Final
Engineering Evaluation/
Cost Analysis
Red Devil Mine
Alaska

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List of Abbreviations and Acronyms

%	percent
°F	degrees Fahrenheit
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tank
BEI	Philips Burlington Environmental, Inc.
BLM	U.S. Department of Interior Bureau of Land Management
BMPs	best management practices
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
COCs	contaminants of concern
COPCs	contaminants of potential concern
DHSS	Alaska Department of Health and Social Services
E & E	Ecology and Environment, Inc.
EE/CA	Engineering Evaluation/Cost Analysis
EPA	United States Environmental Protection Agency
NAD	North American Datum
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance
PAHs	polycyclic aromatic hydrocarbons

List of Abbreviations and Acronyms (cont.)

RAOs	removal action objectives
RDM	Red Devil Mine
RI	Remedial Investigation
SVOCs	semivolatile organic compounds
SWPPP	stormwater pollution plan
TBC	to-be-considered materials
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
XRF	x-ray fluorescence

Executive Summary

The Red Devil Mine Site (RDM) is abandoned mercury mine and ore processing facility located on public lands managed by the Bureau of Land Management (BLM). Tailings generated by historical mining and ore processing operations dominate the central area of the site and have been identified as the primary source of mercury, arsenic, and antimony being released to the environment (BLM 2013). Sediment sampling results indicate that mine tailings are migrating into the Kuskokwim River via Red Devil Creek. The BLM is planning an action for 2014 that is intended to prevent tailings from continuing to erode into Red Devil Creek and migrate to the Kuskokwim River.

The BLM initiated a Remedial Investigation and Feasibility Study (RI/FS) at Red Devil Mine in 2009 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The project is being performed in coordination with multiple federal and state agencies. The action planned for 2014 (early action) will halt the spread of tailings during the interim period between the RI/FS and the sitewide remedial action. The early action is being performed on a non-time-critical basis, which is consistent with CERCLA guidance, including sections of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) applicable to removal actions (40 Code of Federal Regulations [CFR] Section 300.415). This Engineering Evaluation/Cost Analysis (EE/CA) presents the RI data that demonstrate the need for the early action, the regulatory framework for early action, and four alternatives considered for the project, including a feasibility analysis that yielded a preferred alternative.

Previous Investigations and Removal Actions

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 also by boat or barge on the Kuskokwim River. Because of its remote location, site work has proceeded in phases over the course of a number of years.

The first investigations and cleanup actions at RDM were performed in 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).

Basis for Early Action

This early action EE/CA presents four alternative approaches to preventing active erosion and movement of tailings in the section of Red Devil Creek that runs through the central portion of the mine, called the Main Processing Area. The segment of Red Devil Creek that has been identified for the non-time-critical removal action has been observed to actively erode tailings, and sediment sampling results for the Kuskokwim River indicate that material is being transported to the Kuskokwim River.

A baseline risk assessment that was prepared as part of the RI concluded that tailings/waste rock, soil, and Red Devil Creek sediment pose potential risks to human and ecological receptors. Based on the site conditions, BLM, in consultation with the Alaska Department of Environmental Conservation (ADEC) and U.S. Environmental Protection Agency (EPA), determined that an early action is warranted to control or eliminate ongoing erosion of eroded material into the Kuskokwim River.

Objectives of the Early Action

The primary objective of the early action is to minimize those tailings within Red Devil Creek identified as containing the highest concentrations of antimony, arsenic, and mercury, and to reduce their potential to migrate into the Kuskokwim River. Secondary objectives were also considered when developing the removal alternatives for the site and include the following:

- Provide adequate hydraulic conveyance of Red Devil Creek;
- Provide measures, as needed, to cover exposed waste excavated from Red Devil Creek and stored on site; and
- Provide measures to stabilize slopes of the stream banks of Red Devil Creek to reduce further erosion.

Risk-based cleanup levels (i.e., remedial goals) for the site based on sitewide remedial action objectives (RAOs) were not developed as part of the design criteria for the early action due to the nature of these activities.

Early Action Alternatives

Three different alternative engineering approaches were developed and evaluated in order to identify a preferred method of reducing migration of contaminated sediments into the Kuskokwim River. The following alternatives were evaluated:

1. Alternative 1 – No Action

2. Alternative 2 – Channelization and Line Creek with Solidifying Concrete Cloth
3. Alternative 3 – Line Creek with Culvert
4. Alternative 4 – Excavate Red Devil Creek Sediment

A number of design assumptions must be made to fully develop and evaluate each alternative. The basis of the design assumptions was provided in the engineering analysis presented in the Hydraulic Analysis Report prepared by the U.S. Army Corps of Engineers (see Appendix C).

Alternative 1, the No Action Alternative, was prepared and evaluated to provide a baseline with which other alternatives can be compared. Under this alternative, no action would be taken to reduce contaminant concentrations in affected site media.

Alternative 2 involves the channelization and installation of a concrete cloth liner along the existing stream bed, and Alternative 3 involves installing a culvert liner. Both alternatives would be constructed in the portion of Red Devil Creek that flows through the Main Processing Area.

Alternative 4 involves the excavation of sediment within the portion of Red Devil Creek that extends through the Main Processing Area, which has been identified as actively eroding and containing contaminated sediments. It also involves regrading tailings on the south side of the creek in the Main Process Area to prevent future erosion.

Evaluation Process

Three broad criteria—effectiveness, implementability, and cost—were used to evaluate each alternative against the scope of the early action. The alternatives were initially evaluated individually using the three broad criteria, and then compared against one another. Tables E-1 through E-3 provide a summary of the comparative analysis.

Table E-1 Summary of Alternatives Comparative Analysis for Effectiveness

	Effectiveness			
Ranking*	Overall Protection of Human Health and the Environment	Long-Term Effectiveness	Reduction of Toxicity, Mobility or Volume Through Treatment	Short-Term Effectiveness
1	Alternative 3	Alternative 4	Alternative 4	Alternative 1
2	Alternative 2	Alternative 2	Alternative 2	Alternative 3
3	Alternative 4	Alternative 3	Alternative 3	Alternative 2
4	Alternative 1	Alternative 1	Alternative 1	Alternative 4

*Note: Rankings are from most favorable (1) to least favorable (4).

It should be noted that each of the four alternatives can be implemented such that it will be in compliance with Applicable or Relevant and Appropriate Requirements (ARARs) and will allow for the ARARs to be met in full once a full-scale remedy is selected and implemented. Therefore, compliance with ARARs was not included in the comparative alternatives analysis.

Table E-2 Summary of Alternatives Comparative Analysis for Implementability

Ranking*	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Implementability: Availability of Service and Materials
1	Alternative 4	Alternative 3	Alternative 1
2	Alternative 3	Alternative 2	Alternative 4
3	Alternative 2	Alternative 4	Alternative 3
4	Alternative 1	Alternative 1	Alternative 2

* Note: Rankings are from most favorable (1) to least favorable (4)

Table E-3 Summary of Alternatives Comparative Analysis for Cost

Alternative	Capital	Operations and Maintenance: Yearly	Operations and Maintenance: Present Worth*	Total Present Worth Cost
1	$0	$0	$0	$0
2	$1,900,000	$23,000	$190,000	$2,090,000
3	$1,920,000	$23,000	$190,000	$2,110,000
4	$1,950,000	$23,000	$190,000	$2,140,000

* Present worth costs were calculated using an inflation factor of 3.5%, and 5 years' worth of operations and maintenance.

Recommended Early Action Alternative

Based upon the alternatives evaluations, Alternative 4, Excavation of Actively Eroding Contaminated Sediment, is the recommended early action alternative.

Based on individual and comparative analysis, Alternative 4 is considered the most effective and constructable (implementable) approach. The final configuration of the tailings piles defined for Alternative 4 is also the most consistent with the sitewide remedial action alternatives being developed as part of the Feasibility Study. Although Alternative 4 is not the least expensive to implement, the additional costs would be offset in part by avoiding potential cost increases due to administrative and technical feasibility concerns such as coordination of materials shipments to the site. Additionally, Alternative 4 is likely the most adaptable to evolving site-specific conditions that would emerge during cleanup activities under the future full-scale remedy.

1 Introduction

The Red Devil Mine Site (RDM) is an abandoned mercury mine and ore processing facility located on public lands managed by the U.S. Department of Interior Bureau of Land Management (BLM) (see Figure 1-1). Tailings generated by historical mining and ore processing operations dominate the central area of the site and have been identified as the primary source of mercury, arsenic, and antimony being released to the environment (BLM 2013). In some areas, the tailings also contained fuel released from large storage tanks while the mine was in operation; these tanks were subsequently addressed under a previous removal action. Tailings are migrating into the Kuskokwim River via Red Devil Creek.

The BLM is applying the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process at RDM in coordination with the Alaska Department of Environmental Conservation (ADEC), U.S. Environmental Protection Agency (EPA) Region 10, the Alaska Department of Health and Social Services (DHSS), the Alaska Department of Fish and Game (ADF&G), and the Alaska Department of Natural Resources (ADNR). Recognizing the significance of tailings migrating away from the source area, BLM is planning an early action at RDM to minimize future migration. The early action is being performed on a non-time-critical basis. The early action approach is consistent with CERCLA guidance, including sections of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) applicable to removal actions (40 Code of Federal Regulations [CFR] Section 300.415). Section 300.415(b)(4)(i) of the NCP requires that an Engineering Evaluation/Cost Analysis (EE/CA) be completed for all non-time-critical removal actions. The regulations for the contaminated site cleanup promulgated by the State of Alaska also provided a framework for the EE/CA evaluation process. This EE/CA documents BLM's plans for an early action intended to minimize transport of tailings to the Kuskokwim River.

BLM tasked Ecology and Environment, Inc., (E & E) to prepare this EE/CA for the RDM site in southwest Alaska. E & E has prepared this report on behalf of the BLM under Delivery Order Number L09PD02160 under General Services Administration Contract Number 10F-0161J.

An EE/CA is an analysis of removal action alternatives selected for a site. The EE/CA identifies the objectives of the early removal action and documents analysis of each alternative for effectiveness, implementability, and cost. This EE/CA also summarizes the nature and extent of contamination and potential risks posed by the contaminants to human and ecological receptors. The EPA document, *Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA* (EPA 1993), was used in the preparation of this document.

