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REVIEW AND ANALYSIS OF SITE INVESTIGATIONS AND ENGINEERING EVALUATION FOR DETERMINATION OF A CONTAMINATED SITE CLEANUP OPTION FOR THE RED DEVIL MERCURY MINE, ALASKA

BY

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Maps showing:

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1. Introduction

Statement of the problem

The Red Devil mercury mine was operated by multiple operators from 1933 until 1971. During its operational life, approximately 35,000 flasks of mercury were produced. One flask weighs 76 pounds and is about two quarts in volume. Due to the mining operations, the site has contaminated soil, water, and sediment. The primary contaminants of concern are metals: mercury, antimony, arsenic, and lead. Other site contaminants, or hazardous materials, include petroleum hydrocarbons, Polychlorinated biphenyls (PCBs), and asbestos. This site is currently listed under the U.S. Environmental Protection Agency's (EPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program (a.k.a. "Superfund"). The investigation and cleanup of this site is managed by the Bureau of Land Management (BLM), Anchorage Field Office.

Purpose of the study

The purpose of this study is to determine a preferred remedial option for the cleanup of the Red Devil Mine. This study reviews multiple reports describing site investigations, removal actions, and an Engineering Evaluation/Cost Analysis. Information was gathered from published and unpublished scientific sources regarding site climatology, geology, soils, surface- and ground-water, ecological environment, remedial options, and human population distribution. This information will help determine the site environmental characteristics and the level of risk the site poses. The remedial options were analyzed according to U.S. Environmental Protection Agency (EPA) criteria to assist in determining the cleanup method that should be used for this contaminated site. The outcome of this study will likely be the actual cleanup method utilized for this site.

Scope of Study

This study was limited to available literature, site reports and data, and the author's knowledge, as site Project Manager. BLM currently has extensive files that contain the above literature resources. They have been collected from multiple federal and state agencies, environmental consulting firms, and private scientific organizations.

Site Location and Access

The Red Devil Mine is located approximately 250 miles west of Anchorage, Alaska, 8 miles northwest of Sleetmute, and 2 miles southeast of the community of Red Devil (Figure 1). The mine is on the south side of the Kuskokwim River at T. 19 N., R. 44 W., Southeast quarter of Section 6, Seward Meridian. From Anchorage, air travel is the only practical mode of transportation. Commercial airline service is available to Aniak, from where a small aircraft can be chartered to fly to the Red Devil airstrip. A small aircraft could also be chartered in Anchorage. An unimproved track leads to the mine site located two miles to the southeast. Heavy equipment may be barged on the Kuskokwim River, but it is less expensive to fly all equipment into the airstrip.

Background

The site consists of a surface mining area, open and collapsed adits and inclined shafts, tailing piles, settling ponds, five large fuel tanks, drum storage areas, approximately 18 buildings used for housing, laboratory, mill, steam plant, and chemical storage sheds (Figure 2). A Site Investigation was completed in June, 1989 by BLM's contractor. BLM agreed with EPA to remove or neutralize site chemicals and electrical transformers, to annually monitor surface water, post site warnings, and restrict site access. With the results of the Site Investigation and the above stipulations, EPA designated the site No Further Action required in 1990. In the early 1990's, BLM did post warnings, remove most of the PCB contaminated oil, and attempted to restrict access.

In July, 1999, BLM's contractor removed hazardous and non-hazardous wastes from the site and sampled soil, water, and sediment. The wastes included: mineral processing chemicals (copper sulfate, sodium hydroxide, potassium carbonate, sodium dichromate dihydrate), 55-gallon drums (contents included used engine oil, PCB oil, fuel, solvents, grease); lead-acid batteries, and mercury contaminated slag (soot). BLM's contractor also completed site soil, water, and sediment sampling that was requested by EPA to reevaluate the site.

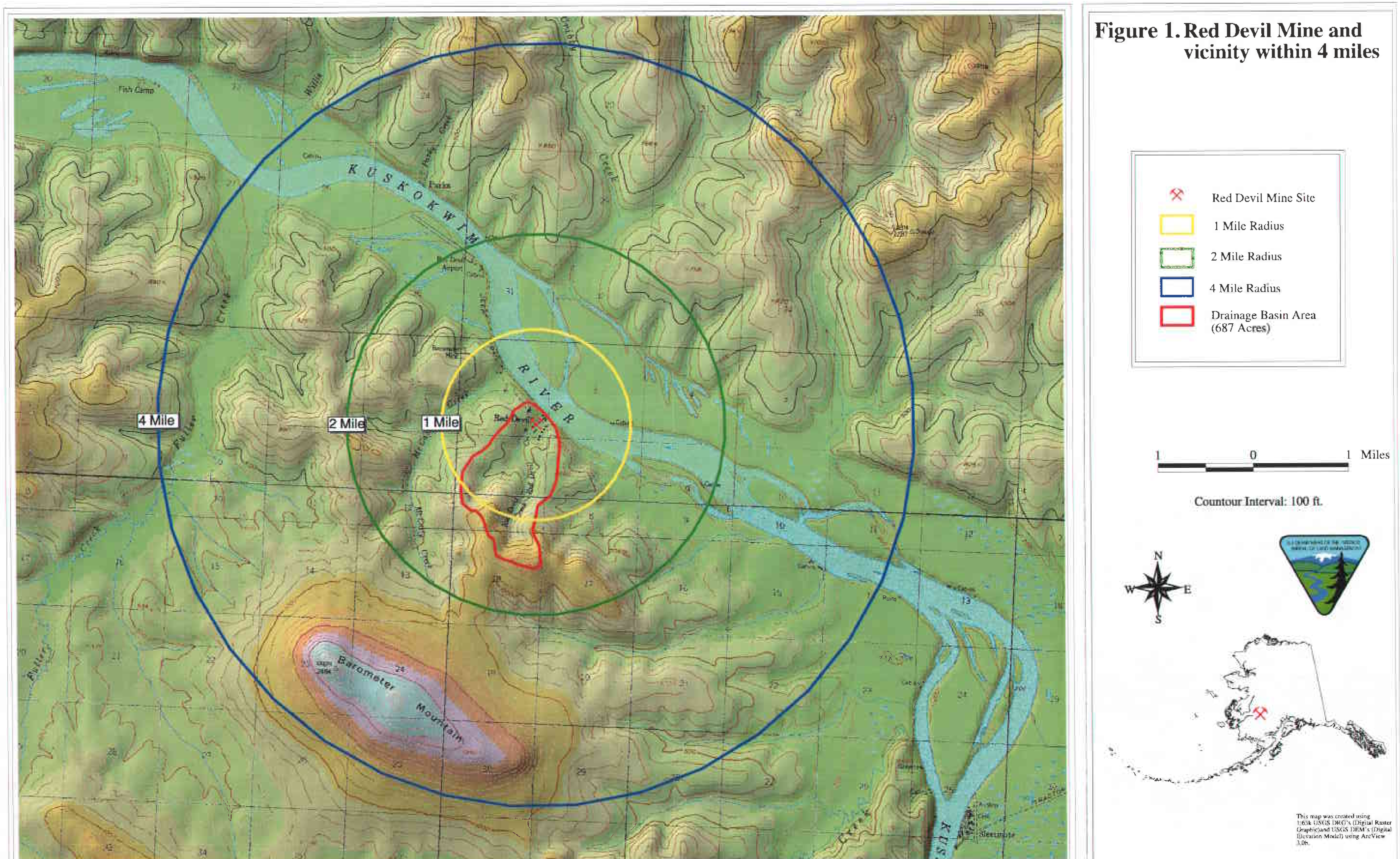
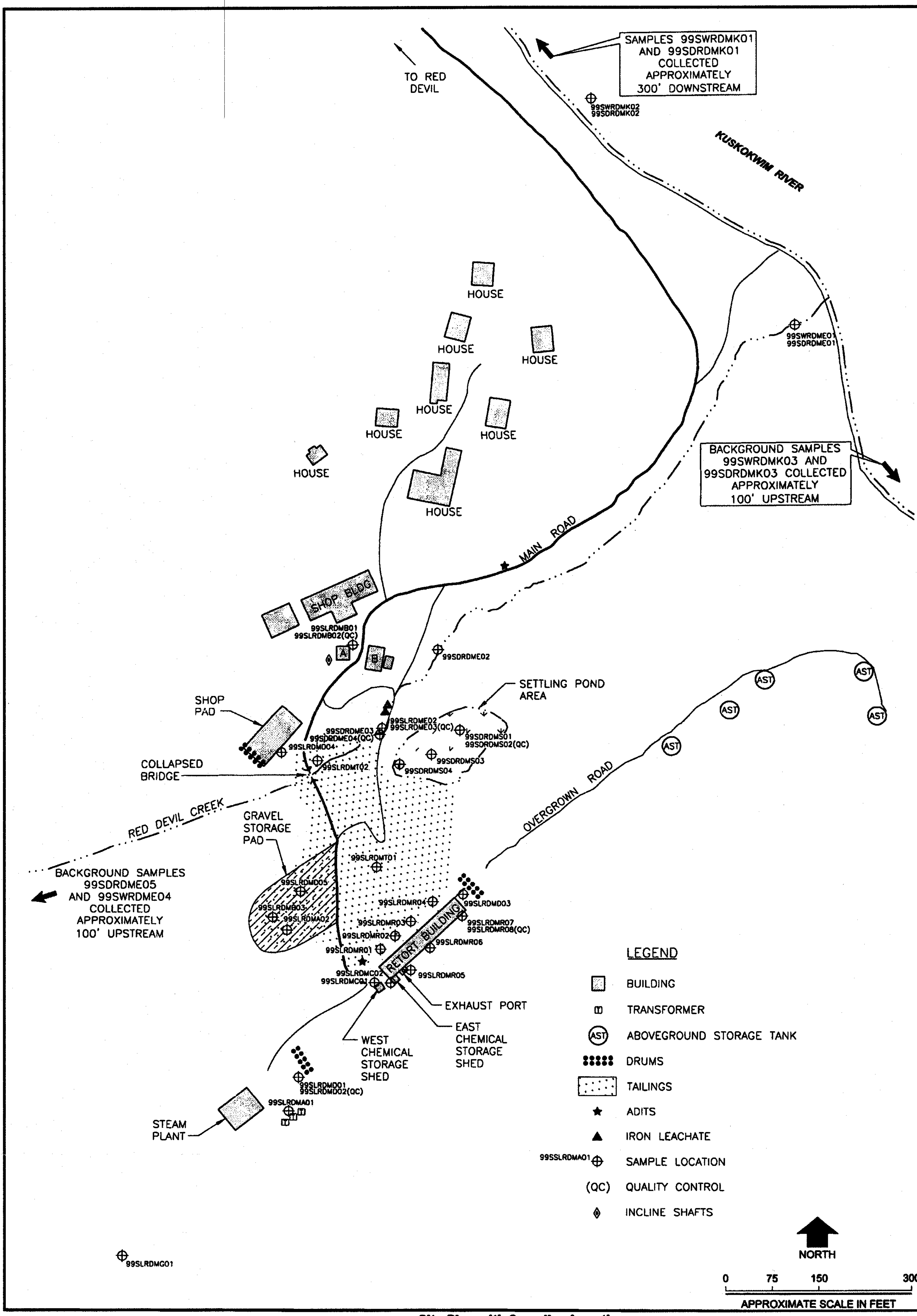


