OPEN-FILE REPORT 01-12

History, Geology, and Environmental Setting of the Lienhart Mine, Pike/San Isabel National Forest, Chaffee County, Colorado

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FOREWORD

Open-File Report 01-12 describes the history, geology, and environmental setting of the Lienhart Mine near the boundary of the Collegiate Peaks Wilderness northwest of Buena Vista. The Lienhart Mine lies entirely on U.S. Forest Service-administered land above the headwaters of Morris Creek, a tributary to the upper Arkansas River. The U.S. Forest Service selected this site for detailed investigation because of the results of an abandoned mine inventory recently completed by the Colorado Geological Survey. State and Federal agencies and private owners can use this study for developing realistic and cost-effective reclamation plans for the Lienhart Mine.

Funding for this project was provided mostly by the U.S. Forest Service (Agreement No. 1102-0007-98-035). Partial funding came through the Water Quality Data program of the Colorado Geological Survey from the Colorado Department of Natural Resources Severance Tax Operational Fund. Severance taxes are derived from the production of gas, oil, coal, and minerals.

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ABBREVIATIONS AND SYMBOLS

ATV	all-terrain vehicle
bk..	book
cm	centimeter
CGS	Colorado Geological Survey
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cps	counts per second
CR	County Road
°	degree
EE/CA	Engineering Evaluation/Cost Analysis
EDR	Environmental Degradation Rating
EPA	United States Environmental Protection Agency
=	equals
FR	Forest Road
4WD	four-wheel drive
gpm	gallons per minute
<	less than
µg/L	micrograms per liter
µ	microns
µS	microSiemens
mg/L	milligrams per liter
>	more than
NPL	National Priorities List
n/a	not applicable
no.	number
oz(s)	ounce(s)
p.	page(s)
ppm	parts per million
%	percent
PHR	Physical Hazard Rating
pCi	picoCuries
lb(s)	pound(s)
PBS	Primary Base Series
SH	State Highway
x	times (when factoring ion concentrations or radioactivity)
trec	total recoverable
U.S.	United States
USFS	United States Department of Agriculture - Forest Service
BLM	United States Department of Interior - Bureau of Land Management
v.	volume

INTRODUCTION

During an abandoned mine inventory in 1996, the Colorado Geological Survey (CGS) assigned Environmental Degradation Ratings (EDRs) of 2 (significant environmental degradation) to the Lienhart Mine and its associated waste-rock and tailings piles. This work was done as part of a statewide inventory of abandoned mines either on U.S. Forest Service-administered lands or causing potential environmental impacts to them. In 1999 the U.S. Forest Service requested more information regarding the Lienhart Mine.

Mine features described in this report are within the "Lienhart Mine" inventory area (USFS-AMLIP form 12-01-391/4310-1) and include adit #102, associated waste-rock pile #202, and tailings pile #203. Other mine features within this inventory area were not considered environmental problems and were not included in this study (Appendix).

Older literature referred to the Lienhart Mine by other names. Only more recent references such as Brock and Barker (1972), Baskin (1987, p. 15), and the 1982 U.S. Geological Survey Mount Harvard 7.5-minute topographic map label this site as the Lienhart Mine. Early names for the Lienhart Mine include the Mount Harvard Mine, Mount Harvard Tunnel, Harvard Tunnel, and Doris Ruby Lode. Different references cited exactly the same production figures for 1935 and 1937 for the Mount Harvard Mine/group and Lienhart Mine. The name Lienhart was probably derived from Leonhardy, the last name of a family that owned and/or operated the mine prior to 1925 and probably later. Although unlikely, some mine activities associated with the nearby Tamarack Mine could be confused with the Lienhart Mine. The Tamarack mine is on private land (Humbolt and Tamarack Lode claims, Mineral Survey No. 17190) about 1½ miles northeast of the Lienhart Mine.

SITE LOCATION

The Lienhart Mine is on the eastern slope of Mount Harvard above Morris Creek at an elevation of about 11,000 feet. The mine, associated waste-rock pile, tailings, and mine drainage are totally on National Forest System (NFS) land. A legal description places the portal in the northwest quarter of section 8, T. 13 S., R. 79 W. of the Sixth Principal Meridian in Chaffee County, Colorado. Access is via Forest Road 387, a 4WD road that branches off U.S. Highway 24 about 9 miles north of Buena Vista (Figure 1). The Colorado Trail is about 1,000 feet west and 400 vertical feet above the Lienhart Mine.

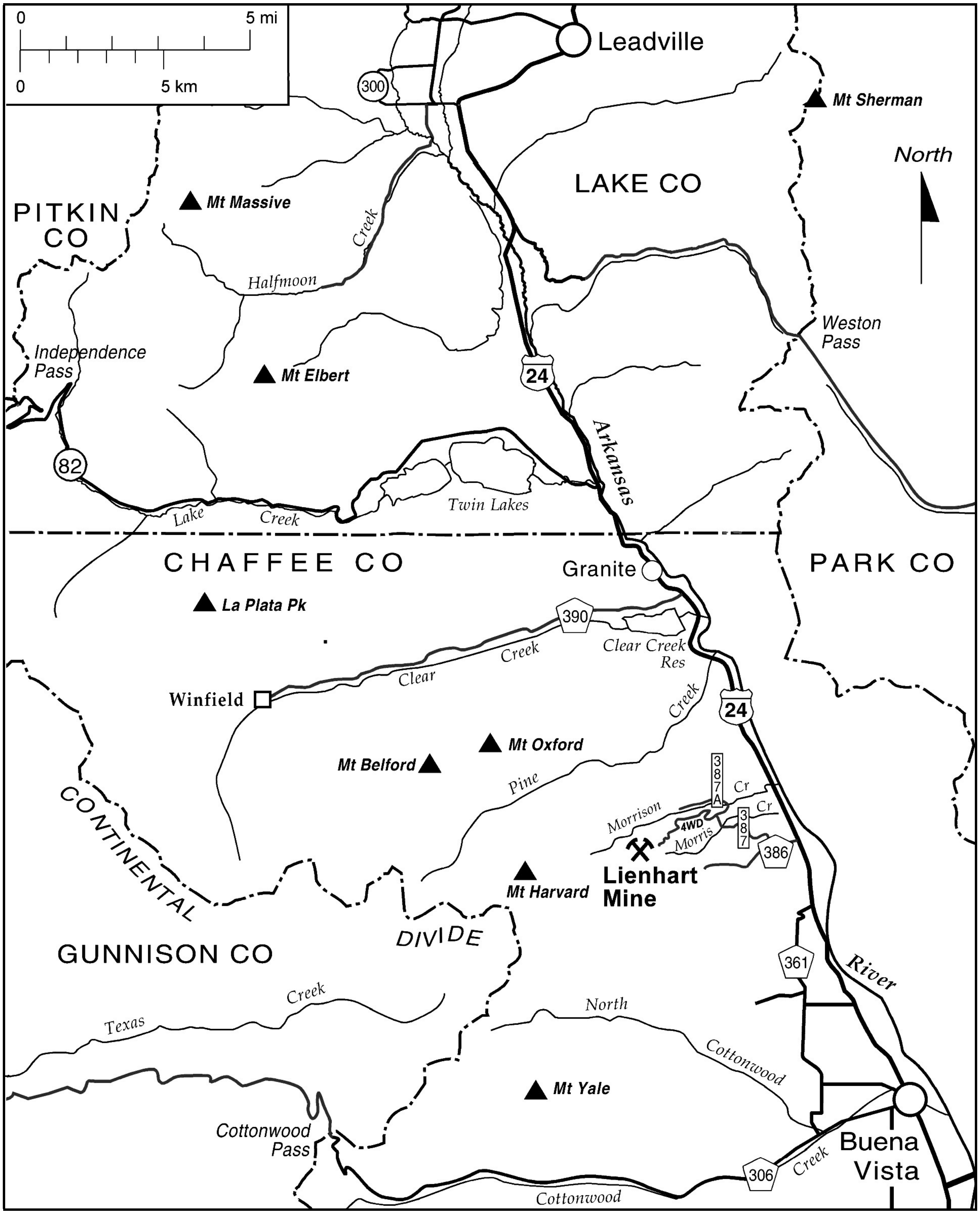


Figure 1. Index map of the Lienhart Mine (scale is approximate).

MINING HISTORY

Although discovered prior to 1900 and operated intermittently for more than 30 years, the Lienhart Mine was never a major producer. Summaries of the history and production of the Lienhart Mine are tabulated below. Limited details are revealed in the following text.

According to Baskin (1987, p. 15), "work began on the property in 1867; the mine was active intermittently until 1906". No reference was cited and no other literature was found suggesting that the mine was active before the 1890's. The 1867 date may be an error.

Table 1. Historical summary of the Lienhart Mine.

Year	Activity
1891	Mt. Harvard Lode claim located.
1896	Mt. Harvard Tunnel Site claim located.
First recorded production in 1906.	
1906–1918	Ore shipped from the Harvard Tunnel every year except 1916.
1919	Development work done on the Mount Harvard Mine.
1922	Ore shipped from the Mount Harvard Mine, opened by a 1,250-foot long tunnel.
1925	Ore shipped from the Mount Harvard group.
1934	Doris Ruby lode claim located.
1935–1938	Ore shipped from the Mount Harvard group. Doris Ruby mill erected in 1937.
No known production after 1938.	
1939	Leonhardy lode claims located.
1979	Sara lode claims located.
1983	1,600 feet of adit opened and drained, dump tested, 6 miles of access road upgraded.
1984?	Remediation cells installed below dump.
1993	Sara lode claims voided.
1997	Elsa lode claims located.
1998	Reclamation work completed and remediation cells removed.
1999	Elsa lode claims voided.

Various members of the Leonhardy family were probably the principal owner/operators at least until 1925. Doris Ruby Mining Company and Williams Mining Company operated the mine in the 1930s. Jackson Mines Company controlled the property and did intermittent exploration and reclamation work from 1979 to 1998.

