

# 2

## Site Characterization

This section contains a summary of key findings from the RI conducted at RDM from 2009–2013. The regional and site setting, nature and extent of contamination, and estimated environmental risks are presented in sufficient detail to support the analysis of early action alternatives presented in Sections 3 through 7. A more detailed discussion of the information summarized here is presented in *Draft Final Remedial Investigation Report, Red Devil Alaska* (BLM 2013).

### 2.1 Site Description

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 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 [NAD] 27).

The RDM site is in a remote location with no road or rail connection to any community. The site can be accessed via an all-terrain vehicle (ATV) track from the village of Red Devil, which includes an airstrip. Direct site access is by boat or barge on the Kuskokwim River.

Areas impacted through the mining operations and waste sources have been identified through previous investigations and/or removal actions. The RDM site includes the following general areas:

- The Main Processing Area.
- Red Devil Creek, extending from a reservoir south of the site to the creek's delta at its confluence with the Kuskokwim River.
- The area west of the Main Processing Area where historical surface exploration and mining occurred, referred to as the Surface Mined Area. The Surface Mined Area is underlain by the area of underground mine workings. The "Dolly Sluice" and "Rice Sluice" and their respective deltas on the banks of the Kuskokwim River are associated with the Surface Mined Area.
- Sediments in the Kuskokwim River.

Figure 2-1 illustrates the site area and major features, which are overlain on an aerial photograph taken in 2010 (AeroMetric, Inc. 2010a and 2010b).

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. The monofills are essentially landfills that contain demolished mine structural debris and other material. 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 building debris and materials from the demolished post-1955 retort structure.

The east side of Red Devil Creek is also the former location of petroleum above-ground storage tanks (ASTs), which were used to store fuel for site operations. Figure 2-2 illustrates the main historical and current features in the Main Processing Area. A detailed history of the site mining operations, ore processing, mining and ore processing waste generation, and petroleum-related waste observed at the RDM site is provided in the draft final RI report (BLM 2013).

### **2.2 Previous Investigations and Removal Actions**

Investigations and cleanup actions have been performed at the site since the 1970s. Removal/cleanup actions involving selective waste removal, building demolition, debris segregation and on-site burial, and contaminated soil stockpiling were conducted between 1998 and 2002. These actions included off-site disposal of hazardous waste and materials and on-site consolidation of mine structural debris. Site investigation was initiated in 1988, and groundwater monitoring was the primary focus of site activity between 2003 and 2009. To date, the mine structures have been demolished and three debris burial areas (monofills) have been constructed. A more complete history of environmental sampling and monitoring at the RDM site is described in the draft final RI report (BLM 2013).

### **2.3 Physical Setting**

The physical setting for the RDM site was characterized and reported as part of the RI (BLM 2013). Key elements of the physical setting are summarized below to provide an understanding of the setting in which the early action will be performed.

### **2.3.1 Geology**

The RDM site is located within the central Kuskokwim region, which contains a 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).

#### **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 to 3 feet thick, range in thickness from 0.5 feet to about 20 feet. The graywacke is a medium- or dark-gray rock that weathers brown and is fine-grained and well-indurated. The larger and more abundant minerals are quartz, muscovite, pyrite, 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 Kuskokwim group sedimentary rocks are tightly folded and intruded by hydrothermally altered dikes composed of quartz basalt. The dikes range from 1 foot to about 14 feet in thickness. The main dike at the RDM site 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. (MacKevett and Berg 1963)

#### **Structure**

The RDM site is located on the southwest limb of the Sleetmute anticline and contains multiple northeastward-trending faults that are 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):

- a. Folding of the sedimentary rocks forming the Sleetmute anticline and the probable concurrent development of steep, northeastward-striking tensional joints.
- b. Intrusion of dikes into a few of these joints.
- c. Development of steep, northwestward-trending faults that offset the dikes right laterally.

- d. Minor strike-slip movement of some of the northwestward-trending faults, caused by gravitational adjustments.

### **Ore and Mineralization**

The RDM site 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 the 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-foot level (MacKevett and Berg 1963).

Some of the RDM site ore is exceptionally high grade and contains as much as 30% mercury, but most of the ore contains between 2% and 5% mercury. Cinnabar, the primary mercury ore mineral, is associated with abundant stibnite; some realgar, orpiment, 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 the RDM site 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).

### **2.3.2 Soils**

Native soils at the RDM site consist of loess, soils derived from the Kuskokwim group bedrock, and alluvial deposits associated with the Kuskokwim River and Red Devil Creek. Non-native materials at the site consist of various types of mining and ore processing wastes and fill. Mining waste at the site comprises waste rock and dozed and sluiced overburden. Ore processing waste primarily consists of tailings (here defined as thermally processed ore, also known as calcites, burnt ore, and retorted ore) and flotation tailings. Tailings and waste rock were deposited at various locations at the site during mining and mineral processing operations and subsequently redistributed for disposal or use as construction fill and road base. Native materials have been removed, disturbed, relocated, and covered and/or mixed with other native soils and/or mine waste and tailings and filled locally across the site. Both native soils and mine waste are

also subject to redistribution by erosion and transport downslope and by alluvial processes in Red Devil Creek and the Kuskokwim River.

