Work Plan
Remedial Investigation/Feasibility Study
Red Devil Mine, Alaska

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Prepared for:

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Glossary of Mining Terms

Adit. A horizontal opening into an underground mine.

Calcine. By heating, to expel volatile matter as carbon dioxide, water, or sulfur, with or without oxidation; to roast or burn; the waste material left by calcining.

Crosscut. A horizontal underground mine passage driven to intersect an ore body.

Drift. A horizontal passageway driven into or along the path of a vein or rock layer.

Gangue. The valueless minerals in an ore; that part of an ore that is not economically desirable but cannot be avoided by mining. It is separated from desirable ore minerals during concentration.

Ore. A combination of minerals from which a metal or metals can be profitably extracted.

Raise. A mine opening driven upward from inside to connect upper levels or explore areas above a level.

Retort. A vessel used for the distillation of volatile materials, as in the separation of some metals.

Rotary Kiln. A large furnace used for calcining ores.

Shaft. A vertical or downward slanting opening into an underground mine.

Skip. A car being hoisted from a slope or shaft.

Slag. The vitreous mass separated from the fused metals in the smelting process.

Sluice. To mine using a hydraulic mining method consisting of excavating alluvial or other mineral deposits by means of high-pressure water jets; a channel, drain, or small stream for carrying off surplus or overflow water.

Slusher. A mechanical dragshovel loader.

Stope. An underground cavity made by the removal of ore above or below a drift.

Strike. The trace of a mineral deposit, vein, or fault on the horizontal plane, at right angles to the direction of dip.

Stull. A support or framework within a mine used to prevent cave-ins.

Tailings. The gangue and other waste material resulting from the washing, concentration, or treatment of ore.

Waste Rock. Rock that is not minable at a profit.

Winze. A mine opening sunk downward from inside to connect lower levels of explore areas beneath a level.

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List of Abbreviations and Acronyms

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ARARs	applicable or relevant and appropriate requirements
AST	aboveground storage tank
AWQC	Ambient Water Quality Criteria
BEI	[Philips] Burlington Environmental, Inc.
bgs	below ground surface
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CISs	[Alaska Community Database] Community Information Summaries
COPCs	contaminants of potential concern
DOI	U.S Department of the Interior
DQO	Data Quality Objectives
DRO	diesel range organics
E & E	Ecology and Environment, Inc.
EPA	U.S. Environmental Protection Agency
ERS	Energy Recovery Services, Inc.
ESA	Endangered Species Act
FLPMA	Federal Land Policy and Management Act
FS	Feasibility Study
FSP	Field Sampling Plan
HgS	mercury sulfide
HLA	Harding Lawson Associates
IDW	investigation-derived waste
LDRs	Land Disposal Restrictions
MACTEC	MACTEC Engineering and Consulting
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram
mm	millimeter
ng/g	nanograms/gram
NHPA	National Historic Preservation Act
NPDES	National Pollution Discharge Elimination System
PCB	polychlorinated biphenyl
ppm	parts per million
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act

List of Abbreviations and Acronyms (cont.)

RDM	Red Devil Mine
RI	Remedial Investigation
RMCs	risk management criteria
RRO	residual range organics
Sb_2S_3	stibnite (antimony sulfide)
SI	site inspection
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TSD	treatment, storage, and disposal
TSDF	treatment, storage, and disposal facility
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
Wilder	Wilder Construction Company
XRF	X-ray fluorescence spectrometer

1 Introduction

This document is a Remedial Investigation (RI)/Feasibility Study (FS) Work Plan to address contamination at the Red Devil Mine (RDM) site. The RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) in the state of Alaska (see Figure 1-1). Historical mining activities included underground and surface mining. Ore processing included crushing, retorting/furnacing, milling, and flotation. Ecology and Environment, Inc. (E & E), has prepared this Work Plan on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J.

The BLM is performing this work pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead-agency authority. Therefore, the RI/FS will follow applicable CERCLA guidance. In addition, the regulations for contaminated site cleanup promulgated by the State of Alaska provide a framework for the RDM RI/FS process.

A companion document, the RI/FS Project Management Plan, covers several elements typically included in RI/FS Work Plans, including BLM, contractor, and agency roles and responsibilities; project schedule; quality control; and contracting documents. These topics are not repeated here.

This Work Plan provides detailed background information on the RDM and types and quality of data that will be needed to address existing data gaps, as well as information on the regulatory framework for the RI/FS. Detailed field investigation and risk assessment approaches and procedures are included in appendices.

1.1 Purpose and Objectives

The purpose of this Work Plan is to present the RI/FS activities, procedures, and methods that will be conducted to characterize known areas of environmental contamination and additional areas of potential contamination at the site. The objectives of the RI/FS are to:

- Characterize the nature and extent of environmental contamination released from the site.
- Assess the magnitude of potential human health and ecological risks from site-related contaminants.

- Evaluate potential remedial alternatives to reduce or eliminate human health and ecological risks posed by site contamination.

1.2 Definition of the Site

For this RI/FS, the RDM site is defined as the area where mining operations were conducted, where mine-related waste sources exist, and where mine-related contamination of media (soil, surface water, sediment, groundwater) is known to exist or potentially exist. Accordingly, the site includes the following general areas:

- The Main Processing Area.
- Red Devil Creek, extending from a reservoir south of the site to and including the creek's delta at its confluence with the Kuskokwim River.
- Locations within the Kuskokwim River down-river of the Red Devil Creek delta.
- The underground mine workings.
- The area west of the main mine processing area where historical surface exploration and mining occurred, inclusive of the "Dolly Sluice" area and its related delta on the bank of the Kuskokwim River, the Rice Series area, the areas of trenching, and the area immediately west of the Main Processing Area.

Figure 1-2 illustrates the site area and the vicinity of the major features identified above based on an aerial photograph taken in 2001 (AeroMetric, Inc. 2001).

The Main Processing Area contains most of the former site structures and is where ore beneficiation and mineral processing were conducted. The area is split by Red Devil Creek. Underground mine openings (shafts and adits) and ore processing and mine support facilities (housing, warehousing, and so forth) were located on the west side of Red Devil Creek until 1955. After 1955, all ore processing was conducted at structures and facilities on the east side of Red Devil Creek. The Main Processing Area includes three monofills. These monofills are essentially landfills that contain demolished mine structure debris and other wastes. Two monofills are unlined (Monofills #1 and #3). Monofill #2, on the east side of Red Devil Creek, is an engineered and lined containment structure for contaminated debris and materials from the demolished Post-1955 Retort structure. The east side of Red Devil Creek is also the former location of petroleum aboveground storage tanks (ASTs), which were used to store fuel for site operations; however, the AST area is not included in this investigation (see Section 2.2). The AST area is the subject of a separate investigation and remediation project (Marsh Creek 2011.

Figure 1-3 illustrates the main historical and current features in the Main Processing Area. Underground and surface mining operations and ore beneficiation and mineral processing are discussed further in Chapter 2.

1.3 Interim Remedial Actions

The BLM will adopt a "bias for action" philosophy, providing the necessary flexibility to reach an early determination regarding an interim corrective action on all or a portion of the site when there is sufficient information to do so. The determination may be that no further action is necessary, that an early action is appropriate, or, the default assumption, that the site should proceed through the RI/FS process to a final action. An early action can be decided upon at any time during the investigation and proceed directly to an Action Memo when there is adequate information to support such a decision. The process also provides the BLM Project Manager with the flexibility to prioritize work in a manner that will achieve the most benefit with the available funds.

If an interim action at the site is deemed necessary and appropriate, its objectives will be to:

- Reduce or eliminate the potential for human and wildlife exposure to contaminants at the site.
- Reduce or eliminate the loading of site contaminants to the Kuskokwim River.

1.4 Document Organization

The Work Plan is organized into the following chapters:

- **Chapter 1, Introduction –** Describes the purpose of the Work Plan and objectives of the RI/FS and defines the site.
- **Chapter 2, Site Background and Setting –** Describes the project location and regional setting, the operational history and current conditions at the RDM, and environmental setting aspects relevant to the technical assessment (climate and weather, geology, hydrogeology, surface water, and ecology).
- **Chapter 3, Evaluation of Existing Data –** Summarizes the previous investigations and cleanup actions at the RDM; assesses the quality of data generated from previous investigations for use in the RI/FS; summarizes the known nature and extent of contamination at the site; and summarizes information regarding naturally occurring background levels of metals in the RDM area.
- **Chapter 4, RI/FS Data Quality Objectives –** Identifies the major study questions that need to be answered and outlines how the study questions will be addressed through RI/FS activities.
- **Chapter 5, Preliminary Identification of Response Objectives and Remedial Action Alternatives –** Summarizes potential remedial technologies that could achieve objectives for cleanup at the site. Information is presented to guide data collection for FS activities.
- **Chapter 6, Identification of Preliminary Applicable and Relevant or Appropriate Requirements –** Summarizes the federal, state, and local regulations and guidance that need to be considered for the RI/FS and future remedies.

- **Chapter 7, Overview of RI/FS Study Design –** Summarizes the study design concept for the RI/FS based on the outputs of the Data Quality Objective (DQO) process.
- **References –** Lists the guidance documents and literature resources cited in this document.
- **Figures**
- **Charts**
- **Appendices**
  - A Field Sampling Plan
  - B Risk Assessment Work Plan
  - C Quality Assurance Project Plan
  - D Site-Specific Health and Safety Plan
  - E Air Dispersion Model
  - F 2010 Limited Sampling Event Laboratory and XRF Data

2 Site Background and Setting

2.1 Project Location and Regional Setting

The RDM site is approximately 250 air miles west and 1,500 marine/river barge miles from Anchorage, Alaska (see Figure 1-1). Located on the southwest bank of the Kuskokwim River approximately 2 miles southeast of the village of Red Devil, the site is 75 air miles northeast of Aniak, the largest village in the region, and approximately 8 miles northwest of the village of Sleetmute. Approximately 15 villages are located downstream of Red Devil on the Kuskokwim River.

The legal description for the RDM site is Township 19 North, Range 44 West, Southeast Quarter of Section 6, Sleetmute D-4 Quadrangle, Seward Meridian. The RDM site's approximate coordinates are 61° 45' 38.1" north latitude and 157° 18' 42.7" west longitude (North American Datum 27).

The RDM site is in a remote location, and access to the site is available by boat or barge on the Kuskokwim River or by means of an airstrip at the nearby village of Red Devil. An unimproved road leads from the airstrip through the village of Red Devil and to the site.

2.2 Operational History

The RDM is an abandoned mercury mine. This section summarizes available information about the history of the RDM. Existing historical documents do not provide complete clarity regarding ownership and other topics related to the mine's history. The ore minerals at the RDM consisted of cinnabar (mercury sulfide [HgS]), the primary mercury ore mineral, and stibnite (antimony sulfide [Sb_2S_3]). Some realgar (arsenic sulfide [As_4S_4]), orpiment (arsenic sulfide [As_2S_3]) and secondary antimony minerals were locally associated with these ore minerals.

2.2.1 Mining Operations

In 1933, Hans Halverson discovered mercury ore in Red Devil Creek and staked the original claim for the RDM. By 1939, there were four claims, Red Devil numbers 1 through 4 (Roehm 1939). Ore was obtained from creek float (sediment) and overburden (Webber et al. 1947).

In 1941 and 1942, the operators sluiced the overburden from the southeast extremity of the ore zone, as then delineated, leaving a considerable depth of bedrock rubble. Ore from this loose material yielded much of the early mercury production. Sluiced overburden materials apparently were washed into Red Devil Creek. A 1941 photograph (Cady 1941a) shows a steamboat landing believed to be located on the delta of Red Devil Creek. It is likely that the delta consisted largely of sluiced overburden materials at that time. Surface exploration by the U.S. Bureau of Mines in 1942 consisted of more than 2,000 feet of bulldozer and hand trenching (Wright and Rutledge 1947).

In 1941, underground mine workings consisted of two adits and a shaft. The first adit, reported to be at an elevation of 311 feet above sea level, is referred to in this document as the 311 Adit. A second adit was started approximately 70 feet north of the portal of the 311Adit and at a reported elevation of 325 feet. This second adit is referred to as the 325 Adit in this document. The main shaft, located approximately 55 feet southeast of the 311 Adit portal, was sunk to a depth of 30 feet on a 59-degree incline (Wright and Rutledge 1947).

In 1941, Harold Schmidt and L.J. Stampe secured a lease on the claims. The New Idria Quicksilver Mining Company entered into a sublease agreement with Schmidt and Stampe. The New Idria-Alaska Quicksilver Mining Company was formed, and this company installed new thermal processing equipment for mercury that included a 40-ton rotary kiln (Wright and Rutledge 1947). Production as of June 30, 1944, amounted to 1,096 flasks of mercury recovered from 2,652 tons of ore. Most of the ore was recovered from stopes above the 325 Adit and 276-foot level (Wright and Rutledge 1947). Ore processing during this time and subsequent operations are discussed in Section 2.2.2, below.

The price of mercury fell in 1944 and the New Idria Quicksilver Mining Company shut down mining operations and subsequently subleased its interest in the mine to the Kuskokwim Mining Company. The Kuskokwim Mining Company operated the mine for two seasons in 1945 and 1946 (Webber et al. 1947). In 1946, the price of mercury fell again, and the Kuskokwim Mining Company shut down its operation. Harold Schmidt and C. J. Stampe bought out the New Idria Quicksilver Mining Company lease, including all the mining equipment. Robert Lyman also held a lease on the mine in 1946 and produced 491 flasks of mercury, although Mr. Lyman’s relationship to the other owners at this time is unclear (MACTEC 2005).

As of 1947, the ore recovered was reported to be soft and friable. The country rock was reported to be weak and to require close spacing of stulls for support of stope walls and drifts. All ore was mined from stulled stopes. Broken ore was trammed to the shaft on the 276-foot and 236-foot levels and to the storage bin on the 375-foot level. As of 1947, power for the reduction plant and mine was generated by two Caterpillar 46-30 diesel-electric units. Water was pumped from the mine at the rate of 100 gallons per minute with a 2-inch centrifugal pump (Wright and Rutledge 1947).

Between 1947 and 1951 the mine was not in operation (MACTEC 2005). In 1952, the DeCoursey Mountain Mining Company leased the mine. Various organizational changes in the operating companies occurred subsequently. As of 1962, the operating unit was called Alaska Mines and Minerals, Inc.

In 1952, DeCoursey Mountain Mining Company dewatered the mine workings and resumed production. In October 1954, a fire destroyed a large portion of the mine surface structures and equipment. The “Pre-1955 Retort” and the “Pre-1955 Rotary Furnace” facilities were rendered unusable by the fire. Some of the mine camp buildings were also damaged by the fire, but it is unknown if they were destroyed or repaired (Malone 1962).

Following the 1954 fire, DeCoursey Mountain Mining Company rebuilt a modern ore processing plant, an airfield, a camp with bunkhouses, a commissary, a mess hall, offices, shops, warehouses, a diesel electric power station, and a modern furnace (Malone 1962). Extensive surface exploration and mining took place at the mine sometime after 1956. The reservoir was created after 1956 by constructing an earthen dam across Red Devil Creek. Aerial images indicate that soils from the hillsides adjacent to the reservoir dam were scraped and used for dam material; however, it is unknown whether tailings were used to supplement the hillside soils for dam construction. The reservoir may have been constructed to provide a source of water for the hydraulic sluicing operations such as those conducted at the “Dolly Sluice Area,” where loose overburden was washed through a sluice to recover ore. The waste material from the sluice operation was washed down a gully toward to the Kuskokwim River. This resulted in the formation of the Dolly Sluice delta on the Kuskokwim River at the base of the gully (MacKevett and Berg 1963).

As of 1963, the underground workings consisted of approximately 9,600 feet of shafts, adits, crosscuts, drifts, raises, and winzes, with workings on five levels. As indicated above, the underground mine workings began with the 311Adit and 325 Adit. Later, the Red Devil inclined shaft (referred to in this document as the main shaft) was sunk with stations at the 33, 73, 150, 300, and 450 levels. The Dolly shaft was connected with the main shaft on the 300 level (Malone 1962). Other mine openings documented as of 1963 are the “F” Zone shaft and a caved shaft located northwest of the main shaft.

In a description of mine operations as of 1962, ore shoots were characterized as extremely short in strike length but locally persisting along the plunge for several hundred feet. Strike lengths ranged from 6 to 30 feet and vein widths from 3 to 10 inches. The ore shoots plunge at an average of 39 degrees. The combination of short strike length, narrow width, and low-angle plunge resulted in high mining costs. After a level had been opened for mining, raises were driven on the ore shoots. Stoping proceeded from the top down; the stope width was controlled by the closest convenient hanging wall that would stand until it could be supported. Stope widths ranged from 3 to 6 feet. Stulls and headboards were used for support. Muck from the stopes would not run by gravity, and the relatively small tonnage from a stope did not warrant installing slusher setups. Hence, mucking to the level was accomplished by hand, assisted with water run in from above. Where ore could not be moved economically by raises, slusher crosscuts were used to transfer muck to shafts, winzes, or ore passes. The scraper dumped directly into skips or into ore passes to the haulage level. Drifts and crosscuts were 5 by 7 feet in the clear (Malone 1962).

A large part of the 200 level and most of the shallower workings were driven during the early period of mining, and the rest of the workings present as of 1962 were excavated after 1953. The most extensive workings were near the main shaft, the portal and main shaft headworks of which were located in the vicinity of what have been referred to in previous investigations as Shop Pad A and Shop Pad B, respectively. Five main levels connect with the main shaft. The Dolly series of ore bodies was discovered in 1957. By 1963, underground workings in the vicinity of the Dolly shaft had been extensively developed and the surface had been mined by sluicing.

As of 1962, the Rice series of ore bodies had been explored by shallow trenches and pits (MacKevett and Berg 1963) and was being explored by a shaft sunk along the plunge of the strongest surface showing of ore revealed by the surface exploration, with a shaft sunk to 84 feet deep on the plunge of the shoot (Malone 1962).

The approximate locations of underground workings and associated mine openings as of 1962 are illustrated in Figure 2-1. As of 1963, many of the older shallow workings were caved and inaccessible (MacKevett and Berg 1963). It should be noted that nomenclature of the underground workings varies depending upon the report, potentially resulting in confusion as to the identification and depth of several mine levels. For example, Wright and Rutledge (1947) and Webber et al. (1947) refer to adits driven at the 311-foot level and 325-foot levels, and report that these adits were driven at 311 and 325 feet above sea level, respectively. These two adits are referred to in one subsequent report as the 311 Adit and 325 Adit (MacKevett and Berg 1963), and in another report as the 1311 Adit and 1325 Adit (Malone 1962). Furthermore, several levels referred to in earlier reports, such as the 236-foot level and 276-foot level, are not reported in subsequent reports (e.g., MacKevett and Berg 1963 and Malone 1962), likely because the levels were assigned different identifiers at later stages of mine development. The underground mine workings as presented in Figure 2-1 represent a combination of information presented in Malone (1962) and MacKevett and Berg (1963). Mine openings documented as of 1962 are as follows.

- 311 Adit.
- 325 Adit.

- Main Shaft.
- “F” Zone Shaft.
- Caved shaft located southeast of the “F” Zone Shaft.
- Dolly Shaft.
- Rice Shaft.
- Two stopes that reached the surface from the 325 Adit level approximately 300 feet northwest of the 325 Adit portal.
- Two stopes that reached the surface from the 503 Crosscut (“D-3” and “D-4” Stopes) and one stope that reached the surface from the 507 Crosscut southeast of the Dolly Shaft.

In 1963, a new adit was reportedly driven on the “left limit of Red Devil Creek gulch an estimated 100 feet to mine a faulted ore-body segment in the vicinity of the mine shaft” and 40 tons of high-grade ore were stockpiled from that effort (Jasper 1964). The specific location of this adit is not known. Production in 1963 and 1964 was minimal. The mine was subsequently shut down and allowed to flood, and equipment was removed from the site. The mine remained inactive until 1969.

In 1969, Alaska Mines and Minerals, Inc., resumed operations at the mine. Mining operations included open pit and underground mining (Buntzen and Miller 2004). Information on the location of the underground workings from this period is not available. Surface mining was conducted over a large area on the hillside west of the Main Processing Area by trenching, bulldozing, pit excavation, and possibly sluicing. The surface expression of these features is visible in aerial images dated 1974 and illustrated in Figure 2-2. Based on aerial photographs between 1953 and 1955 and a surficial geologic map (MacKevett and Berg 1963), most of the surface exploration and mining that had been conducted prior to 1974 lies within the footprint of the post-1969 surface mining activities.

Cinnabar and stibnite concentrates were produced post-1969 using flotation and were reportedly shipped to Japan. In addition, some mercury was also reported to be retorted at the mine. The flotation mill operated for most of 1970, and the mine closed in June 1971 due to a sharp drop in the price of both mercury and antimony. There has not been any production since that time (Buntzen and Miller 2004).

On June 1, 1971, the mine owner, Alaska Mine and Minerals, Inc., ceased operations at the mine. Dewatering of the underground mine workings continued with the intent that the disruption in mine operations would be temporary. In 1982, the mine was permanently closed and dewatering operations ceased (MACTEC 2005).

During a site visit on June 14, 2010, two mine openings believed to be the D-3 and D-4 stope surface openings were observed. Each opening was partially covered by vegetative debris.

2.2.2 Ore Processing

Early production from the mine used a Johnson-McKay retort to process the ore (Webber et al. 1947). The location of early retorting operations is unknown.

Two "D" retorts were used to process ore beginning in 1940 (Webber et al. 1947); these retorts are assumed to have been constructed within the "Pre-1955 Retort Building."

In 1941, the New Idria Quicksilver Mining Company installed a 40-ton rotary kiln (Wright and Rutledge 1947). In 1943, the New Idria-Alaska Quicksilver Mining Company installed modern equipment for furnacing and retorting the Red Devil ore. The reduction plant was equipped with a 50-ton fine ore bin, a 12-ton burned ore bin, a 36-inch by 40-foot rotary kiln, Sirocco dust collectors, fan, condensers, and redwood tanks. A jaw crusher reduced the ore to less than 2 inches (Webber et. al. 1947). Wood was used for furnace fuel from 1943 to 1946. In 1947, the furnace was equipped with a burner and diesel oil was used thereafter (Wright and Rutledge 1947). It is assumed that this rotary kiln was installed in the structures labeled "Pre-1955 Rotary Furnace building" in Figure 1-3. The term "Pre-1955 Rotary Furnace" is retained for the purpose of this Work Plan to maintain consistency with previous reports.

The 1954 fire destroyed several mine structures and processing facilities, including the "Pre-1955 Retort" and the "Pre-1955 Rotary Furnace" facilities. In 1956, a new processing facility and other plant facilities were built on the east side of Red Devil Creek. A modified Herreshoff furnace was installed (Malone 1962); the location of this newly installed furnace was the "Post-1955 Retort building" (MACTEC 2005). The thermal ore processing equipment installed in the "Post-1955 Retort" building is believed to consist of the Herreshoff furnace rather than a retort. The term "Post-1955 Retort" is retained for the purpose of this Work Plan to maintain consistency with previous reports. In 1955, five diesel ASTs were installed on a road northeast of the Post-1955 Retort building.

Sometime after production resumed in 1969, a flotation mill was installed within an addition to the northern end of the Post-1955 Retort building to produce cinnabar and stibnite concentrates. A ball mill was used to mill the ore, and various chemical agents, including "pine oil," lead acetate, and Dowfroth 250, were used as well. Flotation tailings from the flotation unit were sluiced from the flotation mill into the three settling ponds via a wooden chute (TNH 1987).

Processing of mercury ores at the RDM by thermal methods (in retorts, kilns, and furnaces) was greatly complicated by the close association of stibnite (antimony sulfide) with the cinnabar within the ore. The antimony content of RDM ores was many times that of the mercury content and averaged more than double the mercury content. Various remedies, most of them aimed at eliminating the stibnite before thermally processing the cinnabar, had been proposed over the course of mine operations (e.g., Webber et al. 1947; Wright and Rutledge 1947), but none had been considered sufficiently promising to justify installing special equipment as of 1962. The installation of the flotation mill in 1969 was likely intended to eliminate the problems encountered over the previous decades of thermal ore processing (Webber et al. 1947; Wright and Rutledge 1947; Malone 1962).

The operational difficulties encountered as a result of furnacing mixed stibnite and cinnabar ores are summarized below based on a description by Malone (1962).

Like cinnabar, stibnite breaks down at a relatively low temperature. Its rate of reaction is similar to that of cinnabar within the operational temperature range of furnacing practices. There are, however, two differences in the way stibnite and cinnabar react during thermal treatment. First, unlike cinnabar, which transitions directly from the solid to gaseous phase, stibnite passes through a liquid state. Second, the newly liberated antimony combines with oxygen to form oxides of antimony, particularly antimony trioxide, within the temperature range of mercury furnacing. These differences allowed some separation of the mercury from stibnite ore during the furnacing operations. However, in practice at the RDM, such separation was limited (Malone 1962).

From the instant the stibnite burned in the furnaces, it caused problems throughout the process. Antimony oxides would be transported by the furnace gas flow and rabble arms, slagging with the dust and adhering to the inside of the furnace. The burner blocks and drop holes required frequent cleaning to keep them from plugging up entirely with antimony glass, and periodic shutdowns were required to clean the entire inside of the furnace. The portion of the antimony oxide that passed into the condensing system with the mercury-laden gases passed through a cyclone dust collector. A cyclone, however, is ineffective at separating most of the antimony oxides due to the small particle size. For the same reason, a cyclone also is ineffective at separating arsenic trioxide, which resulted from furnacing of the arsenic sulfides that also were associated with the cinnabar ore. Within the furnace, the arsenic fumes are mostly vapor. The heavy concentration of these antimony and arsenic oxides in the cyclone and associated ducts resulted in coating of the surfaces, requiring daily blowing with compressed air and hammering with a rubber mallet to keep these components clean (Malone 1962).

When the furnace gases bearing antimony oxide and arsenic oxide reached the condensers, some of the oxides fell out as a result of the reduced gas flow velocity. Much of the oxide was so finely divided that it never settled, and it passed through the condenser and out of the stack. Enough oxide, however, settled into the launders, where the recovered mercury also accumulated, to greatly dilute the condenser mud, or soot, as it is commonly called. This makes the process of removing the mercury from the soot a much greater problem than in most other mercury mines at that time. At most mines, up to 80% free mercury was recovered from the soot by simply settling and pouring off the mercury from under the soot, with the remainder dumped on an inclined metal hoe table and worked over by hand.

At the RDM, the soot showed no visible mercury, and free metal did not separate from the mud without treatment. The soot was worked both wet and dry by hoeing, paddling, pushing, agitating, stirring, scraping, vibrating, rolling, pressing, raking, and jigging, with or without various additives (Malone 1962).

At times during the mine's operations, the impoverished soot from the hoeing table was returned to the furnace. This resulted in considerable recycling of the antimony and arsenic oxides and the coating issues discussed above. Retorting the worked-over soot was found to be not only unsatisfactory but also expensive and hazardous because, unless a large amount of lime was added to the soot before retorting, the charge fused into an antimonial-arsenical glass, which boiled and frothed in the retort, resulting in molten oxide glass sticking to the retort charging pans as well as condensing of the oxides in the head of the retort and in the condenser pipes, thus sealing them (Malone 1962).

The practice of hoeing the mud/soot in a mechanical hoeing machine with quicklime was used at the RDM until late 1959. In November 1959, equipment was installed to treat the condenser mud by a wet method, in which mercury was separated from the mud by (1) agitating and aerating the heated mud and (2) centrifuging with a wet cyclone. Although this process did not generate tailings that could be discarded, treatment time was reduced to about 5% of that formerly needed with the hoeing machine. As of 1962, the tailings were dried and fluxed with lime for refurnacing (Malone 1962).

The processes and operational difficulties summarized above based on Malone (1962) pertain to the Herreshoff furnace. Similar operational difficulties were described for the rotary kiln (Webber et al. 1947' Wright and Rutledge 1947).

2.2.3 Mining and Ore Processing Wastes

Wastes generated during the mine operations consisted primarily of overburden, waste rock, tailings generated from thermal processing of ore, and tailings generated from flotation. These and other mining and mineral processing wastes at the RDM are discussed further below.

Waste rock included the overburden material that resulted from surface mining processes (including trenching, open pit mining, and sluicing) and sub-ore grade material generated during underground mining activities. The disposition of all waste rock generated during underground mining activities is not known. Based on a 1941 photograph (Cady 1941b), at least some waste rock generated was disposed in dumps near the 311 Adit and 325 Adit portals. At least some of the waste rock was likely deposited in the Red Devil Creek drainage.

Early mining operations included sluicing of overburden on the southeast-facing slope above Red Devil Creek, with the overburden apparently being washed into Red Devil Creek and downstream to the Kuskokwim River. During the later surface mining activities, overburden was locally bulldozed into dumps northwest of the Main Processing Area and overburden was sluiced from the Dolly and Rice ore zone areas. Wastes generated from sluicing locally accumulated in deposits, including the Dolly Sluice delta. A second delta located between the Red Devil Creek delta and the Dolly Sluice delta appears to have formed as a result of sluicing the Rice ore zone and/or as a consequence of increased erosion of the upland area in the vicinity of the Rice ore body during surface mining operations. These features are illustrated in Figure 2-2.

As of 1962, prior to furnacing, coarse ore material was passed over a 1.5-inch screen. The ore material that passed through the screen was conveyed to the furnace. The material retained by the screen was passed over a sorting table to segregate the material to be furnaced from waste rock. The waste rock was conveyed via a 24-inch by 20-foot conveyor to a dump (Malone 1962). The location of the dump is not specified.

Tailings included thermally processed ore—also variously referred to as calcines, burnt ore, and retorted ore—and flotation tailings, which consist of the fraction of milled ore remaining after selected ore minerals are separated from the bulk ore slurry using water and flotation agents. For the remainder of this document, the term “tailings” will refer to the tailings derived by the thermal processing of ore, and “flotation tailings” will refer to tailings derived by processing ore using a flotation process. Historical aerial images and historical documents indicate that throughout much of the history of mining and ore processing at the site, tailings were sluiced or bulldozed into the channel of Red Devil Creek from the ore processing areas. Tailings also were used for some unknown building foundations and road ballast or surfacing material.

A 1941 photograph illustrates the Pre-1955 Retort building and apparent tailings and/or waste rock deposited east of the retort building (Cady 1941c). This tailings/waste rock pile is evident in subsequent photographs and maps (Cady et al. 1955 and MacKevett and Berg 1963).

A geologic map illustrating underground mine workings and surface features, including ore processing buildings, indicates the presence of a “Burnt Ore Disposal Tunnel” that apparently discharged tailings from the Pre-1955 Furnace building to the Red Devil Creek drainage (Cady et al. 1955).

As of 1962, disposal of tailings generated from the furnace at the Post-1955 Retort building was accomplished by sluicing and bulldozing. A 7- by 10-inch sluicebox, at a slope of 2 inches per foot, extended from under the burned-ore bin to a waste dump 100 feet away. From there, the tailings were reportedly bulldozed away every second day. When road surfacing material was needed, it was sometimes loaded directly into a truck spotted under the sluiceway (Malone 1962). No information is available regarding the location of the tailings for road-surfacing.

From 1969 through 1971, a flotation mill was operated at the site to process ore into cinnabar and stibnite concentrates for shipment to Japan. The resulting flotation tailings were discharged into the settling ponds north of the Post-1955 Retort building area. Various flotation agents, including pine oil and Dowfroth 250 (frothers and flotation agents), lead acetate (activator for stibnite), and other chemicals may have been used as part of the flotation process. Although these materials were likely recycled to some extent, some quantities of the flotation agents potentially were discharged to the settling ponds.

Other wastes generated during mining operations include the dust and “slag” generated during the furnacing operations, as discussed above. Dust generated from the cyclone-dust bin was reportedly discharged with the aid of several water jets and discharged to the tailing sluicebox (Malone 1962). Mercury vapor and particulates that did not accumulate in the furnaces, condensing system, or other components of the processing system were discharged from the stack and may have precipitated in the vicinity of the mine.

Based on review of historical and recent aerial photographs, land-based photographs, and records of mine operations summarized above, the locations where mining and ore processing wastes were disposed of at the site during mine operations has been approximated, as illustrated in Figure 2-3. In the Main Processing Area, the tailings are locally mixed with waste rock, overburden, and native soil and alluvial materials. The historical and present channel and delta of Red Devil Creek likely consist of sluiced overburden, tailings, waste rock, and native alluvial material. The materials in the Surface Mined Area likely consist of reworked overburden and residual ore zone materials.

2.3 Environmental Setting

2.3.1 Climate and Weather

The RDM is located in the upper Kuskokwim River Basin and lies in a climatic transition between the continental zone of Alaska’s interior and the maritime zone of the coastal regions. Average temperatures can vary from 7 to 65 degrees Fahrenheit. Annual snowfall averages 56 inches, with a total mean annual precipitation of 18.8 inches.

2.3.2 Geology

The RDM site is located within the central Kuskokwim region, which contains a mobile belt of mountain building and volcanic activity. The regional geology is dominated by a thick sequence of folded sedimentary rocks of Cretaceous age, known as the Kuskokwim group (MacKevett and Berg 1963).

2.3.2.1 Lithologic Units

This Kuskokwim group generally contains a very thick sequence of interbedded sedimentary rocks consisting of graywacke and argillaceous rock. The graywacke beds, which commonly are 2 or 3 feet thick, range in thickness from half a foot to about 20 feet. The graywacke is a medium- or dark-gray rock that weathers brown and is fine grained and well indurated. Its fine-grained character makes macroscopic identification of its minerals and textures difficult.

Descriptions of similar graywackes from throughout the central Kuskokwim region indicate that many of them contain a variety of detrital rock fragments. Microscopic examination reveals that the graywacke is poorly sorted and composed of subrounded to angular lithic fragments and mineral grains ranging from less than 0.001 to 0.5 millimeters (mm) in average diameter. The larger and more abundant minerals consist of quartz, muscovite, pyrite (iron sulfide), plagioclase, and calcite.

