Tailings	Auger hole KMT8; interval: 0 to 1 ft	3.34	2.32	2.14
KMT9-1	Tailings	Auger hole KMT9; interval: 0 to 1 ft	1.82	1.15	0.56
KMT10-1	Tailings	Auger hole KMT10; interval: 0 to 1 ft	2.28	<1.0	NA
KMT11-1	Tailings	Auger hole KMT11; interval: 0 to 1 ft	1.21	<1.0	NA
KMT12-1	Tailings	Auger hole KMT12; interval: 0 to 1 ft	2.21	<1.0	NA
KMT13-1	Tailings	Auger hole KMT13; interval: 0 to 1 ft	1.48	<1.0	NA
KMT14-1	Tailings	Auger hole KMT14; interval: 0 to 1 ft	1.57	<1.0	NA
KMT15-1	Tailings	Channel sample collected along wash	1.63	<1.0	NA

Table A-4. Cyanide concentrations in samples from the tailings and millsite-continued

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KMT15-5	Tailings at contact with gravels in wash	Channel sample collected along wash	1.69	<1.0	NA
KMT17-1	Tailings	Select sample of tailings enclosed in outline of rusted barrel in what appears to be a debris pile at NE corner of tailings impoundment	2.33	<1.0	<1.0
KMT17-2	Tailings mixed with brown to gray-brown soil	Select sample from a debris pile at NE corner of tailings impoundment near KMT17-1	3.55	<1.0	<1.0
KMT17-3	Tailings mixed with brown soil	Select sample from debris pile consisting of rusted barrels, glass, and other debris; near KMT17-2	1.23	<1.0	<1.0
KMST-1	Tailings	Channel sample through 26-in. vertical section of tailings exposed in wash SW of mill site	2.15	<1.0	NA
KMST-2	Tailings	Channel sample through 19-in. vertical section of tailings exposed in was S of tailings impoundment	14.42	<1.0	NA
KMSR-1	Rocky to sandy soil	Sample of material from 24 in. by 44 in. rectangular, filled-in hole in mill building foundation	11.46	<1.0	NA

Table A-4. Cyanide concentrations in samples from the tailings and millsite-continued

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KMS-33	Tailings	Auger sample of material underlying the foundation of thickener tank	42.44	< 1.0	NA
KMS-34	Tailings	Auger sample of reddish-brown material collected at depth of 8 in. to 10 in. from rectangular opening near center of thickener tank foundation	26.92	< 1.0	NA
KMS-35	White to gray to brown powdery material	Sample collected from floor of old tank at mill site	76.30	< 1.0	NA
KMS-36	Layered, white to gray-brown material	Sample collected from floor of old vat or agitation tank at mill site. Same material as KMS-35	66.68	< 1.0	NA
KMS-37	Same materia as samples KMS-35 and KMS-36	Sample collected from floor of old vat or agitation tank at mill site	62.42	< 1.0	NA
KMS-38	Reddish-brown, fine-grained, sandy material	Sample collected from center of area of concrete foundation pilings at site of large tank	2.03	< 1.0	NA
KMS-39	Brown to light, reddish-brown soil	Channel sample through 20-in. vertical section at west end of settling pond south of mill site	0.637	< 1.0	NA

Table A-4. Cyanide concentrations in samples from the tailings and millsite-continued

Sample Number	Type of Material	Sample Location	CN-T (ppm)	CN-W (ppm)	CN-F (ppm)
KMBC-1	White, powdery to clayey, very fine-grained material	Sample collected from material in old, rusty barrel lying about 15 ft NW of collar of concrete-capped shaft in wash NE of mine site	<0.05	NA	NA

Table A-5. Stream sediment sample analyses (All data given in ppm)

Element	Sample Number									
	KMT-1SS	KMT-2SS	KMT-3SS	KMSS-1	KMSS-2	KMSS-3	KMSS-4	KMSS-5	KMSS-6	KMSS-7
Au	0.263	0.203	0.224	0.466	0.151	0.280	0.190	0.136	0.210	0.135
Ag	3.6	2.5	2.8	15.0	3.1	14.9	7.6	6.0	3.7	5.6
As	6	7	6	3	3	3	6	7	3	14
Cu	25	21	21	35	17	41	28	24	24	23
Pb	22	23	24	93	47	128	58	58	70	51
Zn	51	44	37	158	66	139	112	84	193	125
Hg	0.025	0.034	0.032	0.057	0.041	0.046	0.052	0.077	0.093	0.055
Be	ND	ND	ND	16.5	11.8	16.1	11.9	10.6	10.8	10.0
Cd	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Sb	< 0.5	< 0.5	< 0.5	ND	ND	ND	ND	ND	ND	ND

ND-not analyzed

APPENDIX B.--HYDROLOGIC DATA

Table B-1. Arizona Department of Environmental Quality groundwater sample analyses for the Katherine mine shaft from 1986 to 1994 (results are in mg/l unless otherwise specified).

Contaminant	Code	Reasonable Limit (mg/l)	Test Results (mg/l)
Flouride	1025	4	< 0.2 to 3.2
Arsenic	1005	0.05	< 0.01 to < 0.02
Barium	1010	1	0.1
Cadmium	1015	0.01	< 0.005
Calcium	1016	162	188 to 200
Chloride	1017	464	570 to 600
Chromium	1020	0.05	< 0.01 to < 0.02
Copper	1022	0.43	< 0.05
Iron	1028	5.7	0.01 to 0.27
Lead	1030	0.05	< 0.002 to < 0.02
Magnesium	1031	60.4	20 to 23
Manganese	1032	2.3	< 0.05
Mercury	1035	0.0018	< 0.001
Nitrate	1040	10	6.6 to 7.6
Selenium	1045	0.01	< 0.005
Silver	1050	0.05	< 0.02
Sodium	1052	300	240 to 251
Sulfate	1055	n.s.	110 to 140
Zinc	1095	27	< 0.05 to 0.05
Hardness (total)	1915	n.s.	532 to 590
pH	1925	10.8	7.29 to 7.8
Alkalinity (total)	1927	n.s.	74 to 124
TDS	1930	n.s.	1560 to 1700
Calcium	1919	n.s.	282
Temperature (C)	1996	43.56	27.8

n.s. - not specified

APPENDIX C.-- GEOTECHNICAL DATA

TAILINGS BULK DENSITY AND GRAIN SIZE ANALYSIS

Introduction

Seven samples (KMT B1-B7) collected from various locations at the Katherine mill tailings site were subjected to measurement of bulk density and to analysis of particle size distribution using U.S. Standard Testing (USST) sieves. These tests were conducted to determine the tonnage and geotechnical characteristics of the pile. Sample locations were selected (figure 13) to ascertain whether bulk density and grain size distribution varies laterally and vertically within the impoundment.

Bulk Density

Procedure

Each sample (KMT B1-B7) was collected in situ from the tailings as a coherent block and cut into a roughly orthogonal shape. Dimensions of the blocks were measured in the field. Each sample was then labeled, placed in a heavy plastic bag, and sealed. The volume of each block was calculated to the nearest 0.1 in³ and to the nearest 0.001 ft³.

At the WFOC lab in Spokane, Washington, each sample was weighed before and after drying in an oven for 24 hrs. Net sample weights in g and lbs were then corrected by subtracting the weight of the sample bag. Bulk density of each sample was calculated by dividing the net sample weight in lbs by the

volume of each sample block in ft³ and then rounded to the nearest whole lb/ft³. Tonnage factor of each sample is calculated as the inverse of bulk density converted to ft³/st.

Data

Bulk densities and tonnage factors of the seven samples are listed in table C-1, and supporting calculations are reported in table C-2. Bulk densities range from 82 lb/ft³ to 93 lb/ft³ and average 89 lb/ft³, and tonnage factors range from 22 ft³/ton to 24 ft³/ton. Moisture was negligible, therefore drying did not significantly change the bulk density calculations. Lateral variation within the tailings is not demonstrated, but bulk density clearly increases with depth (with the exception of KMT-B5). Three samples from the top or upper third average 86 lb/ft³, two samples from the middle third average 91 lb/ft³, and two samples from the lower third average 92.5 lb/ft³. Compaction is the most probable cause of vertical variation.

Grain Size Distribution

Procedure

Seven samples (KMT B1-B7) of tailings were collected as described above and subjected to grain size analysis after completion of bulk density procedure. In order to select the optimum suite of U.S. Standard Sieve mesh sizes, a test sample (KMT B-TEST), also collected from the tailings, was disaggregated and passed through ten sieves [USST Nos. 10 (2mm), 25 (0.710 mm), 40 (.425 mm), 50 (.297

mm), 70 (.212 mm), 80 (.180 mm), 100 (.149 mm), 140 (.106 mm), 200 (.074 mm), and 325 (.044 mm). Based on the results of the test sieve analysis, five sieves were selected for the remaining samples (KMT B1-B7). The No. 50 sieve was chosen from the larger screens to represent the largest diameter grain size present in the tailings, and mesh Nos. 100, 140, 200, and 325 were selected because they retained 84 percent of the sample.

Prior to placement in the sieve stack, samples were disaggregated by several moderate impacts with a mallet because the tailings are lightly cemented. The sieve set was then subjected to one hour of ro-tap (rotating and tapping) action to allow complete segregation of particle sizes fractions. Upon completion of the shaking action, each sieve with the retained sample was weighed to the nearest tenth of a gram. To insure accuracy, all sieves were cleaned and weighed between samples. By subtracting the empty sieve weight from the weight of the sieve plus the retained sample, the weight of the sample retained in each sieve, the cumulative weight, the total weight of sample finer than each sieve, and the percent of sample finer than each sieve was calculated.

Quality Control/Assurance

Sieve weight varied plus or minus 0.1 gram probably due to humidity and air pressure changes. Percent of sample lost during ro-tap action ranged from 0.16 to 0.87 percent and averaged 0.56 percent calculated using the original and final weight of each sample. Slight variations in the percent of samples B3 and B7 finer

than No. 200 sieve may be due to minor tears discovered at the edge of the sieve after completion of the tests. Errors associated with this particle size analysis are not considered to be significant.

SURFACE TAILINGS PARTICLE SIZE DISTRIBUTION

Introduction

Twelve samples from the top inch of tailings were collected at various locations on the Katherine mill tailings for particle size analysis. A study of the percentage of particles passing through U.S. Standard Sieve No. 200 will provide an understanding of the amount and particle-size of potential airborne constituents of the tailings. Twelve sample locations (figure 13) were selected on the tailings in order to observe effects of wind velocity and the difference in particle size throughout the Katherine mill tailings.

Procedure

A particle size analysis was conducted on each of the twelve samples using U.S. Standard Sieves. In order to select appropriate mesh sizes, a test sample, KMT B-TEST, was disaggregated and passed through ten sieves, [Nos. 10 (2mm), 25 (.710mm), 40 (.425mm), 50 (.297mm), 70 (.212mm), 80 (.180mm), 100 (.149mm), 140 (.106mm), 200 (.074mm), 325 (.044mm)]. From this test, five sieves (Nos. 80, 100, 140, 200, and 325) were selected for the remaining samples. The No. 80 sieve was chosen from the larger screens to represent the largest diameter grain size present in the tailings. Nos. 100, 140, 200, and 325 sieves were also chosen for the analysis

because 94% of the sample passed through them.

Each sample in the sieve set was then subjected to ro-tap action for one hour. Upon completion of the test, each sieve with the retained sample was weighed to the nearest tenth of a gram. All sieves were cleaned and weighed between samples to insure accuracy. By subtracting the empty sieve weight from the weight of the sieve plus the retained sample, the weight of sample retained in each sieve, the cumulative weight, and the total weight and percent of sample finer than each sieve (table C-1) was calculated.

Data

The number and size of the sieves used with the Katherine mill tailings samples was determined from the test sample (KMT B-TEST) results. The amount of tailing particles finer than No. 80 sieve ranged from 94 to 100% and averaged 98.0%; particles coarser than No. 80 sieve consisted predominately of organic material. Particles finer than No. 100 sieve ranged from 84 to 98% and

averaged 94.1%; particles finer than No. 140 sieve ranged from 63 to 90% and averaged 79.8%; particles finer than the No. 200 sieve ranged from 50 to 80% and averaged 64.5%; particles finer than No. 325 sieve ranged from 32 to 60% and averaged 45.2%.

Quality control and assurance

Sieve weight varied plus or minus 0.1 gram probably due to humidity and air pressure changes. Percent of sample lost due to air current, force of ro-tap sieving, and small sample weight was between 0.5% and 1.5% with an average loss of 0.8%. This was calculated using the original and final weight of the sample. Slight variations in the percent of sample KMT 6-1A finer than No. 200 sieve may be explained by two minor holes found at the edge of the sieve, and two slits found at the edge of the No. 325 sieve. Errors associated with this particle size analysis are considered to be of low significance and probably have no effect on the characterization of Katherine mill tailings samples KMT 1-12 1A.

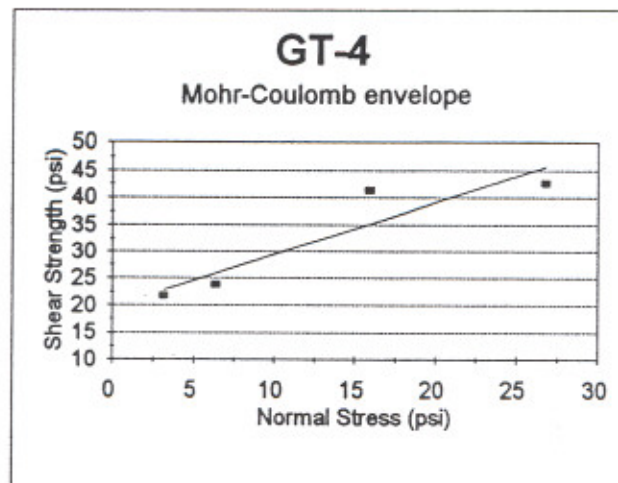
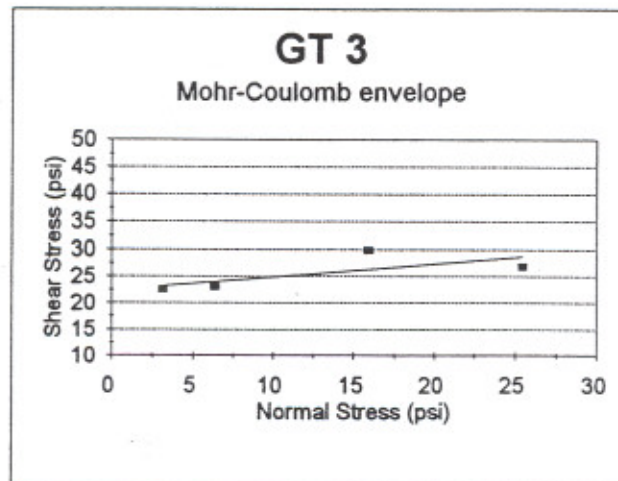
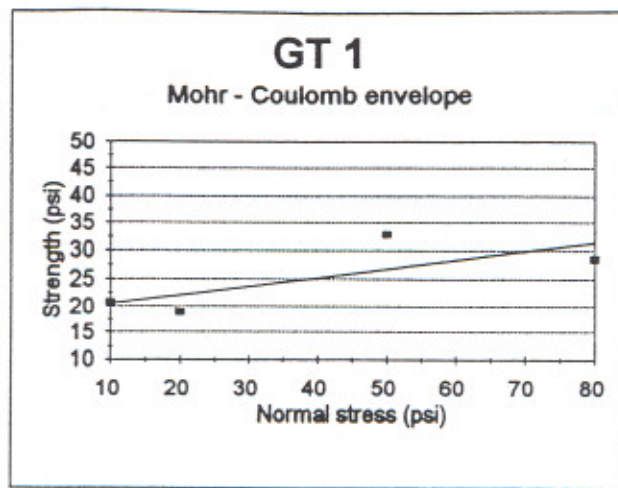


Figure C-1. Shear test results from tailings sample cores

Table C-1. Bulk density of the Katherine mill tailings

SAMPLE #	LOCATION IN THE TAILINGS	BULK DENSITY lb/ft ³	TONNAGE FACTOR ft ³ /ton
KMT-B1	top	82	24
KMT-B2	lower 1/3	93	22
KMT-B3	middle 1/3	92	22
KMT-B4	upper 1/3	83	24
KMT-B5	top	92	22
KMT-B6	lower 1/3	92	22
KMT-B7	middle 1/3	89	22

Table C-2. Bulk density calculations from seven samples, Katherine mill tailings, Lake Mead National Recreation Area, Arizona

SAMPLE NO. (WET)	VOLUME Vf (ft ³)	WEIGHT			BULK DENSITY Db (lb/ft ³)	TONNAGE FACTOR Tf (ft ³ /ton)
		Wgn gram	Wgc gram	Wpc lb		
1	.0544	2063.8	2021.3	4.46	82	24
2	.0241	1056.9	1014.4	2.24	93	22
3	.0539	2288.9	2246.4	4.95	92	22
4	.0157	637.0	594.5	1.31	83	24
5	.0228	993.1	950.6	2.1	92	22
6	.0238	1033.6	991.1	2.19	92	22
7	.0377	1562.4	1519.9	3.35	89	22

SAMPLE NO. (DRY)	VOLUME Vf(ft ³)	WEIGHT			BULK DENSITY Db (lb/ft ³)	TONNAGE FACTOR Tf (ft ³ /ton)
		Wgn gram	Wgc gram	Wpc lb		
1	.0544	2063.6	2021.1	4.46	82	24
2	.0241	1055.5	1013.0	2.23	93	22
3	.0539	2288.2	2245.7	4.95	92	22
4	.0157	637.1	594.6	1.31	83	24
5	.0228	992.5	950.0	2.09	92	22
6	.0238	1033.7	991.2	2.19	92	22
7	.0377	1562.9	1520.4	3.35	89	22

APPENDIX D.--GEOPHYSICAL DATA

SEISMIC REFRACTION DATA

Introduction and Purpose

Seismic instruments detect and measure low-energy elastic waves which are generated by artificial sources and transmitted by vibration of rock particles and sediments to one or more acoustic receivers called geophones. Although many types of seismic waves are generated in such a survey - body waves known as P-waves (pressure) or S-waves (shear), Love waves, and Rayleigh waves - typical refraction and reflection surveys utilize the first-arrival P-waves. Refraction surveys deal with waves which are refracted (change direction) as they pass through or along a zone or contact of acoustic impedance (differing velocity), whereas, reflection surveys measure waves which reflect (return) from an acoustic impedance contrast. Seismic refraction surveys are generally utilized to determine the stratigraphy, seismic character, and structure of multiple, sub-horizontal strata such as various sedimentary layers overlying bedrock. These characteristics are related to seismic velocities determined for each underlying strata. For instance, top soils, unconsolidated sediments, and mine tailings typically range from less than 1,000 ft/s to 3,000 ft/s, whereas, dense bedrock such as granite may exceed 15,000 ft/s. Although historically utilized on engineering site investigations, shallow refraction and reflection surveys are now commonly applied to environmental site assessments as well.

Seismic Refraction Instrument and Methodology

A SmartSeis S12 Digital Instantaneous Floating Point (DIFP) Signal Enhancing 12-Channel Seismograph, was used to conduct the seismic refraction investigation on the site. This instrument is specifically designed for shallow seismic surveys and has the following specifications: sample interval, 31, 62, 125, 250, and 500 microseconds; record lengths 64 to 1024 milliseconds; low-cut (25 to 400 Hz), notch (50, 60, 150, and 180 Hz), and high-cut (250 to 1,000 Hz) filters; 16-bit analog-to-digital converter and 32-bit digital memory; an on-board 386 computer with 40 Mb hard drive and built-in processing software; 1.44 Mb, 3.5 in floppy drive; sealed tactile keyboard; 640 by 480 pixel liquid crystal display; thermal plotter; and external 12-V DC power.

Seismic surveys were performed in linear arrays with geophone intervals (generally 10 to 20 ft) and hammer shot (acoustic source) stations designed to optimize illumination of the tailings and underlying stratigraphy. Once a site is surveyed and the instrument and equipment deployed, data acquisition proceeds rapidly. However, selection of first arrival wave forms, data verification and preliminary modeling using internal SIPQC software, necessary to assure validity of the data, may be time consuming. Verified data sets are carefully reprocessed and modeled using standard software such as SIP.

Interpretation of seismic refraction data is facilitated by collection of multiple data sets for verification.

A total of 17 seismic refraction surveys were conducted at the Katherine site, 14 on the tailings and 3 in Katherine Wash. Some spreads were done on line and are thus combined into composite profiles. Seismic refraction layer (acoustic stratigraphy) models are presented on the following pages (figures D-1 through D-12).

MAGNETIC DATA

Introduction and purpose

A proton-precession magnetometer is a portable instrument designed to measure the magnetic field of the earth using a specially designed sensor. The magnetic gradient function is achieved by addition of a second sensor which allows the operator to simultaneously collect two measurements from separate locations, generally 2 ft to 3 ft (approx. 1 m) apart and along a vertical axis. The gradient is calculated by dividing the difference in total magnetic intensity (measured in gammas; typical total intensity is about 50,000 gammas) between the two sensors by the separation distance. A series of such readings, collected along a transect or in a grid and reported in gammas/ft or gammas/m, can be profiled or contoured to reveal anomalies. Depending on the magnetic susceptibility of the host rocks, this method is very sensitive to shallow buried ferrous objects, such as drums or pipelines, and is commonly utilized in environmental site assessment to detect such objects. An additional advantage of the magnetic "gradient" method is that the

data are not affected by diurnal fluctuations in the earth's magnetic field; therefore, use of a base station is not required to correct for this phenomena.

Magnetic gradient instrument and methodology

The instrument used for this investigation was a Memory-Mag G-856 AGX Proton Precession Magnetometer. Field portable and programmable for base station or field surveys, the instrument has the following specifications: resolution, 0.1 gamma; accuracy 0.5 gamma; tuning, 20,000 to 90,000 gammas; gradient tolerance, 5000 gammas; memory, 2850 pairs of gradient readings; download, RS-232; and power, 12 V with 9 D-cell batteries.

Magnetic gradient surveys on the site were designed as linear transects or orthogonal grids so that the processed data could be interpreted from graphical products such as profiles, contour maps or rasterized color plots. Station intervals are generally 5 ft but may range from 1 ft to 25 ft, depending on target size and site conditions. Once a site is surveyed, collection of magnetic data proceeds fairly rapidly. The data are then downloaded onto a personal computer and processed using software (MAGLOC) which accompanies the instrument. Data sets may then be modeled in standard spread sheet or two-dimensional modeling programs. Interpretation of magnetic data is complex; references cited earlier in the report are useful.

Magnetic gradient profiles over the Katherine tailings and the underground mine subsidence area, as well as the

magnetic gradient grid over the buried drum site in the tailings, are presented in the following pages (figures D-13 through D-36). Magnetic gradient data tables (D-1, D-2, and D-3) accompany the graphic illustrations. Magnetic susceptibility measurements of seven samples collected from the Katherine site are presented in table D-4.

ELECTROMAGNETIC DATA

Introduction and purpose

The electromagnetic (EM) method measures magnetic and/or electric fields associated with artificially induced subsurface currents. Effectively, such instruments measure lateral and/or vertical variations in bedrock, groundwater, or any other features which contrast electrically with their surroundings. Unlike the magnetometer, which is sensitive primarily to the presence and condition of magnetic materials, the EM method measures the electrical response of all conductive substances. In addition, the inphase component of the EM-31 instrument is useful for detecting shallow metallic objects. EM instruments are capable of rapidly and efficiently collecting a large data set. A series of such readings, collected along a transect or in a grid, can be profiled or contoured to reveal anomalies. This method is commonly used in both mineral exploration and environmental site assessments; however, careful consideration must be given to background noise, such as powerlines and metal fences.

Electromagnetic instruments and methodology

An EM-31 Ground-Conductivity Meter was the primary instrument utilized for this investigation. Field portable by one operator, measurements are reported as 1) apparent conductivity in units of millisiemens per meter (mS/m) or 2) inphase ratio of the secondary to primary magnetic field in parts per thousand (ppt). The instrument is a self-contained dipole transmitter and receiver with the following specifications: intercoil spacing, 3.66 m.; operating frequency, 9.8 kHz; measuring range, conductivity - $\pm 10, 100, 1,000$ mS/m, and inphase - ± 12 ppt; precision, ± 0.1 % of full scale; accuracy, ± 5 % at 20 mS/m; noise level, conductivity - 0.1 mS/m, inphase - 0.03 ppt; power, 12 V with 8 C-cell batteries.

An EM-16 Very Low Frequency Electromagnetic (VLF-EM) Receiver was also used during this investigation. Field portable, this instrument measures secondary electromagnetic fields generated when radio waves from any one of a global network of very low frequency (VLF) broadcast stations pass through and are effected by conductive bodies, typically buried mineral deposits. Operating frequency ranges from 15 to 30 kHz; selection of frequency is attained by plug-in crystal. In-phase ranges from ± 150 %, Quad-phase is ± 40 %, and resolution is ± 1 %.

EM conductivity surveys on the site were generally designed as linear transects so that the processed data could be interpreted from graphical products such as profiles; however, the waste dump area at the northeast corner of the tailings was surveyed by random traverse. Station intervals typically range from 2 ft to about 25 ft, depending on site conditions and target size. Once a site is surveyed and the instrument calibrated, collection of EM data proceeds rapidly. Data are entered into a personal computer and

processed using standard spread sheet and two-dimensional modeling programs. Care must be taken in the interpretation of EM data, especially with respect to cultural interference.

Five EM-31 profiles over the upper Katherine tailings (level A) and three EM-16 profiles over the suspected underground mine subsidence area are presented in the following pages (figures D-37 through D-44). Data are listed in tables D-5 and D-6.

Figure D-1A. Seismic refraction layer model, tailings level A, Line SR-A1-3.

FILE SRA1.3.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-A1-3
SPREAD 1

4-18-1993

115

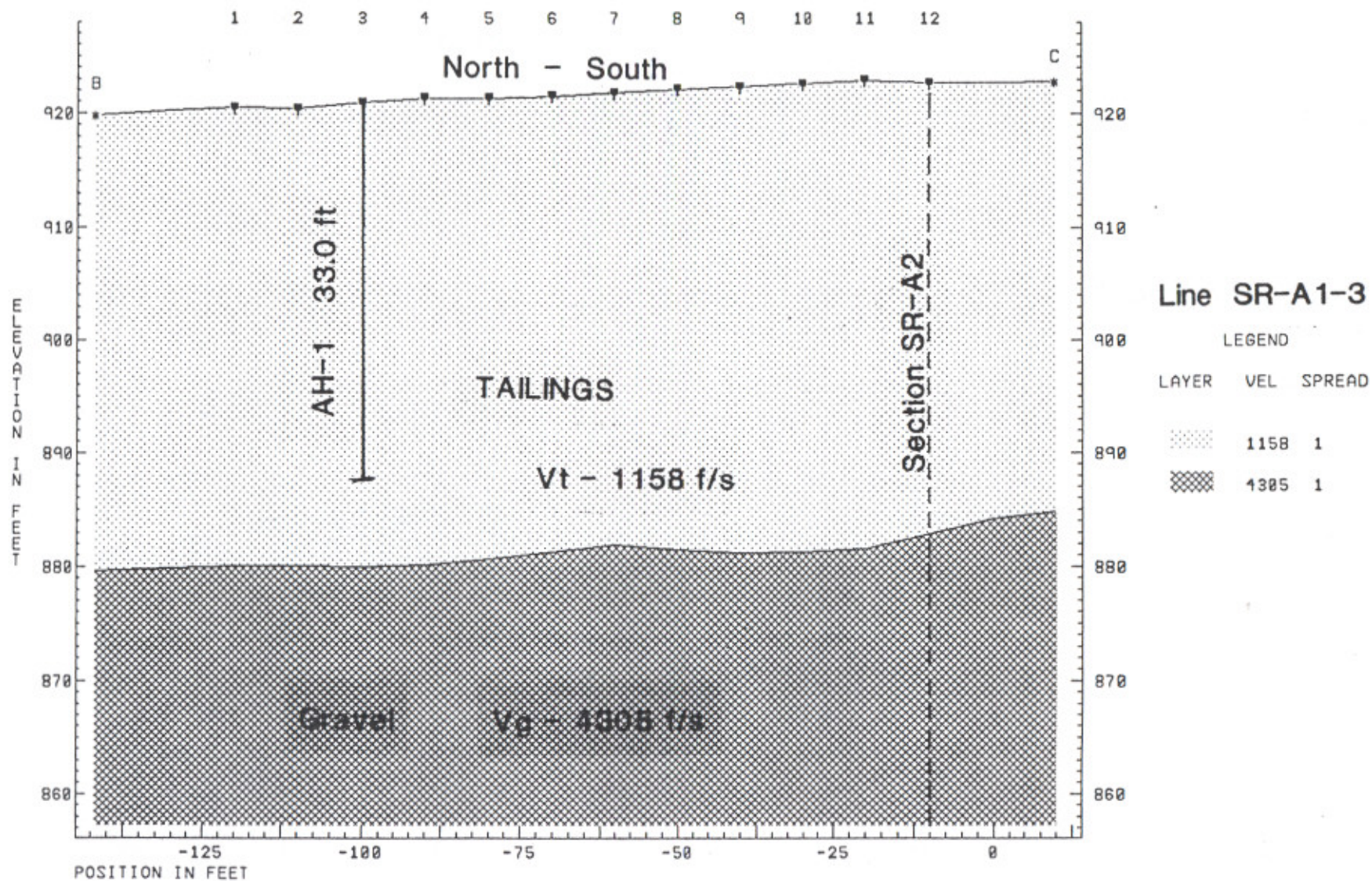


Figure D-1B. Seismic refraction layer model, tailings level A, Line SR-A1-3.

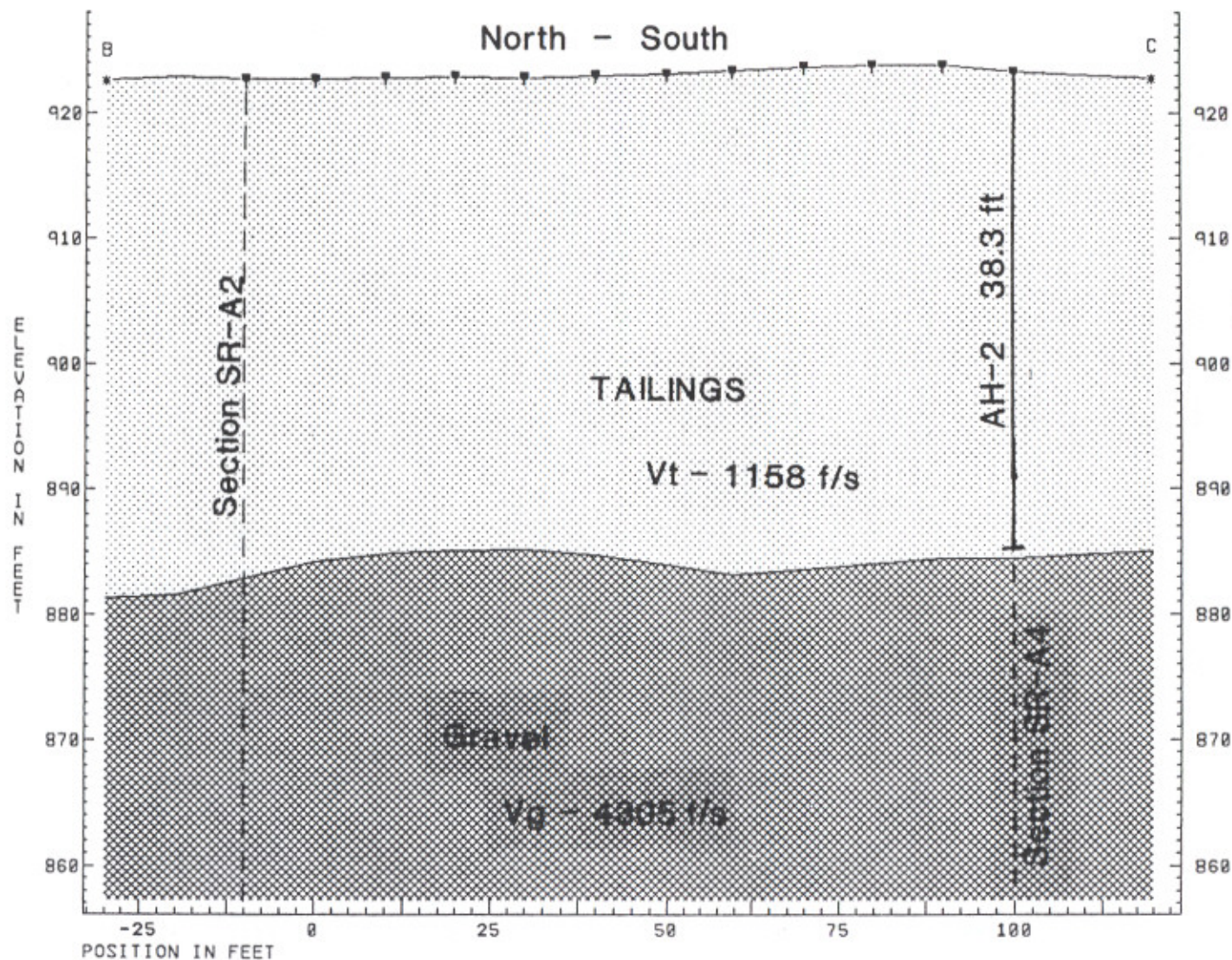
FILE SRA1_3.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-A1-3
SPREAD 3

4-18-1993

1 2 3 4 5 6 7 8 9 10 11 12

North - South



Line SR-A1-3

LEGEND

LAYER VEL SPREAD

890 1158 3

880 4305 3

870

860

Figure D-2. Seismic refraction layer model, tailings level A, Line SR-A2.

FILE SRA2.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-A2
SPREAD A

4-17-1993

East - West

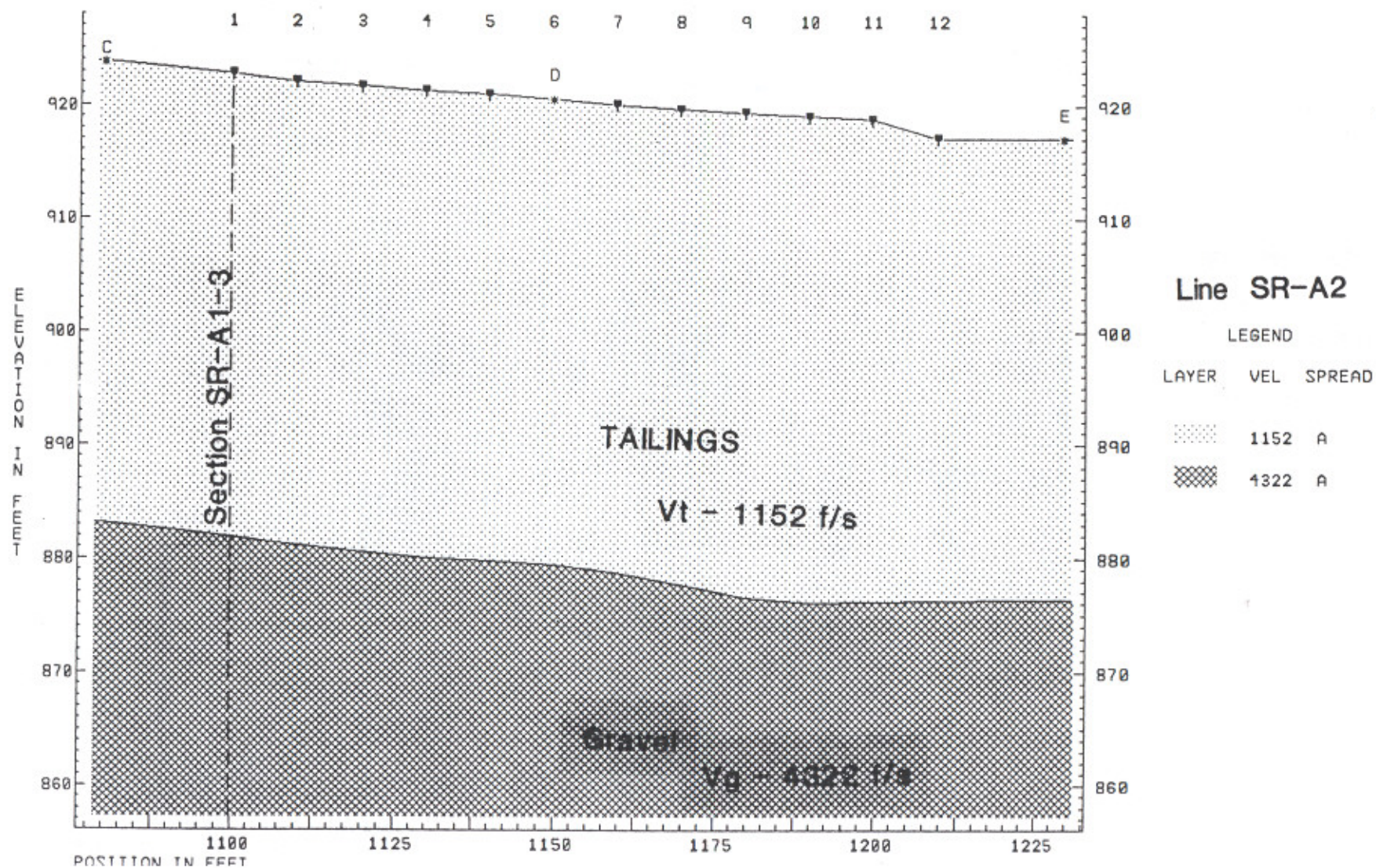


Figure D-3. Seismic refraction layer model, tailings level A, Line SR-A4.

FILE SRA4.SIP

KATHERINE MINE TAILINGS, AZ - SEISMIC LINE SR-A4

SPREAD F

5-19-1994

East - West

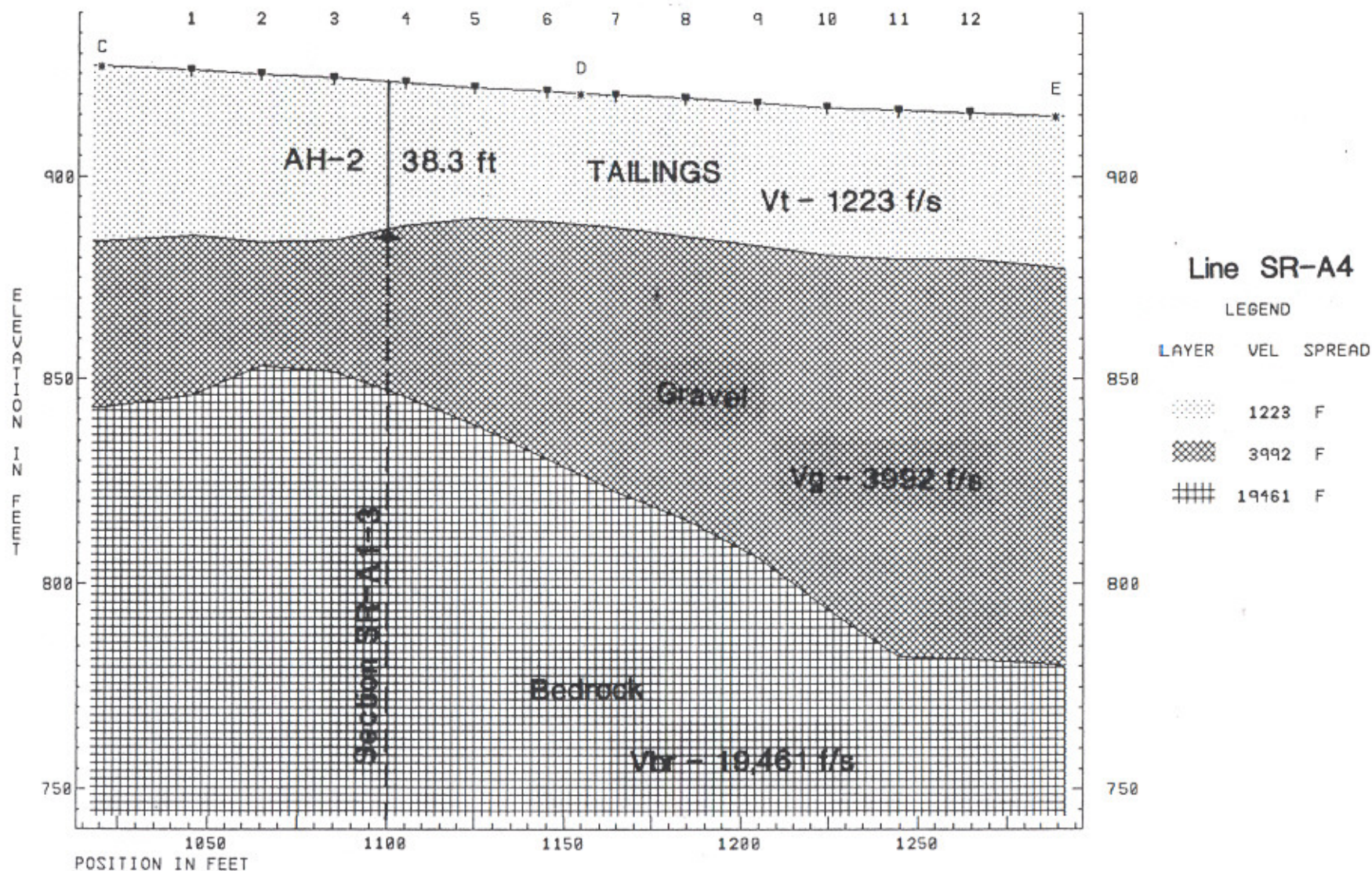


Figure D-4A. Seismic refraction layer model, tailings level B, Line SR-B1-3.