Table 2. Production summary for the Lienhart Mine. (X indicates that the commodity was produced, but the quantity is not known).

Year	Production	Gold	Silver	Copper	Lead	Zinc
1906	Unknown quantity					
1908	Unknown quantity					
1909	Unknown quantity					
1910	Unknown quantity				X	
1911	Unknown quantity	X	X	X	X	
1912	Unknown quantity	X	X	X	X	
1913	Unknown quantity	X	X	X	X	
1914	2 small shipments	X	X	X	X	
1915	1 small shipment				X	X
1917	1 shipment		X		X	
1918	2 small shipments	X	X	X	X	
1921	1 shipment	X	X		X	
1925	Unknown quantity	X	X		X	
1935	87 tons	44.1 oz	780 oz	2,246 lbs	10,628 lbs	9,599 lbs
1936	3 carloads	X	X	X	X	X
1937	1,317 tons	X	X	X	X	
1938	12 tons	18 oz	57 oz		2,000 lbs	

M.C. Heffron located the Mt. Harvard Lode in 1891. According to the location notice, the claim was about 5 miles north of the mouth of North Cottonwood Creek Canyon next to the Exchange Lode (Chaffee County Courthouse, bk. 32, p. 355).

M. Leonhardy located the Mt. Harvard No. 7 Lode and the Mt. Harvard Tunnel Site in 1896. The Mt. Harvard Tunnel Site was located to develop the Mt. Harvard No. 1 and No. 2 Lodes (Chaffee County Courthouse, bk. 42, p. 467; bk. 99, p. 78).

Leonhardy & Son drove 400 feet along a vein in the Harvard Tunnel in 1906. An unspecified amount of gold-silver-copper-lead ore was produced. (See Naramore, 1907, p. 210.)

A “considerable” amount of development work was done during 1907, and ore production increased slightly. The Harvard Tunnel was the most active mine in the Riverside mining district. (See Naramore, 1908, p. 247.)

Several cars of ore were shipped from the Harvard Tunnel/Mount Harvard Mine in 1908 and 1909 (Henderson, 1909, p. 373; Henderson, 1911a, p. 305).

Lead ore was shipped from the Mount Harvard Mine in 1910 (Henderson, 1911b, p. 403).

From 1911 through 1913, gold-silver-copper-lead ore was shipped from the Mount Harvard Mine (Henderson, 1912, p. 535; Henderson, 1913, p. 670; Henderson, 1914, p. 247).

Two small shipments of gold-silver-copper-lead ore were made from the Riverside district in 1914 (Henderson, 1916, p. 275). The ore probably came from the Mount Harvard Mine.

In 1915 the Harvard Mine made one shipment of lead-zinc ore, and in 1917 the mine made one shipment of lead-silver ore (Henderson, 1917, p. 440; Henderson, 1920, p. 814). The mine probably operated, but did not produce in 1916.

In 1918 two small shipments of gold-silver-copper-lead ore were made from the Mount Harvard Mine, but only development work was reported for 1919. One shipment of lead-silver-gold ore was made in 1921. (See Henderson, 1921, p. 836; Henderson, 1922, p. 765; Henderson 1925, p. 492.)

During 1922 the Mount Harvard Tunnel Company (Mark Leonhardy-President; Jack Chaney-Treasurer) operated the Mount Harvard Tunnel. The mine was located at timberline on the east slope of Mount Harvard, 5 miles west of the Riverside switch on the Denver and Rio Grande Western Railroad. A steep wagon road accessed the 1,250-foot-long adit. Ore consisted of copper, lead, and zinc sulfides and was jigged by hand prior to shipping. In October a carload of ore awaited shipment to Leadville. (See R.J. Murray, Mine Inspector report-Mt. Harvard Tunnel, October 21, 1922, Colorado Bureau of Mines.)

No production is recorded for 1923 and 1924, but in 1925 an unspecified amount of gold-silver-lead ore was shipped to Leadville (Henderson, 1928, p. 713). No activity was reported between 1926 and 1933.

Doris Ruby Mining Company (Henry Krueger-president) located the Doris Ruby Lode in March 1934 (Chaffee County Courthouse, bk. 199, p. 375). Apparently this claim was located on or close to the Lienhart Mine.

Doris Ruby Mining Company amended the location of the Doris Ruby Lode in January 1935 (Chaffee County Courthouse, bk. 165, p. 145). The Mount Harvard group shipped 87 tons of ore, yielding 44.1 oz of gold, 780 oz of silver, 10,628 lbs of lead, 9,599 lbs of zinc, and 2,246 lbs of copper to Leadville in 1935 (Henderson, 1936, p. 253). The U.S. Bureau of Mines cited the same production figures for the Lienhart Mine (Baskin, 1987, p. 15).

Williams Mining Company operated the Mount Harvard group under a lease between 1935 and July 1936. During 1936 the company shipped three carloads of gold-silver-lead-zinc-copper ore before closing the mine in July. (See Henderson and Martin, 1937, p. 319.)

Doris Ruby Mining Company operated the Mount Harvard Mine under a lease between April and October 1937. A total of 1,317 tons of gold-silver-lead-copper ore from the mine was treated at a new 65-ton flotation mill on the Doris Ruby claim. (See Henderson and Martin, 1938, p. 263.) Baskin (1987, p. 15.) reported that the flotation mill was at the Lienhart Mine and cited the same production figures for the Lienhart Mine. Ruins of a mill inventoried by CGS near the base of the dump were probably the remains of the Doris Ruby mill (Figures 2, 3; Appendix).

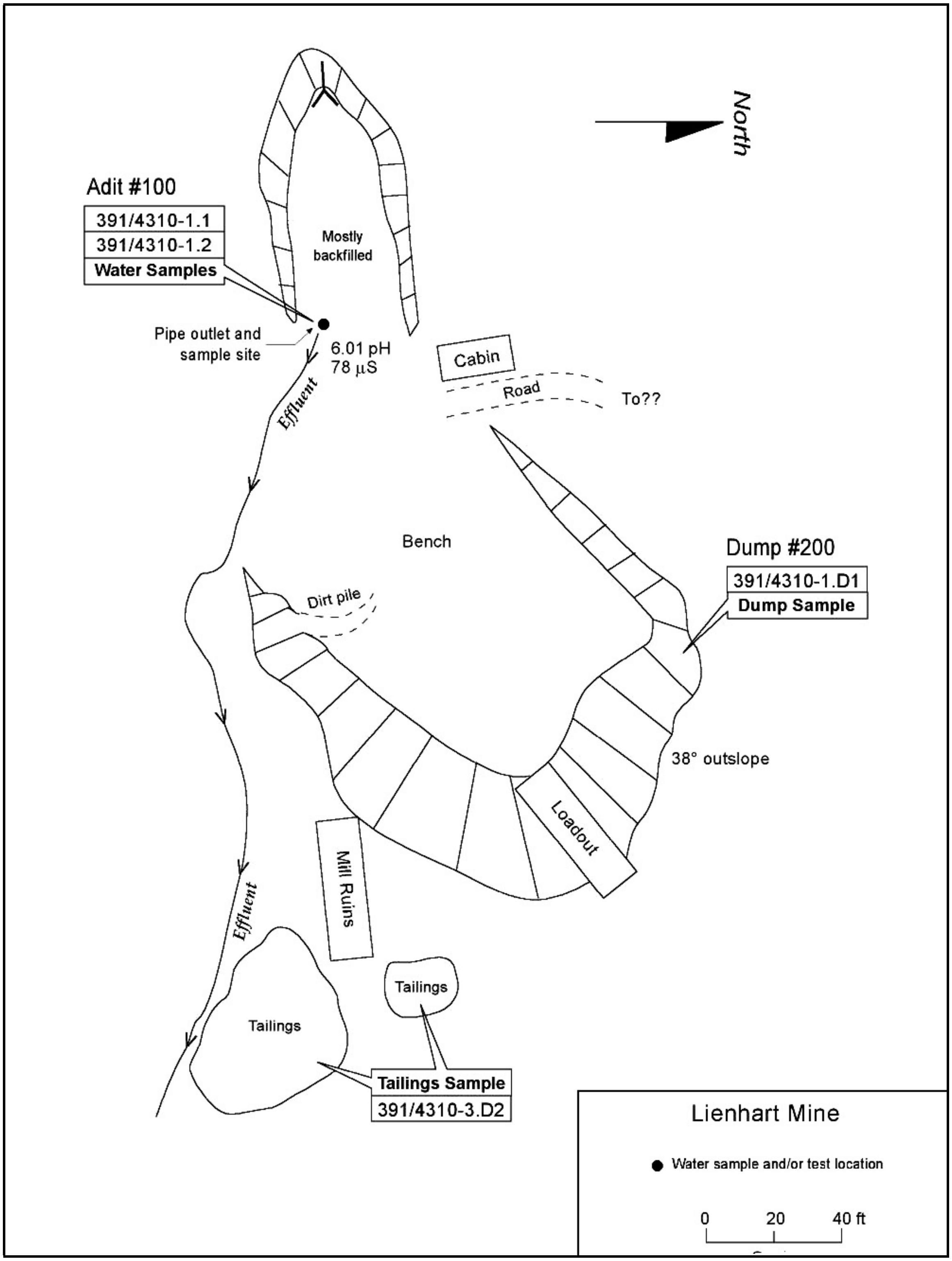


Figure 2. Map showing adit, dump, tailings, and effluent path at the Lienhart Mine.

Figure 3. Mill ruins and tailings at the Lienhart Mine.

In 1938 Doris Ruby Mining Company shipped 12 tons of ore containing 18 oz of gold, 57 oz of silver, and 2,000 lbs of lead (Henderson and Martin, 1939, p. 284, 289).