Figure 1. Red Devil Mine and vicinity within 4 miles



Harding Lawson Associates/
Wilder Construction Company
Joint Venture

Site Plan with Sampling Locations

Limited Waste Removal Action Report
Red Devil, Alaska

FIGURE **2**

DRAWN	PROJECT NUMBER	APPROVED	DATE	FILE NAME
CEH	47411	[illegible]	10/99	47411a1.dwg

2. Review of Site Investigations

Multiple independent site investigations have been completed for this site. Investigations have been completed by EPA, the Alaska Department of Environmental Conservation (ADEC), BLM and its environmental consultants. The results of these investigations are summarized and presented below. The results include historical and recent chemical analysis of site soil, water, and sediment. The primary Historic investigations were completed in 1987 and 1989 by environmental consultants for ADEC (Tryck, Nyman & Hayes, 1987) and BLM (Weston, Roy F., Inc., 1989), respectively. The Current site investigation is a compilation of two documents, 1) Limited Waste Removal Action Report (HLA/Wilder JV, 1999), completed by an environmental consultant for BLM, and 2) Preliminary Assessment Data Requirements for Federal Facility Docket Sites, Site Investigation for Red Devil Mine Site, completed by BLM (Alcorn and Griffin, 1999).

Historic Site Investigations

The first known site investigation completed at the Red Devil Mine was done in 1971 by EPA, with additional investigations in 1979. Sampling results from these investigations are found in ADEC's 1987 and BLM's 1989 Site Investigation reports (Tryck, Nyman & Hayes, 1987; Weston, Roy F., Inc., 1989), (Table 1). No new samples were collected for ADEC's 1987 report.

The 1989 BLM Site Investigation report indicated soil/sediment concentrations of mercury up to 787 mg/kg, arsenic to 8,474 mg/kg, antimony to 22,737 mg/kg, and lead to 1,391 mg/kg. Water in Red Devil Creek had concentrations as high as 9,000 ug/l mercury in 1971, but had only 0.4 ug/l in 1988. Downstream from the Red Devil Creek, the Kuskokwim River sampling results for total mercury have ranged between 1.0 ug/l in 1971 (Weston, Roy F., Inc., 1989) to <0.0001 ug/l in 1994 (Gray and others, 1996). Sediments in Red Devil Creek have recorded mercury values as high as 4,120 mg/kg.

The ADEC 1987 report did not recommend any action, but it did identify the presence of mercury and arsenic in the Red Devil Creek, in tailings piles, and settling ponds. The BLM 1989 report concluded that although significant metals were present in the tailings and stream sediments, the surface water leaving the site was not a "significant migration pathway," due to the insolubility of the metals in water and the low concentrations of metals found in the surface water. The report also noted that this area is naturally rich in mercury and lies within a mineralized mercury belt 500 miles long and 200 miles wide, virtually all drained by the Kuskokwim River basin. The report identified other hazardous materials at the site, PCBs, copper sulfate, potassium carbonate, and sodium hydroxide. They concluded: [the metals,] "...mercury, antimony, and arsenic at the site do not pose an imminent threat to humans or animals". EPA classified the site as "No Further Action Required," after evaluation of this report in 1992.

TABLE 1
SUMMARY OF ANALYTICAL RESULTS

Background Samples	Hg	As	Location
Surface Water (ug/l)			
Sceva, 1971	0.3	6	RDC**, above mill
	1.7	56	Kuskokwim River, above RDC
Morris, 1979	0.21	--	RDC, above mill
	0.28	--	Kuskokwim River, above RDC
Wheeler, 1988	0.2	--	RDC, above mill]
	0.2	--	RDC, above mill
Sediments/Soils (mg/kg)			
Wheeler, 1988	0.2	--	RDC, above mill
	6.4	--	Above power plant
	7.8	--	Above Kuskokwim River
	8.0	--	West of mine access road

Settling Ponds	Sb	Hg	As	Location
Surface Water (ug/l)				
Sceva, 1971 (mine in operation)	--	12,850	85,000	Settling Pond #1
Sediments/Soils (mg/kg)				
Morris, 1979	--	216*	--	Settling Pond #1
Wheeler, 1988	--	195	--	Settling Pond #1
Weston, 1988	1,872	395	8,474	Settling Pond #1

* Wet Weight
** Red Devil Creek

BUREAU OF LAND MANAGEMENT
RED DEVIL MINE SITE INSPECTION REPORT, JUNE 1989

TABLE 1
(continued)

Tailings/ Piles	Sb	Hg	As	Location
Soils (mg/kg)				
Wheeler, 1988	--	649	--	Pile above Settling Pond #1
Weston, 1988	1,872	295	8,474	From Settling Pond #1
	872	550	8,053	From Settling Pond #2
	664	83	6,498	From Settling Pond #3
	7,074	787	8,024	Pile above Settling Pond #1
	22,737	498	5,851	Pile above Settling Pond #1

Kuskokwim River	Hg	As	Location
Surface Water (ug/l)			
Sceva, 1971	1.0	32	At Red Devil airstrip
Morris, 1979	0.14	--	100' Downstream from mouth of RDC
	0.2	--	100' Downstream from mouth of RDC

TABLE 1
(continued)

Red Devil Creek	Sb	Hg	As	Location
Surface Water (ug/l)				
Brovant, 1971	--	9,000	--	Discharge from Settling Pond #1
Morris, 1979	--	0.14	--	Below third Settling Pond
	--	0.14	--	Mouth of creek
Wheeler, 1988	--	0.2	--	Adit #6
	--	5.5	--	Mouth of creek
	--	0.6	--	Below third Settling Pond
Weston, 1988	--	0.4	--	Above Settling Pond #1
		0.3	--	Southern border
	278	0.4	244	Mouth of creek
Sediments/Soils (mg/kg)				
Wheeler, 1988	--	967	--	Downstream of bridge
	--	41	--	Below adit
	--	136	--	Mouth of creek
	--	68	--	Below third Settling Pond
Weston, 1988	3,450	29	2,449	Above Settling Pond #1
	--	0.6	165	Southern border
	4,015	4,120	3,185	Below Settling Ponds
	3,113	33.3	2,194	Mouth of creek

Recent Site Investigation

By 1998, many of the identified hazardous materials on the site remained. That, coupled with requests from native groups, lead EPA to request BLM to complete additional sampling and a new Site Investigation. BLM's 1999 Site Investigation outlines and/or references all the information required by EPA to evaluate the site according to its Hazard Ranking System II (HRS) (Alcorn and Griffin, 1999). This information is input into a computer program that produces a quantitative result, or "score". If the score is 28.5 or higher, then the site is eligible for placement on the National Priorities List (NPL). The NPL contains the most contaminated sites in the country and have a high priority for cleanup. EPA establishes strict time lines and milestones for completion of the site cleanup phases. Non-federal sites listed on the NPL may be eligible for "Superfund" money. Since this is a federal site, funding must come from the agency or through cost recovery from a Potentially Responsible Party (PRP). BLM's Site Investigation responds to specific EPA questions. This information is used to quantitatively describe the risk a site poses based on three key factors: contaminant source, contaminant pathways (or mobility), and receptors (human or ecological). The following information was provided:

Known or suspected sources

The primary source of contamination at the Red Devil Mine was due to the extraction of mercury from ore. The tailings at the site naturally have high levels of mercury, antimony, and arsenic. The retorting operation caused additional mercury contamination in the tailings/soils in the vicinity of the retort building. Retorting is an extraction process in which mercury sulfide ore is heated to vaporize elemental mercury. The mercury vapor is condensed in cooling tubes, then the liquid mercury is containerized. All original sources of contamination have been removed from the site. Source contaminants are spread out across approximately 10 acres. See Figures 1 and 2 for site maps. Other site contaminants may include chromium, copper, lead, oil, and PCBs. Metals contamination are from tailings, settling ponds, lead-acid batteries, and runoff from chemical storage sheds. Waste sources removed during the 1999 Limited Waste Removal Action (HLA/Wilder JV, 1999) include: 6,100 pounds of mercury contaminated slag and debris which contained visible free mercury; 10,500 pounds of abandoned mineral processing chemicals (copper sulfate, sodium dichromate, sodium hydroxide, and potassium carbonate); 27, 55-gallon drums of liquid wastes (used oil, PCB oil, fuel, solvents, and grease); and 6,400 pounds of lead-acid batteries (Table 2).

Sampling results

Results from 1999 samples indicated the water in Red Devil Creek contains up to 366 ug/l of antimony, 116 ug/l of arsenic, and 0.104 ug/l of mercury (Table 3) . Sediments in Red Devil Creek in 1999 were as high as 399 mg/kg mercury, 2,030 mg/kg antimony, and 963 mg/kg arsenic (Table 4). 1999 soil samples showed mercury up to 35,000 mg/kg, antimony to 1,780 mg/kg, arsenic to 8,740 mg/kg, and lead to 13,500 mg/kg (Table 5, Figure 3).

Solid waste remaining on-site includes: 5 above ground fuel storage tanks, 30 drained transformers, the ruins of 20 wood buildings (concrete foundations with friable and non-friable asbestos in siding, roofing, and insulation), and scrap metal (3 vehicles, 5 diesel generators, about 200 empty 55-gallon drums, and mining related equipment). There are 3 adits and 5 incline shafts that are open to partially collapsed.

Human Population

The surrounding human population is the first concern for risk evaluation of a site. In risk studies, they are considered the primary "receptors". The total number of residents in the nearby village of Red Devil is 44, according to Alaska Department of Community and Regional Affairs' (1999), Red Devil Community Profile. There are no people residing, working, attending school or day care within 200 feet of the source.