This EE/CA is organized into the following sections:

- Section 1 - Introduction
- Section 2 - Site Characterization: Summarizes site characterization results from the Remedial Investigation (RI) report, including the site description and background, previous investigation and removal actions at the site, a summary of analytical data for the site, a discussion of the source, nature, and extent of contamination, and details about the streamlined risk evaluation
- Section 3 - Early Action Scope, Goals, and Objectives
- Section 4 - Early Action Alternatives
- Section 5 - Individual Analysis of Individual Early Action Alternatives
- Section 6 - Comparative Analysis of Early Action Alternatives.
- Section 7 - Recommended Early Action Alternative
- Section 8 - References

Ecology & Environment, Inc.
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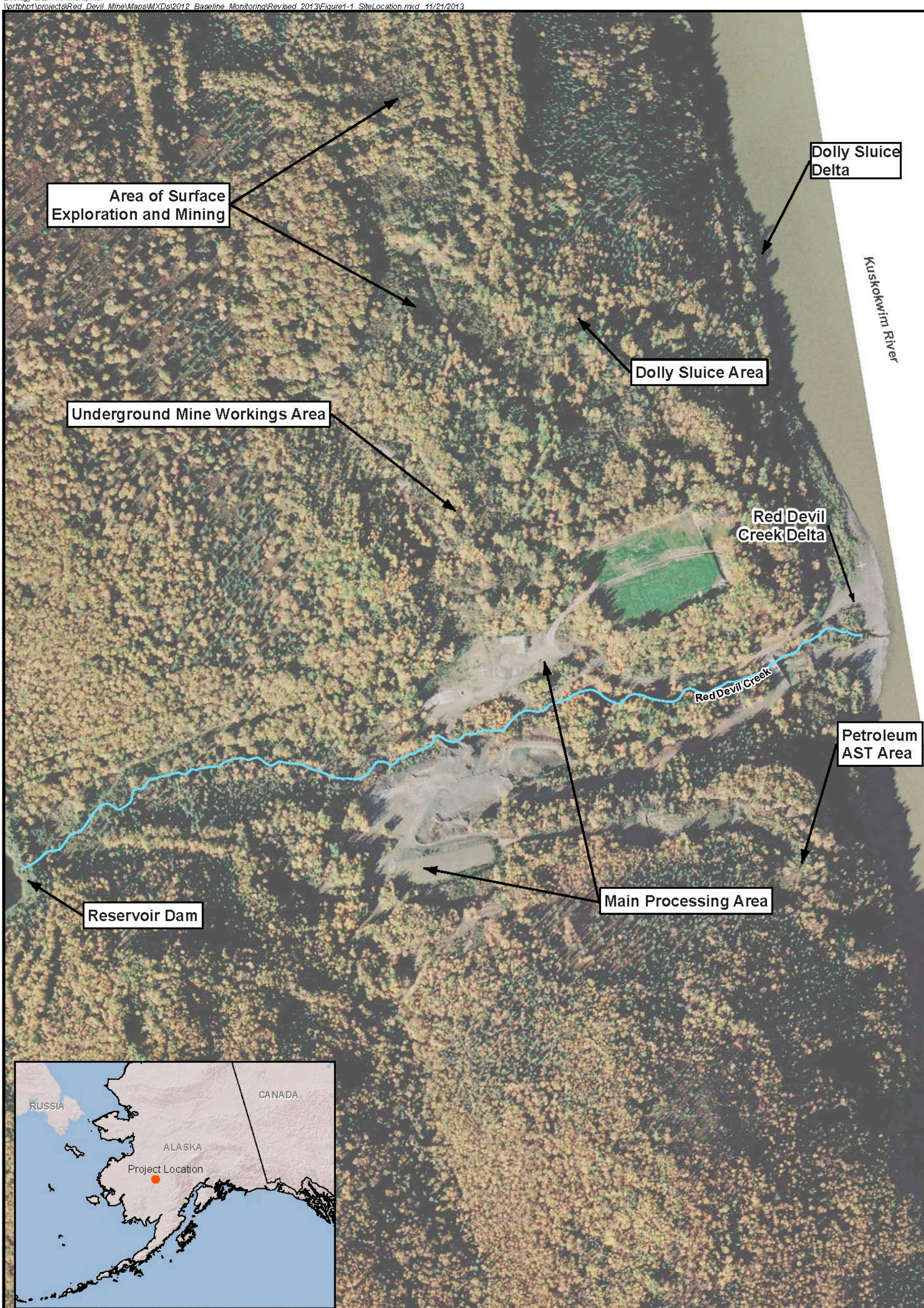


RED DEVIL MINE

Red Devil, Alaska

Figure 1-1
Site Location Map

0 50 100 200 300 400 500
Feet
0 20 40 80 120
Meters
Scale 1:2,800

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 primary 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 pennycress), and *Arnica lessingii* sp. *Norbergi* (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 Streamlined 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
Semivolatile Organic Compounds		
1-Methylnaphthalene		X
Naphthalene		X

Key:
X = Contaminant of Potential Concern (COPC) based on screening.
BIO = COPC based on bioaccumulative properties.

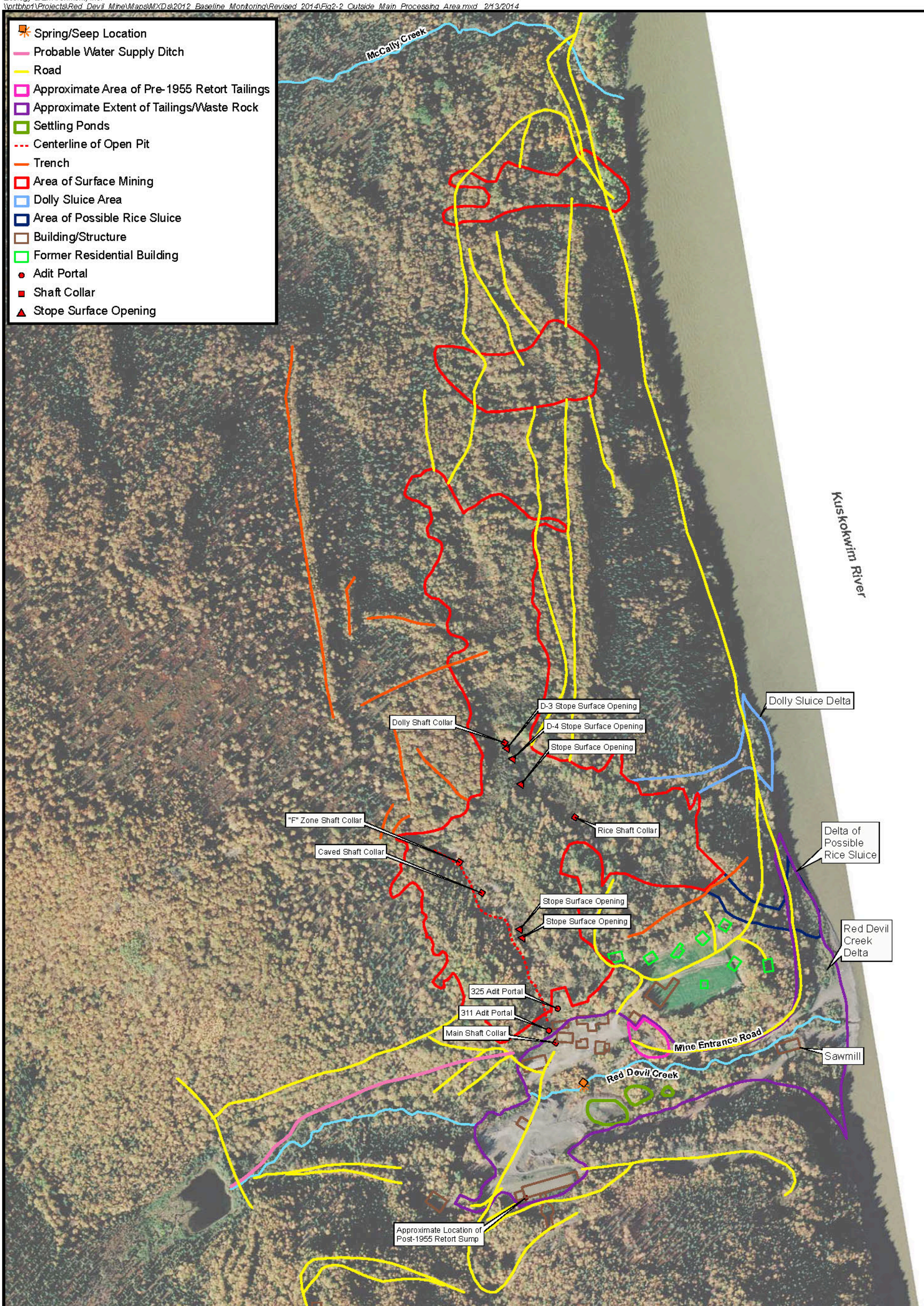
Ecology & Environment, Inc.
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2012_Baseline_Monitoring\Revised_2014\Fig2-1_Main_Processing_Area_Site_Features.mxd 2/13/2014

RED DEVIL MINE

Red Devil, Alaska

Figure 2-1
Main Processing Area
Site Features

Image Source: Aero-Metric, Inc. 2010a



See Figure 2-1 for identification of Main Processing Area buildings/structures.

Aerial Photo Reference:
Aero-Metric, Inc., 2010a.

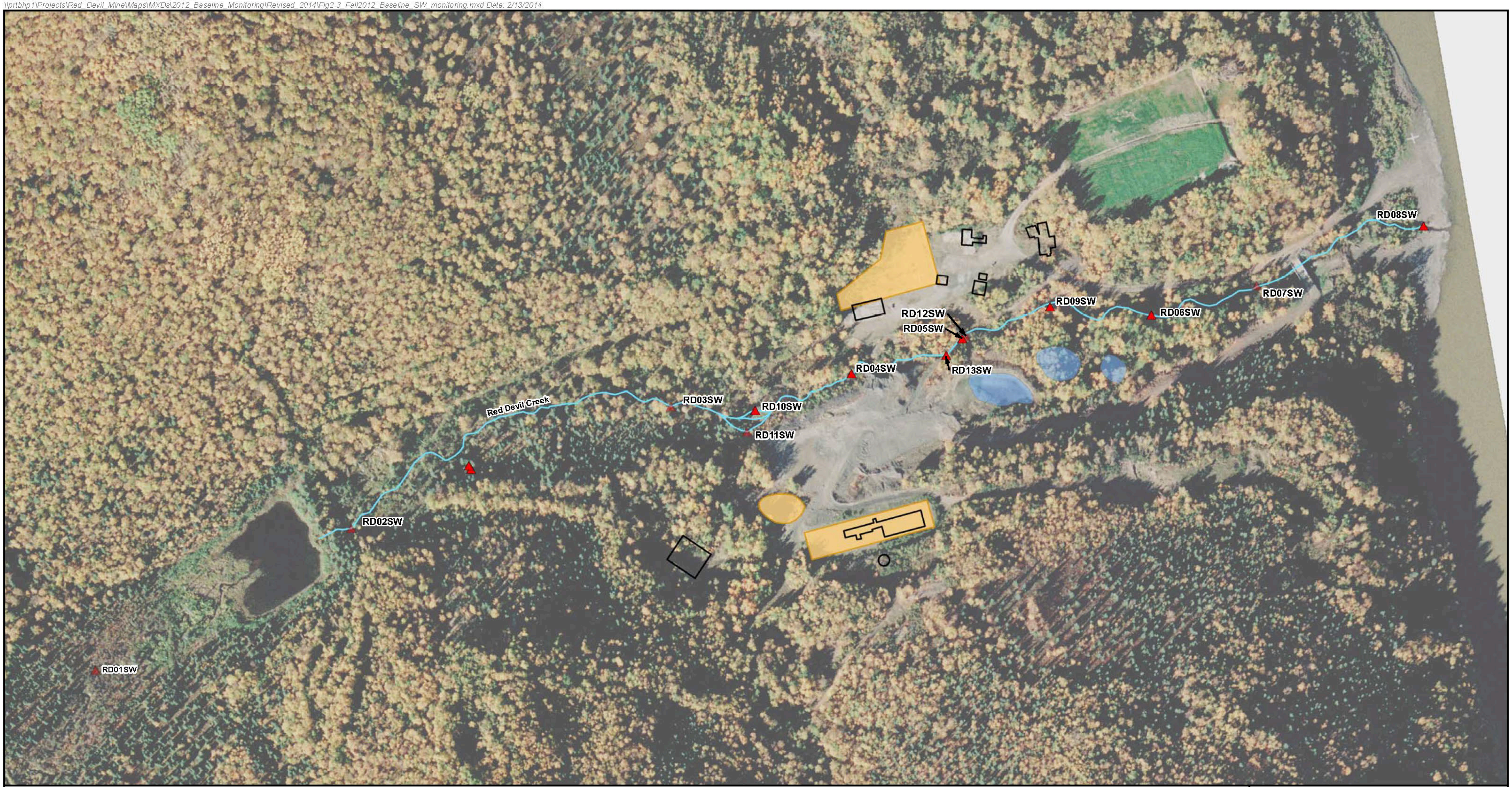
RED DEVIL MINE

Red Devil, Alaska

Figure 2-2
Outside Main Processing Area
Site Features

0 120 240 480 720
Feet
0 20 40 80 120 160 200
Meters
Scale 1:4,000

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2012_Baseline_Monitoring\Revised_2014\Fig2-3_Fall2012_Baseline_SW_monitoring.mxd Date: 2/13/2014