FILE SRB1_3.SIP
 KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-B1_3
 SPREAD 1

4-18-1993

North - South

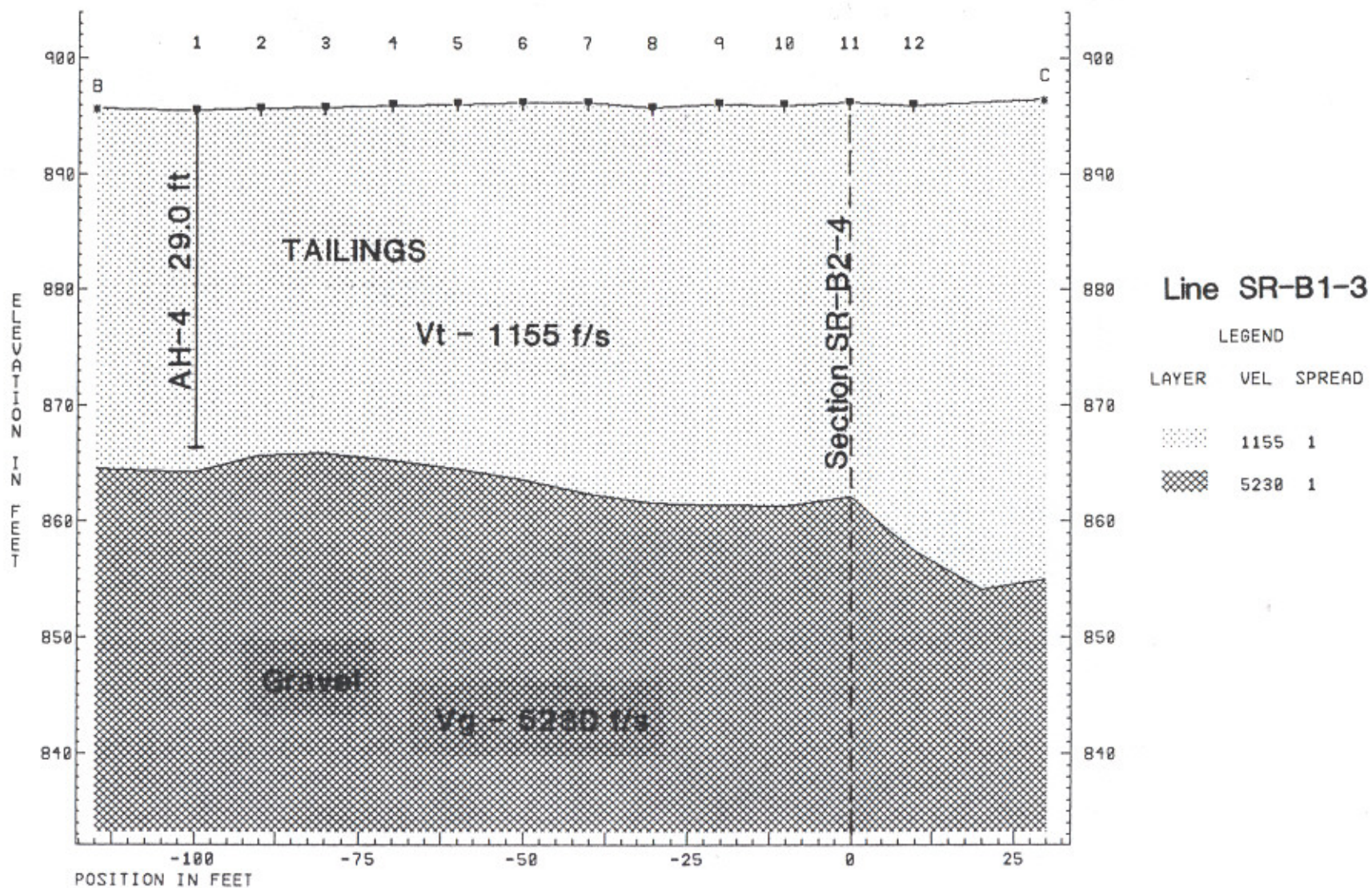


Figure D-4B. Seismic refraction layer model, tailings level B, Line SR-B1-3.

FILE SRB1-3.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-B1-3
SPREAD 3

4-18-1993

North - South

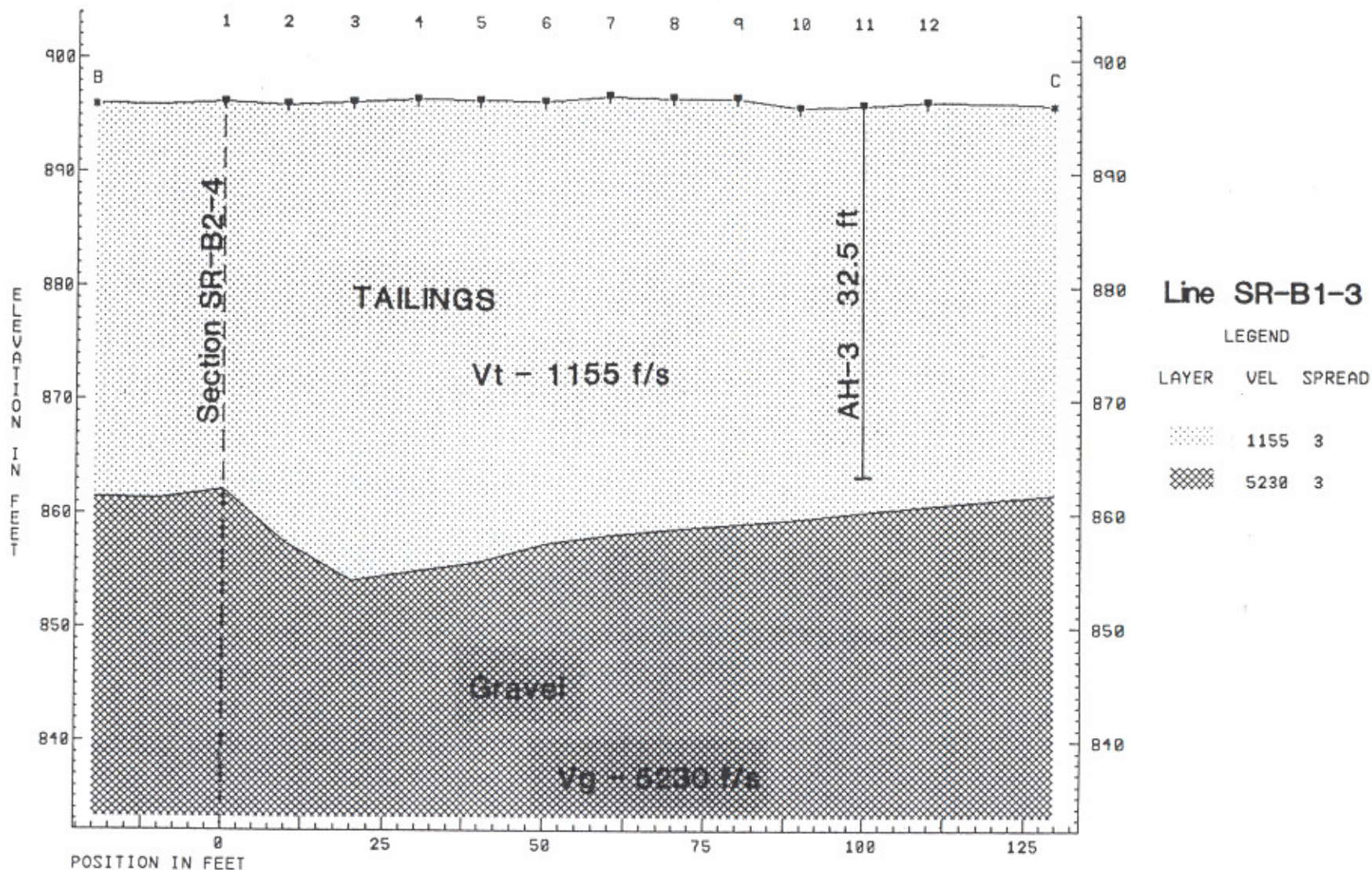


Figure D-5A. Seismic refraction layer model, tailings level B, Line SR-B2-4.

FILE SRB2_4.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-B2-4
SPREAD 2

4-19-1993

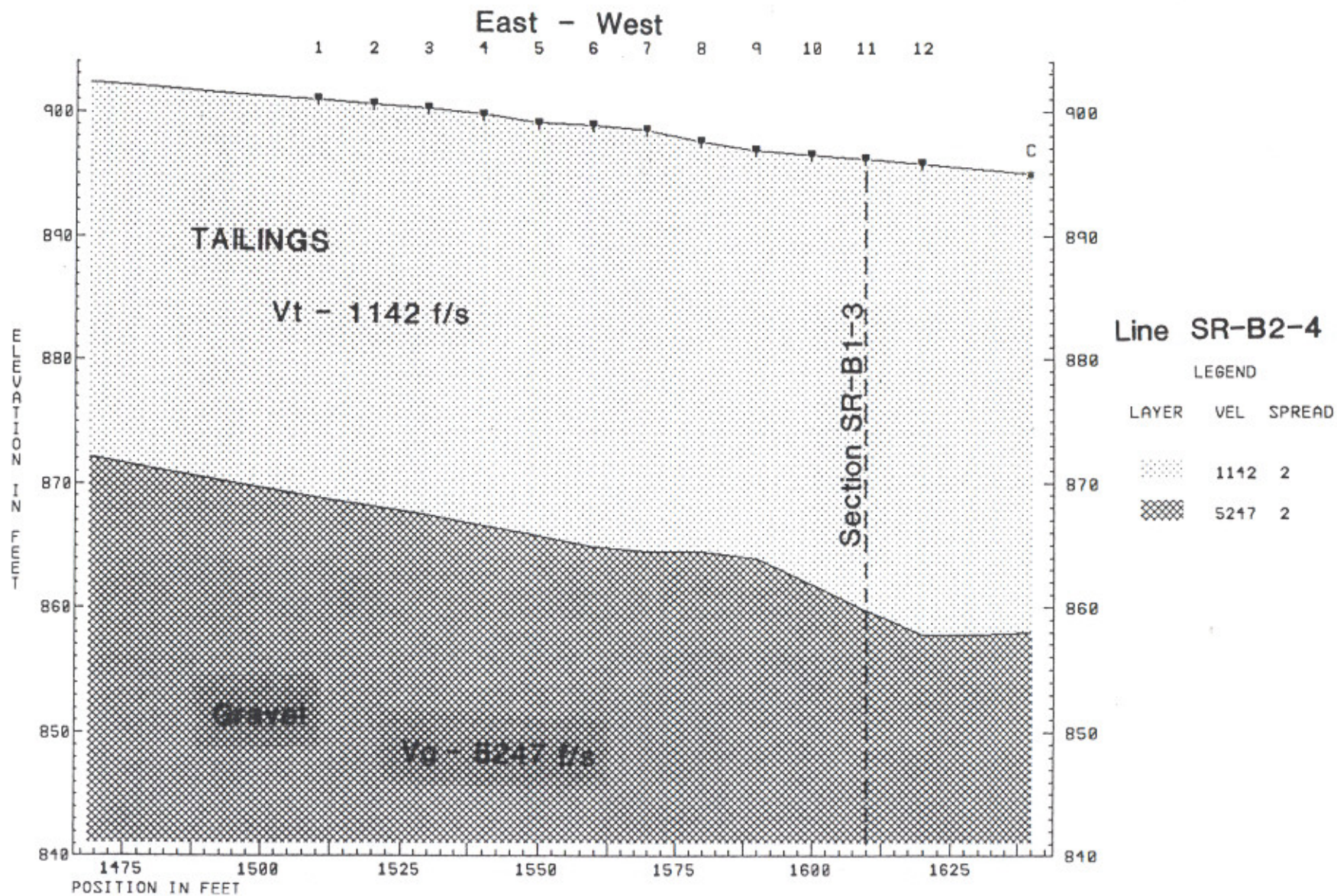


Figure D-5B. Seismic refraction layer model, tailings level B, Line SR-B2-4.

FILE SRB2-4.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-B2-4
SPREAD 4

4-19-1993

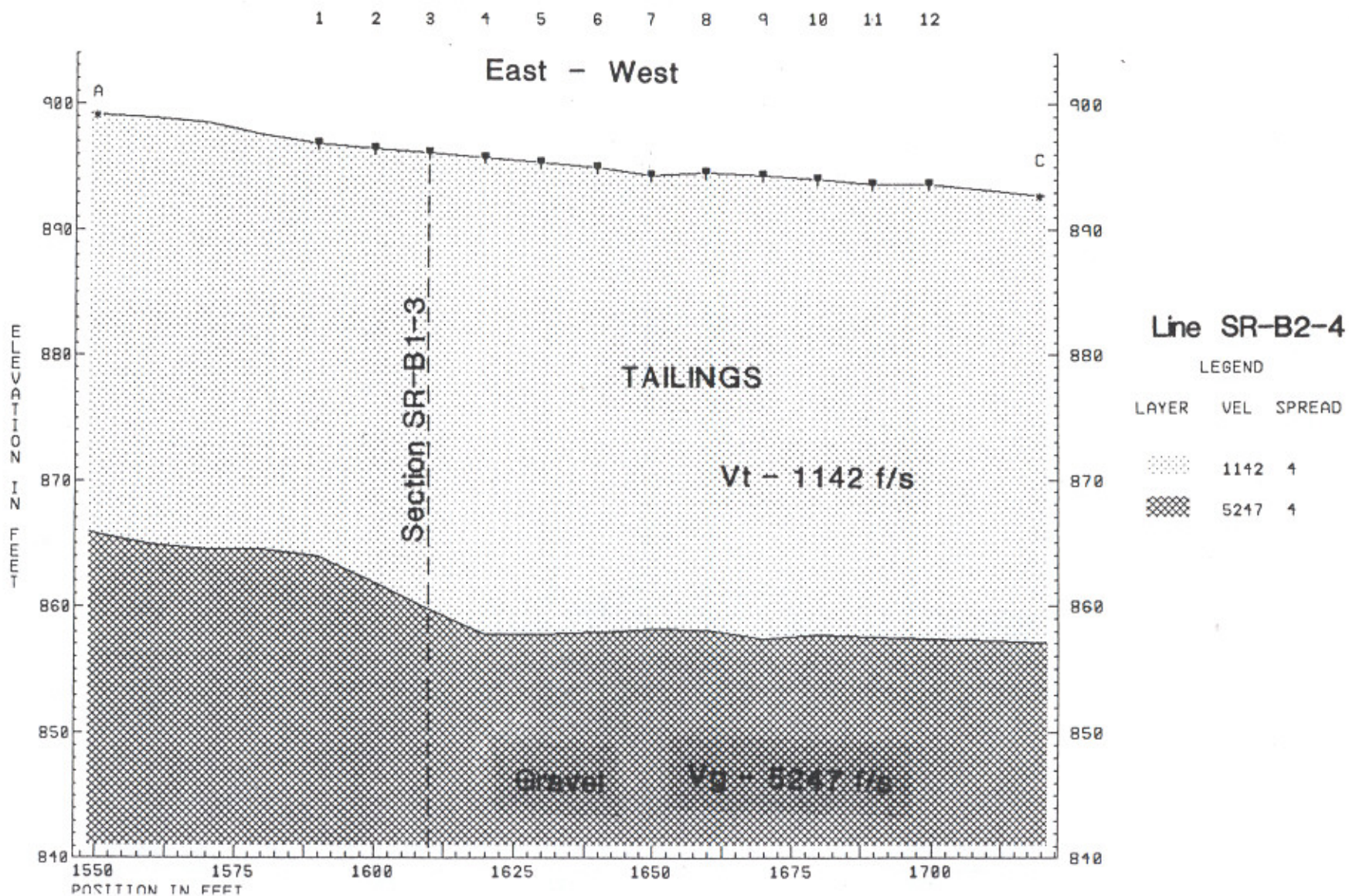


Figure D-6. Seismic refraction layer model, tailings level C, Line SR-C1.

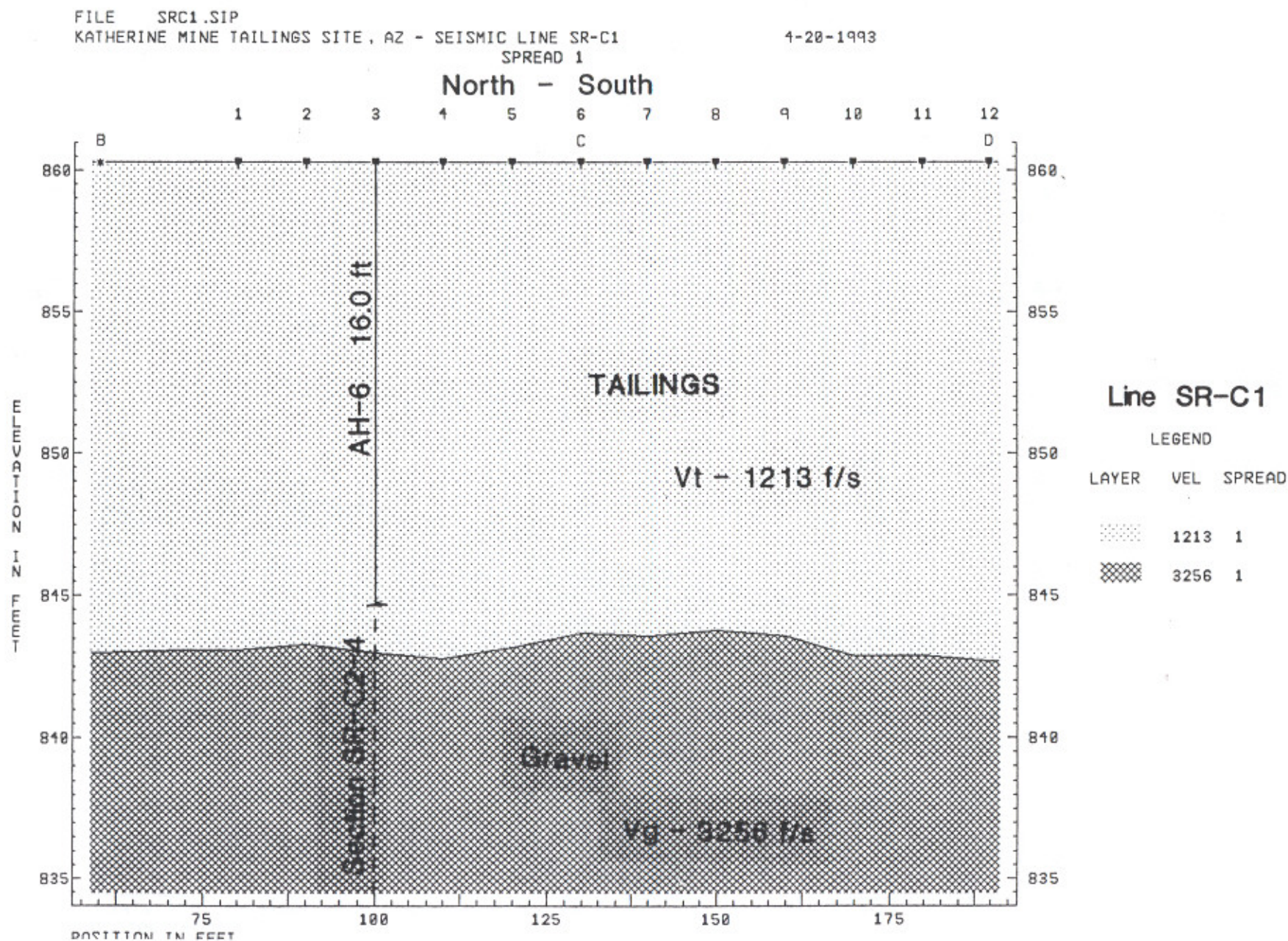


Figure D-7A. Seismic refraction layer model, tailings level C, Line SR-C2-4.

FILE SRC2_4.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-C2-4
SPREAD 2

4-20-1993

East - West

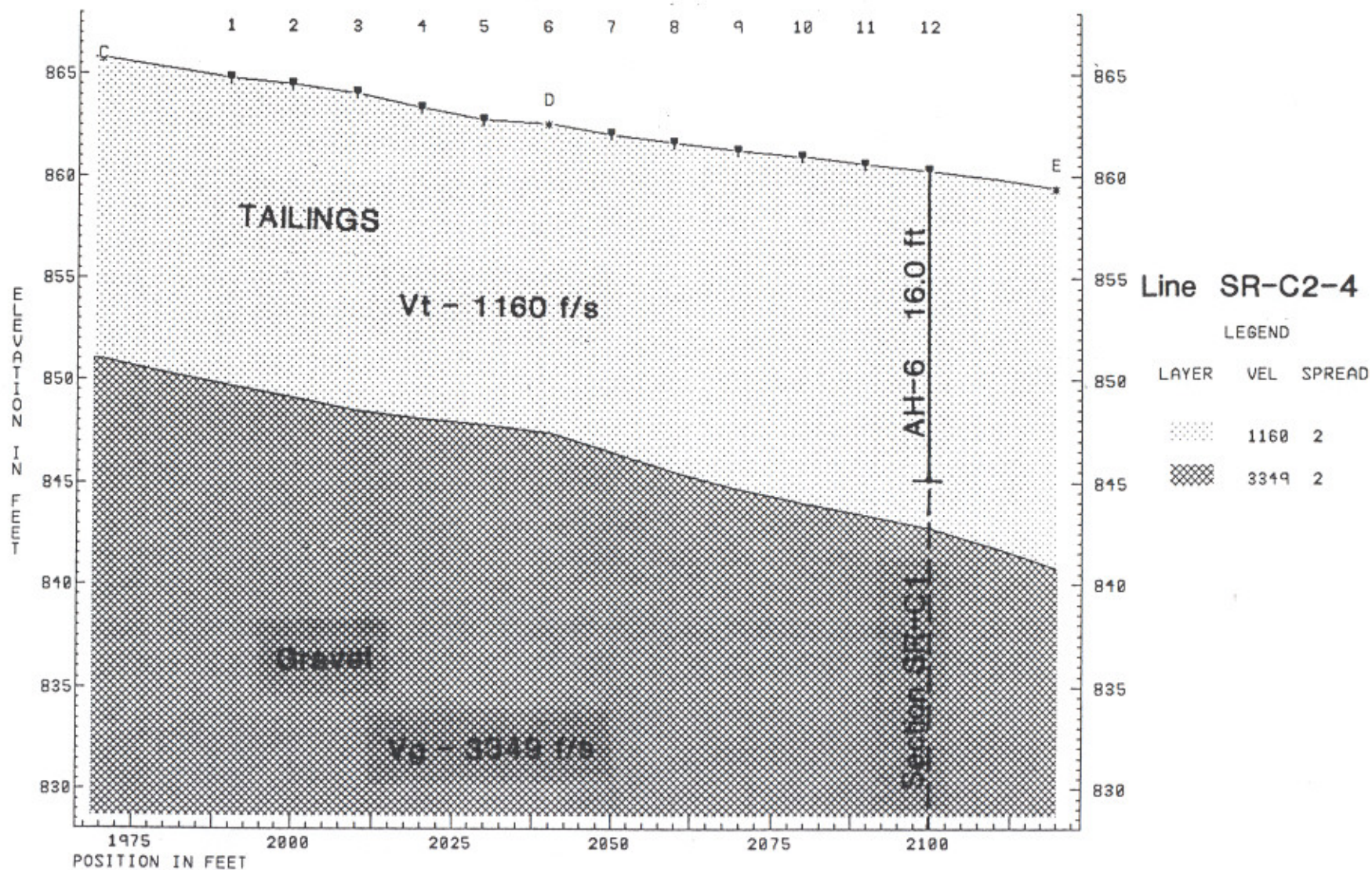


Figure D-7B. Seismic refraction layer model, tailings level C, Line SR-C2-4.

FILE SRC2.4.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-C2-4
SPREAD 4

4-28-1993

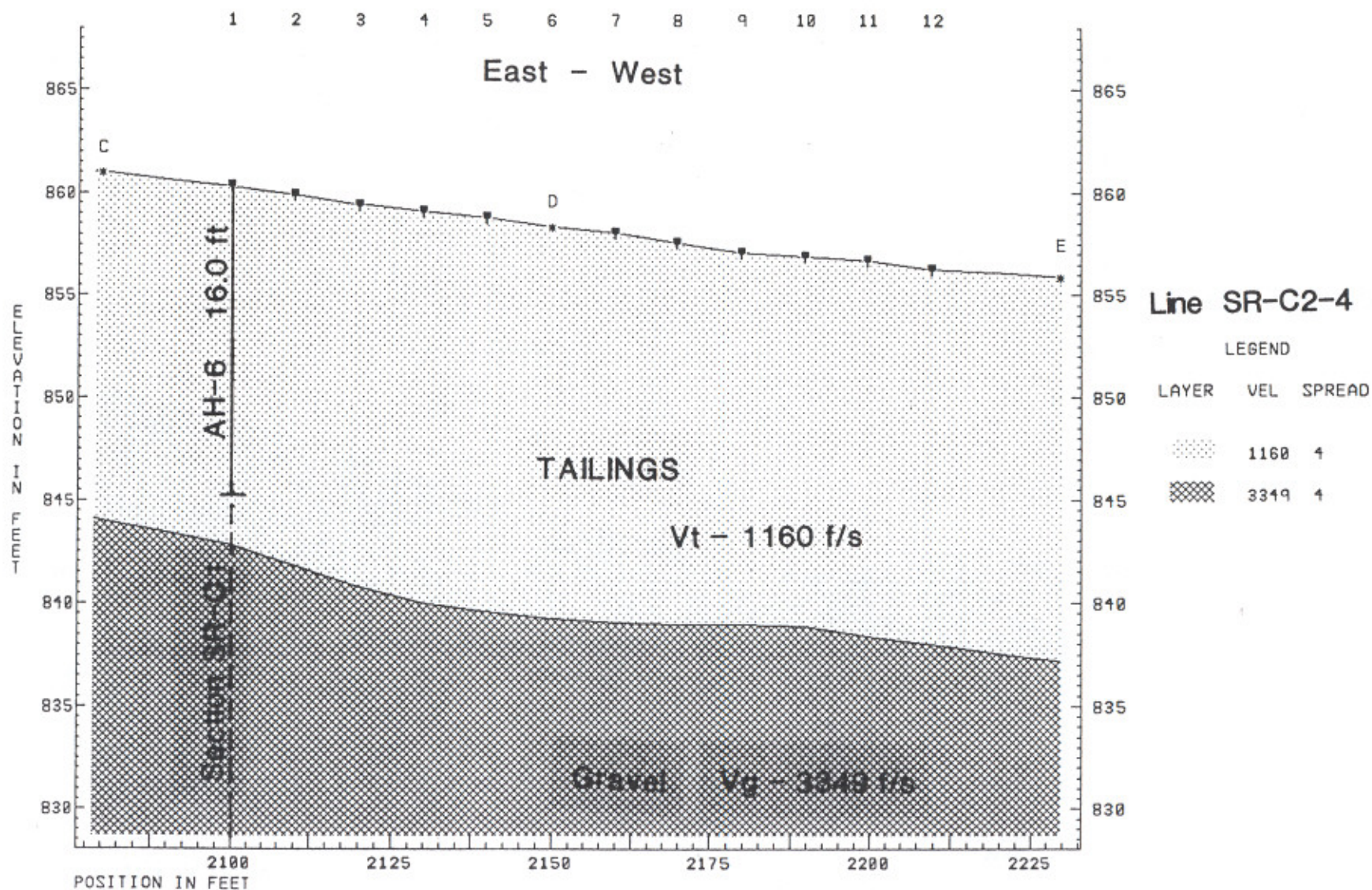


Figure D-8A. Seismic refraction layer model, tailings level C, Line SR-C6-8.

FILE SRC6_8.SIP
KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINES SR-C6-8
SPREAD 6

4-28-1993

East - West

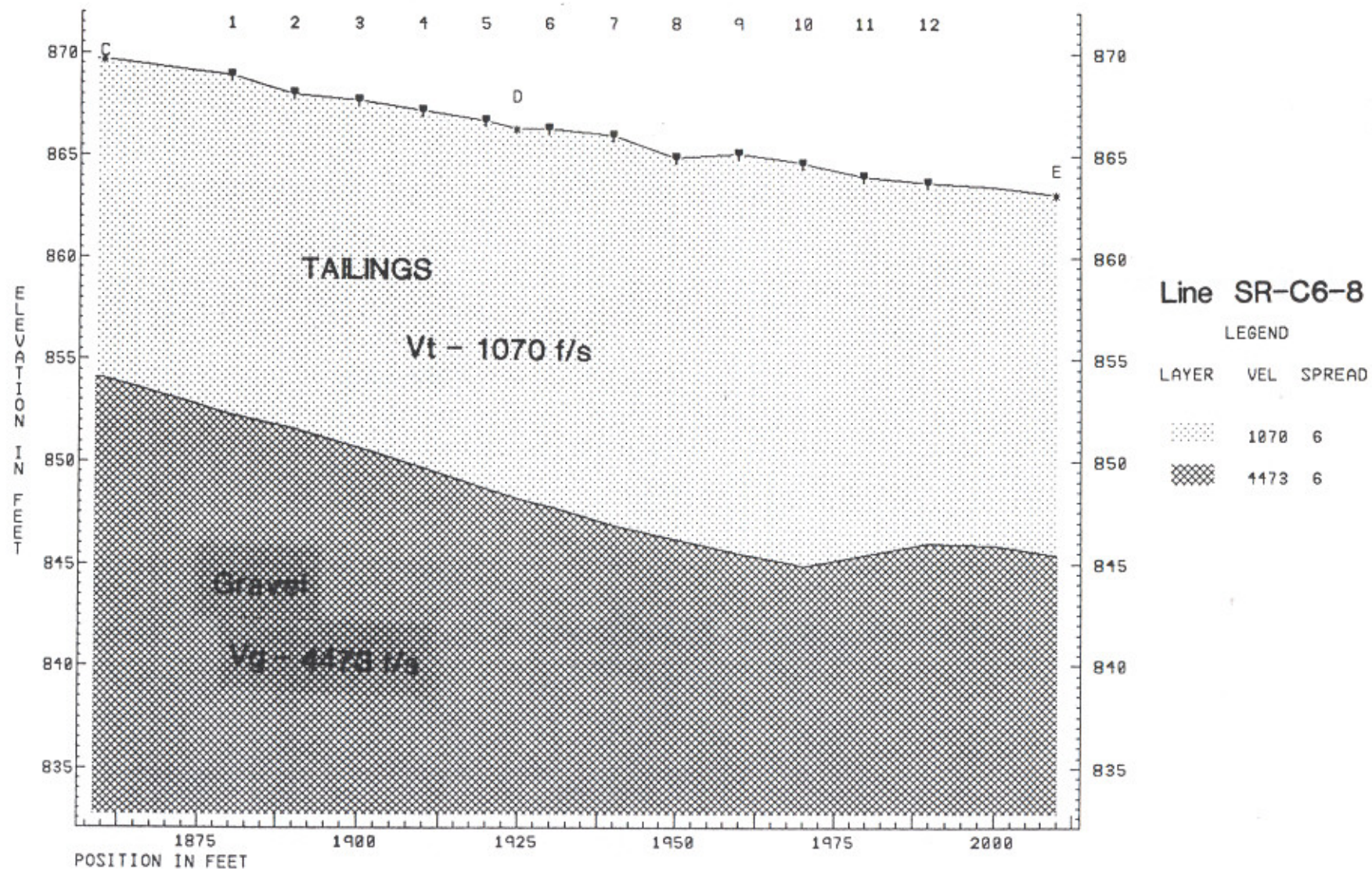


Figure D-8B. Seismic refraction layer model, tailings level C, Line SR-C6-8.

FILE SRC6-8.SIP
KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINES SR-C6-8
SPREAD 8

4-20-1993

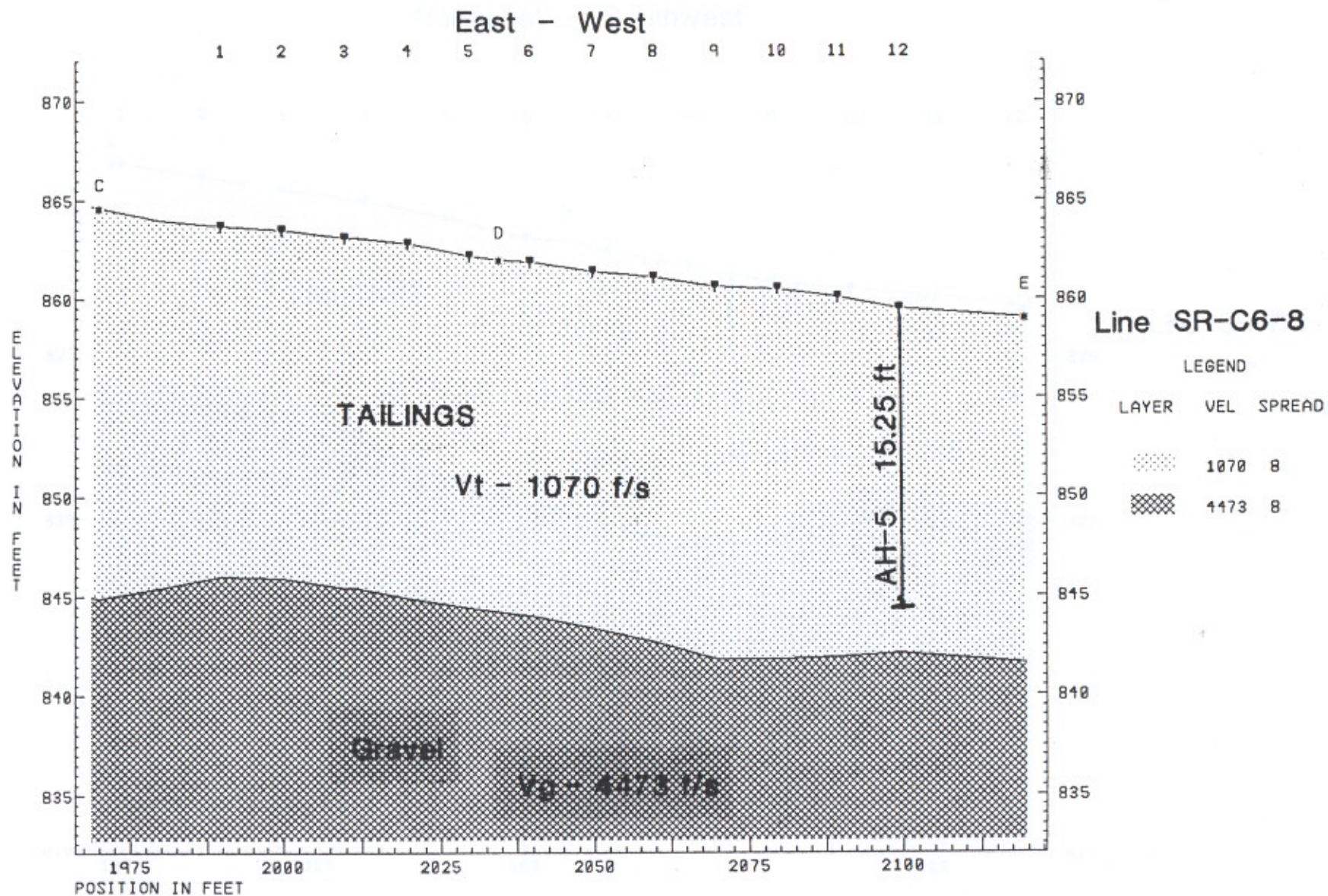


Figure D-9. Seismic refraction layer model, tailings level D, Line SR-D2.

FILE SRD2.SIP

KATHERINE MINE TAILINGS SITE, AZ - SEISMIC LINE SR-D2
SPREAD A

4-21-1993

Northeast - Southwest

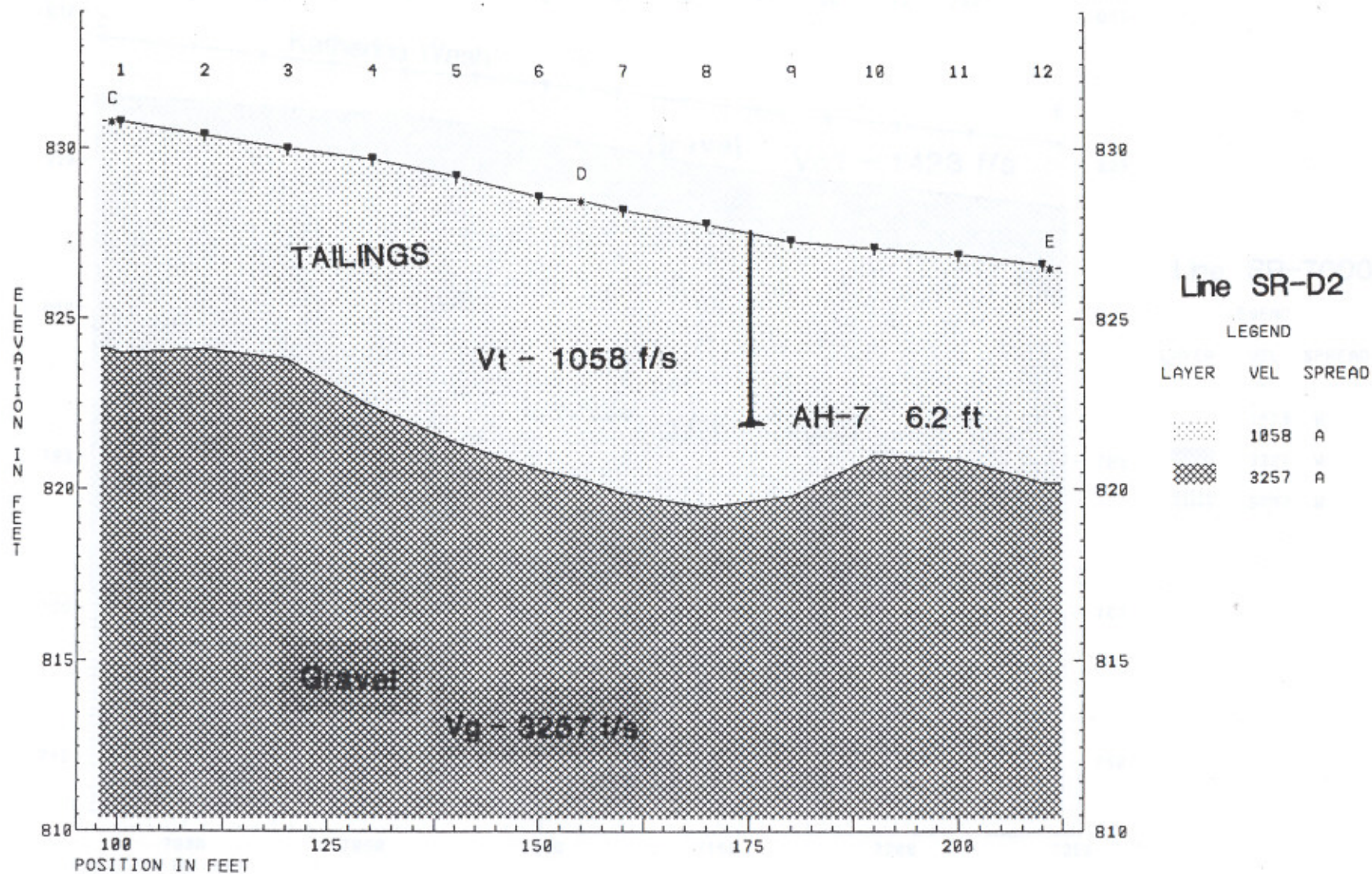


Figure D-10. Seismic refraction layer model, Katherine Wash, Line SR-7000.