The total number of people within the following distance categories are:

0-1/4 mile:	0; Confirmed by site visit.
1/4-1/2 mile:	0; Confirmed by site visit.
½-1 mile:	2; Two people live in a small cabin on the north side of McCally Creek. These people are trespassing on federal lands. They have been notified. The BLM is in the process of removing them from this location. Final resolution of trespass cases in remote locations often take considerable time to resolve. If EPA determines these occupants are at risk, elevating BLM's Hazard Ranking Score, BLM can accelerate this process. Confirmed by site visit and local interviews.
1-2 miles:	35; Estimate based on the official population of Red Devil (44) and the known layout of the community.
2-3 miles	6; Estimate based on topographic map and local interviews; none confirmed living in this zone.
3-4 miles	3; Estimate based on topographic map and local interviews; none confirmed living in this zone.

Site accessibility

The site is slightly accessible, with some public recreation use. There is no road access to the site. The site is approximately 250 miles from Anchorage, Alaska. The entire region is very sparsely populated. The closest community is Red Devil, which has 44 residents between 1-2.5 miles away. There is an unimproved dirt track leading to the site from the community of Red Devil. The next closest community is Sleetmute, 8 miles upstream, with no road access. Sleetmute has 103 residents. No other communities lie within 15 miles of the site (Alaska Department of Community and Regional Affairs, 1999). The communities of Parks and Eightmile were not in the database and are likely abandoned.

Warning signs and no trespassing signs have been posted at the site since about 1990. The trail/track leading to the community of Red Devil has been closed with a chain gate several times, only to have the chain stolen. Local residents are known to enter the site to scavenge construction materials from the building ruins.

Table 2. Waste Removal and Characterization Summary

Area of Concern		Quantity/Description of Material Removed
Battery Storage	5	EP-2 boxes/batteries
Transformer Areas		
Power Plant	1	55-gallon drum/used oil
Gravel Storage Pad	2	55-gallon drums/suspected PCB-contaminated transformer oil
	1	55-gallon drum/suspected non-PCB-contaminated transformer oil
Drum Areas		
Power Plant	13	55-gallon drums/used oil
	3	55-gallon drums/Stoddard solvent
Shop Pad	4	55-gallon drums/used oil
	3	55-gallon drums/grease
Near Retort Building		None
Retort Building	2	55-gallon drums/mercury-contaminated ash
	2	55-gallon drums/mercury-contaminated concrete
	3	Supersacks™/mercury-contaminated ash
	2	Supersacks™/mercury-contaminated PPE and debris
Chemical Storage	2	55-gallon drums/sodium dichromate dihydrate
	7	Supersacks™/potassium carbonate
	5	Supersacks™/chemical-contaminated soil and debris
	2	Supersacks™/sodium hydroxide
	2	55-gallon drums/copper sulfate

PCB Polychlorinated biphenyls
PPE Personal protective equipment

Table 3. Surface-Water Analytical Results

Analyte	Method	Unit	99SWRDMK03 Kuskokwim River Background 7/16/99 PR	99SWRDMK01 Kuskokwim River 1,100 ft Downstream 7/16/99 PR	99SWRDMK02 Kuskokwim River 550 ft Downstream 7/16/99 PR	99SWRDME04 Red Devil Creek Background 7/16/99 PR	99SWRDME01 Red Devil Creek Mouth 7/16/99 PR	99SWRDME02 Red Devil Creek Below Settling Ponds 7/16/99 PR	99SWRDME03 Red Devil Creek Below Settling Ponds 7/16/99 QC
Target Analyte List									
Aluminum	6010B	mg/L	**1.71**	1.76	1.48	**ND (0.111)**	ND (0.111)	0.185	ND (0.111)
Antimony	7041	mg/L	**ND (0.00556)**	ND (0.0556)	ND (0.00556)	**ND (0.00556)**	0.366	0.0754	0.0878
Arsenic	7060	mg/L	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	**ND (0.00556)**	0.116	0.0249	0.0303
Barium	6010B	mg/L	**0.0547**	0.0549	0.0508	**0.0232**	0.0298	0.0227	0.0227
Beryllium	7091	mg/L	**ND (0.000556)**	ND (0.000556)	ND (0.000556)	**ND (0.000556)**	ND (0.000556)	ND (0.000556)	ND (0.000556)
Cadmium	7131	mg/L	**ND (0.000556)**	ND (0.000556)	ND (0.000556)	**ND (0.000556)**	ND (0.000556)	ND (0.000556)	ND (0.000556)
Calcium	6010B	mg/L	**17.2**	17.3	17	**14.9**	16.2	14.2	14.1
Chromium	7191	mg/L	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	ND (0.00556)
Cobalt	6010B	mg/L	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	ND (0.0111)
Copper	6010B	mg/L	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	ND (0.0111)
Iron	6010B	mg/L	**3.49**	3.73	3.12	**0.0934**	0.089	0.106 J	ND (0.0556) J
Lead	7421	mg/L	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	ND (0.00556)
Magnesium	6010B	mg/L	**4.72**	4.73	4.59	**7.77**	10.4	7.61	7.59
Manganese	6010B	mg/L	**0.0832**	0.0877	0.0809	**ND (0.0222)**	ND (0.0222)	ND (0.0222)	ND (0.0222)
Mercury	7471	mg/L	**ND (0.000200)**	ND (0.000200)	ND (0.000200)	**ND (0.000200)**	0.00143	ND (0.000200)	0.000262
Nickel	6010B	mg/L	**ND (0.0222)**	ND (0.0222)	ND (0.0222)	**ND (0.0222)**	ND (0.0222)	ND (0.0222)	ND (0.0222)
Potassium	6010B	mg/L	**ND (5.0)**	ND (5.0)	ND (5.0)	**ND (5.00)**	ND (5.00)	ND (5.00)	ND (5.00)
Selenium	7740	mg/L	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	ND (0.00556)
Silver	7761	mg/L	**ND (0.00111)**	ND (0.00111)	ND (0.00111)	**ND (0.00111)**	ND (0.00111)	ND (0.00111)	ND (0.00111)
Sodium	6010B	mg/L	**2.04**	2.02	2.03	**1.53**	2.71	1.67	1.64
Thallium	7841	mg/L	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	**ND (0.00556)**	ND (0.00556)	ND (0.00556)	ND (0.00556)
Vanadium	6010B	mg/L	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	**ND (0.0111)**	ND (0.0111)	ND (0.0111)	ND (0.0111)
Zinc	6010B	mg/L	**ND (0.0222)**	ND (0.0222)	ND (0.0222)	**ND (0.0222)**	ND (0.0222)	ND (0.0222)	ND (0.0222)

ft Feet
mg/L Milligrams per liter
ND Not detected at or above the method detection limit in parentheses
PR Project sample
QC Quality control sample

Data Qualifiers:
J *Estimated concentration*

Notes:

Results highlighted with a box exceed background concentrations.
Background samples have been highlighted with bold text for reference.
All metal analyses results are presented. Samples collected from Red Devil Creek were also analyzed for volatile organic compounds, semivolatile organic compounds, and polychlorinated biphenyls/pesticides, which were not detected at or above the method detection limits.

Table 4. Sediment Analytical Results

Analyte	Method	Unit	99SDRDMK03	99SDRDMK01	99SDRDMK02	99SDRDME05	99SDRDME01	99SDRDME02	99SDRDME03	99SDRDME04
		Sample Location	**Kuskokwim River Background**	Kuskokwim River 1,100 ft Downstream	Kuskokwim River 550 ft Downstream	**Red Devil Creek Background**	Red Devil Creek Mouth	Red Devil Creek Below Settling Ponds	Red Devil Creek Below Settling Ponds	Red Devil Creek Below Settling Ponds
		Date Collected	**7/16/99**	7/16/99	7/16/99	**7/16/99**	7/16/99	7/16/99	7/16/99	7/16/99
		Sample Type	**PR**	PR	PR	**PR**	PR	PR	PR	QC
Target Analyte List										
Aluminum	6010B	mg/kg	**11,300**	6,790	10,500	**6,800**	5,680	8,420	6,650	8,490
Antimony	7041	mg/kg	**ND (0.303)**	7.78	ND (3.04)	**18.4**	238	618	963	809
Arsenic	7060	mg/kg	**7.1**	104	12.4	**61.8**	975	1,590	2,030	1,940
Barium	6010B	mg/kg	**164**	335	116	**125**	275	405	482	487
Beryllium	7091	mg/kg	**0.505**	0.215	0.399	**0.26**	0.712	0.922	0.963	1.01
Cadmium	7131	mg/kg	**0.399**	0.191	0.233	**0.315**	0.37	0.344	0.474	0.373
Calcium	6010B	mg/kg	**3,210**	2,070	3,330	**1,860**	3,150	6,340	3,360 J	6,790 J
Chromium	7191	mg/kg	**23.5**	15.3	24.2	**15.3**	18.8	24.9	18.8	24.3
Cobalt	6010B	mg/kg	**13.1**	8.55	7.87	**14.8**	16.5	14.2	10.5	11.4
Copper	6010B	mg/kg	**28.7**	22.3	13.5	**23.2**	40.4	49.6	40.9	47.3
Iron	6010B	mg/kg	**23,400**	31,800	22,600	**38,200**	35,500	32,700	28,400	31,800
Lead	7421	mg/kg	**8.37**	4.25	4.68	**7.76**	6.68	9.07	12.7	11.3
Magnesium	6010B	mg/kg	**4,820**	3,580	4,540	**2,220**	3,550	6,620	4,480 J	7,820 J
Manganese	6010B	mg/kg	**351**	1,190	406	**1,240**	1,120	711	584	769
Mercury	7471	mg/kg	**0.138**	55.5	0.185	**0.309**	166	48.4	292	399
Nickel	6010B	mg/kg	**30.3**	27	23.7	**35.5**	50.2	53.3	41.3	50.6
Potassium	6010B	mg/kg	**946**	874	747	**566**	1,670	2,100	2,030	1,880
Selenium	7740	mg/kg	**ND (0.303)**	ND (0.215)	ND (0.304)	**ND (0.230)**	0.243	ND (0.250)	ND (0.249)	ND (0.245)
Silver	7761	mg/kg	**0.074**	ND (0.0429)	ND (0.0608)	**0.13**	0.0963	0.0831	0.096	0.101
Sodium	6010B	mg/kg	**131**	89.1	113	**ND (49.2)**	127	214	181	199
Thallium	7841	mg/kg	**ND (0.303)**	ND (0.215)	ND (0.304)	**ND (0.230)**	0.636	0.296	0.304	0.333
Vanadium	6010B	mg/kg	**43**	28.8	30.3	**31.7**	21.5	24	20.1	26
Zinc	6010B	mg/kg	**82.7**	58	62.8	**87.2**	83.5	122	80.2	83.6