J. Ralph Leonhardy and Frank McFadden located the Leonhardy and Leonhardy No. 1 lode claims in October 1939 (Chaffee County Courthouse, bk. 236, p. 88, 95). Leonhardy, McFadden, and N. Theodoran located the Leonhardy No. 2 through No. 6 lode claims in October and November (Chaffee County Courthouse bk. 183, p. 74-76; bk. 236, p. 101). This claim block covered the Lienhart Mine, and the mine name probably changed to Lienhart after the Leonhardy claims were located. The new name was probably derived from Leonhardy.

No activity was reported between 1940 and 1978. In May 1979 Jackson Mines Company located the Sara #17-21 lode claims, which covered the Lienhart Mine. Jackson Mines Company (Rowland Jackson-Chairman/CEO) held the Sara #17-21 lode claims from 1979 to 1993. (See BLM files.)

By 1983 Jackson Mines Company had opened, mapped, and sampled 1,600 feet of workings in the mine (Figure 4) and dug two large trenches in the mine dump (Figure 5). Material from the trenches was analyzed to determine the possible grade of material left in the main adit, which was flooded. Samples of dump material contained 0.01 to 0.08 oz/ton of gold and 1.1 to 2.5 oz/ton of silver. (See Baskin, 1987, figure 23, p. 34-35.) The company also built a small settling pond near the portal to treat mine effluent as required by the Colorado Department of Health for a Colorado Wastewater Discharge permit. This permit was terminated in 1988. (See Colorado Division of Minerals and Geology files.)

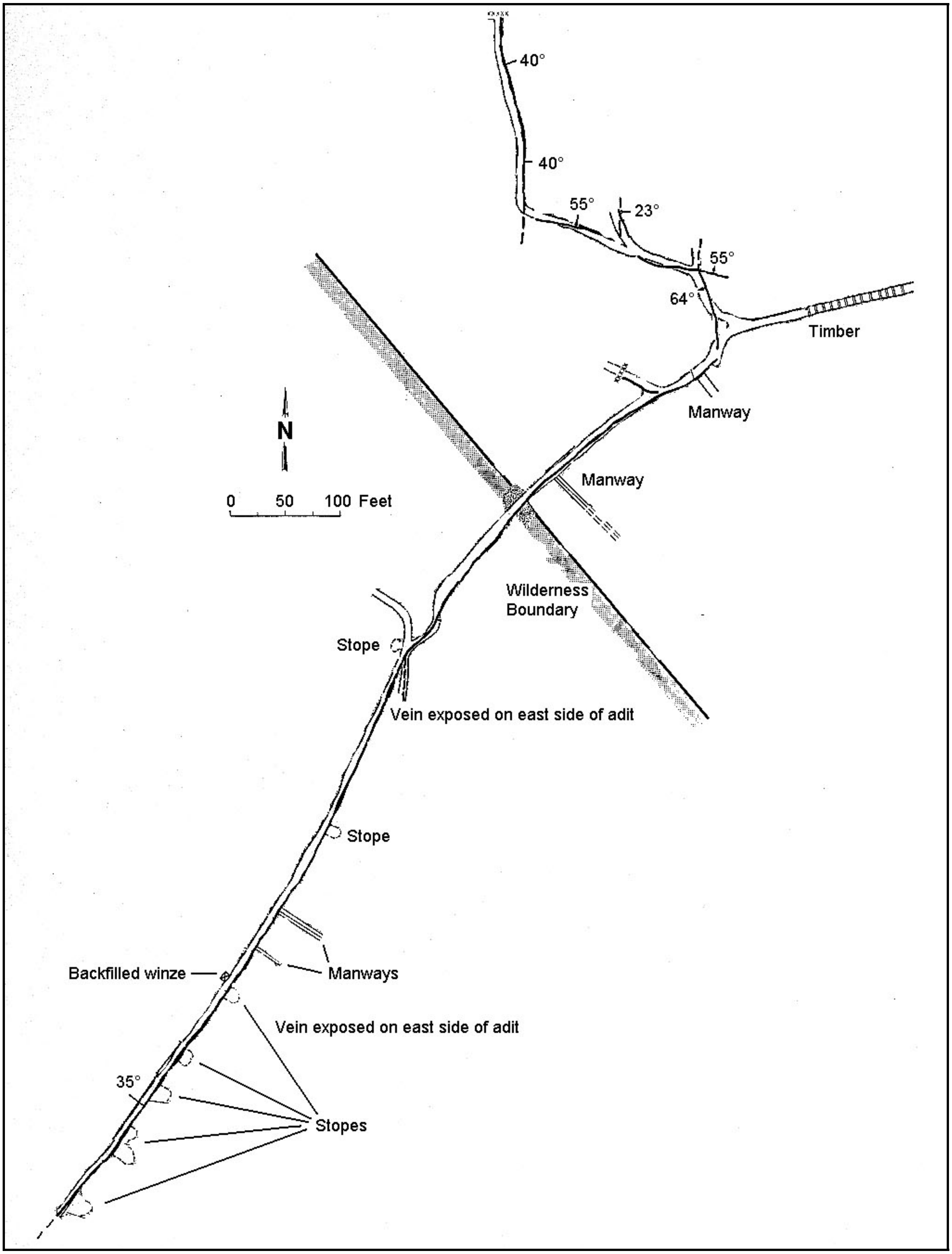
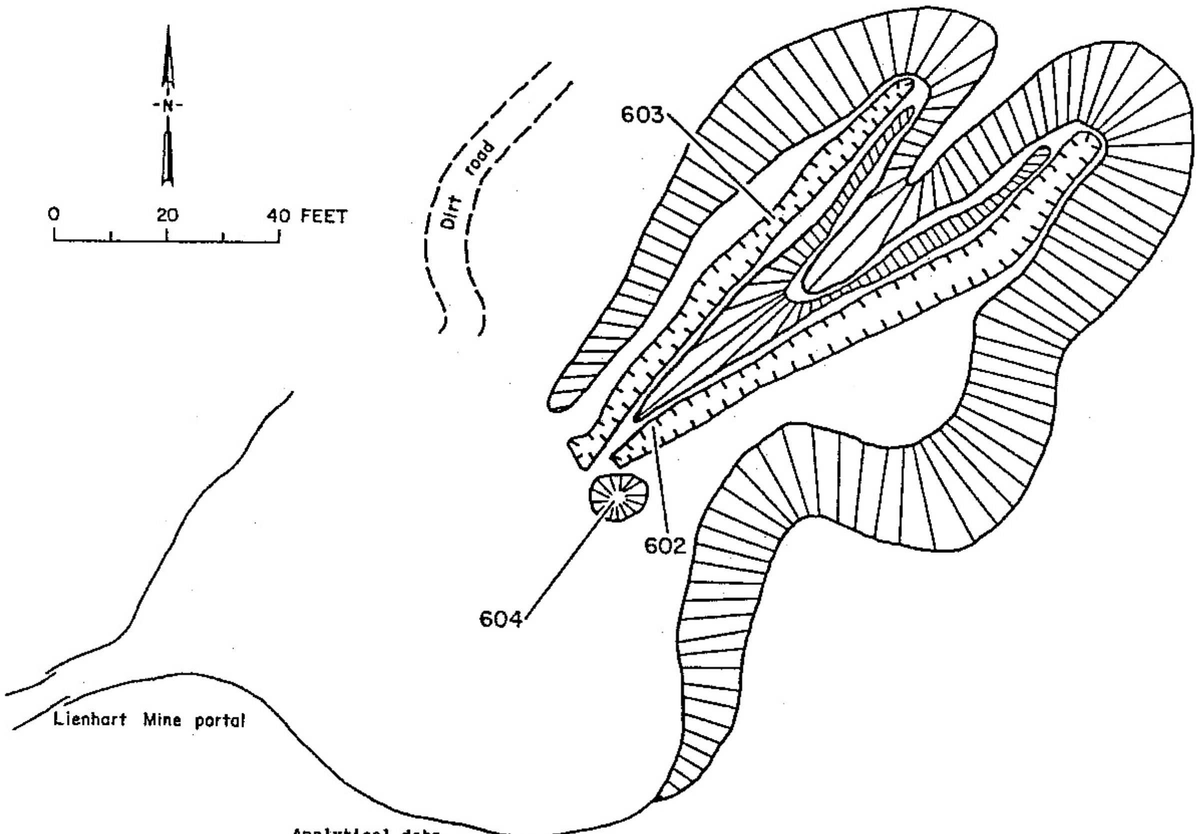


Figure 4. Map of the Lienhart Mine. (Modified from Baskin ,1987, Plate 3.)



Sample		Analytical data		
		Au	Ag	
No.	Type	oz/st		Description
602	grab,	0.01	1.1	Granodiorite, quartz vein fragments, pyrite, limonite. Vertical sample through trench in dump.
603	do.	.08	2.5	Do.
604	select	.01	.2	Quartz, massive and disseminated pyrite.

Figure 5. 1983 map and sample results for the Lienhart Mine dump. (From Baskin, 1987, Figure 23.)

Between 1983 and 1984 Jackson Mines Company built 6 miles of access road and submitted operating plans to the USFS (Baskin, 1987, p. 16). In 1984 the USFS approved the plan of operation for the Lienhart Mine. In September 1984 a State mine inspector recommended the construction of additional water treatment cells below the dump. The new cells were scheduled for completion in November. (See Colorado Division of Minerals and Geology files.) No mining or production is recorded, despite the approved plan.

BLM closed the case on the Sara #17-21 claim block in 1993, then Rowland Jackson located the Elsa #1-4 claims over the Lienhart Mine in 1997 (Figure 6; BLM files).

Jackson Mines Company requested the release of their bond in 1996, but several minor reclamation issues needed to be resolved. The most important issue involved the small treatment ponds below the dump. A decision was made, possibly by the USFS, that removal of the ponds was the preferred option. The ponds were backfilled prior to an inspection in October 1997. (See Colorado Division of Minerals and Geology files.)

In 1998 the Colorado Division of Minerals and Geology inspected reclamation work and released Jackson Mines Company's bond at the Lienhart (Colorado Division of Minerals and Geology files).