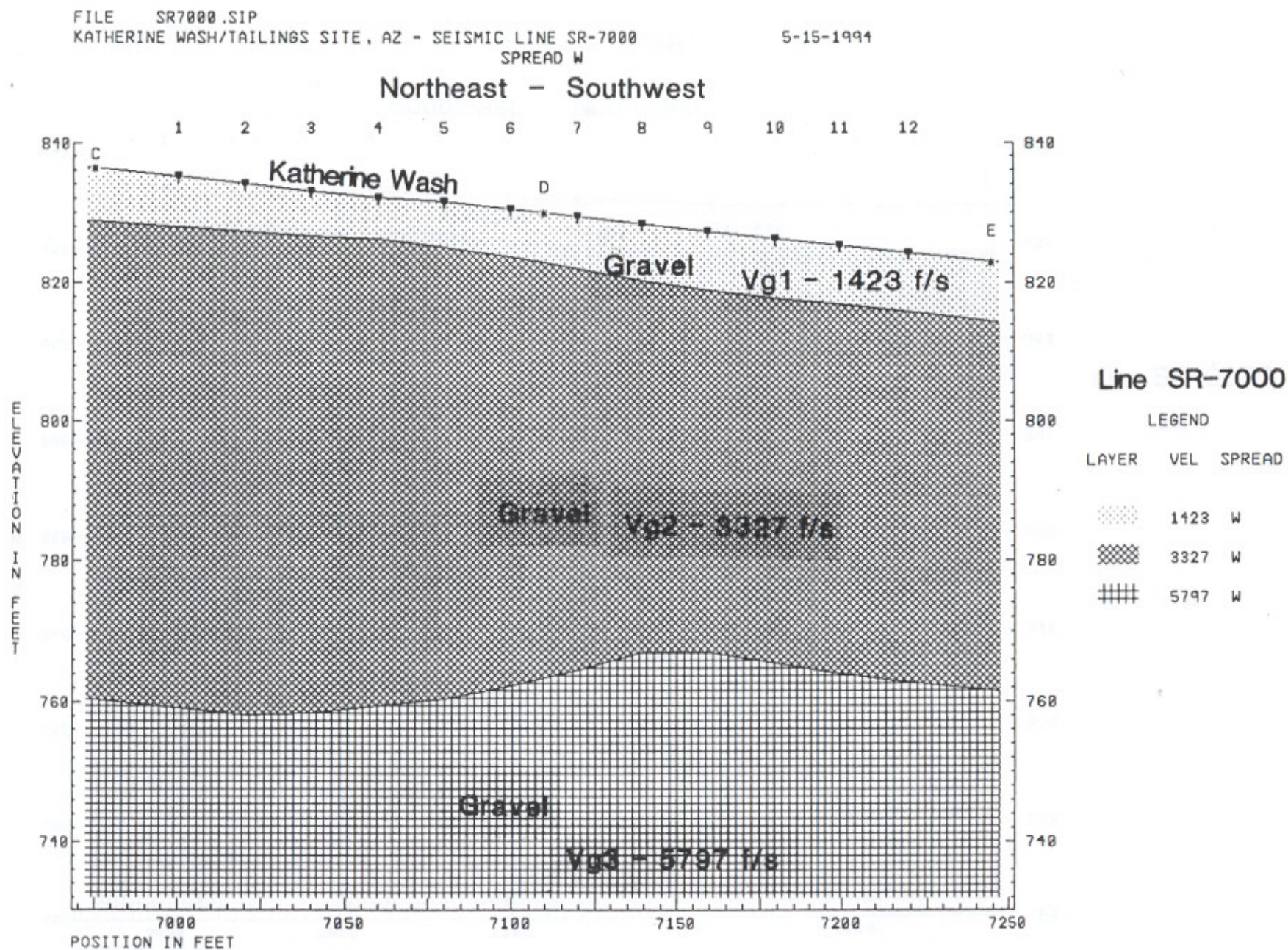


Figure D-11. Seismic refraction layer model, Katherine Mine subsidence, east shaft, Line SR-2000.

FILE SR2000.SIP

KATHERINE MINE SUBSIDENCE PROJECT, AZ - SEISMIC LINE SR-2000
SPREAD A

5-20-1994

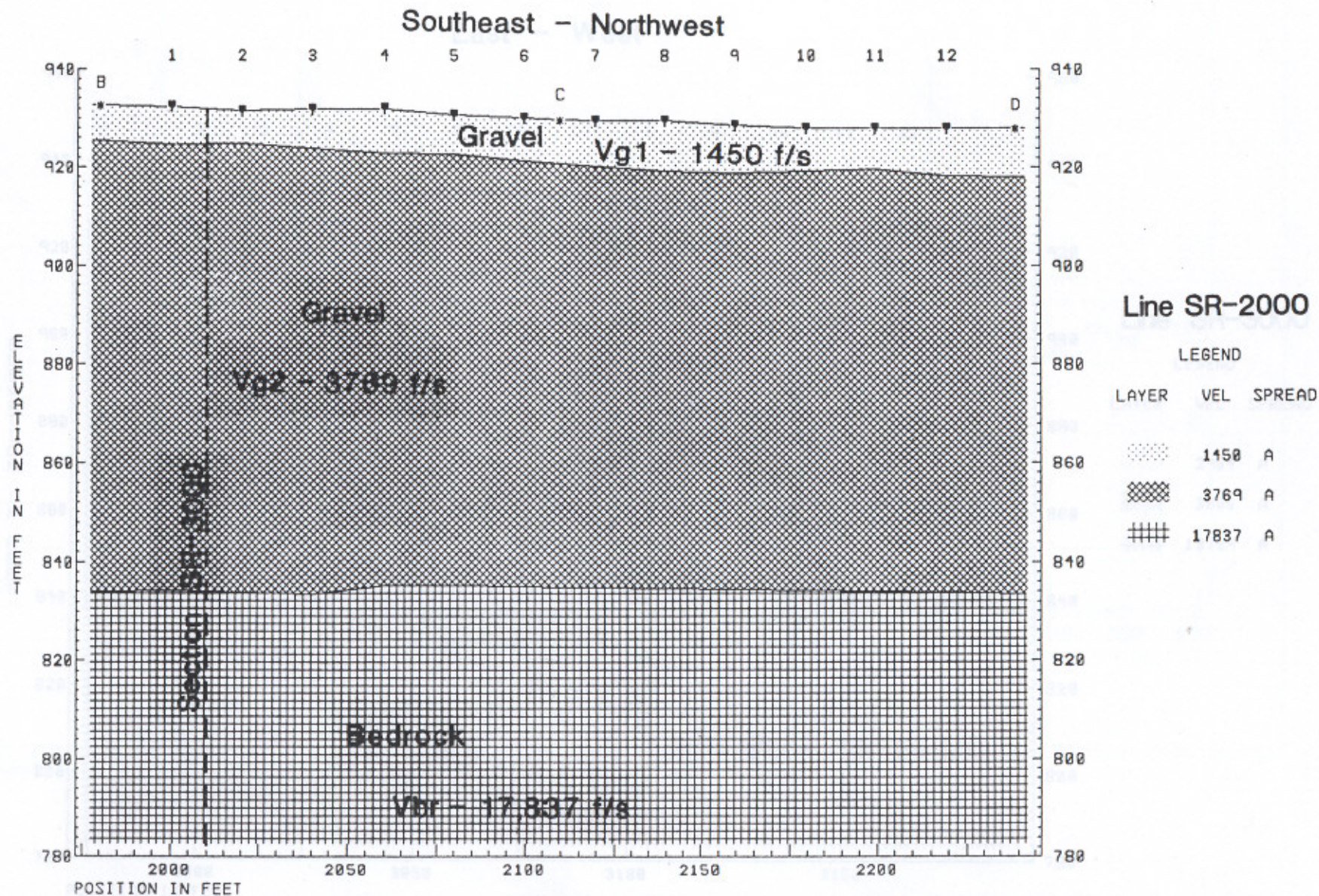


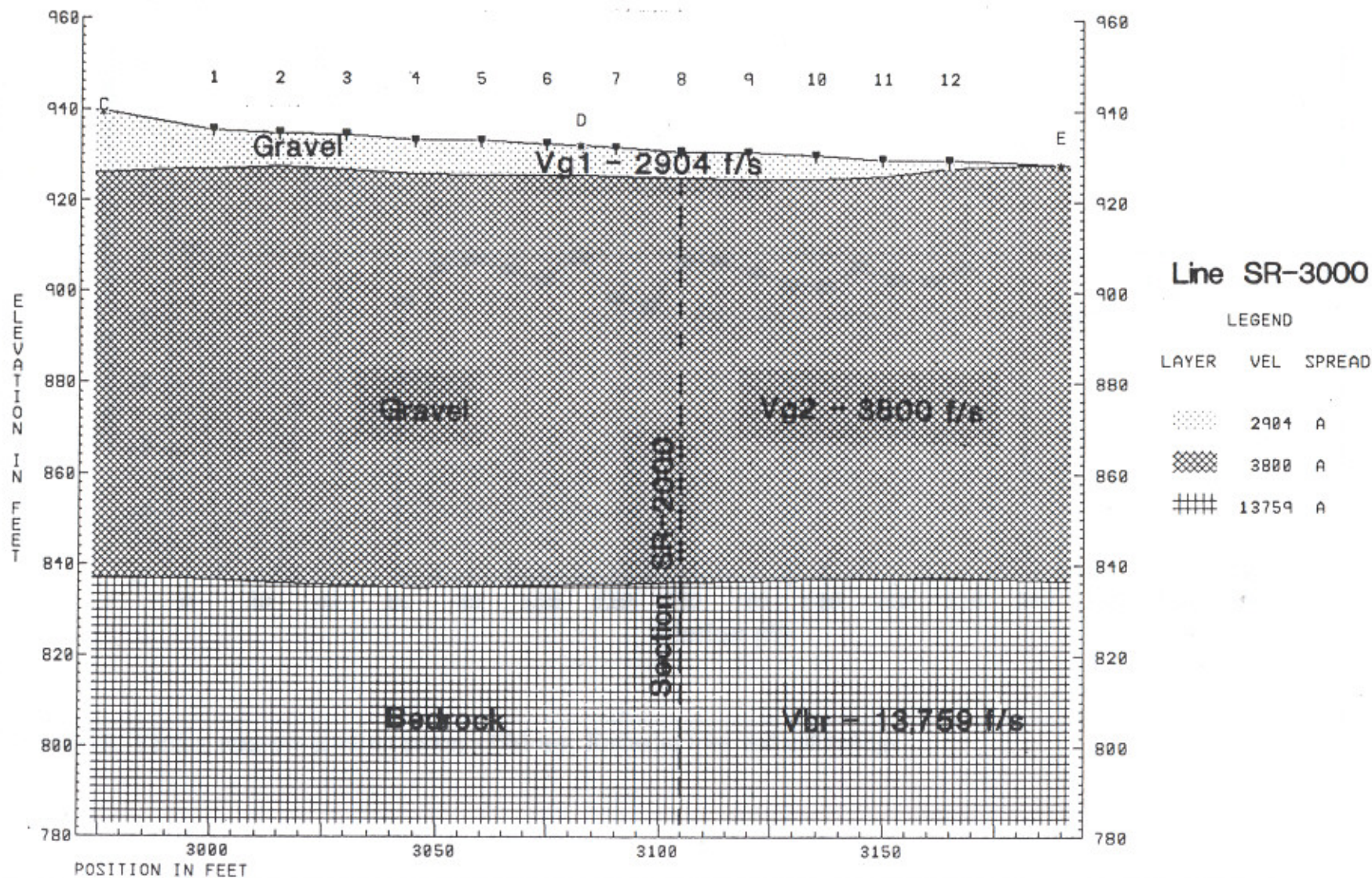
Figure D-12. Seismic refraction layer model, Katherine Mine subsidence, east shaft, Line SR-3000.

FILE SR3000.SIP

KATHERINE MINE SUBSIDENCE PROJECT, AZ - SEISMIC LINE SR-3000
SPREAD A

5-20-1994

East - West



Magnetic Gradient Survey - GM Test
Katherine Mine and Mill Tailings, AZ

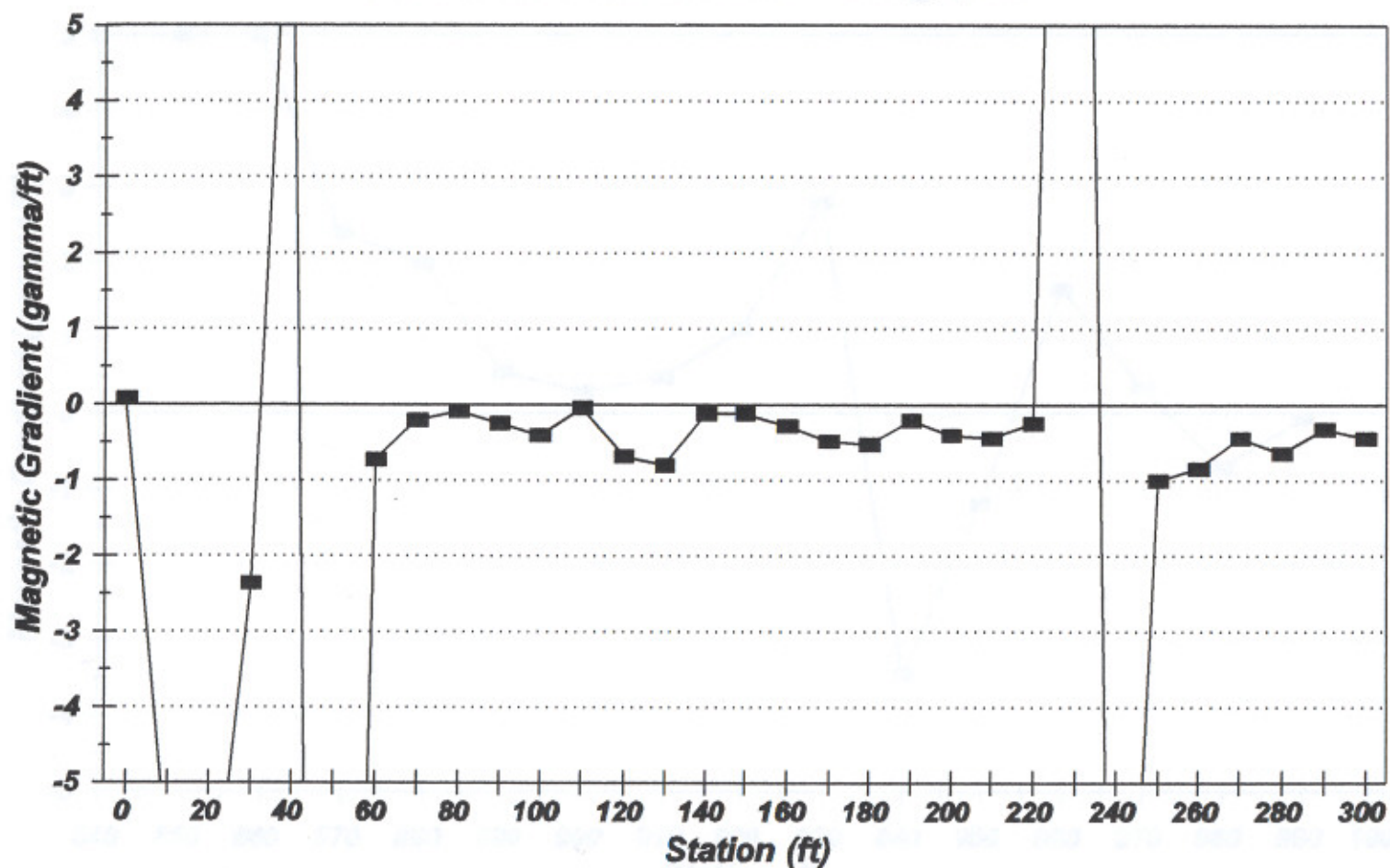


Figure D-13. Vertical magnetic gradient survey - GM-test, Katherine mine and mill tailings.

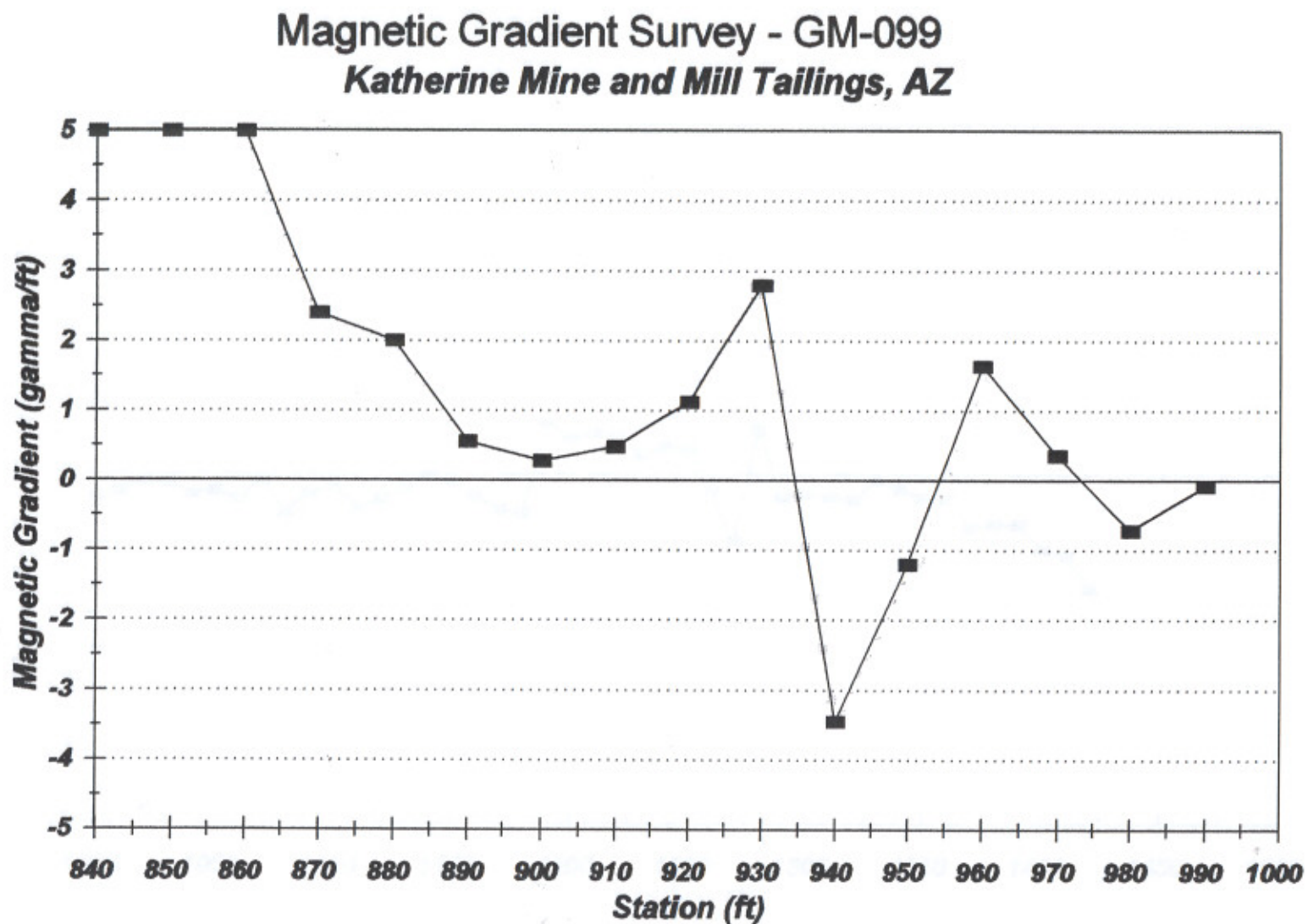


Figure D-14. Vertical magnetic gradient survey - GM-099, Katherine mine and mill tailings

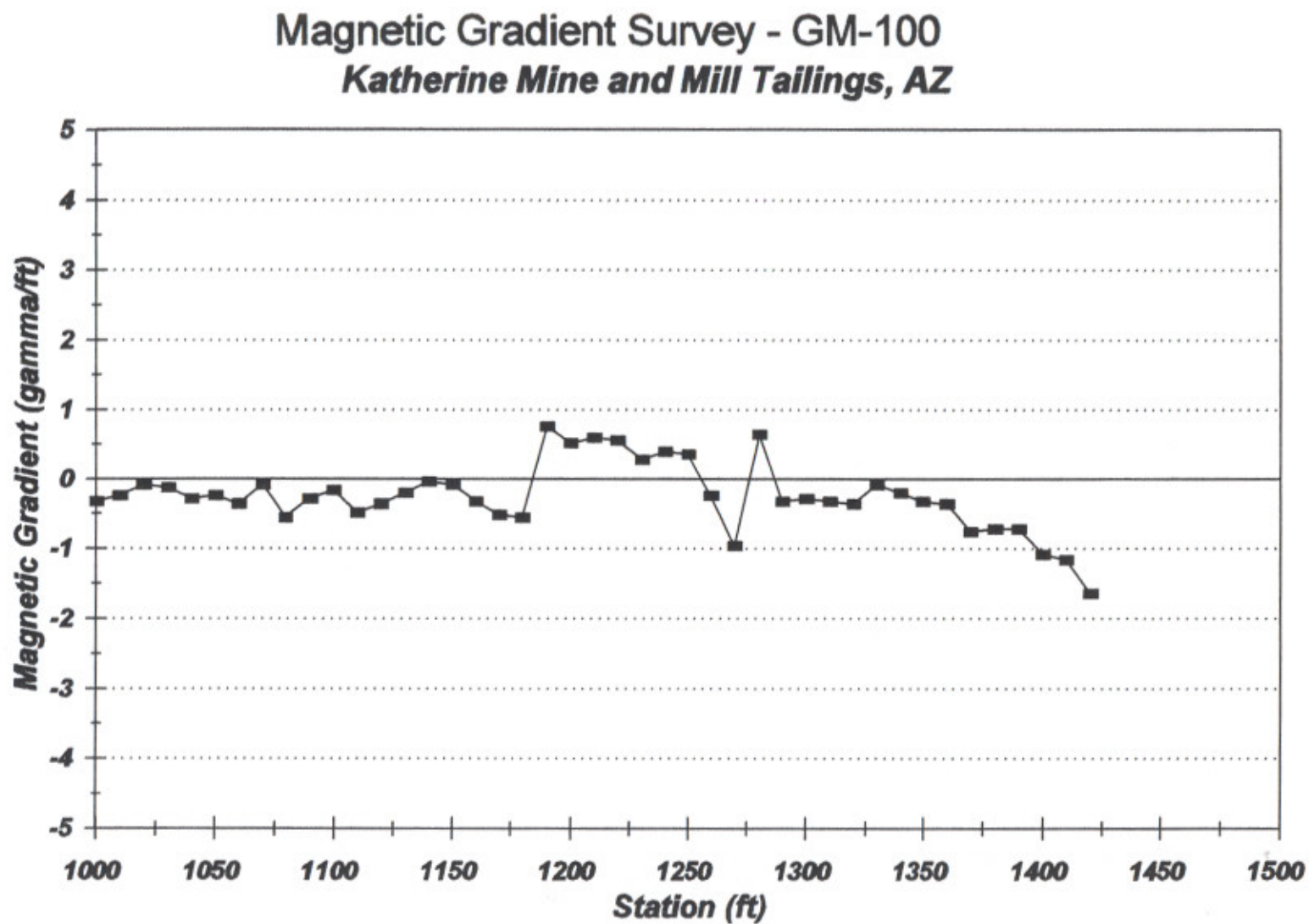


Figure D-15. Vertical magnetic gradient survey - GM-100, Katherine mine and mill tailings.

Magnetic Gradient Survey - GM-101,103
Katherine Mine and Mill Tailings, AZ

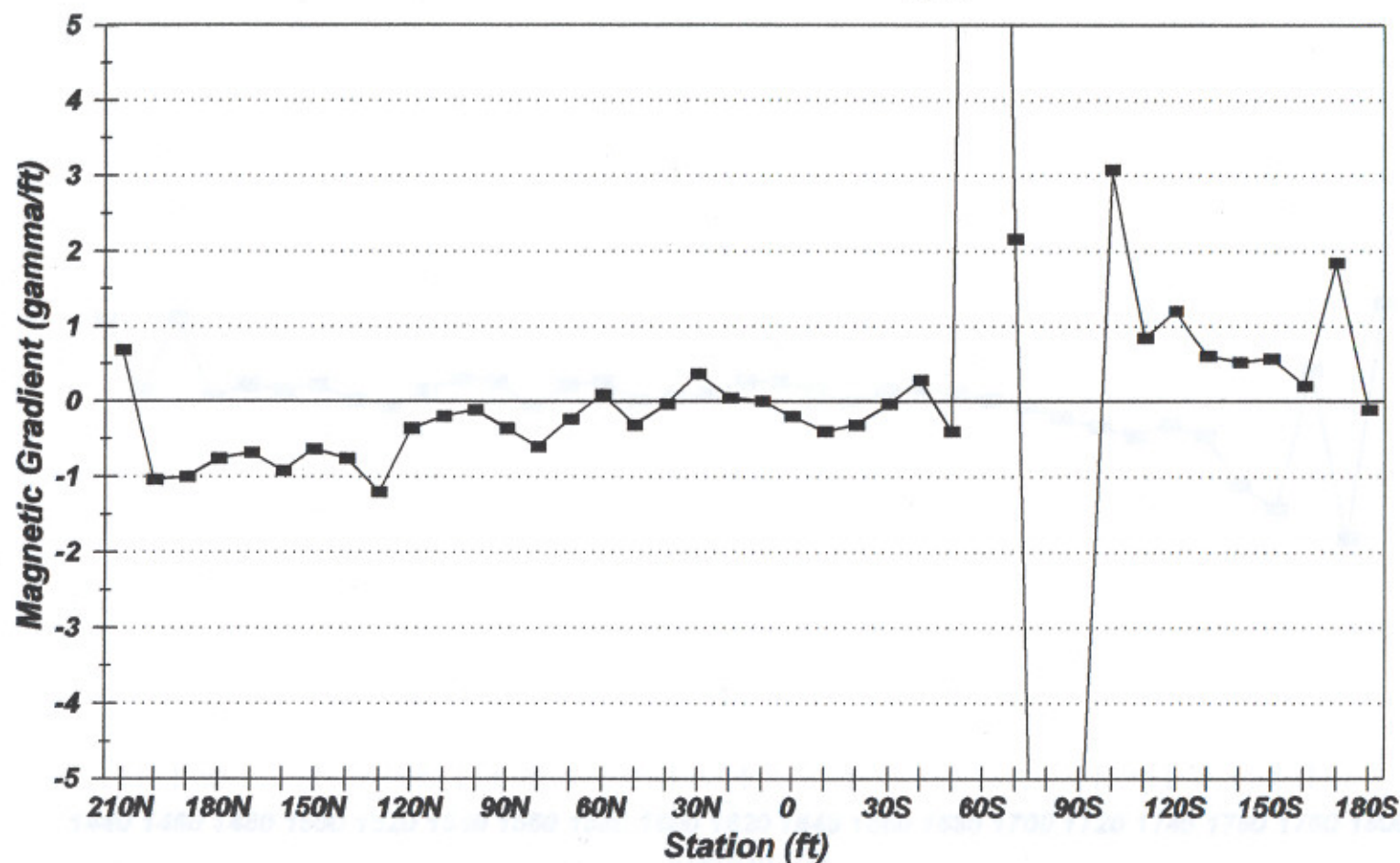


Figure D-16. Vertical magnetic gradient survey - GM-101, 103, Katherine mine and mill tailings.

Magnetic Gradient Survey - GM-200
Katherine Mine and Mill Tailings, AZ

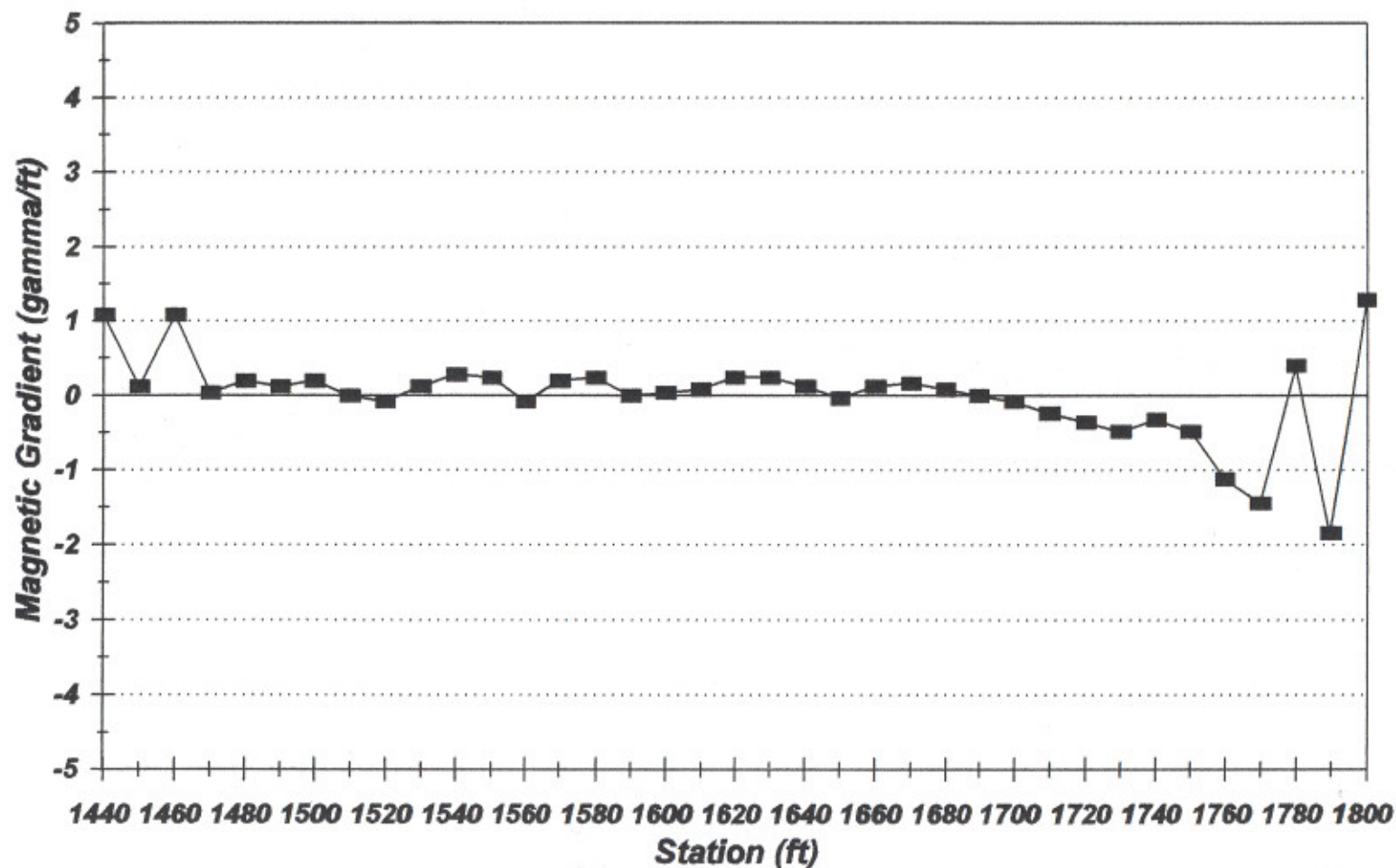


Figure D-17. Vertical magnetic gradient survey - GM-200, Katherine mine and mill tailings.

Magnetic Gradient Survey - GM-201, 203
Katherine Mine and Mill Tailings, AZ

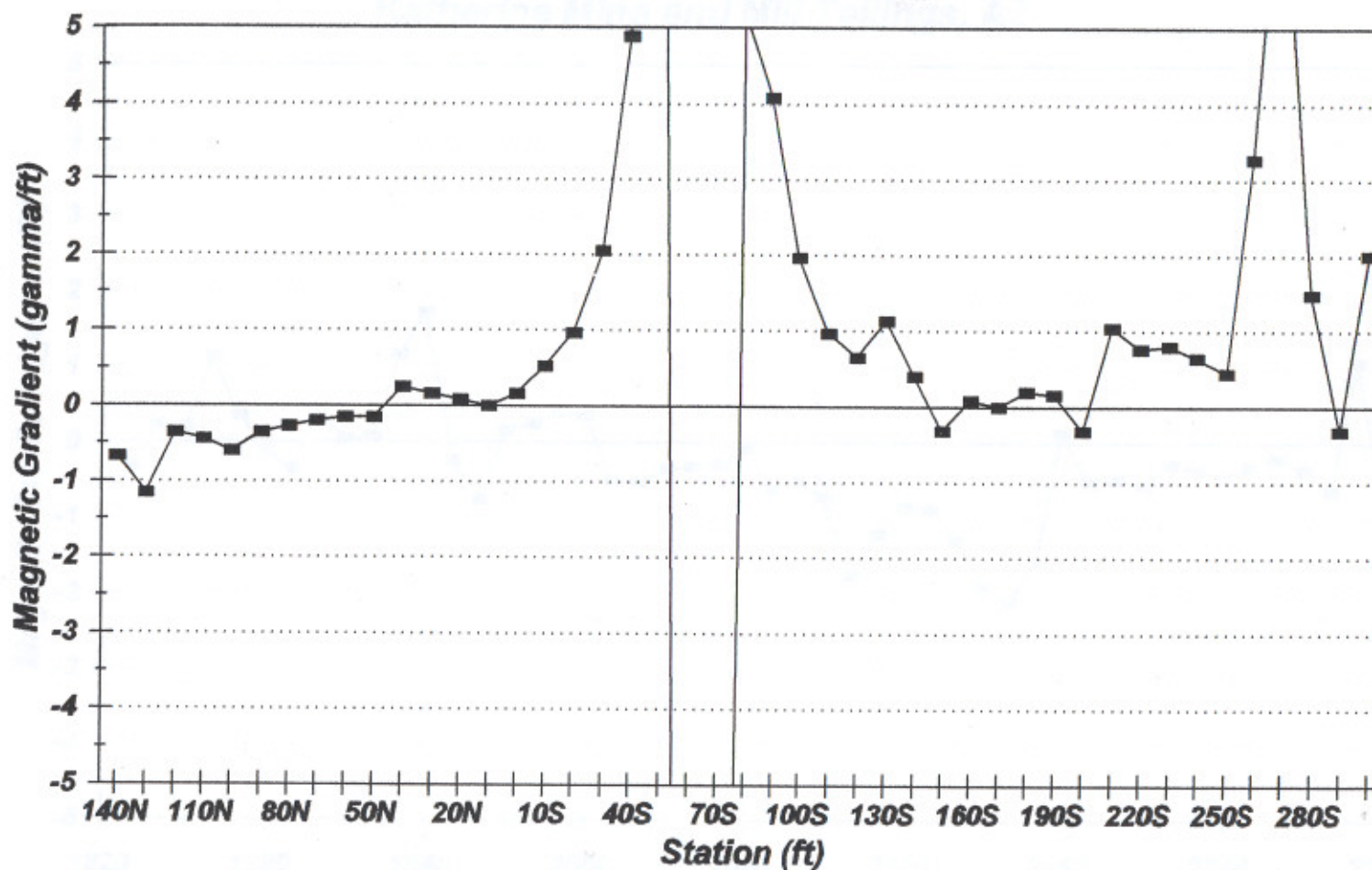


Figure D-18. Vertical magnetic survey - GM-201, 203, Katherine mine and mill tailings.

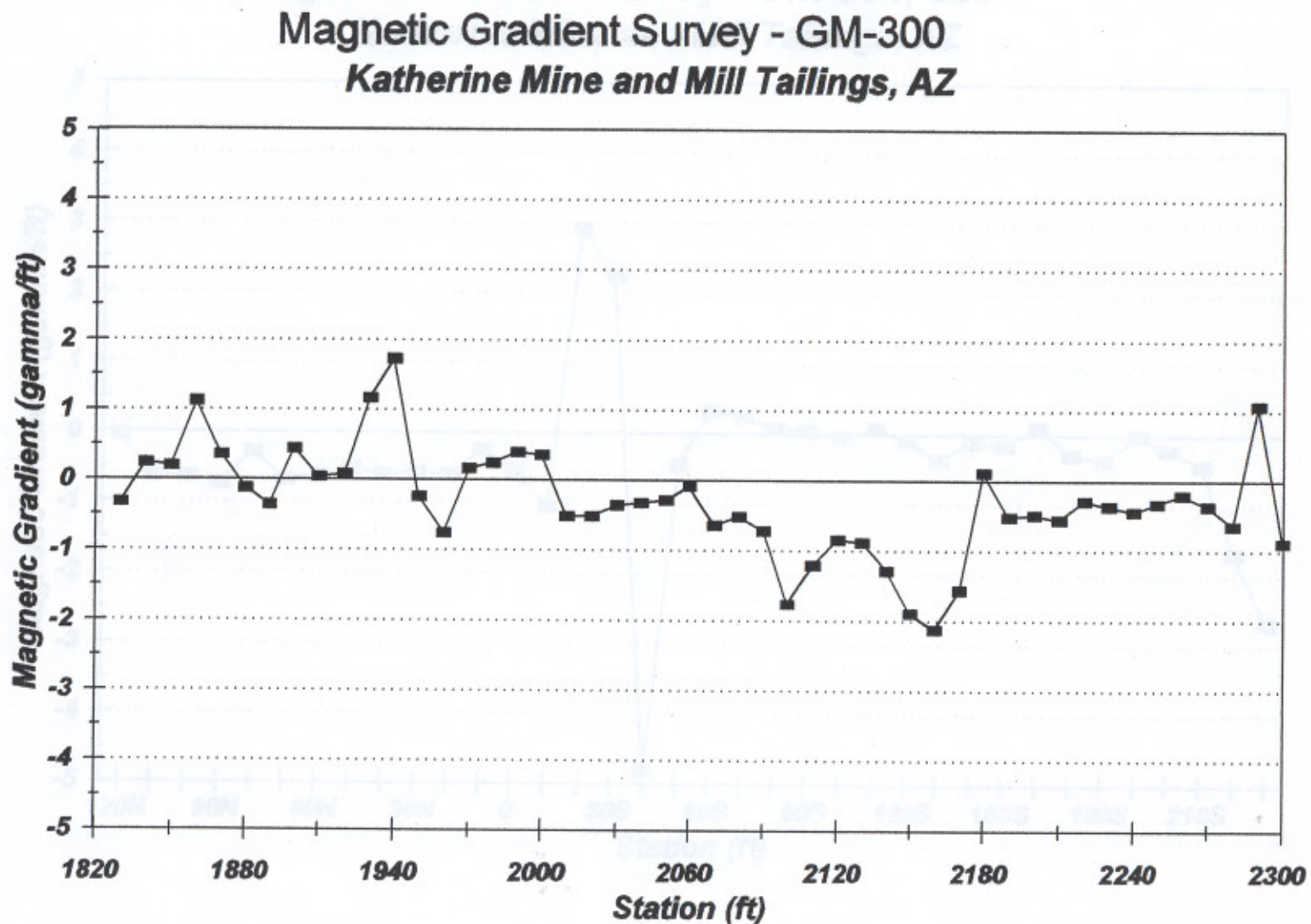


Figure D-19. Vertical magnetic gradient survey - GM-300, Katherine mine and mill tailings.

Magnetic Gradient Survey - GM-301, 303
Katherine Mine and Mill Tailings, AZ

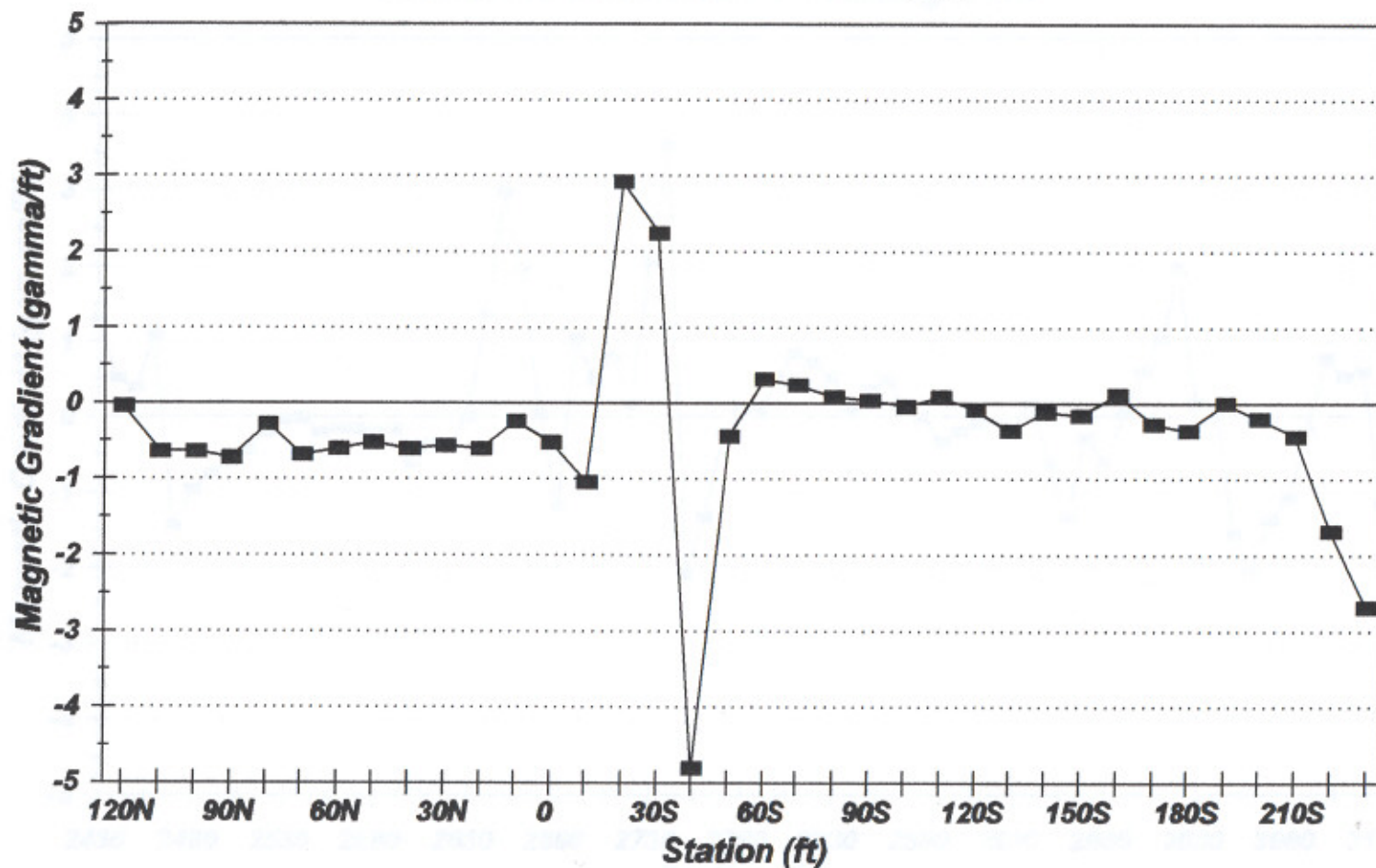


Figure D-20. Vertical magnetic gradient survey - GM-301, 303, Katherine mine and mill tailings.