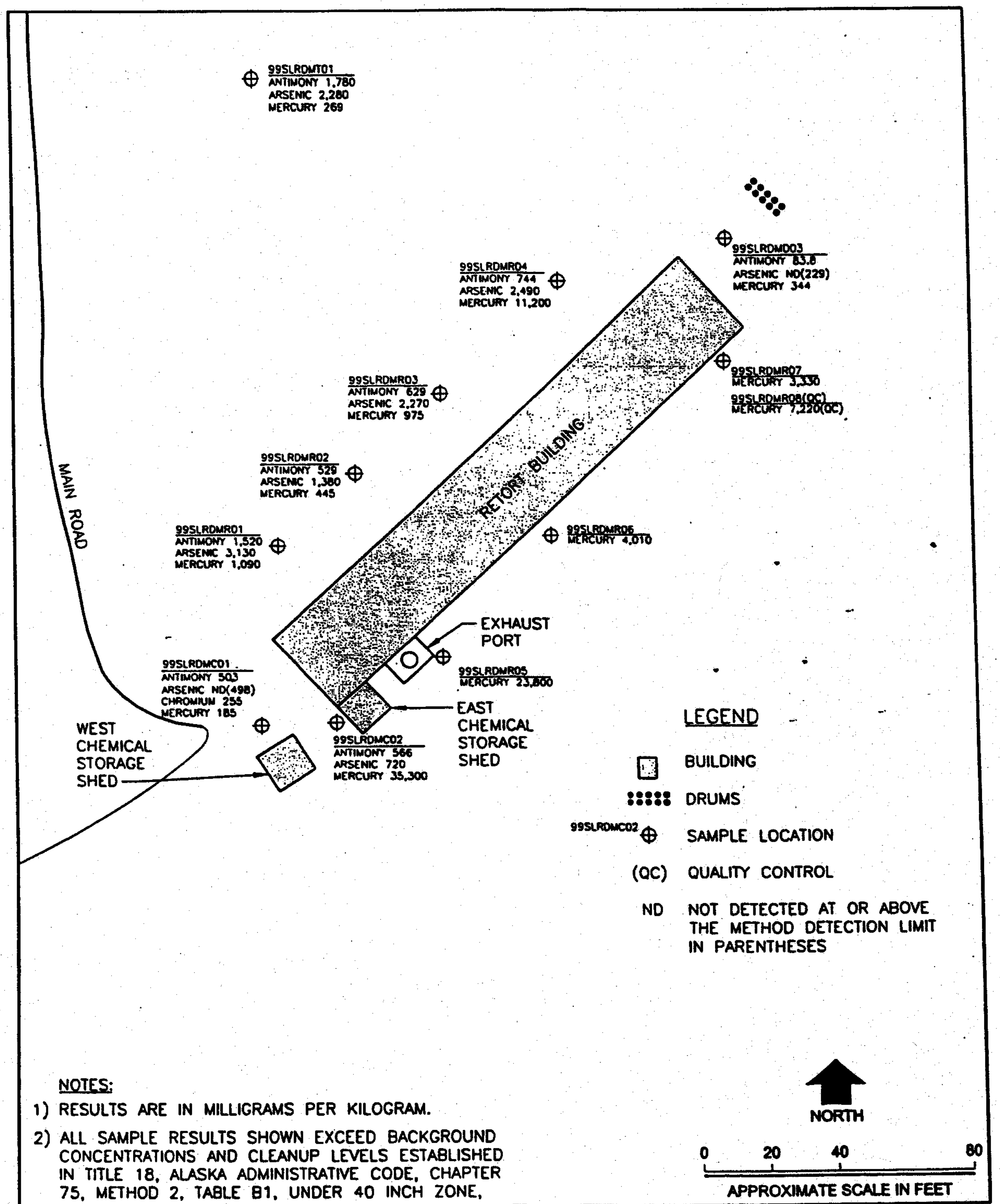
ft Feet
mg/kg Milligrams per kilogram
ND Not detected at or above the method detection limit in parentheses
PR Project sample
QC Quality control sample

Data Qualifiers:
J Estimated concentration

Notes:
Background samples have been highlighted with bold text for reference.
Results highlighted with a box exceed the background concentration.

Table 5. Soil Analytical Results

Analyte	Method	Regulatory Level[a]	Unit	99SLRDMG01	99SLRDMB01	99SLRDMB02	99SLRDMB03	99SLRDMR01	99SLRDMR02	99SLRDMR03	99SLRDMR04	99SLRDMR05	99SLRDMR06	99SLRDMR07	99SLRDMR08	99SLRDMT01
Sample Location				Background Soil	Battery Pile - Near Building A	Battery Pile - Near Building A	Battery Pile - Gravel Storage Pad	Transformer Drums West of Retort Building	West of Retort Building	West of Retort Building	West of Retort Building	East of Retort Building - Near Exhaust port Base	East of Retort Building - Middle	East of Retort Building - North End	East of Retort Building - North End	Tailings Pile - South of Settling Ponds
Date Collected				7/23/99	7/17/99	7/17/99	7/23/99	7/19/99	7/19/99	7/19/99	7/19/99	7/22/99	7/22/99	7/22/99	7/22/99	7/19/99
Sample Type				PR	PR	QC	PR	PR	PR	PR	PR	PR	PR	PR	QC	PR
Target Analyte List																
Aluminum	6010B	100,000[b]	mg/kg	10,300	NA	NA	NA	4,400	3,640	2,920	3,340	NA	NA	NA	NA	8,850
Antimony	7041	3.6	mg/kg	27.6	NA	NA	NA	1,520	529	629	744	NA	NA	NA	NA	1,780
Arsenic	7060	2	mg/kg	160	NA	NA	NA	3,130	1,380	2,270	2,490	NA	NA	NA	NA	2,280
Barium	6010B	1,100	mg/kg	44	NA	NA	NA	287	211	193	182	NA	NA	NA	NA	614
Beryllium	7091	1.9	mg/kg	0.22	NA	NA	NA	0.824	0.871	1.49	0.0745	NA	NA	NA	NA	1.14
Cadmium	7131	5	mg/kg	0.134	NA	NA	NA	0.54	0.584	0.55	0.368	NA	NA	NA	NA	0.463
Calcium	6010B	--	mg/kg	253	NA	NA	NA	5,630	2,620	3,190	3,290	NA	NA	NA	NA	6,790
Chromium	7191	26	mg/kg	12	NA	NA	NA	10.9	12.9	11.1	23.5	NA	NA	NA	NA	23.1
Cobalt	6010B	29,000[b]	mg/kg	2.61	NA	NA	NA	17.0	18.7	14.9	21.3	NA	NA	NA	NA	17.8
Copper	6010B	70,000[b]	mg/kg	8.31	NA	NA	NA	57.2	70.2	69.0	77.2	NA	NA	NA	NA	121
Iron	6010B	100,000[b]	mg/kg	12,000	NA	NA	NA	24,400	28,700	31,200	38,800	NA	NA	NA	NA	34,600
Lead	7421	1,000	mg/kg	6.79	13,500	10,700	1,080	12.6	48.5	55.3	900	NA	NA	NA	NA	13.8
Magnesium	6010B	--	mg/kg	712	NA	NA	NA	1,360	1,520	4,890	4,320	NA	NA	NA	NA	7,140
Manganese	6010B	45,000[b]	mg/kg	45.4	NA	NA	NA	746	733	748	719	NA	NA	NA	NA	551
Mercury	7471	1.4	mg/kg	3.49	NA	NA	NA	1,090	445	975	11,200	23,800	4,010	3,330	7,220	269
Nickel	6010B	87	mg/kg	5.83	NA	NA	NA	44.5	59.6	36.8	64.1	NA	NA	NA	NA	55.1
Potassium	6010B	--	mg/kg	ND (430)	NA	NA	NA	1,080	743	957	818	NA	NA	NA	NA	2370 J
Selenium	7740	3.5	mg/kg	ND (0.414)	NA	NA	NA	ND (0.242)	ND (0.197)	0.353	ND (2.09)	NA	NA	NA	NA	0.241
Silver	7761	21	mg/kg	0.142	NA	NA	NA	0.131	0.121	0.209	ND (0.0419)	NA	NA	NA	NA	0.164
Sodium	6010B	--	mg/kg	ND (95.5)	NA	NA	NA	67.7	ND (39.3)	56.3	55.5	NA	NA	NA	NA	ND (40.3)
Thallium	7841	140[c]	mg/kg	ND (0.414)	NA	NA	NA	ND (0.242)	ND (0.197)	ND (0.210)	0.280	NA	NA	NA	NA	0.358
Vanadium	6010B	710	mg/kg	17.6	NA	NA	NA	23.0	24.9	19.0	23.3	NA	NA	NA	NA	22.8
Zinc	6010B	9,100	mg/kg	13.8	NA	NA	NA	115	115	116	116	NA	NA	NA	NA	113
Mercury	TCLP 1311/7470	0.2[d]	mg/L	NA	NA	NA	NA	NA	NA	NA	0.0026	0.00835	NA	NA	NA	NA
TCL VOCs																
Benzene	8260	0.02	mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	8260	5.4	mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	8260	43	mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
p&m-Xylene	8260	78	mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA



Harding Lawson Associates/
Wilder Construction Company
Joint Venture

Selected Results for Samples Collected Near the Retort Building

Limited Waste Removal Action Report
Red Devil, Alaska

FIGURE 3

DRAWN	PROJECT NUMBER	APPROVED	DATE	FILE NAME
CEH	47411		10/99	47411a2.dwg

Site hydrogeology

This section includes a description of overlying materials (i.e., hydraulic conductivity/ permeability), thickness, composition and depth at which aquifer is first encountered. Specific published technical data is unavailable regarding underlying aquifers at this site. No aquifer studies have been done in this immediate area due to its remote location and relative inaccessibility. EPA's request for a site groundwater study was tentatively withdrawn based on available geologic and water quality information, and the high cost of well installation at this remote site. However, the following site geologic and regional hydrogeologic information is known.