Soils derived from the weathering of the Kuskokwim group bedrock contain silt, sand, and gravel derived from the underlying graywacke and argillite bedrock, and are found in both disturbed and undisturbed areas of the site. Loess commonly overlies soil derived from the Kuskokwim group bedrock along most of the site.

The Kuskokwim River alluvial deposits include gravel, sand, and silt that have been deposited on the floodplains 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 deposits are buff colored and friable, range from a few inches to about 30 feet in thickness, and commonly lack bedding. The loess commonly overlies rocky soil derived from weathering of the Kuskokwim group bedrock. Kuskokwim River alluvium was also encountered during site investigations beneath the Red Devil Creek delta and the Dolly and Rice Sluice Deltas.

Red Devil Creek alluvium occurs within the present Red Devil Creek channel, the Red Devil Creek Delta, and floodplain upstream of the Main Processing Area and locally beneath and mixed with other soil types. Sediment in Red Devil Creek within the Main Processing Area consists of Red Devil Creek alluvium locally mixed with mine and ore processing waste materials. Red Devil Creek alluvium is composed of mixtures of silt, sand, and predominantly sub-angular to sub-rounded gravel. Fine materials in the alluvium within the present Red Devil Creek channel contain organic matter and display a medium to dark brown color. 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).

### 2.3.3 Hydrogeology

Based on the groundwater elevations from the existing monitoring wells and the assumption that Red Devil Creek is a gaining stream in the vicinity of the site, it appears that the general direction of groundwater flow 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 the 2008 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 western bank of Red Devil Creek at the base of a bench comprising tailings/waste rock in the Main Processing Area. The underlying bank and stream bed is coated with “yellowboy,” an iron oxide flocculent 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.

#### **2.3.4 Climate**

The RDM site 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 (°F). Annual snowfall averages 56 inches, with a total mean annual precipitation of 18.8 inches.

#### **2.3.5 Surface Water Hydrology and Sediment**

Red Devil Creek is a tributary of the Kuskokwim River and has a basin of about 687 acres (Wilder/HLA 2001). The reach of Red Devil Creek extends from the reservoir dam to the Kuskokwim River, with an approximately linear distance of 2,500 feet, varying with the stage of the Kuskokwim River. Red Devil Creek feeds into the Kuskokwim River less than 1,000 feet from the main portion of the RDM site. A barge landing is present at the Red Devil Creek delta, and it appears that the channel centerline has evidently migrated over time likely due to placement of mine waste materials in the channel bed within the Main Processing Area. The channel has likely also migrated as a result of heavy sediment loading in the downstream portion.

Red Devil Creek has an average gradient of approximately 5% between the reservoir dam and the Kuskokwim River and is generally consistent except in the Main Processing Area, where the gradient of the stream flattens and then abruptly steepens to approximately 10%. During the 1999 investigation, Red Devil Creek was reported to have a flow of 0.5 cubic feet per second (cfs); however, the flow rate varies significantly seasonally (Wilder/HLA 1999). Discharge was also measured along Red Devil Creek during August 2011, May 2012, and September 2012 (to coincide with groundwater baseline monitoring events) at locations where sediment and surface water samples were collected (see Figure 2-3). Seasonal variations were also observed during recent flow monitoring events as shown in Table 2-1.

Discharge conditions in Red Devil Creek were relatively high during the 2011 field investigation due to high precipitation levels prior to and during the collection of discharge data. This may account for the discrepancy in measurements collected in 2011 compared to the historically reported discharge of 0.5 cfs measured in 1999. The May 2012 discharge was measured a short time after the beginning of ice breakup in the hydrologic area and likely is representative of high flow conditions for the creek. Sediment samples were also collected from Red Devil Creek during flow monitoring, and were evaluated for grain size.

Upstream of the Main Processing Area, the stream substrate is composed primarily of natural alluvium; however, the creek substrate was observed to be dominated by the tailings and waste rock for those sample locations downstream of the Main Processing Area to the confluence with the Kuskokwim River. The sediment indicated percent fines (<75 millimeters in size) from 2 to 85%. Results are presented in the draft final RI Report (BLM 2013).