2012 Baseline Surface Water Monitoring Location
RI Surface Water Sample Location, not Sampled in 2012
Settling Pond
Monofill
Historical Structure

RED DEVIL MINE

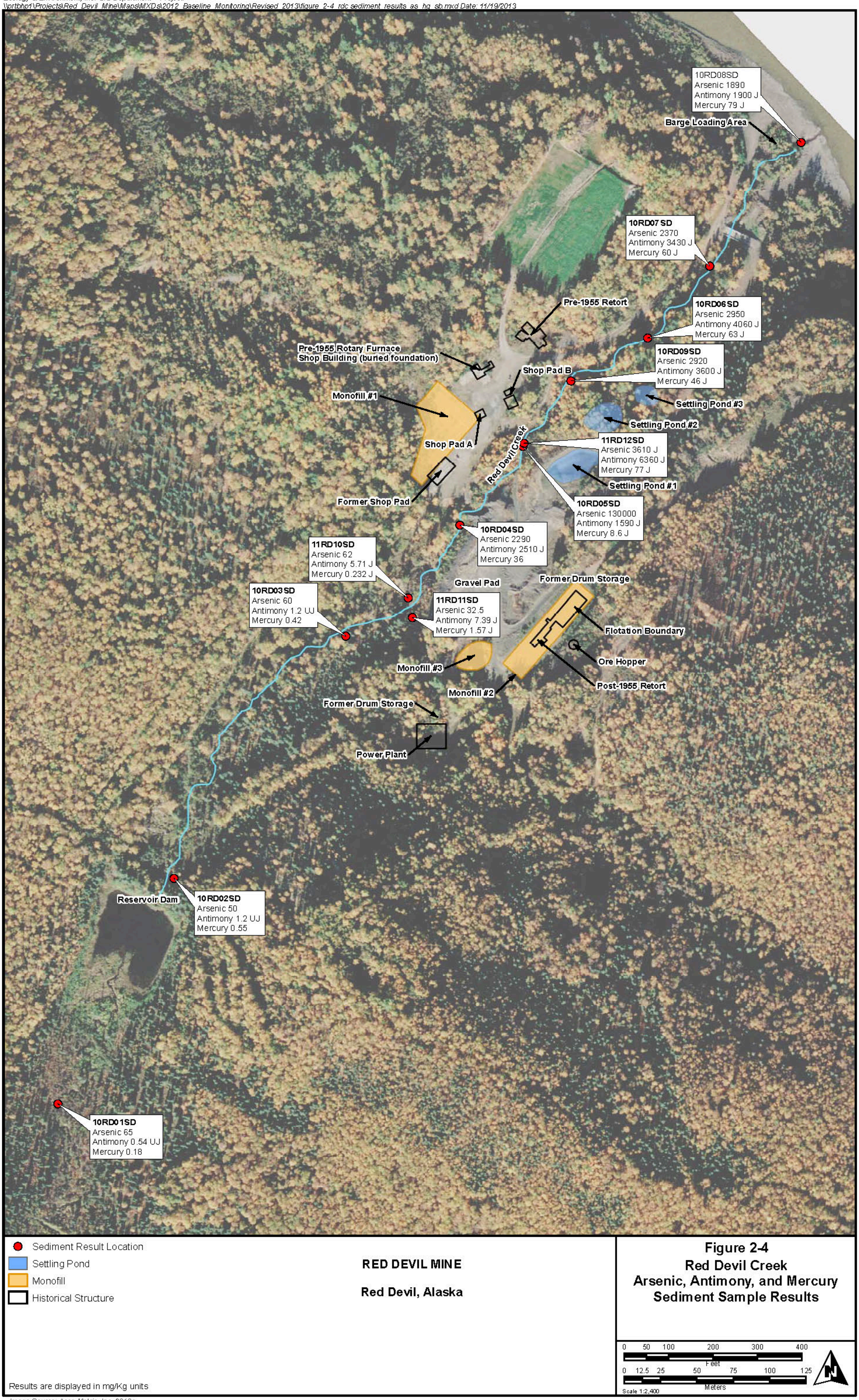
Red Devil, Alaska

Figure 2-3
Baseline SW Monitoring
Spring and Fall 2012

0 25 50 100 150 200 250 300 350
Feet
0 12.5 25 50 75 100
Meters

Image Source: Aero-Metric, Inc. 2010a

Ecology & Environment, Inc. GIS Department Project: \\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2012_Baseline_Monitoring\Revised_2013\figure_2-4_rdc_sediment_results_as_hg_sb.mxd Date: 11/19/2013



RED DEVIL MINE

Red Devil, Alaska

Figure 2-4
Red Devil Creek
Arsenic, Antimony, and Mercury
Sediment Sample Results

Image Source: Aero-Metric, Inc. 2010a

3 Early Action Scope, Goals, and Objectives

This chapter presents the removal action objectives (RAOs), applicable or relevant and appropriate requirements (ARARs), and the identification and screening of removal technologies and specific options to address the contaminated sediment observed along Red Devil Creek. The technologies and options developed in this document represent actions that can be implemented in the interim to address sediment that has been noted to be actively eroding and is anticipated to continue to erode within the Main Processing Area and migrate to the Kuskokwim River.

3.1 Early Action Scope

The early actions presented in this EE/CA are primarily related to mitigating the ongoing transport of contaminants that are sloughing from the banks of Red Devil Creek and then migrating into the Kuskokwim River. Alternatives developed involve removing contamination and mitigating the site conditions that may result in off-site contaminant migration that is anticipated to continue prior to the selected full-scale remediation. The early actions will comply with the ARARs to the extent practicable, as well as limit the number of restrictions for future use of the site.

Currently, contaminated sediment from mine tailings is being transported off site to the Kuskokwim River through surface water. The scope of the potential early action ranges from removal of contaminated sediment and local surface soils for on-site storage until the final remedial action for the RDM site is implemented, to lining the creek to prevent surface water exposure to contaminants. The proposed early actions have been developed to reduce potential impacts to human health and the environment from exposure to contaminated sediment (particularly those receptors identified off site) by preventing the further release of COCs, eliminating exposure pathways, and preventing contaminant migration to the Kuskokwim River. The design of all the early actions proposed under this EE/CA will also provide for unimpeded flow of Red Devil Creek so that no additional exposure pathways are created.

3.2 Objectives of the Early Action

The primary RAO selected for the site is to minimize those tailings within Red Devil Creek identified as containing the highest concentrations of antimony, arsenic, and mercury, and reducing their potential to migrate into the Kuskokwim River. This RAO will aid in mitigating further off-site exposure of humans and ecological receptors to contamination from the site to the extent possible until the full-scale remedial action has been implemented. Secondary RAOs were also considered when developing the removal alternatives for the site and include the following:

- Provide adequate hydraulic conveyance of Red Devil Creek;
- Provide measures, as needed, to cover exposed waste excavated from Red Devil Creek and stored on site; and
- Provide measures to stabilize slopes of the stream banks of Red Devil Creek to reduce further erosion.

Risk-based cleanup levels (i.e., remedial goals) for the site based on RAOs were not developed as part of the design criteria for the early action due to the nature of these activities. The RAOs identified above must be achieved while attaining the ARARs to the extent practicable.

The early action alternatives evaluated in this EE/CA are presented in detail in Sections 4, 5, and 6. Generally, the alternatives fall into two broad categories: (1) diversion of surface water around contaminated media, and (2) removal of contaminated sediment from Red Devil Creek.

3.3 Applicable or Relevant and Appropriate Requirements

In addition to RAOs, potential ARARs have been screened to aid in technology and alternative evaluation. For the early action, on-site actions are intended to comply with the substantive requirements of any identified ARARs, to the extent practicable considering the needs of the situation. On-site actions do not have to comply with the corresponding procedural requirements such as permit applications, reporting, and recordkeeping.

ARARs are divided into the following categories:

- Chemical-specific requirements are health- or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants.
- Action-specific requirements are controls or restrictions on particular types of activities, such as hazardous waste management or wastewater treatment.
- Location-specific requirements are restrictions on activities that are based on the characteristics of a site or its immediate environment.

Additionally, to-be-considered (TBC) materials are advisories, criteria, guidance or policy documents, and proposed standards that are not legally binding, but that may provide useful information or recommended procedures relevant to a removal action.

Because the removal action alternatives are relatively limited in scope and are intended to mitigate ongoing transport of tailings/waste rock material into the Kuskokwim River, chemical-specific ARARs are not an effective criterion for evaluating removal options. Therefore, chemical-specific ARARs are not addressed further in this document. The location- and action-specific ARARs and TBC materials used for the evaluation of alternatives in this EE/CA are summarized in Appendix B.

BLM intends to evaluate chemical-specific ARARs for the final remedy in the project Feasibility Study.

3.4 Early Action Schedule

The BLM intends to construct the early action at RDM in 2014, subject to availability of funding. The construction season in southwest Alaska in general, and at RDM specifically, extends from early June to mid-September. Upon receipt of feedback from the community and local tribes during the public meeting, the BLM will select a contractor to execute the preferred alternative during the 2014 construction season.

4 Early Action Alternatives

Three different alternative engineering approaches were developed and evaluated in order to identify a preferred method of reducing migration of contaminated sediments into the Kuskokwim River. The following alternatives were evaluated:

5. Alternative 1 – No Action
6. Alternative 2 – Channelization and Line Creek with Solidifying Concrete Cloth
7. Alternative 3 – Line Creek with Culvert
8. Alternative 4 – Excavate Red Devil Creek Sediment

A number of design assumptions must be made to develop and evaluate each alternative. The basis of the design assumptions was provided in the engineering analysis presented in the Hydraulic Analysis Report prepared by the U.S. Army Corps of Engineers, which is provided in Appendix C. These design assumptions are applicable to the technologies proposed in the individual alternatives. Additionally, based on the level of effort associated with implementing each of the action alternatives, it was assumed that each could be implemented in a single construction season.