The regional geology is dominated by a thick sequence of Cretaceous age sedimentary rocks of the Kuskokwim Group (MacKevett and Berg, 1963). The rock types at the mine consist of approximately 1300 feet of well-bedded graywacke strata and very fine-grained argillaceous rocks (shales). Regionally, these rocks yield 0-10 gallons per minute (gpm) of groundwater from tested wells (Selkregg, 1975). The hydraulic conductivity can be assumed to be similar to shale, ranging between 10^{-4} to 10^{-8} gpd/ft^2 (10^{-3} to 10^{-7} m/day), (Driscoll, 1995). Three hydrothermally altered dikes of silica-carbonate rock are exposed at the mine. The dikes strike N 50°-70° E and dip 40°-65° SE and vary in thickness from 1 to 14 ft. (MacKevett and Berg, 1963). These dikes will likely restrict horizontal groundwater flow.

The surficial deposits at the mine vary in depth from zero to an estimated thirty feet and consist of loess and alluvium (MacKevett and Berg, 1963). The deposits, as well as thousands of cubic yards of gravel-like tailings, have been reworked by mine operators to build roads, building sites, ponds, and to process and dispose of ore. Regionally, these deposits yield 10-100 gpm (Selkregg, 1975). The hydraulic conductivity will likely vary widely, similar to coarse gravel to loess, which ranges between 10^6 to 10^{-3} gpd/ft^2 (10^5 to 10^{-4} m/day), (Driscoll, 1995).

Well information gathered from owners in the community of Red Devil indicated two water bearing zones with unknown connectivity (Gail Vanderpoole and Richard Wilmarth, oral commun., 1999). A surficial aquifer, with a water table 24-26 ft. below ground surface (bgs), is most commonly used. It consists of silt to sand-size sediment. The flow rate from these wells is reportedly low, but can supply enough water for a single family residence. The lower aquifer, in which wells are screened between 80-90 feet bgs, consists of clean gravels, and produces enough water to supply the school and multiple families.

The Red Devil community lies 1 to 2.5 miles from the site. Although it is very unlikely that the community's saturated zones are hydraulicly connected to the site, it is reasonable to assume their alluvial and aeolian sediments have similar groundwater flow characteristics due to their common origin. Furthermore, the topographic differences in the site and the community will limit similarities such as sediment depth and areal extent. The site has relatively steep terrain with bedrock outcrops, whereas the community is on a relatively flat depositional plain.

The Red Devil Creek, is at least in part, an influent stream, as evidenced by a feeder spring several feet above the Creek. Correlating the spring to topography, the site's water table is similar to the surficial aquifer described above, or roughly between 20-30 ft. bgs.

Another important consideration affecting the site's hydrogeology are the extensive shafts and tunnels that extend down to 450 ft. bgs, and horizontally at least 1,400 ft.(N 26° W) x 600 ft (N 64° E), (MacKevett and Berg, 1963). Although the mine surface entrances are slumped closed and restrict visual inspection, it is reasonable to assume that most, if not all, of the mine workings (shafts and tunnels) are flooded, based on the afore mentioned spring and the regional groundwater levels. These workings will likely function as conduits for groundwater flow.

Drinking water wells near the site

There are no wells within a 1-mile radius of the site. There are wells between 1- and 4-miles of the site in the community of Red Devil. No well log information for these wells is known to exist. BLM checked federal (USGS), State, and local offices to confirm this. By interviewing the local population of Red Devil, BLM learned the following about local wells:

Table 6. Wells within four miles of site

Owner/location[1]	Depth (ft bgs[2])	Population served	Well type
Gail Vanderpool	28	single family	2" drive point
Richard Wilmarth	34	single family	2" drive point
Red Devil School[3]	85	25 (estimate)	6" drilled
Paul Kinegak	~30	single family	2" drive point

1. All listed wells are within the community of Red Devil, which is between 1- and 2.5-miles from the site. Well locations are at each of the private homes listed and at the school. No map coordinates are available.
2. bgs: below ground surface.
3. Used by school children and local population without wells. Tested monthly by Kuspuk School District.

No additional information was available for screen interval, depth of aquifer, or average annual pumpage. No standby wells were found. There are several temporarily abandoned wells at private residences that are not used because of poor water quality or low water production. The Red Devil School well is the only known well currently using the lower aquifer. The water from the well at the Red Devil School is reportedly of good quality and is analyzed monthly by the Kuspuk School District (Kuspuk School District maintenance staff, oral commun., 1999). Local residents who don't have a well, haul water from the school well. Another local well screened in the lower aquifer was temporarily abandoned due to excessively high iron content in the water (Richard Wilmarth, oral commun., 1999).

In response to an EPA question, no wells within 4-miles are used for the following specific purposes: a) to irrigate 5 or more acres of commercial food or forage crops, b) for watering of commercial livestock, c) as an ingredient in commercial food preparation, d) as a supply to aquaculture, or e) as a supply for a major or designated water recreation area, excluding drinking water use. None of these activities are known to exist within 4 miles of the site.

Surface water

Surface water constitutes a major contaminant transportation mechanism at any site, and is therefore evaluated closely. Surface water bodies located within two miles of the Red Devil Mine include the Kuskokwim River and its tributaries (Red Devil Creek, McCally Creek, Cribby Creek); oxbow lakes; and smaller unnamed creeks fed by runoff from Barometer Mountain, surrounding highlands, and ridges (Figure 1). The average annual flow for the Kuskokwim River below the Red Devil Mine is 38,890 ft^3/sec (Wang, 1999). Water discharge from Red Devil Creek is 1.16 ft^3/sec (Bureau of Land Management, unpub. data, 1999). The Red Devil Creek drainage basin is 687 acres (Bureau of Land Management, unpub. data, 1999). The Kuskokwim River drainage basin below the Red Devil Mine is 18.82 million acres (Wang, 1999).

There are no known drinking water intakes within 15 miles downstream of the site. It is unlikely that water from the Kuskokwim River is used for drinking water purpose in this vicinity due to its high suspended sediment load. Water would need to be filtered and boiled (or otherwise treated) to be potable. It is much more likely that individual households that do not have wells collect water from small creeks, since these sources have a lower sediment content and are less likely to be contaminated by human activities. Some residents in Red Devil haul water from the school well.

The largest communities down river are Aniak and Bethel. They are about 80 and 180 miles down river, with populations of 604 and 5,471, respectively. These communities do not use river water for drinking water purposes (Alaska Department of Community and Regional Affairs, 1999) .

In response to an EPA question, there are no known intakes within 15 miles downstream (rivers, streams, etc.) or within a 15-mile radius (lakes, bays, etc.) that are used: a) to irrigate 5 or more acres of commercial food or forage crops, b) for watering of commercial livestock, c) as an ingredient in commercial food preparation, d) as a supply for aquaculture, or e) as a supply for a major or designate water recreation area, excluding drinking water use.

Food chain

EPA requires the analysis of fisheries in the vicinity of contaminated sites to help determine the risk involved in contaminant transport through the food chain and the subsequent consumption of the contaminants by humans. The average annual human food chain production of surface water bodies within 15 miles downstream is 9.06 pounds/acre.

The surface water body within 15 miles downstream is the Kuskokwim River. It covers 2,640 acres. The average annual weight of fish harvested is 23,928 pounds. This number was calculated from published and unpublished data received from the Alaska Department of Fish and Game (Burkey and others, 1998; Mike Coffing, oral commun., 1999). It includes all available data for fish harvest in this area. Counted fish include Chinook, Sockeye, Coho, and Chum salmon. Uncounted fish known to be harvested in the Kuskokwim River include resident fish: Whitefish, Grayling, Sheefish, Dolly Varden, and Pike.

While no data is available for resident fish, several other factors may balance out the use of the calculated number. Salmon do make up the majority of the fish harvested and consumed by weight. Some of the salmon (especially Chum), although harvested, are not consumed by humans, but are often fed to dogs. Salmon are anadromous, meaning they spend only a fraction of their life in fresh waters, and most of their life in the ocean.

Studies of fish in the Kuskokwim watershed have shown detectible levels of mercury in fish (Duffy, Rodgers, and Patton, 1998; Gray and others, 1996). Resident and anadromous fish collected in tributaries of the Kuskokwim River contained up to 0.62 and 0.08 ppm Hg, respectively (Gray and others, 1996). The Food and Drug Administration action level for mercury advisories is 1 ppm, while EPA uses 0.2 ppm as a hazard assessment model human critical value threshold. These studies clearly indicate that mercury levels in fish is a regional phenomenon, verses a site specific phenomenon. This is due to the regional geology, which is naturally abundant in mercury and other metals. Mining activities have further liberated these metals into the water systems.

<u>Soils</u>

The texture of soil controls the rate in which water and contaminants can pass through them and into ground- and surface-waters. Moderately fine-textured soils with low infiltration rates (silt loam) are found in both the Red Devil Creek drainage area, and the Kuskokwim River Drainage area (Tolbert and Sprouse, 1964).

<u>Precipitation and flooding</u>

Precipitation can flush contaminants from a site. There are no official weather stations in the immediate vicinity of Red Devil. However, climatological studies have been completed that include this area. Site data from these studies can be extrapolated from climatological maps included in these reports. The two-year, 24-hour rainfall for the Red Devil Mine is approximately 1.5 inches (Miller, 1963). The annual net precipitation for the Red Devil Mine is approximately 25 inches (Jones and Fahl, 1994).

The flood plain category for each source must be determined from Federal Emergency Management Agency or U.S. Army Corps of Engineers flood plain maps. There is no known evidence of source flooding. There are no Federal Emergency Management Agency or U.S. Army Corps of Engineers (ACE) flood plain maps for this area (Harlan Legare, U.S. Army Engineer District, Alaska, oral and written commun., 1999). However, ACE installed a flood gauge in the community of Red Devil, which indicated the highest recorded flood level was 212.84 feet in 1971. The lowest elevation at the site is approximately 279 feet, a difference of approximately 66 feet. There is no containment at the source.

Sensitive Environments/wetlands

EPA requests identification of all Sensitive Environments that exist within a 4-mile radius on land, 15 miles downstream (rivers, streams, etc), or 15 mile radius (lakes, bays, etc). Sensitive Environments are defined as: a wetland (as defined in 40 Code of Federal Regulations (CFR)) or any area that meets the criteria listed in the HRS tables (U.S. Environmental Protection Agency, 1992).

From EPA tables, the site has the following Sensitive Environments:
1. Spawning areas critical for the maintenance of fish/shellfish species within river, lake, or coastal waters.
2. Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal waters in which the fish spend extended periods of time.

Fish found in this stretch of the Kuskokwim River include: Chinook, Sockeye, Coho, and Chum salmon; Whitefish, Grayling, Sheefish, Dolly Varden, and Pike. (Mike Coffing, Alaska Department of Fish and Game, oral commun., 1999; Van Waggoner, Bruce Seppi, Jeff Denton, Bureau of Land Management, oral commun., 1999).