These minerals and the lithic fragments, which were principally derived from slate, schist, and volcanic rocks, are surrounded by very fine-grained assemblages of quartz, calcite, plagioclase, muscovite, clay minerals, epidote, and chlorite. Calcite is the dominant cementing mineral, and it also forms veinlets (MacKevett and Berg 1963).

The very fine-grained argillaceous rocks of the Kuskokwim group are dark gray or black and weather brown. Most of these rocks that are exposed underground are argillites, but some of their surface and near-surface counterparts are shales. Discrete argillaceous beds are commonly a few inches thick, but locally they have a cumulative thickness of 20 or 30 feet. Commonly, the argillaceous rocks are well indurated. Some of them are fissile, and many tend to fracture subconchoidally. The argillites are flecked with fine crystals of muscovite, the only megascopically visible mineral. The argillaceous rocks are similar to the graywackes in composition. A typical argillite from the mine consists of subangular grains of quartz, epidote, muscovite, and pyrite that are less than 0.03 mm in average diameter, associated with clots and lamellar aggregates of very fine-grained clay minerals and mica (MacKevett and Berg 1963).

The Kuskokwim group sedimentary rocks are tightly folded and intruded by hydrothermally altered dikes composed of quartz basalt (MacKevett and Berg 1963). The dikes range from 1 foot to about 14 feet in thickness. The main dike at the mine has a few plug-like and sill-like offshoots and a few small discontinuous branching dikes. In underground exposures, the dikes are light gray. At the surface, the dikes are masked by pervasive hydrous iron oxides and are difficult to distinguish from similarly weathered graywacke. The dikes consist entirely of fine-grained and very fine-grained masses of calcite, chalcedony, limonite, and sericite, and subordinate amounts of quartz, hematite, and clay minerals. Small relict phenocrysts are largely replaced by calcite in a very fine-grained groundmass. A few veinlets composed of calcite and minor amounts of quartz cut the dikes. As of 1963, surface exposures of bedrock at the mine were largely confined to road cuts, stripped areas, and trenches (MacKevett and Berg 1963).

The Kuskokwim group and dikes are locally overlain by surficial deposits of loess and alluvium that consist of fluvial deposits associated with the Kuskokwim River and the Red Devil Creek and slope wash (MacKevett and Berg 1963). The loess deposits are buff colored and friable, range from a few inches to about 30 feet in thickness, and commonly lack bedding. The fluvial deposits include gravel, sand, and silt that have been deposited on the flood plains of the Kuskokwim River. The oldest of these deposits is locally overlain by the loess, but most of the fluvial deposits postdate the loess. In some places, as much as 20 feet of the fluvial deposits are exposed. The loess commonly overlies rocky soil derived from weathering of the Kuskokwim group bedrock. Minor quantities of recently deposited alluvium, including slope wash, are exposed on the lower slopes of some of the hills, in the valley of Red Devil Creek and along the Kuskokwim River (MacKevett and Berg 1963).

Surficial geology as mapped by MacKevett and Berg (1963) is illustrated in Figure 2-4. It should be noted that much of the area shown in the geologic map overlay in Figure 2-4 west of the Main Processing Area has been modified by surface mining operations subsequent to the geologic mapping.

2.3.2.2 Structure

The RDM is located on the southwest limb of the Sleetmute anticline and contains multiple northeastward-trending faults cut by northwestward-trending faults that are exposed in some areas of the underground workings. The chronological sequence of structural events is as follows (MacKevett and Berg 1963):

1) Folding of the sedimentary rocks forming the Sleetmute anticline and the probable concurrent development of steep, northeastward-striking tensional joints.
2) Intrusion of dikes into a few of these joints.
3) Development of steep, northwestward-trending faults that offset the dikes right laterally.
4) Minor strike-slip movement of some of the northwestward-trending faults, caused by gravitational adjustments.

2.3.2.3 Ore and Mineralization

The RDM mercury deposit, like other deposits in the southwestern Alaska mercury belt, is classified as an epithermal, hydrothermal deposit. Diagnostic characteristics of such deposits include a strong association of mercury, antimony, and arsenic; formation temperatures of about 200°Centigrade; and mineralized forms, including vein, vein breccias, stockworks, replacements, and disserninations, open space ore textures, quartz and carbonate gangue, and argillic alteration. Many of these characteristics are similar to those of hot-spring mercury deposits (Gray, et al. 2000). Information regarding the RDM deposit is summarized below.

The RDM ore consists of discrete ore bodies localized along and near intersections between the northeastward-trending altered dikes and the many northwestward-trending faults. The ore bodies are crudely prismatic and range from a few inches to about 2 feet in thickness and from 1 foot to 30 feet in length along strike.

Although some of the ore bodies diminish in size or pinch out with increasing depth, most of them continue to depths beyond the limits of exploration (as of 1962). The longest known ore bodies, of the Dolly series, extend from the surface at least to the 450 level (MacKevett and Berg 1963).

Some of the RDM ore is exceptionally high grade and contained as much as 30% mercury, but most of the ore contained between 2% and 5% mercury. Cinnabar (mercury sulfide [HgS]), the primary mercury ore mineral, is associated with abundant stibnite (antimony sulfide [Sb_2S_3]); some realgar (arsenic sulfide [As_4S_4]), orpiment (arsenic sulfide [As_2S_3]), and secondary antimony minerals; and minor amounts of iron minerals, in a quartz, carbonate, and clay gangue. The stibnite is commonly more abundant than cinnabar (MacKevett and Berg 1963). The only sulfides found throughout the deposit at Red Devil are stibnite and cinnabar; small amounts of orpiment and realgar are present locally. Rare, local pyrite films on joints are probably due to migration and redeposition of authigenic pyrite during ore deposition (Malone 1962).

The dominant process of ore formation was open-space filling, although some of the rich ore bodies were probably formed partly by replacement. Cinnabar and stibnite have locally replaced parts of the altered dikes. The high-grade ore typically consists of masses of intimately associated cinnabar and stibnite. Much of the ore consists of closely spaced intricate networks of veinlets, breccia cemented by vein minerals, and cinnabar-bearing incrustations. Some of the veinlets contain numerous vugs (MacKevett and Berg 1963).

2.3.3 Hydrogeology

Limited information is available about the hydrogeology within the RDM site. A bedrock aquifer is likely hydraulically connected to a shallow aquifer within surficial deposits at the site. Seven soil boring wells were drilled with the intent of installing monitoring wells during the August 2000 field work for the Red Devil Mine Retort Building Demolition and Limited Site Investigation. Groundwater was encountered in five of these soil borings at depths ranging from approximately 16 to 25 feet below ground surface (bgs); monitoring wells (MW-1, MW-3, MW-4, MW-6, and MW-7) were constructed in these boreholes. The groundwater in these wells was encountered within unconsolidated materials described as tailings and mixtures of gravel, sand, and silt (Wilder/HLA 2001). Available information on groundwater levels in the existing monitoring wells at the site includes water depth measurements on the following dates: August 14, 2000 (Wilder/HLA 2001); September 5, 2007; September 18, 2008; June 19, 2009; October 6 and 7, 2009; and September 20 and 21, 2010. For those monitoring events, measured depths to groundwater in these wells ranged from approximately 18 to 28 feet below ground surface. Seasonally, depth to groundwater varied by as much as 3.5 feet, with the highest recorded groundwater elevations occurring in June 2009 and the lowest recorded elevations occurring in October 2009 or August 2000.

Based on the groundwater elevation from the existing monitoring wells and an assumption that Red Devil Creek is a gaining stream in the vicinity of the site, it appears that the general direction of groundwater is toward Red Devil Creek locally, and the Kuskokwim River on a more regional scale, generally mimicking topography. Annual groundwater monitoring was conducted in September 2008. Groundwater elevations measured during this field event were similar to those observed during the August 2000 field event and appear to indicate groundwater flow in a generally north-northeast direction (Shannon and Wilson 2008).

A spring is located along the left bank of Red Devil Creek at the base of a bench comprising tailings/waste rock in the Main Processing Area. The underlying bank and streambed is coated with “yellowboy” an iron oxide flocculant associated with excess iron content. Yellowboy is commonly associated with acid mine drainage or acid rock drainage.

Groundwater may migrate through the mine workings. It is possible that groundwater within the mine workings may discharge from former mine openings and/or interconnected bedrock fractures through overlying surface soils, alluvium, or tailings. Such groundwater could discharge to surface waters. The spring along Red Devil Creek could represent localized preferential flow of groundwater originating from underground mine workings.

In general, the geologic characteristics of mercury deposits exert control on the composition of mine drainage. Geologic factors, including ore and host rock mineralogy and chemical composition, and type and amount of iron sulfides, are important in determining the pH and metal and anion concentrations in mine drainage. Mine drainage from hot spring type mercury deposits is usually moderately acidic because the pyrite content is typically low (2–5%) and the host rock buffering capacity is sufficient to reduce the acidity (Rytuba 2002).

The mineraology of the Red Devil Mine ore and host rock, as discussed above, suggests low to moderate potential for acid generation. This is supported by available surface water and groundwater pH data collected during the 2009 and 2010 surface water and groundwater monitoring events (E & E 2010a, 2010b).

There is one private drinking water well within a 1-mile radius of the site; it is located at a cabin near the mouth of McCally Creek, approximately 0.6 miles from the mouth of Red Devil Creek. The well is used for drinking purposes. Construction details of this well are unknown. Nineteen private drinking water wells were installed in Red Devil Village in 2004 by the Alaska Village Safe Water Program. These wells range in depth from 28 feet to 172 feet bgs. Some of the wells have been sampled for class A drinking water analyses; however, the results of the samples are reportedly unavailable (Wilson 2010).

Permafrost does not appear to be present in the area of the mine (MacKevett and Berg 1963).

2.3.4 Surface Water

Red Devil Creek is a tributary of the Kuskokwim River and has a basin of about 687 acres (Wilder HLA/2001). Red Devil Creek feeds into the Kuskokwim River less than 1,000 feet from the main portion of the mine site. During the 1999 investigation, Red Devil Creek had a flow of 0.5 cubic feet per second; however, the flow rate varies significantly seasonally (Wilder/HLA 1999). The Kuskokwim River is generally ice-free from mid-June through October.

A spring is located along the left bank of Red Devil Creek in the Main Processing Area. This spring is discussed in Section 2.3.3.

2.3.5 Ecology

The vegetation around the RDM is characterized by spruce-poplar forests and upland spruce-hardwood forests. There are no known rare plants in the area of the mine site, but there is insufficient survey data to perform a complete evaluation. Aleutian cress (*Aphragmus eschscholtzianus*), arctic pennycress (*Thlaspi arcticum*), and Norberg arnica (*Arnica lessingii ssp. Norbergi*), all rare or sensitive plant species, are found in the region (Wilder/HLA 1999).

Fish found in the Kuskokwim River in the vicinity of RDM include whitefish, grayling, sculpin, sheefish, dolly varden, and Northern pike, as well as chinook, sockeye, coho, and chum salmon (Wilder/HLA 1999). Red Devil Creek was nominated for the Alaska anadromous waters catalogue by the BLM based on the observed presence of juvenile chinook and coho salmon in the creek in 2010. Moose, wolves, black bears, brown bears, lynx, martens, foxes, beavers, minks, muskrats, otters, and various small rodents are known to live in the area.

The bird species that migrate through the area are olive-sided flycatcher, gray-cheeked thrush, Townsend’s warbler, blackpoll warbler, and Hudsonian godwit (Wilder/HLA 1999). A raptor survey done on the Kuskokwim River in July 2000 found an active peregrine falcon nest 7 miles downstream of the RDM site (BLM 2001). Both the arctic peregrine falcon and American peregrine falcons are listed as Alaska species of special concern. However, no data could be found regarding what kind of peregrine falcon nested near RDM.

2.4 Demographics

The community of Red Devil is approximately 2 miles northwest of the RDM, and the community of Sleetmute is approximately 8 miles southeast of the RDM. Subsistence activities are practiced by many members of both communities. During their respective seasons, salmon, bear, moose, caribou, rabbit, and waterfowl are taken and wild berries are harvested (ADC 2010). The Kuskokwim River is used for transportation for both communities; boats are used in the summer and snow machines in the winter. The river is generally ice-free from mid-June through October. Both communities have gravel airstrips that aircraft can fly in and out of year-round.

According to the Alaska Community Database Community Information Summaries (CIS), the population of Red Devil in 2008 was 48, and 52.1% of the population is either full or part Native Alaskan. The Native Alaskans identify either as Yup'ik Eskimos or as Tanaina Athabascans. The 2000 census shows that seven people in the village were employed and that the median household income was $10,938. In the village, 40.9% of individuals and 33.3% of families were below the poverty level. One school serves six students in the community as of the 2010–2011 school year.

Sleetmute is a larger community than Red Devil and was founded by Ingalik Indians. Sleetmute remains an Ingalik Indian village, with 89% of the population identifying as Alaskan Native. According to the Alaska Community Database CIS, the population in 2008 was 70 people. The 2000 census found that 29 people in the community were employed and that 57.7% of the individuals in the community were below the poverty level. One school serves all students in the community.

3 Evaluation of Existing Data

3.1 Previous Investigations

Regional studies, contaminant investigations, and sampling programs associated with cleanup activities have been conducted at and near the RDM over the past 40 years. The history of environmental sampling and monitoring at the RDM is described below. Table 3-1 provides a chronological summary. Refer to Figure 1-3 for the locations of features discussed in this section.

1971 EPA Study. While the flotation mill was operating, the U.S. Environmental Protection Agency (EPA) collected surface water samples for mercury and arsenic analyses. One background water sample from Red Devil Creek was collected above the mine and mill. It contained 0.3 micrograms per liter (µg/L) mercury. Arsenic and mercury concentrations in Settling Pond #1 contained 12,850 µg/L mercury and 85,000 µg/L arsenic. A water sample collected from Red Devil Creek below Settling Pond #1 contained 265 µg/L mercury and 39,000 µg/L arsenic. Two water samples were collected from the Kuskokwim River, one upstream of Red Devil Creek and one downstream, near the Red Devil Airstrip. The upstream sample contained 1.7 µg/L mercury and 56 µg/L arsenic, and the downstream sample contained 1.0 µg/L mercury and 32 µg/L arsenic (EPA 1971).

1979 EPA Study. The EPA collected five surface water samples and one sediment sample at the site. Two background sites were sampled; one water sample in Red Devil Creek from above the mine workings contained 0.21 µg/L mercury. Two water samples collected from Red Devil Creek below the settling ponds both reportedly contained 0.14 µg/L mercury. Two water samples were collected from the Kuskokwim River, one upstream of Red Devil Creek and one downstream. Mercury was detected in the upstream sample at 0.28 µg/L, and the downstream sample contained 0.14 µg/L mercury (EPA 1979).

1985 Alaska Department of Environmental Conservation Well Sampling. In October 1985, the Alaska Department of Environmental Conservation (ADEC) sampled two residential wells in Red Devil Village. The identity of the well owners was confidential, so the exact locations are unknown. Neither well sample contained detectable levels of mercury or arsenic; however, one of the two wells tested “extremely high” for zinc (ADEC 1987).

1988 BLM Sampling Event. The BLM collected six surface water and 10 sediment and soil samples from Red Devil Creek, the settling ponds, and other areas around the RDM site (Weston 1989). The results of the sampling indicated the presence of mercury in Red Devil Creek water from 0.2 to 5.5 µg/L and in Red Devil Creek sediments from 41 to 967 mg/kg. A tailings pile near Settling Pond #1 contained 649 mg/kg mercury. Four background soil samples were collected and contained 0.2 to 8.0 mg/kg mercury.

Table 3-1 Summary of Previous Investigations

Year	Organization and Report Reference	Major Findings
1971	EPA Study	Mercury and arsenic were detected in surface water samples collected at and near the RDM.
1979	EPA Study	Mercury and arsenic were detected in surface water samples collected at and near the RDM.
1985	ADEC Well Sampling	Two residential use wells in Red Devil Village were sampled; neither well had detectable concentrations of mercury or arsenic.
1988	BLM Sampling Event (unpublished)	Mercury was detected in Red Devil Creek surface water and sediment and in a sample of tailings.
1989	Weston Site Inspection	Antimony, arsenic, and mercury were detected in Red Devil Creek surface water and sediment, in the settling ponds, and in tailings samples.
1997	Bailey and Gray Study	Elevated levels of total mercury and methyl mercury in soil and vegetation samples were found at the RDM compared with background locations.
1997	USGS Kuskokwim River Study	Water sample in Red Devil Creek contained arsenic, antimony, copper, chromium, and zinc.
1999	Wilder/HLA Limited Waste Removal Action	Antimony, arsenic, lead, and mercury were detected in soil samples collected near site sources in the Main Processing Area. Benzene was detected in soil at the Gravel Pad.
2001	Wilder/HLA Source Area Removal and Investigation	Monitoring wells were installed at the site. Visible elemental mercury was observed in subsurface soils adjacent to the Post-1955 Retort slab. Groundwater samples contained antimony, arsenic, lead, and zinc at concentrations above federal MCLs.
2002	Wilder Debris Consolidation and Disposal	Construction of Monofill #1 and Monofill #2. No environmental sampling was performed.
2002	Bailey et al. Study	Elevated levels of total mercury and methylmercury in soil and vegetation samples were found at RDM compared with background locations.
2004	MACTEC ASTs/Ore Hopper Demolition and Petroleum Release Investigation	Construction of Monofill #3. Petroleum Release Investigation detected hydrocarbons (DRO) in subsurface soil at the AST area. Samples from existing monitoring wells contained antimony, arsenic, and mercury above ADEC groundwater cleanup levels.
2005	MACTEC Historic Source Area Investigation	Pre-1955 ore processing structures were located through research and subsurface exploration. Mercury and arsenic were detected in surface and subsurface soil samples within and around the historical structure footprints.
2005, 2006	Wilder Contaminated Soil Stockpiling and Debris Removal	Petroleum-contaminated soil from the former AST area was excavated and stockpiled. Existing monitoring wells were sampled and contained antimony, arsenic, and mercury above ADEC groundwater cleanup standards.

Table 3-1 Summary of Previous Investigations

Year	Organization and Report Reference	Major Findings
2007, 2008, 2009	Shannon & Wilson and BLM, 2007 and 2008 Monitoring Events	Groundwater monitoring events of the existing monitoring wells showed continued presence of antimony, arsenic, and mercury in groundwater.
2009	E & E October 2009 Monitoring Event	Groundwater monitoring event of the existing monitoring wells showed continued presence of antimony, arsenic, and mercury in groundwater. Groundwater samples collected in October 2009 showed lower concentrations of metals, likely due to the use of low-flow groundwater sampling methods.
2010	USGS August 2010 Geophysical Investigation	A geophysical survey was conducted at the site using direct-current resistivity and electromagnetic induction surface methods. Based on the geophysical data and existing soil borings, there was not sufficient electrical or electromagnetic contrast to confidently distinguish between tailings, waste rock, and weathered bedrock. However, a water table was interpreted based on a correlation with the existing monitoring wells.
2010	E & E September 2010 Limited Sampling Event	Data was collected to characterize the nature and extent as well as the fate and transport of COPCs at and near the site; to provide data for human health and ecological risk assessments; and to provide data and information for use in the analysis of remedial alternatives.

Key:

ADEC = Alaska Department of Environmental Conservation
AST = aboveground storage tank
BLM = Bureau of Land Management
COPC = contaminant of potential concern
DRO = Diesel range organics
E & E = Ecology and Environment, Inc.
EPA = Environmental Protection Agency
HLA = Harding Lawson Associates
MACTEC = MACTEC Engineering and Consulting
MCL = Maximum Contaminant Level
TCLP = toxicity characteristic leaching procedure
USGS = U.S. Geological Survey
Wilder = Wilder Construction Company

1989 Site Inspection. Weston performed a CERCLA site inspection (SI) at the RDM site on behalf of the BLM during the 1988 field season. The objective of the SI was to characterize conditions for the completion of a Hazard Ranking System score for the site. The SI involved collection of samples from tailings, surface water, and sediment in Red Devil Creek and sediment in the settling ponds. Soil, sediment, and surface water samples were analyzed for a combination of analytes, including arsenic, barium, cadmium, chromium, mercury, lead, antimony, selenium, and silver. Dielectric fluid in the transformers and oil stained soil was sampled for polychlorinated biphenyls (PCBs) using field test kits. Table 3-2 presents the results of the 1989 SI samples for the applicable RI/FS contaminants of potential concern (COPCs).

Table 3-2 Summary of 1989 Site Inspection Sample Results

Sediment	Settling Pond #1	1,872	395	8,474	N/A	418.7	mg/kg
Surface Water	Above Settling Pond #1	200 U	0.4	200 U	10 U	200 U	µg/L
Surface Water	Southern border	200 U	0.3	200 U	10 U	200 U	µg/L
Surface Water	Mouth of creek	278	0.4	244	10 U	200 U	µg/L
Sediment	Above Settling Pond #1	3,450	29	2,449	25.9	480.7	mg/kg
Sediment	Southern border	0.243 U	0.6	165	17.7	261.7	mg/kg
Sediment	Below settling ponds	4,015	4,120	3,185	N/A	N/A	mg/kg
Sediment	Mouth of creek	3,113	33.3	2,194	N/A	N/A	mg/kg
Soil	Settling Pond #2	872	550	8,053	N/A	N/A	mg/kg
Soil	Settling Pond #3	664	83	6,498	N/A	N/A	mg/kg
Soil	Pile above Settling Pond #1	7,074	787	8,024	N/A	N/A	mg/kg
Soil	Pile above Settling Pond #1	22,737	498	5,851	N/A	1391.1	mg/kg

Key:

mg/kg = milligrams per kilogram.
N/A = not analyzed
U = non-detect, value listed is the method detection limit
µg/L = micrograms per liter.

Figures 3-1 and 3-2 illustrate the locations of the SI samples and list the analytical results for arsenic, mercury, and antimony.

Weston estimated approximately 51,600 cubic yards of tailings are located at the mine and mill area and an unknown quantity of tailings have been deposited in Red Devil Creek (Weston 1989).

Bailey and Gray 1997. The U.S. Geological Survey (USGS) analyzed samples from the RDM, Cinnabar Creek Mine, and regional background sites as part of a study to characterize the geochemistry of southwestern Alaska, and to evaluate environmental conditions at abandoned mercury mines in the region. The study was conducted for research purposes and was not intended to define the full extent of heavy metals contamination from specific sites. The samples included vegetation, surface water, and soil. Results of samples collected in the RDM area are summarized in Table 3-3.

Table 3-3 Summary of Bailey and Gray 1997 Mercury and Methylmercury Data for Vegetation at Red Devil Mine Site

Matrix	Location	Total Hg Range (ppb)		MeHg Range (ppb)	
Alder	Retort area (unmined)	30	310	0.45	90
Willow	Retort area (unmined)	30	330	—	—
Black spruce	Retort area (unmined)	40	370	—	—
Blueberry	Retort area (unmined)	30	330	2.60	2.76
Paper birch	Retort area (unmined)	30	180	—	—
Alder	Mined area	<20	900	0.54	0.87
Willow	Mined area	<20	560	2.73	
White spruce	Mined area	20	140	—	—
Cottonwood	Mined area	20	280	—	—
Black spruce	Mined area	20	200	—	—
Blueberry	Mined area	<20	150	—	—
Paper birch	Mined area	<20	130	—	—
Soil	Retort area (unmined)	0.14	120	8.21	
Soil	Mined area	0.15	1,200	2.73	4.19
Water	Red Devil Creek	<0.10	0.28	—	—

Source: Bailey and Gray 1997

Key:
Hg = mercury.
MeHg = methyl mercury.
ppb = parts per billion.

The study concluded that vegetation and soil samples at the mine sites contained significantly higher concentrations of total mercury and methyl mercury than background locations.

1997 USGS Kuskokwim River Study. As part of a regional study to assess water quality in the Kuskokwim River, suspended sediment and bed sediment samples were collected from stations located on the river between the villages of McGrath and Akiak. Three tributaries were sampled during the study, including Red Devil Creek. A dissolved surface water sample was collected in Red Devil Creek at its confluence with the Kuskokwim River. Mercury was not analyzed in the sample. Table 3-4 summarizes the results of selected inorganic elements from this sample (USGS 1999).

Table 3-4 Summary of 1997 USGS Red Devil Creek Sample Results

Analyte (Dissolved)	Concentration (μg/L)
Arsenic	180
Antimony	281
Copper	1.4
Chromium	1.6
Zinc	<1

Source: USGS 1999

Key:
μg/L = micrograms per liter

1999 Limited Waste Removal Action. Wilder Construction Company (Wilder)/Harding Lawson Associates (HLA) conducted an offsite waste removal and a pre-remediation sampling investigation. This project included collection of background soil samples and sampling of known contaminant source areas in the Main Processing Area, Red Devil Creek, and the Kuskokwim River.

Contaminants were detected above Alaska soil cleanup standards (Method 2, Table B1) in samples from multiple locations around sources in the Main Processing Area (see Table 3-5). Surface water and sediment samples collected from Red Devil Creek contained concentrations of metals including arsenic, antimony, and mercury above background concentrations. Sediment samples collected from the Kuskokwim River contained concentrations of arsenic, antimony, and mercury above background concentrations. Figure 3-3 summarizes soil and sediment sample results for antimony, arsenic, and mercury from this investigation (Wilder/HLA 1999).

Table 3-5 Summary of 1999 Limited Waste Removal Action Selected Soil Sample Results at Source Locations

Source/Location	Contaminants Detected Above Cleanup Levels	Detected Concentrations (mg/kg except where otherwise noted)
Battery Pile Near Shop Pad A	Lead	10,700–13,500
West Side of Post-1955 Retort Building	Antimony	529–1,520
	Arsenic	1,380–3,130
	Mercury	445–1,090
East Side of Post-1955 Retort Building	Mercury	3,330–23,800
Tailings South of Settling Pond 1	Antimony	1,780
	Arsenic	2,280
	Mercury	269
Gravel Storage Pad	Benzene	98.8 μg/kg
	Antimony	8.53
	Arsenic	1,160
	Mercury	88
Chemical Storage Sheds (near south end of Post-1955 Retort Building)	Antimony	503–720
	Arsenic	183
	Chromium	255
	Mercury	185–35,300
Settling Ponds	Antimony	162 (J)–892
	Arsenic	2,450–3,680
	Chromium	27.1
	Mercury	191 (J)–982

Key:

J = Estimated concentration.
mg/kg = milligrams per kilogram.
μg/kg = micrograms per kilogram.

2001 Source Area Removal and Investigation. This project involved asbestos abatement, demolition of structures, plugging of mine shafts, offsite waste removal, and environmental sampling in the Main Processing Area and the AST area. Soil borings and monitoring wells were installed in the Main Processing

Area. Nine subsurface borings were drilled and sampled; five were completed as monitoring wells. In addition, an extensive subsurface soil investigation was conducted around the slab of the Post-1955 Retort Building.

Surface and near-surface soil samples collected from soil borings contained antimony, arsenic, and mercury at concentrations exceeding background concentrations, consistent with result of previous investigations. Concentrations of these metals decrease significantly with depth.

The soils investigation around the Post-1955 Retort Building slab indicated the presence of relatively high concentrations of arsenic and mercury in surface and subsurface soils using x-ray fluorescence (XRF) field screening and fixed laboratory methods. Elemental mercury was observed in samples from five soil borings on the west side of the slab at depths between 2 and 6 feet bgs (see Figure 3-4).

Groundwater samples collected after well installation contained concentrations of antimony, arsenic, lead, and zinc above federal Maximum Contaminant Levels MCLs (Wilder/HLA 2001).

2002 Debris Consolidation and Disposal Project. Wilder/URS was contracted by BLM to perform further building demolition, debris segregation, and debris burial. This project involved construction of Monofill #1 and Monofill #2. No environmental sampling was performed during this project (Wilder/URS 2003).

Bailey et al. 2002. This study conducted vegetation and soil sampling at three abandoned mercury mines and at regional background sites in southwestern Alaska. Total mercury and methylmercury concentrations were found to be higher in the vegetation and soil samples from the mines sites compared to the samples collected from the regional background sites. No correlation was found between total mercury in soil and total mercury in vegetation or between total mercury and methylmercury. Results of samples collected in the RDM area are summarized in Table 3-6.

Table 3-6 Summary of Bailey et al. 2002 Mercury and Methylmercury Data for Vegetation at Red Devil Mine Site

Alder leaves and stems[a]	Tailings	ng/g	226	149-374	3	0.5	0.4–0.6	3
	Retort	ng/g	310	--	1	--	--	0
	Mined Area	ng/g	211	24-900	10	0.3	0.1–0.7	7
Willow leaves and stems[a]	Tailings	ng/g	350	346-353	2	1.6	1.4–1.8	2
	Retort	ng/g	166	74-330	19	1.8	0.4–3.4	6
	Mined Area	ng/g	136	11-560	7	5	0.3–11	6
Soil	Tailings	µg/g	970	12-1578	5	0.4	0.1–0.7	5
	Retort	µg/g	8.5	0.05-120	21	3.3	0.7–8.2	8
	Mined Area	µg/g	210	6-1200	12	2.2	0.3–7.2	10

Notes:

a Current year's growth.
b Different units are used for vegetation (ng/g) and soil (ug/g).

Key:
-- = Not available or not relevant.
n = Number of samples.
ng/g = Nanograms per gram (parts per billion).
ug/g = Micrograms per gram (part per million).

2003 Historic Source Area Investigation. For the BLM, MACTEC Engineering and Consulting (MACTEC) conducted a literature review, interviews of local persons knowledgeable about the mine history, and a sampling investigation of the Pre-1955 Retort Building, the Pre-1955 Rotary Furnace, the Pre-1955 Rotary Furnace Stack, and a “burnt ore” (tailings) disposal pile located southeast of the Pre-1955 Retort Building (MACTEC 2005).

Pre-1955 Retort Building. Nine surface soil samples were collected from within and around the historical structure footprint. Samples were analyzed for mercury and arsenic. Mercury speciation analysis was also performed. Arsenic was detected at concentrations from 89 to 1,250 mg/kg. Mercury was detected at concentrations from 2.9 to 32.0 mg/kg. Mercury speciation indicated methyl mercury concentrations from 0.357 to 1.688 micrograms per kilogram (µg/kg).

Pre-1955 Rotary Furnace. Eleven soil samples were collected around the historical footprint of the structure. The samples were collected from the surface to 2.7 feet bgs. Samples were analyzed for mercury and arsenic. Mercury speciation analysis was also performed. Arsenic was detected at concentrations from 38 to 2,000 mg/kg. Mercury was detected at concentrations from 2.5 to 140 mg/kg. Mercury speciation indicated methyl mercury concentrations from 0.186 to 0.563 µg/kg.

Pre-1955 Rotary Furnace Stack. One surface soil sample was collected and analyzed for mercury, arsenic, and mercury speciation at the site of the historical rotary furnace stack. Arsenic was detected at a concentration of 118 mg/kg. Mercury was detected at a concentration of 3.4 mg/kg. Mercury speciation indicated a methyl mercury concentration of 0.050 μg/kg.

Pre-1955 Retort "Burnt Ore" Stockpile. One surface soil sample was collected and analyzed for mercury, arsenic, and mercury speciation at the site of the "burnt ore" (tailings) disposal pile southeast of the Pre-1955 Retort Building. Arsenic was detected at 1,390 mg/kg. Mercury was detected at 940 mg/kg. Mercury speciation indicated a methyl mercury concentration of 0.445 μg/kg.

Figure 3-5 illustrates soil sample results for mercury and arsenic from the 2003 investigation.

2004 AST/Ore Hopper Demolition and Petroleum Release Investigation. MACTEC was contracted by the BLM to demolish and dispose of the ASTs and ore hopper. This project involved construction of Monofill #3. Environmental sampling, including 12 soil borings, was conducted to characterize the AST area, and the existing monitoring wells were sampled.

Soils investigations at the AST area detected petroleum hydrocarbons (diesel range organics [DRO]) above ADEC cleanup levels in excavations and soil borings. Groundwater samples collected from the existing monitoring wells contained antimony, arsenic, and mercury at concentrations above ADEC cleanup levels; DRO and residual range organics (RROs) were detected in groundwater samples below ADEC cleanup levels (MACTEC 2004).

2005/2006 AST Soil Stockpiling and Debris Removal. Wilder and URS Corporation excavated petroleum-contaminated soil in the AST area and sampled the excavated soil prior to placing the material in covered stockpiles. Environmental sampling was not conducted except for the annual sampling of the five monitoring wells. Antimony, arsenic, and mercury were detected in the groundwater samples above ADEC cleanup levels.

2007, 2008, and 2009 Monitoring Events. The monitoring wells were sampled in 2000, 2003, 2005, 2006, 2007, 2008, and 2009. The 2007 and 2008 sampling events were done by Shannon & Wilson, Inc., and are summarized in groundwater sampling reports for each year. The 2008 monitoring event also included one sample taken from a hillside seep.

2009 Monitoring Event. The October 2009 sampling event was conducted by E & E and included five surface water samples in addition to the monitoring well samples (E & E 2010a). The October 2009 data is presented in the E & E groundwater and surface water sampling report. A summary of the analytical data in presented in Figures 3-6 and 3-7. A comparison of the 2009 and 2010 groundwater data is presented in Table 3-7.

2010 USGS Geophysical Investigation. In August 2010, in cooperation with the BLM and in conjunction with the RI/FS, the USGS conducted a geophysical investigation at the RDM site using surface-based; direct-current resistivity and electromagnetic induction methods. Eight two-dimensional cross-sections and one three-dimensional grid of direct-current resistivity data, and 5.7 kilometers of electromagnetic induction data was obtained along Red Devil Creek valley, from the Main Processing Area to Red Devil Creek's confluence with the Kuskokwim River. Results of the geophysical investigation indicate that there is no significant contrast in resistivity between the tailings, waste rock, and bedrock at the site. However, based on correlation with existing monitoring wells, a water table was interpreted on the direct-current resistivity cross-sections. Several anomalies were also identified in the direct-current resistivity profiles and the three-dimensional grid. Down-hole geophysical logs and analyzing soil and rock samples to determine how water content affects the bulk resistivity values were recommended and useful additional analyses.