4.1 Early Action Alternatives

4.1.1 Alternative 1: No Action

Under this alternative, no action would be taken to remove, treat, or contain sediment migration in Red Devil Creek. Site conditions that promote tailings migration in Red Devil Creek would not be expected to change, and the ongoing loading in the Kuskokwim River would continue unabated.

4.1.2 Alternative 2: Channelization and Line Creek with Solidifying Concrete Cloth

In this alternative, approximately 250 linear feet of the creek in the area of the tailings pile would be channelized and lined with concrete cloth. The extent of the creek modifications would run from the upstream end of the Main Processing Area to an existing bridge that connects the north and south banks of Red Devil Creek. This alternative would break the contact between the surface water of Red Devil Creek and the contaminated sediment that has been identified along the channel bed and banks. By reducing contact between the flowing water and the contaminants, there will be a reduction in the fluidization of contaminants, as well as a reduction in dissolved-phase contaminant migration. It should be noted that surface water may still be in contact with contaminated tailings located along the adjacent stream banks during channel overflow that results from large storm and/or snowmelt events until full-scale remediation is implemented.

Concrete cloth is a flexible, cement-infused fabric that hardens when hydrated. It forms a thin, durable, water- and fire-proof concrete layer which takes the shape of the surface to which it is applied. The benefit of this material, particularly for the RDM site, is that it does not require a concrete mix plant or mixing equipment, nor does it require heavy equipment for installation.

Clearing and grubbing of vegetation along the creek banks will be required prior to installation. Large boulders or rocks will need to be removed, hauled, and stockpiled to be addressed under the final remedial action. Additionally, the segment of Red Devil Creek that runs through the Main Processing Area will need to be slightly realigned, and the channel bed and banks excavated and prepared as described below in order to increase the capacity of the creek and mitigate flooding of the tailings pile and waste rock areas that have been the source of surface water contamination through erosion. It is assumed that during earthwork and channelization, approximately 1,050 cubic yards of material will removed from Red Devil Creek to be hauled and stored in the tailings stockpile to be included as part of the full-scale remedial action. It is assumed that erosion and sediment control measures (i.e., silt fences) will be installed around the perimeter of the stockpile to prevent erosion of the excavated sediment. Additionally, stockpiled materials will be covered with a 12-mil, UV-resistant, reinforced polyethylene geomembrane liner with tear-resistant polyester scrim. This cover will reduce the potential for the stockpiled material to leach contaminants into stormwater.

Preliminary hydraulic analysis indicates that channelization of Red Devil Creek will require a minimum channel bed width of 4 feet and channel bank slopes of 3:1 (horizontal to vertical) in order to contain the 100-year flood (approximately 117 cfs). The modified channel will have an approximate maximum water depth of 1 foot during the 100-year storm event, which is similar to what has been observed historically at the site. The channelized segment of Red Devil Creek will retain is natural grade (approximately 4.8%) to provide a relatively smooth transition to the natural stream.

Excavation and grading of the creek banks and channel bed will allow for a consistent base on which the concrete cloth can be applied. It is assumed that excavated material can be used as fill along Red Devil Creek where needed and excess excavated material can be stored temporarily in the stockpiles to be incorporated into the full-scale remedial action. The extent of the proposed lined channel is shown on Figure 4-1, and Figure 4-4 provides the cross sectional details of the concrete cloth installation methods. Installation can be achieved using conventional construction methods and equipment. The cloth will be unrolled in horizontal strips across the width of the channelized creek bed, keyed into the stream bank, and secured with stakes at 2- to 3-foot intervals as shown on Figure 4-4. At the overlap of the strips, a layer of bonding sealant will be installed, and the concrete cloth layers will be screwed together prior to setting the material.

Standard construction equipment will be used to perform the earthwork and to remove excess sediment and load the material directly onto dump trucks for transport to the temporary stockpile locations identified on Figure 4-1. Side slopes of the temporary stockpile would have a maximum slope of 2:1 (horizontal to vertical). To minimize stormwater infiltration into the sediment stockpile, it will be covered with a 12-mil, UV-resistant, reinforced polyethylene geomembrane liner with tear-resistant polyester scrim. This cover will reduce the potential for the stockpiled material to leach contaminants into stormwater. A soil or vegetation cover will not be required as the stockpile is anticipated to be temporary. It is assumed that erosion and sediment control measures will be installed in the vicinity of the stockpiles to reduce erosion of the excavated sediment.

A dissipation pool is also proposed under Alternative 2 to help diffuse the increased energy and velocities of the stream flow that may result from modifying the channel bed material. Additionally, the dissipation pool will act as a settlement pond for suspended sediment. The dissipation pool will be sited immediately upstream of an existing bridge that is located downstream of the Main Processing Area. Preliminary design calculations show that the pool will require a minimum depth of 3 feet to contain the 100-year storm event. The basin will consist of a pool followed by a scour apron lined with riprap to help transition Red Devil Creek back to natural hydraulic conditions. Riprap fill required for the dissipation pool will be obtained from a local borrow source that will be identified prior to initiating construction. The conceptual dimensions and details of the cross section of the proposed dissipation pool are shown on Figure 4-6. Material excavated from the dissipation pool will be temporarily stored in a stockpile and will be incorporated into the final full-scale remedial design. It is estimated that approximately 161 cubic yards of contaminated sediment will need to be excavated in order to construct the dissipation pool.

Diversion of surface flow within Red Devil Creek will be required during channelization and installation of the concrete liner to prevent premature hardening of the concrete cloth. Dewatering of the construction areas will ultimately be determined by the contractor during implementation of the early action; however, for cost estimating purposes, it was assumed that construction would occur during low-flow conditions for Red Devil Creek with maximum anticipated stream flow rates of approximately 5 cfs (the estimated 2-year flood) based on stream measurements collected by E & E during the summer 2011 and fall 2012 (USACE 2013). Construction will be staged from the most upstream portion of the Mine Tailings Area and will progress downstream in 50-foot segments so that Red Devil Creek can be diverted during installation of the concrete cloth. An inflatable dam will be installed along the width of Red Devil Creek immediately upstream of the proposed work area, and stream flow will be pumped around the proposed construction zones and back into the creek or directly to the Kuskokwim River while earthwork is being performed and the concrete cloth is placed. It is anticipated that the concrete cloth installation can be completed within one construction season and will require 3 months from the time of mobilization to the time of demobilization.

Erosion and sediment controls will also be implemented along the stream banks and will be installed above the concrete cloth to stabilize soil, minimize erosion, and reduce the conveyance of sediment to surface water once the liner has been put into place. Best management practices (BMPs) considered under this alternative include silt fences, bank regrading, and vegetation. These controls would be temporary and could easily be removed or replaced during the installation of the full-scale remedial activities.

An annual visual inspection would be required for this alternative to record the concrete's integrity, which could be adversely impacted from damage associated with abrasion from ice and/or sediment, as well as to check for beaver dams that could restrict flow of Red Devil Creek. Therefore, there may be minor maintenance and debris removal required.

4.1.3 Alternative 3: Line Creek with Culvert

For Alternative 3, approximately 250 feet of Red Devil Creek within the area of the tailing piles would be lined with a 6-foot-diameter, bolted-together galvanized corrugated metal culvert. The culvert would be delivered in pieces and would be assembled on site. A hydraulic analysis was performed by the U.S. Army Corps of Engineers (USACE; see Appendix C), which indicates that the estimated 100-year flow (approximately 117 cfs), in its entirety, would be contained by the culvert; the water depth within the culvert was calculated to be approximately 3.0 feet during the large flood events. The culvert would extend from the most upstream portion of the Main Processing Area and discharge immediately upstream of the existing bridge into a constructed dissipation pool, as shown on Figure 4-2. Approximately 550 cubic yards of material will be excavated. Further discussion associated with the disposition of material is provided below.

This alternative would temporarily break the contact between the surface water of the creek and the contaminated sediment with the highest concentrations of metals that has been observed along the channel bed and banks of Red Devil Creek. Therefore, there will be a reduction in both solid and dissolved-phase contaminant transport. Since this is an interim action, the culvert will not be buried so that it can be removed during the implementation of the full-scale remedial action selected for the RDM site. The culvert will be secured using a series of straps anchored into the soil or bedrock. Based on the analysis performed and reported in the USACE Hydraulic Memo, the spacing of the straps was assumed at 25-foot intervals; however, confirmation of the final strap spacing will need to be conducted during the design phase to ensure stability during flood events to prevent the piping network from being shifted or transported due to soil failure.

Limited excavation of the creek bed will be required under this alternative in order to provide a uniform grade for the placement of the culvert in the creek bed. The excavated material will be used where fill is required, and excess will be stockpiled on the tailings pile, which will be included as part of the full-scale remedial activities. Standard construction equipment will be used to perform the earthwork, remove excess sediment, and load the material directly onto dump trucks for transport to the temporary stockpile locations shown on Figure 4-2. Side slopes of the temporary stockpile would have a maximum slope of 2:1 (horizontal to vertical). To minimize stormwater infiltration into the sediment stockpile, it will be covered with a 12-mil, UV-resistant, reinforced, polyethylene geomembrane liner with tear-resistant polyester scrim. This cover will reduce the potential for the stockpiled material to leach contaminants into stormwater. A soil or vegetation cover will not be required as the stockpile is anticipated to be temporary. It is assumed that erosion and sediment control measures will be installed in the vicinity of the stockpiles to reduce erosion of the excavated sediment.

A headwall will be installed at the upstream end of the culvert to direct the stream flow into the piping network. It is assumed that the headwall will be constructed of gabions as shown on details provided on Figure 4-5. The culvert and gabion baskets will be barged into the RDM site; however, it is anticipated that the fill rock required for the gabion headwall will be obtained from a local borrow source that will be identified prior to commencement of construction. Figure 4-5 shows the proposed location of the culvert as well as a cross section representation of the proposed gabion headwall inlet. In the future, the gabion headwall could also be utilized during the full-scale remedial action to assist in dewatering and stream flow diversion prior to dismantling the culvert during the full remediation.

The piping network may cause increases in the stream velocity when compared to natural conditions. Therefore, Alterative 3 will also require a dissipation pool to help diffuse the energy of the stream flow during large storm events and mitigate potential scour of the natural creek bed downstream of the modified segment of Red Devil Creek. The dissipation pool will be located immediately downstream of the culvert discharge point and immediately upstream of the existing bridge. Preliminary designs show that the pool will require a minimum depth of 3 feet to contain the 100-year storm event, and the basin will consist of a pool and scour apron to help transition Red Devil Creek back to natural hydraulic conditions. The conceptual dimensions and details of the cross section of the proposed dissipation pool are shown on Figure 4-6.