All the above sources, as well as representatives from the U.S. Fish and Wildlife Service (oral commun., Gary Wheeler, Nov 2, 1999), and Natural Heritage Database (Julie Michaelson, oral and written commun., 1999) confirmed there are no recognized threatened or endangered species within 15 miles of the site. No other Sensitive Environment categories from EPA tables apply to this site.

The linear frontage (miles) of all wetlands 15 miles downstream (rivers, streams, etc) or 15-mile radius (lakes, bays, etc) are requested by EPA. The downstream linear frontage of wetlands within 15 miles downstream of the site is 7.7 miles. This number was determined from U.S. Fish and Wildlife Service National Wetlands Inventory maps. Figure 4 shows this map within 4 miles of the site. Only small portions of this area has been mapped as wetlands by the U.S. Fish and Wildlife Service.

The entire river bank generally does not fit EPA's definition of a wetland, that being a marsh, bog, swamp (U.S. Environmental Protection Agency, 1991, page 133). However, the river banks do experience fluctuations in water levels, and thus water coverage, due to precipitation and seasonal discharge fluctuations.

EPA evaluates the location and area (in acres) of all wetlands within 4 miles of the site. See Figure 4 for wetland locations. No wetlands are on the site. Based on the U.S. Fish and Wildlife map, less than 5% of the land within 4 miles of the site is classified as wetlands. This computes to <1,609 acres per 50.26 mi^2.

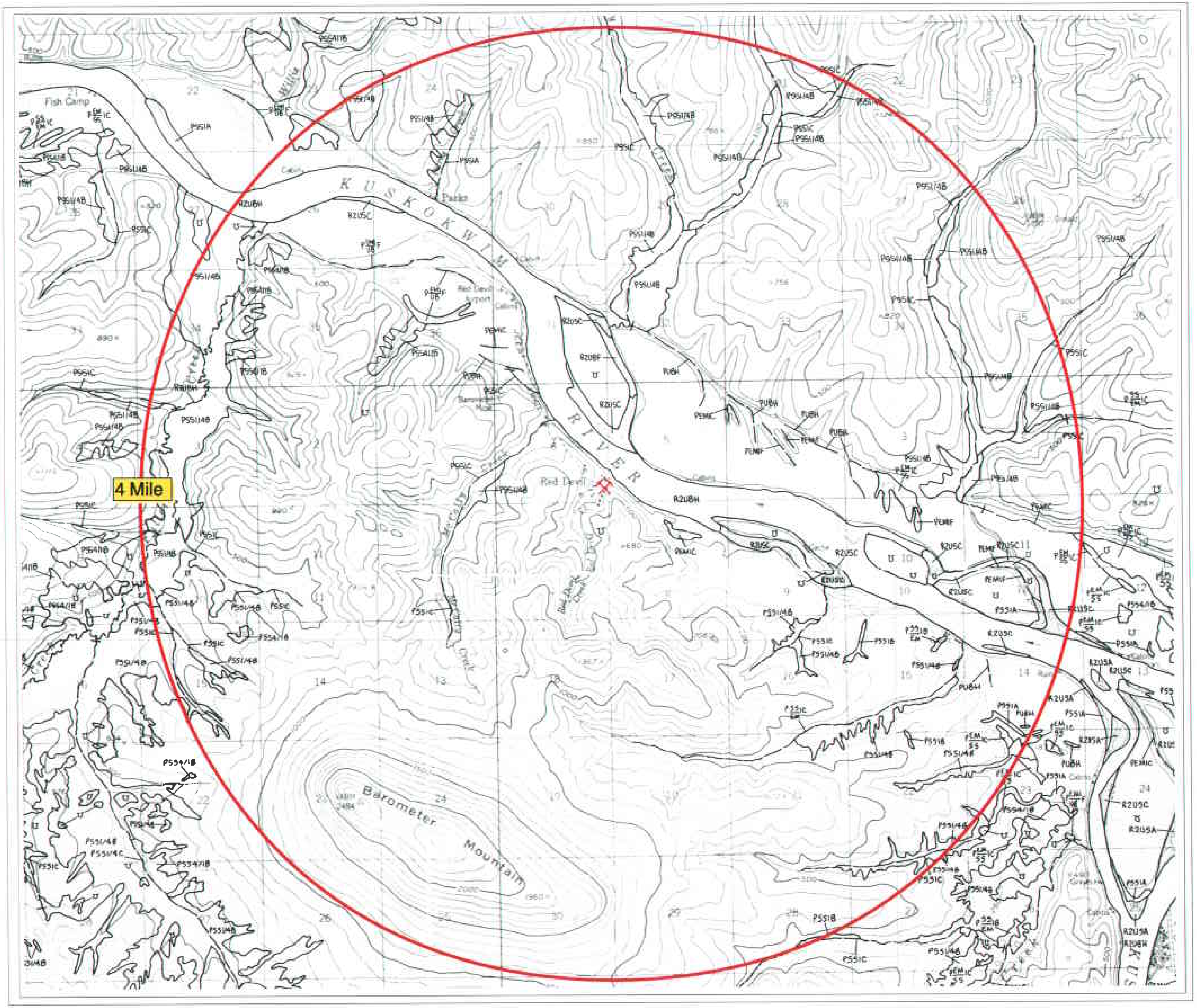


Figure 4. National Wetlands Inventory

Red Devil Mine and
vicinity within 4 miles

Red Devil Mine Site

4 Mile Radius

1 0 1 Miles

Contour Interval: 100 ft.

N S E W

This map was created from scanned U.S. Fish and Wildlife Service NWI (National Wetlands Inventory) 1:63k maps Sleetmute C-4 and D-4. The 4 mile boundary was created using ArcView 3.0b. The scanned image was not georectified and should only be used as a general reference.

Figure 4a. Classification Scheme for National Wetlands Inventory.

AERIAL PHOTOGRAPHY

DATE	SCALE	TYPE
7 / / 80	1:66 000	CIR
7 / / 80	1:120000	B - W
6 / / 78	1:120000	B-W

U Primarily represents **upland** areas, but may include unclassified wetlands such as man-modified areas, non photo-identifiable areas and/or unintentional omissions.

E — ESTUARINE (SYSTEM)

1 — SUBTIDAL (SUBSYSTEM)

RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	RF — REEF	OW — *OPEN WATER/ Unknown Bottom*
1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Submergent Vascular 3 Rooted Vascular 4 Floating-Leaved Vascular 5 Floating Vascular 6 *Unknown Submergent* 7 *Unknown Surface*	2 Mollusc 3 Worm	

2 — INTERTIDAL (SUBSYSTEM)

AB — AQUATIC BED	RF — REEF	SB — STREAMBED	RS — ROCKY SHORE	FL — FLATS	BB — BEACH/BAR	US — UNCONSOLIDATED SHORE	EM — EMERGENT	SS — SCRUB-SHRUB	FO — FORESTED
1 Algal 2 Submergent Vascular 3 Rooted Vascular 4 Floating-Leaved Vascular 5 Floating Vascular 6 *Unknown Submergent* 7 *Unknown Surface*	2 Mollusc 3 Worm	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Cobble-Gravel 2 Sand	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Persistent 2 Nonpersistent 5 Narrow-Leaved Persistent	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*

CLASS

Subclass

L — LACUSTRINE (SYSTEM)

1 — LIMNETIC (SUBSYSTEM)

RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	OW — *OPEN WATER/ Unknown Bottom*
1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Submergent Vascular 3 Rooted Vascular 4 Floating-Leaved Vascular 5 Floating Vascular 6 *Unknown Submergent* 7 *Unknown Surface*	

2 — LITTORAL (SUBSYSTEM)

RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	RS — ROCKY SHORE	FL — FLATS	BB — BEACH/BAR	US — UNCONSOLIDATED SHORE	EM — EMERGENT	OW — *OPEN WATER/ Unknown Bottom*
1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Submergent Vascular 3 Rooted Vascular 4 Floating-Leaved Vascular 5 Floating Vascular 6 *Unknown Submergent* 7 *Unknown Surface*	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Cobble-Gravel 2 Sand	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

CLASS

Subclass

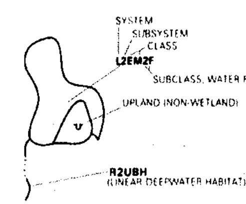
MODIFIERS

In order to more adequately describe wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy.

WATER REGIME: Non-Tidal		WATER REGIME: Tidal		WATER CHEMISTRY: Coastal Halinity	WATER CHEMISTRY: Inland Salinity	WATER CHEMISTRY: pH Modifiers for all Fresh Water	SOIL	SPECIAL MODIFIERS	
A Temporarily Flooded B Saturated C Seasonally Flooded D *Seasonally Flooded/ Well Drained* E *Seasonally Flooded/ Saturated* F Semipermanently Flooded G Intermittently Exposed	H Permanently Flooded J Intermittently Flooded K Artificially Flooded W Intermittently Flooded/Temporary Y Saturated/Semipermanent/ Seasonal Z Intermittently Exposed/Permanent U *Unknown*	K *Artificially Flooded* L Subtidal M Irregularly Exposed N Regularly Flooded P Irregularly Flooded	*S Temporary-Tidal *R Seasonal-Tidal *T Semipermanent-Tidal *V Permanent-Tidal U *Unknown*	1 Hyperhaline 2 Euhaline 3 Mixohaline *(Brackish)* 4 Polyhaline 5 Mesohaline 6 Oligohaline 0 Fresh	7 Hypersaline 8 Eusaline 9 Mixosaline 0 Fresh	a Acid t Circumneutral i Alkaline	g Organic n Mineral	b *Beaver* d *Partially Drained/Ditched* f Farmed	h *Diked/Impounded* r Artificial Substrate s *Spoil* x Excavated

*These water regimes are only used in tidally influenced, freshwater systems.

SYMBOLOGY EXAMPLE



U Primarily represents **upland** areas, but may include unclassified wetlands such as man-modified areas, non photo-identifiable areas and/or unintentional omissions.

Figure 4b. Classification Scheme for National Wetlands Inventory.