BLM closed the case on the Elsa claim block in 1999 (BLM files).

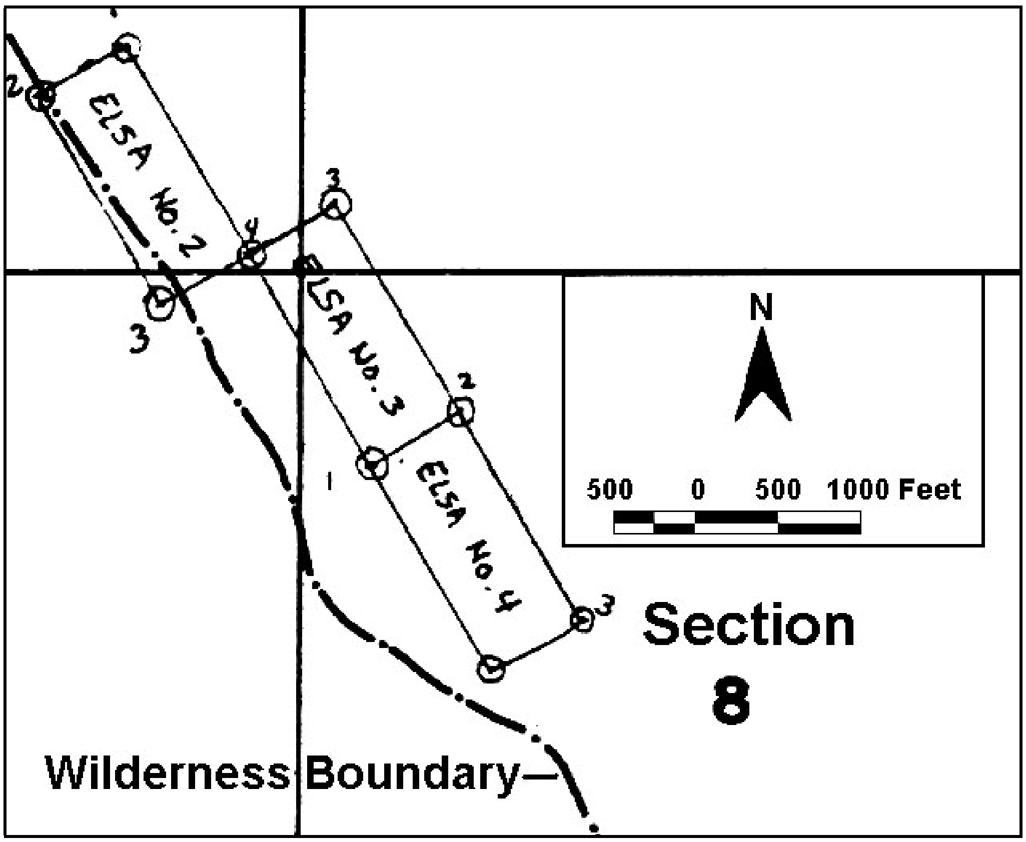
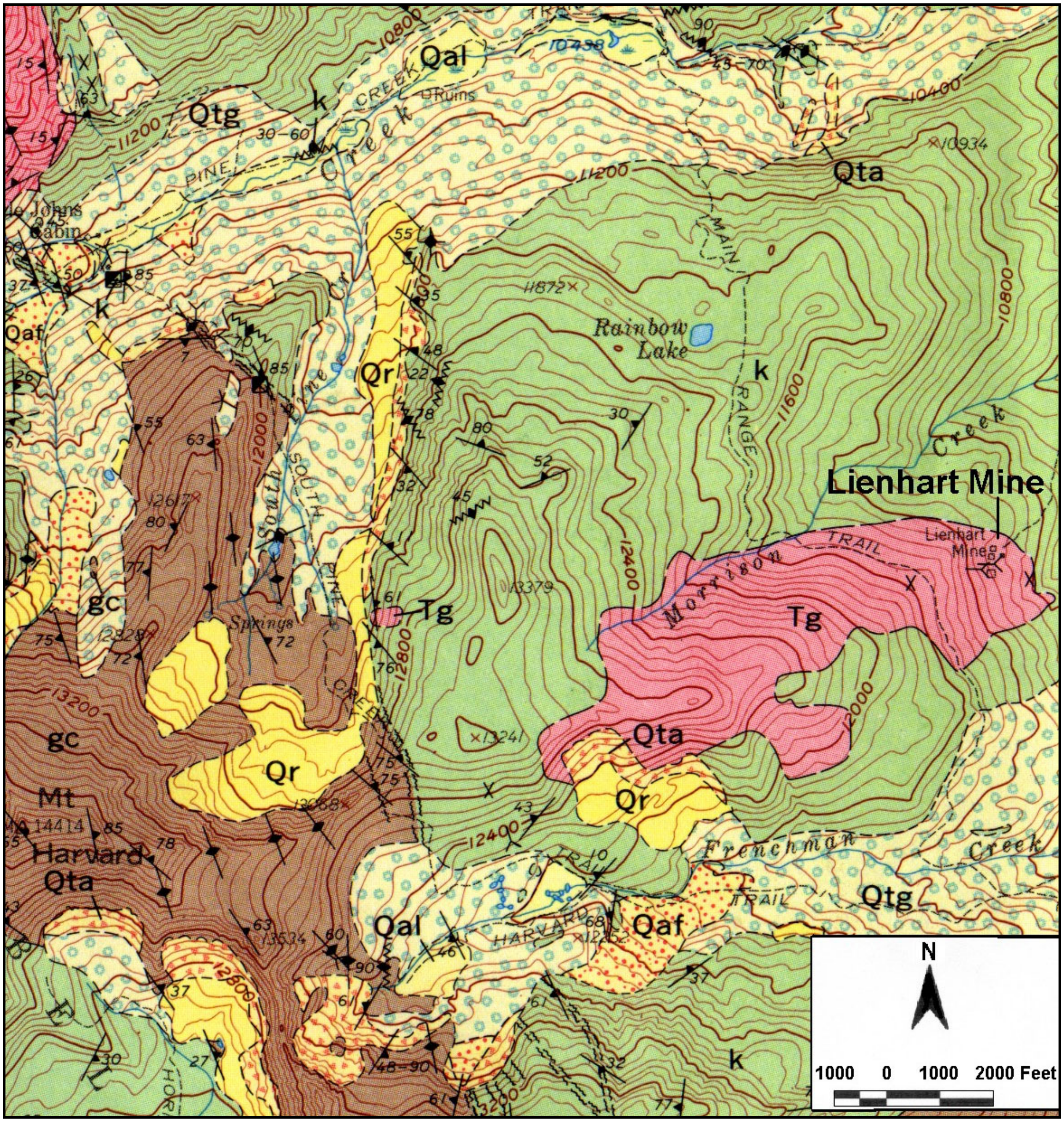


Figure 6. Location map of the Elsa claim block.
(From BLM files; scale is approximate.)

GEOLOGY

Host rock at the Lienhart Mine is Tertiary granodiorite (Figure 7). This rock unit is gray, medium-grained, and contains abundant biotite and hornblende. Precambrian Kroenke Granodiorite surrounds the Tertiary granodiorite. (See Brock and Barker, 1972.)

The most important vein strikes about 30° to 40° northeast and dips 35° northwest (Figure 4). Pyrite, sphalerite, galena, chalcopyrite, bornite, and limonite were identified in the vein, and gold, silver, lead, copper, and zinc were produced from the mine. More than 37,000 tons of ore reserves containing 0.078 oz/ton gold and 2.36 oz/ton silver remain in the last 400 feet of workings underlying the Collegiate Peaks Wilderness. (See Baskin, 1987, plate 3; p. 15, 34-35.)



Qal-Quaternary alluvium
Qaf-Quaternary alluvial fan
Qta-Quaternary talus
Qr-Quaternary rock glacier
Qtg-Quaternary till in ground moraine deposits
Tg-Tertiary granodiorite
k-Precambrian Kroenke granodiorite
gc-Precambrian brecciated gneisses

Figure 7. Geologic map of the Lienhart Mine area.
(From Brock and Barker, 1972; scale is approximate.)

SITE DESCRIPTION

Forest Road 387 ends at the Lienhart Mine, but a locked gate blocks the road about 500 feet from the portal. Reclamation activities occurred on this site after the inventory in 1996 and were apparently completed by 1998 when the bond was released. Restoration measures included backfilling the portal and installing a pipe to allow mine drainage, and removing passive remediation cells that had been placed below the dump and tailings piles to treat mine effluent.

In August 1996 log cribbing kept adit #102 open, and mine water was directed into a pipe inside the mine. The pipe drained into a small and shallow pond/puddle on the bench of dump #202. The effluent flowed from the pond along the south side of dump #202 and mill tailings pile #203, through small passive remediation cells, and eventually disappeared at a sharp break-in-slope about 750 feet downstream of the portal. (See USFS-AMLIP form 12-01-391/4310-1.)

By July 1999 the portal had been backfilled, and a buried plastic pipe transported mine water to a ditch at the top of the dump (Figures 2, 8). The remediation cells below dump #202 had been removed, and mine effluent was flowing past the break-in-slope at a rate of 30 gpm. Both in 1996 and in 1999 surface flow in this gulch originated at the portal of the Lienhart Mine.

Dump #202 contained about 2,000 cubic yards and had two lobes. A small, unmineralized dirt pile on the bench composed less than 5 percent of the dump (Figures 2, 9). Gullies, rills, and sheet wash indicate moderate rates of erosion. A well-preserved log cabin was at the top of dump #202 near the portal, and a wooden loading chute was on the north side of the dump (Figures 9-11).

Mill tailings (feature #203) were concentrated in two piles with a total volume of about 100 cubic yards. Mine effluent was actively eroding the southern tailings pile, which was the largest (Figure 3). Thin coatings of tailings were in the streambed for several hundred feet downstream (Brown and others, 1996, p. 27).