Dewatering of the construction areas will ultimately be determined by the contractor during implementation of the removal action; however, for cost estimating purposes, it was assumed that the culvert installation will be conducted during the low-flow season to the extent practical. For the purposes of this EE/CA, it is assumed that the low-flow conditions for Red Devil Creek would result in maximum flow rates of approximately 5 cfs during the proposed construction months (estimated 2-year flood) based on stream measurements collected by E & E during the summer 2011 and fall 2012 (USACE 2013). Work will be conducted so that installation of the culvert will start at the most upstream portion of the Mine Tailings Area and progress downstream in 50-foot segments. An inflatable dam will be installed along the width of Red Devil Creek immediately upstream of the proposed work area, and stream flow will be pumped around the proposed construction zones (approximately 50-foot segments) while earthwork is being performed and the culvert is installed. It is anticipated that the culvert installation will require 3 months from the time of mobilization to the time of demobilization.

Annual inspections will be required for this alternative to visually inspect the culvert for beaver dams, damage from ice, abrasion from sediment, and performance of the anchor straps. Minor maintenance and debris removal may be required.

4.1.4 Alternative 4: Excavate Red Devil Creek Sediment

Under Alternative 4, approximately 5,000 cubic yards of contaminated sediment along the tailings pile not meeting cleanup criteria would be excavated, loaded into haul trucks, and transported to a designated temporary storage area on site. A partial excavation of the tailings pile to 6 to 7 feet (or until bedrock is encountered) would remove the sediment that is available for transport within the Main Processing Area. Depths and distances for excavation are based on longitudinal limits and hydraulic limits associated with maintaining a flow consistent with the existing conditions.

The excavation is proposed to extend along Red Devil Creek for approximately 200 feet within the Main Processing Area. The excavation will be limited to the south side of the stream within the area of concern (see Figures 4-3 and 4-7). Excavation will begin at the existing centerline of Red Devil Creek below the processing area and proceed in a straight upstream direction, realigning the creek and maintaining its natural slope. The excavation will then terminate upstream of the processing area and rejoin the existing creek. The excavation will be 12 feet wide at the bottom and extend up at a 3:1 slope (horizontal to vertical) on the south side. The slope on the north side of the creek will vary between a 4:1 (horizontal to vertical) to a 6:1 slope (horizontal to vertical) on the north side. Excavation on the north side will terminate when the slope reaches the existing creek's north edge. The realigned channel sidewalls will be lined on each side with 3-foot gabion baskets to maintain the constructed alignment. The fill rock required for gabion protection is assumed to be obtained from a local borrow source that will be identified prior to commencement of construction.

No excavation is proposed to occur along the north bank of Red Devil Creek as part of the early action because the existing northern bank is well armored and does not contribute tailings to Red Devil Creek.

A vertical gabion drop structure is proposed to be installed just upstream of the excavated area to act as a transition between the gradient of the excavated channel and the longitudinal gradient in the upstream section of Red Devil Creek. The drop structure will also slow water velocities during larger storm events, and mitigate potential channel erosion. The drop structure will consist of side wall gabions and four gabion steps on the channel bottom, each of which will provide a 2-foot drop over a total stream length of approximately 28 feet (for total vertical drop of approximately 8 feet). The proposed realigned profile showing the drop structure, as well as cross section details of the drop structure, is provided on Figure 4-7.

A sediment trap will be installed downstream of the realigned channel, immediately upstream of an existing bridge near the mouth of Red Devil Creek as shown on Figure 4-3. This sediment trap will be sized to allow settling of medium-sized sand (0.50 millimeters) and greater, but not allow re-suspension of material. However, there is still the potential for some fine-grained sand to pass through the trap. Cross section details of the sediment trap are provided on Figure 4-7. Material excavated from the sediment trap will be hauled to the on-site stockpile and incorporated into the mine tailings and contaminated sediment excavated from the Main Processing Area.

Dry dredging methods are proposed for sediment excavation along Red Devil Creek. This will require isolating the sediment from the creek through dewatering, or diverting Red Devil Creek around the excavation area. Dry dredging will reduce the potential for re-suspension and releases of contaminants into the surface water. Dewatering of the construction areas will ultimately be determined by the contractor during implementation of the removal action; however, for cost estimating purposes, it was assumed that the work will be completed in 50-foot segments. It is anticipated that a dam and diversion system will be feasible to redirect stream flow around the disturbed area. An inflatable dam would be temporarily installed immediately upstream of the work area, and stream flow from Red Devil Creek will be pumped and discharged downstream of the disturbed areas or directly to the Kuskokwim River. BMPs will be implemented to ensure that the discharge does not cause re-suspension of sediment downstream of the Main Processing Area.

Standard construction equipment will be used to remove sediment and load the material for transport to the temporary stockpile locations identified on Figure 4-3. Side slopes of the temporary stockpile would have a maximum slope of 2:1 (horizontal to vertical). To minimize stormwater infiltration into the sediment stockpile, it will be covered with a 12-mil, UV-resistant, reinforced polyethylene geomembrane liner with tear-resistant polyester scrim. This cover will reduce the potential for the stockpiled material to leach contaminants into stormwater. A soil or vegetation cover will not be required as the stockpile is anticipated to be temporary. Erosion and sediment control measures will be installed in the vicinity of the stockpiles as needed to prevent erosion of the excavated sediment.

Restoration of the stream in the area of excavation is not part of the proposed action for interim sediment excavation activities. Once the excavation is complete, the stream will be directed into the realigned channel in the vicinity of the tailings pile, then allowed to flow through the current channel between downstream of the Main Process Area before entering the sediment trap.

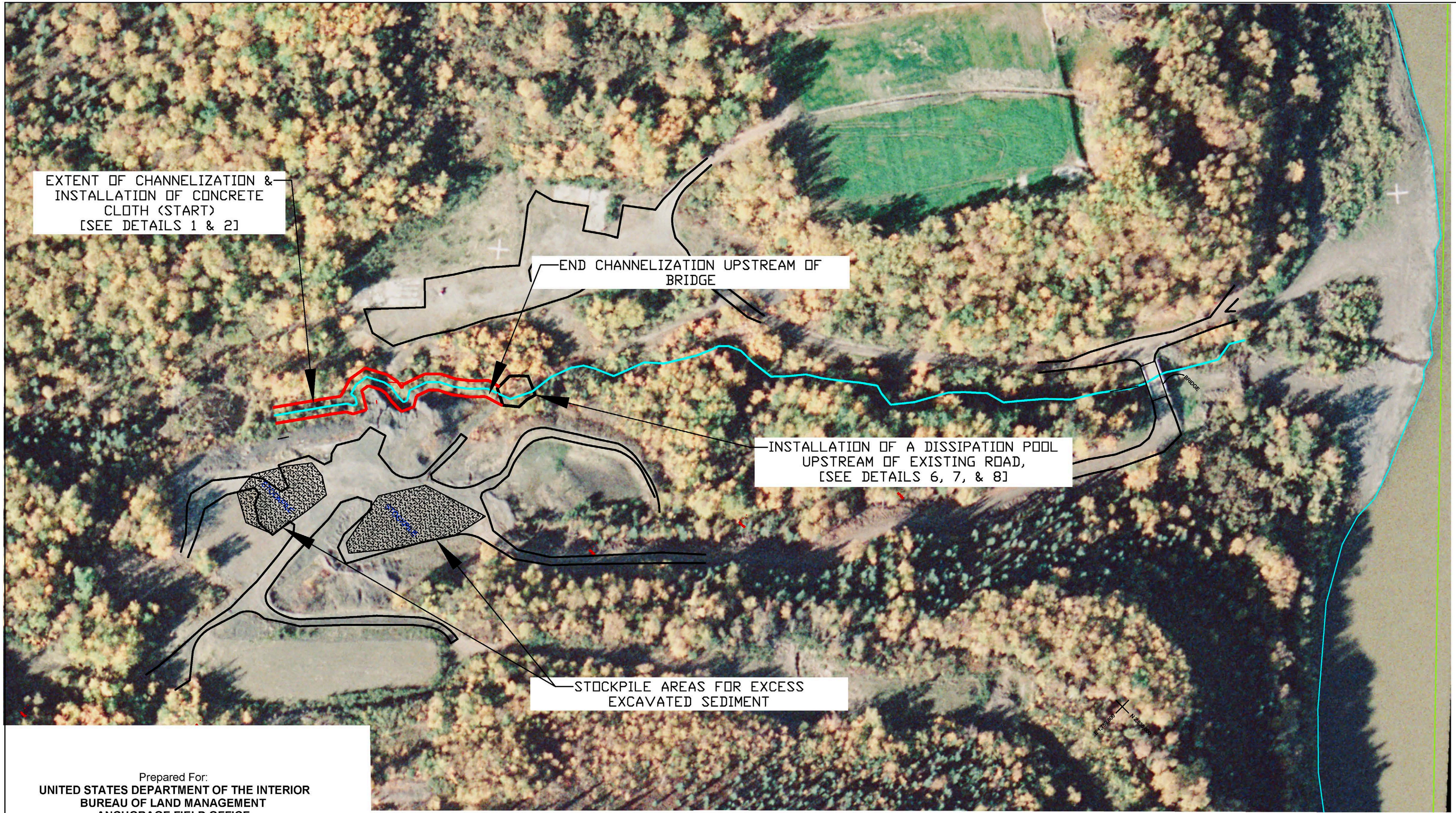
Based on the estimated volume of soil that exceeds cleanup criteria, it is estimated that this alternative would require approximately 3 months from the time of mobilization to the time of demobilization.

4.2 Common Components and Assumptions

All equipment and materials required to complete each of the alternatives described above will need to be transported to the site by barge. Navigation season for the Kuskokwim River is limited to the months of late May through early September; logistical constraints are key in meeting the construction schedules estimated in this EE/CA. No contaminated material will be removed from the site.

Alternatives 2, 3, and 4 assume that existing access roads will be used to haul equipment and material within the RDM site during the early action. Minor improvements may be required to the existing access roads, in which case any materials needed to stabilize or improve the road (i.e., sand, gravel) will be obtained from a nearby borrow source.

Alternatives 2 through 4 will require some earthwork or excavation of sediment within Red Devil Creek. Excess excavated material will be stored on site in a stockpile that will be covered with a 12-mil, reinforced polyethylene geomembrane liner. BMPs (such as silt fences and hay bales) will be installed around the perimeter of the toe of the stockpile to ensure that the excavated material will not erode and run off into Red Devil Creek.