SYSTEM: M — MARINE

SUBSYSTEM: 1 — SUBTIDAL

- CLASS: RB — ROCK BOTTOM
  - Subclass: 1 Bedrock; 2 Rubble
- CLASS: UB — UNCONSOLIDATED BOTTOM
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
- CLASS: AB — AQUATIC BED
  - Subclass: 1 Algal; 2 Submergent Vascular; 3 Rooted Vascular; 4 Floating-Leaved Vascular; 6 *Unknown Submergent*; 7 *Unknown Surface*
- CLASS: RF — REEF
  - Subclass: 1 Coral; 3 Worm
- CLASS: OW — *OPEN WATER/ Unknown Bottom*

SUBSYSTEM: 2 — INTERTIDAL

- CLASS: AB — AQUATIC BED
  - Subclass: 1 Algal; 2 *Submergent Vascular*; 3 Rooted Vascular; 4 Floating-Leaved Vascular; 6 *Unknown Submergent*; 7 *Unknown Surface*
- CLASS: RF — REEF
  - Subclass: 1 Coral; 3 *Worm*
- CLASS: RS — ROCKY SHORE
  - Subclass: 1 Bedrock; 2 *Rubble*
- CLASS: FL — FLATS
  - Subclass: 1 Cobble-Gravel; 2 *Sand*; 3 Mud; 4 Organic; 5 Vegetated
- CLASS: BB — BEACH/BAR
  - Subclass: 1 Cobble-Gravel; 2 Sand
- CLASS: US — UNCONSOLIDATED SHORE
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated

SYSTEM: R — RIVERINE

SUBSYSTEM: 1 — TIDAL; 2 — LOWER PERENNIAL; 3 — UPPER PERENNIAL; 4 — INTERMITTENT; 5 — *UNKNOWN PERENNIAL*

- CLASS: RB — ROCK BOTTOM
  - Subclass: 1 Bedrock; 2 Rubble
- CLASS: UB — UNCONSOLIDATED BOTTOM
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
- CLASS: *SB — STREAMBED
  - Subclass: 1 Bedrock; 2 Rubble; 3 Cobble-Gravel; 4 Sand; 5 Mud; 6 *Organic*; 7 Vegetated
- CLASS: AB — AQUATIC BED
  - Subclass: 1 Algal; 2 Submergent Vascular; 3 Rooted Vascular; 4 Floating-Leaved Vascular; 5 *Floating Vascular*; 6 *Unknown Submergent*; 7 *Unknown Surface*
- CLASS: RS — ROCKY SHORE
  - Subclass: 1 Bedrock; 2 Rubble
- CLASS: FL — FLATS
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- CLASS: BB — BEACH/BAR
  - Subclass: 1 Cobble-Gravel; 2 Sand
- CLASS: US — UNCONSOLIDATED SHORE
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- CLASS: **EM — EMERGENT
  - Subclass: 2 Nonpersistent
- CLASS: OW — *OPEN WATER/ Unknown Bottom*

*STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM

**EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS.

SYSTEM: P — PALUSTRINE

- CLASS: RB — ROCK BOTTOM
  - Subclass: 1 Bedrock; 2 Rubble
- CLASS: UB — UNCONSOLIDATED BOTTOM
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
- CLASS: AB — AQUATIC BED
  - Subclass: 1 Algal; 2 Submergent Vascular; 3 Rooted Vascular; 4 *Floating-Leaved Vascular*; 5 Floating Vascular; 6 *Unknown Submergent*; 7 *Unknown Surface*
- CLASS: FL — FLATS
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- CLASS: US — UNCONSOLIDATED SHORE
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- CLASS: ML — MOSS-LICHEN
  - Subclass: 1 Moss; 2 Lichen
- CLASS: EM — EMERGENT
  - Subclass: 1 Persistent; 2 Nonpersistent; 5 Narrow-Leaved Persistent
- CLASS: SS — SCRUB-SHRUB
  - Subclass: 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 *Deciduous*; 7 *Evergreen*
- CLASS: FO — FORESTED
  - Subclass: 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 *Deciduous*; 7 *Evergreen*
- CLASS: OW — *OPEN WATER Unknown Bottom*

Terrestrial sensitive environments
Terrestrial sensitive environments are defined as: a terrestrial resource, fragile natural setting, or other area with unique or highly-valued environment or cultural features (U.S. Environmental Protection Agency, 1991). The Red Devil Mine site does not have any terrestrial sensitive environments as described by EPA. U.S. Fish and Wildlife Service, Natural Heritage Database, Alaska Department of Fish and Game were consulted (Gary Wheeler, oral commun., 1999; Julie Michaelson, oral and written commun., 1999; Mike Coffing, oral and written commun., 1999; Van Waggoner, Bruce Seppi, Jeff Denton, Bureau of Land Management, oral commun., 1999) . All sources indicated this site does not have sensitive environments as defined. This site was analyzed for impacts to threatened and endangered species due to a removal action completed in 1999 during a National Environmental Policy Act (NEPA) Environmental Assessment (EA) (EA#: AK-040-99-013). No impacts were found.

Air quality
EPA requests information on air quality of hazardous waste sites. EPA uses the term "gas containment" to categorize the air emissions, or the control of those emissions. Ambient air quality at the site is good. Air quality at the site has been monitored with a mercury vapor monitor and a Photo Ionization Detector to monitor for mercury and Volatile Organic Compounds. Both measures indicated the air quality was within Permissible Exposure Limits for site workers. Air quality in the immediate work area was temporarily degraded when mercury contaminated soot was shoveled into disposal containers during the removal action. This degradation was primarily from particulate aeration.

From an EPA table, air emission source types at the site include: 1) Contaminated soil, and 2) Pile: tailings pile, and other waste piles. The primary site contaminant is mercury. Other contaminants include: antimony, arsenic, lead and asbestos. All containerized waste has been removed from the site. See HLA/Wilder JV (1999). Site particulate containment description: no containment.

Site Investigation summary
The primary threat to off-site receptors may be from the bioaccumulation of mercury in fish and the subsequent consumption of the fish by humans. Current on-site hazards include the possibility of direct contact and contamination with mercury, antimony, arsenic, and lead.

3. Review of Engineering Evaluation/Cost Analysis

Harding Lawson Associates (HLA/Wilder JV, 2000), a BLM contractor, completed an Engineering Evaluation/Cost Analysis (EE/CA) under direction of, and with input from BLM. Other information evaluated for this analysis included additional literature resources and input from Federal and State regulatory agencies (EPA, ADEC). The summation of this information is used to determine or recommend the most appropriate solution to remediating the site.

Review of site characterization

The EE/CA documents the current level of site characterization, similarly to that presented above. This includes site description, background, previous removal actions, source, nature and extent of contamination; and analytical data.

Streamline risk evaluation

Risk has not been quantified for this site. However, risk can be evaluated based on known media contaminant levels (sources), receptors (humans or ecology), and pathways. The following risk factors can be determined or expected:

Human Health Risk: Risk to human health offsite is low. A possible contaminant pathway to humans offsite is through the bioaccumulation of mercury in fish, and the consumption of the fish by humans (see discussion of food chain above). Area mercury-in-fish studies indicate the fish in the entire watershed have detectible, yet not toxic levels of mercury due to the regional geology and associated mining activities (Duffy, Rodgers, and Patton, 1998), (Gray and others, 1996).

Human health risk onsite may be high for some activities. Although the site is posted, it is known that humans visit the site, so some onsite risk to humans can be established. If humans disturb certain site soils and sediments, they could be exposed to mercury through inhalation, ingestion, and dermal absorption.

Ecological Risk: Ecological risk onsite may be high in specific areas. Again, while no ecological risk studies have been done, it appears that elevated levels of mercury may be impacting the soils in the vicinity of the retort building. Impacted soils affect soil micro- and macro-invertebrates, which may affect higher species that come in contact with soils or lower species. Little to no vegetation has grown in the vicinity of the retort building since the operation ceased nearly 30 years ago.

Identification of objectives

The EE/CA identifies the regulatory statutes that apply to the contaminants of concern at the site. The soils surrounding the retort building have high levels of mercury, antimony, and arsenic, and any disposal options will be influenced by whether the soils are classified as hazardous or nonhazardous (solid) waste. The Resource Conservation and Recovery Act (RCRA) states that materials will be classified as solid waste if a representative sample of the material passes a Toxicity Characteristic Leaching Procedure (TCLP). Basically, TCLP entails the analysis of water that is flushed through a material to determine how chemicals will leach from the material. In order for a soil sample to pass, analytical results for mercury must be less than 0.2 mg/L. If the results are higher than 0.2 mg/L, the soils are hazardous waste. Hazardous waste containing mercury over 260 mg/kg are "high level" wastes, and must be retorted before disposal by landfilling. The retorting process removes the mercury from the materials. Hazardous waste are classified as "low level" if they contain 260 mg/kg or less mercury, and must be stabilized and disposed of by landfilling. The State of Alaska regulates solid waste. Contaminated soils classified as solid waste may be disposed of in a permitted Solid Waste Landfill. Two samples with the highest concentration of mercury (11,200 and 23,800 mg/kg) were analyzed for TCLP mercury. Both samples passed because they did not exceed the 0.2 mg/L mercury concentration.

The goal of the EE/CA is to determine options to deal with the known environmental contamination to reduce the risk associated with the site. The following tasks will need to be completed to meet this goal:

1. Demolish and dispose of the retort building to remove the associated mercury contamination.
2. Further characterize the soils in the vicinity of the retort building; sampling and analysis must be completed to determine the horizontal and vertical extent of the contamination.
3. Determine the best method to remove, treat, and or dispose of the contaminated soils.

<u>Identification and analysis of removal action alternatives</u>

The overall assumptions for the remedial alternatives include: (1) the volume of contaminated soil used to calculate costs is 7,000 cubic yards and (2) alternatives 1-5 assume soils pass TCLP test; other assumptions are listed in Table 7.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Section 121 and the National Contingency Plan (NCP) provide nine criteria to compare remedial alternatives. The nine criteria are subdivided into three categories: (1) threshold criteria, which relate directly to statutory findings and must be satisfied by each chosen alternative; (2) primary balancing criteria, which include technical factors such as the long- and short-term effectiveness, implementability, reduction of toxicity, mobility, and volume and cost; and (3) modifying criteria, which are measures of the acceptability of the alternatives to state agencies and the community.

<u>The nine criteria are</u>:

1. Protection of human health and environment
2. Compliance with applicable or relevant and appropriate requirements (ARARs)
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume
5. Short-term effectiveness

6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

These criteria are used to analyze each alternative in Table 8, based on the current information available for this site. In reference to criteria eight and nine, none of the alternatives have yet been presented, so have not been accepted or denied by the state or the public. Specific definitions for each criteria are found in Title 40 of the U.S. Code of Federal Regulations (CFR), Section 300.430.