Remains of a collapsed mill (old equipment and foundations) were at the base of the south side of dump #202, just above the tailings piles (Figure 3). This was probably the Doris Ruby Mining Company's mill constructed in 1937.

WASTE AND HAZARD CHARACTERISTICS

In August 1996 about 10 gpm of effluent with 4.20 pH and 145 µS/cm conductivity was flowing through a pipe at the portal of adit #102. This effluent greatly exceeded state water-quality standards in cadmium, copper, lead, and zinc concentrations (sample 391/4310-1.300, Table 3). Aluminum, iron, and manganese concentrations also exceeded standards. At the break-in-slope about 750 feet downstream of the portal and below the passive remediation cells, the flow had diminished to about 2 gpm, and the effluent had 6.20 pH and 95 µS/cm conductivity (sample 391/4310-1.303, Table 3). This water exceeded standards in cadmium, copper, and zinc, but the concentrations of these metals were greatly reduced. (See Brown and others, 1996, p. 27-29.)

Figure 8. Backfilled portal and effluent at the Lienhart Mine.

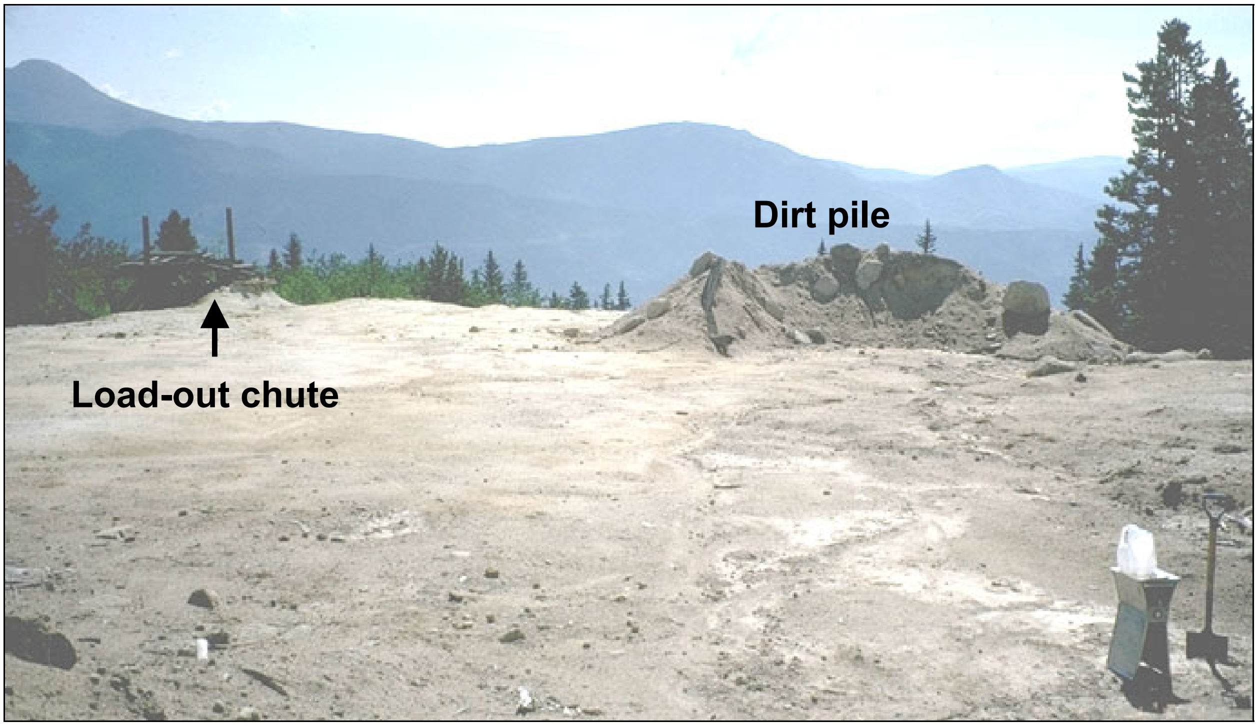


Figure 9. Bench of dump and unmineralized dirt pile at the Lienhart Mine.

Figure 10. Rills and load-out chute on the Lienhart Mine dump.

Figure 11. Cabin at the Lienhart Mine.

In July 1999 about 21 gpm of effluent with 6.01 pH and 78 µS/cm conductivity was flowing through a plastic pipe from the backfilled portal (sample 391/4310-1.1, Table 3). State standards were exceeded in aluminum, cadmium, copper, lead, manganese, and zinc. At the break-in-slope about 750 feet downstream of the portal, flow had increased to about 30 gpm, and the water had 6.76 pH and 68 µS/cm conductivity (sample 391/4310-1.3, Table 3). Standards were exceeded in cadmium, copper, lead, and zinc, although the concentrations of these metals were reduced.

The effluent channel near the portal had minor reddish-orange precipitate that diminished to slight orange coatings at the lower sample site 750 feet below the portal. A moderate amount of light yellow-red precipitate was collected on filters at both sample sites.

A seep below the dump and tailings was flowing at about 0.1 gpm and had 4.4 pH and 108 µS/cm conductivity. Elevated conductivity and depressed pH suggest that the water was probably affected by contact with the tailings or dump.

Waste-rock pile #202 contains about 2,000 cubic yards of crushed rock that is mostly light yellow with some red-stained areas. Gullies, rills, and sheetwash erosion have affected the dump. Abundant fine-grained pyrite and a moderate amount of muscovite were observed. Pyrite, sphalerite, galena, chalcopyrite, and bornite occurred in the vein (Baskin, 1987, p. 35) and are probably on the dump. Composite sample 391/4310-1.D1 from dump #202, excluding material from the apparently unmineralized pile on the southwest side of the dump (Figures 2, 9), indicates that the dump is moderately to highly mineralized with lead, silver, arsenic, iron, gold, copper, zinc, and manganese. The sample produced a paste pH of 4.00 and a high acid-generating potential of -29.5 tons $CaCO_3$/1,000 tons (Table 4).

Table 3. Analytical results for water samples from the Lienhart Mine.

Sample	391/4310-1.300, Lienhart Portal (8/96)				391/4310-1.303, Lienhart Below (8/96)			
Parameter	Concentration/ measurement	Standard	Factor above standard	Load (grams/day)	Concentration/ measurement	Standard	Factor above standard	Load (grams/day)
Flow (gpm)	10.0				2.0			
pH (standard units)	4.20				6.20			
Conductivity (µS/cm)	145.0				95.0			
Alkalinity (mg/L CaCO3)								
Hardness (mg/L CaCO3)	35	None	N/A		74	None	N/A	
Aluminum (trec) (µg/L)	510	None	N/A	27.8	<50	None	N/A	N/A
Antimony (trec) (µg/L)	1.0	6.0	Below standard	N/A	<1.0	6.0	Below standard	N/A
Arsenic (trec) (µg/L)	2.0	10	Below standard	0.1	<1.0	50.0	Below standard	N/A
Iron (trec) (µg/L)	3,900	1,000.0	3.9	212.6	18	1,000.0	Below standard	0.2
Thallium (µg/L)	<1.0	0.5	Not detected	N/A	<1.0	0.5	Not detected	N/A
Zinc (trec) (µg/L)		2,000.0	N/A			2,000.0	N/A	
Aluminum (µg/L)	440	87.0	5.1	24.0	<50	87.0	Below standard	N/A
Cadmium (µg/L)	11.0	0.5	22.2	0.6	3.4	0.5	7.3	0.0
Calcium (mg/L CaCO3)	29	None	N/A	1,580.8	28.00	None	N/A	305.3
Chloride (mg/L)	<10.0	250.0	Below standard	N/A	<10.0	250.0	Below standard	N/A
Chromium (µg/L)	<10	11.0	Below standard	N/A	<10	11.0	Below standard	N/A
Copper (µg/L)	310.0	4.8	64.7	16.9	9.0	4.5	2.0	0.1
Fluoride (mg/L)	0.35	2.0	Below standard	19.1	0.26	2.0	Below standard	2.8
Iron (µg/L)	890	300.0	3.0	48.5	<10	300.0	Below standard	N/A
Lead (µg/L)	110.0	0.9	126.5	6.0	<1.0	0.8	Not detected	N/A
Magnesium (mg/L)	1.40	None	N/A	76.3	1.00	None	N/A	10.9
Manganese (µg/L)	220	50.0	4.4	12.0	8	50.0	Below standard	0.1
Nickel (µg/L)	<20	42.8	Below standard	N/A	<20	40.3	Below standard	N/A
Potassium (mg/L)	1.3	None	N/A	70.9	1.4	None	N/A	15.3
Silicon (mg/L)		None	N/A			None	N/A	
Silver (µg/L)	<0.2	0.0	Not detected	N/A	<0.2	0.0	Not detected	N/A
Sodium (mg/L)	3.40	None	N/A	185.3	3.00	None	N/A	32.7
Sulfate (mg/L)	57	250.0	Below standard	3,107.1	19	250.0	Below standard	207.1
Zinc (µg/L)	2,000	43.3	46.2	109.0	500	40.5	12.4	5.5

Table 3. Analytical results for water samples from the Lienhart Mine—continued.