2010 Limited Sampling Event. E & E conducted a sampling investigation of surface soil, sediment, surface water, and groundwater (E & E 2010b). Data was collected to characterize the nature and extent as well as the fate and transport of COPCs at and near the site; to provide data for human health and ecological risk assessments; and to provide data and information for use in the analysis of remedial alternatives. Laboratory and XRF data from the 2010 Limited Sampling Event are provided in Appendix F.

Soil Visual Inspection and XRF Screening

Forty-four grid locations and 33 transect locations were visually inspected and field screened with the XRF. At each grid and transect location, soil was analyzed in situ with an XRF. Soil descriptions from the visual inspection are presented in Table 3-8. Grid locations were used to characterize the nature of the tailings/waste rock within the portions of the Main Processing Area and Red Devil Creek Valley expected to contain tailings/waste rock based on existing information. Transect locations were used to confirm or refine the extent of the tailings/waste rock within the Main Processing Area and Red Devil Creek Valley. Each transect initially consisted of two points – Stations A and B – on a line segment oriented perpendicular to and straddling the expected lateral limit of tailings/waste rock. If tailings/waste rock materials were identified at the initial Station B location along any given transect, that transect was extended further outward by approximately 25 feet from the initial Station B to assess whether the soil materials at that location contain tailings/waste rock. Similarly, if it appeared that tailings/waste rock were not present at the Station A position along a given transect, the transect line was extended inward approximately 25 feet from Station A. This process was repeated until the apparent lateral extent of tailings/waste rock materials at that transect was preliminarily identified, to the extent possible. At most transects, the boundary between materials containing tailings/waste rock was confirmed or refined. At several transects, the boundary was not resolved.

Table 3-7 2009 and 2010 Groundwater Laboratory Results

General Geographic Area				Main Processing Area												
Sub-Area				Gravel Pad / Monofill #3 Area			Settling Pond Area			Mine Openings / Monofill #1 / Former Shop Buildings / Tailings			Pre-1955 Retort Area		Power Plant / Former Drum Storage Area	
Location Description				Gravel Pad / Downgradient from Monofill #3			Berm of Settling Pond #1 / Downgradient of Settling Pond #1 Tailings			Downgradient of Former Shop Pad			Possibly downdradient of Pre-1955 Retort Area		Downgradient from Power Plant / Former Drum Storage Area	
				MW-01			MW-03			MW-04			MW-06		MW-07	
				2009	2010		2009		2010	2009	2010		2009	2010	2009	2010
Analyte	Method	Units	Comparison Values*	09RDMMW01 10/2009	10MW01GW 9/20/2010 6:24:00 PM	10MW40GW (Duplicate of 10MW01GW) 9/20/2010 8:00:00 PM	09RDMMW03 10/2009	09RDMMW08 (Duplicate of 09RDMMW03)	10MW03GW 9/21/2010 7:55:00 PM	09RDMMW04 10/2009	10MW04GW 9/21/2010 4:10:00 PM	10MW41GW (Duplicate of 10MW04GW) 9/21/2010 5:00:00 PM	09RDMMW06 10/2009	10MW06GW 9/21/2010 1:30:00 PM	Well was dry on 10/7/2009	10MW07GW 9/21/2010 10:20:00 AM
Bromobenzene	AK101	mg/l		--	23.8	23.2	--	--	--	--	--	--	--	--	--	--
Gasoline Range Hydrocarbons	AK101	mg/l		--	0.1 U	0.1 U	0.10 U	0.10 U	--	--	--	--	0.10 U	--	--	--
Trifluorotoluene	AK101	mg/l		--	48.6	47.5	--	--	--	--	--	--	--	--	--	--
Diesel Range Hydrocarbons	AK102/AK103 TPHD	mg/l	1.5	--	0.1 U	0.1 U	0.25 U	0.25 U	--	--	0.11	--	0.25 U	--	--	--
Motor Oil	AK102/AK103 TPHD	mg/l		--	0.2 U	0.2 U	0.50 U	0.50 U	--	--	0.2 U	--	0.50 U	--	--	--
n-Triacontane	AK102/AK103 TPHD	mg/l		--	44.8	44.8	--	--	--	--	44.6	--	--	--	--	--
o-Terphenyl	AK102/AK103 TPHD	mg/l		--	37.2	40.5	--	--	--	--	37.2	--	--	--	--	--
Total Dissolved Solids	EPA 160.1	mg/L		--	230	--	--	--	158	--	343	349	--	218	--	--
Total Suspended Solids	EPA 160.2	mg/L		--	20.4	--	--	--	1.1 U	--	2.1 U	1 U	--	2.4	--	--
MeHg	EPA 1630	ng/L	NA	--	1.71	--	0.020 U	0.020 U	0.05 U	--	0.081	0.063	0.020 U	0.049 U	--	--
Total Hg	EPA 1631	ng/L	2.00	41.3	16.7	--	9.73	9.77	16.5	81.0	150	148	11.8	1.85	--	--
Dissolved Hg	EPA 1631	ng/L	2.00	--	8.5	--	--	--	6.47	--	149	139	--	0.41 U	--	12.1
As(III)	EPA 1632	µg/L		--	7.23	6.66	0.861 M	0.906	--	3.91	--	--	--	--	--	--
As(Inorg)	EPA 1632	µg/L		--	9.57	11.2	45.3 J	28.6 J	--	10.4 J	--	--	--	--	--	--
As(V)	EPA 1632	µg/L		--	2.34	4.54	44.4 J	27.7 J	--	6.49 J	--	--	--	--	--	--
Chloride	EPA 300.0	mg/L		--	0.7	--	--	--	0.5	--	0.5	0.5	--	0.8	--	0.8
Fluoride	EPA 300.0	mg/L		--	0.1	--	--	--	0.1 U	--	0.1	0.1	--	0.1	--	0.1 U
Sulfate	EPA 300.0	mg/L		--	38.9	--	--	--	35.4	--	180	182	--	29	--	3.5
Nitrate + Nitrite	EPA 353.2	mg-N/L		--	0.05 U	--	--	--	0.109	--	0.011	0.01 U	--	0.01 U	--	
Alkalinity	SM 2320	mg/L CaCO3		--	124	--	--	--	113	--	92.8	93.3	--	180	--	30.3
Bicarbonate	SM 2320	mg/L CaCO3		--	124	--	--	--	113	--	92.8	93.3	--	180	--	30.3
Carbonate	SM 2320	mg/L CaCO3		--	1 U	--	--	--	1 U	--	1 U	1 U	--	1 U	--	1 U
Hydroxide	SM 2320	mg/L CaCO3		--	1 U	--	--	--	1 U	--	1 U	1 U	--	1 U	--	1 U
Aluminum	SW6010B-Diss	µg/L		--	50 U	--	50 U	50 U	50 U	--	50 U	50 U	--	50 U	--	140
Calcium	SW6010B-Diss	µg/L		--	23900	--	26400	27000	22200	--	34000	34200	--	32000	--	7180
Iron	SW6010B-Diss	µg/L		--	19100	--	20 U	20 U	50 U	--	50 U	50 U	--	1680	--	60
Magnesium	SW6010B-Diss	µg/L		--	14900	--	26300	26300	22700	--	45200	45600	--	29100	--	2900
Potassium	SW6010B-Diss	µg/L		--	500 U	--	960	1020	870	--	880	880	--	730	--	500
Silicon	SW6010B-Diss	mg/L		--	6.47	--	--	--	5.02	--	4.97	--	--	8.18	--	--
Sodium	SW6010B-Diss	µg/L		--	7040	--	3580	3530	2730	--	4850	4920	--	4120	--	2480
Antimony	SW6020-Diss	µg/L	6	--	1.4	--	736	727	724	--	30	30.5	--	5.2	--	4.9
Arsenic	SW6020-Diss	µg/L	10	--	9	--	46.7	46.1	55.8	--	8.8	9.3	--	26.3	--	0.4
Barium	SW6020-Diss	µg/L	2000	--	85.9	--	42.2	42.5	31.8	--	35.7	36	--	79.2	--	29
Beryllium	SW6020-Diss	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	0.2 U
Cadmium	SW6020-Diss	µg/L	5	--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 J	0.3 J	--	0.2 U	--	0.2 U
Chromium	SW6020-Diss	µg/L		--	0.5 U	--	0.5 U	0.5 U	0.5 U	--	0.5 U	0.5 U	--	0.5 U	--	1.8
Cobalt	SW6020-Diss	µg/L		--	0.7	--	0.2 U	0.2 U	0.2 U	--	1.7	1.6	--	1.4	--	0.2
Copper	SW6020-Diss	µg/L	1000	--	0.5 U	--	0.5 U	0.5 U	0.5 U	--	1.8	1.5	--	0.5 U	--	1.1
Lead	SW6020-Diss	µg/L		--	1 U	--	1 U	1 U	1 U	--	1 U	1 U	--	1 U	--	1 U
Manganese	SW6020-Diss	µg/L		--	712	--	0.5 U	0.5 U	0.5 U	--	1030	1080	--	575	--	10.1
Nickel	SW6020-Diss	µg/L	100	--	0.9	--	1.1	1	1.1	--	34.6	36.3	--	2.3	--	1.8
Selenium	SW6020-Diss	µg/L	50	--	0.5 U	--	2 U	2 U	0.9	--	0.5 U	0.5 U	--	0.5 U	--	0.5 U
Silver	SW6020-Diss	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	0.2 U
Thallium	SW6020-Diss	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	0.2 U
Vanadium	SW6020-Diss	µg/L	260	--	1.4	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	1
Zinc	SW6020-Diss	µg/L	5000	--	4 U	--	4 U	4 U	4 U	--	15	13	--	4 U	--	17
Aluminum	SW6010B-Total	µg/L		--	50 U	--	50 U	50 U	50 U	--	50 U	50 U	--	50 U	--	--
Calcium	SW6010B-Total	µg/L		--	26300	--	26800	26300	20200	--	33000	33000	--	32600	--	--
Iron	SW6010B-Total	µg/L		20100	22400	--	20 U	20 U	50 U	30	50 U	50 U	1060	1780	--	--
Magnesium	SW6010B-Total	µg/L		--	16300	--	26300	26400	20700	--	43700	44000	--	29700	--	--
Potassium	SW6010B-Total	µg/L		--	500 U	--	990	960	830	--	880	870	--	750	--	--
Sodium	SW6010B-Total	µg/L		--	7580	--	3370	3470	2580	--	4880	4890	--	4340	--	--
Antimony	SW6020-Total	µg/L	6	1.3	1.8	--	740	727	748	38.9	29.1	29.3	5	5.4	--	--

Table 3-7 2009 and 2010 Groundwater Laboratory Results

General Geographic Area				Main Processing Area												
Sub-Area				Gravel Pad / Monofill #3 Area			Settling Pond Area			Mine Openings / Monofill #1 / Former Shop Buildings / Tailings			Pre-1955 Retort Area		Power Plant / Former Drum Storage Area	
Location Description				Gravel Pad / Downgradient from Monofill #3			Berm of Settling Pond #1 / Downgradient of Settling Pond #1 Tailings			Downgradient of Former Shop Pad			Possibly downdradient of Pre-1955 Retort Area		Downgradient from Power Plant / Former Drum Storage Area	
				MW-01			MW-03			MW-04			MW-06		MW-07	
				2009	2010		2009		2010	2009	2010		2009	2010	2009	2010
Analyte	Method	Units	Comparison Values*	09RDMMW01 10/2009	10MW01GW 9/20/2010 6:24:00 PM	10MW40GW (Duplicate of 10MW01GW) 9/20/2010 8:00:00 PM	09RDMMW03 10/2009	09RDMMW08 (Duplicate of 09RDMMW03)	10MW03GW 9/21/2010 7:55:00 PM	09RDMMW04 10/2009	10MW04GW 9/21/2010 4:10:00 PM	10MW41GW (Duplicate of 10MW04GW) 9/21/2010 5:00:00 PM	09RDMMW06 10/2009	10MW06GW 9/21/2010 1:30:00 PM	Well was dry on 10/7/2009	10MW07GW 9/21/2010 10:20:00 AM
Arsenic	SW6020-Total	µg/L	10	**12.9**	**10.6**	--	**48.2**	**46.9**	**57.8**	**9.6**	**8.8**	**8.9**	**28.9**	**28.1**	--	--
Barium	SW6020-Total	µg/L	2000	--	**100**	--	**44**	**43.1**	**31.4**	--	**35**	**35**	--	**79.3**	--	--
Beryllium	SW6020-Total	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	--
Cadmium	SW6020-Total	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2	0.2	--	0.2 U	--	--
Chromium	SW6020-Total	µg/L		--	0.5 U	--	0.5 U	0.5 U	0.5 U	--	0.5 U	0.5 U	--	0.5 U	--	--
Cobalt	SW6020-Total	µg/L		--	**0.7**	--	0.2 U	0.2 U	0.2 U	--	**1.6**	**1.6**	--	**1.4**	--	--
Copper	SW6020-Total	µg/L	1000	--	0.5 U	--	0.5 U	0.5 U	0.5 U	--	**1.5**	**1.6**	--	0.5 U	--	--
Lead	SW6020-Total	µg/L		--	1 U	--	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	--	--
Manganese	SW6020-Total	µg/L		--	**914**	--	0.5 U	0.5 U	0.5 U	--	**1040**	**1030**	--	**569**	--	--
Nickel	SW6020-Total	µg/L	100	--	**1**	--	**1.3**	**1.3**	**1.3**	--	**35.4**	**35.7**	--	**2.3**	--	--
Selenium	SW6020-Total	µg/L	50	--	0.5 U	--	2 U	**1.2**	**0.9**	--	0.5 U	0.5 U	--	0.5 U	--	--
Silver	SW6020-Total	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	--
Thallium	SW6020-Total	µg/L		--	0.2 U	--	0.2 U	0.2 U	0.2 U	--	0.2 U	0.2 U	--	0.2 U	--	--
Vanadium	SW6020-Total	µg/L	260	--	**1.7**	--	0.2 U	0.2 U	**0.2**	--	0.2 U	0.2 U	--	0.2 U	--	--
Zinc	SW6020-Total	µg/L	5000	--	4 U	--	4 U	4 U	4 U	--	**13**	**13**	--	4 U	--	--
Benzene	SW8021BMod	µg/L		--	1 U	1 U	1.0 U	1.0 U	--	--	--	--	1.0 U	--	--	--
Bromobenzene	SW8021BMod	µg/L		--	**24.2**	**23.6**	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	SW8021BMod	µg/L		--	1 U	1 U	1.0 U	1.0 U	--	--	--	--	1.0 U	--	--	--
m,p-Xylene	SW8021BMod	µg/L		--	1 U	1 U	1.0 U	1.0 U	--	--	--	--	1.0 U	--	--	--
o-Xylene	SW8021BMod	µg/L		--	1 U	1 U	1.0 U	1.0 U	--	--	--	--	1.0 U	--	--	--
Toluene	SW8021BMod	µg/L		--	1 U	1 U	1.0 U	1.0 U	--	--	--	--	1.0 U	--	--	--
Trifluorotoluene	SW8021BMod	µg/L		--	**49.8**	**48.6**	--	--	--	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
1,2-Dichlorobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
1,3-Dichlorobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
1,4-Dichlorobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
1-Methylnaphthalene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2,2'-Oxybis(1-Chloropropane)	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2,4,5-Trichlorophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2,4,6-Trichlorophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2,4-Dichlorophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2,4-Dimethylphenol	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2,4-Dinitrophenol	SW8270D	µg/L		--	10 U	10 U	--	--	--	--	10 U	--	--	--	--	--
2,4-Dinitrotoluene	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2,6-Dinitrotoluene	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2-Chloronaphthalene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2-Chlorophenol	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2-Methylnaphthalene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2-Methylphenol	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
2-Nitroaniline	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
2-Nitrophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
3,3'-Dichlorobenzidine	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
3-Nitroaniline	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
4,6-Dinitro-2-Methylphenol	SW8270D	µg/L		--	10 U	10 U	--	--	--	--	10 U	--	--	--	--	--
4-Bromophenyl-phenylether	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
4-Chloro-3-methylphenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
4-Chloroaniline	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
4-Chlorophenyl-phenylether	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
4-Methylphenol	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
4-Nitroaniline	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
4-Nitrophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
Acenaphthene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Acenaphthylene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--

Table 3-7 2009 and 2010 Groundwater Laboratory Results

General Geographic Area				Main Processing Area												
Sub-Area				Gravel Pad / Monofill #3 Area			Settling Pond Area			Mine Openings / Monofill #1 / Former Shop Buildings / Tailings			Pre-1955 Retort Area		Power Plant / Former Drum Storage Area	
Location Description				Gravel Pad / Downgradient from Monofill #3			Berm of Settling Pond #1 / Downgradient of Settling Pond #1 Tailings			Downgradient of Former Shop Pad			Possibly downdradient of Pre-1955 Retort Area		Downgradient from Power Plant / Former Drum Storage Area	
				MW-01			MW-03			MW-04			MW-06		MW-07	
				2009	2010		2009		2010	2009	2010		2009	2010	2009	2010
Analyte	Method	Units	Comparison Values*	09RDMMW01 10/2009	10MW01GW 9/20/2010 6:24:00 PM	10MW40GW (Duplicate of 10MW01GW) 9/20/2010 8:00:00 PM	09RDMMW03 10/2009	09RDMMW08 (Duplicate of 09RDMMW03)	10MW03GW 9/21/2010 7:55:00 PM	09RDMMW04 10/2009	10MW04GW 9/21/2010 4:10:00 PM	10MW41GW (Duplicate of 10MW04GW) 9/21/2010 5:00:00 PM	09RDMMW06 10/2009	10MW06GW 9/21/2010 1:30:00 PM	Well was dry on 10/7/2009	10MW07GW 9/21/2010 10:20:00 AM
Anthracene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzo(a)anthracene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzo(a)pyrene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzo(b)fluoranthene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzo(g,h,i)perylene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzo(k)fluoranthene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Benzoic Acid	SW8270D	µg/L		--	10 U	10 U	--	--	--	--	10 U	--	--	--	--	--
Benzyl Alcohol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
bis(2-Chloroethoxy) Methane	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Bis-(2-Chloroethyl) Ether	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
bis(2-Ethylhexyl)phthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Butylbenzylphthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Carbazole	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Chrysene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Dibenz(a,h)anthracene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Dibenzofuran	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Diethylphthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Dimethylphthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Di-n-Butylphthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Di-n-Octyl phthalate	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Fluoranthene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Fluorene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Hexachlorobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Hexachlorobutadiene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Hexachlorocyclopentadiene	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
Hexachloroethane	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Isophorone	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Naphthalene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Nitrobenzene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
N-Nitroso-Di-N-Propylamine	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
N-Nitrosodiphenylamine	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
Pentachlorophenol	SW8270D	µg/L		--	5 U	5 U	--	--	--	--	5 U	--	--	--	--	--
Phenanthrene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Phenol	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Pyrene	SW8270D	µg/L		--	1 U	1 U	--	--	--	--	1 U	--	--	--	--	--
Unknown Hydrocarbon	SW8270D	µg/L		--	**2 J**	4 U	--	--	--	--	4 U	--	--	--	--	--
Temperature	Field Test	°C		4.50	13.16	--	5.38	--	5.41	4.81	6.67	--	4.54	5.14	--	14.24
pH	Field Test	N/A		6.45	6.33	--	6.13	--	6.30	6.23	6.16	--	6.37	6.72	--	6.24
ORP	Field Test	mV		-15.7	-41	--	217.8	--	0.00	143.80	0.00	--	13.60	0.00	--	199
Conductance	Field Test	mS/cm		0.430	0.355	--	0.428	--	0.307	0.450	0.565	--	0.509	0.432	--	0.069
Turbidity	Field Test	NTU		-1.6	2.2	--	15.2	--	0.00	-2.1	0.00	--	-0.7	0.00	--	102
Dissolved Oxygen	Field Test	mg/L		--	0.27	--	--	--	2.97	--	0.00	--	--	0.00	--	9.69
Static Water Level	Field Test	ft below top of inner casing		22.27	20.04	--	23.01	--	20.95	27.77	26.79	--	19.29	19.03	Dry	20.61

Table 3-7 2009 and 2010 Groundwater Laboratory Results

General Geographic Area				Main Processing Area												
Sub-Area				Gravel Pad / Monofill #3 Area			Settling Pond Area			Mine Openings / Monofill #1 / Former Shop Buildings / Tailings			Pre-1955 Retort Area		Power Plant / Former Drum Storage Area	
Location Description				Gravel Pad / Downgradient from Monofill #3			Berm of Settling Pond #1 / Downgradient of Settling Pond #1 Tailings			Downgradient of Former Shop Pad			Possibly downdradient of Pre-1955 Retort Area		Downgradient from Power Plant / Former Drum Storage Area	
				MW-01			MW-03			MW-04			MW-06		MW-07	
				2009	2010		2009		2010	2009	2010		2009	2010	2009	2010
Analyte	Method	Units	Comparison Values*	09RDMMW01 10/2009	10MW01GW 9/20/2010 6:24:00 PM	10MW40GW (Duplicate of 10MW01GW) 9/20/2010 8:00:00 PM	09RDMMW03 10/2009	09RDMMW08 (Duplicate of 09RDMMW03)	10MW03GW 9/21/2010 7:55:00 PM	09RDMMW04 10/2009	10MW04GW 9/21/2010 4:10:00 PM	10MW41GW (Duplicate of 10MW04GW) 9/21/2010 5:00:00 PM	09RDMMW06 10/2009	10MW06GW 9/21/2010 1:30:00 PM	Well was dry on 10/7/2009	10MW07GW 9/21/2010 10:20:00 AM

Key	
BOLD	Result is above method reporting limit
Highlited	Result exceeds comparison value
°C	Degrees Celsius
ft	Feet
J	Analyte detected but relative percent difference was outside control limits therefore concentration is estimated.
L/min	Liters per Minute
M	Presence of material is verified but not quantified; the actual value is less than the value given. The level is too low to permit accurate quantification, but the estimated concentration is greater than the method detection limit
mS/cm	Millisiemens per Centimeter
mV	Millivolt
NTU	Nephelometric Turbidity Unit
ORP	Oxidation reduction potential
mg/L	Milligrams per Liter
µg/L	Microgram per Liter
ng/L	Nanogram per Liter
U	Analyte was analyzed for but not detected. Value provided is reporting limit.
--	not analyzed

*ADEC Cleanup Level (2009) Table C

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP03	9/18/2010	1025	Sand and gravel. Black, moist, well graded silt through gravel. Sand and gravel are subangular. Gravels are a combination of graywacke, argillites, and calcines, somewhat loose. Calcines: scattered throughout, red w large pore spaces. Minerals: graywacke with a white opaque mineral.	Yes	Yes	No
10MP80	9/18/2010	1055	Sand and gravel. Black, moist, well graded silt through gravel. Sand and gravel are subangular. Gravels are a combination of graywacke, argillites, and calcines, somewhat loose. Calcines: scattered throughout, red w large pore spaces. Minerals: graywacke with a white opaque mineral.	Yes	Yes	No
10MP04	9/18/2010	1110	Sand and gravel - gravel is fine up to 3/4 inch. Black, moist, well graded silt through gravel, sand and gravel are subangular, gravels are a combination of graywacke, argillites and calcines, somewhat loose. Calcines: scattered throughout area, red, some with large pores. Minerals: graywacke with white opaque minerals.	Yes	Yes	No
10MP05	9/18/2010	1130	Sand and gravel - gravel is fine up to 3/4 inch. Black, moist, well graded silt through gravel, sand and gravel are subangular, gravels are a combination of graywacke, argillites and calcines, somewhat loose. Calcines: scattered throughout area, red, some with large pores. Minerals: graywacke with white opaque minerals.	Yes	Yes	No
10MP06	9/17/2010	1420	Silt and gravel (50/50). Black to brown. Somewhat loose well graded silt through gravel up to 3/4", mainly calcines and graywacke (gray) present, graywacke's tend to have rust colored staining, no cinnabar or stibnite noted, but white opaque mineral vein deposits noted in sample graywackes, calcines vary in color from orange to red, blackish to light brown.	Yes	Yes	No
10MP07	9/17/2010	1230	Silt and gravel (50/50). Bare rock surface, black to brown, somewhat loose, some sand, well graded silt through gravel up to 3/4". Argillites (black), graywacke (weathered rust color on outside), calcines red and black (very prevalent) with pores --> easy to crumble. Calcines - red and black + orange gravel size mixed throughout. Minerals: some white mineral veins noted in graywacke and black shale argillites.	Yes	Yes	No
10MP08	9/17/2010	1200	Silt and gravel. Brown to black, moist, somewhat loose, some medium sand, some gravel, angular to subangular, little rounded pieces. Argillites - calcines - graywackes present, stibnite/cinnabar vein in one piece of graywacke. Calcines: scattered throughout, red porous, soft. Minerals: stibnite/cinnabar in one piece of graywacke.	Yes	Yes	Yes
10MP09	9/18/2010	1300	Silt and gravel (50/50). Overall brown to black, moist, argillites, graywacke, and red calcines present, angular to subangular, little foreign granitic river rock scattered at surface, rand I size up to 4", well graded, some graywackes with brown weathering on outside. argillites are black shale. Stibnite and cinnabar bearing graywacke in vicinity. Some brown sandstone in area, white opaque mineral veins present.	Yes	Yes	No
10MP11(1)	9/16/2010	1747	Dark brown, moist, gravelly silt/salty gravel with sand. ~35% gravel, up to 2". ~35% silt. ~20% coarse sand. ~10 fine sand. Gravel is angular to sub rounded and comprised on sandstone, siltstone and one piece of dike material, one piece of slag. No burnt ore found in sample but some found near sample. No mineralized vein material.	No	No	No
10MP11(2)	9/19/2010	1240	Silt and gravel (50/50). Brown, somewhat dry, well graded, some sand, gravel up to 1.5", mostly graywacke (gray; not weathered on outside), little argillites (black shale) and calcines (brick red, porous) that are under 1/2 inch, gravel is subangular, several rounded nonnative river rock in area, no minerals of note.	Yes	No	Yes