Table 7. Red Devil Mine - Retort Building Contaminated Soil Engineering Evaluation / Cost Analysis Cost Estimates

Alternative	Task	Cost
1	Stabilize surface soil and leave in situ	$790,000
2	Excavate and dispose in onsite solid waste landfill	$1,633,000
3	Excavate and dispose in offsite solid waste landfill	$13,393,000
4	Excavate, stabilize and dispose in onsite solid waste landfill	$3,463,000
5	Excavate, retort and dispose in onsite solid waste landfill	$2,933,000
6	Excavate and transport to hazardous waste treatment and disposal facility	$43,853,000

Notes:
1. Alternatives include retort building demolition, with construction and debris (C & D) monofill disposal, cost: $393,000.
2. Retort building demolition, onsite temporary storage of debris, then C& D monofill disposal cost: $592,000. (2 separate mobilizations)
3. Cost to construct onsite solid waste landfill: $1,020,000.

Assumptions:
1. Costs are rough order of magnitude estimates for comparison purposes and are not actual estimates to complete work.
2. The volume of contaminated soil used to calculate costs is 7,000 cubic yards.
3. Cost for site characterization and assessing regulatory status of contaminated soil is not included in estimates.
4. Disposal and or resale of recovered mercury in alternative 6 is not included in the cost.
5. For alternatives 1 - 5, the soil is presumed to pass the Toxicity Characteristic Leachate Procedure (TCLP) test.
6. For alternative 6, the soil is presumed to fail the TCLP test.
7. The site is barge accessible for mobilization/demobilization.

Reference: HLA/Wilder JV, 2000

Table 8. Summary of Comparative Analysis of Engineering Evaluation / Cost Analysis Alternatives

	Criteria[1] / Alternatives:	1 Stabilize/In Situ	2 Onsite SWLF[2]	3 Offsite SWLF	4 Stabilize, onsite SWLF	5 Retort, onsite SWLF	6 Hazardous waste TSDF
1	Protection of human health, environment	low	high	high	high	high	high
2	Comply with ARARs[3]	no	yes	yes	yes	yes	yes
3	Long-term effectiveness	low	high	high	high	high	high
4	Reduces toxicity, mobility, volume	medium	high	high	high	high	high
5	Short-term effectiveness	medium	high	high	high	high	high
6	Implementability	low	high	medium	low	medium	medium
7	Cost[4]	$790,000	$1,633,000	$13,393,000	$3,463,000	$2,933,000	$43,853,000
8	State acceptance	unknown	unknown	unknown	unknown	unknown	unknown
9	Community acceptance	unknown	unknown	unknown	unknown	unknown	unknown

1. Reference: U.S. Code of Federal Regulations, Title 40, Section 300.430
2. SWLF: Solid Waste Landfill
3. ARARs: Applicable, Relavent, and Appropriate Requirements
4. Estimate rounded to nearest thousand, based on soil voume of 7,000 yds^3

Alternative 1, Stabilize surface soil and leave in situ

In this option, only the surface soils are treated, with the lower soils left as is. The upper soils would be excavated and chemically treated to bind the metals in the soil matrix. Alternative 1 is the least expensive alternative noted in the EE/CA, at a cost of $790,000. Cost is an important factor because if the project is prohibitively expensive, then it will not be started until the cost can be brought within budget or additional funding is found. However, this option may not be acceptable due to regulatory constraints and technical feasibility.

At least two stabilization processes are known; the first, Maectite, a registered trade name for a proprietary chemical stabilizer, has been successfully used to stabilize metals in soils. However, Maectite is not known to have been used to stabilize mercury contaminated materials. Information available indicates the primary use of this product is to stabilize lead in soils, with concentrations up to 6,500 mg/kg (Sevenson Environmental Services, Inc., 2000). Mercury is a metal with unique properties that may make its stabilization more complex. Mercury is liquid metal, with a melting point of -38.87 degrees Celsius (Weast, 1976). It vaporizes readily under ambient temperatures and atmospheric pressures (U.S. Environmental Protection Agency, 1997). Bench scale tests are needed to prove this technology.

Another chemical stabilizer is Sulfur Polymer Cement (SPC). SPC was developed by the U.S, Department of Energy, specifically to stabilize radioactive and mercury contaminated materials (Kalb and others, 1998). This process combines the mercury with sulfur and forms a cement. This form is very stable, does not leach, and is not toxic. In essence, it returns the mercury to its pre-mining process form: HgS (cinnabar). Unfortunately, this technology is still in an experimental stage. It has been proven in small-scale laboratory tests, but is not currently available due to pending process licencing. Furthermore, mercury concentrations at the Red Devil Mine almost double those of the materials tested with this technology (35,000 vs. 18,000 mg/kg). When this technology does come available, bench-scale feasibility studies would need to be completed.

Another possible problem with using this alternative is regulatory acceptance. Under this alternative, the stabilized mercury will be left in-place, and un-stabilized subsoils will remain in-place and untreated. Solid waste regulations require mercury contaminated soils to be disposed of in a permitted solid waste landfill (SWLF). This alternative may not be protective of human health and the environment.

Alternative 2, Excavate and dispose in onsite solid waste landfill

Alternative 2, excavate, dispose in onsite solid waste landfill, involves the excavation of soils, and the design, permitting, construction and monitoring of a landfill at the mine site. The estimated cost is $1,633,000, or approximately double the cost for alternative 1. Currently, this option appears to be the best alternative. It is both technically feasible and will satisfy regulatory requirements for disposal of mercury contaminated soils, and is protective of human health and the environment. Several assumptions must be worked out to allow this option to be implemented. A suitable location for the landfill will need to be determined and approved in the permitting process. This estimate assumes the State will waive leachate collection system requirements for the Class I landfill and require a 5-year post-closure monitoring period. Institutional Controls, such as deed restrictions, will need to be used to restrict future land uses at the landfill site. As with any alternative, this alternative will be presented to the public and area native corporations for comments.

Alternative 3, Excavate and dispose in offsite landfill

This alternative, to excavate and dispose of soils in an offsite landfill, is significantly more expensive, with a cost of $13,393,000. While this alternative eliminates the design, permitting, construction, and monitoring of an onsite landfill, the cost of transportation and disposal far out-weigh the cost of the onsite landfill. This estimate assumes the wastes (soils) will be disposed of in the Anchorage landfill. The Anchorage landfill does not accept wastes outside the Anchorage Borough. Unless exceptional agreements can be made, the contaminated soils would actually have to be transported to the lower 48, since no Alaskan landfill is known to be able or willing to accept these materials. Furthermore, this option is limited to addressing only an estimated 7,000 cubic yards in the vicinity of the retort building, while the site also has thousands of cubic yards of uncontaminated tailings that will eventually need to be addressed. With an onsite landfill, additional waste volumes can easily be added. This option is not preferred and does not currently appear to be viable.

Alternative 4, Excavate, stabilize, and dispose in onsite SWLF.

This option is a combination of alternatives 1 and 3. It combines the tasks, problems, and costs of both alternatives, but may add some margin of safety to the long-term stability of the soils in the SWLF. The estimated cost is $3,463,000. Stabilizing the soils may more easily allow ADEC to permit the landfill without long-term monitoring. Based on the previously mentioned technical feasibility problems with the stabilization process, and the added cost of stabilization with limited benefit, this option is not likely to be preferred.

Alternative 5, Excavate, retort, and dispose in onsite SWLF

This option is similar to alternative 4, except the soil would be retorted instead of stabilized before being placed in an onsite SWLF at a cost of $2,933,000. Retorting is only required if soils fail the TCLP test and exceed the 260 mg/kg mercury concentration. Preliminary testing has shown that most, if not all, of the site soils will likely pass the TCLP test. With the cost of this option nearly double that of alternative 2, and with little added benefit, this option is not likely to be preferred.

Alternative 6, Excavate and transport hazardous waste to treatment, storage, disposal facility (TSDF)

This alternative is the most costly, at $43,853,000, assumes that 7,000 cubic yards of soil will not pass the TCLP test and will require retorting before landfilling. Clearly, if retorting was required, alternative 5 would be the preferred alternative due to the extreme cost savings to the American taxpayer. Once again, preliminary testing has shown that most, if not all, of the site soils will likely pass the TCLP test. This option is not likely to be preferred.

4. Summary, Conclusions, and Recommendations

Site Inspections at the Red Devil Mine have revealed numerous sources of contamination and environmental concerns. Fortunately, most of the concentrated sources were removed in 1999, when approximately 35,000 pounds of waste materials were removed and disposed. What remains are high levels of metals (mercury, arsenic, antimony, and lead) in the soils and stream sediments. The primary contaminant of concern is mercury, due to its toxicity. The antimony and arsenic are by-products from the host rock and ore processing. These metals will be simultaneously addressed with the mercury in what ever treatment and disposal option is chosen. The lead in the soils is primarily from leaking lead-acid batteries that have now been removed. The lead concentrations appear to affect a very small area. These soils may also follow the mercury contaminated soils in treatment and disposal. Some TCLP testing has been completed and has shown that most, if not all, of the site soils may pass the TCLP test and will not be classified as hazardous waste. If limited quantities of the soil do fail the test, they would have to be addressed by retorting before disposal.

Prior to selecting a final remedy, additional site characterization is necessary to determine the horizontal and vertical extent of the contaminated soils. Additionally, input will be gathered from state and federal regulatory agencies (ADEC, EPA), the public, and local native corporations. However, based on the current information available from the EE/CA and other sources, it appears that alternative 2, excavate and dispose in onsite SWLF, will be the preferred option. This option is preferable because it currently scored the best in a comparison of alternatives using EPA's nine criteria for analysis. Option 2 is technically feasible, protective of human health and the environment, and is cost effective.

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Appendix

Photos

Red Devil Mine Photos

Aerial view of the Red Devil Mine; Kuskokwim River is seen at bottom.

Mine building ruins: structure at left is the head frame over an incline shaft.

Retort building and vicinity; portal seen below building

A flask in which mercury is dispensed, transported and sold.

Mercury retort building and mercury slag that was removed in 1999

Close up view of mercury contaminated slag/ash.

Mineral processing chemicals removed in 1999; from top, sodium dichromate dihydrate, sodium hydroxide, copper sulfate, and the removal process.

Removal of drums containing used oil, fuel, and solvents.

Lead-acid batteries removed (caused lead contaminated soils).

Transformers drained of oil; some contained PCBs.

Above ground fuel storage tanks now overgrown by trees; now empty.