The Kuskokwim River drains an area of approximately 130,000 square kilometers, and flows approximately 1,130 kilometers (700 miles) from interior Alaska to the Bering Sea. At the RDM site, the Kuskokwim River is more channelized than in upriver locations as it bisects the Kuskokwim Mountains. Flow in the river near the RDM site has been reported at 1,102 cubic meters per second (38,916 cfs). Flow was not measured during the RI field investigations; however, the U.S. Geological Survey (USGS) monitoring gage station indicated that the maximum discharge measured during the 2011 season occurred on August 16, 2011, and was recorded at 99,200 cfs. Both shoreline and off-shore sediment samples were collected from the Kuskokwim River near the RDM site. Results are presented in the draft final RI Report (BLM 2013).

### 2.3.6 Sensitive Species and Environments

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 a lack of survey data for a complete evaluation. *Aphragrnus eschscholtzianus* (Aleutian cress), *Thlaspi arcticum* (arctic penny-cress), and *Arnica lessingii* sp. *Norbergii* (Norgerb arnica), all rare or sensitive plant species, are found in the region (Wilder/HLA 1999).

Fish found in the Kuskokwim River in the vicinity of the RDM site include whitefish, grayling, 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 also known to inhabit the area.

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

## **2.4 Nature and Extent of Contamination**

The nature and extent of contamination was defined for the RDM site using field screening data and field observations, and confirmed using analytical data. Analytical results for all media investigated are available in the draft final RI Report (BLM 2013). Analytical summary tables for sediment and surface water results from Red Devil Creek were summarized from the 2013 draft final RI report, and are included in Appendix A.

Only analytical results for surface water and sediment are discussed further as part of the Early Action EE/CA evaluation. The nature and extent of contamination for soil, groundwater, and vegetation are less significant for the early action, and therefore sediment and surface water are summarized below and presented in greater detail in the RI (BLM 2013).

### **2.4.1 Red Devil Creek Surface Water**

Seventeen inorganic elements (including both total and dissolved analysis) and methylmercury were detected at concentrations above background values from samples collected from the surface water of Red Devil Creek. In addition, semi-volatile organic compounds (SVOCs) were detected in several surface water samples but at concentrations below any applicable comparison criteria including those identified in the Risk Assessment. See Appendix A for surface water analytical results.

The highest concentrations of inorganics included antimony, arsenic, and mercury. These contaminants of concern (COCs) were selected based on the Stream-lined Risk Assessment evaluation and a comparison of total concentrations against background values collected at the RDM site. Total and dissolved concentrations of antimony, arsenic, and mercury were observed to be significantly elevated above background in samples collected at several locations extending from just upgradient of the Main Processing Area to the mouth of Red Devil Creek. Methylmercury was detected at all sample locations within Red Devil Creek (including near the reservoir dam) and was observed to be significantly elevated above background within the Main Processing Area, particularly at the seep location; however, methylmercury concentrations were below the comparison criteria. Surface water will not be addressed under this Early Action EE/CA because ambient water flowing in Red Devil Creek does not contain contaminant concentrations above Alaska surface water quality criteria (BLM 2013).

### **2.4.2 Red Devil Creek Sediment**

Seventeen inorganic elements, as well as methylmercury, were detected above background values in the Red Devil Creek sediment samples. SVOCs were detected in several sediment samples but at concentrations below any applicable comparison criteria.

Antimony, arsenic, and mercury compounds were detected at the greatest concentrations above background and are significantly elevated in the creek section



extending from the Main Processing Area to the Red Devil Creek delta. Methylmercury was detected above the background value in all but one of the sediment samples collected from Red Devil Creek, with the highest concentrations detected at the reservoir dam area and at the seep in the Main Processing Area; however, none of the samples contained concentrations above the comparison criteria.

This early action EE/CA will present alternatives to deal with the actively eroding tailings that have been observed in the Main Processing Area in order to mitigate further off-site migration of contamination observed within the Kuskokwim River sediment samples (see section 2.4.3 below). Figure 2-4 shows the sediment sample results that were collected along Red Devil Creek within the Main Processing Area where historically a considerable volume of tailings have deposited within Red Devil Creek due to erosion of the stream banks and adjacent tailings piles, as well as due to the collapse of the old bridge at the RDM site just upstream of the Main Processing Area. This segment of Red Devil Creek was also observed to be actively eroding contaminated material into surface waters during recent field investigations and is anticipated to continue being a primary source of contaminated sediment to the Kuskokwim River.



*Tailings erosion into Red Devil Creek.*

### **2.4.3 Location of Contaminated Material**

At the RDM site, tailings/waste rock, flotation tailings, contaminated soil, and contaminated creek sediment were identified as media of concern. Soils with

total concentrations of antimony, arsenic, and/or mercury (the primary soil COCs at the RDM site) that indicated significant levels of contamination were identified through a comparison with background levels. For the purposes of delineating the extent of contaminated material, a combination of physical characteristics (e.g., soil type, topography, and bathymetry) and COC concentrations was used. As indicated in the RDM draft final RI Report, soil COC concentrations were determined based on laboratory analytical data, if available for a given soil sample, or were estimated based on x-ray fluorescence (XRF) field-screening data collected during the 2010, 2011, and 2012 field activities. Laboratory sample results, field-screening results, and results of soil type identification are presented in the draft final RI Report (BLM 2013).