Magnetic Gradient Survey - GM-400
Katherine Mine and Mill Tailings, AZ

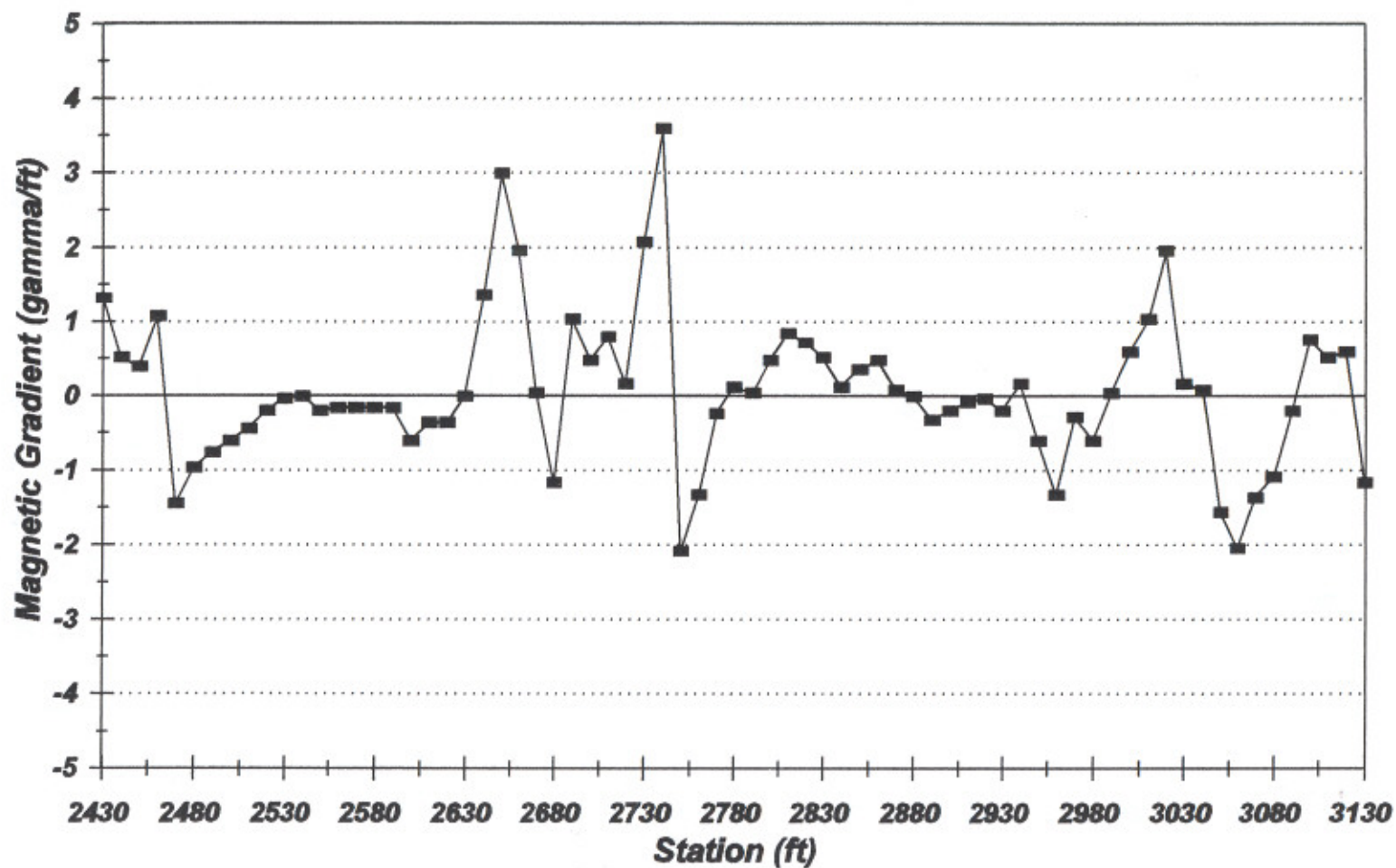


Figure D-21. Vertical magnetic gradient survey - GM-400, Katherine mine and mill tailings.

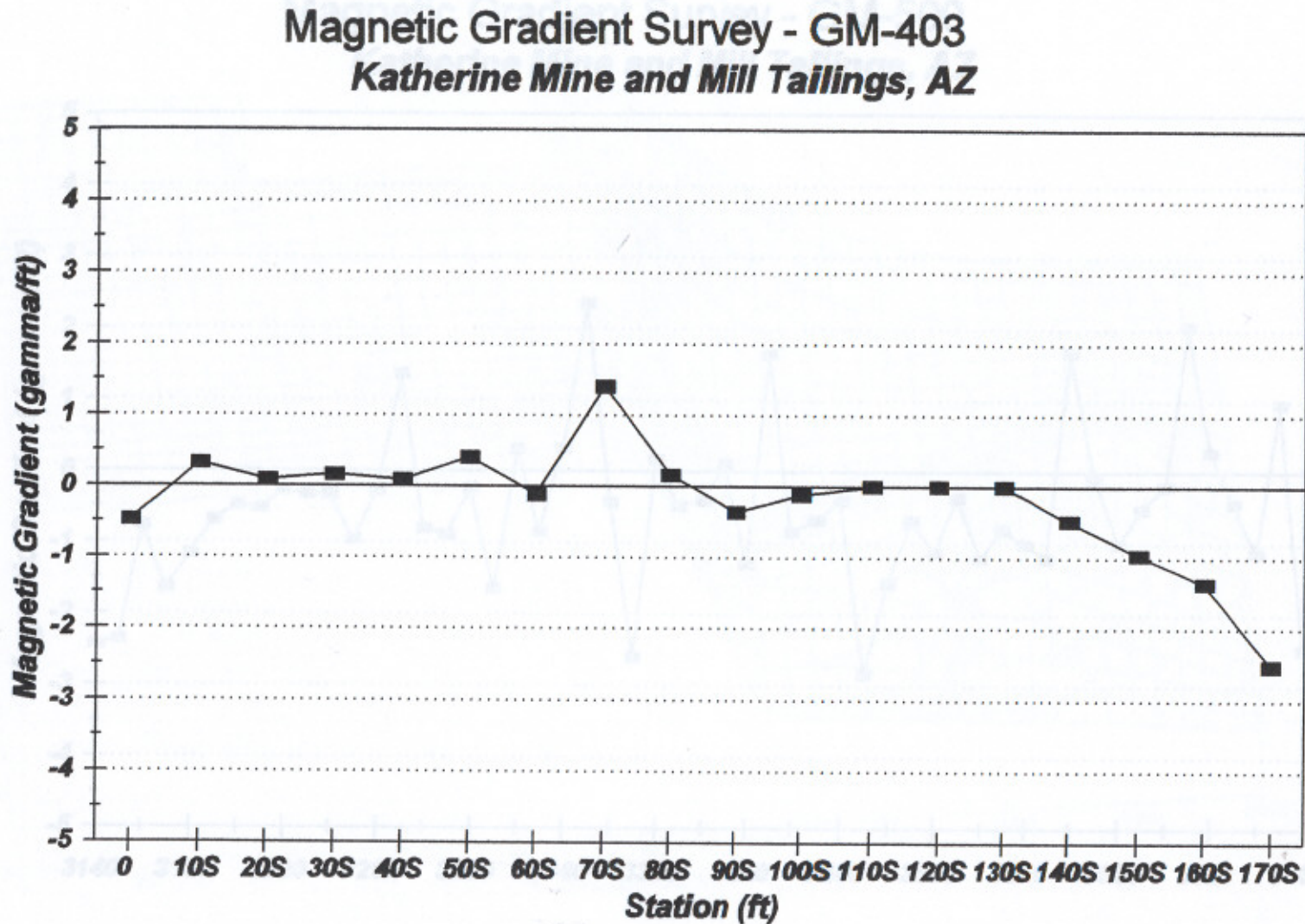


Figure D-22. Vertical magnetic gradient survey - GM-403, Katherine mine and mill tailings.

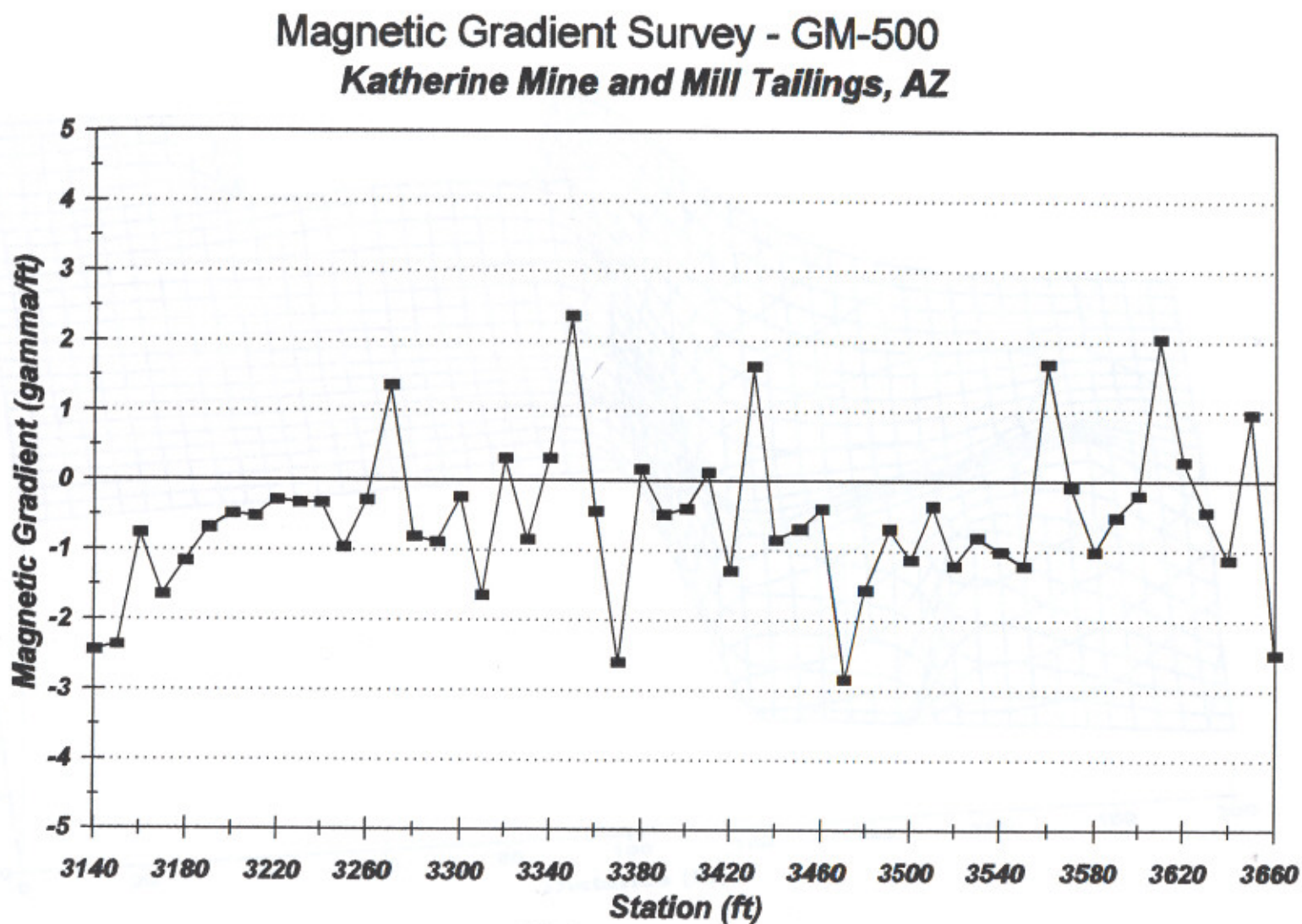


Figure D-23. Vertical magnetic gradient survey - GM-500, Katherine mine and mill tailings.

Katherine Mine and Mill Tailings Buried Drum Site, Lake Mead Recreation Area, AZ

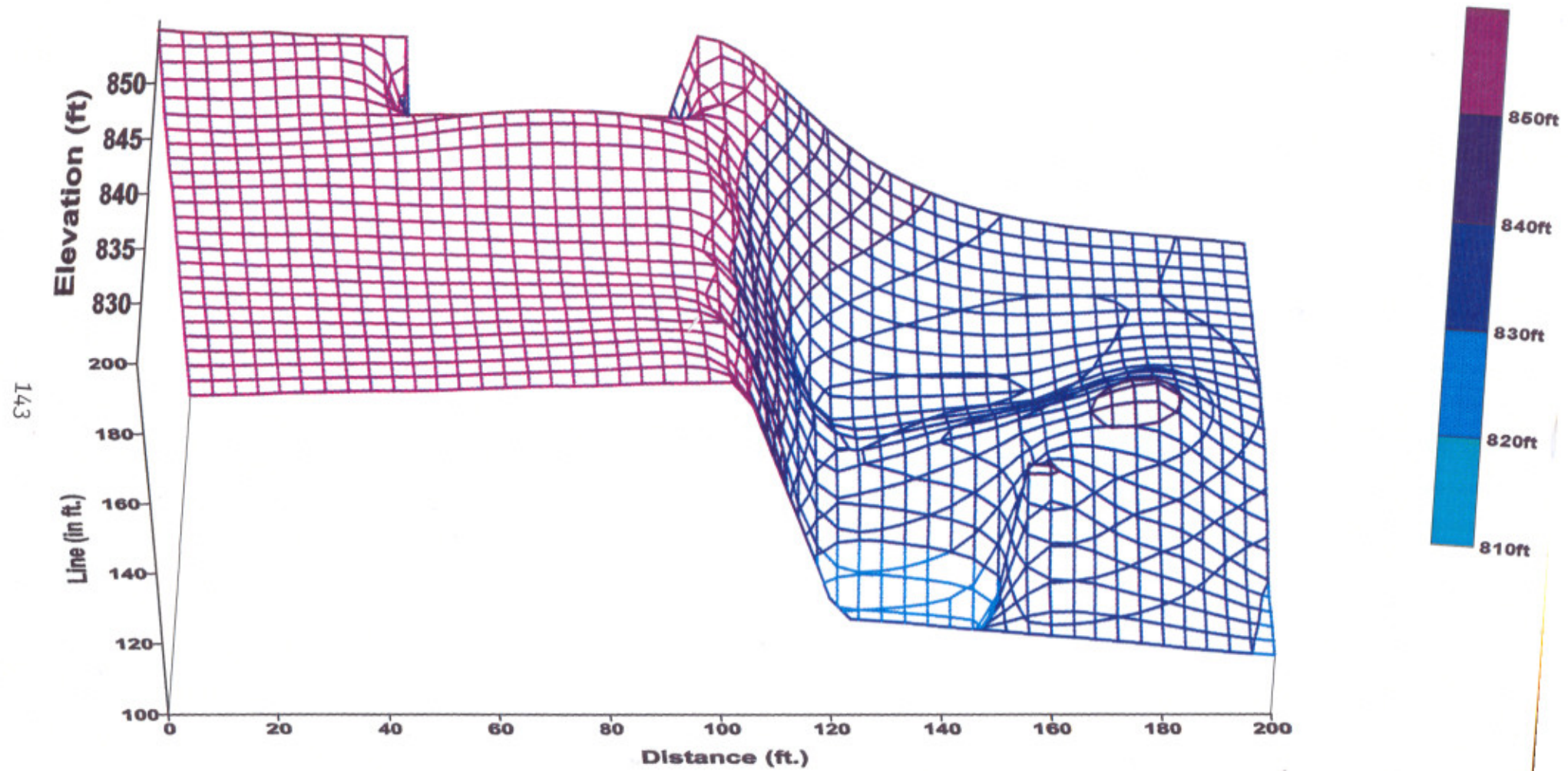


Figure D-24. Tailings surface - three-dimensional perspective.

Katherine Mine and Mill Tailings Buried Drum Site, Lake Mead Recreation Area, AZ

Vertical Magnetic Gradient - Reverse Polarized

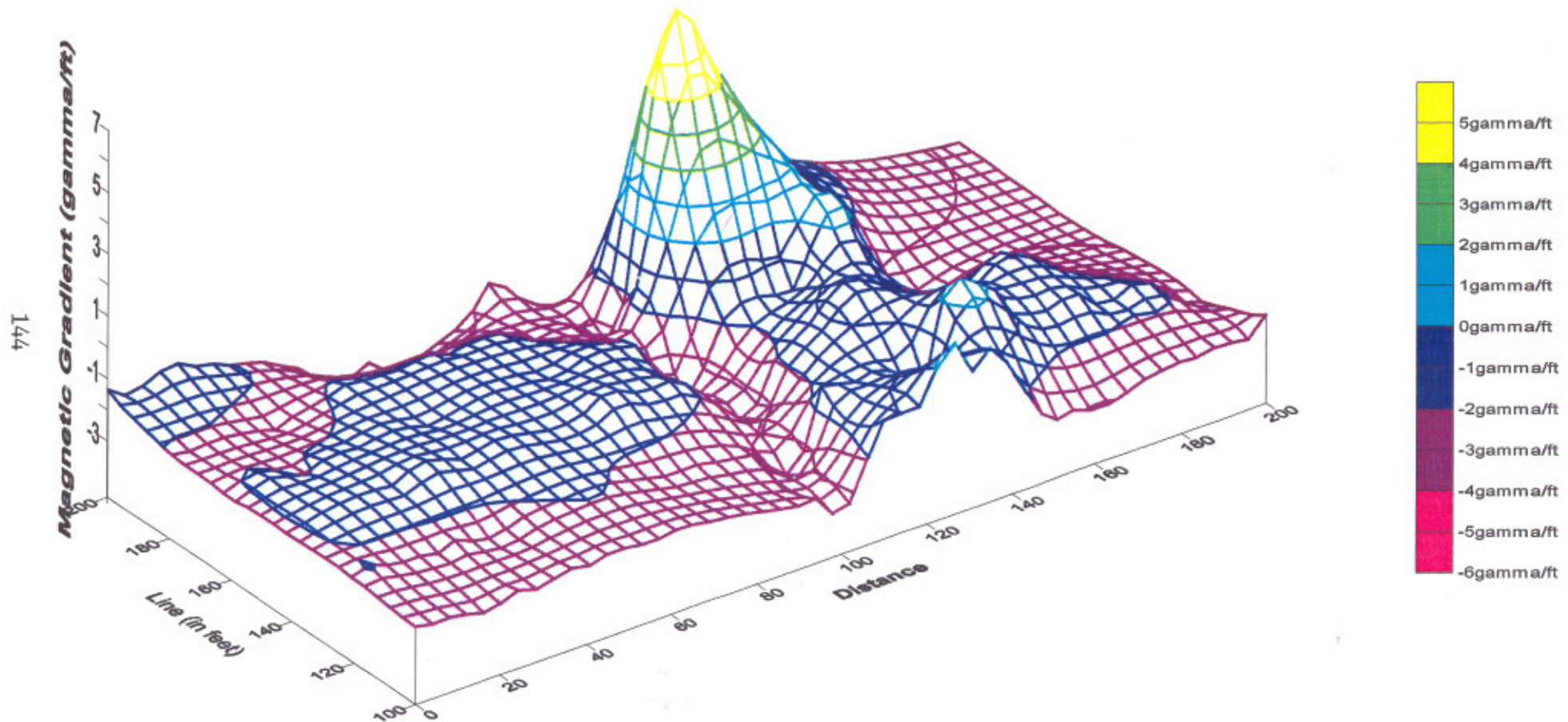


Figure D-25. Vertical magnetic gradient - three dimensional perspective.

Magnetic Gradient Survey T-1 Katherine Mine - Void Detection

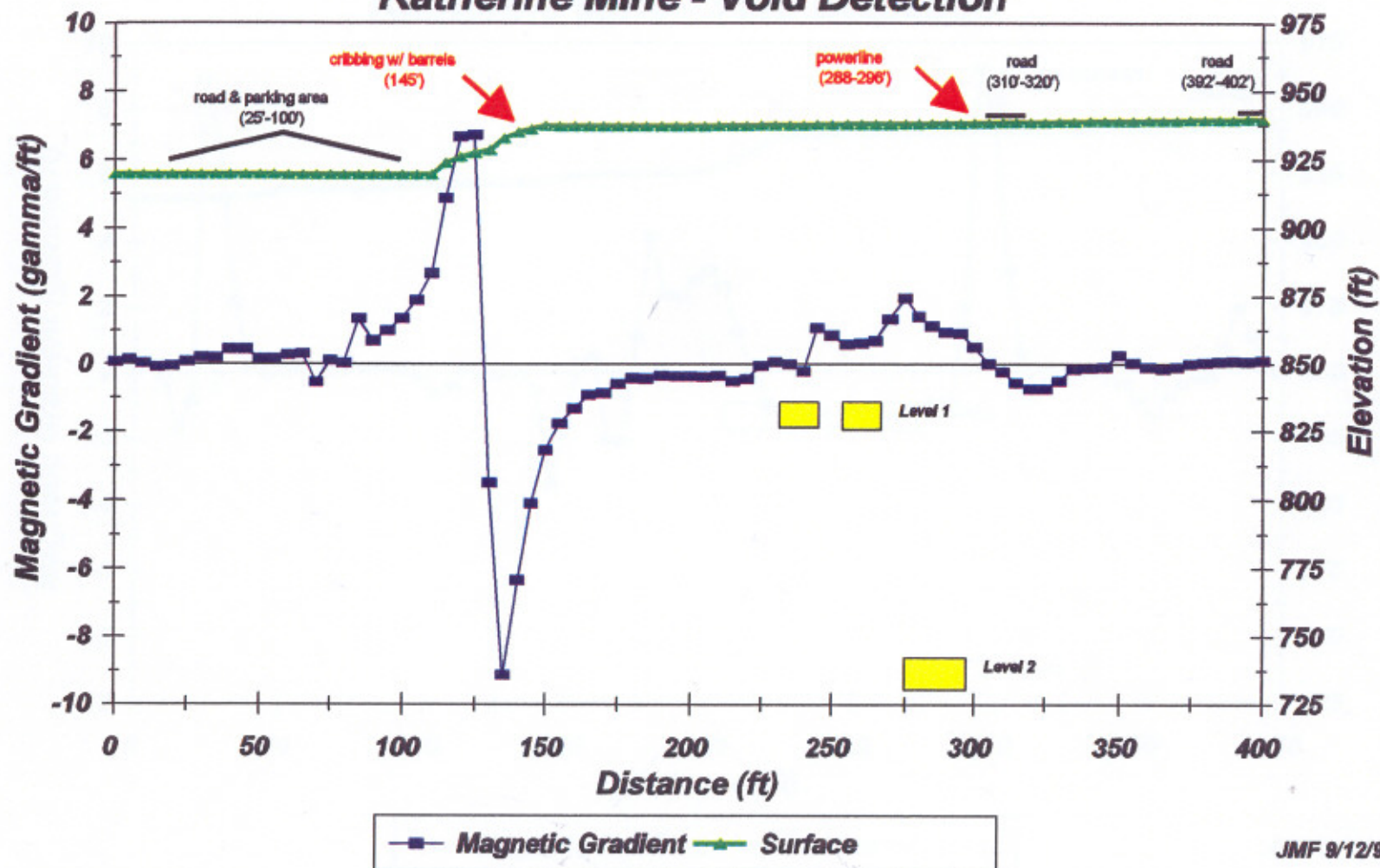


Figure D-26. Vertical magnetic gradient profile T-1, Katherine mine void detection.

Magnetic Gradient Survey T-2 Katherine Mine - Void Detection

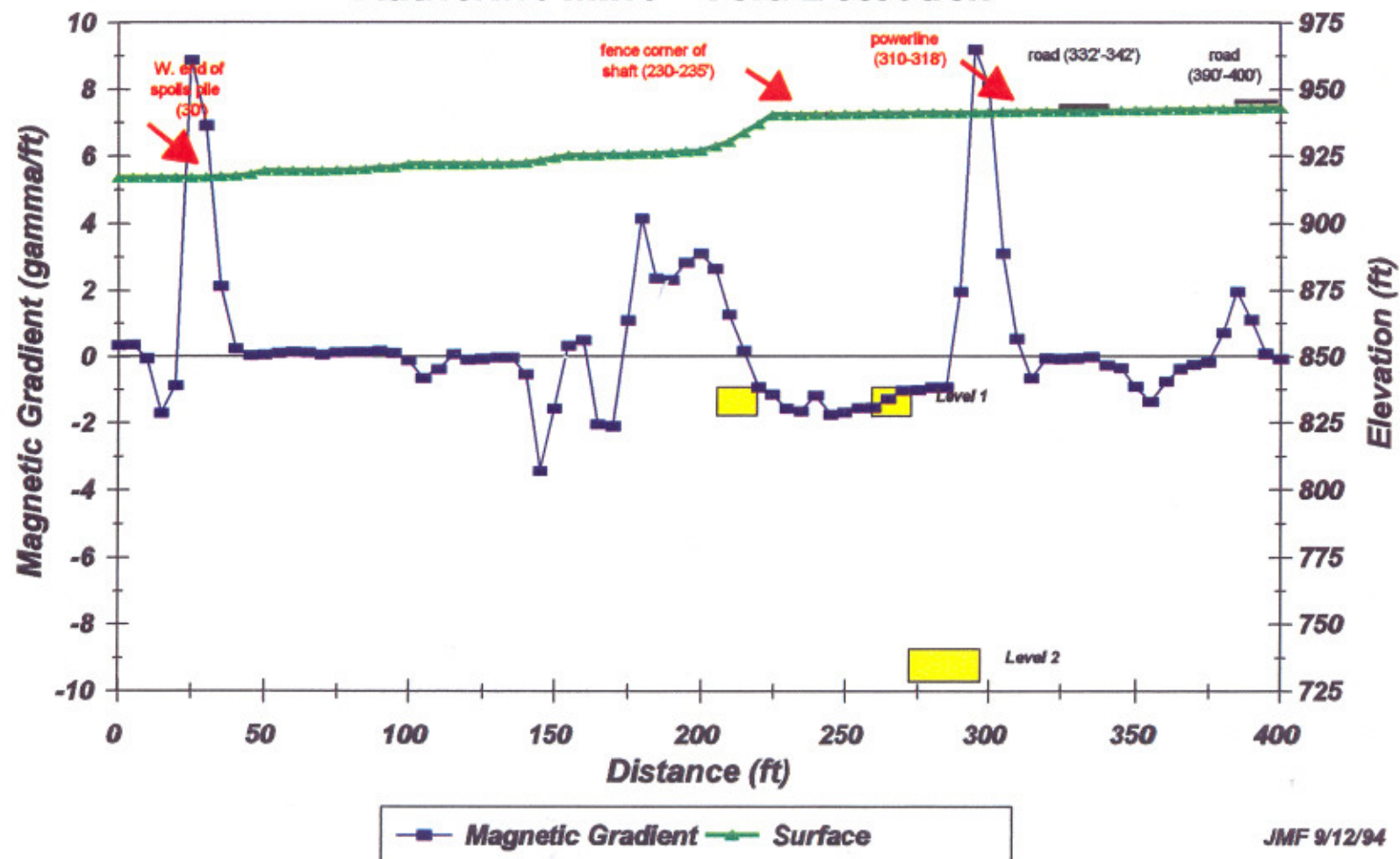


Figure D-27. Vertical magnetic gradient profile T-2, Katherine mine void detection.

Magnetic Gradient Survey T-3

Katherine Mine - Void Detection

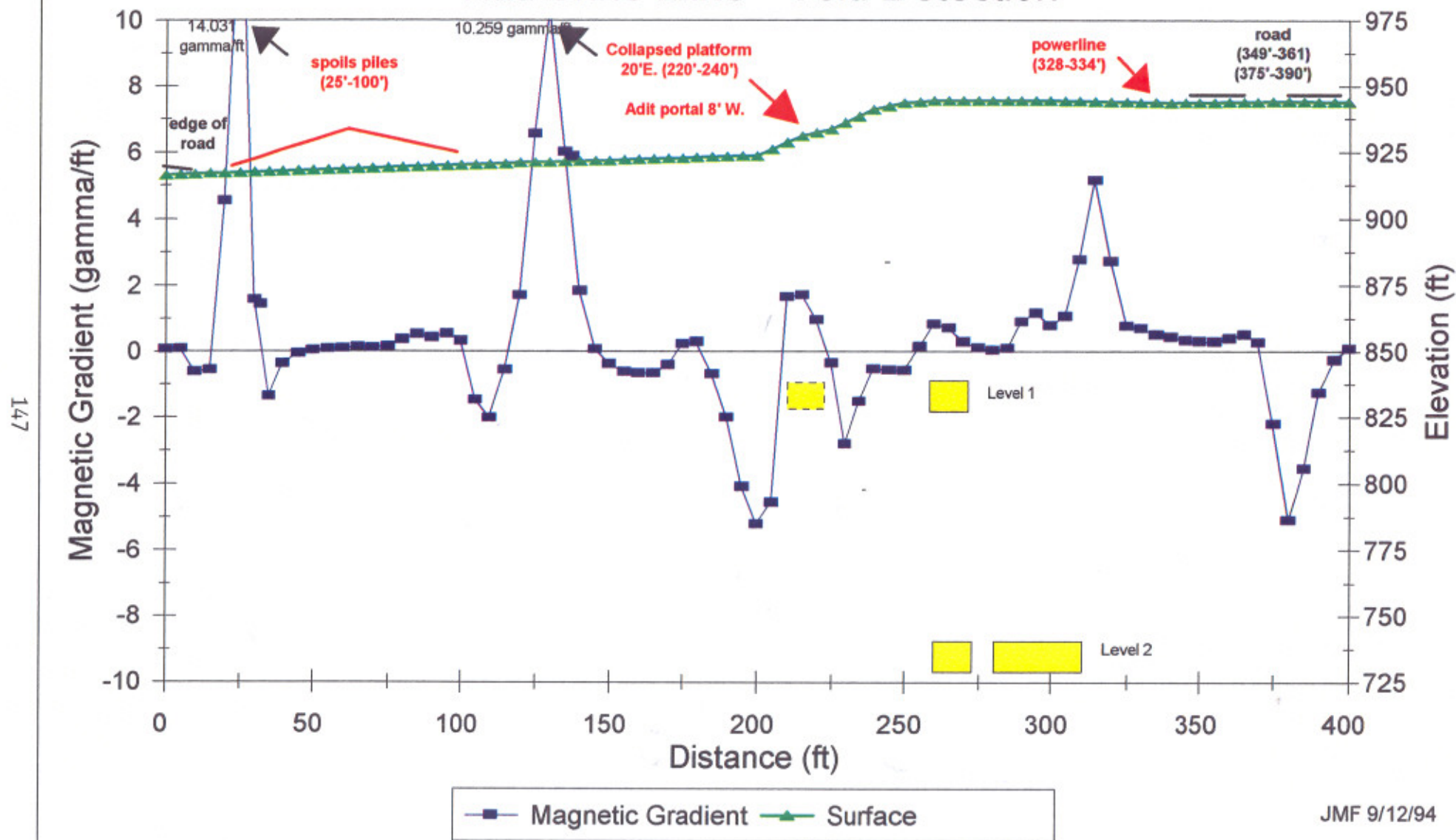


Figure D-28. Vertical magnetic gradient profile T-3, Katherine mine void detection.

Magnetic Gradient Survey T-4 Katherine Mine - Void Detection

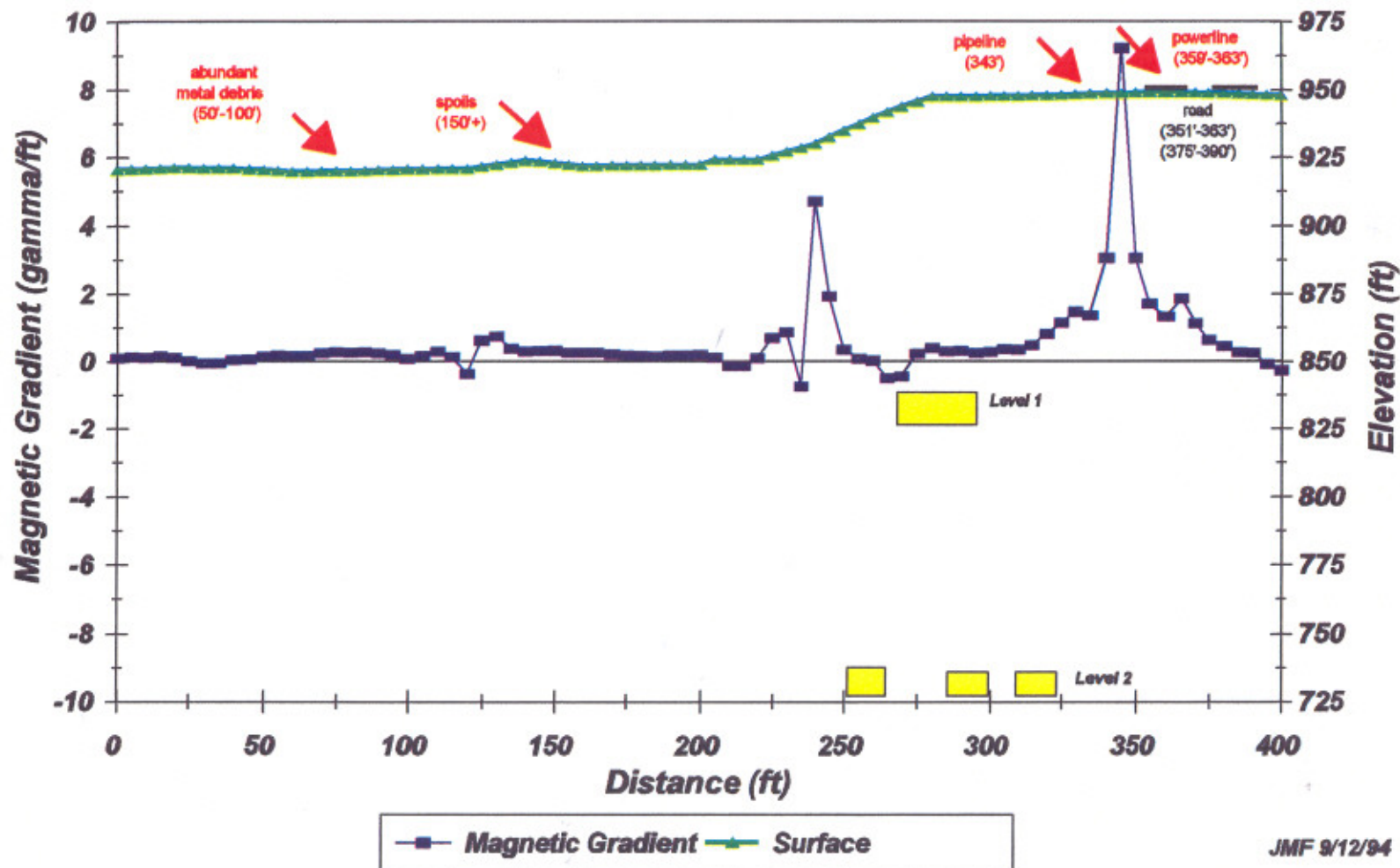


Figure D-29. Vertical magnetic gradient profile T-4, Katherine mine void detection.

Magnetic Gradient Survey T-5 Katherine Mine - Void Detection

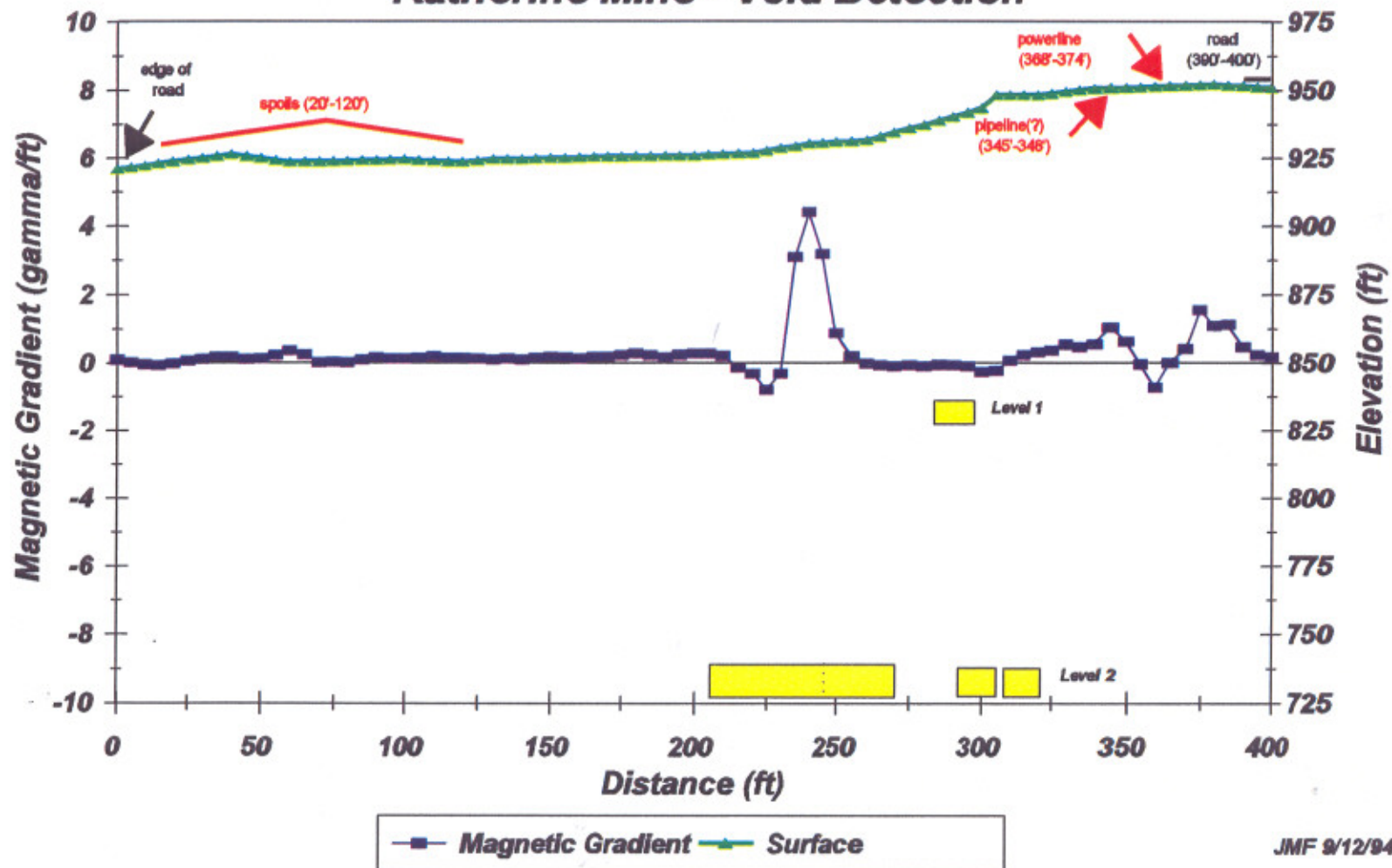


Figure D-30. Vertical magnetic gradient profile T-5, Katherine mine void detection.