Sample	12-01-391/4310-1.1, Lienhart Portal (7/11/99)				12-01-391/4310-1.3, Lienhart Below (7/11/99)			
Parameter	Concentration/ measurement	Standard	Factor above standard	Load (grams/day)	Concentration/ measurement	Standard	Factor above standard	Load (grams/day)
Flow (gpm)	21.0				30.2			
pH (standard units)	6.01				6.76			
Conductivity (µS/cm)	78.0				68.0			
Alkalinity (mg/L CaCO3)	14.00				16.00			
Hardness (mg/L CaCO3)	26	None	N/A		25	None	N/A	
Aluminum (trec) (µg/L)	170	None	N/A	19.5	140	None	N/A	23.0
Antimony (trec) (µg/L)	<1.0	6.0	Below standard	N/A	<1.0	6.0	Below standard	N/A
Arsenic (trec) (µg/L)	<1.0	50.0	Below standard	N/A	<1.0	50.0	Below standard	N/A
Iron (trec) (µg/L)	1,200	1,000.0	1.2	137.4	640	1,000.0	Below standard	105.4
Thallium (µg/L)	<1.0	0.5	Not detected	N/A	<1.0	0.5	Not detected	N/A
Zinc (trec) (µg/L)	710	2,000.0	Below standard	81.3	540	2,000.0	Below standard	88.9
Aluminum (µg/L)	88	87.0	1.0	10.1	<50	87.0	Below standard	N/A
Cadmium (µg/L)	4.3	0.4	10.9	0.5	3.3	0.4	8.7	0.5
Calcium (mg/L CaCO3)	22	None	N/A	2,518.4	21	None	N/A	3,457.0
Chloride (mg/L)	<20.0	250.0	Below standard	N/A	<50.0	250.0	Below standard	N/A
Chromium (µg/L)	<10	11.0	Below standard	N/A	<10	11.0	Below standard	N/A
Copper (µg/L)	94.0	3.7	25.1	10.8	21.0	3.6	5.9	3.5
Fluoride (mg/L)	<0.10	2.0	Below standard	N/A	0.11	2.0	Below standard	18.1
Iron (µg/L)	170	300.0	Below standard	19.5	32	300.0	Below standard	5.3
Lead (µg/L)	12.0	0.6	20.8	1.4	1.0	0.5	1.9	0.2
Magnesium (mg/L)	0.98	None	N/A	112.2	0.89	None	N/A	146.5
Manganese (µg/L)	65	50.0	1.3	7.4	46	50.0	Below standard	7.6
Nickel (µg/L)	<20	34.4	Below standard	N/A	<20	33.0	Below standard	N/A
Potassium (mg/L)	1.0	None	N/A	114.5	<1.0	None	N/A	N/A
Silicon (mg/L)	6.0	None	N/A	686.8	6.1	None	N/A	1,004.2
Silver (µg/L)	<0.2	0.0	Not detected	N/A	<0.2	0.0	Not detected	N/A
Sodium (mg/L)	2.50	None	N/A	286.2	2.60	None	N/A	428.0
Sulfate (mg/L)	22	250.0	Below standard	2,518.4	19	250.0	Below standard	3,127.8
Zinc (µg/L)	720	33.9	21.3	82.4	520	32.4	16.1	85.6

Table 4. Laboratory results for composite samples of waste rock and tailings at the Lienhart Mine. (Sample numbers are shown in parentheses. Waste rock was collected from about 1 to 3 inches deep on an approximate 15-foot grid. Tailings were collected from about 4 to 6 inches deep on an approximate 5-foot grid.)

Parameter	Lienhart Mine, Dump #202 (391/4310-1.D1)	Lienhart Mine, Tailings #203 (391/4310-1.D2)
Paste pH	4.00	3.57
Neutralization potential (tons $CaCO_3$/1,000 tons)	0.9	<0.1
Potential acidity (tons $CaCO_3$/1,000 tons)	30.5	15.6
Net acid-base potential (tons $CaCO_3$/1,000 tons)	-29.5	-15.6
Al_2O_3 (%)	8.79	5.11
CaO (%)	0.80	0.03
Fe_2O_3 (%)	7.23	4.46
K_2O (%)	2.74	2.82
MgO (%)	0.40	0.13
Na_2O (%)	0.78	0.14
Sulfur (%)	2.36	2.31
Antimony (ppm)	5	4
Arsenic (ppm)	230	74
Beryllium (ppm)	1	1
Boron (ppm)	<1	<1
Cadmium (ppm)	1.3	3.0
Cobalt (ppm)	8	5
Copper (ppm)	415	1975
Gold (ppm)	1.10	5.07
Lead (ppm)	4138	9171
Lithium (ppm)	17	38
Manganese (ppm)	873	147
Mercury (ppm)	0.62	0.46
Molybdenum (ppm)	9	8
Nickel (ppm)	7	3
Phosphorus (ppm)	499	86
Silver (ppm)	29.0	53.5
Strontium (ppm)	186	42
Vanadium (ppm)	39	32
Zinc (ppm)	381	1101

Tailings (feature #203) are light-yellow fine sand- to clay-size material. In addition to erosion from the adjacent effluent stream, rills and sheet wash indicate additional water erosion (Figure 3). The material is too finely crushed to identify any minerals, but a weak sulfide smell suggests the presence of pyrite. Composite sample 391/4310-1.D2 from the tailings produced a paste pH of 3.57 and net acid-base potential of -15.6 tons $CaCO_3$/1,000 tons. In general, the tailings contained higher metal concentrations than dump #202. Concentrations of gold, silver, lead, copper, and zinc were high (Table 4).

MIGRATION PATHWAYS

Groundwater Pathway

Granitic rocks underlying the Lienhart Mine are faulted and fractured, providing conduits for surface water to infiltrate and groundwater to migrate. At the Lienhart Mine, some of the faults contain sulfide minerals. Because of the faulted and fractured nature of the bedrock, water from the Lienhart Mine and associated mineralized veins may enter the alluvial aquifer associated with Morris Creek, a tributary of the Arkansas River. The moderate volume of discharge from the Lienhart Mine suggests that subsurface flow through the mine is minor.

The nearest water well is about a mile north of the Lienhart Mine, in the southwest quarter of the northwest quarter of section 5. Permitted for domestic use in 1958, the 66-foot-deep well yielded 6 gpm (Colorado Division of Water Resources, well records, July 2000). Although the exact position of the well was not determined, it is probably near Morrison Creek on private land at the Tamarack and Humbolt patented mining claims. If this is the case, any metal loading in water at this well is more likely associated with mining activities on the Tamarack and Humbolt claims, rather than the Lienhart Mine.

Six other domestic-use wells, from 163 to 365 feet deep, are within ½ mile of Morris Creek and 2 to 3 miles downstream of the Lienhart Mine (Colorado Division of Water Resources, well records, July 2000). Depths of these wells suggest that they draw from a bedrock aquifer, rather than the alluvial aquifer of Morris Creek or the Arkansas River. The quality of the water from these wells is not known.

All of the 210 wells that are within 4 miles of the Lienhart Mine are topographically lower than the mine. Wells are up to 520 feet deep and yield a maximum of 113 gpm. Most of the wells are less than 200 feet deep, yield 15 gpm or less, and are designated for household or domestic use. About half of the wells are within a mile of the Arkansas River, and most are in drainage basins other than Morris Creek (Colorado Division of Water Resources, well records, July 2000).

Presumably, some water enters the fractured bedrock aquifer at the Lienhart Mine. Any contaminated groundwater that may originate from the Lienhart is probably diluted prior to reaching the nearest wells, which are more than a mile away.

Contaminated mine effluent may enter the alluvial aquifer of upper Morris Creek, but the closest wells appear to be drawing water from the bedrock aquifer. Regardless, the distance to the downstream wells probably allows for sufficient dilution and dispersion of any contaminated groundwater.

Although the groundwater pathway is not an obvious significant threat at the Lienhart Mine, samples should be collected from the nearest downstream wells for verification.

Surface Water Pathway

Sample results show high concentrations of zinc, cadmium, copper, and other metals, but only minor metal loads in effluent from the Lienhart Mine at the portal. Because of natural attenuation, most metal concentrations and loads have significantly decreased by the time the effluent has reached the break-in-slope about 750 feet downstream of the portal. At the downstream site, cadmium, zinc, lead, and copper concentrations are reduced compared to the portal water, but remain above standards (Table 3). Other metals fall within standards.

The Lienhart Mine is above the headwaters of Morris Creek. Effluent was the source of surface flow in the gulch hosting the mine, but it was not determined if mine effluent flows directly into Morris Creek. According to topographic maps, Morris Creek starts as an intermittent stream about 2,000 feet downstream of the Lienhart and becomes a perennial stream near a series of ponds about 4,000 feet downstream of the portal. Less than a mile from the Arkansas River and about 4 miles below the Lienhart, much of Morris Creek is diverted for irrigation purposes.

No samples were collected near the pastures that Morris Creek irrigates, and water quality at the irrigation diversions is not known. Lienhart Mine water eventually reaches the Arkansas River, either at the surface or through the alluvial aquifer. Because of the low metal loads in the effluent and the distance to the river, quality of the Arkansas River is probably not measurably affected by drainage from the Lienhart.

A moderate volume of contaminated water emerges from the portal of the Lienhart Mine, but natural attenuation apparently partly mitigates the contamination within a few hundred feet. The surface water pathway is probably not a significant problem, but water samples should be collected near the irrigation diversions to fully evaluate the downstream effect of effluent from the Lienhart Mine.

Soil Exposure Pathway

No one lives within 2 miles of this site, and no one is currently working at the mine. This area is accessed by a 4WD road that becomes very steep about 2 miles below the mine. The mine probably receives few visitors. Although the waste rock and tailings are moderately mineralized, exposure times for Forest visitors are brief. The soil exposure pathway is not considered a significant risk.

Air Exposure Pathway

No evidence of windblown particulates or wind erosion was observed at the site. Although much of the dump is composed of small fragments, the surface of the dump is well cemented. Mill tailings are composed of unconsolidated fine material and are more susceptible to wind erosion, but no evidence of wind erosion was observed. The tailings are frozen or covered with snow for much of the year. Nearby dump #202 and the wooded slopes may provide some protection from high winds, however, small volumes of tailings may occasionally become windblown. This pathway is considered insignificant because of the small surface area of the tailings and the lack of long-term exposure to the public.

CONCLUSIONS

The Lienhart Mine discharges a moderate volume of poor quality water. Water sampled at the portal in 1996 and 1999 exceeded state standards in aluminum, cadmium, copper, iron, manganese, lead, and zinc. Metal concentrations were greatly reduced in water samples collected 750 feet below the portal, and only cadmium, copper, lead, and zinc approached or exceeded standards in 1996 and 1999.