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SCALE IN FEET: 1"= 100'
0 100 200 300

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RED DEVIL MINE EECA RED DEVIL, ALASKA

FIGURE 4-1 PLAN VIEW

ALTERNATIVE 2 - CONCRETE CLOTH LINER

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FIGURE 4-2 PLAN VIEW

ALTERNATIVE 3 - CULVERT LINER

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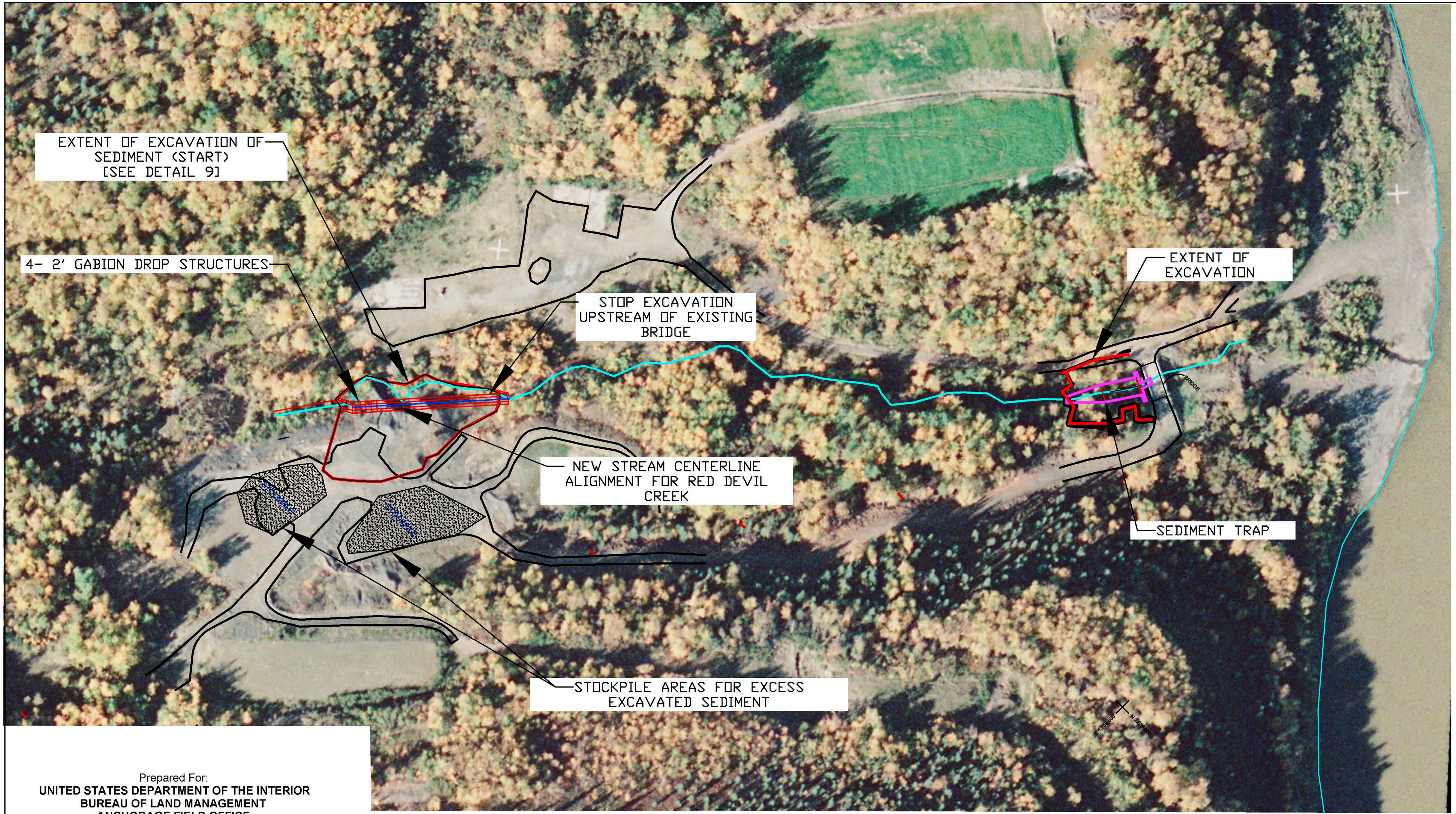

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FIGURE 4-3 PLAN VIEW

ALTERNATIVE 4 - EXCAVATION OF CONTAMINATED SEDIMENT NEAR TAILING PILE

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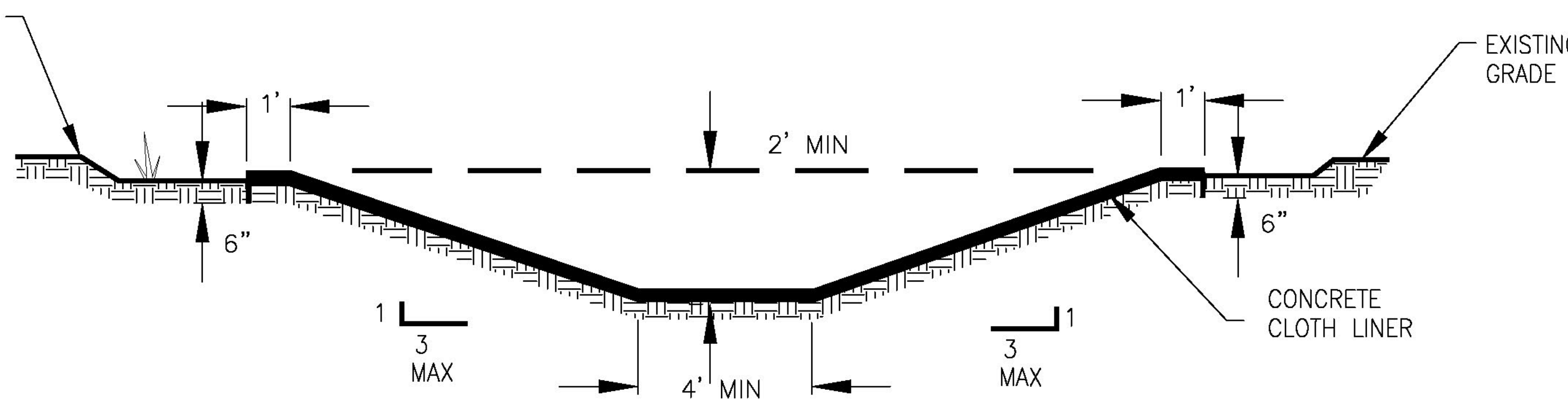
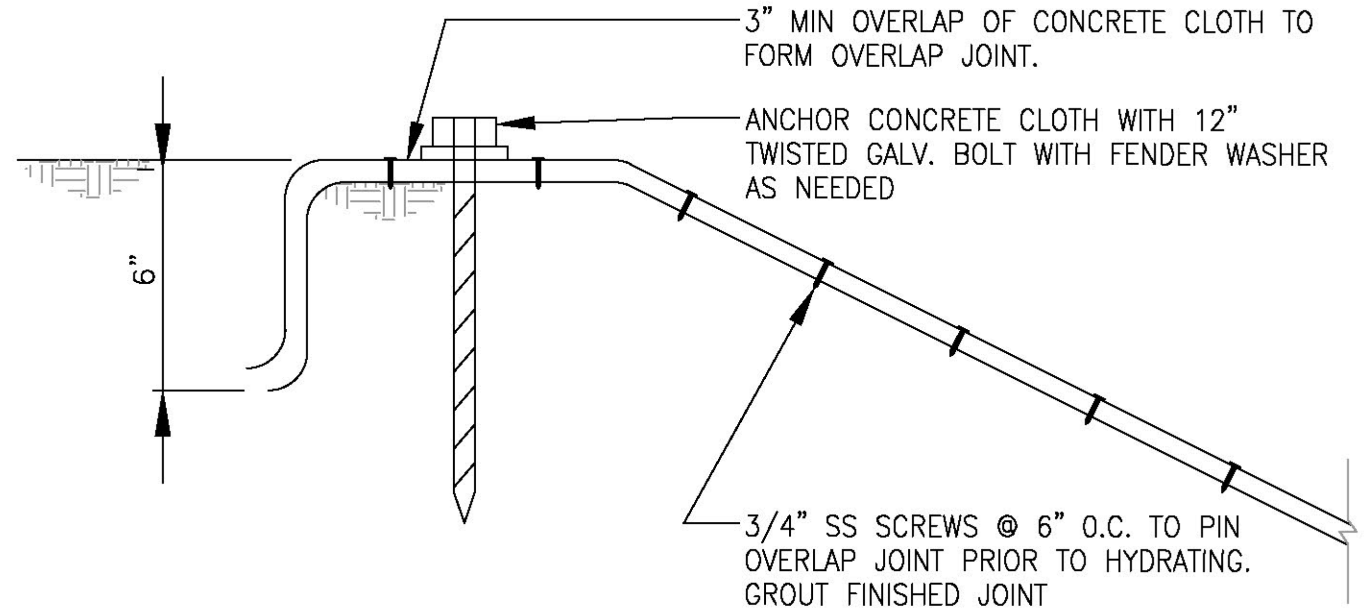