Magnetic Gradient Survey T-6 Katherine Mine - Void Detection

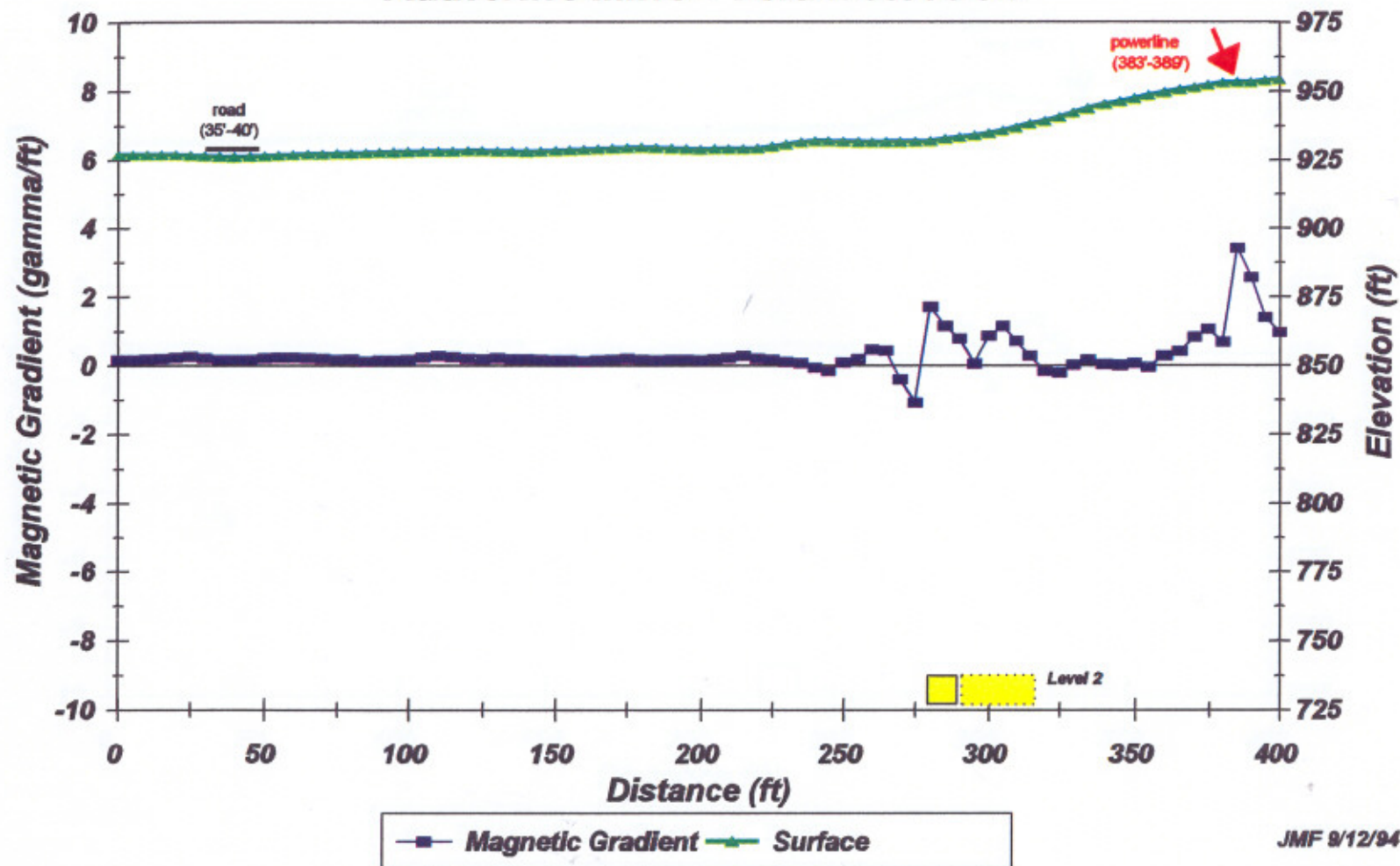


Figure D-31. Vertical magnetic gradient profile T-6, Katherine mine void detection.

Magnetic Gradient Survey T-7 **Katherine Mine - Void Detection**

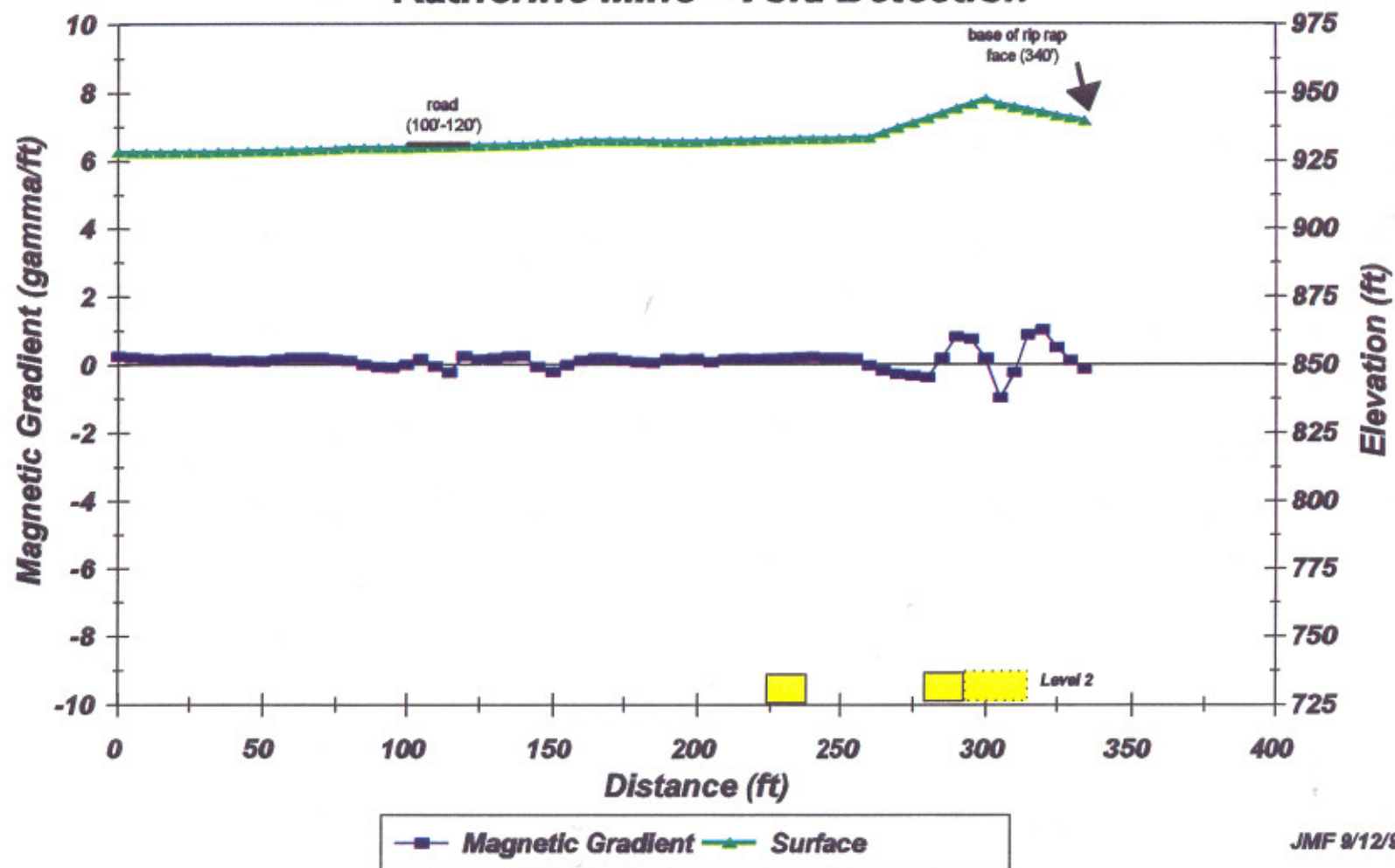


Figure D-32. Vertical magnetic gradient profile T-7, Katherine mine void detection.

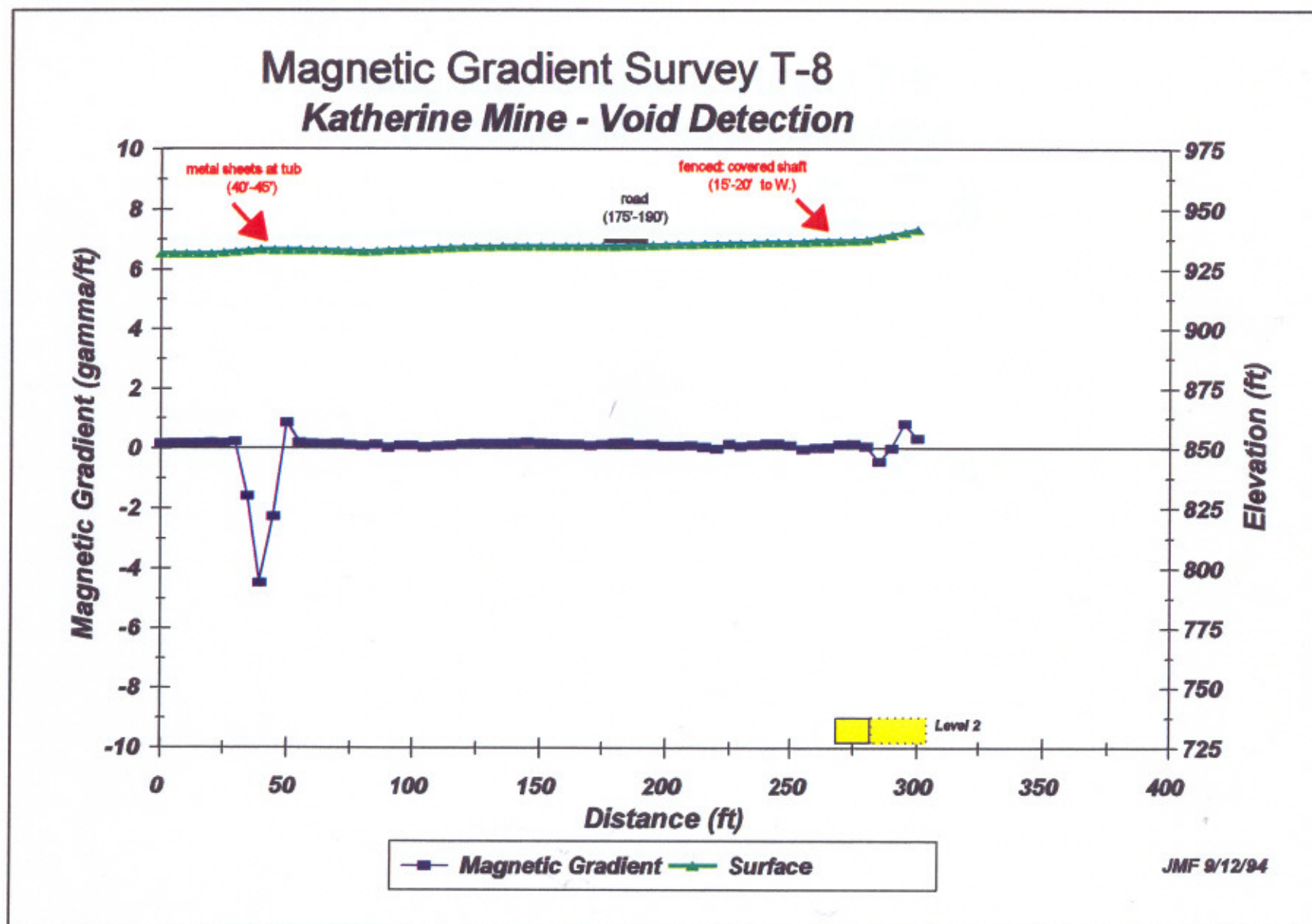


Figure D-33. Vertical magnetic gradient profile T-8, Katherine mine void detection.

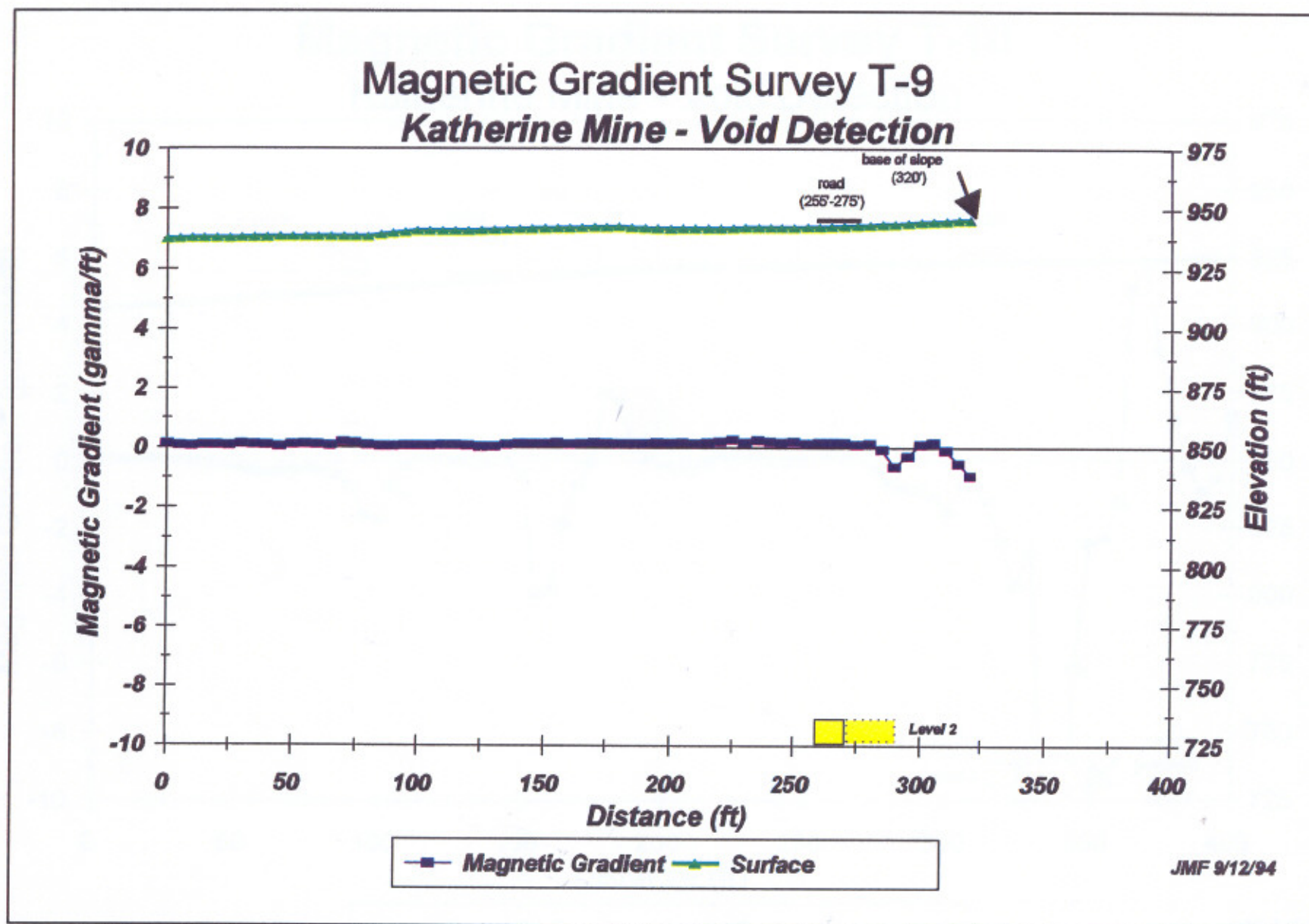


Figure D-34. Vertical magnetic gradient profile T-9, Katherine mine void detection.

Magnetic Gradient Survey T-10

Katherine Mine - Void Detection

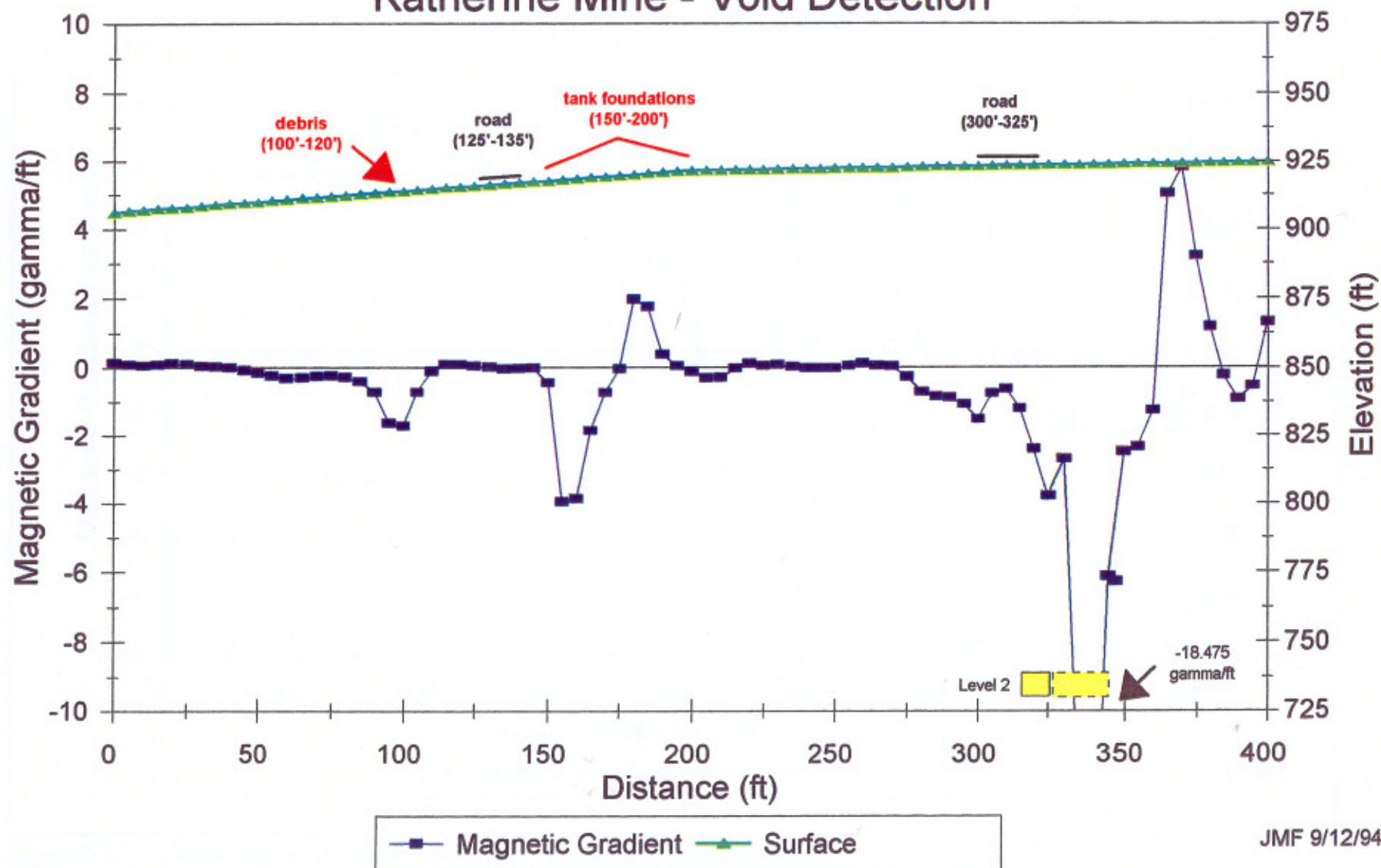


Figure D-35. Vertical magnetic gradient profile T-10, Katherine mine void detection.

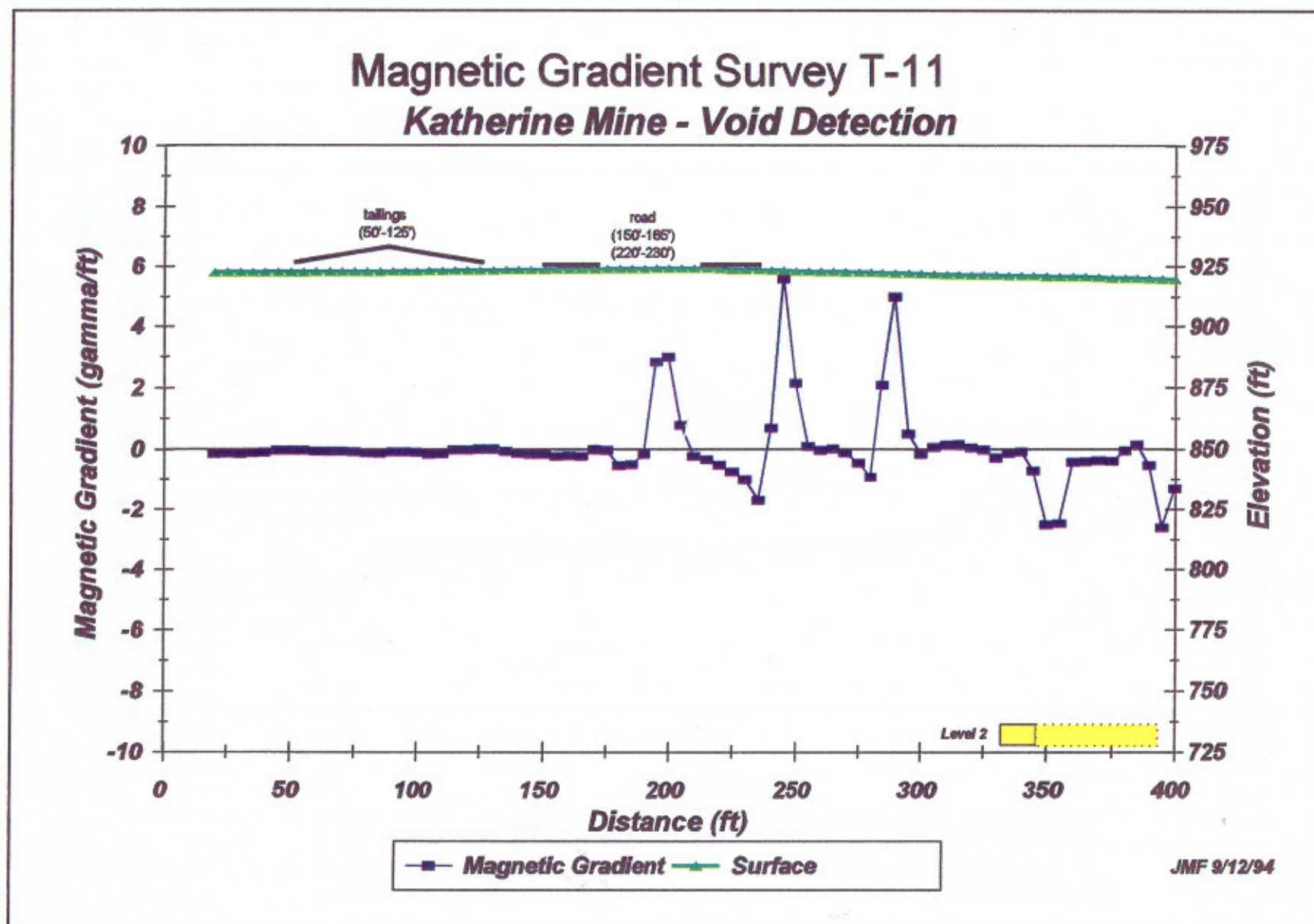


Figure D-36. Vertical magnetic gradient profile T-11, Katherine mine void detection.

Electromagnetic Survey (EM-31) **300-Ft-Trans, Katherine Mill Tailings**

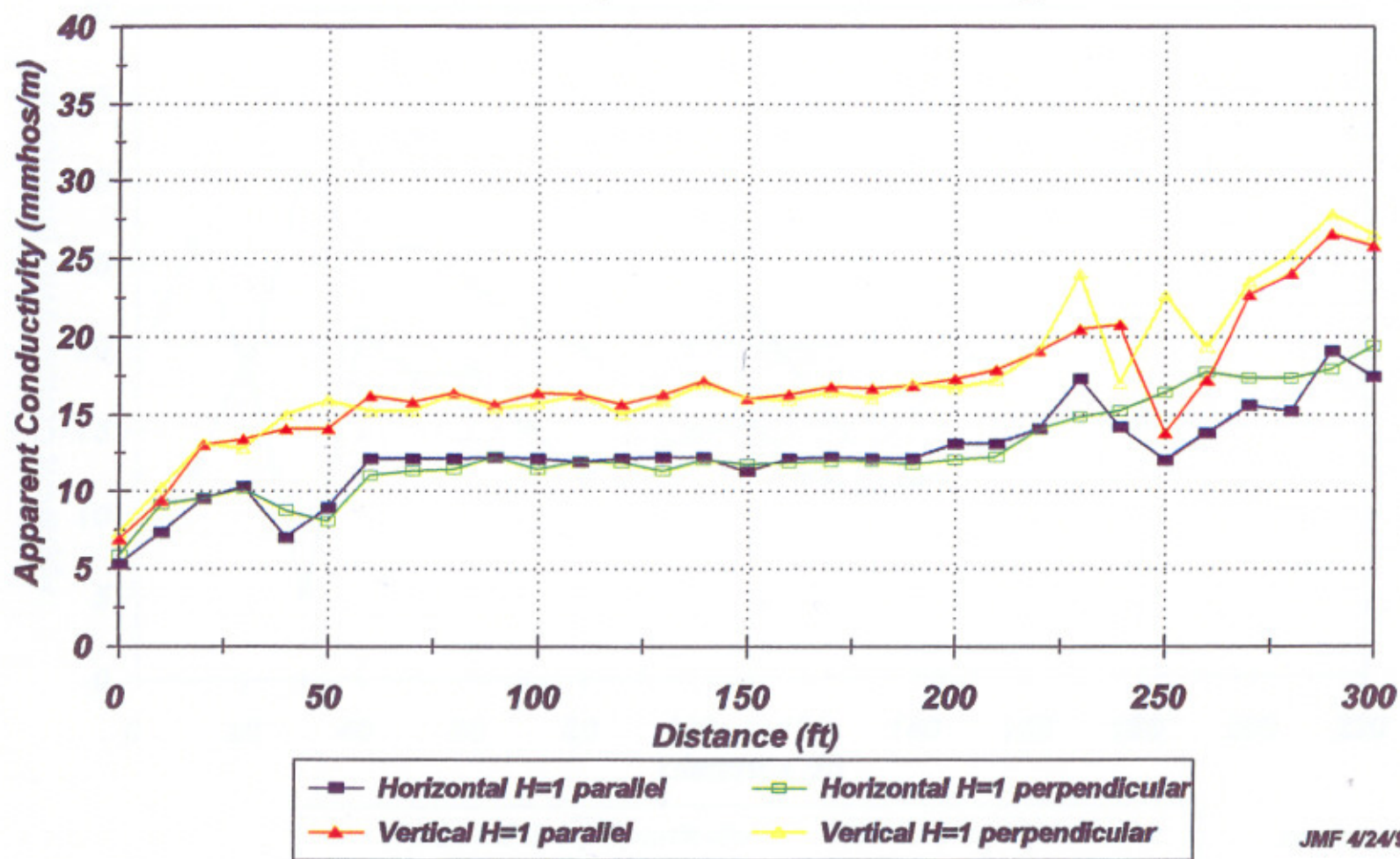


Figure D-37. Electromagnetic survey (EM-31), 300-ft transect, Katherine mill tailings.

Electromagnetic Survey (EM-31) Transect 099, Katherine Mill Tailings

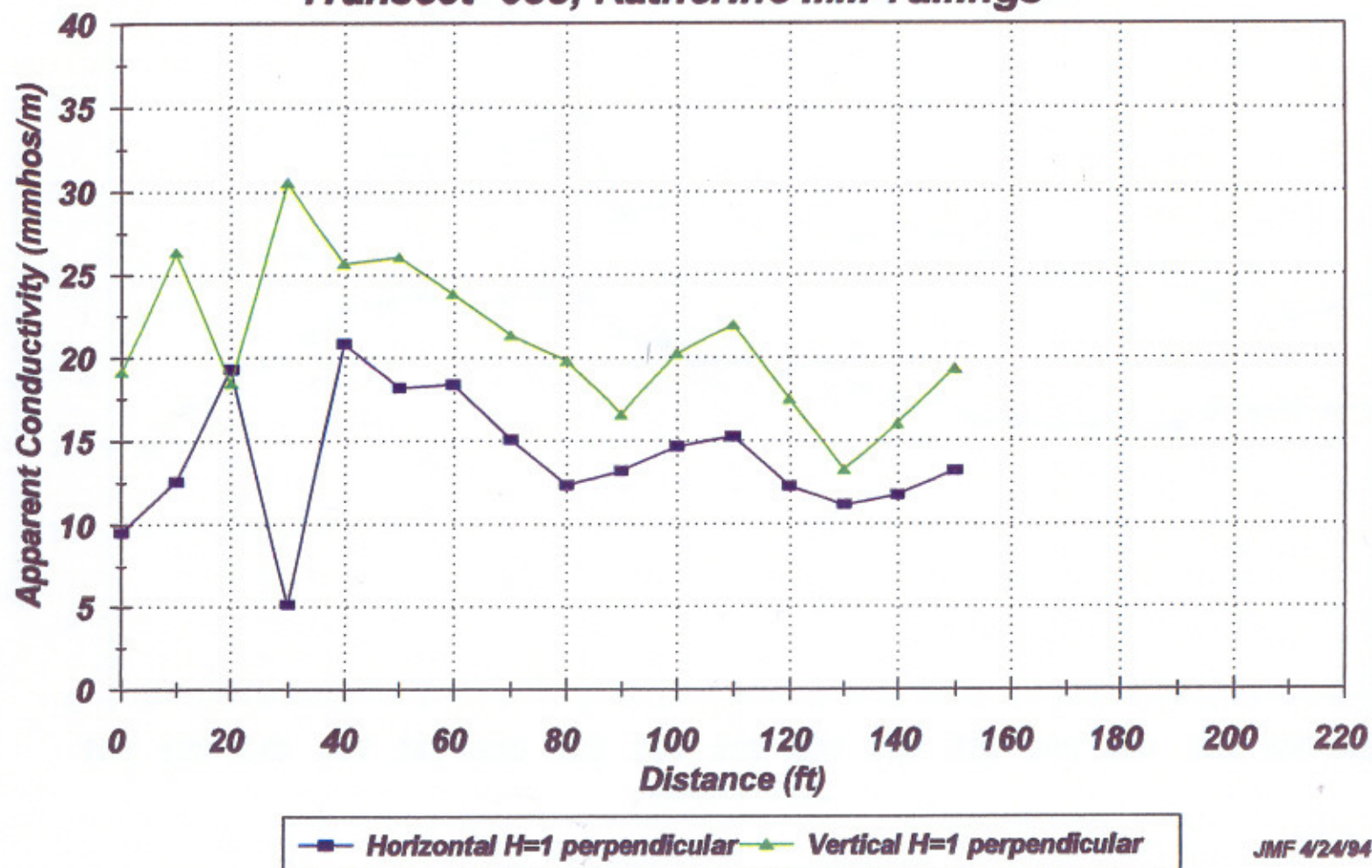


Figure D-38. Electromagnetic survey (EM-31), Transect 099, Katherine mill tailings.

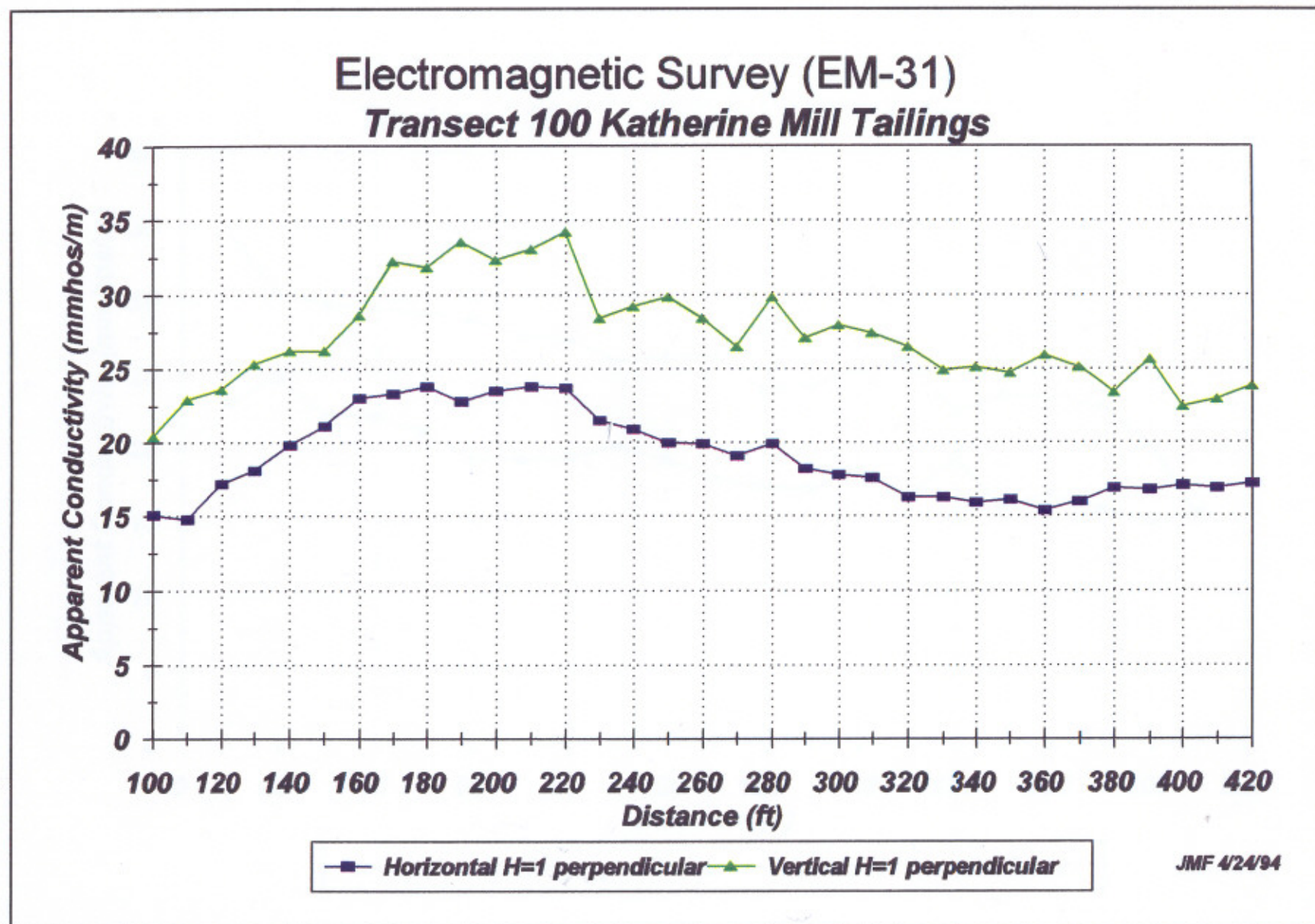


Figure D-39. Electromagnetic survey (EM-31), Transect 100, Katherine mill tailings.

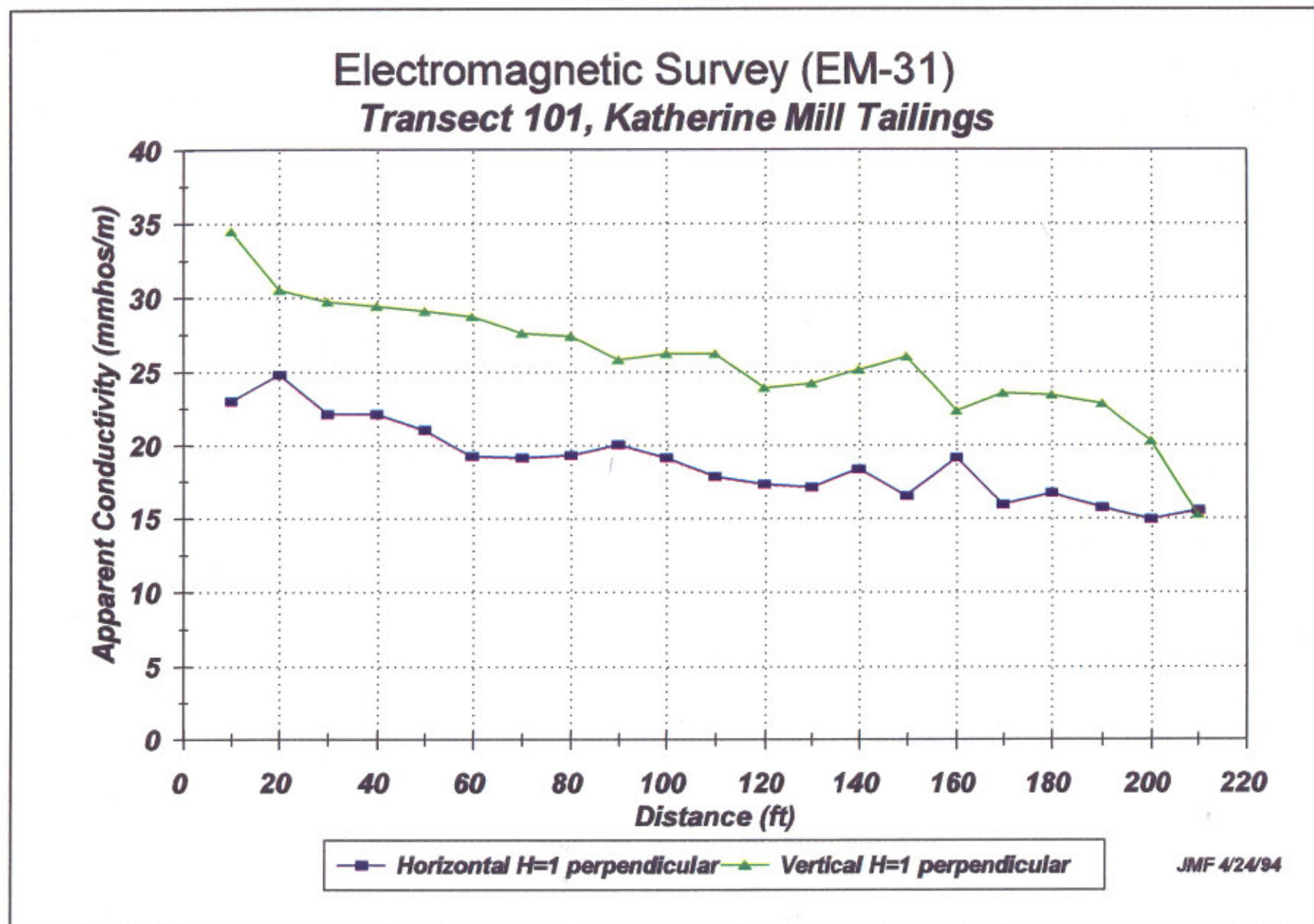


Figure D-40. Electromagnetic survey (EM-31), Transect 101, Katherine mill tailings.

Electromagnetic Survey (EM-31) Transect 103, Katherine Mill Tailings

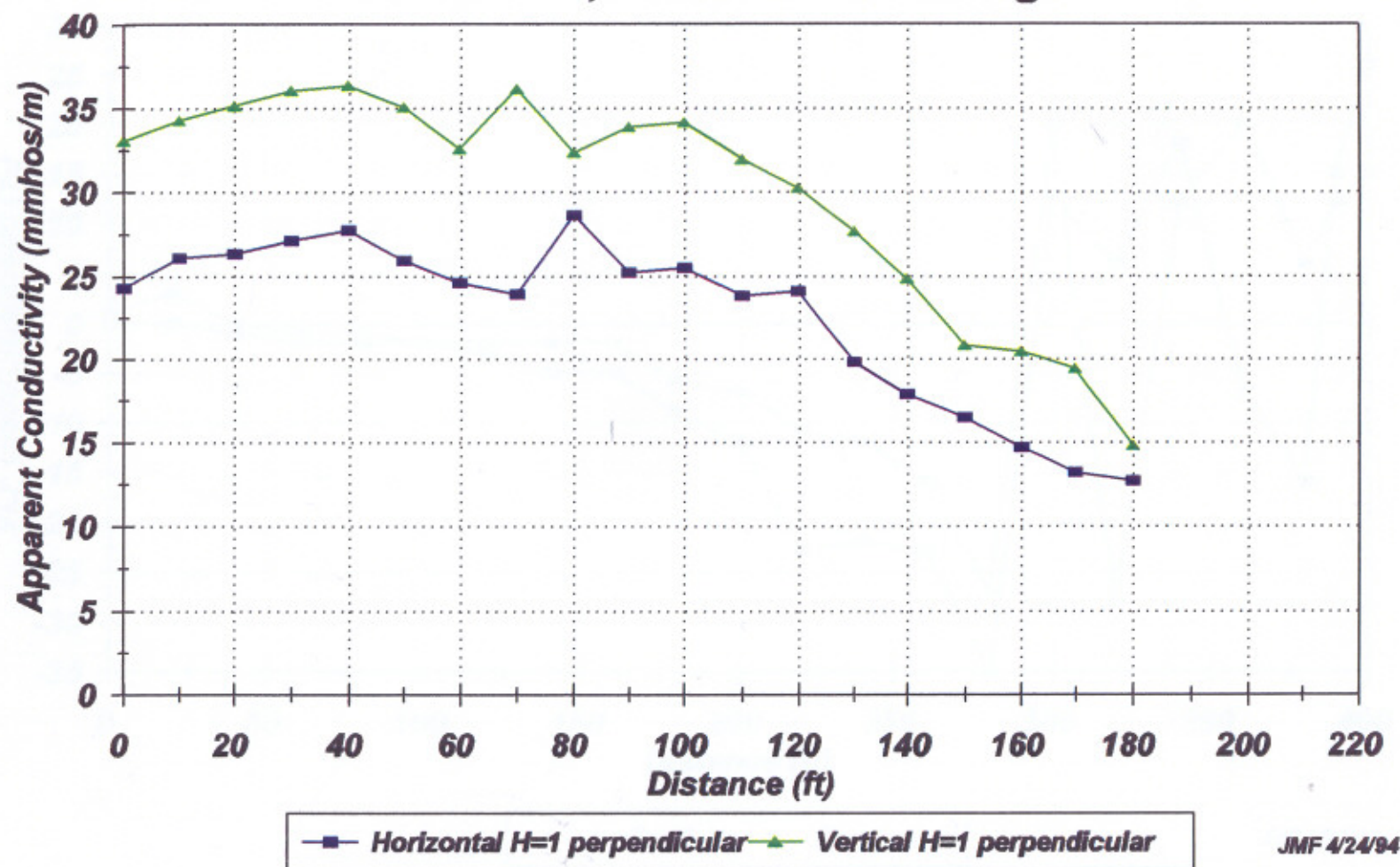


Figure D-41. Electromagnetic survey (EM-31), Transect 103, Katherine mill tailings.