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP88SS	9/19/2010	1300	Silt and gravel (50/50). Brown, somewhat dry, well graded, some sand, gravel up to 1.5", mostly graywacke (gray; not weathered on outside), little argillites (black shale) and calcines (brick red, porous) that are under 1/2 inch, gravel is subangular, several rounded nonnative river rock in area, no minerals of note.	Yes	No	Yes
10MP12(1)	9/16/2010	1720	Dark brown moist gravelly sand with silt. ~35% med-coarse sand and pebbles. 30% gravel, angular to rounded up to 2". 30% silt. Trace fine sand. Gravel consists mostly of sandstone and siltsotne, one rounded river rock, granitoid and one piece of burnt ore. no mineralized veins observed in sample.	No	No	Yes
10MP12(2)	9/18/2010	1023	Dark gray/brn, moist. Sandy gravel with silt. ~70% gravel from 1/4" to 3". ~20% med-coarse sand. ~10% silt. Gravel consists of angular to subrounded mostly sandstone & siltstone. Some of the sandstone was a rusty orange color. Some of the siltstone had white veins. Several pieces of red/orange cooked ore observed in sample, also a yellow mineral (possibly or pigment) observed in sample. One 1" rock appeared to be all mineral/ vein material.	Yes	Yes	No
10MP13(1)	9/16/2010	1658	Dark brown gravelly sand with some silt. 35% gravel. 30% sand. 20% pebbles. 15% silt. Gravel is angular to rounded. No burnt ore observed in sample. No mineralization observed in sable.	No	No	Yes
10MP13(2)	9/18/2010	0956	Dark brown/gray, moist. Sandy gravel w/ silt. ~70% gravel up to 4.5". ~20% med-coarse sand, ~10% silt. Gravel is subangular to subrounded. Consist manly of sandstone and siltstone. Some of the siltstone had white and orangish veins. Several high mineralized chunks of gravel observed, 2 of them which may have contained cinnabar. One piece of gravel appeared red/orange and was likely baked ore.	No	Yes	No
10MP14 (1640)	9/16/2010	1640	Dark brown/reddish brown gravelly sand/sandy gravel with silt. ~40 gravel up to 1.5". 40% fine to coarse sand. 20% silt. Gravel is subangular to sub rounded. Contains sandstone siltstone and a fair amount of cooked ore, particularly towards the bottom of the hole. no mineralized veins found in sample.	No	No	No
10MP14 (1753)	9/17/2010	1753	Sample recollected in road. Dark gray to med-brn sandy gravel with silt. ~60% gravel up to 5". ~30% silt and 10% med sand. Gravel is angular to rounded and is comprised mostly of sandstone and siltstone. 4 Small round river rocks were observed in sample. 1 piece of reddish orange sandstone with small ___ was observed in sample. It was likely burnt ore. Several pieces of silt stone had white veins. No mineralized (cinnabar) was observed in sample.	No	No	No
10MP15(1)	9/16/2010	1540	Medium brown moist gravelly silt, trace sand. 40% gravel, angular to subangular. 15% pebbles. 30% silt. 15% med-fine sand. Gravel is mainly sandstone and some siltstone. No burn ore or mineralized veins observed in sample.	No	Yes	No
10MP15(2)	9/17/2010	1820	Silt and Gravel. Brown and black, moist, very tight, mostly gravel, fine through 1", Mostly graywacke some reddish weathering to graywacke, well graded, mainly granular, little clay.	No	No	No
10MP18	9/16/2010	1445	Medium/dark brown, moist gravelly silt. 30% gravel, angular to subrounded. 20% pebbles. 40% silt. 10% med-fine sand. Gravel is composed on mainly sandstone and some siltstone. Some fragments of sandstone were rusty orange colored. No burnt ore or mineralized veins observed in sample.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP10	9/21/2010	1835	Clayey silt + gravel (15/45/40). Brown, moist, well graded clay through gravel, gravel at surface is graywacke and argillites, subsurface has discolored (orange, red, black) graywacke - possibly burnt ore (contains cinnabar)- some rounded river rock in general area.	No	No	Yes
10MP19	9/23/2010	1815	Silt + gravel (40/60). Brown, moist, fine to organic layer, well graded silt through 1.5" gravel. Most gravel composed of gray, non-weathered subangular graywacke, very little argillite. No mineralization. Tightly compacted.	No	No	No
10MP01	9/18/2010	1553	Sandy gravel (25/75). Mostly black with some rusty weathering browns and deep reds, well graded silts through fine cobble, larger grains mostly graywacke, smaller grains (less than 1/2") largely argillites (black shale). Most graywackes weathered to rusty colors outside, some white opaque mineralization in graywacke. No noted cinnabar, stibnite, or realgar, calcines are absent.	No	Yes	No
10MP01(2)	9/24/2010	1845	Med -dark brown gravelly silt with sand. ~70% silt, 20% gravel and 10% fine sand. Gravel consists primarily of Kusko sandstone, one piece of siltstone, black. Sandstone was grey to brown, some was brownish grey. No rinds observed. No cinnabar, stibnite, realgar, free Hg, odor, sheen or evidence of cooked ore observed.	No	No	No
10MP02	9/18/2010	1520	Sandy gravel (50/50). Well graded. Gray-red-black mottled, crushed rock silt size through cobble, argillites and graywacke present, graywackes have high percentage of mineralization, minerals are mostly realgar and cinnabar, present. No stibnite noted. No calcines noted. Some white dike material in area, angular.	No	Yes	No
10MP81	9/18/2010	1605	Sandy gravel (50/50). Well graded. Gray-red-black mottled, crushed rock silt size through cobble, argillites and graywacke present, graywackes have high percentage of mineralization, minerals are mostly realgar and cinnabar, present. No stibnite noted. No calcines noted. Some white dike material in area, angular.	No	Yes	No
10MP16	9/18/2010	1110	Med to dark reddish brown moist gravelly sand with silt. ~25% gravel up to 1.5", ~10% silt, ~40% med to fine sand, 15% coarse sand, 10% pebbles. Gravel consists mostly of 'burnt' ore. Some of the material had a red/orange rind. Some was reddish orange vein-like material. Some was black siltstone, some was crystallized and possibly dike material, nothing in the sample appeared to be unprocessed ore. Reddish sandy lens observed in sample ~1/4" thick approx 3" down from ground surface.	Yes	No	No
10MP89SS	9/18/2010	1200	Med to dark reddish brown moist gravelly sand with silt. ~25% gravel up to 1.5", ~10% silt, ~40% med to fine sand, 15% coarse sand, 10% pebbles. Gravel consists mostly of 'burnt' ore. Some of the material had a red/orange rind. Some was reddish orange vein-like material. Some was black siltstone, some was crystallized and possibly dike material, nothing in the sample appeared to be unprocessed ore. Reddish sandy lens observed in sample ~1/4" thick approx 3" down from ground surface.	Yes	No	No
10MP17	9/20/2010	1015	Silt and gravel (50/50). Brown-black-red, moist, somewhat compacted, well graded silt through gravel, up to 1.5", graywacke - argillites - and calcines, high density of red calcines which were collected into sample in sand size fragments (~2% of sample), some fine gravel pieces of stibnite noted, some granite (large portion of white mineral) in sample area, some graywacke weathered to rust color on outside, some brown sandstone type gravel, argillites are similar to back slate, several rusty nails found in borehole, subangular.	Yes	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP82	9/20/2010	1030	Silt and gravel (50/50). Brown-black-red, moist, somewhat compacted, well graded silt through gravel, up to 1.5", graywacke - argillites - and calcines, high density of red calcines which were collected into sample in sand size fragments (~2% of sample), some fine gravel pieces of stibnite noted, some granite (large portion of white mineral) in sample area, some graywacke weathered to rust color on outside, some brown sandstone type gravel, argillites are similar to back slate, several rusty nails found in borehole, subangular.	Yes	No	No
10MP27	9/18/2010	1530	Dark brown, moist sandy gravel with silt. ~15% silt, ~30% med-coarse sand and 55% gravel, angular to sub round and 1/4" to 1.5". Gravel consists of sandstone siltstone and crystalline vein material. The sandstone was typically grey, but sometimes it had a rusty orange rind. The siltstone was dark grey to black. Some has white or yellow veins. The crystalline vein material appeared red, orange, and black and appeared to be cooked ore. No odor, no sheen and no identifiable stibnite cinnabar or realgar/orpiment observed in sample.	No	No	No
10MP26	9/18/2010	1556	Medium to dark reddish brown gravelly sand with silt. ~10% silt, 40% gravel, and 50% fine to very coarse sand. Gravel is subangular to sub rounded and is between 1/4 1.5 inches. It consists mainly of material which appears baked. Most of the sandstone has a red/orange rind with a grey center. Some is gray all the way through. Most of the siltstone has a light grey rind within dark grey to black center. Some has white or yellowish veins. Some of the gravel appears to be mineralized. Vein material is a dull rusty red/orange color. No odor, no sheen, no apparent cinnabar, stibnite, realgar/orpiment in sample.	No	Yes	No
10MP28	9/18/2010	1405	Medium gray/brown sandy gravel with silt. 10% silt. ~40% gravel, ~50% med-coarse sand. Gravel is angular to sub rounded and is from 1/4" to 1.5". Consists of sandstone, shale and mineralized vein material. Some sandstone is gray all the way through some is grey with an orange/red crust. Siltstone is dark grey to black, some has white/yellow vein material. Mineralized vein material appear burnt. it is reddish in color but shows no definite shinny crystals. no odor, no sheen, no uncooked ore.	No	Yes	No
10MP29	9/20/2010	1105	Silt and gravel (50/50). Brown-black-red-gray-white, dry, somewhat loose, silt through gravel - well graded. Up to 1", varied composition. Graywacke (no weathering on outside), Argillites (black generally smaller gravel size), some granitic type gravel (whitish minerals), red/black calcines (fine gravel through 1/2" size), white minerals noted associated with granite mineral and intrusion into graywacke and argillites (calcite?). some white mineral intrusion weathered brown.	Yes	Yes	No
10MP30	9/18/2010	1500	Medium to Dark gray brown. Moist. Gravelly silt with sand. ~30% gravel + cobbles from 1/4" to 4". ~50% silt and 20% medium to coarse sand. Gravel consists of sandstone, siltstone. Dike material and mineralized vein material. Most sanstone is grey, some pieces had a orangish rind. Most silt was dark grey to black, some had white veins. Mineralized vien material appears dull orange/red and may have been baked. Dike material is dark grey and crystalline. No odor, no shee, no gross contamination.	No	Yes	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP67	9/18/2010	1325	Med brn/gry sandy gravel with silt. ~15% silt, ~30% med-coarse sand. ~55% gravel, angular to subrounded 1/4" t0 1.5". Gravel consist of sandstone, siltstone, one baked ore: sandstone occurs as grey throughout or gray w/ and orange/red rind. Siltstone occurs as black though or with a gray rind. Some exhibit whit mineralized veins. One sold piece o stibnite (~1") was found and one piece of reddish orange vein material was found.	No	Yes	No
10MP23	9/18/2010	1753		No	No	No
10MP24	9/18/2010	1700	medium to dark grey/brn with silt. ~10% silt, ~40% gravel, 50% sand (med-very coarse). Gravel is angular to subrounded and between 1/4 to 2.5". It consists of sandstone, siltstone. Most of the siltstone has white or yellow veins, some pieces were very mineralized. Sandstone is gray with some rust orange veins/rinds. One piece of rock did have a red mineral, likely cinnabar and a orange mineral possibly realgar or orpiment. No odor, no sheen, no stibnite observed in sample. Woody debris, nail & insulation found in hole.	No	Yes	No
10MP83	9/18/2010	1745	medium to dark grey/brn with silt. ~10% silt, ~40% gravel, 50% sand (med-very coarse). Gravel is angular to subrounded and between 1/4 to 2.5". It consists of sandstone, siltstone. Most of the siltstone has white or yellow veins, some pieces were very mineralized. Sandstone is gray with some rust orange veins/rinds. One piece of rock did have a red mineral, likely cinnabar and a orange mineral possibly realgar or orpiment. No odor, no sheen, no stibnite observed in sample. Woody debris, nail & insulation found in hole.	No	Yes	No
10MP25	9/18/2010	1636	Medium to dark grey/brn gravelly sand with silt. This sample is identical to 10MP26SS except that the silt stone did not have a light grey rind. Also a nail was found in the sample.	No	No	No
10MP22	9/16/2010	1805	Dark brown, moist, silty gravel. ~60% gravel up to 3". ~30% silt. ~10% sand coarse. Gravel is angular to subrounded. Mostly sandstone and siltstone. One piece of burnt ore. One piece of silt stone with mineralized (white) vein.	No	Yes	No
10MP20	9/23/2010	1900	Silty gravel (20/80), poorly graded silt and gravel, likely near top of bedrock, argillite, angular to subangular, no calcines or minerals noted. Note: found old rectangular can, metallic, too rusted out to determine contents; also rotted wood in hole.	No	No	No
10MP21	9/23/2010	1950	Silt + gravel (50/50). Moist, brown, tightly compacted. Graywacke - non-weathered, subangular, up to 1", well graded silt and gravel, no minerals present, no calcines present.	No	No	No
10MP87SS	9/23/2010	1920	Silt + gravel (50/50). Moist, brown, tightly compacted. Graywacke - non-weathered, subangular, up to 1", well graded silt and gravel, no minerals present, no calcines present.	No	No	No
10MP31	9/18/2010	1250	Medium brown, moist gravelly silt, trace sand. ~50% brown silt. ~15% med-coarse sand. ~35% subangular gravel from 1/2" to 5" gravel consists of gray/orange mottled sandstone. No crust was observed. No odor, no sheen, no gross contamination. No apparent burnt ore.	No	No	No
10MP32	9/20/2010	1230	Sand with silt (85/15). Brown, moist, 1" layer of silt on top of sand, silt is moist and cohesive, sand is loose, sand is poorly graded fine through medium. No gravel, mostly brown with black, orange, white, sand grains mixed throughout sand appears to have low density, grains are angular to subangular.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP33	9/17/2010	1020	Dark to medium brown gravelly silt, moist. ~20% angular to sub rounded gravel up to 4". ~70% silt. ~10% fine sand. Fine sand is concentrated in the top 3" of the hole as is the bark brown soil. The top of this hole may be infiltrated by flotation tailings but not a definitive layer. Gravel consists of sandstone. Several pieces were a rusty orange color.	No	No	No
10MP34	9/20/2010	1500	Sand with silt (85/15) Black and brown, moist, and is loose and barely cohesive, poorly graded fine to medium sand, no gravel, mostly brown with black, orange, white sand grains throughout, sand has a low density, grains are subangular to angular.	No	No	No
10MP35	9/17/2010	1230	Med to dark brown/grey. Moist gravelly sand with silt. ~20% silt, ~30% gravel upt to 2" sub angular to sub round. ~35% fine to med sand and 10% coarse to pebbles. Gravel consists of sandstone (some is rusty orange color). Some pieces of gravel apper reddish with weathered veins. Silt stone was also present. It is like that bunt ore is present. Also some of the silt stone had white vein material. no cinnabar observed in sample.	No	No	No
10MP36	9/20/2010	1550	Sand with silt (85/15) Black and brown, moist, and is loose and barely cohesive, poorly graded fine to medium sand, no gravel, mostly brown with black, orange, white sand grains throughout, sand has a low density, grains are subangular to angular.	No	No	No
10MP84SS	9/20/2010	1615	Sand with silt (85/15) Black and brown, moist, and is loose and barely cohesive, poorly graded fine to medium sand, no gravel, mostly brown with black, orange, white sand grains throughout, sand has a low density, grains are subangular to angular.	No	No	No
10MP37	9/17/2010	1125	Med-dark brown, moist gravelly silt. ~30% gravel, angular to sub rounded up to 3". ~40% silt, ~20% pebbles and 10% sand. Gravel consists of sandstone, some of which was a rusty orange color; not believed to be cooked ore. No silt stone or mineralized veins observed in sample.	No	No	No
10MP68	9/19/2010	1430	Silty sand (40/60). Brown, upper 3" moist, mostly fine sand; not well graded, silty gravel (50/50) from 3"-6" up to 3/4" graywacke (not weathered) no argillites or calcines, subangular. No minerals noted.	No	No	No
10MP38	9/17/2010	1302	Dark brown gray silty gravel with trace fine sand (moist). ~60% gravel, ~35% silt, ~5% fine sand. Gravel is angular to rounded. Majority are subrounded to subangular. Sandstone and siltstone. A couple pieces of sandstone were orange in color but did not appear burnt.	No	No	Yes
10MP39	9/17/2010	1150	Medium gray/brown moist sandy gravel. 50% gravel up to 4" angular to subrounded. 15% silt, 30% med sand and 5% pebbles. Gravel consists of sandstone, siltstone and several pieces of what appears to be cooked ore. They are ~1" subrounded and a orangish red color. No crystals present but it looked like veins ran through the 'cooked ore'. No mineralized veins observed in sample.	No	No	No
10MP40	9/17/2010	1045	Dark gray brown gravelly silt with pebbles. 50% silt, 20% gravel, rounded to angular. One river rock found in hole. 15% pebbles. 5% medium to fine sand. Gravel consists of mainly sandstone with some siltstone.	No	No	Yes
10MP60	9/20/2010	1715	Silt and gravel (50/50). Brown, dry, well graded through 3" gravel, gravel is angular to subangular, sever compositions present, argillites, graywacke, calcines, the majority of graywackes are generally gray and not weathered, argillites are black. Calcines are mostly red (varying gravel size) with some black, some calcines have visible pores.	Yes	No	No
10MP63	9/17/2010	1010	Silt and Gravel. Tightly compacted silt and gravel, brown to black, little shale and calcines, some graywacke, angular to subangular, well graded, up to 1". Calcines: several gravel size up to 1", ~5%. Minerals: none noted.	Yes	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP64	9/17/2010	1045	Silt and gravel. Black, moist, somewhat loose. Gravel mainly composed of graywacke up to 1", little argillites (less than 1/2"), subangular. Calcines: none noted. Minerals: none noted.	No	No	No
10MP65	9/17/2010	1105	Silt. Black, moist, somewhat loose, gravel layer of 1/2" to 1" on top, mostly graywacke, finer gravel up to 1/2" within borehole, mixture of argillites, graywacke, and calcines. Calcines: red, friable. Minerals: none noted.	Yes	No	No
10MP66	9/17/2010	1230	Silt and Gravel. Black, very tightly compacted, mostly gravel, well graded graywacke. Subangular, few with white mineralization,, area has some rounded river rock up to 1.5". Calcines: appears some small (less than 1/2") throughout. Minerals: few graywacke exhibiting opaque white mineral veins.	Yes	Yes	Yes
10MP85SS	9/17/2010	1310	Silt and Gravel. Black, very tightly compacted, mostly gravel, well graded graywacke. Subangular, few with white mineralization,, area has some rounded river rock up to 1.5". Calcines: appears some small (less than 1/2") throughout. Minerals: few graywacke exhibiting opaque white mineral veins.	Yes	Yes	Yes
10MP42	9/19/2010	0915	Med-dark brown sily gravel, moist to dry. 330% coarse gravel up to 2", 40% fine gravel (1/4-1/2"), 20% silt and 10% med-coarse sand. Gravel is angular to rounded and consists mostly of sandstone, most of which is gray. Some has orange micro veins, some is orange throughout. Siltstone is also present and dark grey to black in all pieces, no veins observed in siltstone. One piece (~2") of rock was comprised almost entirely of cinnabar and stibnite. One piece was reddish orange and had small veins likely baked ore. 2 rounded granitoid river rocks were in sample. no odor, no sheen, no realgar/orpiment.	No	No	Yes
10MP43	9/19/2010	0950	Same as 10MP42SS except no cinnabor or stibnite found in sample and more (3 pieces) of red/orange sandstone w/ small veings were found in sample and one piece of siltstone with many white veins found in sample.	No	No	No
10MP44	9/19/2010	1020	Medium brown to grayish brown. Moist silty gravel. Trace sand. ~70% gravel from 1/4" to 3", ~20% silt and 10% med-coarse sand. Gravel is angular to rounded. Comprised mostly of sandstone, which varies in color from dark gray to rusty orange (and very crumbly) to a greenish brown. No rinds observed on sandstone. Siltstone was present in both angular pieces and polished river gravel, some had white veins all siltstone was black, normal. One piece of dark gray dike material noticed in sample as well as a small amount of woody debris. No odor, no sheen, no cinnabar, stibnite, realgar/orpiment in sample.	No	No	Yes
10MP45	9/21/2010	1600	Silty sand and gravel (15/50/35). Brown, dry; well graded silt through gravel, gravel is mostly angular and subangular, gravel is composed of graywacke and argillites (black). Graywacke is weathered in the area to rusty color (red/brown/orange/purple), weathering extends through gravel, some pieces have stibnite and cinnabar within, some graywacke have white opaque mineral veins.	No	Yes	No
10MP46	9/21/2010	1650	Silty gravel (30/90) black, dry, well graded silt through 2.5" gravel, angular to subangular, graywacke and argillites present, some graywacke weathered rust colors (red/brown/purple), cinnabar vein noted in one piece of graywacke. Some materials that may be calcines present (red appear to have been burnt), no stibnite or realgar noted. Some granite type river rocks noted.	Yes	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP47	9/20/2010	1815	Silt and Gravel (50/50). Brown, dry. Compacted/tight. Well graded through 1.5", angular to subangular, graywacke (gray mostly non-weathered) argillites (black, smaller gravel size), little calcines present (red, fine gravel through 1/2"), few rounded river rock of various composition present. No cinnabar, stibnite, or realgar present.	Yes	No	Yes
10MP48	9/16/2010	1645	Silty gravel. Gray to black, slightly moist, very compacted, tight, little fine sand, gravel is mix of rounded river rock and subangular gravel, fine through coarse ground mixture of native graywacke and little granitic and non-native river rock. Calcines: little fine to medium gravel size.	Yes	No	Yes
10MP49	9/16/2010	1745	Silt and gravel. Silt, tight very compacted, brown to black, slightly moist, mostly angular graywacke, little rounded river rock, up to 1". No calcines noted. No minerals noted.	No	No	Yes
10MP55	9/18/2010	1943	Gravelly silt (30/70). Silt is brown moist, gravel is mostly fine to 1/2", mix argillite and graywacke, subangular, argillite is black, graywacke is gray, gravel concentration increased with depth, well graded, sand represented well. No calcines or minerals noted.	No	No	No
10MP56	9/18/2010	1805	Silty sand (40/60). Poorly sorted (no gravel). Fine to medium sand, loose, somewhat coherent, moist, subangular sand. No calcines or minerals.	No	No	No
10MP57	9/19/2010	1010	Silt and gravel (70/30). Brown to black, moist, poorly graded, silt and larger gravel (1"), angular to subangular, graywacke (dark gray). No mineralization, no calcines.	No	No	No
10MP58	9/19/2010	0930	Silt and gravel (70/30). Brown to black, moist, well graded, gravel up to 1 inch, angular to subangular. Mostly graywacke, no argillites noted. Orangish material on sidewall - possible broken down calcines (silt/sand size), thin mineral veins weathered brown, graywacke is dark gray.	Yes	Yes	No
10MP59	9/21/2010	1725	Silty gravel (30/70). Dry, well graded silt through cobbles, angular to subangular graywacke and argillites (black shale), argillites have white mineral veins through them, graywackes are mostly weathered on surface to dark gray, cinnabar bearing gravel present but not very dense at this location, blast cord at location. tight/compact.	No	Yes	No
10MP86SS	9/21/2010	1745	Silty gravel (30/70). Dry, well graded silt through cobbles, angular to subangular graywacke and argillites (black shale), argillites have white mineral veins through them, graywackes are mostly weathered on surface to dark gray, cinnabar bearing gravel present but not very dense at this location, blast cord at location. tight/compact.	No	Yes	No
10MP61	9/16/2010	1825	Silt and gravel. Tight, very compacted, brown to black, slightly moist, subangular graywacke with wide range of gravel size - up to 4", mostly subangular. No calcines noted. No minerals noted.	No	No	No
10MP62	9/20/2010	1840	Silt and gravel (60/40). Brown to black, compacted/tight. Well graded through 3", mainly graywacke (gray, non-weathered), argillites not present, two calcines noted 1/4", 1 3/4" rounded gravel on top, no cinnabar, realgar, or stibnite noted.	Yes	No	Yes
10MP50	9/19/2010	1050	Brown to dark brown sandy silt with gravel. ~20% fine to very fine sand, ~15% gravel up to 1.5" and 65% silt. Gravel consits of sandstone and siltstone. Sandstone was gray or rusty orange. Some rusty orange pieces were that color through, some just has rusty orange veins. SIlstone was black, no veins. All gravel seemed well wethered. no rounded river rocks, no odor, no sheen, no cinnabar, stibnite, realgar or orpiment observed in sample. no evidence of baking sample.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10MP51	9/19/2010	1135	Dark grayish brown to black sandy gravel with silt. ~15% silt, ~25% med-coarse sand, 60% gravel from 1/4 to 1.5". Gravel is angular to sub angular and consists mostly of sandstone and silt stone. Sandstone occurs dark grey ~50% of sandstone has a lighter grey rind. Siltstone is dark gray to black and some has a lighter gray rind. One piece has white vein material. 3 pieces were highly mineralized with with and yellowish orange crystals. One piece was brick red and crumbly. One piece had cinnabar & stibnite crystals. no odor, no sheen.	No	Yes	No
10MP52	9/19/2010	1205	Silt and gravel (60/40). No vegetation at surface, black, somewhat dry, well graded, gravel up to 1", mostly rounded river rock, non-native, granitic pieces within area. Some sand, no calcines or mining ore minerals noted in immediate vicinity. No weathering of outside of rocks.	No	No	Yes
10MP53	9/19/2010	1136	Silt and gravel (50/50). Brown, dry, well graded gravel up to 3/4" and 1" + in general area, mostly angular to subangular with few rounded river rock in area, graywacke generally dark gray inside and weathered to rusty colors, some white opaque minerals in area, little black shale/argillites, some medium gravel size calcines (red/black) non friable, no cinnabar or realgar or stibnite observed.	Yes	Yes	Yes
10MP54	9/19/2010	1048	Silt and gravel (50/50). Brown, dry, well graded, up to 2.5", angular to subangular, graywacke (weathered to rust colors). Some calcines scattered at surface (orange and red, friable, 1/4" to 1/2"). No mineralization noted.	Yes	No	No
10MP41	9/19/2010	1545	Silt and gravel (60/40). 2" organic layer, gray to brown, somewhat dry. Thin 1" layer of loess on top of Kuskokwim group soils, well graded, numerous argillites (black shale) and some graywacke (gray). Subangular, somewhat compact. Fine sand throughout. No calcines or minerals noted.	No	No	No
10SM20		1626	Medium grey to light brown mottled silt with sand, loess. ~85% silt, 15% very fine sand. No gravel. Slightly moist.	No	No	No
10SM21	9/19/2010	1548	Medium gray/brown sandy silt with gravel, moist. ~65% silt, 20% very fine sand, ~15% gravel. Gravel is sub-angular and up to 2". Gravel consists of grayish brown/orange sandstone. One piece of sandstone had a vein with a rusty red area on it, which may have been cinnabar. difficult to say. A test pit was dug to 18", no stratigraphy change observed other than roots/organic layer. No sheen, no odor, no stibnite, no realgar/orpiment observed in sample. Sample likely loess with gravel from Kusko group.	No	No	No
10SM22	9/19/2010	1412	Medium to light brown, moist, sandy silt, trace gravel; ~70% silt, 25% very fine sand, ~5% gravel from 1/4" to 1.5". Gravel is subangular and consists of grayish brown sandstone and dark grey siltstone. (stratigraphy: 0-3" roots and organics, 3-6" mineral soils, 6-6.5" dark brown organic/root layer, 6.5-18" mineral soil. mineral soil is likely loess.)	No	No	No
10SM23	9/19/2010	1334	Sandy silt, trace gravel. ~70% silt, 25% very fine sand and 5% gravel from 1/4" to 3/4". Likely loess with some gravel fragment form Kusko group. Gravel was sub angular and a rusty orange color sandstone. No sheen, no odor, no cinnabar, stibnite, realgar or orpiment. Note: I dug a hole to ~18", did not get to the bottom of loess deposit. I believe it to be reconstituted loess mixed with some Kusko group sediments.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10DS01	9/19/2010	1740	Medium to dark brown, moist sandy gravel with silt. ~20% silt, ~30% sand, med-coarse. ~50% gravel, subangular to subrounded between 1/4" and 4". Gravel consists of mostly sandstone and some siltstone, sandstone tends to be orangey brown to dark grey. Some is slightly banded between the two colors. Siltstone is dark grey to black. No siltstone had veins. One piece with undetermined lithology was light brown to dull orange. no odor, no sheen, no cinnabar, realgar/orpiment, or stibnite. no free Hg observed in sample.	No	No	No
10DS02	9/19/2010	1750	Gravelly silty sand, grayish brown color. 4" of organic soil, sand ranges in size from fine to medium grains, gravel ranges in size from ¼" to 2.5", gravel consists of black to dark gray sandstone and yellow brown sandstone, all sandstone has a brownish weathered surface. Soil profile shows no obvious bedding, gravel is not mineralized.	No	No	No
10DS03	9/16/2010	1445	Silt + gravel. Gray/brown, very saturated. Somewhat compacted, mostly gravel, angular to subrounded, well graded, gravel up to 1", mostly graywacke, under peat.	No	No	No
10RS01	9/19/2010	1500	Grayish brown silt and very fine and fine sand	No	No	No
10RS02	9/19/2010	1530	Organic rich silt and very fine to fine sand. Grayish brown, moist. Organics include roots, rootlets, and twigs. Organics from 0-6" with concentrated zone (layer) from 2-4". Sample collected 0-6" below organic layer on surface, which is 2" thick.	No	No	No
10RS03	9/16/2010	1554	Clayey silt. Gray, semi stiff, very moist, some clay, poorly sorted, no gravel, under peat.	No	No	No
10SM10	9/21/2010	1439	Silt (loess) brown with reddish iron staining deposits, poorly graded, little fine sand, no gravel. Somewhat cohesive, distinct gray, loess layer at 18" in geotech borehole. Layer has more clay content and is more cohesive than loess above.	No	No	No
10SM11	9/21/2010	1240	Silt (loess) brown, moist, poorly graded, little fine sand. No gravel. Somewhat loose, some iron staing layers.	No	No	No
10SM12	9/21/2010	1107	Clayey silt + gravel (15/40/45). Gray; moist, well graded clay through 2" gravel, sand absent, gravel is angular to subangular; graywacke is weathered throughout rock with rust colors, (reds/browns); well indurated balck argillites present, graywacke are brown throughout.	No	No	No
10SM40SS	9/21/2010	1130	Clayey silt + gravel (15/40/45). Gray; moist, well graded clay through 2" gravel, sand absent, gravel is angular to subangular; graywacke is weathered throughout rock with rust colors, (reds/browns); well indurated balck argillites present, graywacke are brown throughout.	No	No	No
10SM13	9/24/2010	1040	Med brown to gray silty gravel with sand, moist. 50% angular to subangular gravel from 1/4" to 2", 30% silt, ~20% graded sand fine-coarse. Gravel appears to be Kusko group sandstone. No siltstone observed. Sandstone ranges in color from browny orange to dark browny gray. 2 pieces were browny orange all the way through. Several pieces had a blk/bwn/orng staining in cracks. Several pies had a very thin rind. Several pieces were dark brn/gry. No apparent loess in sample. No sheen odor, cinnabar, stibnite, free Hg.	No	No	No
10SM14	9/24/2010	1140	Medium grey brown, slightly moist silt with fine sand (loess). ~90% silt, ~10% very fine sand; no gravel.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10SM15	9/23/2010	1840	Medium grey brown, moist silt with gravel. Likely loess. ~75% silt, ~10% gravel, ~15% very fine sand. Gravel is angular to subangular Kusko group sand and siltstone from 1/4-2". Also 2 red/rusty looking iron oxide concretions were found. Sandstone ranged from orangish brown to dark grey, no staining or rinds observed in gravel fragments. Siltstone has some orangish brown staining in cracks but mostly dark gray to black nor odor or sheen or mineralization.	No	No	No
10SM16	9/23/2010	1925	Medium brown moist gravelly silt. Unclear if it is loess. ~80% silt. ~15% gravel and trace coarse sand. Gravel is 1/4" to 3" angular to subangular sand and siltstone from Kusko group. Some of he siltstone had orangish veins ~1/8" thick. Sandstone was rusty orange in color to dark grey. Some has a rusty orange rind others did not. Some had black/brown/orange mottled staining in veins. No odor sheen, cinnabar, stibnite, realgar, orpiment.	No	No	No
10SM17	9/24/2010	1350	Med-dark brown gravelly silt with sand, moist. ~25% angular to sub rounded gravel from 1/4" to 3", ~65% silt and 10% coarse sand. Gravel is comprised mostly of Kusko group sandstone, 1 piece of siltstone found in sample. Sandston was mostly rusty orange in color and somewhat crumbly. Some pieces were brownish gray. Some had staining (brown/orange/blk) in fractures. No odor, sheen, highly mineralized zones, or free Hg.	No	No	No
10SM18	9/23/2010	1630	Med to dark brown sandy gravel with silt. 80% gravel to small cobbles; angular to subrounded. 10% coarse sand and 10% silt and maybe clay. Strange fist size blobs of an orangey brown silty clay material were found in sample. Gravel consisted on Kusko group sandstone with some siltstone. Most pieces of sandstone were brownish grey and had staining occurring in cracks. Stain color ranged from brown to black to orange. Some pieces of sandstone were dark grey. Some were completely orangey brown. no odor, no sheen, no free Hg, no cinnabar, no stibnite, no orpiment/realgar.	No	No	No
10SM19	9/23/2010	1720	Med-dark brown sandy gravel with silt. Moist. ~60% gravel, 1/4" to 2.5" angular to sub angular. ~25 coarse to med sand. ~15% silt + fine sand. Gravel consists of Kusko group sand and silt stone. Mostly Sandstone which occurs from dark gray to rusty orange. Some staining occurs within cracks. some pieces break in concentric sphere's. Siltstone did not have mineralized veins and was black. no odor, sheen, stibnite, cinnabar, free Hg, realgar, orpiment or evidence of baking were present in sample. Test pit to 12" - no change in lithology.	No	No	No
10SM04	9/24/2010	1550	Silt, sand gravel, and cobble, overall color brown, moist. Silt content 0-20%, brown, sand gravel and cobble weathered graywacke, angular to subangular, brown to grayish brown on fresh surface, brown on weathered surfaces. Proportion of sand, gravel and cobble vary with depth but overall 50% cobble, 15-20% each gravel and sand.	No	No	No
10SM05	9/24/2010	1510	Poorly developed soil in Kuskokwim group bedrock. Bedrock with layering noted at 2-3" depth below mossy, duff- and twig- covered surface. Bedrock and gravel and cobble derived from it is interlayered graywacke and argillite. Soil fine consist of brown silt and sand derived from bedrock, including crumbly pieces of argillite (decomposed). Graywacke weathers brown and rusty brown on facture surfaces. Fresh surfaces are gray with brown- rusty brown weathering rind. noted on one fracture clear vein minerals (qtz or calcite?). No cinnabar or As or SB or other Hg mineral noted. No sig of contamination visually or by odor. All gravel and cobble angular.	No	Yes	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10SM06	9/24/2010	1630	Thin soil, silt and clay, rusty and yellowish brown. Soil is similar to crack filling in underlying (>5") bedrock. Bedrock is decomposing argillite, rusty brown on weathered surface, dark gray on fresh surface. No evidence of mineralization. No sign of contamination.	No	No	No
10SM01	9/24/2010	1600	Dark brown, moist, cobbley gravel with silt. ~85% cobbles & gravel from 1/4" to 6", angular to sub angular. ~10% silt and trace coarse sand. Gravel is difficult to identify. It is highly altered and weathered. Some pieces are sandstone ans siltstone, otheres appear to be dike material no fresh surfaces found. Gravel crumbled easily. Sandstone ranged in color from rusty orange to deep red to brown and black. Siltstone was black with some orange. Dike material was a light grey color. Some pieces had weathered xsecs yellowish white in color and occurring in thin (1/16") veins. No odor, no sheen, no free Hg. Note: dike in bedrock noted up gradient (W)	No	No	No
10SM02	9/24/2010	1715	Med-dark brown silty gravel. Moist. ~60% gravel, angular to subangular 1/2-4". ~30% silt and ~10% coarse sand. Gravel consists of sandstone ans siltstone of the Kusko group. Gravel seems to be much less altered or weathered than gravel from 10SM01SS. Sandstone is orangey brown to dark grey. On spherical pieces of sandstone was observed in sample (possibly concretion). Siltstone was dark grey t black. No gravel in sample was highly mineralized. No dike material noted in sample no odor, no sheen.	No	No	No
10SM03	9/24/2010	1745	moist, med-dark brown gravelly sand with silt. ~35% med sand. ~30% silt 35% gravel. Gravel is from 1/4-3" and angular to subangular and consists primarily of sandstone & siltstone of the kusko group. Sandstone ranges from rusty orange to brownish gray. Siltstone was dark gray to black. Some orangish staining noted in fractures. Rock does not seem highly altered or weathered. no x/s observed. no odor, no sheen	No	No	No
10SM41SS	9/24/2010	1800	moist, med-dark brown gravelly sand with silt. ~35% med sand. ~30% silt 35% gravel. Gravel is from 1/4-3" and angular to subangular and consists primarily of sandstone & siltstone of the kusko group. Sandstone ranges from rusty orange to brownish gray. Siltstone was dark gray to black. Some orangish staining noted in fractures. Rock does not seem highly altered or weathered. no x/s observed. no odor, no sheen	No	No	No
10SM07	9/24/2010	1725	2-5" soil developed, overlying bedrock. Bedrock is argillite and graywacke. Argillite is friable and soft, weathers gray, locally brown. Sandstone is blocky, breaking, dusty brown weathered fractures. Soil is sandy silt with some gravel. Silt is grayish brown to rusty brownish gray. moist. gravel and sand is angular to subangular. No evidence of mineralization, contamination.	No	No	No
10SM08	9/24/2010	1750	from 1 to 4 or 5" blow surface is soil derived from underlying bedrock. Bedrock is argillite ant sample location. Below 5" is solid bedrock. Soil 1-5" is sandy gravelly silt. Sand and gravel are soft friable pieces of argillite, weathered. Argillite is brownish gray. Silt is grayish brown. Moist. No evidence of mineralization or contamination.	No	No	No
10SM09	9/24/2010	1820	Material is broken argillite, mostly gravel and cobble size , with some sand sized fragments. Argillite is slightly weathered, soft and friable, though not as much as 10SM07SS and 10SM08SS. Argillite is dark gray.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10SM24	9/21/2010	1205	Medium brown to gray slightly moist, gravelly cobble with silt. ~80% gravel and cobbles from 1/2" to 6", ~10% silt and 10% fine to coarse sand. Gravel is angular to subangular and is completely comprised of sandstone. Fresh faces are dark brown grey, weathered faces are a mottled orangey/brown/grey. Gravel tended to break along weathered areas, had to break rock several times to find a fresh face. Note: during digging of sample hole a small 'blob' of loess was found ~ 2" tall, 1/2" deep & 1 1/2" wide.	No	No	No
10SM25	9/21/2010	1300	Medium brown to gray gravelly cobble with silt. ~80% gravel & cobbles from 1/2" to 8", ~10% sand (fine, coarse). Gravel is same as 10SM24SS. No loess lens observed at this location. No odor, no sheen, no cinnabar, stibnite, realgar, orpiment, no free Hg, no evidence of cooked ore.	No	No	No
10SM26	9/21/2010	1345	Medium grey brown, moist sandy silt with gravel. ~70% silt. ~10% gravel and 20& very fine to medium sand. Gravel consist of angular to subangular pieces from 1/4" to 1.5". Lithology consists of sandstone and siltstone. One piece of rusty red gravel was found. It was likely a iron oxide concretion from the loess. Sandstone was dark grey to rusty orange, mottled in some pieces. Siltstone was dark grey to black. Material seemed to be loess with some Kusko gravel. No sheen, no odor, no free Hg, no realgar/orpiment, no cinnabar, no stibnite, no apparent burnt ore.	No	No	No
10SM27	9/23/2010	1520	Medium brown and medium grey silt with gravel. Moist. ~75% brown to grey mottled silt; ~15% angular to subangular gravel from 1/2" to 2". ~10% fine to coarse sand. Gravel consists of Kusko group sand and siltstone, mostly sandstone. The sandstone ranges from rusty brown to dark grey and in some pieces, mottled grey/brown/orange. The siltstone was very dark grey to black. No 'rinds' were observed on either the sand or siltstone. No odor, sheen, free Hg, cinnabar, veins, realgar, orpiment or stibnite were observed in sample. No change in lithology noted in 24" test pit.	No	No	No
10SM28	9/19/2010	1635	Silt (Loess). Gray, moist, somewhat loose, little fine sand, some iron staining, one piece of graywacke (rust stains on outside) in borehole. No mineral or calcines.	No	No	No
10SM29	9/19/2010	1655	Silt (Loess). Gray, moist, somewhat loose, little fine sand, some iron staining, no gravel, minerals or calcines.	No	No	No
10SM30	9/19/2010	1730	Silt (Loess). Gray, moist, somewhat loose, little fine sand, some iron staining, no gravel, minerals or calcines.	No	No	No
10RD08	9/15/2010	1515	Silt and gravel and cobbles. Silt is brown, moist, organic rich. Gravel and cobble is similar to that at 10RD09SS location, comprising sandstone (graywacke) that weathers rusty brown. Blocky, plate, to 12" across.	No	No	No
10RD30SS	9/15/2010	1540	Silt and gravel and cobbles. Silt is brown, moist, organic rich. Gravel and cobble is similar to that at 10RD09SS location, comprising sandstone (graywacke) that weathers rusty brown. Blocky	No	No	No
10RD09	9/15/2010	1415	Organic containing silt and gravel and cobble. Silt is medium brown, moist. Gravel and cobble are sandstone, likely graywacke of Kuskokwim group, consisting of dark gray dirty SS that weathers rusty brown. Most gravel and cobble highly angular, blocky. Fragments up to 10 inches. No odor- no evidence of red colored calcines such as observed in MPA. No evidence of cinnabar or other minerals.	No	No	No
10RD05	9/17/2010	1715	Silt. Brown to black, moist, somewhat loose, little gravel on top, graywacke, subrounded. Calcines: none noted. Minerals: none noted.	No	No	No
10RD06	9/17/2010	1410	Silt. Brown to black, moist, somewhat loose, no gravel, alluvium. Calcines: none noted. Minerals: none noted.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10RD07	9/17/2010	1450	Silt and gravel. Black, moist, somewhat loose. Little gravel throughout, graywacke, angular to subangular up to 3/4". Calcines: none noted. Minerals: none noted.	No	No	No
10RD20	9/17/2010	1430	Silt and gravel. Brown to black, moist, somewhat tight, some gravel - mostly 1/2" to 1" graywacke subrounded, slightly well graded. Calcines: none noted. Minerals: none noted.	No	No	No
10RD01	9/16/2010	1633	Brown silt, abundant organics, moist, no odor, no gravel or rocks.	No	No	No
10RD02	9/16/2010	1715	Brown gravelly silt, moist, 60% angular to subangular gravel consisting of brown weathered sandstone, black sandstone, black siltstone, dike material and one small red calcines was identified, no odor or organics, 40%silt. Gravel ranges in size from 1/4" to 1.5". heavily compacted.	Yes	No	No
10RD03	9/16/2010	1741	Brown gravelly silt, moist, 20% angular to sub angular gravel consisting of brown/black sandstone and dike material. Gravel ranges in size from 1/4" to 1", loosely consolidated, no odor, some organics. 80% silt.	No	No	No
10RD04	9/16/2010	1800	Brown gravelly silt, moist, no odor, many organics, 30% gravel consisting of brown sandstone, dike rock and mineralized vein rock (possibly weathered cinnabar). Gravel is angular to subangular and ranges in size from 1/4" to 1.5".	No	Yes	No
10RD10	9/17/2010	1625	Dark to medium brown silty gravel with sand. Moist. ~40% subangular to subrounded gravel. Up to 6", ~25% silt, ~15% med-coarse sand, 20% pebbles. All gravel/rock was sandstone same was dark grey to black. Other pieces were rusty orange.	No	No	No
10RD11	9/17/2010	1547	Dark brown gravelly silt w/ sand. Moist. ~20% subangular to subrounded gravel. ~10% fine to very find sand. ~70% silt. Gravel consists of sandstone. One piece was ~8"; most were 1-3". Some sandstone was a rusty orange color.	No	No	No
10RD12	9/17/2010	1448	~6" of broken rock (sandstone) almost like a buried talus pile. Sample collected between 12" and 18" BGS. Consists of 80% silt and 20% fine to very fine sand. Rocks pulled out of the hole were up to 10", mostly flat. As small as 1". No rusty orange coloring. Only dark gray to black.	No	No	No
10RD13	9/17/2010	1410	Brown to dark brown silt and fine sand. ~80% moist silt, 20% very fine sand. No gravel however one large piece of sandstone (6") was removed from the hole.	No	No	No
10RD14	9/15/2010	1705	Upper 2" is dark brown organics. Below 2" is (2-8") brownish gray silt. 8-10" is layer of mixed silt and organics. 10-15" is mixed silt and cobble. Two pieces of sandstone to 7" across at bottom of test pit. Refusal at 15"	No	No	No
10RD31SS	9/15/2010	1735	Upper 2" is dark brown organics. Below 2" is (2-8") brownish gray silt. 8-10" is layer of mixed silt and organics. 10-15" is mixed silt and cobble. Two pieces of sandstone to 7" across at bottom of test pit. Refusal at 15"	No	No	No
10RD15	9/15/2010	1620	>1ft thich moss. At about 15" from suface soil becomes silty. Silt is medium gray, possibly with some clay, slightly plastic. Recovered a single Olympia pull-top beer can approximatly 6" below top surface within organic mat layer.	No	No	No
10RD16	9/15/2010	1730	Brownish gray silt with organics, moist to wet.	No	No	No
10RD17	9/15/2010	1755	3-9" is brownish gray silt. Moist. 9-12" is mixed organics and silt, dark brown. Wet.	No	No	No
10RD18	9/15/2010	1850	2-6"brownish gray silt, wet. 6-7" dark brown organics (peat), wet. 7-9" brownish gray silt, wet. 9-11" dark brown pat, wet. 11-12" silt and gravel and cobble. Silt is brownish gray, wet. Gravel and cobble is angular to subangular rock probably Kuskokwim group graywacke.	No	No	No
10RD19	9/15/2010	1825	Brownish gray silt from 0-6" below surface organic layer	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10UP01	9/17/2010	1710	8" BGS is soil. Apparently derived from Kuskokwim group. Mixed silt with minor sand and 15% gravel. Silt is moist med. Reddish brown. Minor sand to 2 mm, subangular. Gravel is 1 to 2 1/2" across, angular to subangular, elongate, apparently derived from blocky bedrock. gravel is brown - weathered graywacke. Fresh surface is also brown. Sand is rock up to 1 mm with fine brown matrix.	No	No	No
10UP02	9/23/2010	1450	5-15" organic rich sandy, gravelly, silt. Minor very fine sand. Overall color of sandy silt is dark brown. Gravel consists of angular to subangular graywacke to 1 1/2". Soil is moist. No odor, mineralization, visible or other evidence of contamination.	No	No	No
10UP03	9/23/2010	1555	5-9" Silt with minor small gravel, dark brown with localized Fe stained blobs, moist to very moist. Minor gravel is graywacke to 1/8", subrounded. 9-14" silt with minor gravel grayish brown with localized Fe staining. Gravel to 1/8", graywacke. 14" gravel and cobble with silt. Silt is brownish gray with Fe staining. Gravel and cobble angular graywacke to 3". refusal at 14".	No	No	No
10UP04	9/23/2010	1640	0-14" moss and twigs. 14-17" grayish brown silt, moist. 17"-deeper cobble and silt. Silt is brownish gray moist. Cobble is angular graywacke in platey pieces to 4". Cobble to >75% at base of hole at 20". No sign of mineralization, odor, visual contamination. Graywacke weathers rusty brown. Brown and grayish brown on fresh surface.	No	No	No
10UP05	9/23/2010	1720	6-12" silt with trace gravel, medium brown, moist, some organics. Gravel is graywacke to 3/8", subangular.12-15" Silt with 20% gravel and cobble. Silt medium brown moist. Gravel and cobble graywacke subangular to angular, brown on fresh surface. No Sign of mineralization or contamination. Gravel and cobble to 3".	No	No	No
10UP06	9/23/2010	1810	6-12" grayish brown silt with minor gravel. Moist. Locally brownish gray. Gravel to 2", graywacke, subangular. Weathers brown. Rusty brown on fresh surface. No sign of mineralization. No odor or sign of contamination.	No	No	No
10UP07	9/23/2010	1855	5-10" sandy, gravelly silt. Overall color grayish brown to brown. <5% sand fine to coarse, subangular. 10% gravel. Gravel subangular, graywacke. Moist. 10-14" as above except with 10% cobble to 4" consisting of platey angular pieces of graywacke. Graywacke brown on fresh surface, brown on weathered surface. No indication of mineralization. No sign of contamination.	No	No	No
10UP08	9/23/2010	1945	2-8" Sandy, gravelly, cobbly silt. Overall color med. Brown. Sand med. coarse, subangular, ~5%. Gravel angular to subangular both graywacke and argillite, 20%. Cobble angular graywacke to 4", platey pieces of graywacke weathered rusty brown, brown on fresh surface. Soil is slightly moist. No mineralization, odor, evidence of contamination.	No	No	No
10UP09	9/24/2010	1920	Sandy, gravelly, cobbly, silt. Moist. Sand minor. Gravel 10%. Cobble to 30% at bottom of test pit. Gravel and cobble are subangular graywacke, brown on fresh surface, brown on weathered surface. Silt ~60% is grayish brown. No evidence of mineralization or contamination.	No	No	No
10UP30	9/24/2010	1945	Sandy, gravelly, cobbly, silt. Moist. Sand minor. Gravel 10%. Cobble to 30% at bottom of test pit. Gravel and cobble are subangular graywacke, brown on fresh surface, brown on weathered surface. Silt ~60% is grayish brown. No evidence of mineralization or contamination.	No	No	No
10UP10	9/24/2010	1950	Gravelly, cobbly, silt with minor sand. Gravel and cobble are graywacke; weathered brown and brown on fresh surfaces. Subangular. Silt is moist, grayish brown and rusty grayish brown. No sign of mineralization or contamination.	No	No	No