DETAIL 1/X
IDEALIZED CROSS SECTION WITH CHANNELIZATION & CONCRETE CLOTH LINER (TYP)
NTS



DETAIL 2/X
CONCRETE CLOTH ANCHOR AND OVERLAP JOINT DETAIL
NTS

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FIGURE 4 - 4: DETAILS 1 & 2
ALTERNATIVE 2 - CONCRETE CLOTH LINER

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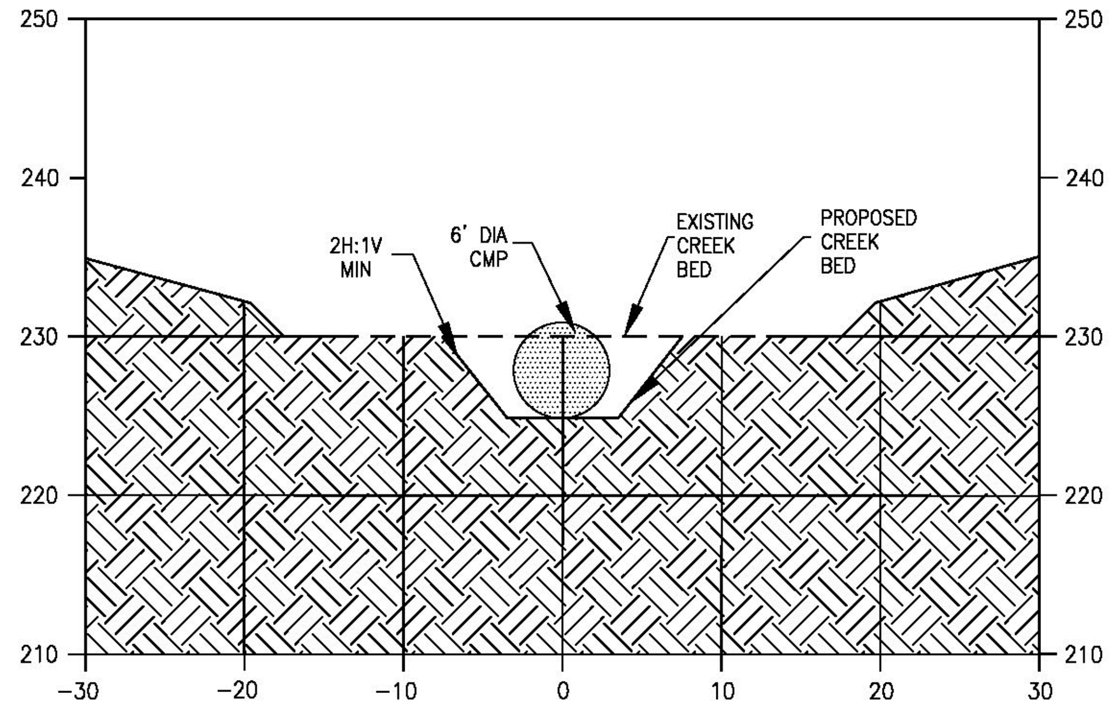
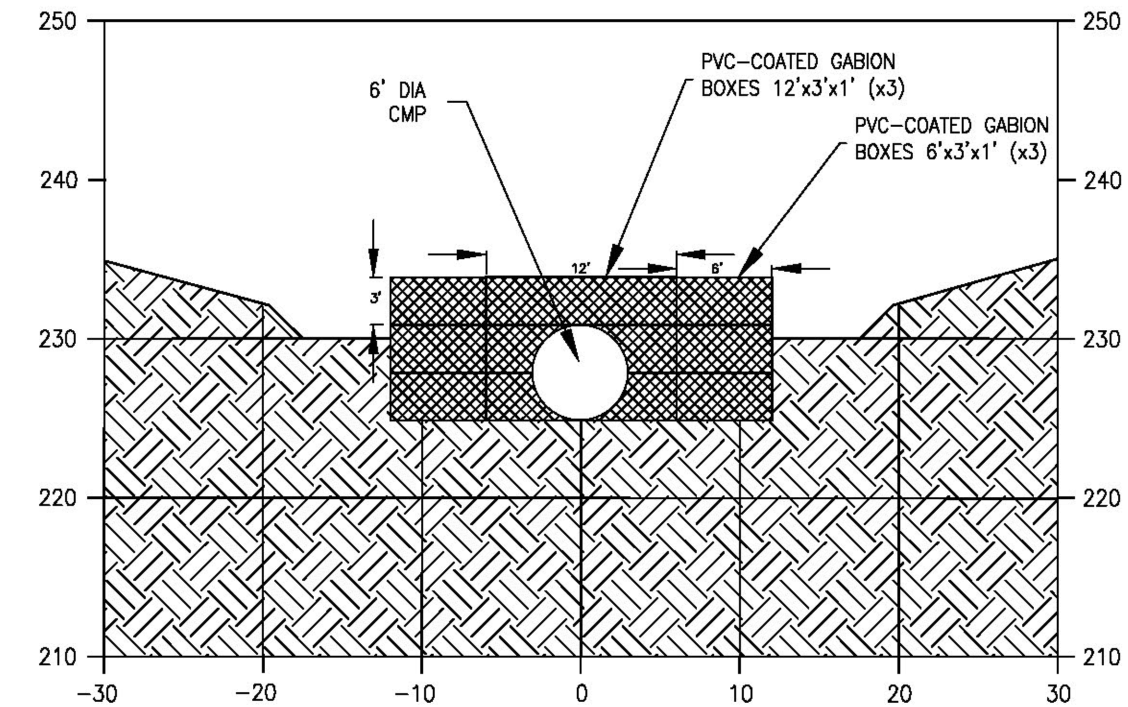


DETAIL

TYPICAL IDEALIZED CULVERT CROSS SECTION (TYP) 3/X

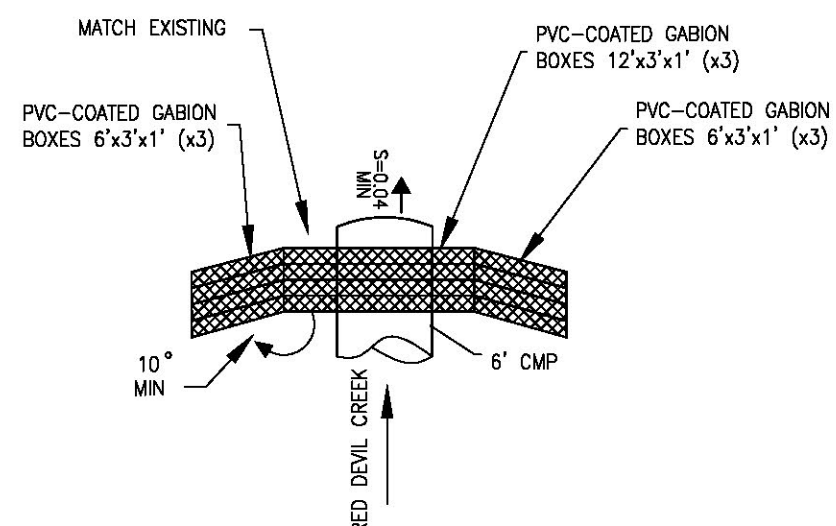
NTS



DETAIL

IDEALIZED HEADWALL & CULVERT CROSS SECTION 4/X

NTS



DETAIL

PLAN VIEW OF HEADWALL & CULVERT INLET 5/X

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FIGURE 4 - 5: DETAIL 3,4 & 5

ALTERNATIVE 3 - CULVERT LINER & HEADWALL

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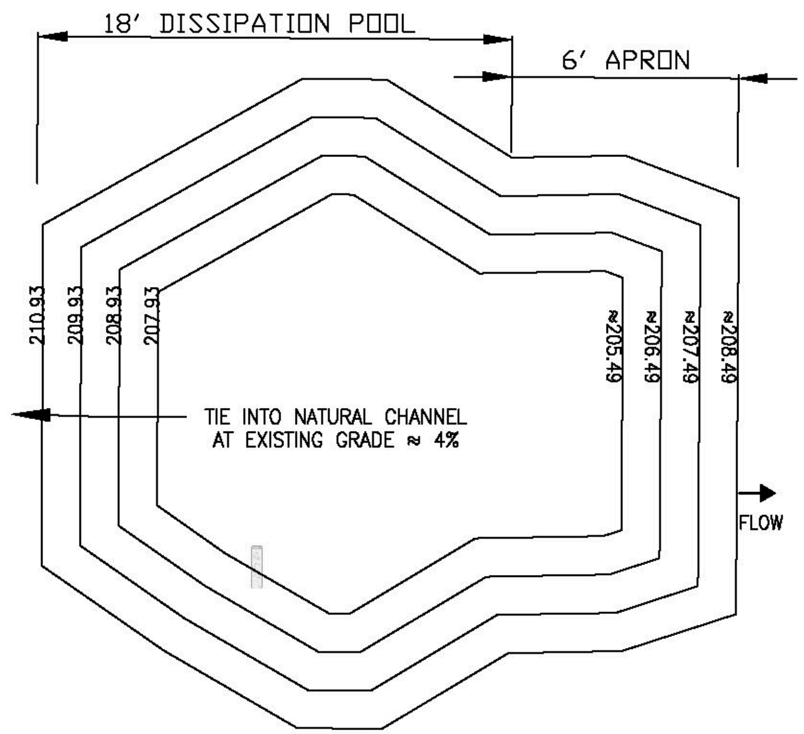
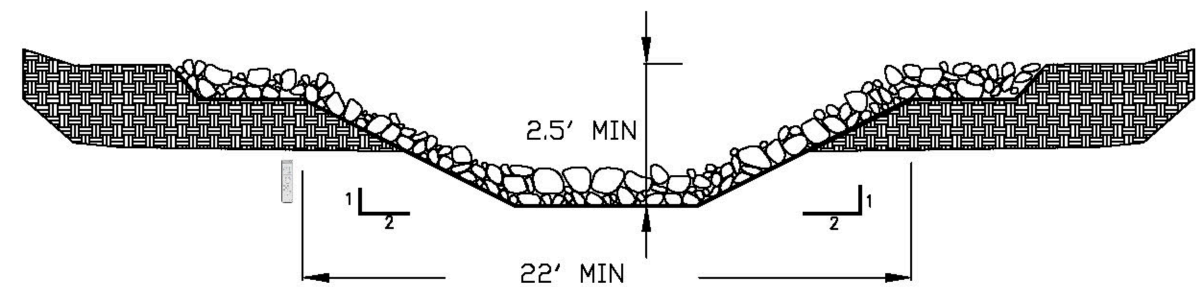


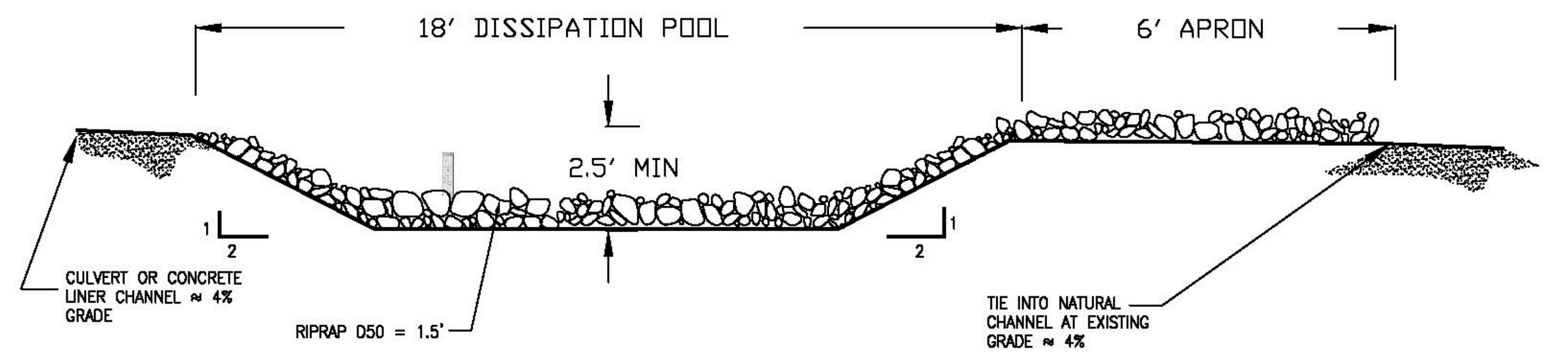
PLAN VIEW DISSIPATION POOL 6/X

NTS



TYPICAL CROSS SECTION OF DISSIPATION POOL 7/X

NTS



PROFILE OF DISSIPATION POOL 8/X

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FIGURE 4 - 6: DETAILS 6,7 & 8