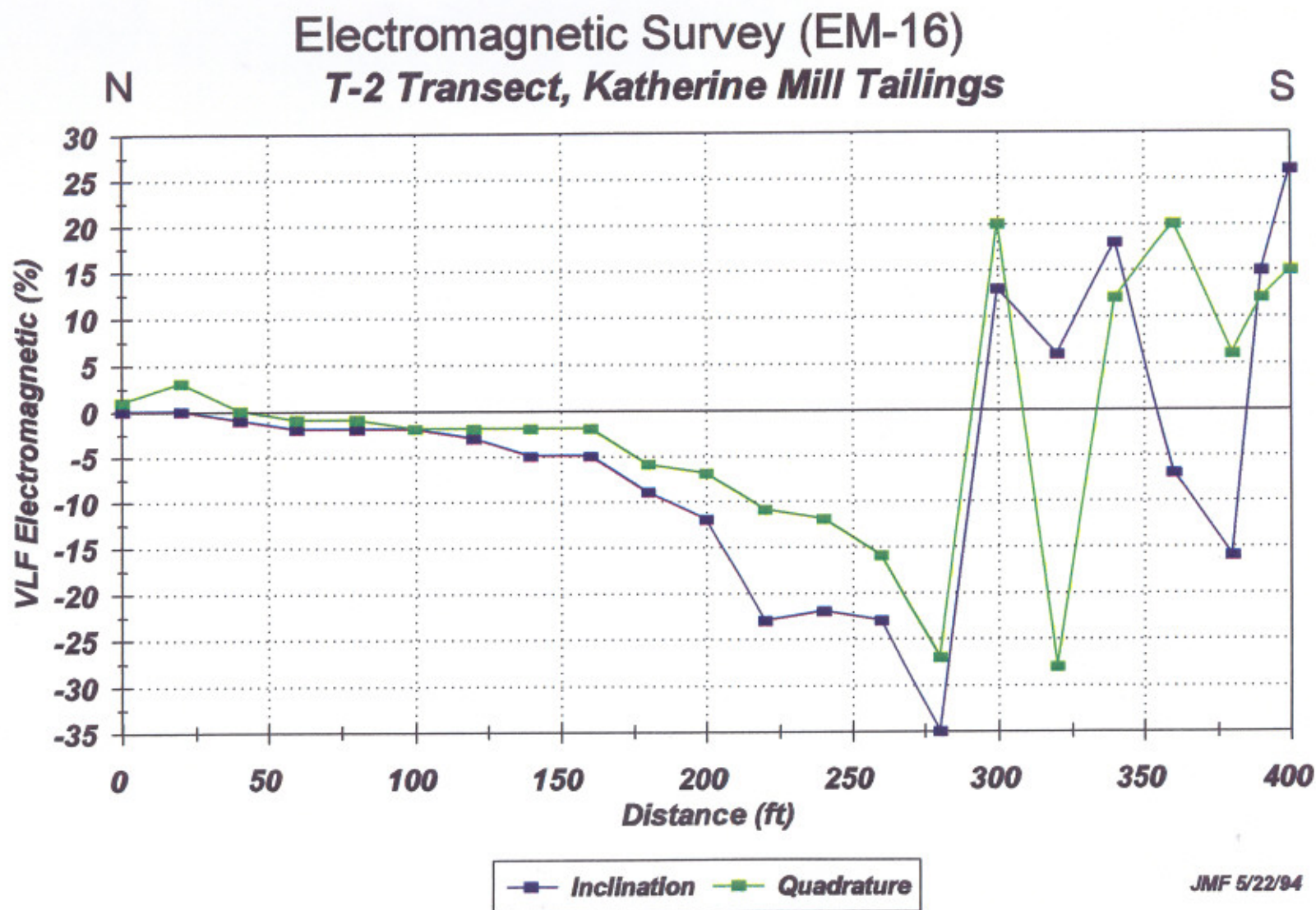


Figure D-42. Electromagnetic survey (EM-16), Transect T-2, Katherine mill tailings.

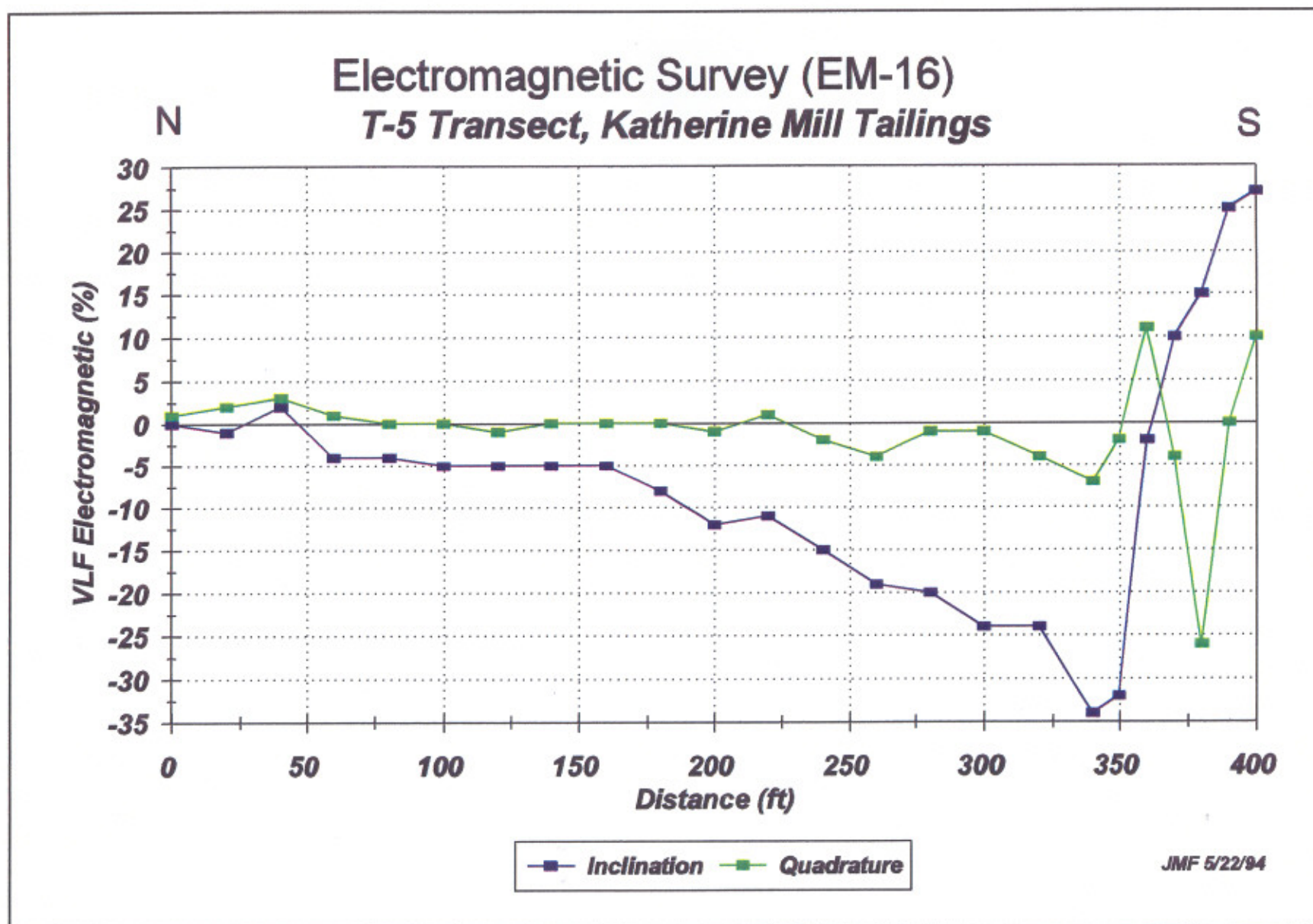


Figure D-43. Electromagnetic survey (EM-16), Transect T-5, Katherine mill tailings.

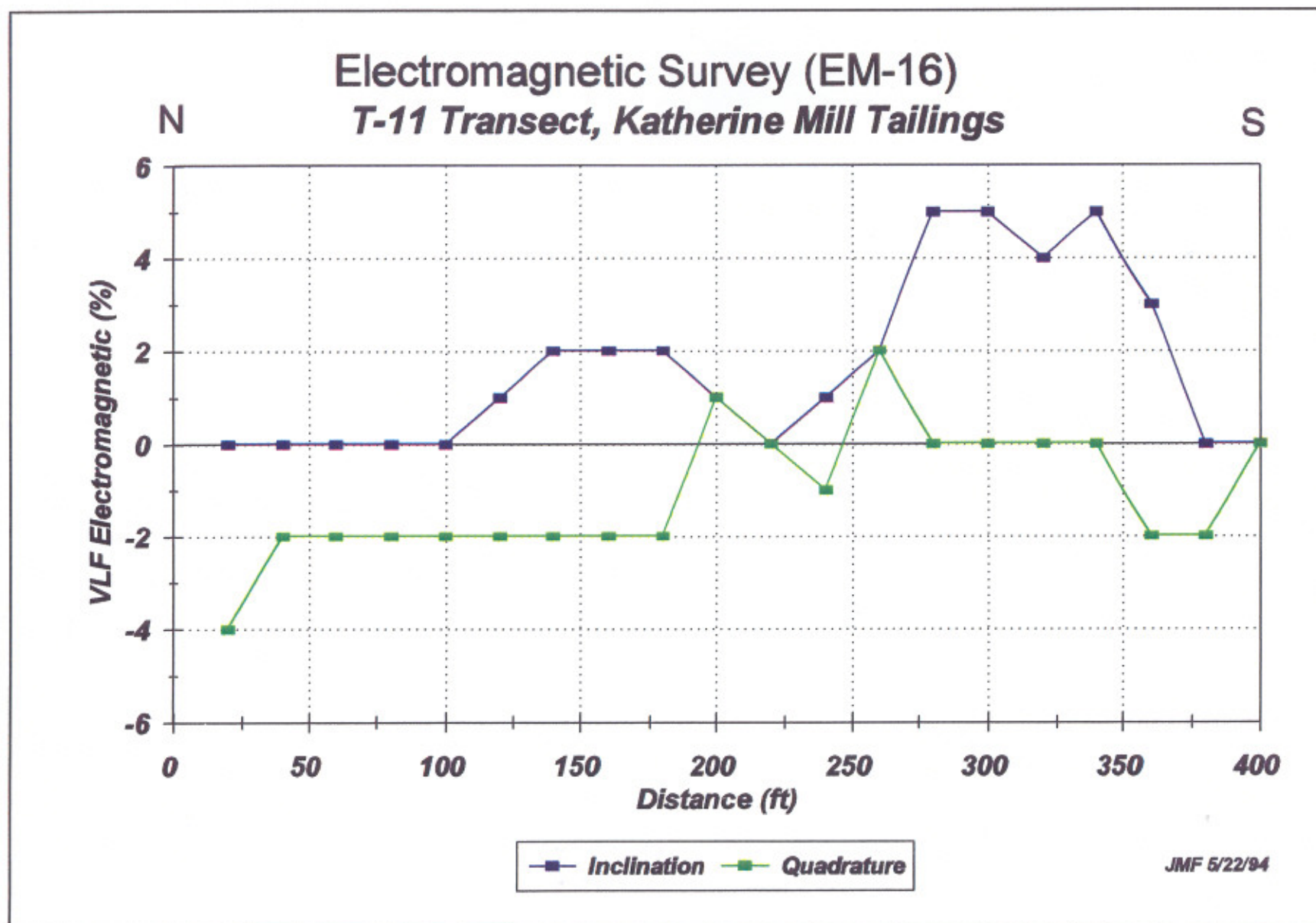


Figure D-44. Electromagnetic survey (EM-16), Transect T-11, Katherine mill tailings.

Table D-1. Vertical magnetic gradient survey data

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
test	0	50327.0	50327.2	0.08
test	10	50381.6	50366.9	-5.88
test	20	50394.2	50375.0	-7.68
test	30	50390.3	50384.4	-2.36
test	40	50348.9	50369.5	8.24
test	50	50502.6	50436.3	-26.52
test	60	50384.5	50382.7	-0.72
test	70	50367.7	50367.2	-0.20
test	80	50361.5	50361.3	-0.08
test	90	50358.8	50358.2	-0.24
test	100	50356.6	50355.6	-0.40
test	110	50354.1	50354.0	-0.04
test	120	50358.3	50356.6	-0.68
test	130	50359.0	50357.0	-0.80
test	140	50355.1	50354.8	-0.12
test	150	50354.4	50354.1	-0.12
test	160	50354.8	50354.1	-0.28
test	170	50355.1	50353.9	-0.48
test	180	50354.2	50352.9	-0.52
test	190	50351.4	50350.9	-0.20
test	200	50350.7	50349.7	-0.40
test	210	50348.2	50347.1	-0.44
test	220	50334.9	50334.3	-0.24
test	230	50251.5	50297.4	18.36
test	240	50428.2	50398.3	-11.96
test	250	50372.5	50370.0	-1.00

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
test	260	50364.6	50362.5	-0.84
test	270	50363.6	50362.5	-0.44
test	280	50363.6	50362.0	-0.64
test	290	50360.8	50360.0	-0.32
test	300	50358.3	50357.2	-0.44
GM-099	850	49753.6	49849.7	38.44
GM-099	860	50110.6	50141.7	12.44
GM-099	870	50190.9	50196.9	2.40
GM-099	880	50223.1	50228.1	2.00
GM-099	890	50245.6	50247.0	0.56
GM-099	900	50255.3	50256.0	0.28
GM-099	910	50259.5	50260.7	0.48
GM-099	920	50257.8	50260.6	1.12
GM-099	930	50255.8	50262.8	2.80
GM-099	940	50294.3	50285.7	-3.44
GM-099	950	50290.3	50287.3	-1.20
GM-099	960	50278.0	50282.1	1.64
GM-099	970	50295.4	50296.3	0.36
GM-099	980	50306.2	50304.4	-0.72
GM-099	990	50308.0	50307.8	-0.08
GM-100	1000	50310.6	50309.8	-0.32
GM-100	1010	50312.2	50311.6	-0.24
GM-100	1020	50313.5	50313.3	-0.08
GM-100	1030	50315.1	50314.8	-0.12
GM-100	1040	50318.0	50317.3	-0.28
GM-100	1050	50319.5	50318.9	-0.24

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-100	1060	50321.5	50320.6	-0.36
GM-100	1070	50323.1	50322.9	-0.08
GM-100	1080	50326.8	50325.4	-0.56
GM-100	1090	50327.5	50326.8	-0.28
GM-100	1100	50328.0	50327.6	-0.16
GM-100	1110	50330.3	50329.1	-0.48
GM-100	1120	50331.3	50330.4	-0.36
GM-100	1130	50331.0	50330.5	-0.20
GM-100	1140	50330.8	50330.7	-0.04
GM-100	1150	50331.6	50331.4	-0.08
GM-100	1160	50333.9	50333.1	-0.32
GM-100	1170	50336.3	50335.0	-0.52
GM-100	1180	50338.1	50336.7	-0.56
GM-100	1190	50335.1	50337.0	0.76
GM-100	1200	50337.8	50339.1	0.52
GM-100	1210	50340.3	50341.8	0.60
GM-100	1220	50344.3	50345.7	0.56
GM-100	1230	50346.9	50347.6	0.28
GM-100	1240	50349.0	50350.0	0.40
GM-100	1250	50352.0	50352.9	0.36
GM-100	1260	50356.3	50355.7	-0.24
GM-100	1270	50360.6	50358.2	-0.96
GM-100	1280	50354.8	50356.4	0.64
GM-100	1290	50359.2	50358.4	-0.32
GM-100	1300	50361.9	50361.2	-0.28
GM-100	1310	50362.1	50361.3	-0.32

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-100	1320	50362.5	50361.6	-0.36
GM-100	1330	50361.1	50360.9	-0.08
GM-100	1340	50361.4	50360.9	-0.20
GM-100	1350	50362.6	50361.8	-0.32
GM-100	1360	50363.1	50362.2	-0.36
GM-100	1370	50364.9	50363.0	-0.76
GM-100	1380	50365.1	50363.3	-0.72
GM-100	1390	50364.2	50362.4	-0.72
GM-100	1400	50364.5	50361.8	-1.08
GM-100	1410	50363.5	50360.6	-1.16
GM-100	1420	50361.8	50357.7	-1.64
GM-200	1440	50325.3	50328.0	1.08
GM-200	1450	50327.8	50328.1	0.12
GM-200	1460	50323.1	50325.8	1.08
GM-200	1470	50326.7	50326.8	0.04
GM-200	1480	50326.3	50326.8	0.20
GM-200	1490	50326.3	50326.6	0.12
GM-200	1500	50323.7	50324.2	0.20
GM-200	1510	50324.2	50324.2	0.00
GM-200	1520	50324.0	50323.8	-0.08
GM-200	1530	50322.5	50322.8	0.12
GM-200	1540	50321.2	50321.9	0.28
GM-200	1550	50320.6	50321.2	0.24
GM-200	1560	50322.6	50322.4	-0.08
GM-200	1570	50322.3	50322.8	0.20
GM-200	1580	50321.9	50322.5	0.24

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-200	1590	50322.9	50322.9	0.00
GM-200	1600	50323.9	50324.0	0.04
GM-200	1610	50324.7	50324.9	0.08
GM-200	1620	50325.0	50325.6	0.24
GM-200	1630	50326.8	50327.4	0.24
GM-200	1640	50329.8	50330.1	0.12
GM-200	1650	50333.5	50333.4	-0.04
GM-200	1660	50335.4	50335.7	0.12
GM-200	1670	50337.5	50337.9	0.16
GM-200	1680	50339.5	50339.7	0.08
GM-200	1690	50341.9	50341.9	0.00
GM-200	1700	50344.5	50344.3	-0.08
GM-200	1710	50347.4	50346.8	-0.24
GM-200	1720	50351.0	50350.1	-0.36
GM-200	1730	50354.0	50352.8	-0.48
GM-200	1740	50355.3	50354.5	-0.32
GM-200	1750	50359.8	50358.6	-0.48
GM-200	1760	50364.9	50362.1	-1.12
GM-200	1770	50369.8	50366.2	-1.44
GM-200	1780	50361.9	50362.9	0.40
GM-200	1790	50376.8	50372.2	-1.84
GM-200	1800	50360.1	50363.3	1.28
GM-300	1830	50356.8	50356.0	-0.32
GM-300	1840	50366.7	50367.3	0.24
GM-300	1850	50365.2	50365.7	0.20
GM-300	1860	50357.1	50359.9	1.12

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-300	1870	50355.6	50356.5	0.36
GM-300	1880	50358.1	50357.8	-0.12
GM-300	1890	50359.5	50358.6	-0.36
GM-300	1900	50354.5	50355.6	0.44
GM-300	1910	50354.1	50354.2	0.04
GM-300	1920	50353.0	50353.2	0.08
GM-300	1930	50347.3	50350.2	1.16
GM-300	1940	50346.2	50350.5	1.72
GM-300	1950	50359.8	50359.2	-0.24
GM-300	1960	50363.2	50361.3	-0.76
GM-300	1970	50357.7	50358.1	0.16
GM-300	1980	50355.4	50356.0	0.24
GM-300	1990	50353.7	50354.7	0.40
GM-300	2000	50354.1	50355.0	0.36
GM-300	2010	50359.7	50358.4	-0.52
GM-300	2020	50361.6	50360.3	-0.52
GM-300	2030	50362.8	50361.9	-0.36
GM-300	2040	50363.1	50362.3	-0.32
GM-300	2050	50363.8	50363.1	-0.28
GM-300	2060	50365.6	50365.4	-0.08
GM-300	2070	50373.1	50371.5	-0.64
GM-300	2080	50376.5	50375.2	-0.52
GM-300	2090	50380.6	50378.8	-0.72
GM-300	2100	50404.4	50400.0	-1.76
GM-300	2110	50402.2	50399.2	-1.20
GM-300	2120	50399.4	50397.3	-0.84

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-300	2130	50400.1	50397.9	-0.88
GM-300	2140	50403.1	50399.9	-1.28
GM-300	2150	50406.1	50401.4	-1.88
GM-300	2160	50405.5	50400.2	-2.12
GM-300	2170	50400.2	50396.3	-1.56
GM-300	2180	50388.0	50388.3	0.12
GM-300	2190	50389.1	50387.8	-0.52
GM-300	2200	50389.0	50387.8	-0.48
GM-300	2210	50388.6	50387.2	-0.56
GM-300	2220	50387.7	50387.0	-0.28
GM-300	2230	50388.2	50387.3	-0.36
GM-300	2240	50389.2	50388.1	-0.44
GM-300	2250	50388.6	50387.8	-0.32
GM-300	2260	50388.6	50388.1	-0.20
GM-300	2270	50391.5	50390.6	-0.36
GM-300	2280	50391.9	50390.3	-0.64
GM-300	2290	50385.1	50387.8	1.08
GM-300	2300	50395.3	50393.1	-0.88
GM-400	2430	50353.8	50357.1	1.32
GM-400	2440	50361.8	50363.1	0.52
GM-400	2450	50362.0	50363.0	0.40
GM-400	2460	50361.2	50363.9	1.08
GM-400	2470	50378.1	50374.5	-1.44
GM-400	2480	50380.6	50378.2	-0.96
GM-400	2490	50377.8	50375.9	-0.76
GM-400	2500	50375.7	50374.2	-0.60

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-400	2510	50374.0	50372.9	-0.44
GM-400	2520	50371.9	50371.4	-0.20
GM-400	2530	50369.5	50369.4	-0.04
GM-400	2540	50367.7	50367.7	0.00
GM-400	2550	50367.2	50366.7	-0.20
GM-400	2560	50366.4	50366.0	-0.16
GM-400	2570	50364.9	50364.5	-0.16
GM-400	2580	50363.2	50362.8	-0.16
GM-400	2590	50360.8	50360.4	-0.16
GM-400	2600	50360.1	50358.6	-0.60
GM-400	2610	50377.0	50376.1	-0.36
GM-400	2620	50372.3	50371.4	-0.36
GM-400	2630	50366.3	50366.3	0.00
GM-400	2640	50357.7	50361.1	1.36
GM-400	2650	50336.8	50344.3	3.00
GM-400	2660	50340.9	50345.8	1.96
GM-400	2670	50357.5	50357.6	0.04
GM-400	2680	50367.9	50365.0	-1.16
GM-400	2690	50360.2	50362.8	1.04
GM-400	2700	50364.1	50365.3	0.48
GM-400	2710	50366.5	50368.5	0.80
GM-400	2720	50372.0	50372.4	0.16
GM-400	2730	50367.7	50372.9	2.08
GM-400	2740	50370.0	50379.0	3.60
GM-400	2750	50400.5	50395.3	-2.08
GM-400	2760	50399.2	50395.9	-1.32

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-400	2770	50392.6	50392.0	-0.24
GM-400	2780	50388.5	50388.8	0.12
GM-400	2790	50386.1	50386.2	0.04
GM-400	2800	50383.4	50384.6	0.48
GM-400	2810	50380.9	50383.0	0.84
GM-400	2820	50380.1	50381.9	0.72
GM-400	2830	50382.8	50384.1	0.52
GM-400	2840	50387.3	50387.6	0.12
GM-400	2850	50389.4	50390.3	0.36
GM-400	2860	50391.4	50392.6	0.48
GM-400	2870	50395.8	50396.0	0.08
GM-400	2880	50399.6	50399.6	0.00
GM-400	2890	50404.0	50403.2	-0.32
GM-400	2900	50407.7	50407.2	-0.20
GM-400	2910	50410.6	50410.4	-0.08
GM-400	2920	50412.9	50412.8	-0.04
GM-400	2930	50416.5	50416.0	-0.20
GM-400	2940	50417.8	50418.2	0.16
GM-400	2950	50423.8	50422.3	-0.60
GM-400	2960	50429.8	50426.5	-1.32
GM-400	2970	50426.0	50425.3	-0.28
GM-400	2980	50427.9	50426.4	-0.60
GM-400	2990	50426.3	50426.4	0.04
GM-400	3000	50425.0	50426.5	0.60
GM-400	3010	50426.5	50429.1	1.04
GM-400	3020	50430.5	50435.4	1.96

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-400	3030	50458.6	50459.0	0.16
GM-400	3040	50445.7	50445.9	0.08
GM-400	3050	50450.7	50446.8	-1.56
GM-400	3060	50455.9	50450.8	-2.04
GM-400	3070	50452.0	50448.6	-1.36
GM-400	3080	50447.9	50445.2	-1.08
GM-400	3090	50440.7	50440.2	-0.20
GM-400	3100	50431.7	50433.6	0.76
GM-400	3110	50438.2	50439.5	0.52
GM-400	3120	50445.7	50447.2	0.60
GM-400	3130	50461.0	50458.1	-1.16
GM-500	3140	50471.1	50465.0	-2.44
GM-500	3150	50472.3	50466.4	-2.36
GM-500	3160	50460.2	50458.3	-0.76
GM-500	3170	50457.5	50453.4	-1.64
GM-500	3180	50451.9	50449.0	-1.16
GM-500	3190	50446.1	50444.4	-0.68
GM-500	3200	50442.9	50441.7	-0.48
GM-500	3210	50444.0	50442.7	-0.52
GM-500	3220	50444.0	50443.3	-0.28
GM-500	3230	50444.4	50443.6	-0.32
GM-500	3240	50444.7	50443.9	-0.32
GM-500	3250	50447.6	50445.2	-0.96
GM-500	3260	50445.8	50445.1	-0.28
GM-500	3270	50440.0	50443.4	1.36
GM-500	3280	50450.3	50448.3	-0.80

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-500	3290	50451.1	50448.9	-0.88
GM-500	3300	50446.3	50445.7	-0.24
GM-500	3310	50449.1	50445.0	-1.64
GM-500	3320	50440.2	50441.0	0.32
GM-500	3330	50443.4	50441.3	-0.84
GM-500	3340	50436.8	50437.6	0.32
GM-500	3350	50427.4	50433.3	2.36
GM-500	3360	50446.0	50444.9	-0.44
GM-500	3370	50455.9	50449.4	-2.60
GM-500	3380	50443.0	50443.4	0.16
GM-500	3390	50445.4	50444.2	-0.48
GM-500	3400	50445.7	50444.7	-0.40
GM-500	3410	50443.7	50444.0	0.12
GM-500	3420	50448.6	50445.4	-1.28
GM-500	3430	50430.1	50434.2	1.64
GM-500	3440	50441.5	50439.4	-0.84
GM-500	3450	50445.2	50443.5	-0.68
GM-500	3460	50445.2	50444.2	-0.40
GM-500	3470	50456.5	50449.4	-2.84
GM-500	3480	50450.1	50446.2	-1.56
GM-500	3490	50443.4	50441.7	-0.68
GM-500	3500	50445.5	50442.7	-1.12
GM-500	3510	50442.4	50441.5	-0.36
GM-500	3520	50446.8	50443.8	-1.20
GM-500	3530	50445.8	50443.8	-0.80
GM-500	3540	50448.4	50445.9	-1.00

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-500	3550	50445.6	50442.6	-1.20
GM-500	3560	50427.7	50431.9	1.68
GM-500	3570	50434.3	50434.1	-0.08
GM-500	3580	50438.5	50436.0	-1.00
GM-500	3590	50432.5	50431.2	-0.52
GM-500	3600	50428.1	50427.6	-0.20
GM-500	3610	50416.9	50422.0	2.04
GM-500	3620	50427.0	50427.7	0.28
GM-500	3630	50433.4	50432.3	-0.44
GM-500	3640	50439.9	50437.1	-1.12
GM-500	3650	50433.0	50435.4	0.96
GM-500	3660	50450.4	50444.2	-2.48
GM-101	210N	50354.8	50356.5	0.68
GM-101	200N	50371.2	50368.6	-1.04
GM-101	190N	50374.6	50372.1	-1.00
GM-101	180N	50375.3	50373.4	-0.76
GM-101	170N	50375.5	50373.8	-0.68
GM-101	160N	50377.8	50375.5	-0.92
GM-101	150N	50377.6	50376.0	-0.64
GM-101	140N	50376.0	50374.1	-0.76
GM-101	130N	50376.2	50373.2	-1.20
GM-101	120N	50371.7	50370.8	-0.36
GM-101	110N	50369.9	50369.4	-0.20
GM-101	100N	50367.9	50367.6	-0.12
GM-101	90N	50367.2	50366.3	-0.36
GM-101	80N	50366.6	50365.1	-0.60

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-101	70N	50362.8	50362.2	-0.24
GM-101	60N	50359.2	50359.4	0.08
GM-101	50N	50357.5	50356.7	-0.32
GM-101	40N	50353.3	50353.2	-0.04
GM-101	30N	50349.2	50350.1	0.36
GM-101	20N	50348.8	50348.9	0.04
GM-101	10N	50347.7	50347.7	0.00
GM-103	0	50348.6	50348.1	-0.20
GM-103	10S	50347.9	50346.9	-0.40
GM-103	20S	50344.6	50343.8	-0.32
GM-103	30S	50338.9	50338.8	-0.04
GM-103	40S	50332.7	50333.4	0.28
GM-103	50S	50322.0	50321.0	-0.40
GM-103	60S	50233.7	50297.9	25.68
GM-103	70S	50326.9	50332.3	2.16
GM-103	80S	50426.4	50393.6	-13.12
GM-103	90S	50412.7	50396.2	-6.60
GM-103	100S	50330.3	50338.0	3.08
GM-103	110S	50326.2	50328.3	0.84
GM-103	120S	50320.1	50323.1	1.20
GM-103	130S	50320.6	50322.1	0.60
GM-103	140S	50320.9	50322.2	0.52
GM-103	150S	50320.8	50322.2	0.56
GM-103	160S	50320.1	50320.6	0.20
GM-103	170S	50313.3	50317.9	1.84
GM-103	180S	50336.5	50336.2	-0.12

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-201	140N	50385.6	50383.9	-0.68
GM-201	130N	50397.1	50394.2	-1.16
GM-201	120N	50396.1	50395.2	-0.36
GM-201	110N	50395.8	50394.7	-0.44
GM-201	100N	50394.4	50392.9	-0.60
GM-201	90N	50390.2	50389.3	-0.36
GM-201	80N	50387.1	50386.4	-0.28
GM-201	70N	50382.9	50382.4	-0.20
GM-201	60N	50379.5	50379.1	-0.16
GM-201	50N	50376.3	50375.9	-0.16
GM-201	40N	50370.6	50371.2	0.24
GM-201	30N	50364.7	50365.1	0.16
GM-201	20N	50360.9	50361.1	0.08
GM-201	10N	50356.0	50356.0	0.00
GM-203	0	50349.1	50349.5	0.16
GM-203	10S	50340.5	50341.8	0.52
GM-203	20S	50331.1	50333.5	0.96
GM-203	30S	50317.7	50322.8	2.04
GM-203	40S	50297.1	50309.3	4.88
GM-203	50S	50290.2	50321.0	12.32
GM-203	60S	50546.7	50497.8	-19.56
GM-203	70S	50632.6	50557.3	-30.12
GM-203	80S	50393.3	50406.3	5.20
GM-203	90S	50342.2	50352.4	4.08
GM-203	100S	50339.2	50344.1	1.96
GM-203	110S	50341.2	50343.6	0.96

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-203	120S	50343.3	50344.9	0.64
GM-203	130S	50343.1	50345.9	1.12
GM-203	140S	50343.9	50344.9	0.40
GM-203	150S	50348.8	50348.0	-0.32
GM-203	160S	50346.0	50346.2	0.08
GM-203	170S	50345.9	50345.9	0.00
GM-203	180S	50344.2	50344.7	0.20
GM-203	190S	50342.4	50342.8	0.16
GM-203	200S	50341.8	50341.0	-0.32
GM-203	210S	50330.6	50333.2	1.04
GM-203	220S	50330.6	50332.5	0.76
GM-203	230S	50331.2	50333.2	0.80
GM-203	240S	50333.2	50334.8	0.64
GM-203	250S	50332.8	50333.9	0.44
GM-203	260S	50315.0	50323.2	3.28
GM-203	270S	50313.7	50332.3	7.44
GM-203	280S	50358.1	50361.8	1.48
GM-203	290S	50373.9	50373.1	-0.32
GM-203	300S	50368.8	50373.8	2.00
GM-301	120N	50376.7	50376.6	-0.04
GM-301	110N	50392.7	50391.1	-0.64
GM-301	100N	50400.9	50399.3	-0.64
GM-301	90N	50407.6	50405.8	-0.72
GM-301	80N	50409.5	50408.8	-0.28
GM-301	70N	50414.1	50412.4	-0.68
GM-301	60N	50416.8	50415.3	-0.60

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-301	50N	50417.1	50415.8	-0.52
GM-301	40N	50417.6	50416.1	-0.60
GM-301	30N	50416.9	50415.5	-0.56
GM-301	20N	50416.0	50414.5	-0.60
GM-301	10N	50414.8	50414.2	-0.24
GM-303	0	50414.7	50413.4	-0.52
GM-303	10S	50413.6	50411.0	-1.04
GM-303	20S	50385.0	50392.3	2.92
GM-303	30S	50386.5	50392.1	2.24
GM-303	40S	50427.5	50415.5	-4.80
GM-303	50S	50414.7	50413.6	-0.44
GM-303	60S	50405.9	50406.7	0.32
GM-303	70S	50403.7	50404.3	0.24
GM-303	80S	50403.4	50403.6	0.08
GM-303	90S	50402.7	50402.8	0.04
GM-303	100S	50403.4	50403.3	-0.04
GM-303	110S	50402.7	50402.9	0.08
GM-303	120S	50402.8	50402.6	-0.08
GM-303	130S	50404.4	50403.5	-0.36
GM-303	140S	50403.3	50403.0	-0.12
GM-303	150S	50404.0	50403.6	-0.16
GM-303	160S	50402.9	50403.2	0.12
GM-303	170S	50406.7	50406.0	-0.28
GM-303	180S	50408.2	50407.3	-0.36
GM-303	190S	50406.4	50406.4	0.00
GM-303	200S	50407.9	50407.4	-0.20

Table D-1. Vertical magnetic gradient survey data-continued

Line Number	Station (ft)	Bottom Sensor (gamma)	Top Sensor (gamma)	Gradient (gamma/ft)
GM-303	210S	50408.3	50407.2	-0.44
GM-303	220S	50412.3	50408.1	-1.68
GM-303	230S	50402.4	50395.7	-2.68
GM-403	0	50380.3	50379.1	-0.48
GM-403	10S	50379.4	50380.2	0.32
GM-403	20S	50380.9	50381.1	0.08
GM-403	30S	50380.7	50381.1	0.16
GM-403	40S	50381.8	50382.0	0.08
GM-403	50S	50381.6	50382.6	0.40
GM-403	60S	50385.3	50385.0	-0.12
GM-403	70S	50380.1	50383.6	1.40
GM-403	80S	50389.5	50389.9	0.16
GM-403	90S	50396.8	50395.9	-0.36
GM-403	100S	50399.6	50399.3	-0.12
GM-403	110S	50401.6	50401.6	0.00
GM-403	120S	50403.3	50403.3	0.00
GM-403	130S	50405.3	50405.3	0.00
GM-403	140S	50409.0	50407.8	-0.48
GM-403	150S	50414.4	50412.0	-0.96
GM-403	160S	50416.1	50412.7	-1.36
GM-403	170S	50414.0	50407.7	-2.52

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
100	0	50352.1	50358.1	2.317	853.4
100	5	50353.0	50359.4	2.472	853.5
100	10	50354.0	50360.2	2.394	853.5
100	15	50354.6	50361.6	2.703	853.6
100	20	50355.2	50361.9	2.588	853.7
100	25	50355.6	50361.6	2.317	853.7
100	30	50356.7	50363.4	2.588	853.8
100	35	50356.5	50362.1	2.163	853.9
100	40	50356.8	50362.9	2.356	853.9
100	45	50357.4	50363.0	2.161	854.0
100	50	50358.2	50363.8	2.163	854.1
100	55	50359.3	50365.3	2.317	854.2
100	60	50360.2	50365.8	2.163	854.2
100	65	50361.1	50366.8	2.200	854.3
100	70	50362.5	50368.5	2.317	854.4
100	75	50364.8	50370.9	2.356	854.4
100	80	50366.5	50373.0	2.510	854.5
100	85	50369.5	50376.4	2.665	854.6
100	90	50372.3	50379.5	2.780	854.6
100	95	50375.1	50382.1	2.703	854.7
100	100	50369.0	50379.1	3.900	854.8
100	105	50369.6	50375.8	2.394	849.4
100	110	50362.8	50365.4	1.004	844.1
100	115	50356.0	50358.5	0.965	838.7
100	120	50352.2	50354.7	0.965	833.4
100	125	50345.9	50342.8	-1.198	833.2

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
100	130	50345.5	50346.8	0.502	832.9
100	135	50340.9	50340.5	-0.155	832.7
100	140	50341.2	50343.1	0.734	832.5
100	145	50344.2	50350.2	2.317	832.3
100	150	50346.5	50354.3	3.012	832.0
100	155	50346.6	50354.0	2.857	831.8
100	160	50346.8	50354.8	3.089	831.6
100	165	50346.2	50354.1	3.051	831.4
100	170	50345.5	50352.5	2.703	831.1
100	175	50344.5	50351.2	2.587	830.9
100	180	50344.1	50350.6	2.510	830.7
100	185	50344.2	50350.9	2.588	830.5
100	190	50343.0	50349.1	2.356	830.2
100	195	50342.5	50349.5	2.703	830.0
100	200	50340.9	50346.1	2.007	829.8
120	200	50332.6	50340.3	2.973	829.6
120	195	50331.8	50338.9	2.742	831.1
120	190	50330.4	50335.5	1.968	832.6
120	185	50330.3	50334.1	1.467	834.1
120	180	50329.6	50334.7	1.968	834.9
120	175	50328.7	50333.6	1.893	835.6
120	170	50326.9	50329.8	1.119	837.1
120	165	50326.3	50330.3	1.544	838.6
120	160	50325.8	50329.5	1.428	840.1
120	155	50324.2	50327.5	1.274	841.6
120	150	50322.3	50322.1	-0.077	824.6

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
120	145	50320.9	50320.1	-0.309	843.1
120	140	50315.7	50313.0	-1.042	844.6
120	135	50335.6	50342.2	2.547	846.1
120	130	50339.1	50345.0	2.277	846.9
120	125	50342.1	50345.4	1.274	847.6
120	120	50345.4	50349.5	1.582	849.1
120	115	50348.9	50352.7	1.466	850.6
120	110	50358.1	50360.9	1.081	852.1
120	105	50362.7	50372.7	3.861	852.9
120	100	50360.0	50369.6	3.707	853.6
120	95	50359.2	50366.3	2.742	853.6
120	90	50356.6	50363.5	2.663	853.6
120	85	50354.8	50361.5	2.587	853.6
120	80	50353.1	50359.4	2.433	853.6
120	75	50351.0	50357.5	2.510	853.6
120	70	50349.1	50355.2	2.354	853.6
120	65	50347.0	50352.6	2.163	853.6
120	60	50346.0	50351.2	2.007	853.5
120	55	50345.5	50350.5	1.931	853.5
120	50	50345.8	50351.0	2.007	853.5
120	45	50346.5	50351.9	2.086	853.5
120	40	50346.7	50352.3	2.163	853.5
120	35	50346.8	50353.3	2.510	853.5
120	30	50346.6	50353.0	2.470	853.5
120	25	50345.9	50351.3	2.084	853.5
120	20	50345.7	50352.0	2.433	853.5