Table 3-8 Visual Descriptions of Laboratory Samples

Sample Location ID	Sample Date	Sample Time	Soil Description	Red Porous Rock (aka calcines or burnt ore)	Mineralized Veins	Rounded Rocks
10OP01	9/18/2010	1135	Medium reddish brown, moist. Sandy gravel w/ silt. ~60% gravel up to 1", ~10% silt, ~20% med-coarse sand and ~10% pebbles. Gravel consists of subangular to subrounded apparently burnt ore. Some appeared to be siltstone with a reddish orange rind but black/gray in the center. Some looked like burnt sandstone with an orangish rind and light grey core with small ___. Some material looked burnt and looked like vein material. Some looked like burnt crystallized dike material.	Yes	Yes	No

Results from the visual inspection confirmed that three types of native soil are present at the RDM site: alluvium associated with Red Devil Creek, loess, and soil derived from the Kuskokwim group bedrock. Results also indicated that the native soils within the Main Processing Area and throughout the Red Devil Creek valley are mixed with tailings and waste rock from the RDM. The 2010 LSE results also indicated that the lithological characteristics of tailings/waste rock are similar in some respects to those of soils derived from the Kuskokwim Group bedrock and Red Devil Creek alluvial soils, which are derived at least in part from Kuskokwim Group bedrock soils. Furthermore, tailings/waste rock are locally mixed with the native soils within the Red Devil Creek valley. As such, visually distinguishing tailings/waste rock from Red Devil Creek alluvial soils by visual observations alone is difficult. Similarly, visually distinguishing tailings/waste rock from colluvial soils derived from the Kuskokwim Group bedrock where such soils contain clasts of argillite/shale and greywacke is difficult. Preliminarily, the presence of red porous rock identified in some field screened tailings/waste rock materials is considered likely to indicate thermally processed ore. Results of the 2010 LSE XRF field screening indicate that the presence of red porous rock is commonly associated with relatively high concentrations of arsenic, antimony, and mercury. Relatively high concentrations of arsenic, antimony, and mercury are also commonly associated with the presence of mineralized vein material in rock fragments contained in field screened materials. Such mineralized vein material may be associated with waste rock or tailings. However, such mineralized vein material may also be present in native soils derived from Kuskokwim Group bedrock.

Visual inspection of grid samples resulted in the occurrence of red porous rock in 13 of the 48 grid samples collected. Mineralized veins were observed in gravels from 9 of the 48 grid samples collected. Visual inspection of transect samples resulted in the occurrence of red porous rock in 11 of the 66 grid samples collected. Mineralized veins were observed in gravels from 11 of the 66 grid samples collected.

XRF field screening results for the grid locations within the Main Processing Area for arsenic in soil tends to show the highest concentrations on the east side of Red Devil Creek in the Main Processing Area and settling pond area. The highest arsenic concentration was 8,107 parts per million (ppm) from sample 10IP008 on the east side of Red Devil Creek just north of the old Red Devil Creek bridge crossing. No samples collected from the west side of Red Devil Creek resulted in arsenic concentrations greater than 3,000 ppm. Arsenic concentrations tend to decrease with increased elevation, particularly on the east side of Red Devil Creek. Additionally, arsenic tends to decrease with increased distance from the Main Processing Area. XRF field screening results for arsenic, antimony, and mercury are presented in Figures 3-8, 3-9, and 3-10, respectively.

Mercury concentrations in grid samples tended to follow the same trend as arsenic concentrations, with the highest concentrations occurring on the east side of Red Devil Creek in the Main Processing Area and lesser concentrations in the settling pond area. The highest occurrence of mercury was found in sample 10IP016 on the east side of Red Devil Creek adjacent to Settling Pond # 2, with a concentration of 1,575 ppm. Mercury concentrations on the west side of Red Devil Creek tended to have lower values than those on the east side of Red Devil Creek; only two samples from the west side of Red Devil Creek contained mercury concentrations greater than 100 ppm (10NP003 and 10NP001), both located within the Main Processing Area.

Antimony concentrations are highest in surface soils on the east side of Red Devil Creek in the Main Processing Area. The highest occurrence of antimony was from sample 10IP016, with a concentration of 11,816 ppm. Generally, antimony concentrations decreased with increased elevation on the east side of Red Devil Creek and also decreased with increased distance from the Main Processing Area.

Arsenic concentration in transect samples were generally lower on the ‘B’ side of the transect and tended to have the highest overall concentrations near the Post-1955 Retort Area. Additionally, arsenic concentrations tended to be elevated along the mine entrance road. One transect, 10IT21, had a significantly greater concentration of arsenic on the ‘B’ side (8,185 ppm) of the transect than on the ‘A’ side (191 ppm).

Mercury concentrations in transect samples generally were less in the ‘B’ side (closer to undisturbed area) of the transect than the ‘A’ side. Six ‘B’ side locations had mercury concentrations greater than 100 ppm; those six locations were concentrated around the Post-1955 Retort Area. One of these transects, 10IT21, showed a higher ‘B’ side concentration than ‘A’ side concentration. On the west side of Red Devil Creek, mercury concentrations tended to be less than 20 ppm on both ‘A’ side and ‘B’ side transects.

Similar to arsenic and mercury, antimony concentrations along transects tended to be less on the ‘B’ side of the transect, and the highest concentrations of antimony occurred near the Post-1955 Retort Area. Similar to arsenic, transect 10IT21 had a greater ‘B’ side antimony concentration than ‘A’ side concentration. Additionally, antimony concentrations tended to be elevated near the mine entrance road.

Overall, the concentrations of antimony, arsenic, and mercury were greater on side ‘A’ and less on side ‘B’ of the transects. The difference between the concentrations indicates that the transects worked to delineate the extent of tailings/waste rock in the Red Devil Creek Valley.

XRF Data Evaluation and Correlation

One-hundred-thirty-five samples were submitted to ARI, Inc., for total metals analysis. Each of these samples was field screened with an XRF. The samples were field screened ex situ in zip-sealed plastic bags. The soil materials were not dried or sieved. Results of the laboratory analysis were compared with the XRF field screening results for total antimony, arsenic, and mercury. For both field XRF screening and laboratory analysis, samples that resulted in concentrations less than the instrument/method detection limit were omitted from the correlation. Results were paired, and a linear regression correlation coefficient was calculated for all of the sample pairs. Results of this comparison are illustrated in Charts 3-1 through 3-3. The calculated correlation coefficients for antimony, arsenic, and mercury are R^2 = 0.9072, 0.9013, and 0.9209, respectively. These R^2 values indicate that there was an excellent comparability between field and laboratory total metals data for these metals and that the XRF data can be considered to potentially meet definitive level data criteria. The following general trends were observed within the datasets:

- Field XRF arsenic results tended to be biased low relative to the corresponding laboratory result.
- Field XRF antimony results tended to be biased high relative to the corresponding laboratory result.
- Field XRF mercury results tended to be biased low relative to the corresponding laboratory result.

In conclusion, the field portable XRF is considered an effective screening tool because the data collected can be considered to potentially meet definitive level data criteria. However, some of the analytes are biased low or high. This bias will be taken into account when selecting future samples for laboratory analysis.

Surface Soil

Eighty-four surface soil samples were collected in the Main Processing Area for laboratory analysis. Generally, the highest concentrations of arsenic in surface soil were present near the Post-1955 Retort and in the settling pond area (Figure 3-11). The highest concentrations of antimony in surface soil were present on the road below the Post-1955 Retort and in the area near the Pre-1955 Rotary Furnace (Figure 3-12). The highest concentrations of mercury in surface soil are present near the Post-1955 Retort (Figure 3-13). Generally, the highest concentrations of chromium were present near Monofill #2 and the Tailings Borrow Area. The highest concentration of chromium was in the opportunity sample collected near the Tailings Borrow Area. The highest concentrations of lead were near Monofill #1 and Settling Pond #1.

Thirty six surface soil samples were analyzed for mercury by SSE. Results of the mercury selective sequential extraction (SSE) analysis indicated that samples with higher concentrations of mercury primarily had mercury present in the mineral bound fraction (Chart 3-4). Organic forms of mercury (organo-complexed fraction) were primarily present in samples with lower concentrations of mercury. Several of the samples also had detectable levels of mercury vapor.

Nineteen surface soil samples from the Main Processing Area were analyzed for total Resource Conservation and Recovery Act (RCRA) metals using the toxicity characteristic leaching potential (TCLP). Results indicated that arsenic, barium, and mercury are leaching at detectible concentrations. Nine of these samples had concentrations of leachable arsenic greater than the TCLP regulatory value. These samples were located within the Tailings Borrow Area (Figure 3-14). Arsenic leachability in the tailings within the Main Processing Area is presented in Charts 3-5 and 3-6.

Eleven surface soil samples from the Main Processing Area were analyzed for DROs and motor oil. All samples had detections except MP-32, which was a non-detect for DROs.

Thirty-eight surface soil samples were collected in the Surface Mined Area for laboratory analysis. Generally, the highest concentrations of arsenic in surface soil were present near the Dolly and Rice ore zone areas, and the lowest concentrations of arsenic in surface soil were present near and northwest, of the Dolly Shaft collar (Figure 3-15). Generally, the highest concentrations of antimony in surface soil were present near the Dolly Ore Zone area and in the trenched area west of the former residential structures (Figure 3-16). Generally, the highest concentrations of mercury in surface soil were present near the Dolly and Rice ore zone areas, and the lowest concentrations of mercury in surface soil were present near and northwest, of the Dolly Shaft collar (Figure 3-17). The concentration of chromium ranged from 11 mg/kg to 32 mg/kg. The concentration of lead ranged from 6 mg/kg to 32 mg/kg. The highest concentration of lead was located near the Dolly Shaft.

Fifteen surface soil samples, 10 of them from background locations apparently upstream of mining impacts, were collected in the Red Devil Creek Valley for laboratory analysis. Generally the highest concentrations of arsenic, antimony, and mercury were present near Red Devil Creek and the lowest concentrations are present upstream from the Reservoir Dam (Figures 3-15 through 3-17). Samples collected for chromium analysis ranged in concentration from approximately 20 mg/kg to 30 mg/kg. Concentrations of lead ranged from non-detect to approximately 10 mg/kg.

Eleven background surface soil samples were collected from upland area soils derived from the Kuskokwim Group for laboratory analysis. Arsenic concentrations in the surface soil in the upland background area range from non-detect to 23 mg/kg (Figure 3-18). Antimony concentrations in the surface soils in the upland background area were non-detect for all samples collected (Figure 3-19). Mercury concentrations in the surface soil in upland background area range from 0.15 mg/kg to 0.32 mg/kg (Figure 3-20). Chromium concentrations ranged from 18 mg/kg to 30 mg/kg. Lead concentrations ranged from 7 mg/kg to 10 mg/kg.

Red Devil Creek Surface Water and Sediment
Surface water and surface sediment grab samples were collected from nine locations along Red Devil Creek between the creek’s mouth at the Kuskokwim River and a point upstream of the reservoir south of the Main Processing Area. Generally, the highest concentrations of arsenic in sediment were present within and downstream of the Main Processing Area. The highest concentration of

arsenic in sediment was collected below the seep in the Main Processing Area. Concentrations of antimony above the Main Processing Area were non-detect. Mercury concentrations in the sediment of Red Devil Creek range from 0.18 mg/kg to 79 mg/kg. Generally, the concentrations of mercury in the sediment increased in the downstream direction. Methyl mercury results ranged from non-detect to 14.4 nanograms per gram (ng/g). The highest methyl mercury was present in the sediment below the seep in the Main Processing Area. Sample locations and results for arsenic, antimony and mercury in the surface water and sediment of Red Devil Creek are presented in Figures 3-21 through 3-26. Both chromium and lead were not detected in the surface water samples. Concentrations of chromium in the sediment samples range from 19 mg/kg to 32 mg/kg and do not significantly increase near the Main Processing Area. Concentrations of lead in the sediment samples range from 7 mg/kg to 12 mg/kg and do not significantly increase near the Main Processing Area.

Kuskokwim River Sediment
Seven surface sediment grab samples were collected for laboratory analyses in the Kuskokwim River between a point approximately 900 feet up-river of the mouth of Red Devil Creek and a point approximately 800 feet down-river of the Dolly Sluice Delta (Figures 3-27 through 3-29). Arsenic concentrations ranged from 15 mg/kg to 1,790 mg/kg in the sediment samples. Generally, the highest concentrations of arsenic in sediment are present at the Red Devil Creek and Dolly Sluice Deltas. The highest concentrations of arsenic, mercury and antimony in sediment are present at the Red Devil Creek Delta. Methyl mercury results ranged from 0.218 ng/g to 0.812 ng/g. Concentrations of chromium in the sediment samples range from 17 mg/kg to 36 mg/kg. Concentrations of lead in the sediment samples range from 6 mg/kg to 10 mg/kg.

Groundwater
Groundwater samples were collected from five of the eight existing monitoring wells for laboratory analyses. The highest concentration of arsenic and antimony in groundwater was present in the Settling Pond Area. The highest concentration of mercury in groundwater was present near Monofill #1. Results for arsenic, antimony, and mercury are presented in Figures 3-30 through 3-32. Chromium and lead were not detect in any monitoring wells except for MW-07, where dissolved chromium was detected at 1.8 micrograms per liter. Benzene was not detected in any of the monitoring wells.

3.2 Previous Removal and Cleanup Actions

Five major removal/cleanup actions were performed at the RDM between 1999 and 2006. These actions have included offsite disposal of hazardous waste and materials, and onsite consolidation of mine structure debris.

To date, all mine structures have been demolished, and three debris burial areas (monofills) have been constructed. The major removal/cleanup actions that have been conducted at the RDM are summarized in Sections 3.2.1 through 3.2.5, and data gaps are summarized in Section 3.2.6.

3.2.1 Limited Waste Removal Action (1999)

In 1999, Wilder and HLA conducted limited waste removal and site characterization activities to address the most hazardous conditions observed at the site during the 1988 SI. The following subsections summarize the waste removal activities conducted, by waste type; the information source through Section 3.2.2 is Wilder/HLA 1999. Site features referred to within this section are depicted in Figure 1-3.

3.2.1.1 Battery Storage Areas

Five EP-2 boxes of batteries (approximately 100 batteries) were removed from the vicinity of the “Shop Building,” Shop Pads A and B, the Gravel Pad, and three vehicles. The batteries were taken to Excide in Anchorage, Alaska, for recycling. Following removal, two soil samples were collected from the battery storage areas, and lead was detected at concentrations above the ADEC soil cleanup level established in 18 Alaska Administrative Code (AAC) 75, Method 2, Table B1, Under 40-Inch Zone, Most Conservative Pathway. Lead-contaminated material was addressed in 2002, but it is unknown whether contaminated soil was addressed in these areas (see Section 3.2.3).

3.2.1.2 Transformer Areas

Four 55-gallon drums were identified at the site. One 55-gallon drum containing used oil was recovered from the Power Plant and transported to Energy Recovery Services, Inc. (ERS), in Anchorage for recycling. Philip Services Corporation tested the oil onsite and determined that it contained less than 50 ppm PCBs. One soil sample was collected near the Power Plant, and no contaminants were detected at concentrations above the ADEC soil cleanup levels.

After onsite testing indicated PCBs greater than 50 ppm, two 55-gallon drums containing PCB-contaminated transformer oil were recovered from the Gravel Storage Pad and transported to the Philips Burlington Environmental, Inc. (BEI), disposal facility in Georgetown, Washington. One 55-gallon drum containing non-PCB-contaminated transformer oil (onsite testing indicated PCBs less than 50 ppm) was transported to ERS for recycling. One soil sample was collected from the Gravel Storage Pad, and benzene was detected at a concentration above the ADEC soil cleanup level. The emptied transformers were addressed in 2002 (see Section 3.2.3).

3.2.1.3 Drum Areas

There were three main drum storage areas: an area north of the Post-1955 Retort Building containing 89 drums, an area north of the Power Plant containing 92 drums, and an area near the Former Shop Pad containing 25 drums. Drums were also found near the housing area and on the Gravel Storage Pad. Most of the drums were empty. The contents of the drums were characterized by Philip Services Corporation and bulked into a total of 23 drums for recycling or disposal:

- Seventeen 55-gallon drums of used oil were transported to ERS for recycling.
- Three 55-gallon drums of Stoddard solvent were transported to BEI for disposal.
- Three 55-gallon drums of grease were transported to BEI for disposal.

Four soil samples were collected from the drum areas. Mercury, antimony, and arsenic were detected at concentrations above the ADEC soil cleanup levels. The emptied drums were addressed in 2002, but it is unknown whether contaminated soil was addressed in these areas (see Section 3.2.3).

3.2.1.4 Post-1955 Retort

Wilder/HLA removed mercury-contaminated material from the Post-1955 Retort Building, including the exhaust port concrete base and ash. In addition, approximately 5 pounds of free mercury was collected from the periphery of the Post-1955 Retort Building and placed in one of the drums of mercury-contaminated material. The mercury-contaminated material transported to BEI for disposal consisted of:

- Two 55-gallon drums of mercury-contaminated ash.
- Two 55-gallon drums of mercury-contaminated concrete (broken into small pieces).
- Two Supersacks™ of mercury-contaminated ash.
- Two Supersacks™ of mercury-contaminated personal protective equipment and debris.

Seven soil samples were collected around the Post-1955 Retort Building. Mercury, antimony, and arsenic were detected at concentrations above the ADEC soil cleanup level. This soil was addressed in 2002 (see Section 3.2.3.2).

3.2.1.5 Chemical Storage Areas

Wilder/HLA bulked chemicals from the two dilapidated chemical storage sheds located south of the Post-1955 Retort Building. The East Chemical Storage Shed contained potassium carbonate, and the West Chemical Storage Shed contained copper sulfate, sodium hydroxide, and sodium dichromate dihydrate. The bulked chemicals transported to BEI for disposal were:

- Two 55-gallon drums of sodium dichromate dihydrate.
- Seven Supersacks™ of potassium carbonate.
- Five Supersacks™ of chemical-contaminated soil and debris.
- Two Supersacks™ of sodium hydroxide.
- Two 55-gallon drums of copper sulfate.

One soil sample was collected from each of the chemical storage sheds. Mercury, antimony, arsenic, and chromium were detected at concentrations above the ADEC soil cleanup levels. This soil was further characterized in 2001 and addressed in 2002 (see Section 3.2.3.2).

3.2.2 Post-1955 Retort Demolition (2000)

Wilder/HLA demolished the Post-1955 Retort Building and West Chemical Storage Shed in 2000. Mercury-impacted asbestos, soil, and slag wastes generated during the demolition were transported offsite for disposal. Demolition debris, including wood, steel, tin sheeting, bricks, retort chamber, process piping, and miscellaneous equipment, was pressure-washed in a low area of the retort building foundation. Wash water was collected with sump pumps and discharged into a high-density polyethylene-lined holding pond. Approximately 1,067 cubic yards of washed demolition debris was staged in a pile on the concrete retort building foundation. In addition, approximately 8 cubic yards of furnace slag was stockpiled on a bottom liner adjacent to the concrete foundation. The slag stockpiled adjacent to the Post-1955 Retort Building concrete foundation was addressed in 2002 (see Section 3.2.3.2).

The headworks was also demolished, resulting in a debris pile of wood and steel with a volume of approximately 175 cubic yards. The debris pile remained at the headworks location and the debris was not sampled for contaminants.

Wilder/HLA recovered approximately 55 gallons of fuel from the fuel storage and distribution system. The recovered fuel was transported to Alaska Energy Recovery Services in Anchorage for recycling.

Wilder/HLA also collapsed and backfilled the entrances to five mine shafts and one adit. Large rock debris was placed in each entrance, the entrance walls were collapsed, and the material was compacted in place.

Wilder/HLA conducted source area investigations at the Post-1955 Retort Building and fuel storage and distribution system, including collection of surface soil, subsurface soil, and groundwater samples (see Section 3.1).

3.2.3 Debris Consolidation and Disposal (2002)

In 2002, Wilder demolished several onsite structures, most of which were cleared of hazardous substances in 1999 (see Section 3.2.2). Wilder also segregated and chemically treated debris and constructed Monofill #1 and Monofill #2 (Figure 1-3). In addition, some lead-contaminated material was removed from the vicinity of the houses and mess hall/bunkhouse. This material included drainpipe, sewer pipe, and lead heat trace. No sampling for lead was conducted in soils surrounding this removed debris; however, building materials tested for lead did not exceed RCRA toxicity characteristic levels. One 55-gallon drum of hydraulic fluid was recovered from the drum storage areas and transported offsite for disposal. The debris consolidation and disposal work was intended to reduce arsenic and mercury mobility (Wilder/URS 2003).

3.2.3.1 Monofill #1

Approximately 4,400 cubic yards of "inert debris" (as defined by ADEC, 18 AAC 60) was placed within Monofill #1. The debris placed in Monofill #1 consisted of building debris, wood, concrete, scrap metal, 23 transformers (confirmed dry), and Category I and II non-friable asbestos-containing material (Wilder/URS 2003).

A typical cross-section of Monofill #1 is shown in Figure 3-33. Monofill #1 was constructed below grade, ranging in depth from 8 feet bgs to 15 feet bgs. Following placement of compacted inert debris, the debris was capped with at least 2 feet of soil, and contoured so that it blended with the existing grade. Soil stockpiled during excavation of the monofill was used as void-filling and cap material. The cap slope was less than or equal to 3 feet horizontal to 1 foot vertical (3H:1V) (Wilder/URS 2003).

3.2.3.2 Monofill #2

Monofill #2 contains approximately 938 cubic yards of chemically treated mercury- and arsenic-contaminated debris from the Post-1955 Retort Building. A treatability study of the retort debris demonstrated that mercury and arsenic could be stabilized to RCRA TCLP criteria using chemical encapsulants. Reportedly, treatment of the debris with the chemical encapsulants rendered the debris “inert”; however, there was no confirmation sampling to determine that the treated material met the definition of “inert” as defined by ADEC (18 AAC 60). In addition to the chemical encapsulation treatments, an impermeable geomembrane liner was used in the construction of Monofill #2 as a second precautionary measure (Wilder/URS 2003). Monofill #2 was constructed above the Post-1955 Retort Building foundation where elemental mercury was previously found in the subsurface (see Section 3.1, 2001 Source Area Removal and Investigation). This mercury was not removed or otherwise remediated prior to construction of the monofill.

The debris placed within Monofill #2 consisted of retort building debris, bricks, and slag; tailings; and some arsenic-containing soil excavated from the vicinity of the chemical storage sheds and mess hall/bunkhouse (arsenic was detected in these areas at concentrations above RCRA TCLP criteria during sampling conducted in 2001). The Gravel Storage Pad was used as a temporary staging area for debris segregation and chemical encapsulation treatment. Prior to construction of Monofill #2 above the concrete foundation, the mercury chemical encapsulant was placed over the concrete foundation and inside the cracks, and mercury- and arsenic-contaminated soil surrounding the foundation was also treated with mercury and arsenic chemical encapsulants (Wilder/URS 2003).

A typical cross-section of Monofill #2 is included as Figure 3-34. Monofill #2 was constructed above-grade on top of the concrete foundation of the Post-1955 Retort Building. All debris placed within Monofill #2 was first treated with chemical encapsulants as recommended in the treatability study. Monofill #2 was lined with an impermeable geomembrane layered with geotextile on each side for abrasion protection. The geotextile/geomembrane liner was installed above and below the monofill debris, and welded to seal the liner. Liner installation and welding were supervised by qualified technicians, and Quality Assurance (QA)/Quality Control (QC) reports were provided (Wilder/URS 2003). Tailings treated with the arsenic chemical encapsulant were used as backfill material above, below, and all around the geomembrane-lined portion of Monofill #2. Treated tailings were also placed within the geomembrane-lined portion of Monofill #2 in a 1-foot layer separating the liner from the compacted retort debris to prevent protrusions from damaging the liner. Treated tailings were also used as void-filling material within the geomembrane-lined portion of Monofill #2 (Wilder/URS 2003). The report is inconsistent in stating whether or not all tailings used in the monofill construction were treated with the chemical encapsulant.

Monofill #2 is approximately 9 feet high at the center. The depth of waste in Monofill #2 is approximately 3 feet, and the treated tailings cap on top of the debris is at least 3 feet thick. The cap slope is less than or equal to 20H:1V. The sidewall on the western side is approximately 2H:1V. A crown was constructed at the top to promote surface water drainage (Wilder/URS 2003).

3.2.4 Aboveground Storage Tanks/Ore Hopper Demolition (2003–2004)

In 2003 and 2004, MACTEC conducted demolition and onsite consolidation of the five fuel ASTs and the Ore Hopper, and conducted an assessment of petroleum contamination at the former AST sites. The debris was consolidated in the "AST Metal Disposal Area" (MACTEC 2004). This feature is Monofill #3 (Figure 1-3).

Approximately 12,700 square feet of tank metal was placed in the onsite disposal area, which measured approximately 55 feet long, 15 feet wide, and 12 feet deep. The ASTs were reportedly inspected and emptied during previous site activities. Approximately 1,400 square feet of Ore Hopper metal, and less than 10 cubic yards of broken concrete was also placed in the disposal area. Most of the Ore Hopper concrete structure was left in place and buried with tailings from the bench above the Ore Hopper. The disposal area was capped with more than 3 feet of soil that originated from the original excavation of the monofill pit and graded to facilitate drainage (MACTEC 2004).