During the RI, it was observed that the occurrence of contaminants at the RDM site was directly related to the distribution of mine waste materials, consisting primarily of tailings, waste rock, and flotation tailings, and also included disturbed soils and sluiced overburden from the Surface Mined Area. The present distribution of these materials is explained by the historical mining, ore processing, and modification by cleanup activities and natural surface processes. Migration of these materials and contamination associated with tailings and waste materials currently located within the Main Processing Area is ongoing due to erosion and waste transport from runoff, and is the main driver for the development of this interim Early Action EE/CA.

Tailings/waste rock have historically been disposed of or eroded into Red Devil Creek. In addition, natural ore minerals, particularly from the Surface Mined Area, have been eroded and transported into Red Devil Creek. These tailings and natural materials have been deposited with and transported down the channel of Red Devil Creek and into the Kuskokwim River, where they accumulate in a delta. Sluicing of overburden from the Surface Mined Area created the Dolly and Rice Sluice deltas in the Kuskokwim River. These materials have migrated down river to some extent. Tailings and waste rock that enter Red Devil Creek by erosion and mass wasting have been in the past, as well as currently, subject to surface water transport downstream.

In addition to surface water transport of contaminated sediment, groundwater may also provide a contaminant pathway. Migration of contaminants to groundwater occurs via leaching from tailings, waste rock, and, to a lesser extent, flotation tailings and other soils. Contaminants may also enter groundwater as a result of flow through the remaining underground mine workings (adits, shafts, etc.). Leachable tailings and waste rock make up the primary source of contaminants to surface water at the RDM site.

Surface and subsurface soil containing tailings/waste rock and flotation tailings with the Main Processing Area and the Red Devil Creek downstream alluvial area and delta have been identified as contaminated and in need of remediation. Potential removal actions for surface and subsurface soil will be evaluated in the

RDM Feasibility Study. Sediment within Red Devil Creek that contains tailings/waste rock, as well as some native soil beneath tailings/waste rock and surface soil in or adjacent to the Main Processing Area, has been identified as a target for removal action in this early action EE/CA to help mitigate effects of continued off-site contamination until the final site remedy has been implemented. Contaminated sediment has been observed within the channel bed and stream banks of Red Devil Creek originating from the Main Processing Area to the confluence with Kuskokwim River.

### **2.5 Basis for Early Action**

A baseline risk assessment was prepared as part of the RI, which concluded that tailings/waste rock, soil, and Red Devil Creek sediment pose potential risks to human and ecological receptors. The RI documented that tailings/waste rock are being transported through erosion into Red Devil Creek, and ultimately into the Kuskokwim River. Sediments in the Kuskokwim River off shore and downstream of the mouth of Red Devil Creek were documented to contain site-related contaminants at concentrations above background levels. Table 2-2 presents the final contaminants of concern for the RDM Site.

Based on the site conditions summarized above, BLM, in consultation with ADEC and EPA, determined that an early action is warranted to control or eliminate ongoing erosion of tailings/waste rock material into the Kuskokwim River.

**Table 2-1 Red Devil Creek Discharges**

Monitoring Location	Estimated Discharge (cfs)		
	12-Sep-12	26-May-12	18-Aug-11
RD10	4.64	12.18	5.52
RD04	3.45	12.67	5.95
RD12	NA	NA	8.24
RD13	3.79	10.53	NA
RD09	3.40	13.36	5.98
RD06	3.80	14.47	6.81
RD08	3.09	14.20	7.19

Key:

cfs = Cubic feet per second.

**Table 2-2 Final Contaminants of Potential Concern, Red Devil Mine Site**

Analyte	Sediment	Surface Water
Aluminum	X	
Antimony	X	X
Arsenic	X	X
Arsenic (Inorganic)	X	X
Barium	X	
Cadmium	BIO	BIO
Chromium	X	X
Cobalt	X	X
Copper	BIO	BIO
Iron	X	X
Lead	BIO	BIO
Manganese	X	X
Mercury	X	X
Methylmercury	BIO	BIO
Nickel	X	X
Selenium	BIO	BIO
Silver	BIO	BIO
Thallium	X	
Vanadium	X	
Zinc	BIO	BIO
<b>Semivolatile Organic Compounds</b>		
1-Methylnaphthalene		X
Naphthalene		X

Key:

X = Contaminant of Potential Concern (COPC) based on screening.

BIO = COPC based on bioaccumulative properties.