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
120	15	50345.4	50351.1	2.200	853.5
120	10	50345.4	50351.4	2.317	853.4
120	5	50344.5	50349.4	1.893	853.4
120	0	50344.0	50349.6	2.163	853.4
140	0	50343.8	50349.3	2.124	853.8
140	5	50344.6	50349.6	1.931	853.7
140	10	50344.9	50349.5	1.775	853.6
140	15	50345.7	50350.1	1.700	853.5
140	20	50346.7	50351.0	1.661	853.4
140	25	50347.9	50352.7	1.852	853.4
140	30	50348.3	50351.7	1.312	853.3
140	35	50348.8	50352.3	1.351	853.2
140	40	50350.0	50354.6	1.777	853.1
140	45	50350.0	50354.1	1.584	853.0
140	50	50350.2	50353.9	1.430	853.0
140	55	50351.0	50355.0	1.544	852.9
140	60	50351.7	50356.3	1.777	852.8
140	65	50352.6	50357.2	1.775	852.7
140	70	50353.7	50358.0	1.661	852.6
140	75	50354.4	50357.0	1.003	852.6
140	80	50355.9	50359.8	1.505	852.5
140	85	50358.4	50362.7	1.659	852.4
140	90	50360.0	50363.8	1.467	852.3
140	95	50363.8	50368.8	1.931	852.2
140	100	50367.3	50373.9	2.549	852.2
140	105	50368.5	50377.9	3.630	851.5

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
140	110	50370.0	50379.1	3.514	850.9
140	115	50363.0	50367.1	1.584	850.2
140	120	50357.1	50361.3	1.621	849.6
140	125	50351.0	50353.3	0.888	848.9
140	130	50345.8	50346.3	0.193	848.2
140	135	50343.6	50344.7	0.424	847.6
140	140	50341.5	50343.8	0.888	846.9
140	145	50342.0	50345.3	1.274	845.6
140	150	50344.2	50349.5	2.047	845.0
140	155	50344.2	50348.1	1.507	844.3
140	160	50343.8	50348.4	1.777	843.6
140	165	50342.4	50344.5	0.810	843.0
140	170	50342.2	50345.3	1.198	842.3
140	175	50343.3	50347.6	1.661	842.0
140	180	50344.0	50350.0	2.317	841.7
160	160	50346.3	50356.3	3.861	834.2
160	155	50347.5	50358.1	4.093	836.7
160	150	50347.4	50353.3	2.277	837.9
160	145	50344.5	50343.5	-0.386	839.1
160	140	50345.8	50343.5	-0.888	841.6
160	135	50349.2	50350.1	0.348	842.8
160	130	50352.2	50357.4	2.009	844.0
160	125	50352.3	50355.8	1.351	846.4
160	120	50356.6	50360.1	1.351	847.7
160	115	50360.8	50364.0	1.235	848.9
160	110	50370.0	50378.5	3.282	851.3

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
160	105	50368.4	50379.6	4.324	852.6
160	100	50365.3	50373.3	3.089	853.8
160	95	50361.8	50366.0	1.621	853.8
160	90	50358.4	50362.6	1.621	853.8
160	85	50356.3	50360.1	1.467	853.8
160	80	50354.9	50359.1	1.621	853.8
160	75	50354.1	50359.1	1.931	853.8
160	70	50352.7	50357.1	1.700	853.8
160	65	50351.6	50356.0	1.698	853.8
160	60	50350.9	50355.0	1.582	853.8
160	55	50350.6	50355.0	1.698	853.8
160	50	50350.4	50355.2	1.852	853.8
160	45	50349.5	50354.7	2.007	853.8
160	40	50348.5	50353.0	1.737	853.9
160	35	50348.2	50352.5	1.661	853.9
160	30	50347.9	50352.9	1.931	853.9
160	25	50347.3	50352.0	1.814	853.9
160	20	50347.2	50352.0	1.854	853.9
160	15	50344.9	50350.7	2.238	853.9
160	10	50345.8	50350.4	1.777	853.9
160	5	50345.3	50350.2	1.891	853.9
160	0	50344.6	50350.4	2.240	853.9
180	0	50345.3	50350.6	2.047	853.8
180	5	50345.5	50351.1	2.163	853.8
180	10	50345.8	50351.1	2.047	853.7
180	15	50347.1	50352.7	2.161	853.7

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
180	20	50347.8	50353.6	2.240	853.7
180	25	50348.6	50355.1	2.510	853.6
180	30	50348.9	50354.4	2.124	853.6
180	35	50349.5	50355.0	2.124	853.5
180	40	50350.1	50354.7	1.775	853.5
180	45	50350.9	50355.8	1.891	853.5
180	50	50351.8	50356.7	1.891	853.5
180	55	50353.0	50358.1	1.970	853.4
180	60	50353.0	50357.4	1.700	853.4
180	65	50354.4	50359.8	2.084	853.3
180	70	50355.5	50360.4	1.893	853.3
180	75	50355.7	50360.6	1.893	853.3
180	80	50356.8	50362.0	2.007	853.2
180	85	50357.9	50364.7	2.624	853.2
180	90	50359.5	50365.8	2.433	853.2
180	95	50360.2	50366.7	2.510	853.1
180	100	50361.5	50369.8	3.205	853.1
180	105	50361.9	50371.2	3.590	850.3
180	110	50355.4	50351.5	-1.507	847.4
180	115	50333.6	50318.2	-5.947	844.5
180	120	50332.1	50314.0	-6.989	841.7
200	110	50366.4	50379.1	4.903	851.3
200	105	50359.9	50369.4	3.668	852.7
200	100	50355.8	50365.8	3.861	854.1
200	95	50350.2	50357.3	2.742	854.1
200	90	50346.1	50352.0	2.277	854.1

Table D-2. Vertical magnetic gradient survey data over drum area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
200	85	50349.9	50358.1	3.166	854.2
200	80	50352.3	50361.5	3.552	854.2
200	75	50354.2	50363.9	3.746	854.2
200	70	50355.9	50366.8	4.208	854.3
200	65	50357.2	50367.8	4.093	854.3
200	60	50357.5	50366.0	3.282	854.4
200	55	50357.5	50368.3	4.170	854.4
200	50	50356.6	50366.5	3.822	854.4
200	45	50356.0	50363.4	2.858	854.5
200	40	50354.6	50361.1	2.510	854.5
200	35	50352.9	50358.4	2.124	854.5
200	30	50351.4	50356.7	2.045	854.6
200	25	50350.1	50354.6	1.737	854.6
200	20	50349.6	50353.7	1.582	854.6
200	15	50348.5	50351.6	1.198	854.7
200	10	50349.2	50353.1	1.507	854.7
200	5	50349.0	50353.7	1.814	854.7
200	0	50348.2	50351.7	1.351	854.8

Table D-3. Vertical magnetic gradient survey data over subsidence area

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-1	0	5028.6	5028.8	0.062	919.6
T-1	5	5028.4	5028.8	0.135	919.6
T-1	10	5027.8	5027.8	0.023	919.6
T-1	15	5027.2	5026.9	-0.089	919.6
T-1	20	5026.7	5026.5	-0.062	919.6
T-1	25	5026.6	5026.7	0.066	919.6
T-1	30	5026.6	5027.1	0.209	919.5
T-1	35	5026.6	5027.1	0.193	919.5
T-1	40	5026.7	5027.9	0.444	919.5
T-1	45	5026.1	5027.3	0.436	919.5
T-1	50	5024.9	5025.3	0.158	919.5
T-1	55	5024.1	5024.5	0.166	919.5
T-1	60	5023.6	5024.3	0.262	919.4
T-1	65	5022.1	5022.9	0.305	919.4
T-1	70	5020.2	5018.8	-0.544	919.4
T-1	75	5020.8	5021.1	0.100	919.4
T-1	80	5021.5	5021.5	0.031	919.4
T-1	85	5022.0	5025.5	1.344	919.4
T-1	90	5020.2	5021.9	0.687	919.4
T-1	95	5018.8	5021.4	0.988	919.4
T-1	100	5018.0	5021.5	1.351	919.4
T-1	105	5016.3	5021.2	1.884	919.3
T-1	110	5014.1	5021.0	2.680	919.3
T-1	115	5009.4	5022.0	4.873	923.8
T-1	120	4996.9	5014.2	6.676	926.0
T-1	125	4957.4	4974.8	6.726	927.2
T-1	130	4932.4	4923.3	-3.498	928.3
T-1	135	4942.1	4918.5	-9.135	932.7
T-1	140	4963.3	4946.8	-6.344	935.0

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-1	145	4976.6	4965.9	-4.100	936.1
T-1	150	4989.2	4982.6	-2.560	937.2
T-1	155	4993.9	4989.3	-1.764	937.2
T-1	160	4996.5	4993.0	-1.332	937.2
T-1	165	4999.4	4997.0	-0.919	937.2
T-1	170	5001.1	4998.8	-0.880	937.2
T-1	175	5003.2	5001.7	-0.598	937.1
T-1	180	5004.6	5003.5	-0.421	937.1
T-1	185	5005.5	5004.4	-0.440	937.1
T-1	190	5006.5	5005.6	-0.351	937.1
T-1	195	5007.4	5006.4	-0.367	937.1
T-1	200	5008.0	5007.1	-0.359	937.1
T-1	205	5009.2	5008.2	-0.374	937.2
T-1	210	5010.7	5009.8	-0.355	937.2
T-1	215	5011.8	5010.5	-0.506	937.2
T-1	220	5012.8	5011.6	-0.460	937.3
T-1	225	5014.4	5014.2	-0.054	937.4
T-1	230	5015.9	5016.1	0.054	937.5
T-1	235	5016.8	5016.7	-0.019	937.5
T-1	240	5016.7	5016.1	-0.220	937.5
T-1	245	5018.1	5020.8	1.066	937.6
T-1	250	5018.2	5020.4	0.846	937.7
T-1	255	5016.8	5018.3	0.579	937.8
T-1	260	5015.0	5016.6	0.610	937.8
T-1	265	5011.8	5013.6	0.687	937.8
T-1	270	5008.8	5012.2	1.336	937.9
T-1	275	5007.2	5012.2	1.946	938.0
T-1	280	5004.3	5007.9	1.409	938.1
T-1	285	5001.9	5004.8	1.120	938.1
T-1	290	5002.1	5004.5	0.942	938.2

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-1	295	5002.4	5004.7	0.911	938.2
T-1	300	5003.6	5004.8	0.490	938.3
T-1	305	5004.5	5004.5	0.000	938.5
T-1	310	5005.9	5005.3	-0.239	938.5
T-1	315	5006.8	5005.4	-0.552	938.6
T-1	320	5008.7	5006.7	-0.749	938.6
T-1	325	5012.9	5011.0	-0.741	938.6
T-1	330	5018.1	5016.7	-0.514	938.8
T-1	335	5024.1	5023.8	-0.143	938.8
T-1	340	5025.3	5024.9	-0.123	938.9
T-1	345	5024.1	5023.9	-0.100	938.9
T-1	350	5023.4	5024.0	0.251	938.9
T-1	355	5021.2	5021.3	0.027	939.0
T-1	360	5019.7	5019.5	-0.097	939.0
T-1	365	5018.6	5018.2	-0.139	939.1
T-1	370	5018.8	5018.5	-0.097	939.1
T-1	375	5019.3	5019.2	-0.008	939.2
T-1	380	5019.7	5019.7	0.023	939.3
T-1	385	5020.1	5020.3	0.062	939.3
T-1	390	5020.6	5020.8	0.066	939.4
T-1	395	5020.9	5021.1	0.062	939.4
T-1	400	5021.1	5021.3	0.085	939.5
T-2	400	5025.1	5024.9	-0.089	942.7
T-2	395	5026.5	5026.7	0.077	942.6
T-2	390	5029.2	5032.1	1.104	942.6
T-2	385	5030.2	5035.2	1.942	942.5
T-2	380	5026.2	5028.0	0.707	942.4
T-2	375	5021.2	5020.8	-0.178	942.2
T-2	370	5017.1	5016.5	-0.251	942.1
T-2	365	5013.9	5013.0	-0.371	942.1

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-2	360	5010.2	5008.2	-0.753	942.1
T-2	355	5006.2	5002.7	-1.355	942.0
T-2	350	5006.2	5003.9	-0.907	941.9
T-2	345	5009.8	5008.9	-0.344	941.8
T-2	340	5013.6	5012.9	-0.270	941.7
T-2	335	5017.1	5017.1	-0.008	941.6
T-2	330	5019.4	5019.2	-0.058	941.6
T-2	325	5021.3	5021.1	-0.070	941.5
T-2	320	5023.0	5022.9	-0.054	941.4
T-2	315	5027.1	5025.4	-0.668	941.4
T-2	310	5034.1	5035.5	0.525	941.2
T-2	305	5052.3	5060.3	3.093	941.1
T-2	300	5065.6	5086.5	8.093	941.1
T-2	295	5065.0	5088.8	9.174	941.0
T-2	290	5043.9	5048.9	1.938	940.9
T-2	285	5024.5	5022.1	-0.931	940.8
T-2	280	5016.4	5014.0	-0.934	940.7
T-2	275	5011.5	5008.9	-1.012	940.7
T-2	270	5008.3	5005.7	-1.019	940.7
T-2	265	5003.9	5000.6	-1.282	940.6
T-2	260	4999.7	4995.7	-1.537	940.5
T-2	255	4994.3	4990.2	-1.548	940.5
T-2	250	4988.4	4984.0	-1.695	940.4
T-2	245	4984.4	4979.9	-1.745	940.3
T-2	240	4980.5	4977.4	-1.170	940.2
T-2	235	4975.7	4971.4	-1.641	940.1
T-2	230	4974.8	4970.7	-1.564	940.1
T-2	225	4973.3	4970.3	-1.143	940.0
T-2	220	4972.8	4970.4	-0.927	936.7
T-2	215	4972.1	4972.6	0.166	933.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-2	210	4977.9	4981.1	1.262	930.1
T-2	205	4992.7	4999.5	2.641	928.4
T-2	200	5004.7	5012.7	3.089	926.7
T-2	195	5019.1	5026.4	2.814	926.4
T-2	190	5028.8	5034.8	2.309	926.1
T-2	185	5032.0	5038.1	2.344	925.8
T-2	180	5034.3	5045.0	4.127	925.7
T-2	175	5027.4	5030.2	1.089	925.5
T-2	170	5019.5	5014.1	-2.089	925.4
T-2	165	5017.1	5011.8	-2.035	925.2
T-2	160	5018.5	5019.8	0.486	925.0
T-2	155	5019.1	5019.9	0.320	925.0
T-2	150	5017.1	5013.1	-1.568	924.3
T-2	145	5010.6	5001.7	-3.436	923.0
T-2	140	5014.1	5012.7	-0.541	922.4
T-2	135	5017.5	5017.4	-0.035	922.1
T-2	130	5020.0	5020.0	-0.031	922.0
T-2	125	5021.2	5021.0	-0.081	921.9
T-2	120	5021.7	5021.5	-0.104	921.8
T-2	115	5021.8	5022.0	0.066	921.8
T-2	110	5020.1	5019.1	-0.386	921.8
T-2	105	5018.4	5016.7	-0.652	921.8
T-2	100	5018.3	5017.9	-0.123	921.8
T-2	95	5018.6	5018.9	0.112	920.6
T-2	90	5018.9	5019.4	0.170	920.6
T-2	85	5019.3	5019.7	0.143	919.9
T-2	80	5019.7	5020.1	0.143	919.6
T-2	75	5020.1	5020.4	0.120	919.5
T-2	70	5020.4	5020.5	0.046	919.4
T-2	65	5021.2	5021.5	0.120	919.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-2	60	5021.7	5022.0	0.139	919.3
T-2	55	5022.4	5022.7	0.104	919.3
T-2	50	5023.2	5023.4	0.050	919.3
T-2	45	5025.2	5025.3	0.035	918.1
T-2	40	5028.9	5029.5	0.236	917.5
T-2	35	5037.5	5043.1	2.131	917.2
T-2	30	5047.5	5065.4	6.896	917.0
T-2	25	5043.4	5066.4	8.861	916.9
T-2	20	5015.1	5012.8	-0.876	916.9
T-2	15	5006.0	5001.6	-1.699	916.9
T-2	10	5010.7	5010.5	-0.066	916.9
T-2	5	5016.0	5016.9	0.347	916.9
T-2	0	5019.0	5019.8	0.328	916.9
T-3	0	5018.6	5018.8	0.077	916.4
T-3	5	5016.1	5016.3	0.081	916.7
T-3	10	5012.9	5011.3	-0.618	916.9
T-3	15	5016.2	5014.7	-0.548	917.1
T-3	20	5031.2	5043.0	4.541	917.2
T-3	25	5052.6	5089.0	14.031	917.3
T-3	30	5039.2	5043.3	1.575	917.6
T-3	35	5029.7	5026.2	-1.355	917.8
T-3	40	5026.1	5025.2	-0.367	918.0
T-3	45	5023.9	5023.8	-0.058	918.1
T-3	50	5022.4	5022.5	0.039	918.2
T-3	55	5021.8	5022.0	0.089	918.5
T-3	60	5021.4	5021.7	0.097	918.7
T-3	65	5020.9	5021.3	0.139	918.9
T-3	70	5020.4	5020.8	0.120	919.0
T-3	75	5019.9	5020.3	0.154	919.1
T-3	80	5019.6	5020.5	0.363	919.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-3	85	5018.7	5020.1	0.525	919.6
T-3	90	5016.2	5017.3	0.417	919.8
T-3	95	5012.5	5013.9	0.544	919.9
T-3	100	5006.9	5007.7	0.317	920.0
T-3	105	5001.2	4997.4	-1.475	920.3
T-3	110	5002.5	4997.3	-2.023	920.5
T-3	115	5012.0	5010.6	-0.552	920.7
T-3	120	5026.7	5031.1	1.703	920.9
T-3	125	5049.0	5066.0	6.560	921.2
T-3	130	5075.2	5101.7	10.259	921.3
T-3	135	5069.0	5084.6	6.023	921.4
T-3	140	5051.0	5055.8	1.838	921.6
T-3	145	5033.3	5033.5	0.066	921.7
T-3	150	5024.8	5023.8	-0.374	921.8
T-3	155	5021.5	5019.9	-0.614	922.1
T-3	160	5021.4	5019.7	-0.660	922.3
T-3	165	5023.0	5021.3	-0.664	922.5
T-3	170	5027.5	5026.5	-0.409	922.6
T-3	175	5030.9	5031.5	0.228	922.7
T-3	180	5028.3	5029.0	0.290	923.0
T-3	185	5020.2	5018.5	-0.683	923.2
T-3	190	5010.0	5004.8	-2.008	923.4
T-3	195	5001.6	4991.0	-4.097	923.5
T-3	200	4999.8	4986.3	-5.209	923.6
T-3	205	5008.6	4996.8	-4.552	926.1
T-3	210	5025.9	5030.2	1.672	928.6
T-3	215	5022.3	5026.8	1.730	931.1
T-3	220	5015.6	5018.1	0.961	932.4
T-3	225	5007.7	5006.8	-0.351	933.6
T-3	230	5007.3	5000.1	-2.803	936.1

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-3	235	5010.1	5006.2	-1.525	938.6
T-3	240	5011.7	5010.3	-0.521	941.1
T-3	245	5012.1	5010.6	-0.556	942.4
T-3	250	5014.0	5012.5	-0.575	943.6
T-3	255	5018.9	5019.3	0.158	944.1
T-3	260	5023.0	5025.2	0.834	944.6
T-3	265	5023.3	5025.1	0.710	944.6
T-3	270	5021.2	5021.9	0.297	944.6
T-3	275	5019.3	5019.6	0.123	944.6
T-3	280	5018.8	5018.9	0.046	944.6
T-3	285	5019.2	5019.4	0.097	944.6
T-3	290	5020.9	5023.3	0.907	944.6
T-3	295	5022.2	5025.3	1.174	944.6
T-3	300	5022.5	5024.6	0.788	944.6
T-3	305	5023.4	5026.2	1.062	944.5
T-3	310	5028.4	5035.5	2.772	944.4
T-3	315	5032.1	5045.4	5.154	944.3
T-3	320	5027.9	5035.0	2.738	944.1
T-3	325	5021.7	5023.7	0.776	944.0
T-3	330	5018.9	5020.7	0.695	943.9
T-3	335	5019.1	5020.4	0.506	943.8
T-3	340	5019.2	5020.4	0.436	943.7
T-3	345	5019.0	5019.9	0.340	943.8
T-3	350	5018.8	5019.5	0.301	943.9
T-3	355	5018.5	5019.3	0.293	943.9
T-3	360	5018.2	5019.2	0.394	944.0
T-3	365	5017.0	5018.3	0.517	944.1
T-3	370	5012.5	5013.2	0.274	944.1
T-3	375	5003.8	4998.0	-2.208	944.2
T-3	380	4996.9	4983.7	-5.101	944.2

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-3	385	4998.8	4989.7	-3.548	944.2
T-3	390	5006.3	5003.1	-1.251	944.1
T-3	395	5013.0	5012.3	-0.259	944.1
T-3	400	5016.1	5016.3	0.089	944.0
T-4	400	5014.1	5013.4	-0.274	947.7
T-4	395	5013.4	5013.2	-0.073	947.9
T-4	390	5014.2	5014.9	0.251	948.1
T-4	385	5014.3	5015.0	0.274	948.2
T-4	380	5013.7	5014.9	0.452	948.4
T-4	375	5012.9	5014.6	0.645	948.6
T-4	370	5011.2	5014.1	1.127	948.7
T-4	365	5008.6	5013.4	1.853	948.8
T-4	360	5009.1	5012.6	1.332	948.9
T-4	355	5007.4	5011.8	1.707	948.8
T-4	350	5002.8	5010.7	3.046	948.7
T-4	345	5002.5	5026.4	9.216	948.6
T-4	340	5004.6	5012.5	3.046	948.5
T-4	335	5009.2	5012.7	1.367	948.3
T-4	330	5013.7	5017.6	1.475	948.1
T-4	325	5017.0	5019.9	1.151	948.0
T-4	320	5018.2	5020.3	0.811	947.8
T-4	315	5018.4	5019.7	0.498	947.7
T-4	310	5018.8	5019.7	0.363	947.7
T-4	305	5018.9	5019.9	0.378	947.6
T-4	300	5018.8	5019.6	0.282	947.5
T-4	295	5018.7	5019.4	0.259	947.5
T-4	290	5018.6	5019.4	0.309	947.5
T-4	285	5018.3	5019.1	0.301	947.4
T-4	280	5017.9	5018.9	0.398	947.4
T-4	275	5016.3	5016.9	0.235	945.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-4	270	5012.7	5011.5	-0.444	943.4
T-4	265	5010.5	5009.2	-0.498	941.4
T-4	260	5010.3	5010.4	0.023	939.4
T-4	255	5011.2	5011.4	0.085	937.0
T-4	250	5012.9	5013.8	0.351	934.5
T-4	245	5017.5	5022.5	1.931	932.1
T-4	240	5022.4	5034.6	4.699	929.6
T-4	235	5015.4	5013.4	-0.749	928.2
T-4	230	5013.4	5015.6	0.865	926.7
T-4	225	5010.3	5012.1	0.699	925.2
T-4	220	5007.3	5007.6	0.104	923.7
T-4	215	5004.2	5003.9	-0.131	923.8
T-4	210	5005.4	5005.1	-0.120	923.9
T-4	205	5007.8	5008.1	0.112	923.9
T-4	200	5010.0	5010.5	0.201	922.0
T-4	195	5011.8	5012.3	0.189	921.9
T-4	190	5012.9	5013.4	0.174	921.9
T-4	185	5013.6	5014.0	0.147	921.8
T-4	180	5014.1	5014.5	0.162	921.7
T-4	175	5014.6	5015.0	0.185	921.7
T-4	170	5015.0	5015.6	0.220	921.7
T-4	165	5015.4	5016.1	0.263	921.7
T-4	160	5015.8	5016.4	0.263	921.6
T-4	155	5016.4	5017.1	0.274	922.1
T-4	150	5016.9	5017.7	0.320	922.6
T-4	145	5017.2	5018.0	0.309	923.2
T-4	140	5017.6	5018.3	0.301	923.7
T-4	135	5018.2	5019.2	0.394	922.9
T-4	130	5019.1	5021.0	0.753	922.2
T-4	125	5019.1	5020.7	0.629	921.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-4	120	5018.0	5017.1	-0.363	920.7
T-4	115	5018.5	5018.8	0.135	920.6
T-4	110	5019.0	5019.8	0.290	920.6
T-4	105	5019.1	5019.5	0.162	920.5
T-4	100	5019.3	5019.6	0.089	920.4
T-4	95	5019.8	5020.3	0.205	920.3
T-4	90	5020.4	5021.1	0.259	920.1
T-4	85	5020.9	5021.6	0.282	919.9
T-4	80	5021.1	5021.8	0.263	919.8
T-4	75	5021.2	5022.0	0.282	919.7
T-4	70	5021.1	5021.8	0.247	919.6
T-4	65	5020.9	5021.4	0.158	919.6
T-4	60	5021.0	5021.5	0.170	919.5
T-4	55	5021.1	5021.6	0.193	919.9
T-4	50	5020.9	5021.3	0.151	920.2
T-4	45	5020.7	5020.9	0.081	920.5
T-4	40	5020.6	5020.7	0.062	920.9
T-4	35	5020.5	5020.4	-0.039	920.9
T-4	30	5020.7	5020.6	-0.046	920.9
T-4	25	5021.0	5021.0	0.008	920.9
T-4	20	5021.3	5021.6	0.116	920.9
T-4	15	5021.2	5021.6	0.162	920.8
T-4	10	5021.1	5021.4	0.123	920.6
T-4	5	5021.0	5021.3	0.127	920.4
T-4	0	5020.7	5021.0	0.104	920.2
T-5	0	5020.2	5020.5	0.089	920.8
T-5	5	5019.8	5019.9	0.019	921.6
T-5	10	5019.9	5019.7	-0.043	922.3
T-5	15	5020.0	5019.8	-0.081	923.0
T-5	20	5020.3	5020.2	-0.019	923.7

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-5	25	5020.4	5020.6	0.066	924.4
T-5	30	5020.5	5020.8	0.112	925.1
T-5	35	5020.5	5020.9	0.174	925.7
T-5	40	5020.3	5020.8	0.178	926.4
T-5	45	5020.1	5020.4	0.120	925.7
T-5	50	5020.0	5020.4	0.135	924.9
T-5	55	5020.3	5020.9	0.228	924.2
T-5	60	5020.5	5021.4	0.347	923.5
T-5	65	5020.2	5020.9	0.247	923.6
T-5	70	5019.7	5019.8	0.015	923.8
T-5	75	5019.5	5019.5	0.023	923.9
T-5	80	5019.6	5019.6	0.012	924.0
T-5	85	5019.9	5020.1	0.108	924.2
T-5	90	5020.1	5020.5	0.162	924.3
T-5	95	5020.3	5020.6	0.135	924.4
T-5	100	5020.3	5020.6	0.135	924.5
T-5	105	5020.1	5020.5	0.147	924.3
T-5	110	5019.9	5020.4	0.197	924.0
T-5	115	5019.6	5020.0	0.151	923.7
T-5	120	5019.3	5019.7	0.147	923.5
T-5	125	5019.1	5019.5	0.139	924.0
T-5	130	5018.8	5019.1	0.108	924.6
T-5	135	5018.6	5019.0	0.135	924.6
T-5	140	5018.4	5018.7	0.104	924.6
T-5	145	5018.3	5018.7	0.154	924.8
T-5	150	5018.2	5018.6	0.178	924.9
T-5	155	5018.0	5018.4	0.158	925.0
T-5	160	5017.8	5018.1	0.127	925.2
T-5	165	5017.7	5018.1	0.174	925.3
T-5	170	5017.6	5018.0	0.174	925.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-5	175	5017.6	5018.1	0.224	925.6
T-5	180	5017.5	5018.2	0.274	925.7
T-5	185	5017.2	5017.7	0.228	925.8
T-5	190	5016.8	5017.2	0.166	925.8
T-5	195	5016.4	5017.1	0.235	925.9
T-5	200	5016.1	5016.8	0.274	925.9
T-5	205	5015.5	5016.3	0.286	926.2
T-5	210	5014.0	5014.5	0.212	926.4
T-5	215	5012.3	5012.0	-0.135	926.7
T-5	220	5011.2	5010.4	-0.309	926.9
T-5	225	5010.5	5008.4	-0.792	927.7
T-5	230	5014.1	5013.3	-0.305	928.6
T-5	235	5024.8	5032.8	3.089	929.4
T-5	240	5030.7	5042.1	4.413	930.2
T-5	245	5029.2	5037.4	3.162	930.6
T-5	250	5022.8	5025.1	0.869	930.9
T-5	255	5018.6	5019.0	0.185	931.2
T-5	260	5016.3	5016.3	-0.012	931.6
T-5	265	5014.9	5014.7	-0.077	933.0
T-5	270	5014.5	5014.2	-0.108	934.4
T-5	275	5014.5	5014.3	-0.081	935.8
T-5	280	5014.6	5014.3	-0.097	937.2
T-5	285	5014.8	5014.7	-0.066	938.7
T-5	290	5015.0	5014.8	-0.073	940.3
T-5	295	5015.0	5014.7	-0.108	941.8
T-5	300	5015.3	5014.6	-0.270	943.4
T-5	305	5015.9	5015.3	-0.239	948.3
T-5	310	5017.0	5017.2	0.066	948.2
T-5	315	5017.8	5018.3	0.228	948.2
T-5	320	5018.3	5019.1	0.313	948.2

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-5	325	5018.4	5019.3	0.355	948.8
T-5	330	5017.7	5019.0	0.533	949.4
T-5	335	5016.0	5017.1	0.456	950.0
T-5	340	5014.1	5015.5	0.544	950.6
T-5	345	5009.4	5012.0	1.031	950.8
T-5	350	5000.5	5002.1	0.618	951.0
T-5	355	4988.4	4988.3	-0.050	951.2
T-5	360	4980.1	4978.2	-0.722	951.3
T-5	365	4011.3	4977.2	0.000	951.5
T-5	370	4982.6	4983.6	0.406	951.7
T-5	375	4991.3	4995.3	1.552	951.8
T-5	380	4997.7	5000.6	1.097	952.0
T-5	385	5002.9	5005.8	1.116	951.7
T-5	390	5009.2	5010.3	0.452	951.5
T-5	395	5011.8	5012.3	0.216	951.2
T-5	400	5012.9	5013.4	0.166	950.9
T-6	400	5014.4	5016.9	0.954	954.1
T-6	395	5017.0	5020.6	1.398	953.7
T-6	390	5020.0	5026.6	2.571	953.3
T-6	385	5019.4	5028.2	3.417	953.2
T-6	380	5017.4	5019.1	0.683	953.1
T-6	375	5012.5	5015.3	1.070	952.2
T-6	370	5012.5	5014.6	0.830	951.4
T-6	365	5013.5	5014.6	0.417	950.5
T-6	360	5013.6	5014.3	0.286	949.7
T-6	355	5013.4	5013.3	-0.035	948.6
T-6	350	5013.5	5013.8	0.085	947.5
T-6	345	5013.5	5013.5	0.015	946.4
T-6	340	5013.4	5013.6	0.054	945.3
T-6	335	5013.5	5014.0	0.185	943.8

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-6	330	5013.4	5013.5	0.031	942.2
T-6	325	5013.2	5012.7	-0.193	940.7
T-6	320	5013.3	5012.9	-0.147	939.2
T-6	315	5014.6	5015.4	0.286	938.0
T-6	310	5016.2	5018.1	0.707	936.8
T-6	305	5017.6	5020.6	1.158	935.7
T-6	300	5016.8	5019.0	0.857	934.5
T-6	295	5014.8	5015.0	0.069	933.8
T-6	290	5014.5	5016.5	0.788	933.2
T-6	285	5013.7	5016.7	1.147	932.5
T-6	280	5011.3	5015.8	1.714	931.9
T-6	275	5005.8	5003.0	-1.070	931.7
T-6	270	5005.5	5004.5	-0.386	931.6
T-6	265	5007.4	5008.6	0.436	931.4
T-6	260	5009.0	5010.2	0.471	931.2
T-6	255	5009.7	5010.3	0.205	931.4
T-6	250	5010.5	5010.8	0.093	931.6
T-6	245	5011.3	5010.9	-0.154	931.7
T-6	240	5012.0	5011.9	-0.050	931.9
T-6	235	5012.8	5013.0	0.077	931.2
T-6	230	5013.9	5014.2	0.104	930.5
T-6	225	5014.9	5015.3	0.178	929.8
T-6	220	5015.3	5015.9	0.216	929.0
T-6	215	5016.0	5016.7	0.286	929.0
T-6	210	5016.2	5016.8	0.220	928.9
T-6	205	5016.4	5016.9	0.197	928.9
T-6	200	5016.5	5016.9	0.158	928.8
T-6	195	5016.5	5016.9	0.182	929.0
T-6	190	5016.6	5017.1	0.178	929.2
T-6	185	5016.8	5017.2	0.154	929.3

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-6	180	5016.9	5017.4	0.186	929.5
T-6	175	5017.1	5017.6	0.212	929.3
T-6	170	5017.1	5017.6	0.181	929.1
T-6	165	5017.2	5017.6	0.147	928.9
T-6	160	5017.3	5017.6	0.131	928.7
T-6	155	5017.5	5017.8	0.147	928.6
T-6	150	5017.6	5018.0	0.154	928.4
T-6	145	5017.9	5018.3	0.174	928.2
T-6	140	5018.0	5018.5	0.193	928.1
T-6	135	5018.2	5018.7	0.201	928.2
T-6	130	5018.6	5019.1	0.224	928.2
T-6	125	5018.8	5019.3	0.205	928.3
T-6	120	5019.0	5019.5	0.209	928.4
T-6	115	5019.1	5019.8	0.251	928.2
T-6	110	5019.3	5020.0	0.290	928.1
T-6	105	5019.1	5019.7	0.235	928.1
T-6	100	5018.9	5019.4	0.170	928.0
T-6	95	5018.8	5019.2	0.158	927.9
T-6	90	5018.8	5019.3	0.158	927.7
T-6	85	5019.0	5019.3	0.127	927.5
T-6	80	5019.1	5019.6	0.201	927.3
T-6	75	5019.2	5019.7	0.178	927.2
T-6	70	5019.5	5020.0	0.212	927.1
T-6	65	5019.7	5020.3	0.232	927.0
T-6	60	5019.8	5020.5	0.235	926.9
T-6	55	5019.9	5020.6	0.247	926.7
T-6	50	5019.9	5020.4	0.220	926.6
T-6	45	5019.6	5020.1	0.174	926.4
T-6	40	5019.7	5020.1	0.178	926.2
T-6	35	5019.6	5020.1	0.182	926.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-6	30	5019.7	5020.2	0.228	926.6
T-6	25	5019.6	5020.3	0.270	926.8
T-6	20	5019.5	5020.2	0.243	926.9
T-6	15	5019.5	5020.0	0.209	926.9
T-6	10	5019.3	5019.8	0.193	926.9
T-6	5	5019.3	5019.7	0.174	926.9
T-6	0	5019.2	5019.6	0.162	926.9
T-7	0	5018.8	5019.5	0.251	928.0
T-7	5	5018.7	5019.2	0.216	928.0
T-7	10	5018.5	5019.0	0.193	928.0
T-7	15	5018.3	5018.7	0.143	928.0
T-7	20	5018.2	5018.6	0.166	928.0
T-7	25	5018.2	5018.7	0.197	928.0
T-7	30	5018.1	5018.6	0.174	928.0
T-7	35	5017.9	5018.2	0.123	928.0
T-7	40	5017.8	5018.0	0.104	928.0
T-7	45	5017.7	5018.0	0.112	928.3
T-7	50	5017.8	5018.1	0.108	928.3
T-7	55	5018.0	5018.4	0.143	928.5
T-7	60	5018.1	5018.6	0.201	928.6
T-7	65	5018.1	5018.7	0.212	928.9
T-7	70	5018.0	5018.6	0.209	929.1
T-7	75	5017.6	5018.0	0.143	929.3
T-7	80	5017.3	5017.6	0.123	929.5
T-7	85	5016.9	5016.9	0.004	929.5
T-7	90	5016.7	5016.6	-0.054	929.6
T-7	95	5016.8	5016.7	-0.070	929.6
T-7	100	5017.2	5017.2	0.000	929.6
T-7	105	5017.5	5017.9	0.158	929.8
T-7	110	5017.4	5017.3	-0.046	930.0

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-7	115	5017.4	5016.8	-0.228	930.0
T-7	120	5018.1	5018.7	0.247	930.1
T-7	125	5017.9	5018.3	0.151	930.4
T-7	130	5017.9	5018.4	0.182	930.6
T-7	135	5017.8	5018.5	0.243	930.6
T-7	140	5017.6	5018.3	0.247	930.7
T-7	145	5016.5	5016.4	-0.054	931.0
T-7	150	5016.0	5015.5	-0.205	931.4
T-7	155	5016.4	5016.3	-0.019	931.7
T-7	160	5017.0	5017.3	0.116	932.0
T-7	165	5017.2	5017.7	0.170	932.0
T-7	170	5017.1	5017.6	0.197	932.0
T-7	175	5016.8	5017.1	0.124	931.9
T-7	180	5016.5	5016.7	0.073	931.9
T-7	185	5016.3	5016.5	0.054	931.7
T-7	190	5016.4	5016.8	0.162	931.6
T-7	195	5016.3	5016.7	0.139	931.6
T-7	200	5016.3	5016.7	0.166	931.5
T-7	205	5016.1	5016.3	0.073	931.8
T-7	210	5016.1	5016.5	0.150	932.0
T-7	215	5016.0	5016.4	0.155	932.2
T-7	220	5015.9	5016.3	0.151	932.4
T-7	225	5015.8	5016.2	0.166	932.5
T-7	230	5015.7	5016.2	0.170	932.6
T-7	235	5015.6	5016.1	0.201	932.6
T-7	240	5015.2	5015.8	0.216	932.7
T-7	245	5014.7	5015.2	0.193	932.8
T-7	250	5014.1	5014.5	0.178	932.9
T-7	255	5013.3	5013.8	0.166	933.0
T-7	260	5012.4	5012.3	-0.031	933.2

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-7	265	5011.8	5011.3	-0.174	935.0
T-7	270	5011.7	5011.0	-0.282	936.7
T-7	275	5012.1	5011.3	-0.317	938.5
T-7	280	5013.2	5012.3	-0.363	940.3
T-7	285	5015.3	5015.7	0.170	942.1
T-7	290	5016.2	5018.3	0.815	943.9
T-7	295	5014.3	5016.3	0.741	945.7
T-7	300	5011.9	5012.4	0.193	947.5
T-7	305	5007.5	5005.0	-0.969	945.5
T-7	310	5010.4	5009.8	-0.216	944.5
T-7	315	5015.0	5017.2	0.872	943.5
T-7	320	5017.6	5020.2	1.015	942.5
T-7	325	5016.6	5017.9	0.502	941.5
T-7	330	5013.3	5013.6	0.124	940.5
T-7	335	5010.2	5009.8	-0.131	939.5
T-8	300	5008.5	5009.4	0.340	941.4
T-8	295	5010.6	5012.7	0.815	940.4
T-8	290	5010.3	5010.3	0.000	939.3
T-8	285	5009.1	5008.0	-0.444	938.3
T-8	280	5010.2	5010.4	0.066	937.2
T-8	275	5011.1	5011.5	0.143	937.1
T-8	270	5011.7	5012.0	0.127	936.9
T-8	265	5012.0	5012.0	0.023	936.8
T-8	260	5012.2	5012.2	0.015	936.7
T-8	255	5012.6	5012.5	-0.035	936.4
T-8	250	5013.5	5013.8	0.100	936.3
T-8	245	5014.4	5014.9	0.166	936.2
T-8	240	5014.8	5015.2	0.158	936.1
T-8	235	5015.0	5015.3	0.112	936.0
T-8	230	5015.3	5015.5	0.077	935.9