3.2.5 Contaminated Soil Stockpiling and Debris Removal (2005–2006)

In 2005 and 2006, Wilder performed petroleum-contaminated soil excavation and stockpiling, debris removal, and inspection/repair of monofill erosion/settling problems. Wilder excavated approximately 3,306 cubic yards of petroleum-contaminated soil from four of the 2003 AST excavation sites, the pipeline area, and the former fuel barge area, and stockpiled the petroleum-contaminated soil in two lined stockpiles. Prior to its placement in the stockpiles, the contaminated soil was screened, and material larger than 2 inches in diameter (large cobbles and boulders) were segregated and used as cap material for Monofill #3. Wilder burned some AST wooden base debris, and added the following debris to Monofill #3 (Wilder/URS 2007):

- A 300-foot, 6-inch-diameter steel fuel delivery pipeline that connected the AST farm to the fuel barge landing area (cut into pieces).
- Approximately 10 cubic yards of debris consisting mainly of empty drums, cans, and boxes collected from a location near the former location of AST 3.
- A collapsed mine portal iron gate.

Following placement of this miscellaneous debris in Monofill #3, the monofill was capped with the material screened from the petroleum-contaminated soil stockpiles (Wilder/URS 2007).

Wilder also performed monofill repair activities in 2005, including (Wilder/URS 2007):

- Monofill #1 – Minor settling/erosion was noted at this monofill site. In particular, the areas of concern were small surficial depressions, which were regraded to prevent pooling of rain and runoff waters.
- Monofill #2 – Precipitation runoff was observed cutting into the southwest corner of Monofill #2. This corner was regraded to stabilize erosion. A runoff ditch was also re-worked to allow runoff to leave the monofill cap in a direction that would prevent future erosion in that area.

3.2.6 Data Gaps

Several data gaps are associated with previous removal and cleanup actions at the site. These data gaps are for information that needs to be filled during the RI/FS process. See also Chapter 4, Data Quality Objectives.

- Although not a strong possibility, Monofill #1 could contain some contaminated debris, including transformer casings.
- Some settling has occurred at Monofill #1, which was repaired in 2005; however, additional future subsidence is possible. Monofill #1 may have been constructed above one or more backfilled mine openings (see Figure 2-1).
- Mercury-contaminated soil adjacent to the Post-1955 Retort concrete foundation, some of the mercury- and arsenic-contaminated debris placed within Monofill #2, and tailings used in the construction of Monofill #2 could lack proper chemical encapsulation treatment.
- It appears as if the top geomembrane layer of Monofill #2 may not have been designed adequately to facilitate subsurface drainage above the liner (see Figure 3-7).
- Although mobilization of the free mercury remaining below the Post-1955 Retort concrete foundation is likely minimized by the installation of Monofill #2 above the concrete foundation, percolating water still has the potential to mobilize free mercury from the outside of the perimeter of the geomembrane-lined portion of the monofill.

- Although mobilization of the other metals, including leachable mercury, arsenic, and antimony compounds remaining below the Post-1955 Retort concrete foundation is likely minimized by the installation of Monofill #2 above the concrete foundation, percolating water still has the potential to mobilize these constituents from areas outside of the perimeter of the geomembrane-lined portion of the monofill.
- Standard construction practices and QA/QC measures do not appear to have been implemented in the construction of Monofill #3.
- The vertical extent of Monofill #3 was not surveyed. The location and lateral extent depicted in Figure 1-3 are approximate.
- The structural integrity of Monofill #3 is suspect. It is unknown whether debris was compacted and voids were filled to reduce the potential for subsidence. Furthermore, Wilder identified surface settling at Monofill #3 as requiring repair in 2005. Future subsidence of this monofill is possible.
- Pre-construction sampling for contaminants was not performed at the location of Monofill #3.

3.3 Data on Naturally Occurring Background Levels

Five previous studies/investigations included collection of samples intended to represent background conditions for the RDM site (see Table 3-9 for a summary of results):

- 1971 EPA Reconnaissance Field Survey of the Kuskokwim River System. Involved collection of surface water samples in the Kuskokwim River up-river of Red Devil Creek (EPA 1971).
- 1979 EPA hazardous waste site survey, Red Devil Mine. Involved collection of surface water samples in the Kuskokwim River up-river of Red Devil Creek, and in Red Devil Creek up-stream of the mining operations area (EPA 1979).
- 1988 BLM sampling investigation. Included collection of surface water and sediment samples in Red Devil Creek above the mine area and soil samples in areas outside of the main mine area (Weston 1989).
- 1996 USGS Mercury in the Terrestrial Environment, Kuskokwim Mountains Region, Southwestern Alaska. Involved collection of soil samples at Moose Creek (20 miles east of the RDM site) and surface water samples from Red Devil Creek above the mine area and at four unspecified “background” locations in the Kuskokwim River (Bailey and Gray 1997).
- 1999 Wilder/HLA Limited Waste Removal Action. Involved collection of one background surface soil sample and background surface water and sediment samples in Red Devil Creek upstream of the mine area (Wilder/HLA 1999).

Table 3-9 Summary of Previous Background Sample Results

Matrix	Concentration/Concentration Range[1]			Units
	Mercury	Arsenic	Antimony	
Soil	0.10–8.0	160	27.6	mg/kg
Red Devil Creek Sediment	0.2–0.309	61.8	18.4	mg/kg
Red Devil Creek Water	<0.1–0.3	<5.6	<5.6	µg/L
Kuskokwim River Water	<0.1–1.7	56	No Data	µg/L

Key:

[1] = Single value indicates that only 1 sample was collected.
mg/kg = milligrams per kilogram.
µg/L = micrograms per liter.

Concerns about the representativeness and quality of the data in Table 3-9 include:

- Analytical methods and quality assurance information are not available for the 1971, 1979, 1988, and 1996 samples.
- The 1988 background soil samples were generally collected in close proximity to the Main Processing Area and may have been impacted by historical dust emissions or mercury vapor emissions from thermal processing facilities.
- Background soil samples collected in the 1996 USGS study were taken from a location 20 miles east of the RDM that is not underlain by a similarly mineralized geologic formation and may have significantly different native soil conditions than the RDM area.
- All of the Red Devil Creek background and surface water samples were collected downstream of the reservoir dam, which may have been partially constructed using tailings material.

Accordingly, a high level of uncertainty is associated with the background data collected and reported to date; therefore, this data is not being considered for use in the RI/FS. The RI/FS study design will include a background characterization of surface and subsurface soil, groundwater, and sediment and surface water in Red Devil Creek and sediment in the Kuskokwim River (see Field Sampling Plan [FSP] Section 2 contained in Appendix A of this RI/FS Work Plan).

3.4 Usability Assessment of Previous Data

This section assesses the usability of data generated from previous investigations and studies at the RDM. The results of this assessment will determine which data sets may be useful for incorporation into the RI/FS report, including the risk assessment, pending QA review of the data. It should be noted that all previous data, regardless of its usability for the RI/FS report, has been considered in the development of the RI/FS study design.

The usability assessment was conducted following a multi-step process of inquiry as follows:

1. Is the data/information applicable to the RDM RI/FS?
   a. Is the data/information geographically applicable to the site?
   b. Is the data/information representative of the current nature and extent of contamination?
   c. Will the data/information provide an understanding of human health or ecological risk?
   d. Is the data/information useful for evaluating contaminant fate and transport?

2. Is the data/information of known and sufficient quality for use in the RI/FS?
   a. Were currently accepted analytical and other investigative methods used?
   b. Is there documentation addressing quality assurance procedures?

If the answer to these questions is "yes," the data will be fully evaluated and validated for potential inclusion in the RI/FS report. A summary of the usability assessment results is presented in Table 3-10.

Table 3-10 Usability Assessment of Previous Data

Year	Organization and Report Reference	Assessment of Data Usability	Retain for RI/FS?
1971	EPA Study	Data are extremely dated and likely do not represent current conditions; sampling and analytical methods are not documented.	NO
1979	EPA Study	Data are extremely dated and likely do not represent current conditions; sampling and analytical methods are not documented.	NO
1985	ADEC Well Sampling	Results are not geographically applicable, and sampling and analytical methods are not documented.	NO
1988	BLM Sampling Event (unpublished)	Data likely do not represent current conditions, and sampling and analytical methods are not documented.	NO
1989	Weston Site Inspection	Data likely do not represent current conditions, and sampling and analytical methods are not documented.	NO
1997	Bailey and Gray, USGS Study	Data are geographically applicable, are likely representative of current conditions, and may be useful for understanding human health and ecological risks. Sampling and analytical methods are reported.	YES
1997	USGS Kuskokwim River Study	Data likely do not represent current conditions in Red Devil Creek.	NO
1999	Wilder/HLA Limited Waste Removal Action	Surface data likely do not represent current conditions due to subsequent site cleanup activity. Subsurface soil data are usable. Sampling and analytical methods and results of data quality assurance are reported.	YES subsurface soil only

Table 3-10 Usability Assessment of Previous Data

Year	Organization and Report Reference	Assessment of Data Usability	Retain for RI/FS?
2001	Wilder/HLA Source Area Removal and Investigation	Surface data likely do not represent current conditions due to subsequent site cleanup activity; nonetheless, the data provide information on the conditions that existed at the time of sampling. Groundwater data are of limited usefulness because the results may not be representative of aquifer conditions due to sampling methods used. Fixed laboratory subsurface soil data are usable, but the reported depths of the concentrations are not representative of the current conditions because of subsequent site cleanup activities that include construction of Monofill #2. However, these data, combined with as-built information for Monofill #2, provide information regarding the contaminant concentrations at depth under the Monofill #2 footprint. Sampling and analytical methods and results of data quality assurance are reported.	YES fixed laboratory subsurface soil only
2002	Bailey et al. Study	Data are geographically applicable, are likely representative of current conditions, and may be useful for understanding human health and ecological risks. Sampling and analytical methods are reported.	YES
2003	MACTEC Historical Source Area Investigation	Surface and subsurface data likely represent current conditions. Sampling and analytical methods and results of data quality assurance are reported.	YES
2004	MACTEC ASTs/Ore Hopper Demolition and Petroleum Release Investigation	Soil data likely do not represent current conditions due to subsequent excavation activities. Groundwater data are of limited usefulness because the results may not be representative of aquifer conditions due to sampling methods used.	NO
2005, 2006	Wilder Contaminated Soil Stockpiling and Debris Removal	Groundwater data are of limited usefulness because the results may not be representative of aquifer conditions due to sampling methods used. Sampling methods did not use low flow techniques, and results may overestimate actual concentrations of dissolved analytes in groundwater. Based on available information regarding previous groundwater sampling, bailers were used to collect samples. Such sampling methods likely resulted in higher turbidity samples. Dissolved metals aliquots were not collected. Therefore, the reported total metals concentrations are likely biased high. Therefore, previous metals groundwater results are deemed not useful for any RI/FS purposes, including assessing temporal trends. Previous sampling does not include analysis for organic compounds.	YES, limited

Table 3-10 Usability Assessment of Previous Data

Year	Organization and Report Reference	Assessment of Data Usability	Retain for RI/FS?
2007, 2008, 2009	Shannon & Wilson and BLM, 2007, 2008, 2009 Monitoring Events	Groundwater data from 2007, 2008, June 2009, and September 2009 are of limited usefulness because the results may not be representative of aquifer conditions due to sampling methods used. Sampling methods did not use low flow techniques and results may overestimate actual concentrations of dissolved analytes in groundwater. Previous sampling does not include analysis for organic compounds	Yes, limited
2009	E & E 2009 Monitoring Event	October 2009 groundwater data are usable. Sampling and analytical methods and results of data quality assurance are reported.	YES
2010	USGS August 2010 Geophysical Investigation	Geophysical data represents current conditions at the site.	YES
2010	E & E 2010 Limited Sampling Event	Surface soil, sediment, surface water, and groundwater data are usable. Sampling and analytical methods and results of data quality assurance are reported.	YES

Key:

ADEC = Alaska Department of Environmental Conservation
AST = aboveground storage tank
BLM = Bureau of Land Management
E & E = Ecology and Environment, Inc.
EPA = Environmental Protection Agency
HLA = Harding Lawson Associates
MACTEC = MACTEC Engineering and Consulting
USGS = U.S. Geological Survey
VOC = volatile organic compound
Wilder = Wilder Construction Company

3.5 Nature and Extent of Contamination

Information in Sections 3.1, 3.2, and 3.3 is useful for understanding the general nature of contamination at the RDM, but provides an incomplete understanding of the full extent of contamination at the site. Based on existing data, COPCs for the site have been preliminarily identified and include inorganic elements, methyl mercury, and organic contaminants associated with petroleum releases and other sources. These COPCs have been detected in various site media in previous investigations. Table 3-11 summarizes the known COPCs and potentially affected media at the site.

The COPCs and potentially affected media listed in Table 3-11 may not include all potential COPCs or all affected media at the site. Therefore, the RI/FS will include evaluation of a full suite of inorganic elements and additional organic chemicals associated with petroleum, including volatile organic compounds (VOCs), PCBs, and polycyclic aromatic hydrocarbons.

Table 3-11 COPCs and Potentially Affected Media

Contaminant	Media
Antimony	Soil, Sediment, Groundwater, Surface Water
Arsenic	Soil, Sediment, Groundwater, Surface Water
Chromium	Soil, Groundwater
Lead	Soil, Groundwater
Mercury	Soil, Sediment, Groundwater, Surface Water
Methyl mercury	Soil, Sediment, Groundwater, Surface Water
Benzene	Soil, Groundwater
DRO	Soil, Groundwater
PCBs	Soil, Groundwater

Key:

DRO = diesel range organics.
PCBs = polychlorinated biphenyls

The presence of COPCs in various site media is fairly well documented in certain areas of the site, but the extent of the COPCs has not been completely delineated, and the nature of the contamination has not been fully determined. For example, tailings containing elevated concentrations of metals, including mercury, antimony, and arsenic, are known to overlie much of the Main Processing Area, have been placed or washed into Red Devil Creek, and formed the delta at the mouth of Red Devil Creek on the Kuskokwim River.

Mercury, arsenic, and antimony have been documented at elevated concentrations in soils at various locations within the Main Processing Area. However, the extent of the contamination by these and other potential COPCs is not adequately understood. Furthermore, the chemical forms of these metals within the tailings, waste rock, and soils are not well understood. The form of these metals may influence their mobility and bioavailability in the environment at the site.

Inorganic COPCs are present in tailings and waste rock. Tailings and waste rock are mixed locally at the site. The distribution of tailings and waste rock at the site are not fully delineated. Some previous investigations apparently refer to both tailings and waste rock as tailings. The term “tailings/waste rock” is used throughout the remainder of this document to refer to materials that may comprise tailings and/or waste rock.

Localized areas of soil contamination from ore processing operations and former chemical use/storage exist in the Main Processing Area. Groundwater underlying the Main Processing Area contains site-related metals.

Several areas of the site have the potential to be affected by site-related contamination but have not been characterized. These areas include:

- The former area of surface exploration and mining west of the Main Processing Area.
- The Dolly Sluice and Rice Sluice waste deltas on the Kuskokwim River.

- The reservoir dam (it is unknown whether tailings/waste rock were used to construct the dam).

Figure 3-35 illustrates the current understanding of the areal extent of wastes and/or COPCs at the site. The area of historical surface exploration and mining shown in Figure 3-14 has not been previously characterized, and the presence and mobility of any COPCs in this area is unknown. A major objective of the RI/FS will be to determine the horizontal and vertical boundaries of COPCs in soil, sediment, surface water, and groundwater at the site.

4 Data Quality Objectives

The DQO process specifies project decisions, the data quality required to support those decisions, specific data types needed, and data collection requirements and ensures that analytical techniques are used that will generate the specified data quality (EPA 2000). The process also ensures that the resources required to generate the data are justified. The DQO process consists of seven steps. The output from each step influences the choices that will be made later in the process.

The DQO steps are as follows:

1. State the problem.
2. Identify the decision.
3. Identify the inputs to the decision.
4. Define the study boundaries.
5. Develop a decision rule.
6. Specify tolerable limits on decision errors.
7. Optimize the design.

During the first six steps of the process, the planning team develops decision performance criteria (that is, the DQOs) that will be used to develop the data collection design. The final step involves refining the data collection design based on the DQOs. A discussion of these steps and their application to the RDM RI/FS is provided below.

4.1 Step 1: State the Problem

The key problem statements for the RDM RI/FS are:

- The list of COPCs at the site has not been confirmed.
- The full nature and extent of contamination has not been determined.
- The fate, transport, and bioavailability of contaminants at the site have not been evaluated.
- Risks to human health and ecological receptors at and near the site have not been comprehensively assessed.
- The effectiveness of previous cleanup actions at the site has not been determined.
- Remedial action alternatives to achieve long-term protectiveness have not been evaluated.

4.2 Step 2: Identify the Decision

To accomplish the objectives of the RI/FS, key study questions (data gaps) are as follows:

Nature and Extent of Contamination

1. What COPCs, in addition to those identified in previous investigations, exist at and near the site?
2. Do COPC concentrations differ in areas where different ore processing operations were conducted?
3. Are COPC reporting limits sufficient to characterize human health and ecological risks?
4. Is mercury present in organic forms at the site?
5. What is the areal and vertical extent of tailings, flotation tailings, and waste rock?
6. Are soils in the area of former surface exploration and mining a source of COPCs, and are metals in a mobile or bioavailable form?
7. Are roads at and to the site a source of COPCs?
8. Are the Dolly Sluice and possible Rice Sluice areas sources of COPCs?
9. What is the nature and extent of contamination in native subsurface soil?
10. What is the nature and extent of contamination in groundwater?
11. What is the nature and extent of contamination in aquatic biota?
12. What are the background concentrations of COPCs in native soils and in groundwater, surface water, sediment, and biota in areas undisturbed by mining activities?
13. Are the previous locations of transformers a source of COPCs?
14. What physical and chemical characteristics can be used to define a difference between tailings, waste rock, and native soils at the site?

Fate and Transport of Contamination

15. Is contaminated groundwater impacting Red Devil Creek or the Kuskokwim River?
16. Have tailings, flotation tailings, waste rock, and/or other site sources impacted sediments, surface water, and aquatic biota in Red Devil Creek?
17. Have tailings, flotation tailings, waste rock, and/or other site sources impacted sediments in the Kuskokwim River downriver of the mouth of Red Devil Creek?
18. Have tailings, flotation tailings, waste rock, and/or other site sources impacted native subsurface soils at the site?
19. Has elemental mercury, previously documented in subsurface soil near Monofill #2, mobilized and/or entered groundwater?
20. What is the leaching potential of COPCs in tailings and flotation tailings at the site?

21. What is the fraction of mercury in tailings, flotation tailings, waste rock, and contaminated soil that is available to chemically mobilize?
22. Are COPCs in waste rock and impacted soils leachable?
23. What is the fraction of arsenic in soil, sediment, surface water, and groundwater that is bioavailable to humans?
24. Are the underground mine workings influencing the nature, extent, and migration of COPCs in groundwater and surface water?

Human Health and Ecological Risk

25. What risks to human health under future residential, subsistence user, and industrial land use scenarios are posed by COPCs at and near the site?
26. What risks to ecological receptors at various trophic levels are posed by COPCs at and near the site?

Feasibility Study

27. Are the monofills contributing to contamination of groundwater, Red Devil Creek, or the Kuskokwim River?
28. Are the monofills a long-term solution for containment of wastes at the site?
29. What remedial action technologies could be implemented at the site to reduce or eliminate risks to human health and ecological receptors?
30. What remedial action alternatives can be assembled from the identified technologies to provide long-term protectiveness at the site?

4.3 Step 3: Identify the Inputs to the Decision

Inputs to the decisions for the RDM include:

Nature and Extent of Contamination

- Historical aerial photographs and mine operations information.
- Data and information from previous investigations and cleanup actions at the site that meet data usability criteria (see Section 3.3).
- RI/FS soil, sediment, surface water, groundwater, and biota samples analyzed for a full range of the most likely COPCs at the site using analytical methods with reporting limits suitable for characterizing risk and comparing to regulatory action levels.
- RI/FS surface soil samples to delineate the areal extent of tailings/waste rock and flotation tailings.
- RI/FS surface and subsurface soil samples at the area of former surface exploration and mining as well as the Dolly Sluice and possible Rice Sluice areas to determine the presence and mobility of COPCs.
- RI/FS soil borings and geophysical surveys to delineate the depth of tailings/waste rock, flotation tailings, and contaminated subsurface native soil.

- RI/FS monitoring well installation and sampling to determine the nature and extent of groundwater contamination, identify groundwater depth and flow direction, and to assess potential groundwater contribution to surface water contamination.
- RI/FS sample collection and analyses to determine the natural background concentrations of COPCs in native soils, groundwater, surface water, and sediment.

Fate and Transport of Contaminants
- RI/FS field inspections to determine the location of groundwater seeps.
- RI/FS groundwater and surface water sampling to characterize groundwater–surface water interactions.
- RI/FS sampling of Red Devil Creek and the Kuskokwim River to determine whether tailings/waste rock, flotation tailings, and other sources have impacted sediments, surface water, and aquatic organisms.
- RI/FS sample analyses to determine the chemical mobility of various forms of mercury and other metals in tailings/waste rock, flotation tailings and soils at the site.

Human Health and Ecological Risk
- Assessment of human health risks related to exposures via direct contact with soils, sediments, and groundwater; inhalation of dust; and ingestion of surface water, groundwater, plants, animals, and fish.
- Assessment of ecological risks related to exposure via direct contact with surface water, sediment, and soil and ingestion of sediment, soil, and lower trophic level organisms.

Feasibility Study
- RI/FS analysis of monofill construction (see Section 3.2).
- RI/FS field inspections of monofills.
- RI/FS soil borings and monitoring well installation and sampling to assess whether monofill wastes may have migrated from the containment.
- RI/FS sampling to characterize chemical and geotechnical properties of tailings/waste rock, flotation tailings to support evaluation of potential remedial technologies.
- RI/FS sampling to characterize geotechnical properties of a potential onsite repository.
- RI/FS sampling of groundwater and surface water to assess chemical characteristics.

4.4 Step 4: Define the Study Boundaries

The presently defined spatial boundary of the RDM site is depicted in Figure1-2. Figure 1-3 illustrates the known areas of contaminant sources at the site. The RI/FS will confirm or modify these site and source boundaries.

There are no temporal boundaries for the RI/FS.

4.5 Step 5: Develop a Decision Rule

The RI/FS will apply multiple decision rules for making risk management and cleanup decisions at the RDM site. These include:

- The significance of COPC concentrations will be decided using multiple lines of evidence, including comparison with:
  - Background media concentrations as characterized during the RI/FS.
  - Site-specific risk-based concentrations above which excessive risk exists.
  - Alaska Method 2 Cleanup Levels for soil (18 AAC 75.341, October 2009).
  - Alaska Ambient Water Quality Standards for surface water (18 AAC 70, September 2009).
  - Alaska Table C Cleanup Levels for groundwater (18 AAC 75.345, October 2009).
  - Federal Maximum Contaminant Levels for Groundwater (40 Code of Federal Regulations [CFR] 141.40-141.431).
  - Probable effect level and threshold effect level for sediment (McDonald et al. 2000).
- Risk management decisions will need to consider future land use management, policies, agreements, and ownership exchanges.
- Applicability of possible applicable or relevant and appropriate requirements (ARARs) including the Bevill Amendment will need to be determined.
- If RI/FS activities do not provide sufficient data to allow complete delineation of the extent of contamination, additional phases of RI/FS sampling will be conducted.

4.6 Step 6: Specify Tolerable Limits on Decision Errors

Tolerable limits on decision errors, which are established performance goals for the data collection design, are specified in this step. Since analytical data and other measurements can only estimate true values, decisions that are based on measurement data could be in error. These errors are:

1. Concentrations may vary over time and space. Limited sampling may miss some features of this natural variation because it is usually impossible or impractical to measure every point of a population. Sampling design errors occur when the sampling design is unable to capture the complete extent of natural variability that exists in the true state of the environment.
2. Analytical methods and instruments are never perfect; hence, a measurement can only estimate the true value of an environmental sample. Measurement error refers to a combination of random and systematic errors that inevitably arise during the measurement process.

A sufficient number of samples will be collected to minimize the risks of decision errors. Decision errors will also be minimized through appropriate selection of sample locations.

QC samples will be collected and analyzed with environmental samples to assure that data are of known precision and accuracy. Control limits on both precision and accuracy are addressed in Section 1.4.2 of the Quality Assurance Project Plan, contained in Appendix C of this RI/FS Work Plan.

4.7 Step 7: Optimize the Design for Obtaining Data

Based on the DQO process, RI/FS data gaps were identified. These data gaps are summarized in Tables 4-1 through 4-6 Based on these data gaps and Steps 1 through 6 of this DQO process, a study design for the RI/FS has been developed. A summary of the study design is provided in Section 7, and details of the study design are presented in the FSP.

Additional sampling locations will be added, locations may be changed, and/or the schedule of sampling will be altered to improve sampling design as needed. The effectiveness of the sampling program will be evaluated continuously, and adaptive management will be applied. Onsite evaluation of data, including observations and quantitative field screening results with an XRF spectrometer, will also allow for optimizing sampling locations and depths (see the FSP, Appendix A).

Table 4-1 Surface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Main Processing Area	Gravel Pad	Gravel Pad	Presence and concentration of PCBs in surface soils.	Surface soil sampling and analysis for PCBs. See FSP Table 2-1 and Figure 2-2 locations: 11MP76 11MP77 11MP78 11MP79	▪ Determine presence and concentration of PCB contamination ▪ Assess human health and ecological risk	1, 13, 25, 26, 29
			Bioavailability of arsenic in tailings/waste rock.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-2 locations: 11MP25	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	22, 23, 25
		Location of Abandoned Drum	Presence and concentration of chemicals leaked from drum to surface soil.	Surface soil sampling and analysis for TAL metals, SVOCs, and DRO/RRO. See FSP Table 2-1 and Figure 2-2 location: 11MP70	▪ Delineate presence of drum-related contamination ▪ Assess human health and ecological risk	1, 25, 26, 29
	General, Tailings	Tailings Borrow Area	Bioavailability of arsenic in tailings/waste rock.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-2 location: 11MP17	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	22, 23, 25
	Settling Pond Area	Settling Ponds #1, #2, and #3.	Bioavailability of arsenic in flotation tailings.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-2 locations: 11MP32 11MP34 11MP36	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	22, 23, 25
	Southwest of Power Plant	Area of Surface Disturbance South of Power Plant	Presence, concentration, and mobility of metals in disturbed surface soil.	Surface soil sampling and analysis for TAL metals, mercury SSE, and SPLP. See FSP Table 2-1 and Figure 2-4 location: 11MP71	▪ Determine presence of metals for further potential characterization ▪ Assess fate and transport of metals	1, 2, 25, 26
	Power Plant	Former Drum Storage Area	Presence, concentration, and extent of PCBs in surface soil.	Surface soil sampling and analysis for PCBs. See FSP Table 2-1 and Figure 2-2 locations: 11MP72 11MP73 11MP74 11MP75	▪ Determine presence and concentration of PCB contamination ▪ Assess human health and ecological risk	1, 13, 25, 26, 29
		Exposed Tailings/Waste Rock	Presence and extent of tailings/waste rock and elevated concentrations of metal COPCs in the surface soil in the vicinity of the Power Plant.	Visual assessment and surface field screening using XRF. See FSP Figure 2-1.	▪ Assess the presence of tailings/waste rock and elevated concentrations of metal COPCs in the surface soil	5, 14
	Area of Pre-1955 Processing Facilities	Tailings/ Waste Rock near Pre-1955 Retort	Bioavailability of arsenic in tailings/waste rock.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-2 location: 11MP59	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	22, 23, 25

Table 4-1 Surface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
	Monofill #1 Area	Former Shop Buildings	Presence and concentration of PCBs in surface soils.	Surface soil sampling and analysis for PCBs. See FSP Table 2-1 and Figure 2-2 locations: 11MP83 11MP84 11MP85	▪ Determine presence and concentration of PCB contamination ▪ Assess human health and ecological risk	1, 13, 25, 26, 29
	Pre-1955 Rotary Furnace	Tailings/Waste Rock near Pre-1955 Furnace	Presence and concentration of PCBs in surface soil.	Surface soil sampling and analysis for PCBs. See FSP Table 2-1 and Figure 2-2, locations: 11MP86 11MP87	▪ Determine presence and concentration of PCB contamination ▪ Assess human health and ecological risk	1, 13, 23, 25, 26, 29
			Bioavailability of arsenic.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-2 locations: 11MP52	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	22, 23, 25
	Vicinity of Post-1955 Retort	Exposed Tailings/Waste Rock	Presence and extent of tailings/waste rock on the surface.	Visual assessment and surface field screening using XRF. See FSP Figure 2-1.	▪ Delineate surface extent of tailings/waste rock	5, 14
	West of Gravel Pad	Along Red Devil Creek West of Gravel Pad	Presence and concentration of PCBs in surface soils.	Surface soil sampling and analysis for PCBs. See FSP Table 2-1 and Figure 2-2 locations: 11MP80 11MP81 11MP82	▪ Determine presence and concentration of PCB contamination ▪ Assess human health and ecological risk	1, 13, 25, 26, 29
		Area West of Gravel Pad	Presence and extent of tailings/waste rock on the surface.	Visual assessment and surface field screening using XRF. See FSP Figure 2-1.	▪ Delineate surface extent of tailings/waste rock	5, 14
Area of Surface Mining/Exploration or Other Soil Disturbance	Bulldozed Area away from Ore Trend	Bulldozed Overburden	Bioavailability of arsenic in re-worked overburden materials.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-3 locations: 11SM13 11SM18	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	6, 23, 25
	Trenched Area West of Former Residential Structures	Exploratory Trench	Bioavailability of arsenic in re-worked overburden materials.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-3 location: 11SM28	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	6, 23, 25
	Area of Surface Mining/Exploration or Other Soil Disturbance	Area of Surface Mining/Exploration (including Bulldozing, Trenching, Sluicing) or Other Soil Disturbance (including building construction)	Presence and extent of elevated metal COPC concentrations on the surface.	Visual assessment and surface soil field screening using XRF. See FSP Figure 2-1.	▪ Delineate extent of elevated metals in surface soil ▪ Assess former building foundations for presence of tailings/waste rock	5, 6
	Roads	Roads	Presence and extent of tailings/waste rock and elevated concentrations of metal COPCs on the surface.	Visual assessment and surface soil field screening using XRF. See FSP Figure 2-1.	▪ Delineate extent of tailings/waste rock and elevated metal COPCs in surface soil	5, 7

Table 4-1 Surface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Outside of Main Processing Area and Area of Surface Mining/Exploration	Background Upland Soils: Upland Area Apparently Outside of Mine Impacts	Area Underlain by Soil Derived from Kuskokwim Group bedrock	Bioavailability of arsenic in background soil.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-4 location: 11UP09	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	12, 23, 25
	Alluvial Deposits Upstream of Main Processing Area	Background Alluvial Deposits	Bioavailability of arsenic in background soil.	Surface soil sampling and analysis for arsenic by bioassay method. See FSP Table 2-1 and Figure 2-4 location: 11RD18	▪ Assess fate and transport of arsenic ▪ Qualify human health and ecological risk posed by arsenic	23, 25
	Roads	Roads	Presence and extent of tailings/waste rock and elevated concentrations of metal COPCs on the surface.	Visual assessment and surface soil field screening using XRF. See FSP Figure 2-1.	▪ Delineate extent of tailings/waste rock and elevated metal COPCs in surface soil	5, 7
	Dolly Sluice	Dolly Sluice	Presence and extent of elevated metal COPCs on the surface.	Visual assessment and surface soil field screening using XRF. See FSP Figure 2-1.	▪ Delineate extent of elevated metals in surface soil	8
	Rice Sluice	Rice Sluice	Presence and extent of elevated metal COPCs on the surface.	Visual assessment and surface soil field screening using XRF. See FSP Figure 2-1.	▪ Delineate extent of elevated metals in surface soil	8

Key:

DQO Data Quality Objective
DRO Diesel range organic
FSP Field Sampling Plan
PCB polychlorinated biphenyls
RRO Residual range organics
SPLP Synthetic Precipitation Leaching Procedure
SSE Selective sequential extraction
SVOC Semi-volatile organic compounds
TAL Target analyte list
XRF X-ray fluorescence spectrometer

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
Main Processing Area	Monofill #2/Post-1955 Retort	Road Below Monofill #2	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP11 11MP12 11MP13 11MP14 11MP15 11MP16 11MP17 11MP18	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess possible migration of elemental mercury from foundation of former building ▪ Determine if a release from Monofill #2 has occurred. ▪ Assess fate and transport of metals from tailings/waste rock by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity ▪ Assess engineering properties	1, 2, 5, 18, 19, 20, 21, 22, 25, 27, 28
		North of Monofill #2	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Presence and concentrations of petroleum and SVOCs. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, SVOCs, DRO/RRO, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP10 11MP19	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess potential petroleum or SVOC contamination ▪ Assess fate and transport of metals from tailings/waste rock by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity ▪ Assess engineering properties	1, 2, 5, 9, 18, 20, 21, 22, 25, 28
	Area Upgradient of Monofill #2	Upgradient Area	Presence, concentration, vertical extent, and mobility of metals upgradient of known sources.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, and SPLP metals. See FSP Table 2-2 and Figure 2-5, location: 11MP01	▪ Determine metals concentrations in subsurface soil upgradient of known sources ▪ Assess fate and transport of metals ▪ Assess human health risk	5, 9, 12, 20, 21, 22, 25, 28
	Tailings/Waste Rock East of Red Devil Creek	Tailings Borrow Area and Other Areas with Tailings/Waste Rock	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP27 11MP26 11MP28 11MP29 11MP30	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals from tailings/waste rock by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity ▪ Assess engineering properties	1, 2, 5, 9, 18, 20, 21, 22, 23, 25, 28