Portal water collected in 1996 had much higher concentrations of aluminum, iron, cadmium, copper, lead, manganese, and zinc than the 1999 sample. This difference may be a dilution effect because of the increased flow in 1999. Another possibility is that closing the portal decreased the oxidation rate of sulfide minerals exposed in the vein underground, reducing the dissolution of metals. Metal loads at the portal also decreased after the adit was closed (Table 3). The reduction in metal loading was not as dramatic as the decrease in concentration, implying that dilution and decreased oxidation are both factors in improving the water quality at the portal. More sampling is needed to determine if the reduced metal load revealed at the portal in 1999 was a fluke or is a long-term result.

Water samples collected 750 feet below the portal in 1996 had lower concentrations of aluminum, iron, copper, and manganese than 1999 samples, suggesting that the passive remediation system removed in 1998 was somewhat effective. Zinc and cadmium concentrations were similar at the lower sample site in 1996 and 1999, though loading in 1996 was significantly less because of the lower flow.

It is unknown if effluent ever reaches Morris Creek at the surface. The mine drainage may flow directly into Morris Creek during spring runoff or other periods of elevated flow. Metals from the Lienhart Mine may adversely affect the irrigation water and/or the six wells near the mouth of Morris Creek, but these sites were not sampled for this study. Irrigation diversions and wells are more than 2 miles from the portal and about 2,000 lower in elevation. Natural attenuation, dilution, and dispersion probably reduce metal concentrations and loads before the effluent reaches these features. Some natural attenuation is occurring between the portal and the sample site 750 feet downstream, as indicated by decreased concentrations and lower loads for many parameters, even after the passive remediation system was removed.

To determine if off-site metal contamination is a problem, wells and surface water should be sampled a few miles downstream of the Lienhart Mine in the area where people, crops, or livestock utilize water from Morris Creek.

If metal loading from the Lienhart Mine is significant at the downstream wells and irrigation ditch, reconstruction of the passive remediation cell and isolating the effluent from the tailings and dump may mitigate the problem. Although air and soil exposure pathways are not considered a serious risk, covering and revegetating the waste rock and tailings would eliminate these exposure pathways. Dump #202 and the tailings are moderately to highly mineralized. Eventually, metals in these piles may be economically recoverable.

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APPENDIX: Abandoned Mine Inventory Form for the Lienhart Mine

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) **ID#:** 02- 08- 12 - 01 - 391 / 4310 - 1
rgn st fst rd xutm yutm area#

(2) **Sitename:** Lienhart Mine

(3) **Other name/reference:**

2 (4) **Highest priority Environmental Degradation occurring in this area:**
1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

3 (5) **Highest priority Mine Hazard noted in this area:**
E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) **Commodity:** C=coal; U=uranium; M=metals; I=industrial material.
(Metal or Indust. material type: Gold/Silver)

(7) **Quad name and date:** Mount Harvard

(8) **County:** Chaffee

(9) **2° map:** Leadville

(10) **Water Cataloguing Unit #:** 11020001

(11) **Mining district/coal field:**

(12) **Land survey location:** ___ - ___ - ___ sec 7,8 ,T 13S ,R 79W

(13) **Receiving stream:** Morris Creek flowing into Arkansas River
nearest named stream next named

(14) **Elevation (ft):** 11200

2 (15) **General Slope:** 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) **Regional terrain:** R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

J (17) **Type of access:** N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

G (18) **Quality of access for construction vehicles:** G=good; M=moderate; P=poor; X=very poor

(19) **Nearest town on map:** Buena Vista

13 (20) **Road distance from nearest town (#.# miles)**

(21) **Nearest road (name and/or #):** FR 387
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

0.25 (22) Road

— (23) Dwelling (year-round)

— (24) Campground/picnic area

0 (25) Marked trail

0 (26) Other public use (explain) Colorado Trail

ENVIRONMENTAL INFORMATION

M (27) **Vegetation density adjacent to site:** D=dense; M=moderate; S=sparse; B=barren

P,G,W,A (28) **Vegetation type adjacent to site:** B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

Y (29) **Evidence of intentional reclamation:** Y=yes; N=no (if yes, use comments)

1 (30) **Size of disturbed area in acres**

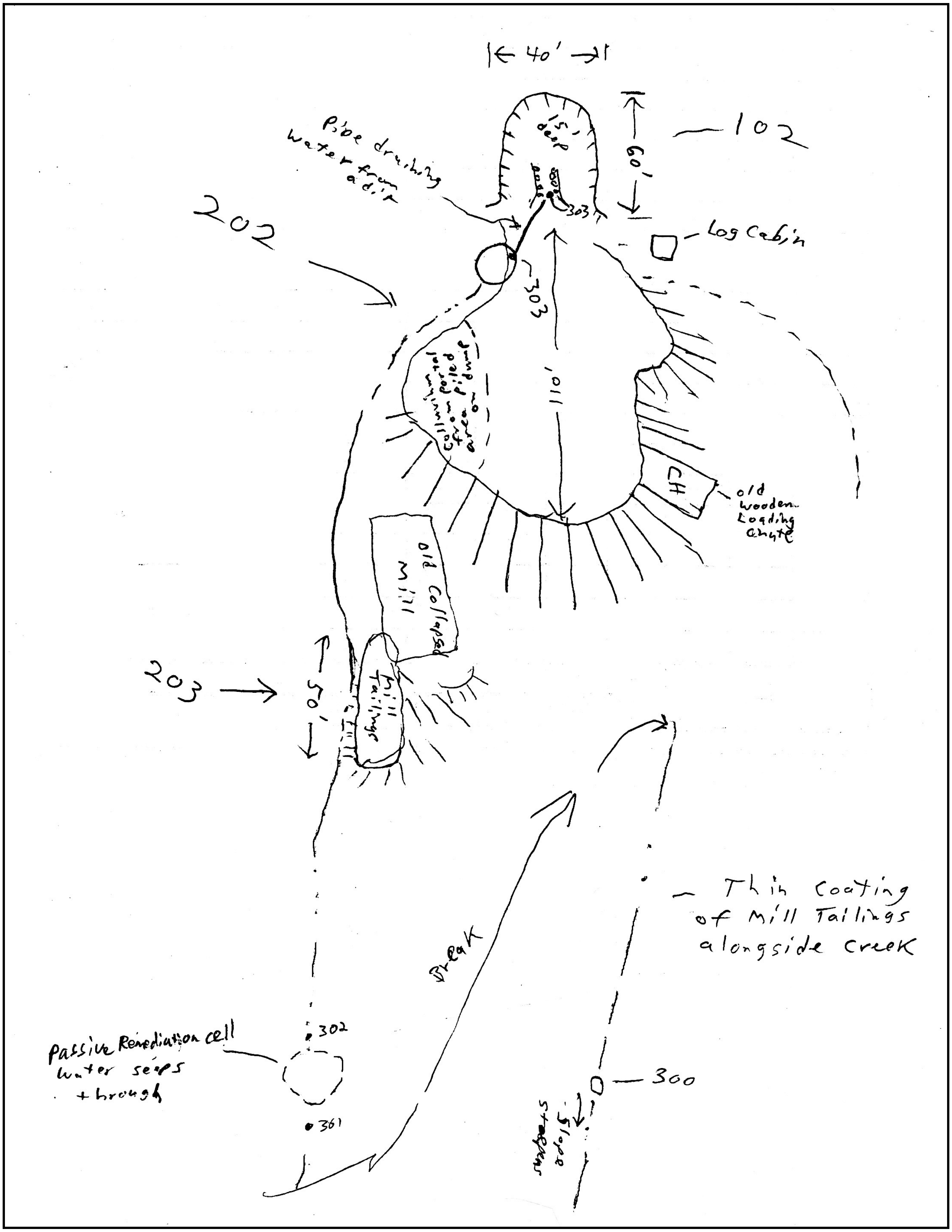
Y (31) **Potential historical structures in area:** Y=yes; N=no (if yes, use comments)

N (32) **Evidence of bats:** G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

(33) **Recorded by/date:** Don Brown Rich Ward Matt Sares 8-22-96

ADITS, SHAFTS, AND OPENINGS													
Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		A	P	A									
Opening Size (ft)	H	O	10	6									
	W	O	10	5									
Depth (ft)		O	5	50+									
Condition		F	P	I									
Drainage		N	N	W									
Access Deterents		N	N	O									
Deterent Condition		—	—	D									
Ratings	Env. Deg.	5	5	2									
	Hazard	5	5	3									
Photo	Roll No.	—	—	RW5									
	Frame No.	—	—	13									
Comments?				Y									

DUMPS, TAILINGS, AND SPOIL BANKS										
Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature				D	T					
Plan view Dimension (ft.)	L			110	50					
	W			80	25					
Volume (yds)				2000	20					
Steepest Slope Angle (dgr)				38	30					
Steepest Slope Length (ft)				30	10					
Size of Materials				F,S,G,L,B	F,S					
Cementation				M	W					
Vegetation Type				B	B					
Vegetation Density				B	B					
Drainage				N	N					
Stability				S	S					
Water Erosion	of Feature			G,R,S	GRS					
	Storm Runoff			S	S					
Wind Erosion				N	N					
Radiation Count				—	—					
Access Deterents				N	N					
Deterent Condition				—	—					
Ratings	Env. Deg.			2	2					
	Hazard			5	5					
Photo	Roll No.			RW5	RW5					
	Frame No.			14, [illegible]	15,16,17					
Comments?				Y	Y					
Soil Sample No.										