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-8	225	5015.7	5016.0	0.147	935.8
T-8	220	5015.7	5015.7	-0.008	935.7
T-8	215	5015.8	5015.9	0.050	935.6
T-8	210	5015.7	5015.9	0.097	935.5
T-8	205	5015.9	5016.1	0.093	935.4
T-8	200	5016.0	5016.2	0.085	935.3
T-8	195	5016.3	5016.6	0.143	935.1
T-8	190	5016.6	5016.9	0.135	934.9
T-8	185	5016.9	5017.4	0.209	934.7
T-8	180	5017.1	5017.5	0.185	934.5
T-8	175	5017.1	5017.4	0.131	934.5
T-8	170	5017.2	5017.4	0.100	934.5
T-8	165	5017.4	5017.7	0.143	934.5
T-8	160	5017.5	5017.9	0.139	934.5
T-8	155	5017.6	5018.0	0.158	934.5
T-8	150	5017.8	5018.2	0.174	934.5
T-8	145	5017.9	5018.5	0.220	934.6
T-8	140	5018.0	5018.4	0.181	934.6
T-8	135	5017.9	5018.3	0.162	934.5
T-8	130	5017.9	5018.3	0.166	934.4
T-8	125	5017.9	5018.3	0.154	934.4
T-8	120	5017.9	5018.3	0.147	934.3
T-8	115	5017.8	5018.0	0.100	934.0
T-8	110	5017.7	5017.9	0.085	933.8
T-8	105	5017.6	5017.8	0.046	933.5
T-8	100	5017.7	5017.9	0.097	933.3
T-8	95	5017.6	5017.9	0.104	933.1
T-8	90	5017.4	5017.5	0.035	932.8
T-8	85	5017.6	5017.9	0.135	932.6
T-8	80	5017.7	5017.9	0.093	932.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-8	75	5018.0	5018.3	0.123	932.5
T-8	70	5018.3	5018.8	0.166	932.7
T-8	65	5018.6	5019.0	0.151	932.8
T-8	60	5018.9	5019.3	0.158	933.0
T-8	55	5019.5	5020.0	0.209	933.0
T-8	50	5020.5	5022.7	0.861	933.1
T-8	45	5014.1	5008.2	-2.262	933.1
T-8	40	5010.3	4998.7	-4.487	933.2
T-8	35	5011.4	5007.4	-1.579	932.8
T-8	30	5015.7	5016.3	0.228	932.4
T-8	25	5017.1	5017.6	0.189	932.0
T-8	20	5017.6	5018.2	0.205	931.6
T-8	15	5017.8	5018.3	0.189	931.6
T-8	10	5017.9	5018.4	0.189	931.6
T-8	5	5017.9	5018.4	0.197	931.6
T-8	0	5017.8	5018.3	0.162	931.6
T-9	0	5016.2	5016.6	0.131	937.5
T-9	5	5016.2	5016.4	0.081	937.7
T-9	10	5016.3	5016.5	0.077	937.7
T-9	15	5016.3	5016.6	0.108	937.8
T-9	20	5016.4	5016.7	0.097	937.8
T-9	25	5016.5	5016.7	0.089	937.9
T-9	30	5016.6	5017.0	0.131	938.0
T-9	35	5016.7	5016.9	0.112	938.1
T-9	40	5016.7	5016.9	0.097	938.2
T-9	45	5016.7	5016.8	0.058	938.4
T-9	50	5016.8	5017.1	0.112	938.5
T-9	55	5016.9	5017.3	0.135	938.5
T-9	60	5016.9	5017.2	0.123	938.5
T-9	65	5017.0	5017.3	0.085	938.6

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-9	70	5017.2	5017.8	0.201	938.6
T-9	75	5017.1	5017.5	0.158	938.6
T-9	80	5017.0	5017.2	0.097	938.7
T-9	85	5016.8	5017.0	0.066	939.2
T-9	90	5016.7	5016.9	0.066	939.8
T-9	95	5016.7	5016.9	0.093	940.4
T-9	100	5016.6	5016.9	0.093	940.9
T-9	105	5016.5	5016.7	0.089	940.9
T-9	110	5016.5	5016.8	0.100	940.9
T-9	115	5016.5	5016.7	0.097	940.9
T-9	120	5016.5	5016.7	0.081	940.9
T-9	125	5016.6	5016.7	0.038	941.1
T-9	130	5016.7	5016.9	0.062	941.3
T-9	135	5016.9	5017.2	0.116	941.5
T-9	140	5017.0	5017.4	0.147	941.7
T-9	145	5017.0	5017.3	0.147	941.9
T-9	150	5016.9	5017.2	0.139	942.0
T-9	155	5016.9	5017.3	0.178	942.2
T-9	160	5016.9	5017.2	0.131	942.3
T-9	165	5016.9	5017.3	0.147	942.4
T-9	170	5017.0	5017.5	0.185	942.5
T-9	175	5017.0	5017.4	0.154	942.7
T-9	180	5017.0	5017.3	0.143	942.8
T-9	185	5016.9	5017.3	0.143	942.4
T-9	190	5017.0	5017.4	0.151	942.1
T-9	195	5017.0	5017.5	0.178	942.0
T-9	200	5017.0	5017.5	0.162	941.9
T-9	205	5017.0	5017.5	0.185	942.0
T-9	210	5016.8	5017.2	0.150	942.1
T-9	215	5016.7	5017.2	0.174	942.1

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-9	220	5016.7	5017.2	0.212	942.1
T-9	225	5016.6	5017.3	0.278	942.3
T-9	230	5016.3	5016.8	0.182	942.3
T-9	235	5016.2	5016.8	0.263	942.4
T-9	240	5015.9	5016.5	0.212	942.4
T-9	245	5015.7	5016.1	0.174	942.5
T-9	250	5015.5	5016.0	0.212	942.5
T-9	255	5015.1	5015.5	0.143	942.5
T-9	260	5014.9	5015.3	0.170	942.5
T-9	265	5014.6	5015.1	0.174	942.7
T-9	270	5014.4	5014.9	0.181	942.9
T-9	275	5013.9	5014.2	0.116	943.1
T-9	280	5013.5	5013.9	0.151	943.3
T-9	285	5012.3	5012.2	-0.039	943.6
T-9	290	5011.2	5009.6	-0.618	943.9
T-9	295	5011.3	5010.6	-0.278	944.2
T-9	300	5011.6	5011.9	0.124	944.5
T-9	305	5010.8	5011.2	0.178	944.8
T-9	310	5008.7	5008.5	-0.073	945.0
T-9	315	5007.0	5005.6	-0.517	945.3
T-9	320	5006.5	5004.1	-0.927	945.5
T-10	0	5023.4	5023.8	0.139	905.7
T-10	5	5022.8	5023.0	0.085	906.2
T-10	10	5022.3	5022.4	0.054	906.7
T-10	15	5022.0	5022.2	0.093	907.1
T-10	20	5021.8	5022.1	0.135	907.4
T-10	25	5021.1	5021.4	0.108	907.6
T-10	30	5020.4	5020.5	0.050	908.1
T-10	35	5019.7	5019.7	0.023	908.6
T-10	40	5019.1	5019.1	-0.004	909.1

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-10	45	5018.5	5018.3	-0.073	909.3
T-10	50	5017.8	5017.4	-0.143	909.5
T-10	55	5017.1	5016.5	-0.235	910.0
T-10	60	5016.6	5015.7	-0.313	910.5
T-10	65	5016.6	5015.8	-0.290	911.0
T-10	70	5016.3	5015.6	-0.251	911.2
T-10	75	5016.0	5015.4	-0.236	911.5
T-10	80	5015.7	5015.0	-0.274	911.9
T-10	85	5015.3	5014.3	-0.390	912.4
T-10	90	5015.1	5013.2	-0.711	912.9
T-10	95	5016.2	5012.0	-1.622	913.1
T-10	100	5018.2	5013.7	-1.707	913.4
T-10	105	5021.4	5019.6	-0.722	913.8
T-10	110	5023.1	5022.9	-0.097	914.3
T-10	115	5023.7	5024.0	0.085	914.8
T-10	120	5023.9	5024.1	0.089	915.0
T-10	125	5023.6	5023.7	0.039	915.3
T-10	130	5023.3	5023.3	0.008	915.8
T-10	135	5022.9	5022.8	-0.039	916.2
T-10	140	5022.4	5022.3	-0.027	916.7
T-10	145	5021.6	5021.6	-0.012	917.0
T-10	150	5018.1	5017.0	-0.432	917.2
T-10	155	5013.3	5003.1	-3.946	917.7
T-10	160	5014.9	5005.0	-3.850	918.2
T-10	165	5018.7	5014.0	-1.834	918.6
T-10	170	5022.7	5020.8	-0.737	918.9
T-10	175	5026.4	5026.3	-0.046	919.1
T-10	180	5030.2	5035.3	1.954	919.6
T-10	185	5030.2	5034.7	1.749	920.1
T-10	190	5027.2	5028.2	0.378	920.6

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-10	195	5024.6	5024.8	0.043	920.8
T-10	200	5022.4	5022.1	-0.120	921.0
T-10	205	5021.3	5020.5	-0.309	921.1
T-10	210	5021.2	5020.4	-0.293	921.3
T-10	215	5022.1	5022.0	-0.035	921.4
T-10	220	5022.3	5022.6	0.123	921.4
T-10	225	5021.9	5022.0	0.043	921.5
T-10	230	5021.4	5021.5	0.066	921.6
T-10	235	5020.9	5020.9	0.019	921.7
T-10	240	5020.4	5020.3	-0.023	921.8
T-10	245	5019.7	5019.7	-0.023	921.8
T-10	250	5019.2	5019.2	-0.031	921.9
T-10	255	5018.9	5019.0	0.046	922.1
T-10	260	5018.6	5018.9	0.112	922.1
T-10	265	5017.9	5018.1	0.050	922.2
T-10	270	5017.0	5017.1	0.023	922.2
T-10	275	5015.5	5014.8	-0.274	922.3
T-10	280	5014.2	5012.3	-0.722	922.5
T-10	285	5014.0	5011.8	-0.853	922.6
T-10	290	5014.9	5012.7	-0.872	922.7
T-10	295	5015.6	5012.9	-1.066	922.7
T-10	300	5016.3	5012.4	-1.521	922.7
T-10	305	5018.3	5016.3	-0.757	922.9
T-10	310	5018.6	5017.0	-0.629	923.0
T-10	315	5015.0	5011.9	-1.193	923.1
T-10	320	5010.0	5003.8	-2.394	923.1
T-10	325	5001.5	4991.7	-3.788	923.2
T-10	330	4987.2	4980.3	-2.691	923.3
T-10	335	4959.8	4926.9	-12.695	923.3
T-10	340	4949.1	4901.2	-18.475	923.4

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-10	345	4972.7	4956.8	-6.135	923.4
T-10	350	4995.1	4988.7	-2.479	923.6
T-10	355	5006.2	5000.2	-2.332	923.7
T-10	360	5026.1	5022.8	-1.255	923.8
T-10	365	5046.2	5059.2	5.023	923.9
T-10	370	5057.9	5072.9	5.803	923.9
T-10	375	5051.1	5059.4	3.205	924.0
T-10	380	5043.1	5046.1	1.170	924.2
T-10	385	5036.4	5035.8	-0.239	924.2
T-10	390	5034.1	5031.7	-0.923	924.3
T-10	395	5037.1	5035.7	-0.544	924.3
T-10	400	5040.8	5044.2	1.301	924.4
T-11	400	5019.4	5016.0	-1.317	919.6
T-11	395	5015.4	5008.6	-2.610	919.8
T-11	390	5019.3	5017.9	-0.537	919.9
T-11	385	5022.2	5022.6	0.143	920.1
T-11	380	5023.3	5023.1	-0.054	920.1
T-11	375	5023.4	5022.4	-0.394	920.2
T-11	370	5023.1	5022.1	-0.371	920.5
T-11	365	5021.6	5020.5	-0.409	920.6
T-11	360	5018.0	5016.8	-0.436	920.7
T-11	355	5010.1	5003.7	-2.460	920.7
T-11	350	5008.9	5002.4	-2.514	920.8
T-11	345	5013.3	5011.4	-0.703	921.0
T-11	340	5016.7	5016.5	-0.085	921.2
T-11	335	5018.0	5017.6	-0.123	921.3
T-11	330	5018.8	5018.0	-0.286	921.3
T-11	325	5020.0	5020.0	-0.023	921.3
T-11	320	5020.9	5021.0	0.039	921.5
T-11	315	5021.7	5022.1	0.162	921.5

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-11	310	5022.0	5022.3	0.124	921.6
T-11	305	5022.3	5022.4	0.054	921.7
T-11	300	5023.0	5022.6	-0.166	921.9
T-11	295	5026.8	5028.1	0.490	922.0
T-11	290	5032.3	5045.2	4.988	922.2
T-11	285	5026.9	5032.3	2.085	922.3
T-11	280	5020.6	5018.2	-0.927	922.4
T-11	275	5019.0	5017.8	-0.456	922.5
T-11	270	5019.8	5019.5	-0.120	922.6
T-11	265	5020.7	5020.7	0.019	922.7
T-11	260	5022.6	5022.5	-0.042	922.9
T-11	255	5026.5	5026.8	0.093	922.9
T-11	250	5036.9	5042.5	2.151	923.0
T-11	245	5043.6	5058.1	5.591	923.3
T-11	240	5040.4	5042.2	0.687	923.4
T-11	235	5028.5	5024.1	-1.707	923.5
T-11	230	5023.1	5020.5	-1.015	923.5
T-11	225	5021.7	5019.8	-0.749	923.6
T-11	220	5021.6	5020.2	-0.521	923.9
T-11	215	5022.2	5021.3	-0.347	924.0
T-11	210	5024.1	5023.5	-0.232	924.1
T-11	205	5028.3	5030.4	0.780	924.1
T-11	200	5033.5	5041.3	2.996	924.1
T-11	195	5033.8	5041.1	2.846	924.0
T-11	190	5026.5	5026.1	-0.170	924.0
T-11	185	5024.4	5023.1	-0.502	923.9
T-11	180	5023.1	5021.7	-0.529	923.9
T-11	175	5023.2	5023.0	-0.050	923.8
T-11	170	5023.0	5022.9	-0.012	923.8
T-11	165	5022.3	5021.7	-0.236	923.7

Table D-3. Vertical magnetic gradient survey data over subsidence area-continued

Line	Station	Bottom Sensor	Top Sensor	Gradient	Elevation
Number	(ft)	(gamma)	(gamma)	(gamma/ft)	(ft)
T-11	160	5021.9	5021.3	-0.220	923.7
T-11	155	5021.5	5020.9	-0.232	923.7
T-11	150	5021.0	5020.6	-0.174	923.6
T-11	145	5020.3	5019.9	-0.166	923.5
T-11	140	5020.3	5019.9	-0.127	923.5
T-11	135	5020.6	5020.4	-0.073	923.5
T-11	130	5020.9	5020.9	0.004	923.4
T-11	125	5021.1	5021.1	0.000	923.4
T-11	120	5021.2	5021.1	-0.031	923.3
T-11	115	5021.3	5021.2	-0.035	923.3
T-11	110	5021.1	5020.7	-0.139	923.2
T-11	105	5020.8	5020.3	-0.174	923.1
T-11	100	5020.7	5020.4	-0.097	923.1
T-11	95	5020.6	5020.4	-0.089	923.1
T-11	90	5020.6	5020.4	-0.089	922.9
T-11	85	5020.5	5020.1	-0.131	922.9
T-11	80	5020.4	5020.1	-0.120	922.9
T-11	75	5020.3	5020.1	-0.093	922.9
T-11	70	5020.4	5020.2	-0.073	922.8
T-11	65	5020.5	5020.4	-0.073	922.8
T-11	60	5020.7	5020.5	-0.077	922.7
T-11	55	5021.0	5020.8	-0.050	922.7
T-11	50	5021.3	5021.2	-0.050	922.6
T-11	45	5021.5	5021.3	-0.046	922.6
T-11	40	5021.5	5021.2	-0.100	922.6
T-11	35	5021.6	5021.3	-0.112	922.5
T-11	30	5021.8	5021.4	-0.139	922.6
T-11	25	5021.9	5021.5	-0.135	922.6
T-11	20	5022.0	5021.6	-0.143	922.4

Table D-4. Magnetic susceptibility measurements¹

Sample No.	Sample Source	Measurements (10x10 ⁻⁴ metric derived ratio)										
		1	2	3	4	5	6	7	8	9	10	Average
KMRM-1	Country rock	.01	.01	.02	.04	.03	.02	.18	.21	.01	.04	.06
KMRM-2	Vein rock	.01	.03	.01	0	0	.01	.04	.07	.01	.09	.03
KMBR-A	Country rock	.22	.21	.25	.26	.19	.21	.28	.29	.01	.19	.2
KMBR-B	Country rock	.12	.10	.14	.14	.11	.09	.13	.12	.19	.11	.1
KMBR-C	Altered country rock	.05	.06	.05	.06	.15	.13	.18	.19	.10	.10	.1
KMBR-D	Altered silicified country rock	.06	.07	.03	.02	.07	.05	.08	.09	.08	.10	.07
KMBR-E	Vein rock	.01	0	.01	.02	0	.03	.01	.02	.03	.03	.02

¹Magnetic susceptibility measurements made using a Scintrex SM-5 digital magnetic susceptibility meter (Product names or references are for information purposes only and do not constitute an endorsement by the U.S. Bureau of Mines).

Table D-5. EM-31 electromagnetic survey data

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Horizontal H=1	Vertical H=1	
	Horizontal H=1 perpendicular	Vertical H=1 perpendicular	
Transect EM-100			
100	15.1	20.4	
110	14.8	22.9	
120	17.2	23.6	
130	18.1	25.3	
140	19.8	26.2	
150	21.1	26.2	
160	23.0	28.6	
170	23.3	32.2	
180	23.8	31.8	
190	22.8	33.5	
200	23.5	32.3	
210	23.8	33.0	
220	23.7	34.2	
230	21.5	28.4	
240	20.9	29.2	
250	20.0	29.8	
260	19.9	28.4	
270	19.1	26.5	
280	19.9	29.8	
290	18.2	27.1	

Table D-5. EM-31 electromagnetic survey data-continued

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Horizontal H=1	Vertical H=1	
	Horizontal H=1 perpendicular	Vertical H=1 perpendicular	
Transect EM-100			
300	17.8	27.9	
310	17.6	27.4	
320	16.3	26.5	
330	16.3	24.9	
340	15.9	25.1	
350	16.1	24.7	
360	15.4	25.9	
370	16.0	25.1	
380	16.9	23.4	
390	16.8	25.6	
400	17.1	22.4	
410	16.9	22.9	
420	17.2	23.8	
430	16.4	22.3	
440	16.3	21.3	
450	16.6	22.0	
460	17.6	23.1	
470	15.8	19.3	
480	14.0	18.2	

Table D-5. EM-31 electromagnetic survey data-continued

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Horizontal H=1	Vertical H=1	
	Horizontal H=1 perpendicular	Vertical H=1 perpendicular	
Transect EM-100			
490	13.5	17.3	
500	12.3	13.4	
510	10.1	13.4	
520	9.9	12.8	

Table D-6. EM-16 VLF electromagnetic survey data

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Inclination	Quadrature	
T-2 Mill Area - EM-16			
400	26.0	15.0	
390	15.0	12.0	
380	-16.0	6.0	
360	-7.0	20.0	nearing pwrline
340	18.0	12.0	
320	6.0	-28.0	under pwrline
300	13.0	20.0	under pwrline
280	-35.0	-27.0	
260	-23.0	-16.0	fences
240	-22.0	-12.0	fences
220	-23.0	-11.0	
200	-12.0	-7.0	
180	-9.0	-6.0	
160	-5.0	-2.0	
140	-5.0	-2.0	
120	-3.0	-2.0	
100	-2.0	-2.0	
80	-2.0	-1.0	
60	-2.0	-1.0	
40	-1.0	0.0	
20	0.0	3.0	
0	0.0	1.0	

Table D-6. EM-16 VLF electromagnetic survey data-continued

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Inclination	Quadrature	
T-5 Mill/Subsidence Area - EM-16			
0	0.0	1.0	
20	-1.0	2.0	
40	2.0	3.0	
60	-4.0	1.0	
80	-4.0	0.0	
100	-5.0	0.0	
120	-5.0	-1.0	
140	-5.0	0.0	
160	-5.0	0.0	
180	-8.0	0.0	
200	-12.0	-1.0	
220	-11.0	-1.0	
240	-15.0	-2.0	
260	-19.0	-4.0	
280	-20.0	-1.0	
300	-24.0	-1.0	
320	-24.0	-4.0	
340	-34.0	-7.0	
350	-32.0	-2.0	
360	-2.0	11.0	
370	10.0	-4.0	
380	15.0	-26.0	
390	25.0	0.0	

Table D-6. EM-16 VLF electromagnetic survey data-continued

STATION NO.	APPARENT CONDUCTIVITY (mmhos/m)		COMMENTS
(feet)	Inclination	Quadrature	
T-11 Mill Area - EM-16			
400	0.0	0.0	
380	0.0	-2.0	
360	3.0	-2.0	
340	5.0	0.0	
320	4.0	0.0	
300	5.0	0.0	
280	5.0	0.0	
260	2.0	2.0	
240	1.0	-1.0	
220	0.0	0.0	
200	1.0	1.0	
180	2.0	-2.0	
160	2.0	-2.0	
140	2.0	-2.0	
120	1.0	-2.0	
100	0.0	-2.0	
80	0.0	-2.0	
60	0.0	-2.0	
40	0.0	-2.0	
20	0.0	-4.0	

APPENDIX E.--ENVIRONMENTAL CHARACTERISTICS OF HEAVY METALS AND OTHER CONTAMINANTS

The mill tailings, mill, adjacent soils and adjacent washes contain arsenic, copper, lead, zinc, mercury, and cyanide, all of which, depending on the concentrations, form, and availability can pose a health hazard. This section provides a review of the possible environmental hazards and health risks associated with heavy metals and chemicals such as those present in the Katherine mill and tailings. The discussion will focus on the general toxic characteristics of the elements and processing chemicals.

ANTIMONY

The geochemical characteristics of antimony are closely related to those of arsenic and in part to those of bismuth. The behavior of antimony during weathering is not yet well known; however, the common occurrence of antimony in water, its concentration in coal, and its association with iron hydroxides indicate that it has a relatively high mobility in the environment. The normal concentration of antimony in surface soils ranges from 0.05 to 4 ppm, with an average of 1 ppm. Soil toxicity levels are as low as 5 to 10 ppm (Alloway, 1990). As with arsenic, antimony may be associated with nonferrous ore deposits and is likely to be a pollutant in industrial environments. Antimony can be easily taken up by plants if present in soluble forms. However, there are no reports of plant toxicity caused by antimony (Kabata-Pendias, 1992, p. 209-210).

ARSENIC

The average crustal abundance of arsenic is 2-5 ppm. In the United States, normal concentrations of arsenic in soils ranges from <0.1 to 93 ppm. The lowest levels are found in sandy soils, in particular those derived from granite, whereas the higher arsenic concentrations are related most often to alluvial soils and soils rich in organic matter. Because of common arsenic pollution, the levels of this element are likely to be higher in topsoils (Kabata-Pendias, 1992, p. 204). Toxic effects in soil occur at ranges at or above 20 to 50 ppm (Alloway, 1990).

The combustion of fossil fuels, particularly coal, introduces large quantities of arsenic into the environment. Arsenic occurs with phosphate minerals and enters into the environment along with phosphate compounds. Arsenic, which is produced as a by-product of copper, gold, and lead refining, greatly exceeds the commercial demand for arsenic. Thus, mine tailings often contain unrecovered arsenic representing a major waste material source (Manahan, 1990, p. 153).

Although arsenic is not a metal, it has many of the same properties of heavy metals, and its toxic effects resemble that of mercury and lead. Of the arsenic compounds, those of arsenic (III), or arsenite, are the most toxic. Acute arsenic poisoning can result from the ingestion of more than about 100 mg of the element. Chronic poisoning occurs

with the ingestion of small amounts of arsenic over a long period of time, and evidence indicates that arsenic may be carcinogenic (Manahan, 1990, p. 153 and 507).

Because of its chemical similarity to phosphorous, arsenic interferes with some biochemical reactions involving phosphorous. One such reaction occurs in the biochemical generation of the crucial energy-yielding substance adenosine triphosphate (ATP). If arsenic is present during this generation, no ATP is formed. Arsenic will also cause coagulation of proteins and will form complexes with coenzymes (Manahan, 1990, p. 507).

Toxicity has commonly been noted in plants growing on mine waste, on soils treated with arsenical pesticides, and on soils with arsenic added by sewage sludge treatment. According to Kabata-Pendias (1992, p. 209), plants may accumulate more than 6,000 ppm arsenic, depending on their location and the source of the pollution. The symptoms of arsenic toxicity are variously described as leaf wilting, violet coloration, root discoloration, and cell plasmolysis (shrinkage of the cytoplasm away from the cell wall due to loss of water) (Kabata-Pendias, 1992, p 207-208).

CADMIUM

The abundance of cadmium in igneous and sedimentary rocks does not exceed about 0.3 ppm, and this metal is likely to be concentrated in argillaceous and shale deposits. The main factor determining the cadmium content of soil is the chemical composition of the parent rock. The average content of cadmium in soils lies

between 0.06 and 1.1 ppm (Kabata-Pendias, 1990, p. 131-133). The estimated toxicity threshold in soils is 3 to 8 ppm (Alloway, 1990).

Cadmium pollution in water may result from industrial discharges and mining waste. It is widely used in metal plating and, chemically, is very similar to zinc. Cadmium and zinc frequently undergo geochemical processes together.

The effects of acute cadmium poisoning in humans are very serious and include high blood pressure, kidney damage, destruction of testicular tissue, and destruction of red blood cells. Much of the physiological action of cadmium probably arises from its chemical similarity to zinc. Specifically cadmium may replace zinc in some enzymes, thereby altering the stereostructure of the enzyme and impairing its catalytic activity. Disease symptoms ultimately result (Manahan, 1990, p. 153).

COPPER

Copper forms several minerals of which the common primary minerals are simple and complex sulfides. These minerals are quite easily soluble in weathering processes and release copper ions, especially in acid environments. Copper is therefore considered among the most mobile of the trace elements in the weathering process; however, copper ions can also precipitate readily with various anions such as sulfide, carbonate and hydroxide. Therefore, copper is a rather immobile element in soils and shows relatively little variation in total content in soil profiles (Kabata-Pendias, 1992, p. 95).

The mean level for copper in soils varies from 13 to 24 ppm. Copper tends to accumulate in the top horizons in the soil profile; this can lead to extremely high copper accumulation in top soils. Copper is possibly toxic in soils at levels exceeding 60 to 125 ppm (Alloway, 1990). Contamination of soil by copper compounds results from use of copper-containing material such as fertilizers, sprays, and agricultural or municipal wastes as well as from industrial emissions. Major sources of pollution (mainly non-ferrous metal smelters) can form halos in which copper concentrations in surface soils decrease with distance in a downwind direction (Kabata-Pendias, 1992, p.95-101).

Copper is an essential trace element that is not very toxic to animals, but is toxic to plants and algae at moderate levels (Manahan, 1990, p. 150).

LEAD

The primary form of lead in its natural state is galena (PbS). Lead occurs mainly as Pb^{2+} , and it forms several other minerals that are quite insoluble in natural waters. During weathering lead sulfides slowly oxidize and can form carbonates and be incorporated in clay minerals, in iron and manganese oxides, and in organic matter. Lead has the ability to replace potassium, barium, strontium, and even calcium, both in minerals and in sorption sites (Kabata-Pendias, 1992, p. 187).

Lead concentrations in the top horizons of different soils from different countries range from 3 to 189 ppm, while the mean values for soil types range from

10 to 67 ppm and average 32 ppm. The natural lead content of soils is strongly related to the composition of the bedrock, and lead is reported to be the least mobile among the heavy metals (Kabata-Pendias, 1992, p. 188). Lead in soil is considered toxic in excess of 100 to 400 ppm (Alloway, 1990).

One of the major biochemical effects of lead is its interference with heme synthesis, which is manifested as hematological damage. Ingestion of lead can also be harmful to the central nervous system, gastrointestinal tract, and kidneys. Lead damages the central nervous system through largely unknown biochemical effects upon nerves and cells in the brain. This can result in symptoms ranging from fatigue and headache through convulsions, cerebral palsy, blindness, and mental retardation. Kidney function is impaired by lead-induced inhibition of the metabolic processes by which the kidney absorbs glucose, phosphates, and amino acids prior to urinary secretion. Mild lead poisoning causes anemia, and the victim may have headaches, sore muscles, and feel generally fatigued and irritable (Manahan, 1990, p. 155 and 508).

Because of the chemical similarities between Pb^{2+} and Ca^{2+} , bones serve as a repository for lead accumulated by the body. Later this lead may be remobilized along with phosphates from the bone. When transported to the soft tissues, the lead released from bone has a toxic effect (Manahan, 1990, p. 508).

Some detrimental effects of lead, such as inhibition of heme synthesis, can be reversed once the lead is removed, as long as the exposure has not been too

prolonged (Manahan, 1990, p. 508).

MERCURY

Background levels of mercury in soils are not easy to estimate because of widespread mercury pollution. Data collected from various soils on a worldwide basis indicate that mean concentrations of mercury in surface soils do not exceed 400 ppb. The normal background concentration of mercury in soil can be approximately estimated within a range of 50 to 300 ppb. Thus, mercury contents exceeding these values should be considered as contamination from anthropogenic or other sources (Kabata-Pendias, 1992, p. 145).

Mercury generates the most concern of any of the heavy-metal pollutants. It enters the environment from a large number of miscellaneous sources related to human activity. These include discarded laboratory chemicals, batteries, broken thermometers, lawn fungicides, amalgam tooth fillings, and pharmaceutical products. Sewage effluent may contain up to ten times the level of mercury found in typical natural waters (Manahan, 1990, p. 155).

Plants differ in their ability to take up mercury and can also develop a tolerance to high mercury concentrations in their tissues when grown in soils overlying mercury deposits. Generally, mercury content of plants is high when the mercury content of soils is also high. Plants grown in contaminated sites may accumulate much higher than normal amounts of mercury. Certain plant species, lichens, carrots, lettuce, and mushrooms in particular, are likely to take

up more mercury than other plants grown at the same sites. For example, the maximum mercury content of edible mushrooms may range from 72 to 200 ppm in mercury-contaminated soils. Also, some parts of plants have a greater ability to adsorb mercury, as is the case of apple flesh and apple pits. Mushrooms, as well as rootless mosses and lichens, are known to be suitable bio-indicators for mercury in ecosystems. Pine needles are also most often reported as sensitive mercury environmental biomonitors (Kabata-Pendias, 1992, p. 149-151).

Among the toxicological effects of mercury are neurological damage, including irritability, paralysis, blindness, or insanity; chromosome breakage; and birth defects. The milder symptoms of mercury poisoning, such as depression and irritability have a psychopathological character. Therefore, mild mercury poisoning may escape detection. Some forms of mercury are relatively nontoxic and have been used as medicines, for example, in the treatment of syphilis, for centuries. Other forms of mercury, particularly organic compounds, are highly toxic (Manahan, 1990, p. 156).

ZINC

During weathering processes, zinc minerals are dissolved and produce mobile Zn^{2+} , especially in acid, oxidizing environments. Zinc is also easily adsorbed by mineral and organic compounds and thus, in most soil types, accumulates in the surface horizons. Mean total zinc contents in surface soils of different countries, including the United States, range from 17 to 125 ppm. Grand mean zinc concentration for world-

wide soils is 64 ppm (Kabata-Pendias, 1992, p. 121). Zinc in soils is considered possibly toxic at levels exceeding 70 to 400 ppm (Alloway, 1990).

Zinc is most readily mobile and available in acid, light-mineral soils. Acid leaching is very active in zinc mobilization; thus, losses of this metal are observed in certain horizons. Solubility and availability of zinc is negatively correlated with calcium saturation and phosphorous compounds present in soils. This relationship may reflect both adsorption and precipitation processes, as well as interactions between these elements (Kabata-Pendias, 1992, p. 124-125).

Soluble forms of zinc are readily available to plants, and the uptake of zinc has been reported to be linear with concentration in the nutrient solution and in soils. The rate of zinc absorption differs greatly among both plant species and growth media (Kabata-Pendias, 1992, p. 127).

Zinc plays essential metabolic roles in plants, of which the most significant is its activity as a component of a variety of enzymes. Zinc also plays important roles in plants in the metabolism of carbohydrates, proteins, and phosphate. Zinc may also influence the permeability of membranes and may stabilize cellular components and systems of microorganisms. Zinc is believed to stimulate the resistance of plants to dry and hot weather and also to bacterial and fungal diseases (Kabata-Pendias, 1992, p. 128).

Most plant species and genotypes have great tolerance for excessive amounts of zinc. Chlorosis (a diseased condition in green plants marked by yellowing or blanching), mainly in new leaves, and depressed plant growth are the common symptoms of zinc toxicity. Zinc phytotoxicity (plant poisoning by zinc) is reported relatively often, especially for acid and heavily sludged soils. Physiology and biochemistry of the toxic effects of zinc in plants are likely to be similar to those reported for other heavy metals; however, zinc is not considered to be highly phytotoxic. The toxicity limit for zinc depends on the plant species and genotypes, as well as on the growth stage. Sensitive plant species are reported to be retarded in growth when their tissues contain 150 to 200 ppm zinc. Most commonly, however, the upper toxic levels range in various plants from 100 to 500 ppm (Kabata-Pendias, 1992, p. 128-129).

CYANIDE¹

The chemistry of cyanide in mine waste is complex. Cyanide can exist as a gas adsorbed on solid matrices as (e.g. calcium or sodium cyanide), dissolved in aqueous solutions. Cyanide and cyanide-

¹ This section was taken from Denton, David K., Stephen R. Iverson, and Burton B. Gosling, HEAPREC, A Methodology for Determining Cyanide Heap Leach Reclamation Performance Bonds, U.S. Bureau of Mines Information Circular 9328, 1992, pp. 37 and 38.

related compounds can also exist in cyanide leach solutions as molecular hydrogen cyanide, free cyanide ions, thiocyanate, various metal complexes, and cyanate. Each of these compounds is subject to a variety of mechanisms that control its fate and transport in the environment.

To understand information about cyanide toxicity and chemistry requires a rudimentary understanding of the terminology used to refer to cyanide and cyanide compounds. Table B-1 presents a listing of cyanide definitions often used in discussions about toxicity and regulations. The definitions are based on analytical techniques used to determine cyanide concentrations in solutions.

Free cyanides are the most toxic and unstable forms of cyanide and include simple cyanide compounds. Free cyanides are referred to as "ephemeral toxins" because they are transient and tend to form more stable and less toxic compounds rapidly in ambient conditions. Free cyanides are rapidly detoxified using natural and chemical degradation processes. The analytical technique for determining free cyanide is subject to interference from thiocyanates, sulfates, oxidizing agents, nitrates, urea, and other organic compounds.

As shown in table B-1, weak-acid-dissociable WAD cyanides include all of the free cyanides as well as most simple cyanide complexes that are less toxic and more stable than free cyanides. WAD cyanides as a group can be detoxified using natural and chemical detoxification methods, however, they do not react as readily as the free cyanide components of

the WAD cyanides. Of all cyanide analyses, WAD cyanide analyses are least effected by interferences and more reliable.

Total cyanides include cyanides detected with the WAD cyanide and free cyanide analyses, as well as cyanide compounds that are less toxic and more stable than WAD cyanides. By and large, the additional compounds detected with the total cyanide analysis can be considered stable under ambient conditions and react to a few aggressive chemical and natural detoxification processes. Total cyanide analysis is subject to interference from thiocyanate; some cobalt, gold, and platinum cyanide complexes may not be accurately measured.

It is important to note that universally reliable techniques and procedures for sampling and analyzing solid matrices for cyanide do not exist; however, research is progressing in this area (Mudder, 1989). The need to determine cyanide species in solids, some of which are extremely transient when subjected to changes in temperature, pH, pressure, etc., has resulted in a profusion of sampling and analytical methods that are complex and cumbersome to use on a routine basis.

Certain aspects of cyanide toxicity are well documented; however, the long-term stability of various cyanide complexes formed in the mineral processing wastes have yet to be adequately evaluated. It has been found that cyanide is less stable near the surface of tailings impoundments. Cyanide that is not quickly percolated downward is decomposed at the surface (Hendrix, 1985).

Free cyanide is rapidly absorbed through ingestion and inhalation and passes into the bloodstream. Free cyanide can also be absorbed through the skin. The lethal toxicity of free cyanide is associated with its high affinity to form strong bonds with iron in an enzyme that controls the cellular use of oxygen. Cyanide bonded to the enzyme inactivates the exchange and utilization of oxygen leading to cellular asphyxiation and tissue death.

Lethal levels of free cyanide for human adults are 1 to 3 mg/kg of body weight if ingested, 118 to 355 mg/m³ if inhaled, and 100 mg/kg of body weight if absorbed through the skin (Huiatt, 1985). Concentrations of free cyanide (HCN and CN⁻) above 0.2 mg/L of water are fatal to most fish (U.S. EPA, July 1980). To reach a lethal dose of 100 mg CN_F for a human weighing 110 lbs or 2 mg CN_F/kg of body weight, would require immediate consumption of 125 gal of water containing 0.2 mg/L CN_F.

Cyanide is noncumulative, nonembryotoxic, and noncarcinogenic. Cyanide occurs naturally in microorganisms, animals, and vegetation. Elevated cyanide levels exist in over 1000 species of plants and may represent the greatest source of cyanide exposure to humans and animals (Eisler, 1991). All forms of cyanide degrade naturally in the environment through a variety of processes including oxidation, photodecomposition, biodegradation, hydrolysis, volatilization, and adsorption.

Once free cyanide (HCN⁻ and CN⁻) forms another compound, its toxicity diminishes dramatically. Table B-1 also

lists the relative stability of metal cyanide compounds in solution, in approximate order of increasing stability.

Toxicity of cyanide solutions is affected by temperature, pH, salinity, amount of dissolved oxygen, ammonia, cyanate, and thiocyanate, and the concentration of dissolved and suspended solids.

Three specific conditions must exist before adverse impacts from cyanide to human health and the environment can occur: (1) a source of toxic or potentially toxic cyanide, (2) a pathway to transport the cyanide to an accessible environment, and (3) a receptor population (humans, fish, wildlife, etc.).

BERYLLIUM

Beryllium is found chiefly as the mineral beryl (Be₃Al₂(SiO₃)₆) typically in granitic pegmatites and high temperature veins (Warner, 1959). Phenakite (Be₂SiO₄) is also found in these geologic environments but is very rare. Beryl is the most common beryllium mineral in beryllium-bearing veins (Warner, 1959). According to Warner (1959), the average beryllium content (BeO) in hydrothermal veins in Mohave County, Arizona is 0.01 pct including one sample taken from the Katherine tailings which contained 0.03 pct BeO. Beryllium is toxic in pure form and as certain beryllium compounds primarily when inhaled. The U.S. Dept. of Health and Human Services (1990) has recommended 0.5 microgram beryllium per m³ as an 8-hr exposure limit.

The average concentration of beryllium in fresh surface waters

throughout the world is less than 1 ppb (Callahan, 1979). In aqueous solution, beryllium does not exist as actual Be^{+2} ions, but as hydrated complexes. Beryllium is among the lightest of elements. It is a member of the alkaline earth elements and is a metal.

Soluble beryllium salts are hydrolyzed to form insoluble beryllium hydroxide. The solubility of beryllium hydroxide is quite low in the pH range of most natural waters. Beryllium will have minimal solubility at about pH 7.5 (Callahan, 1979).

At low pH, beryllium would tend to be adsorbed onto clay mineral surfaces while at high pH, it should be complexed in some insoluble compounds (Callahan, 1979).

Water hardness is inversely related to beryllium toxicity. Beryllium can be concentrated in the stalks of aquatic plants, with lower quantities in the flowers and leaves. Benthos could

accumulate beryllium from sediment and thereby transfer the metal to higher organisms via the food chain (Callahan, 1979).

CALCIUM OXIDE

Calcium oxide or quicklime is a readily available and effective material for pH adjustment in mill solutions. It is made from limestone or marble by converting CaCO_3 to CaO . Quicklime is extremely caustic and is listed in the National Institute for Occupational safety and Health (NIOSH) Pocket Guide to Chemical Hazards, (U.S. Department of Health and Human Services, 1990). The Occupational Safety and Health Administration (OSHA) exposure limit is 5 mg/m^3 as particulates in air. Health hazard routes include inhalation, ingestion, and skin contact. Quicklime will cause irritation to the eyes and upper respiratory track, cause ulcers, will perforate the nasal septum, cause pneumonia, and cause dermatitis.

Table E-1. Cyanide definitions

Term-Analytical technique	Compounds identified
Free cyanide (CN_F)	HCN^- , CN^-
Weak-acid-dissociable cyanide (CN_{WAD})	CN_F compounds plus: (a) relatively soluble compounds Na^+ , K^+ , Ca^{+2} , Mg^{+2} (b) relatively insoluble compounds Zn , Cd , Ag , Cu , Ni
Total cyanide (CN_T)	CN_F , CN_{WAD} compounds plus: (a) very insoluble and stable compounds Fe , Co , Au , Pt , Hg

Source: (Olson, 1983)

Table E-2. Effect of other parameters on cyanide solution toxicity

Parameter	Range	Effect of toxicity
Dissolved oxygen	Less than 100% saturation	Increases toxicity.
Temperature	From 6° C and 18° C	Three-fold increase with 12° increase in temperature.
Salinity	9 to 17 parts per thousand	Toxicity increase with increase in salinity.
Ammonia	0.35 to 0.70 mg/l NH ₃	More than doubles toxicity.
pH	Greater than 8.5	Slight decrease in toxicity at higher pH due to minimized formation of HCN.

Source: (Ingles, 1987)