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Gravel Pad	Gravel Pad	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Presence and concentrations of petroleum and SVOCs. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, SVOCs, DRO/RRO, and grain size. See FSP Table 2-2 and Figure 2-5, locations: 11MP23 11MP23 11MP25	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess potential petroleum or SVOC contamination ▪ Assess fate and transport of metals from tailings/waste rock by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 20, 21, 22, 23, 25, 29
	Monofill #3	Tailings/Waste Rock at Monofill	Presence/extent of tailings/waste rock. Concentration and vertical extent of metals.	Subsurface soil sampling and analysis for TAL metals. See FSP Table 2-2 and Figure 2-5, location: 11MP27.	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess human health risk	1, 5, 9, 18, 25, 28
	Power Plant	Former Drum Storage Area	Presence/extent of tailings/waste rock. Concentration and vertical extent of metals. Presence and concentrations of petroleum and SVOCs Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, SVOCs, and DRO/RRO. See FSP Table 2-2 and Figure 2-5, locations: 11MP20 11MP21	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess potential petroleum or SVOC contamination ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 18, 25
	Settling Pond Area	Upgradient of Settling Pond #1	Presence, concentration, and vertical extent of metals in soil upgradient of known sources. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals and grain size. See FSP Table 2-2 and Figure 2-5, location: 11MP31	▪ Assess metals concentrations in subsurface soil upgradient of known sources ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 9, 12, 25

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Settling Pond Area	Settling Pond #1	Depth of flotation tailings. Concentration, vertical extent, and mobility of metals contaminants in flotation tailings. Presence and concentrations of petroleum and SVOCs in flotation tailings. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, SVOCs, DRO/RRO, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, location: 11MP32	▪ Delineate vertical extent of flotation tailings ▪ Delineate metals contamination ▪ Assess fate and transport of metals from flotation tailings by leaching ▪ Assess potential petroleum or SVOC contamination ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 9, 18, 20, 21, 22, 23, 25, 29
	Settling Pond Area	Upgradient of Settling Pond #2	Presence, concentration, and vertical extent of metals in soil upgradient of known sources. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals and grain size. See FSP Table 2-2 and Figure 2-5, location: 11MP33	▪ Assess metals concentrations in subsurface soil upgradient of known sources ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 9, 12, 25
	Settling Pond Area	Settling Pond #2	Depth of flotation tailings. Concentration, vertical extent, and mobility of metals contaminants in flotation tailings. Presence and concentrations of petroleum and SVOCs in flotation tailings. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, SVOCs, DRO/RRO, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, location: 11MP34	▪ Delineate vertical extent of flotation tailings ▪ Delineate metals contamination ▪ Assess fate and transport of metals from flotation tailings by leaching ▪ Assess potential petroleum or SVOC contamination ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 9, 18, 20, 21, 22, 23, 25, 29
	Settling Pond Area	Berm of Settling Pond #2	Presence/extent of tailings/waste rock or flotation tailings. Concentration and vertical extent of metals.	Subsurface soil sampling and analysis for TAL metals. See FSP Table 2-2 and Figure 2-5, location: 11MP35	▪ Delineate vertical extent of tailings/waste rock or flotation tailings ▪ Delineate metals contamination ▪ Assess human health risk	2, 5, 9, 18, 25

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Settling Pond Area	Settling Pond #3	Depth of flotation tailings. Concentration, vertical extent, and mobility of metals contaminants in flotation tailings. Presence and concentrations of petroleum and SVOCs in flotation tailings. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, SVOCs, DRO/RRO, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, location: 11MP36	▪ Delineate vertical extent of flotation tailings ▪ Delineate metals contamination ▪ Assess fate and transport of metals from flotation tailings by leaching ▪ Assess potential petroleum or SVOC contamination ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 9, 18, 20, 21, 22, 23, 25, 29
	Settling Pond Area	Berm of Settling Pond #3	Presence/extent of tailings/waste rock or flotation tailings. Concentration and vertical extent of metals.	Subsurface soil sampling and analysis for TAL metals. See FSP Table 2-2 and Figure 2-5, location: 11MP37	▪ Delineate vertical extent of tailings/waste rock or flotation tailings ▪ Delineate metals contamination ▪ Assess human health risk	2, 5, 9, 18, 25
	Settling Pond Area	Between Settling Ponds and Red Devil Creek	Presence/extent of tailings/waste rock or flotation tailings. Concentration, vertical extent, and mobility of metals contaminants. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP38 11MP39 11MP40	▪ Delineate vertical extent of tailings/waste rock or flotation tailings ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 9, 16, 18, 20, 21, 22, 23, 25, 29
	East of Pre-1955 Processing Facilities	Near Spring in Red Devil Creek	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals contaminants. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size. See FSP Table 2-2 and Figure 2-5, locations: Paired shallow and deep borings11MP60 and 11MP88	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 9, 16, 18, 20, 21, 22, 23, 25, 29
		Along Mine Access Road	Presence/extent of tailings/waste rock. Concentration and vertical extent of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals and grain size. See FSP Table 2-2 and Figure 2-5, locations: 11MP63 11MP66	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 9, 16, 18, 25, 29

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Monofill #1	Around Monofill #1 and Former Shop Buildings	Presence/extent of tailings/waste rock. Concentration and vertical extent of metals. Presence and concentrations of petroleum and SVOCs. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, SPLP, TCLP, SVOCs, and DRO/RRO. See FSP Table 2-2 and Figure 2-5, locations: 11MP45 11MP46 11MP47 11MP48 11MP49 11MP89	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess potential petroleum or SVOC contamination ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 9, 18, 20, 22, 25, 27, 28
	Pre-1955 Retort	Area of Pre-1955 Retort Building	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP55 11MP56 11MP57 11MP58	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 9, 14, 18, 20, 21, 22, 25, 29
		Burnt Ore Pile	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, location: 11MP59	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5. 9, 14, 18. 20, 21, 22, 25, 29
		Area between Pre-1955 Retort and Red Devil Creek	Presence/extent of tailings/waste rock. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals and grain size. See FSP Table 2-2 and Figure 2-5, location: 11MP61	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 2, 5, 9, 14, 18, 20, 21, 22, 25, 29
		Area between Pre-1955 Retort and Red Devil Creek / Pre-1955 Rotary Furnace Burnt Ore Disposal Pile	Presence/extent of tailings/waste rock. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals and grain size. See FSP Table 2-2 and Figure 2-5, location: 11MP62	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 2, 5, 9, 14, 18, 25, 29

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Pre-1955 Rotary Furnace Building/Tailings/Waste Rock	Area of Pre-1955 Furnace Building / Tailings/ Waste Rock	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-5, locations: 11MP50 11MP51 11MP52 11MP53 11MP54	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties ▪ Assess hydraulic conductivity	1, 2, 5, 9, 14, 18, 20, 21, 22, 25, 29
	Upslope of Pre-1955 processing facilities and Monofill #1	Upslope of Pre-1955 processing facilities and Monofill #1	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals contaminants. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size. See FSP Table 2-2 and Figure 2-6, locations: Paired shallow and deep borings11MP41 and 11MP89	▪ Delineate vertical extent of metals contamination in subsurface soil upgradient of known sources ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 2, 5, 9, 14, 18, 20, 21, 22, 25, 29
Surface Mining / Exploration Area	Dolly Sluice Area	Dolly Sluice Delta	Concentration, vertical extent, and mobility of metals contaminants in soil and/or tailings/waste rock. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-6, locations: 11DS01 11DS02	▪ Delineate vertical extent of metals contamination in subsurface soil downgradient of the Surface Mined Area ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 8, 14, 17, 20, 21, 22, 25, 29
	Rice Sluice Area	Rice Sluice Delta	Concentration, vertical extent, and mobility of metals contaminants in soil and/or tailings/waste rock. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-6, locations: 11RS01 11RS02	▪ Delineate vertical extent of metals contamination in subsurface soil downgradient of the Surface Mined Area. ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 5, 8, 14, 17, 20, 21, 22, 25, 29
	Bulldozed Area Away from Known Ore Trend	Potential Site of On-Site Repository / Bulldozed Area Away from Known Ore Trend	Presence, concentration, vertical extent, and mobility of metals in soil. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-6, locations: 11SM10 11SM11.	▪ Delineate vertical extent of metals contamination in subsurface soil. ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess engineering properties	1, 2, 6, 9, 21, 22, 25. 29, 30

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)
	Bulldozed Area near Known Ore Trend	Upslope of Pre-1955 processing facilities and Monofill #1	Presence, concentration, vertical extent, and mobility of metals in soil. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size. See FSP Table 2-2 and Figure 2-6, locations: Paired shallow and deep borings11SM31 and 11SM32	▪ Delineate vertical extent of metals contamination in subsurface soil. ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 2, 6, 9, 21, 22, 25. 29
	Upland Area West of Area of Surface Mining	Upland Area West of Area of Surface Mining	Presence, concentration, vertical extent, and mobility of metals in soil. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, TCLP metals, and grain size. See FSP Table 2-2 and Figure 2-7, location: 11UP32	▪ Delineate vertical extent of metals contamination in upland subsurface soil outside of area of mining activities. ▪ Assess fate and transport of metals ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 2, 6, 9, 21, 22, 25. 29, 30
Outside of Main Processing Area and Area of Surface Mining / Exploration	Dam	Dam	Presence, concentration, vertical extent, and mobility of metals in soil.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, and SPLP metals. See FSP Table 2-2 and Figure 2-7, locations: 11RD08 11RD09	▪ Delineate vertical extent of metals contamination in subsurface soil. ▪ Assess fate and transport of metals ▪ Assess human health risk	1, 5, 9, 18, 21, 22, 25
	Red Devil Creek Alluvial Deposits Between Main Processing Area and delta	Red Devil Creek Alluvial Deposits and/or Soil	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size/Atterberg limits. See FSP Table 2-2 and Figure 2-7, locations: 11RD05 11RD06 11RD07 11RD20	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity ▪ Assess engineering properties	1, 5, 9, 14, 20, 21, 22, 25, 29
	Red Devil Creek Delta	Red Devil Creek Delta	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size. See FSP Table 2-2 and Figure 2-7. locations: 11RD01 11RD02 11RD03 11RD04	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess human health risk ▪ Assess engineering properties	1, 5, 9, 14, 17, 18, 20, 21, 22, 25, 29
	Red Devil Creek Alluvial Deposits Between Dam and Main Processing Area	Red Devil Creek Alluvial Deposits Between Dam and Main Processing Area	Presence/extent of tailings/waste rock. Concentration, vertical extent, and mobility of metals. Physical characteristics of subsurface soils.	Subsurface soil sampling and analysis for TAL metals, mercury SSE, arsenic speciation, SPLP metals, and grain size. See FSP Table 2-2 and Figure 2-7, locations: 11RD10	▪ Delineate vertical extent of tailings/waste rock ▪ Delineate metals contamination ▪ Assess fate and transport of metals by leaching ▪ Assess human health risk ▪ Assess hydraulic conductivity	1, 5, 9, 14, 20, 21, 22, 25, 29

Table 4-2 Subsurface Soil Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gap	2011 Planned Investigation Approach	Data Uses	DQO Study Questions Addressed (See Section 4.2)

Key:

DQO Data Quality Objective
DRO Diesel range organic
FSP Field Sampling Plan
RRO Residual range organics
SPLP Synthetic Precipitation Leaching Procedure
SSE Selective sequential extraction
SVOC Semi-volatile organic compounds
TAL Target analyte list
TCLP Toxicity characteristic leaching procedure
XRF X-ray fluorescence spectrometer

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Main Processing Area	Area of Monofill #2 / Post-1955 Retort Building	Likely Upgradient and Downgradient of Monofill #2 / Post-1955 Retort Building	Presence, concentration, and extent of metals in groundwater. Presence, concentration, and extent of organics in groundwater. Sources of groundwater contamination. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells at locations upgradient and downgradient of Monofill #2, locations: New monitoring wells planned at boring locations: 11MP01 11MP12 11MP14 11MP17 See FSP Table 2-3 and Figure 2-8. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, and DRO/RRO. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine if a release of COPCs from Monofill #2 has occurred ▪ Delineate extent of potential metals and organics contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess potential groundwater impacts from potential migration of elemental mercury from foundation of former retort building ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29
	Settling Pond Area	Likely Upgradient and Downgradient of Settling Ponds	Presence, concentration, and extent of metals in groundwater. Presence, concentration, and extent of organics in groundwater. Sources of groundwater contamination. Groundwater gradient and	Install new monitoring wells at locations upgradient and downgradient of Settling Ponds #1, #2, and #3, locations: New monitoring wells planned at boring locations: 11MP33 11MP40 11MP38 11MP39 Monitor existing well MW03 (previously referred to as MW-3). See FSP Table 2-3 and Figure 2-8.	▪ Determine if a release of COPCs from the settling ponds has occurred. ▪ Delineate extent of potential metals contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different	1, 2, 4, 10, 12, 23, 25, 27, 28, 29

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
			flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, and DRO/RRO. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	
	Gravel Pad and General Tailings/Waste Rock Area	Gravel Pad and Area Downgradient from Monofill #2 / Post-1955 Retort Building	Presence, concentration, and extent of metals in groundwater. Presence, concentration, and extent of organics in groundwater. Sources of groundwater contamination. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells at locations downgradient from Monofill #2 and the Post-1955 Retort Building and Gravel Pad Area, locations: New monitoring wells planned at boring locations: 11MP25 11MP29 11MP30 Monitor existing well MW01 (previously referred to as MW-1). See FSP Table 2-3 and Figure 2-8. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, RRO, GRO, and BTEX. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine if a release of COPCs from Monofill #2 or the Post-1955 Retort has occurred ▪ Delineate extent of potential metals contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29
	Power Plant / Former Drum Storage Area	Downgradient from Power Plant / Former Drum Storage Area	Presence, concentration, and extent of metals in groundwater. Presence, concentration, and extent of organics in groundwater. Sources of groundwater contamination.	Install new monitoring well at location downgradient from the Power Plant and Former Drum Storage Area, locations: New monitoring wells planned at boring location: 11MP20 Monitor existing well MW-07 (previously referred to as MW-7). See FSP Table 2-3 and Figure 2-8.	▪ Determine if a release of COPCs has occurred within the Power Plan or Former Drum Storage areas ▪ Delineate extent of potential metals and organics contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow	1, 2, 4, 10, 12, 23, 25, 27, 28, 29

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
			Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Groundwater sampling for total and dissolved TAL metals, methylmercury, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, and RRO. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	
	Mine Openings / Monofill #1 / Former Shop Buildings / Tailings/Waste rock	Near spring in Red Devil Creek and Locations Likely Downgradient of Former Mine Openings, Monofill #1, Pre-1955 Rotary Furnace/Shop Building, and Shop Pad B	Presence, concentration, and extent of metals in groundwater. Presence, concentration, and extent of organics in groundwater. Sources of groundwater contamination. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Vertical gradient and flow direction. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells at locations downgradient from Former Mine Openings, Monofill #1, and Shop Pad B Area, locations: New paired shallow and deep monitoring wells planned at boring locations 11MP60/11MP88 11MP52 11MP89 Monitor existing well MW-04 (previously referred to as MW-4). See FSP Table 2-3 and Figure 2-8. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, RRO, and PCBs. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine the source of the spring in Red Devil Creek and if it is a source of COPCs ▪ Determine if a release of COPCs from Former Shop Pad B has occurred ▪ Delineate extent of potential metals contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
	Pre-1955 Retort Area	Area Possibly Downgradient of Pre-1955 Retort Area and Rotary Furnace Burnt Ore Disposal Pile	Presence, concentration, and extent of metals in groundwater. Sources of groundwater contamination. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells at locations in area possibly downgradient of Pre-1955 Retort area and Rotary Furnace Burnt Ore Disposal Pile. New monitoring wells planned at boring locations: 11MP62 11MP66 Monitor existing well MW-06 (previously referred to as MW-6). See FSP Table 2-3 and Figure 2-8. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, RRO, and PCBs. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Delineate extent of potential metals contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29
Outside of Main Processing Area and Area of Surface Mining / Exploration	Red Devil Creek Alluvial Deposits Between Main Processing Area and Red Devil Creek Delta	Red Devil Creek Alluvial Deposits	Presence, concentration, and extent of metals in groundwater. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells at locations within the Red Devil Creek alluvial deposits between Main Processing Area and the delta. New monitoring wells planned at boring locations: 11RD06 11RD20 See FSP Table 2-3 and Figure 2-9. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, and RRO. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine if COPCs are present in the Red Devil Creek alluvial deposits ▪ Delineate extent of potential metals and organics contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
	Red Devil Creek Alluvial Deposits Between Dam and Main Processing Area	Red Devil Creek Alluvial Deposits Between Dam and Main Processing Area	Presence, concentration, and extent of metals in groundwater. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations..	Install new monitoring wells at location at location within the Red Devil Creek alluvial deposits between dam and Main Processing Area. New monitoring wells planned at boring location: 11RD10 See FSP Table 2-3 and Figure 2-9. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, SVOCs, DRO, and RRO. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine if COPCs are present in the Red Devil Creek alluvial deposits. ▪ Delineate extent of potential metals and organics contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29
	Upland Area West of Surface Mined Area	Background area for soils derived from the Kuskokwim Formation bedrock unit.	Presence, concentration, and extent of metals in groundwater. Groundwater gradient and flow paths. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	Install new monitoring wells pairs at locations within the Surface Mined Area at locations upgradient from the Main Processing Area. New monitoring wells planned at boring location: 11UP11 See FSP Table 2-3 and Figure 2-9. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, and total suspended solids. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Determine the background concentrations of COPCs in bedrock. ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	1, 2, 4, 10, 12, 23, 25, 27, 28, 29
Surface Mining / Exploration Area	Upslope of Pre-1955 processing facilities and	Upgradient from Main Processing Area	Presence, concentration, and extent of metals in	Install new monitoring well pairs (shallow and deep) at locations within the Surface Mined Area upgradient from	▪ Determine if the Surface Mined Area is a source of COPCs	1, 2, 4, 10, 12, 23, 25, 27, 28, 29

Table 4-3 Groundwater Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Sub-Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
	Monofill #1		groundwater. Groundwater gradient and flow paths. Vertical gradient and flow direction. Groundwater-Surface Water Interactions. Areal variation/trends in groundwater contaminant concentrations. Temporal variation/trends in groundwater contaminant concentrations.	the Main Processing Area. New paired shallow and deep monitoring wells planned at boring locations: 11MP41/11MP89 11SM31/11SM32 See FSP Table 2-3 and Figure 2-9. Groundwater sampling for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, and total suspended solids. Well elevation survey. Water level measurements. Compare groundwater data collected during other monitoring events.	▪ Delineate extent of potential metals contamination in groundwater ▪ Assess fate and transport of metals in groundwater ▪ Use water elevation data to determine groundwater gradients and flow direction ▪ Use major ion and trace element data to identify similarities and differences between groundwater from different areas and geologic units to determine groundwater flow patterns and changes in groundwater chemistry along its flow paths ▪ Use major ion and trace element data to identify groundwater-surface interactions, including possible stream contaminant loading ▪ Assess human health risk ▪ Assess mobility and toxicity of arsenic	

Table 4-4 Surface Water Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Red Devil Creek	Upstream from Main Processing Area	Presence and concentration of metals methylmercury in upstream Red Devil Creek surface water. Presence and concentrations of organics in Red Devil Creek surface water downgradient of abandoned drum identified in 2010. Spatial and temporal variation in stream discharge. Spatial and temporal variation in stream gaining and losing conditions.	Surface water sampling upstream of reservoir, at reservoir outlet, and at locations immediately upstream of where Red Devil Creek flows through tailings/waste rock in the Main Processing Area, including location near abandoned drum. See FSP Table 2-4 and Figure 2-10. Locations: 11RD01 11RD02 11RD03 11RD11 Analysis for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, and SVOCs. Measurement of stream flow at surface water sampling stations during summer and fall seasons. Survey of spot elevations of stream at locations adjacent to planned and existing monitoring wells. Compare to groundwater elevations.	▪ Determine metals concentrations in upstream locations ▪ Assess fate and transport of arsenic and mercury species ▪ Assess human health and ecological risk ▪ Use major ion and trace element data, stream discharge data, and stream spot elevation data to assess groundwater-surface interactions, including possible stream contaminant loading by groundwater or stream losses to groundwater. ▪ Evaluate mass transport of COPCs in surface water ▪ Assess contributions of groundwater to metals concentrations in Red Devil Creek surface water ▪ Assess contributions of runoff and sediment suspension to metals concentrations in Red Devil Creek surface water ▪ Evaluate mass transport of COPCs in surface water ▪ Assess gaining versus losing conditions in Red Devil Creek ▪ Assess stream flow rates for engineering considerations	1, 4, 12, 25, 26
	Main Processing Area	Presence, concentration, and extent of metals and methyl mercury in stream Red Devil Creek surface water within Main Processing Area. Presence, concentration, and extent of metals and methyl mercury in surface water flowing from seep. Presence and concentrations of organics in Red Devil Creek surface water. Spatial and temporal variation in stream discharge. Spatial and temporal variation in stream gaining and losing conditions.	Surface water sampling at locations bounded by tailings/waste rock in the Main Processing Area and at the seep location. See FSP Table 2-4 and Figure 2-10. Locations: 11RD04 11RD05 11RD09 11RD06 11RD10 11RD12 Analysis for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, and SVOCs. Measurement of stream flow at surface water sampling stations during summer and fall seasons. Measure seep flow during summer and fall seasons. Survey of spot elevations of stream at locations adjacent to planned and existing monitoring wells. Compare to	▪ Determine metals concentrations in Red Devil Creek water in Main Processing Area ▪ Assess nature and transport of arsenic and mercury species ▪ Assess human health and ecological risk ▪ Use major ion and trace element data, stream and seep discharge data, and stream spot elevation data to assess groundwater-surface interactions, including possible stream contaminant loading by groundwater or stream losses to groundwater ▪ Assess contributions of runoff and sediment suspension to metals concentrations in Red Devil Creek surface water ▪ Evaluate mass transport of COPCs in surface water ▪ Assess gaining versus losing conditions in Red Devil Creek ▪ Assess stream flow rates for engineering considerations	1, 4, 15, 16, 22, 23, 24, 25, 26, 29

Table 4-4 Surface Water Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
			groundwater elevations.		
	Downstream of Main Processing Area	Presence, concentration, and extent of metals and methyl mercury in stream Red Devil Creek surface water downstream of Main Processing Area. Presence and concentrations of organics in Red Devil Creek surface water. Spatial and temporal variation in stream discharge. Spatial and temporal variation in stream gaining and losing conditions.	Surface water sampling at locations downstream of the Main Processing Area. See FSP Table 2-4 and Figure 2-10. Locations: 11RD07 11RD08 Analysis for total and dissolved TAL metals, methylmercury, arsenic speciation, major ions, total dissolved solids, total suspended solids, and SVOCs. Measurement of stream flow at surface water sampling stations during summer and fall seasons. Survey of spot elevations of stream at locations adjacent to planned and existing monitoring wells. Compare to groundwater elevations.	▪ Determine metals concentrations in Red Devil Creek water downstream of Main Processing Area ▪ Assess fate and transport of arsenic and mercury species ▪ Assess human health and ecological risk ▪ Use major ion and trace element data, stream discharge data, and stream spot elevation data to assess groundwater-surface interactions, including possible stream contaminant loading by groundwater or stream losses to groundwater ▪ Evaluate mass transport of COPCs in surface water ▪ Assess contributions of groundwater to metals concentrations in Red Devil Creek surface water ▪ Assess contributions of runoff and sediment suspension to metals concentrations in Red Devil Creek surface water ▪ Evaluate mass transport of COPCs in surface water ▪ Assess gaining versus losing conditions in Red Devil Creek ▪ Assess stream flow rates for engineering considerations	1, 4, 15, 16, 22, 23, 25, 26, 29
Main Processing Area	Settling Ponds	Presence and concentration of metals, methyl mercury, and organics in surface water within Settling Ponds #1, #2, and #3. Presence and concentrations of organics in Red Devil Creek surface water.	Surface water sampling at locations within Settling Ponds #1, #2, and #3, if water is present within the ponds at the time of sampling. See FSP Table 2-4 and Figure 2-10. Locations: 11SP32 11SP34 11SP36 Survey of spot elevations of ponded water, if present.	▪ Determine metals concentrations in settling pond water ▪ Assess interactions of ponded water and groundwater ▪ Assess nature and transport of arsenic and mercury species ▪ Assess human health and ecological risk	1, 4, 16, 22, 23, 25, 26, 29

Table 4-5 Sediment Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Red Devil Creek	Upstream from Main Processing Area	Presence and concentration of metals, methylmercury, and organics in surface sediment at locations upgradient and downgradient of abandoned drum identified in 2010. Fate and transport of metals-impacted sediment and arsenic and mercury species. Arsenic and mercury mobility.	Sediment sampling upstream of reservoir, at reservoir outlet, and immediately upstream of tailings in the Main Processing Area. See FSP Table 2-5 and Figure 2-11. Locations: 11RD10 11RD11 Analysis for total TAL metals, methylmercury, arsenic speciation, mercury SSE, grain size, total organic carbon, and SVOCs.	▪ Assess metals and methylmercury concentrations in upstream locations ▪ Assess potential impacts of abandoned drum on surface sediment ▪ Assess fate and transport of metals-impacted sediment and arsenic and mercury species ▪ Assess human health and ecological risk	1, 4, 12, 16, 25, 26
	Main Processing Area	Presence, concentration, and extent of metals and methyl mercury in stream sediments in mixing zone downstream of seep in Main Processing Area. Fate and transport of metals-impacted sediment and arsenic and mercury species. Arsenic and mercury mobility.	Sediment sampling at location in mixing zone downstream of seep in Main Processing Area. See FSP Table 2-5 and Figure 2-11. Location: 11RD12 Analysis for total TAL metals, methylmercury, arsenic speciation, mercury SSE, grain size, and total organic carbon.	▪ Assess metals concentrations in creek bed adjacent to banks composed of tailings ▪ Assess contribution of seep to metals concentrations in Red Devil Creek sediments ▪ Assess fate and transport of metals-impacted sediment and arsenic and mercury species ▪ Assess human health and ecological risk	1, 4, 15, 16, 25, 26
Kuskokwim River Shoreline	Upriver of Red Devil Creek	Presence and concentration of metals and methyl mercury in upriver sediments. Fate and transport of metals-impacted sediment and arsenic and mercury species. Arsenic and mercury mobility.	Sampling of surface sediment along shoreline of Kuskokwim River at locations upstream of mouth of Red Devil Creek. See FSP Table 2-5 and Figure 2-11. Locations: 11KR01 11KR12 11KR14 11KR15 Analysis for total TAL metals, methylmercury, arsenic speciation, mercury SSE, grain size, and total organic carbon.	▪ Assess metals concentrations in shoreline sediment at up-river locations ▪ Assess fate and transport of metals-impacted sediment and arsenic and mercury species ▪ Assess human health and ecological risk	1, 4, 12, 25, 26
	Downriver of Red Devil Creek	Presence and concentration of metals and methyl mercury in downriver sediments. Fate and transport of metals-impacted sediment and arsenic and mercury species. Contribution of sediment impacts from Red Devil Mine sources, including Red Devil Creek, Red Devil Creek delta, and Dolly and Rice Sluice deltas. Arsenic and mercury mobility.	Sampling of surface sediment along shoreline of Kuskokwim River at locations downstream of mouth of Red Devil Creek. See FSP Table 2-5 and Figure 2-11. Locations: 11KR16 11KR17 11KR05 11KR06 11KR08 11KR09 Analysis for total TAL metals, methylmercury, arsenic speciation, mercury SSE, grain size, and total organic carbon.	▪ Assess metals concentrations in shoreline sediment at up-river locations ▪ Assess fate and transport of metals-impacted sediment and arsenic and mercury species ▪ Assess contribution of sediment impacts from Red Devil Mine sources, including Red Devil Creek, Red Devil Creek delta, and Dolly and Rice Sluice deltas ▪ Assess human health and ecological risk	1, 4, 8, 15, 17, 25, 26, 29

Table 4-6 Vegetation Data Gaps, Data Uses, and Investigative Approach

General Geographic Area	Location Description	Data Gaps	2011 Planned Investigation Approach	Data Uses	DQOs Study Questions Addressed (See Section 4.2)
Main Processing Area	Red Devil Creek Drainage Channel	Presence and concentration of contaminants in alder bark and spruce needles.	Vegetation sampling and analysis for TAL metals, percent moisture, and methylmercury. See FSP Tables 2-6 and 2-7 and Figures 2-13 and 2-13a.	▪ Input to ecological risk assessment food chain modeling	4, 26
	Pre-1955 Processing Area	Presence and concentration of contaminants in alder and spruce.	Vegetation sampling and analysis for TAL metals, percent moisture, and methylmercury. See FSP Tables 2-6 and 2-7 and Figures 2-13 and 2-13a.	▪ Input to ecological risk assessment food chain modeling	4, 26
	Post-1955 Processing Area	Presence and concentration of contaminants in alder and spruce.	Vegetation sampling and analysis for TAL metals, percent moisture, and methylmercury. See FSP Tables 2-6 and 2-7 and Figures 2-13 and 2-13a.	▪ Input to ecological risk assessment food chain modeling	4, 26
	Uphill of Post-1955 Processing Area	Presence and concentration of contaminants in blueberries.	Vegetation sampling and analysis for TAL metals, methylmercury, percent moisture, and arsenic speciation. See FSP Tables 2-6 and 2-7 and Figures 2-13 and 2-13a	▪ Input to human health and ecological risk assessment food chain modeling	4, 25, 26
	Settling Ponds	Presence and concentration of contaminants in emergent vegetation.	Vegetation sampling and analysis for TAL metals, percent moisture, and methylmercury. See FSP Tables 2-6 and 2-7 and Figures 2-13 and 2-13a	▪ Input to ecological risk assessment food chain modeling	4, 26
Area of Surface Mining/Exploration	Area of Surface Mining/Exploration	Presence and concentration of contaminants in alder, spruce, and blueberries.	Vegetation sampling and analysis for TAL metals, methylmercury, percent moisture, and arsenic speciation. See FSP Tables 2-6 and 2-7 and Figure 2-13.	▪ Input to human health and ecological risk assessment food chain modeling	4, 25, 26
Background Locations Outside of Main Processing Area and Area of Surface Mining/Exploration	Background Locations of Red Devil Creek Valley	Background concentration of contaminants in alder, spruce, and blueberries.	Vegetation sampling and analysis for TAL metals, methylmercury, percent moisture, and arsenic speciation. See FSP Tables 2-6 and 2-7 and Figure 2-13.	▪ Comparison to on-site vegetation samples.	12, 25, 26
	West of Surface Mining/Exploration Area	Background concentration of contaminants in alder, spruce, and blueberries.	Vegetation sampling and analysis for TAL metals, methylmercury, percent moisture, and arsenic speciation. See FSP Tables 2-6 and 2-7 and Figure 2-13.	▪ Comparison to on-site vegetation samples.	12, 25, 26
	Reservoir	Presence and concentration of contaminants in emergent vegetation.	Vegetation sampling and analysis for TAL metals, percent moisture, and methylmercury. See FSP Tables 2-6 and 2-7 and Figure 2-13 and 2-13.	▪ Comparison to on-site vegetation samples.	4, 26

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5 Preliminary Identification of Response Objectives and Remedial Action Alternatives

This section identifies the overall objectives of remedial action at the RDM and potential remedial alternatives to be evaluated in the FS. This information is presented to help guide appropriate data collection during the RI fieldwork so that sufficient information exists to evaluate the alternatives in the FS.

5.1 Preliminary Remedial Action Objectives

The goal of remedial action(s) at the RDM is to protect human health and the environment from risks associated with COPCs in tailings/waste rock, flotation tailings, and contaminated media at the site. Specific remedial action objectives include:

- Prevent or reduce human exposure (through inhalation, ingestion, or dermal contact) to COPCs in waste materials and contaminated media at the site.
- Prevent or reduce ecological exposure (through ingestion and dermal contact) to COPCs in waste materials and contaminated media at the site.
- Prevent or reduce potential migration of COPCs from waste materials at the site via surface runoff, erosion, or wind dispersion.
- Prevent or reduce potential migration of COPCs in waste materials at the site to groundwater and eventual potential recharge to surface water.

5.2 Potential Remedial Action Alternatives

The following potential remedial action alternatives are identified in this section to help identify data needed to adequately evaluate alternatives in the FS. Many of the potential remedy technology options are based on “presumptive remedies” for mine waste sites. Presumptive remedies are actions or technologies that, based upon past experience, are the most appropriate remedy for a specific type of site. A “no action” alternative will be identified, and all of the alternatives will be evaluated based on the EPA’s nine criteria for evaluating remedial alternatives, which are: (1) overall protection of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, and volume through treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptance; and (9) community acceptance. Additional remedial action technologies may be considered in the FS, and some remedial actions may be determined to be inapplicable at the RDM based on data obtained during the RI fieldwork.

5.2.1 Soil, Tailings/Waste Rock, and Flotation Tailings

The following sections summarize potential remedial action alternatives to address soil, tailings/waste rock, and flotation tailings at RDM.

5.2.1.1 Institutional Controls

Institutional controls are non-engineered controls, such as administrative and legal restrictions, that help minimize the potential for human and ecological receptor exposure to contamination and that help protect the integrity of the remedy. Administrative and legal controls do not actively address site contamination, but attempt to meet the remedial action objectives by reducing the potential for exposure to contaminated media. Institutional controls are often used in conjunction with an active technology and/or access controls (e.g., fencing, warning signs, or vegetation).

5.2.1.2 Surface Water Controls

Surface water run-on controls, or stormwater management structures, include drainage channels, ditches, trenches, and other structures engineered to prevent surface water from coming into contact with contaminated material. Preventing contact reduces erosion of contaminated surfaces and subsequent offsite transport of contaminants via the surface water pathway. However, these controls do not address either direct exposure of contaminants to human or ecological targets or offsite transport via other exposure pathways. Surface water controls may be used in conjunction with other remedial actions to enhance optimal performance.

5.2.1.3 In-Place Stabilization/Containment

This remedial action alternative involves in-place stabilization and containment of contaminated material. Common examples of containment technologies include capping, grading, terracing, layback, and surface-applied soil binders. The contaminated material area lithology, surface water drainage, flood plain, and other relevant factors must be assessed to determine the applicability of this alternative to a site. Final grading promotes surface water runoff and protects against erosion. Establishment of vegetation also protects against erosion.