40'
102
60'
15' deep
Pipe draining water from adit
202
303
Log Cabin
110'
Collapsed jet mining from piled area
old wooden Loading chute
old Collapsed Mill
203
50'
Mill Tailings
Break
Thin Coating of Mill Tailings alongside creek
302
Passive Remediation cell water seeps through
301
300
Slope steepens

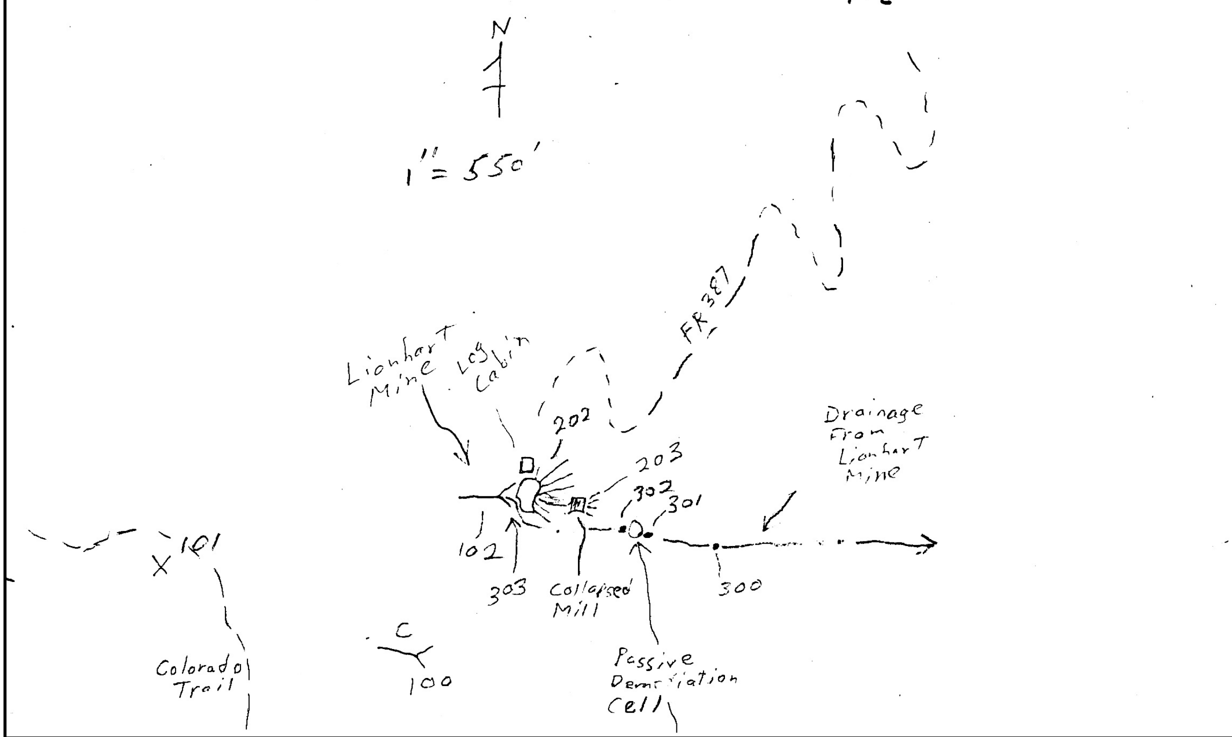
DRAINAGE/WATER SAMPLES						
Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)	102 202 203	102 202 203	102 202 203	102		
pH (standard units)	6.19	6.81	4.23	4.22		
Conductivity (uS)	95.2	85.3	153	145		
Flow (gpm)		2	2	10		
Method of Flow Measure	Flume	E	E	D		
Date Flow/Sample (m/d/y)	8/22/96	8/22/96	8/22/96	8/22/96		
Location of Sample/Flow	B	B	B	A		
Evidence of Toxicity in Site Drainage	N	N	P	P		
Evidence of Toxicity in Receiving Stream	N	N	N	N		
Distance from Stream (ft)						
Comments?	Y	Y	Y	Y		
Lab Water Sample No.	391-4310-1.300	—	—	391-4310-1.303		

GPS READINGS	
Ftr. No.	Location
102	Lat. N 38 56 18.1" 4 Long. W106 15 16.2
300	Lat. N 38 56 44 4 Long. W106 16 22
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: ___ north arrow; ___ scale bar or general size noted; ___ direction to nearest trail/road/town noted; ___ significant mine features numbered

Adit, shaft, prospect hole, building, dump or tailings, collapsed adit and shaft, fence



●81. Local person interviewed ____________________
Name Address

●82. Name and address of person desiring a copy of this form: ____________________

●83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1= less $10,000; 2= $10,000 to $100,000; 3= $100,000 to $500,000; 4= more than $500,000. Code estimated time to complete the activity as: 1= less than 1 month; 2= 1 to 12 months; 3= 1 to 3 years; 4= over 3 years

Cost	Time	Recommended reclamation activity

●84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

101 Three other adjacent smaller prospect pits.
102 adit - Lion Heart - New cribbing at portal; water draining from portal out of pipe into a small pond, then down alongside creek.

202 Lion Heart Dump, Altered granitic rock, bleached, Intense sulfur stains + strong sulfur smell, moderately iron stained. Water drains from adit and runs down alongside dump.
203 - Tailings just below 202 dump.
Tailings from old collapsed ball mill. Prominent erosion of tailings down hill and into water draining from adit. Most of tailings eroded away, thin coating of tailings along drainage creek for several hundred ft downhill.

300 Lowest point in mine drainage just before dropoff.
301 Just below remediation cell
302 Just above remediation cell (Photo Rw 5, Frame 17)
303 at portal of adit

-if more comments use back of page →

General Comment: Well preserved log cabin at adit site 102.

-if more comments use back of page →

OFFICE/LITERATURE INFORMATION

●41. Owner of surface ____________________
●42. Last known operator ____________________
●43. Estimated production ____________________
●44. Dates of production ____________________
●45. Literature not cited in comments ____________________
●46. Citation of any historical register listing ____________________

CODES FOR TABULAR INFORMATION

ALL TABLES: If appropriate code is not listed, use: **N** = none or no; **N/A** = not applicable; **UNK** = unknown; **O** = other, explain in #84

ADITS, SHAFTS, & OPENINGS

- Type of feature: **A** = adit; **S** = vertical shaft; **I** = incline shaft; **P** = prospect hole; **ST** = stope; **G** = glory hole; **SU** = subsidence feature; **PT** = open pit; **O** = other, explain in #84.
- Condition: **I** = intact; **P** = partially collapsed or filled; **F** = filled or collapsed; **N** = feature searched for but not found (mine symbol on map)
- Drainage: **N** = no water draining; **W** = water draining; **S** = standing water only (note at what depth below grade)
- Access deterents: **N** = none; **S** = sign; **F** = fence; **C** = sealed or capped; **D** = open door or hatch; **L** = locked door or hatch; **G** = open grill; **O** = other, explain in #84.
- Deterent condition: **P** = prevents access; **D** = discourages access; **I** = ineffective
- Ratings: Hazard: **E** = emergency; **1** = extreme danger; **2** = dangerous; **3** = potential danger; **5** = no significant hazard
  Env. Deg.: **1** = extreme; **2** = significant; **3** = potentially significant; **4** = slight; **5** = none
- Comments?: **Y** = yes; **N** = no

DUMPS, TAILINGS, AND SPOIL AREAS

- Type of feature: **D** = mine dump; **T** = mill tailings; **W** = coal waste bank; **S** = overburden or development spoil pile; **DS** = dredge spoil; **HD** = placer or hydraulic deposit; **H** = highwall; **P** = processing site
- Size of materials: **F** = fine; **S** = sand; **G** = gravel; **L** = cobbles; **B** = boulders
- Cementation: **W** = well cemented; **M** = moderately cemented; **U** = uncemented
- Vegetation Type: **G** = mixed grass; **S** = sagebrush/oakbrush/brush; **J** = juniper/piñon; **A** = aspen; **P** = pine/spruce/fir; **T** = tundra; **R** = riparian; **F** = tilled crops; **B** = barren/no vegetation; **W** = weeds
- Vegetation Density: **D** = dense; **M** = moderate; **S** = sparse; **B** = barren
- Drainage: **N** = no water draining; **W** = water draining across surface; **S** = standing water only; **SP** = water seeping from side of feature
- Stability: **U** = unstable; **P** = potentially unstable; **S** = stable
- Water erosion: of Feature: **N** = none; **R** = rills; **G** = gullies; **S** = sheet wash
  Storm Runoff: **C** = in contact with normal stream; **S** = near stream or gully, but only eroded during storm or flood; **N** = no storm/flood runoff erosion
- Wind erosion: **N** = none; **D** = dunes; **B** = blowouts; **A** = airborne dust
- Radiation Count: **N** = none taken; record value of reading if taken
- Access deterents: **N** = none; **S** = sign; **F** = fence; **O** = other, explain in #84
- Ratings: Hazard: **E** = emergency; **1** = extreme danger; **2** = dangerous; **3** = potential danger; **5** = no significant hazard
  Env. Deg.: **1** = extreme; **2** = significant; **3** = potentially significant; **4** = slight; **5** = none
- Comments?: **Y** = yes; **N** = no

DRAINAGE/WATER SAMPLES

- Adit/Shaft/Dump No./Other: Indicate Feature No. associated with water information; **0** = other, explain in comments
- Flow (cfs): record seeps as 0.01 cfs (Rule of Thumb: a cfs ≈ one full-blast garden hose)
- Method of flow measure: **E** = estimate; **T** = bobber/stopwatch/x-section; **W** = weir; **D** = catchment; **F** = flow meter
- Location of sample and flow: **A** = immediately adjacent to adit/shaft; **B** = below dump/tailings; **C** = immediately above confluence with receiving stream; **SW** = standing water in/on feature; **RU** = receiving stream upstream of feature; **RD** = receiving stream dowmstream of feature;
- Evidence of toxicity: **N** = none; **A** = absence of benthic organisms; **W** = opaque water; **P** = yellow or red precipitate; **S** = suspended solids; **D** = salt deposits
- Comments?: **Y** = yes; **N** = no