5.2.1.4 Solidification/Fixing Technologies

Fixing technologies (solidification) are treatment processes that alter the physical characteristics of contaminated material to reduce the mobility and/or toxicity of the contaminants. Multiple technologies will be evaluated in the FS, including the Paste Technology, whereby tailings are mixed with cement and water to create an engineered matrix that no longer leaches contaminants.

5.2.1.5 Disposal in an Onsite Repository

This remedial action alternative involves excavation and placement of contaminated material in an onsite engineered repository. The onsite repository location is selected based on available surface area, lithology, groundwater table elevation, surface water drainage, flood plain, and other relevant factors.

Engineered repositories are specifically designed and constructed to contain a specific type of contaminated material. Repository design often includes components such as a barrier layer, leachate collection system, surface water controls, and access controls, as needed.

When placement of contaminated material within the repository is completed, final grading is performed and cap/cover layers are placed. Final grading promotes surface water runoff and protects against erosion. Vegetation is also established in the final cover layer to protect against erosion.

5.2.1.6 Offsite Disposal

This remedial action alternative involves excavation of contaminated material and offsite transportation for disposal. Offsite disposal facilities could include public or private solid waste landfills or hazardous waste landfills. The selection of the offsite facility should be based on the following criteria: haul distance and route, availability of landfill space, waste characterization, cost, regulatory compliance history of the facility, and the facility's ability to accept the contaminated material without substantial facility modifications. Contaminated material is transferred to the offsite facility and placed or treated in a manner determined by the facility operator. The facility is responsible for compliance with all applicable regulations governing solid/hazardous waste disposal, which may include site security, fencing, daily cover, groundwater monitoring, leachate collection, and hazardous waste characterization. Following disposal at an offsite facility, the excavated area is backfilled and/or graded and vegetation is re-established.

5.2.2 Sediment

Potential remedial action alternatives for sediment in Red Devil Creek and the Kuskokwim River include Monitored Natural Attenuation, Thin Layer Capping, and capping. If the sediments can be adequately de-watered, dredging and placement in an onsite repository may also be a suitable remedial action alternative. Depending on the remedial alternative selected, habitat restoration may be a component of the final remedy.

5.2.3 Groundwater

Potential remedial action alternatives for groundwater include Institutional Controls (as discussed in Section 5.2.1.1), In-Place Stabilization/Containment (e.g., impermeable vertical barriers for groundwater diversion), In-Situ Treatment, and Pump and Treatment. Source control achieved through remediation of contaminated soil, tailings/waste rock, or flotation tailings, or Monitored Natural Attenuation requiring the creation of a model to predict contaminant concentration over time may be sufficient to eventually achieve groundwater cleanup goals. These remedial action alternatives are not presented in detail in this section; however, groundwater remedial action alternatives will be fully evaluated in the FS.

5.2.4 Surface Water

Potential remedial action alternatives for surface water include Institutional Controls (as discussed in Section 5.2.1.1), Surface Water Controls (as discussed in Section 5.2.1.2), In-Situ Treatment, and Pump and Treat. As described for groundwater, source control achieved through remediation of contaminated soil/waste rock, or flotation tailings, or Monitored Natural Attenuation requiring the creation of a model to predict contaminate concentration over time will likely be sufficient to eventually achieve surface water cleanup goals. Surface water remedial action alternatives will be evaluated in the FS.

6 Identification of Preliminary Applicable or Relevant and Appropriate Requirements

This section provides preliminary identification of potential ARARs and other standards, criteria, and guidance "to be considered" (TBC) for activities at the RDM. A preliminary identification of ARARs and TBCs can be helpful in guiding investigative efforts and assessing the feasibility of remedial action alternatives; however, ARARs and TBCs are identified iteratively throughout the RI/FS.

Applicable requirements are environmental protection standards, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, remedial action, location, or other circumstance at a potentially contaminated site. Relevant and appropriate requirements are environmental protection requirements promulgated under both federal and state law.

TBCs are non-promulgated federal or state advisories, guidance, or proposed rules that are not legally binding and do not have the status of a potential ARAR, but they are useful in determining the necessary level of cleanup for protection of human health and the environment if ARARs are unavailable.

ARARs and TBCs are divided into three categories:

- Chemical-Specific ARARs: usually health- or risk-based numerical values or methodologies that establish an acceptable amount or concentration of a chemical in the ambient environment
- Action-Specific ARARs: usually technology- or activity-based requirements for remedial actions
- Location-Specific ARARs: restrictions placed on the concentration of hazardous substances or the conduct of activity solely because they occur in special locations

Potential chemical- and location-specific ARARs and TBCs for the RDM were identified on the basis of existing site data and are outlined below. These ARARs and TBCs will be updated based on RI findings.

Potential action-specific ARARs and TBCs are based on potential remedial action alternatives. A more detailed list of action-specific ARARs and TBCs will be presented in the FS. If both federal and state laws address the same issues that are applicable, appropriate, and relevant, the more stringent or specific one is cited below to reduce redundancy. In addition, many regulations refer to other regulations for specific guidance. In these cases, the substantive guidance has been cited.

6.1 Chemical-Specific ARARs and TBCs

Federal and state chemical-specific ARARs and TBCs will be used to conduct a preliminary screening for COPCs in all media at the RDM site, as discussed in the Risk Assessment Work Plan provided in Appendix B. The following factors are important to note with respect to the chemical-specific ARARs and TBCs:

- The EPA has developed tables titled “Regional Screening Levels for Chemical Contaminants at Superfund Sites” (EPA 2009). These tables provide risk-based screening levels, calculated using default exposure assumptions, physical and chemical properties, and the most recent toxicity values. These regional screening levels have been used in other studies as TBCs for soil and water but are not location-specific. The default exposure assumptions for these levels do not reflect conditions at the RDM site. The residential soil risk-based concentrations from the EPA tables were selected as the TBC for soils for the RI/FS.
- Soil cleanup levels for hazardous substances in soils is governed by 18 AAC 75.340 (a) (2) (A), which provides the method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with chemicals other than petroleum hydrocarbons.
- To address the potential for contaminant migration from mining facilities on BLM lands, the BLM developed criteria for chemicals of concern (heavy metals) as they relate to recreational use and wildlife habitat on BLM lands. These risk management criteria (RMCs) provide numerical action levels for metals in various environmental media. RMCs are designed to (1) help land managers make natural resource decisions and (2) support ecosystem management.
- Petroleum contamination at the RDM site is related to leaks at ASTs and other uses of petroleum/oil/lubricants. Cleanup levels for petroleum-contaminated soils is governed by 18 AAC 75.340 (a) (1) (A), which provides the method for determining cleanup levels for petroleum hydrocarbon-contaminated soil in the under 40-inch soil zone.
- Under 18 AAC 80.010 in the State of Alaska Drinking Water Standards, the Federal Drinking Water Standards (40 CFR 141.40–141.43l) are adopted by reference.
- Surface water samples will be compared with Ambient Water Quality Criteria (AWQC) 18 AAC 70.020).
- Sediment samples will be compared to Squirt Probable Effect Level and Threshold Effect Level (McDonald et al. 2000).

6.2 Action-Specific ARARs and TBCs

For this preliminary action-specific ARARs and other pertinent advisories, criteria, or guidance to be considered (TBCs) determination, a few potential technologies were selected for analysis. Remedial actions are only discussed for soil and sediments, since no potential remedial actions have been identified for contaminants in groundwater or surface water at this time. Once remedial action alternatives are screened and refined in the FS report, action-specific ARARs and TBCs will be evaluated more thoroughly for each alternative. Remedial action alternatives, excluding the no-action alternatives, are:

- Ex-situ soils/sediments treatment – offsite disposal or onsite disposal at a repository.
- In-situ soils/sediments treatment – capping.
- Groundwater/surface water – none identified.

The potential action-specific federal ARAR that has the most significant impact on the economic and technical feasibility of these remedial action alternatives is the Bevill Amendment to RCRA Section 3001, 40 CFR 261.4(b)(7). This amendment is explained further in the following section. Once a determination is made about how the wastes on the site are characterized, these other federal ARARs and TBCs may or may not be applicable, appropriate, and/or relevant:

- RCRA Generator Standards (40 CFR 262).
- RCRA Land Disposal Restrictions (LDRs) (40 CFR 268).
- RCRA Treatment, Storage, and Disposal Facility Requirements (40 CFR 264).
- RCRA Closure and Post-Closure Requirements (40 CFR 264.110 to 120, 264.178, 264.197, 264.258, 264.280, 264.310, and 264.90 to 99).
- Criteria for classification of solid waste disposal facilities and practices (40 CFR 257).
- National Pollution Discharge Elimination System (NPDES) (40 CFR 125 and 403).

Potential action-specific Alaska ARARs and TBCs include the following:

- Alaska Oil and Other Hazardous Substances Pollution Control (18 AAC 75).
- Alaska Solid Waste Management Regulations (18 AAC 60).
- Alaska Anti-Degradation Water Quality Standards (18 AAC 70.015).
- Alaska Wastewater Disposal Regulations (18 AAC 72).

These ARARs are likely to apply regardless of the Bevill Amendment determination.

6.3 Federal Regulations

6.3.1 Bevill Amendment to RCRA (RCRA Section 3001; 40 CFR 261.4(b)(7))

RCRA was amended in 1980 to include Section 3001(b)(3)(A)(ii), known as the Bevill exclusion, to temporarily exclude "solid waste from the extraction, beneficiation, and processing of ores and minerals" from regulation as hazardous waste under Subtitle C of RCRA, pending further study. The subsequent regulations are given in 40 CFR 261.4 (b)(7). Mining waste may come within the CERCLA definition of hazardous substance, even if it does not contain RCRA hazardous wastes.

The EPA (2009) gives the following steps to determine how wastes at a particular facility are regulated under 40 CFR 261.4(b)(7):

1. Determine whether the material is a solid waste under RCRA.
2. Determine whether the facility is using a primary ore or mineral to produce a final or intermediate product and also whether less than 50 percent of the feedstocks on an annual basis are from secondary sources.
3. Establish whether the material and the operation that generates it are uniquely associated with mineral production.
4. Determine where in the sequence of operations beneficiation ends and mineral processing begins.
5. If the material is a mineral processing waste, determine whether it is one of the 20 special wastes from mineral processing.
6. This analytical sequence will result in one of three outcomes:
    a. the material is not a solid waste and therefore not subject to RCRA;
    b. the material is a solid waste but is exempt from RCRA Subtitle C because of the Mining Waste Exclusion; or
    c. the material is a solid waste that is not exempt from RCRA Subtitle C and is subject to regulation as a hazardous waste if it is a listed or characteristic hazardous waste.

The BLM, as lead agency, is responsible for determining the applicability of the Bevill Amendment. The BLM has yet to make such a determination. It is anticipated that RI results will inform the determination process.

6.3.2 Resource Conservation and Recovery Act Subtitle C

RCRA Subtitle C governs the cradle-to-grave management of materials that meet the definition of a hazardous waste. Hazardous wastes are characterized as wastes that are either specifically listed in 40 CFR 261 Subpart D or exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity), as determined by the TCLP.

Contaminated soil exhibits the RCRA toxicity characteristic if, after applying TCLP, the concentration in the extract is greater than the TCLP regulatory value. The relevant values for the RDM are listed in Table 6-1.

Soil that fails TCLP generally must be managed in accordance with specific RCRA waste management requirements (for example, LDR; treatment, storage, and disposal (TSD); and closure and post-closure requirements). RCRA hazardous waste management requirements are applicable to RCRA hazardous waste if:

- Spill and disposal occurred after the effective date of the toxicity characteristic rule (November 1980 for metals and September 1990 for VOCs), or
- Response actions constitute treatment, storage, or disposal (i.e., contaminated soil is excavated, treated, or disposed).

Table 6-1 Maximum Concentration of Contaminants for the Toxicity Characteristic

EPA HW No.[1]	Contaminant	CAS No.[2]	Regulatory Level (mg/L)
D004	Arsenic	7440–38–2	5.0
D005	Barium	7440–39–3	100.0
D006	Cadmium	7440–43–9	1.0
D007	Chromium	7440–47–3	5.0
D008	Lead	7439–92–1	5.0
D009	Mercury	7439–97–6	0.2
D010	Selenium	7782–49–2	1.0
D011	Silver	7440–22–4	5.0

Source: 40 CFR 261.24

Notes:
1 Hazardous waste number
2 Chemical abstracts service number

Key:
CAS = Chemical Abstract Service
EPA = Environmental Protection Agency
HW = hazardous waste
mg/L = milligrams per liter

The release of contaminants at the RDM occurred before 1980. The toxicity characteristic rules, RCRA, Subtitle C requirements are potentially applicable to remedial actions that involve treatment, storage, or disposal of toxicity characteristic waste from the RDM (for example, incineration of petroleum-contaminated soils and soil washing of lead-contaminated soils). RCRA closure and post-closure requirements are relevant and appropriate for remedial actions that involve capping or in situ treatment of wastes spilled or disposed of before the effective dates of the toxicity characteristic rules.

The toxicity characteristic rule applies to spills or disposal actions that occurred since 1980. RCRA Subtitle C requirements are applicable for remedial actions involving treatment, storage, or disposal of wastes that fail TCLP.

The most significant RCRA Subtitle C requirements are potential ARARs for remedial actions that involve generation, treatment, storage, or disposal generator standards; LDRs; treatment, storage, and disposal facility (TSDF) requirements; and closure and post-closure requirements. These requirements are applicable if the waste being managed meets the definition of a RCRA hazardous waste (i.e., fails TCLP) but will be relevant and appropriate if the wastes being managed do not meet the definition of a RCRA hazardous waste (i.e., do not fail TCLP).

6.3.3 Generator Standards (40 CFR 262)

The RCRA hazardous waste generator requirements that are most relevant for the RDM are:

- 40 CFR 262.11 – requirement to determine whether waste being generated is a hazardous waste by sampling and analysis or process knowledge (applicable to wastes being generated through excavation or treatment); and
- 40 CFR 262.34 – requirements applicable to the short-term (less than 90 days) storage of RCRA hazardous waste (applicable to excavated RCRA hazardous waste awaiting treatment and disposal) without a permit or interim status.

6.3.4 Land Disposal Restrictions (40 CFR 268)

The LDR program identifies treatment standards for hazardous wastes and specifies requirements that generators, transporters, and owners or operators of TSDFs that manage restricted wastes destined for land disposal must meet. LDRs for toxicity characteristic wastes require that the waste be treated to specified concentration levels before placement in a land-based unit (EPA 2001).

The LDR program consists of three main components:

- Disposal Prohibition – Requires that waste-specific treatment standards be met before a waste can be land disposed.
- Dilution Prohibition – Requires that wastes be properly treated and not simply diluted to mask the concentration of hazardous constituents.
- Storage Prohibition – Prohibits storing hazardous wastes indefinitely instead of treating them promptly.

The LDRs apply to listed hazardous waste or characteristic waste. There are treatment standards for hazardous wastes (40 CFR 268.40). If a waste fails TCLP, it must meet the applicable LDR before being disposed outside a designated area of contamination. Table 6-2 provides numerical limits not to be exceeded by the hazardous constituents before contaminated soil can be disposed in a land disposal facility.

Table 6-2 Universal Treatment Standards

Regulated Constituent Common Name	CAS[1] Number	Wastewater Standard Concentration[2] (mg/L)	Non-wastewater standard Concentration[3] (mg/L TCLP)
Antimony	7440–36–0	1.9	1.15
Arsenic	7440–38–2	1.4	5.0
Barium	7440–39–3	1.2	21
Beryllium	7440–41–7	0.82	1.22
Cadmium	7440–43–9	0.69	0.11
Chromium (total)	7440–47–3	2.77	0.60
Lead	7439–92–1	0.69	0.75
Mercury – Non-wastewater from retort	7439–97–6	NA	0.20
Mercury – all others	7439–97–6	0.15	0.025
Nickel	7440–02–0	3.98	11
Selenium[5]	7782–49–2	0.82	5.7
Silver	7440–22–4	0.43	0.14
Sulfide[4]	18496–25–8	14	NA
Thallium	7440–28–0	1.4	0.20
Vanadium[4]	7440–62–2	4.3	1.6
Zinc[4]	7440–66–6	2.61	4.3

Source: 40 CFR 268.40

Notes:

1 When the waste code and/or regulated constituents are described as a combination of a chemical with its salts and/or esters, the CAS number is given for the parent compound only.

2 Concentration standards for wastewaters are expressed in mg/L and are based on analysis of composite samples.

3 Except for metals (EP or TCLP) and cyanides (total and amenable) the non-wastewater treatment standards expressed as a concentration were established, in part, based on incineration in units operated in accordance with the technical requirements of 40 CFR part 264, subpart O or 40 CFR part 265, subpart O, or based on combustion in fuel substitution units operating in accordance with applicable technical requirements. A facility may comply with these treatment standards according to provisions in 40 CFR 268.40(d). All concentration standards for non-wastewaters are based on analysis of grab samples.

4 These constituents are not "underlying hazardous constituents" in characteristic wastes, according to the definition at 40 CFR 268.2(i).

5 This constituent is not an underlying hazardous constituent as defined at 40 CFR 268.2(i) because its UTS level is greater than its TC level; thus, a treatment selenium waste would always be characteristically hazardous, unless it were treated to below its characteristic level.

Key:

CAS = Chemical Abstract Service
EP = extraction procedure
mg/L = milligrams per liter
TC = toxicity characteristic
TCLP = toxicity characteristic leaching procedure
UTS = universal treatment standards

The applicability of these standards will have to be assessed once a determination about the applicability of the Bevill amendment is evaluated and a remediation technique is analyzed.

6.3.5 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facility Requirements (40 CFR 264)

Specific waste management requirements governing the TSD of hazardous wastes are contained in 40 CFR 264. These requirements normally are associated with facilities that are applying for or have received a RCRA permit. The type of TSD requirements that are potential ARARs depends on the type of hazardous waste management unit being used to treat, store, or dispose of wastes. 40 CFR 264 Subpart N addresses landfills. These RCRA TSD requirements apply to units used to manage wastes that failed TCLP and are potentially relevant and appropriate only for units used to manage non-RCRA wastes.

6.3.6 Closure and Post-Closure Requirements (40 CFR 264.110 to 120)

Specific requirements are contained in 40 CFR 264 governing the closure and post-closure care of RCRA hazardous waste management units:

- General Closure and Post-Closure (40 CFR 264.110 to 120).
- Landfills (40 CFR 264.310).

These requirements are potential ARARs for closure of units used to treat or store wastes and for disposal units (i.e., landfills). These requirements apply to closure of units used to manage wastes that failed TCLP and are potentially relevant and appropriate only for closure of units used to manage non-RCRA wastes.

6.3.7 Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR 257)

The criteria by which solid waste disposal facilities and processes must operate are specified in 40 CFR 257. These criteria are designed to prevent adverse effects on human health and the environment. If facilities fail to meet these criteria, they are considered open dumps. The criteria categories include: floodplains, endangered species, surface water, groundwater, disease, air, and safety.

The potentially applicable provisions of 40 CFR 257 include those that regulate facilities and practices in floodplains. The other criteria have not been identified as potential ARARs because the criteria defer to regulations promulgated under the Endangered Species Act, Clean Water Act, and Clean Air Act, which have been addressed separately.

6.3.8 National Pollutant Discharge Elimination System (40 CFR 122 and 403)

This regulation covers the provision of the NPDES program specified in Sections 318, 402, and 405 of the Clean Water Act. This regulation controls water pollution while regulating point source discharges into waters of the United States. It is unknown at this time whether the provisions of the NPDES program will be relevant to the remediation activities that will occur at the RDM.

6.4 State of Alaska Regulations

Appropriate guidance documents will be followed for all regulations.

6.4.1 Alaska Hazardous Waste Regulations (18 AAC 62)

18 AAC 62 primarily incorporates federal RCRA regulations by reference; therefore, the federal RCRA regulations 40 CFR 260 through 279 are cited where applicable or relevant and appropriate.

6.4.2 Alaska's Oil and Hazardous Substances Pollution Control Regulations (18 AAC 75)

The provisions of Alaska's Oil and Hazardous Substances Pollution Control Regulations are designed to address cleanup of releases other than those from regulated USTs. Many of these regulations are mainly administrative (e.g., discharge notification and reporting, ADEC approval of cleanup and disposal methods). The cleanup operation requirements (18 AAC 75.360) specify the responsibilities and studies and plans required for ex-situ and in-situ cleanup techniques. For example, for in-situ cleanup techniques, the following is required:

- A site monitoring plan showing proposed locations of monitoring wells.
- A hydrogeologic description of the site.
- Results of hydrogeologic modeling performed to address capture zones, effects of hydraulic loading, and plume migration.

Different requirements apply for different cleanup techniques. These regulations will need to be further examined during the feasibility study.

6.4.3 Alaska Solid Waste Management Regulations

The substantive provisions of Alaska's Solid Waste Management regulations (18 AAC 60) may be ARARs for the management of wastes that do not meet the definition of a RCRA hazardous waste but contain contaminants that exceed cleanup levels that are potential ARARs. These regulations are more specific than federal regulations. The following specific subsections are potential ARARs for remedial actions that involve storage, treatment, transportation, or disposal of wastes that exceed cleanup levels:

- Accumulation, Storage, and Treatment – 18 AAC 60.010
- Transport – 18 AAC 60.015
- Polluted Soil – 18 AAC 60.025
- Waste Disposal Permits – 18 AAC 60.200
- Landfills Located on Permafrost – 18 AAC 60.227
- Monofills – 18 AAC 60 Article 4
    - Mining Waste – 18 AAC 60.455
    - Closure Demonstration and Post-Closure Care – 18 AAC 60.490
- Monitoring and Corrective Action Requirements – 18 AAC 60 Article 7

6.4.4 Alaska Water Quality Standards

18 AAC 70.015 specifies that actions may not degrade water that is higher in quality than AWQCs unless approval is received from ADEC. AWQCs also represent potential ARARs for any discharges associated with remedial actions, if any occur.

6.4.5 Alaska Wastewater Disposal Regulations

18 AAC 72.500 governs nondomestic wastewater discharges. Such discharges could occur in conjunction with the RI/FS (e.g., purge water disposal or waste treatment). The engineering requirements in 18 AAC 72.600 must be met.

6.5 Location-Specific ARARS and TBCS

Listed below are location-specific ARARs that may affect remedial actions at the RDM site. The agencies that will be consulted to ensure compliance with these requirements are identified in the following section. The potential impact of these requirements will be clarified during RI activities.

Federal Land Policy and Management Act (43 USC 1701)

The Federal Land Policy and Management Act (FLPMA) is the BLM's organic (fundamental) act. It was enacted to establish a systematic approach to managing public lands to protect "the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values." Under the FLPMA, the BLM is required to establish a planning process to manage public lands for multiple uses of the land and its resources and achieve sustained yields of natural resources (BLM 1976; LexisNexis 2007). This act establishes the standard by which the BLM manages public lands, which is that no undue or unnecessary degradation occurs.

Resource Conservation and Recovery Act

40 CFR 264.18 contains a number of explicit limitations regarding where onsite TSD of hazardous waste may occur. In particular, 40 CFR 264.18(b) contains limitations on TSDFs in floodplains and near major faults.

Clean Water Act, Section 404

Section 404 of the Clean Water Act, which is implemented by the EPA and the U.S. Army Corps of Engineers through regulations in 40 CFR 230 and 33 CFR 320 to 330, prohibits the discharge of dredged or fill material into waters of the United States without a permit. Although CERCLA onsite actions do not require a permit, the substantive requirements of Section 404 and the implementing regulations are potential ARARs for remedial actions that could impact wetlands. During the RI, E & E will contact U.S. Fish and Wildlife Service (USFWS) and U.S. Army Corps of Engineers to determine the presence of wetlands in the RDM area.

National Historic Preservation Act (16 United States Code 470)

The National Historic Preservation Act (NHPA) and its implementing regulations in 36 CFR 800 require that federal agencies consider the effects of remedial activities on historic properties included on or eligible for inclusion on the National Register of Historic Places. The National Register is a list of districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, engineering, and culture.

There are no buildings remaining at this site; therefore, it is unlikely that this act will be applicable to actions at the RDM site.

Archeological and Historical Preservation Act (16 United States Code 469a-1; 40 CFR 6.301(c))
This act and its implementing regulations provide for the preservation of historic and archeological data that might otherwise be lost as a result of terrain alterations. If any remedial actions could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. DOI to do so. This act differs from the NHPA in that it encompasses a broader range of resources than those listed on the National Register and mandates only the preservation of the data.

It is not known whether there are any potential archeological or historic artifacts or structures of significance in or around the mine.

Endangered Species Act (16 United States Code 1531 through 1543)
The Endangered Species Act (ESA) and its implementing regulations in 50 CFR Parts 17 and 402 provide a means for conserving various species of fish, wildlife, and plants that are threatened with extinction. The ESA defines an endangered species as “any species which is in danger of extinction throughout all or a significant portion of its range.” In addition, the ESA defines a threatened species as “any species which is likely to become an endangered species within the foreseeable future.” Furthermore, the ESA provides for the designation of critical habitats that are “specific areas within the geographical area occupied by the [endangered or threatened] species…on which are found those species.”

Section 7(a) of the ESA requires federal agencies, in consultation with the U.S. DOI and National Marine Fisheries Service, as appropriate, to ensure that the actions they authorize, fund, or carry out are unlikely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their critical habitats. Actions that might jeopardize listed species include direct and indirect effects and the cumulative effects of other actions that are interrelated or interdependent with the proposed action.

Substantive compliance with the ESA means that the lead agency must identify whether a threatened or endangered species, or its critical habitat, will be affected by a proposed response action. If so, the agency must avoid the action or take appropriate mitigation measures so that the action does not affect the species or its critical habitat. If, at any point, the conclusion is reached that endangered species are not present or will not be affected, no further action will be taken.

As part of the RI, E & E will consult with the USFWS to determine whether there are any threatened or endangered species or critical habitat onsite.

Executive Order 11988 Floodplain Management
This Executive Order requires federal agencies to evaluate whenever possible all actions that may occur in floodplains to ensure that the action will not adversely impact floodplains. Agencies must plan to minimize flood hazards and budget to restore and preserve undeveloped floodplains. E & E will contact the Federal Emergency Management Agency and U.S. Army Corps of Engineers to determine the floodplain boundaries at the RDM.

Fish and Wildlife Coordination Act
This act requires that the USFWS and National Marine Fisheries Service be consulted regarding any action that modifies a stream, river, or other water of the United States. The intent of this regulation is to protect the fish and wildlife that may be adversely affected by changes in the quality or quantity of water in a river, stream, or other water body.

At this time, it is not anticipated that investigative or remedial action at the RDM site will result in the modification of a water body of the U.S.; therefore, this act is potentially not applicable.

Migratory Bird Treaty Act
The Migratory Bird Treaty Act of 1972 protects all species of native birds in the United States from unregulated "take," which can include poisoning at waste sites. It covers actions that affect migratory birds, including eagles.

It is not anticipated that investigative or remedial action at the RDM will result in the take of migratory birds of the U.S.; however, this possibility will be considered in the risk assessment.

Alaska Department of Fish & Game Title 16
The Alaska Department of Fish and Game (ADF&G) Title 16 requirements protect fish species and fish habitats in Alaska. The ADF&G needs to be consulted, and authorization needs to be grated, for activities that could impede fish passage or activities that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous waterbody.

It is not anticipated that investigations or remedial actions at the RDM site will result in any of the regulated activates.

6.6 ARARs Impact on Field Activities

To better define the extent to which certain ARARs and TBCs will need to be met while remedial actions are conducted, the following field activities will be integrated into the RI process:

- Tailings/waste rock, and flotation tailings will be analyzed by TCLP as appropriate to determine the potential applicability of RCRA, Subtitle C, hazardous waste management regulations.
- The extraction procedure toxicity test may be performed on selected contaminated soil samples to determine whether further treatment is necessary to meet the RCRA LDRs.
- Data will be collected to confirm the presence or absence of floodplains, wetlands, historic and archaeological resources, and endangered or threatened species that could be impacted by remedial actions.
- Onsite management of investigation-derived waste (IDW) generated during investigation activities must comply with ARARs to the extent practicable. The EPA provides guidance on IDW management in Management of Investigation-Derived Wastes during Site Inspections (1991) and Guide to Management of Investigation-Derived Waste (1992).

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7 Overview of RI/FS Study Design

The intent of the RI/FS study design is to provide a comprehensive characterization of the current situation at the RDM, including characterization of contaminant source locations, characterization of contaminant migration pathways and media, assessing potential risks to human and ecological receptors, and collection of data for assessing potential remedial action alternatives. The study design is the result of the DQO planning process (Section 4) and several planning meetings between the BLM, E & E, and agency representatives. It involves activities to be implemented by the BLM and E & E. An overview of the study design concept is provided below. Detailed field investigation locations, methodologies, and rationale are provided in the RI/FS FSP in Appendix A of this Work Plan.

Tailings/Waste Rock Delineation. Tailings/waste rock, including areas within the main processing area, along Red Devil Creek, the Red Devil Creek delta, and the Dolly Sluice delta, will be delineated by a combination of visual observations, chemical sampling, and geophysical methods. The areal extent of tailings/waste rock will be surveyed visually, and boundary locations will be sampled, field screened for mercury, arsenic, and antimony using a portable XRF, and mapped using global positioning system instrumentation. The depth of tailings/waste rock will be determined from drilled soil borings in known tailings/waste rock locations. The soil boring data will be supplemented with results of a geophysical survey conducted by the BLM in 2010. The geophysical survey employed electromagnetic conductivity and electrical resistivity technologies to map tailings/waste rock depths, depths to bedrock, and other important subsurface features.

A portion of the tailings/waste rock delineation was completed in 2010 (E & E 2010b), including the visual survey and XRF screening of tailings/waste rock to determine the surface extent of contamination. In addition, the geophysical survey was completed in 2010. The FSP (Appendix A) for 2011 sampling includes additional surface tailings delineation by visual and XRF field screening methods, and all subsurface soil borings.

Source Characterization. Contaminant sources (other than tailings/waste rock and flotation tailings) at the site will be characterized by a combination of surface soil, subsurface soil, and groundwater sampling. Major sources to be investigated include the following:

- Pre-1955 Rotary furnace/Shop building

- Shop Pads
- Pre-1955 Retort
- Gravel Pad
- Post-1955 Retort
- Settling Ponds #1, #2, and #3
- Monofills #1, #2, and #3
- Power Plant

The study design includes sampling stations in close proximity to each of these source locations. The sampling frequency at each source is based on the availability and/or the significance of historical sample results. See Appendix A, Figures FSP 2-1, FSP 2-2, FSP 2-4, FSP 2-5, FSP 2-6, and FSP 2-7.

A portion of the source characterization was completed in 2010 (E & E 2010b), including surface soil sampling at each major source location and groundwater sampling from existing monitoring wells. The FSP for 2011 sampling includes additional surface soil sampling and all subsurface soil borings and new monitoring wells to further characterize onsite sources (see Appendix A).

Migration Pathway Characterization. Contaminant migration pathways will be characterized by a combination of chemical sampling and a benthic macroinvertebrate study. Surface sediment and surface water samples will be collected from Red Devil Creek, the primary surface water migration pathway at the site, to determine the effects of placement of tailings/waste rock into the waterway, surface runoff from contaminant sources, and the potential contribution of contaminated groundwater. See Appendix A, Figure FSP 2-9. Surface sediment samples will be collected from the Kuskokwim River to characterize the loading of contaminants to river sediments from the Red Devil Creek drainage. See Appendix A, Figure FSP 2-10. Monitoring wells will be installed throughout the site to characterize groundwater contaminant concentrations and migration, including two “sentinel” monitoring wells near the mouth of Red Devil Creek, which will provide data on the contribution of contaminants in groundwater flowing from the site directly into the Kuskokwim River. Other monitoring wells will be installed and sampled to assess potential contribution of groundwater to contamination in Red Devil Creek. See Appendix A, Figures FSP 2-6 and FSP 2-7. The chemical sampling of Red Devil Creek will be supplemented by a benthic macroinvertebrate study to be implemented by the BLM. This study will involve collection of benthic macroinvertebrates in Red Devil Creek for chemical analysis and for community structure (species abundance and diversity). The results of this survey will be correlated with chemical sample results in the creek to provide another line of evidence regarding site impacts to aquatic biota. The benthic macroinvertebrate survey plan has been prepared by BLM under separate cover (BLM 2010). Finally, vegetation sampling will be conducted to assess contaminant uptake into vegetation species utilized as forage by local wildlife and species consumed by humans. See Appendix A, Figures 2-13 and 2-13a.

A portion of the migration pathway characterization was completed in 2010 (E & E 2010b), including surface water and sediment samples in Red Devil Creek, sediment in the Kuskokwim River, and sampling from existing monitoring wells. The benthic macroinvertebrate survey was also completed in 2010. The FSP for 2011 sampling includes additional surface water and sediment sampling in Red Devil Creek, additional sediment sampling in the Kuskokwim River, and additional sampling from new monitoring wells to further characterize the migration pathways (see Appendix A).

Background Characterization. The characterization of background chemical concentrations for soil, sediment, surface water, and groundwater is of high importance for this RI/FS due to the intensively mineralized nature of the site area. The characterization of background soils within the mineralized area is complicated, however, by the extensive mining and mineral exploration activities that have taken place at the site. The characterization also is complicated by historical air emissions from thermal mercury processing activities at the site. E & E developed a screening-level air dispersion model to estimate the likely footprint of mercury emissions from historical ore processing locations (Appendix E). These results were used to guide the selection of appropriate background surface soil sample locations and the background Red Devil Creek sediment samples. See Appendix A, Figures FSP 2-3 and FSP 2-9.

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Figures

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Charts

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A Field Sampling Plan

B Risk Assessment Work Plan

C Quality Assurance Project Plan

D Site-Specific Health and Safety Plan

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E Air Dispersion Model

F

2010 Limited Sampling Event Laboratory and XRF Data

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