ALTERNATIVES 2 & 3 DISSIPATION POOL
CONCEPTUAL DESIGN

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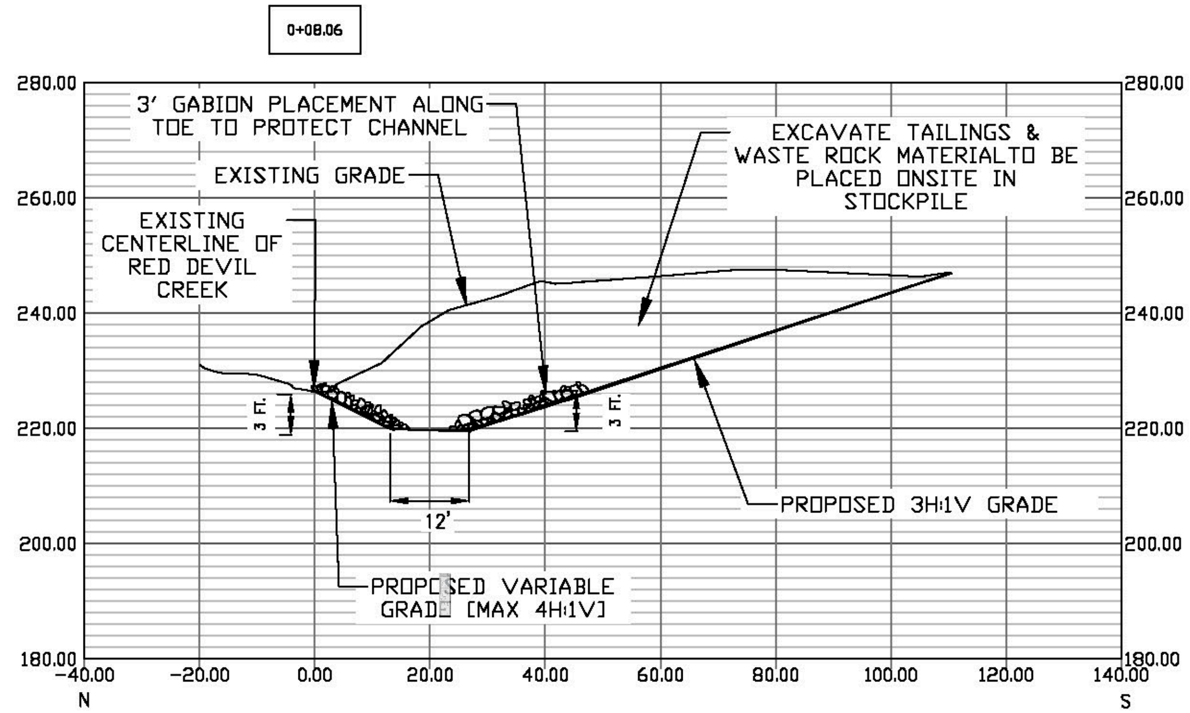
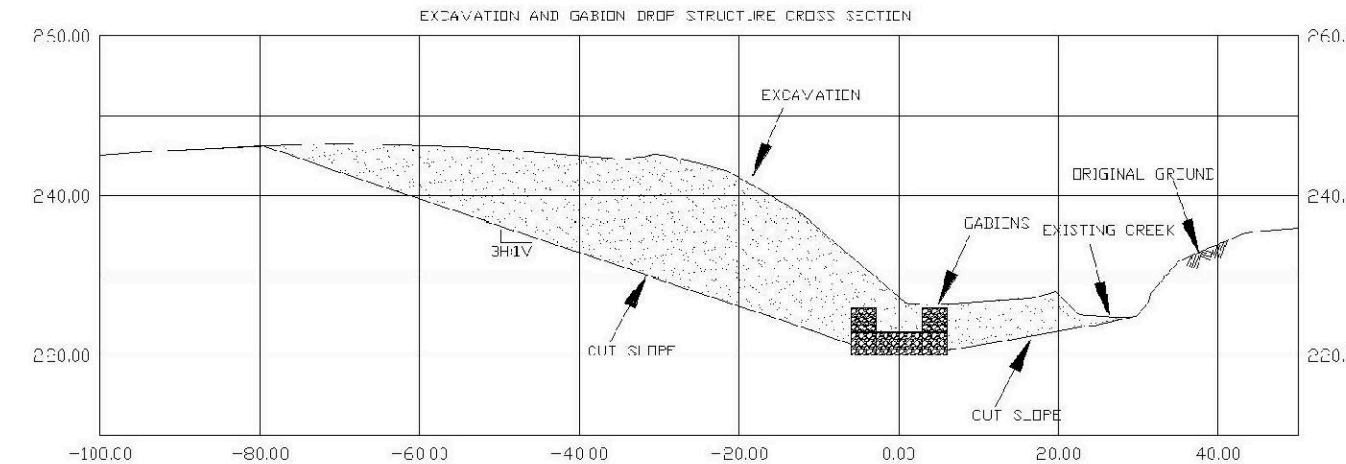


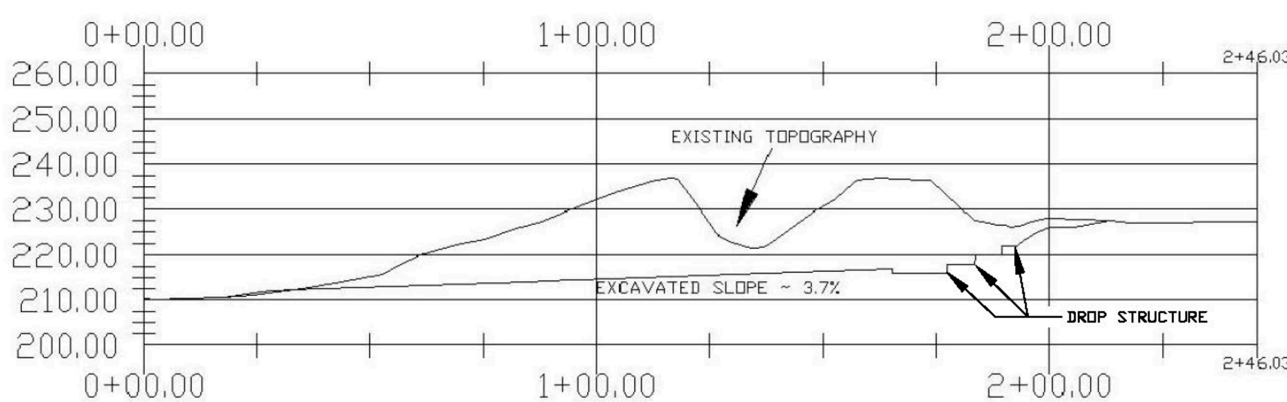
TYPICAL CROSS-SECTION EXCAVATION CHANNEL — 9 / X

NTS



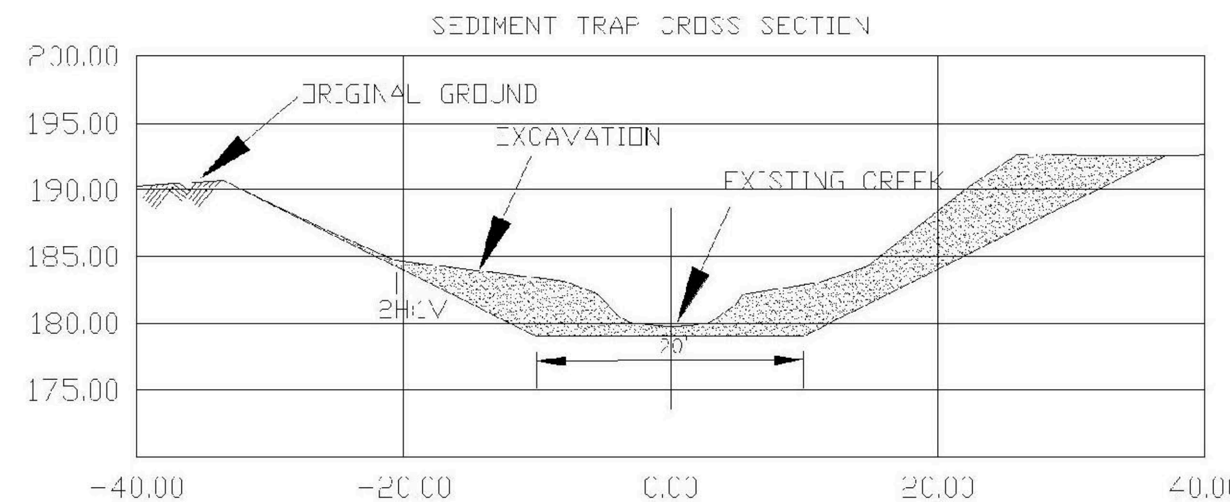
TYPICAL GABION DROP STRUCTURE — 10 / X

NTS



PROPOSED PROFILE — 11 / X

NTS



TYPICAL SEDIMENT TRAP CROSS-SECTION — 12 / X

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FIGURE 4 - 7: TYPICAL CROSS-SECTION VIEWS
ALTERNATIVE 4: EXCAVATION OF CONTAMINATED SEDIMENT

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5 Individual Analysis of Early Action Alternatives

This section presents an individual analysis of the alternatives based on the short- and long-term effectiveness of each alternative relative to reducing contaminated sediment discharges to surface waters and the Kuskokwim River as well as providing overall protection of public health and the environment. Three broad criteria—effectiveness, implementability, and cost—are used to evaluate each alternative against the scope of the early action, and these criteria are described below. The alternatives developed below address contamination associated with COCs (i.e., metals, specifically arsenic, antimony, and mercury) identified in sediment located along and within the Red Devil Creek, which have been determined to be actively eroding within the Main Processing Area at RDM. This early action analysis is intended to evaluate each alternative against the criteria with the understanding that additional removal actions will be required at RDM to address contamination identified in other media sources at the site.

Evaluation Criteria

Effectiveness

Effectiveness includes several evaluation factors, which are defined below.

Overall Protection of Human Health and the Environment: Assesses the ability of the alternative to be protective of human health and the environment under present and future land use conditions.

Compliance with ARARs: Identifies whether or not implementation of the alternative would comply with action-specific, and location-specific ARARs and TBC materials.

Long-term Effectiveness: Addresses the magnitude of residual risk remaining at the conclusion of early action activities; that is, addresses the adequacy and reliability of controls established by an early action alternative to maintain reliable protection of human health and the environment over time.

Reduction of Toxicity, Mobility, and Volume through Treatment: Identifies whether or not implementation of the alternative would reduce contaminant toxicity (e.g., reduction of metals contamination), mobility (e.g., preventing contaminated soil from reaching human receptors), or actual volume of the hazardous substances.

Short-term Effectiveness: This criterion addresses the effects of an alternative during the construction and implementation phase until the early action objectives are met. This criterion includes the time with which the remedy achieves protective-ness and potential to create adverse impacts on human health and the environment during construction and implementation.

Implementability

Implementability is evaluated in accordance with the criteria defined below.

Technical Feasibility: Evaluates construction and operational considerations, as well as demonstrated performance/useful life.

Administrative Feasibility: Evaluates activities such as statutory limits, permitting requirements, easements/rights-of-way, and impact on adjoining property.

Availability of Service and Materials: Considers the availability of qualified contractors to handle site preparation, design, equipment, personnel, services and materials, excavation, disposal capacity, and transportation in time to maintain the early action schedule, as well as the availability of disposal facilities that are licensed to accept hazardous and non-hazardous liquid/solid waste.

Cost

Summaries of the alternatives' costs (except for the No Action alternative) are provided in Tables 5-1 through 5-3, and assumptions and references for the cost estimates are included in Appendix D. Each early action alternative was evaluated to determine its project cost. The cost estimates contain the capital cost and annual operational and maintenance costs for a period of 10 years. The cost estimate for each component of the proposed alternatives is based on assumptions provided in the early action alternative description presented in Section 4, this section, and in Appendix D.

Costs are based in part on the estimated extent of contaminated sediment along Red Devil Creek that is actively eroding within the Main Processing Area. Because of uncertainties about the exact amount of contaminated material and other uncertainties, actual cleanup costs may be expected to be in the range of -30 to +50%.

The present worth should be calculated for alternatives that will last longer than 12 months (EPA 1993). Under this EE/CA, early action alternatives 2, 3, and 4 will require approximately 3 months or less of operation (one construction season); however, 10 years of operation and maintenance (O&M) have also been incorporated into the cost estimate using present worth values.

5.1 Alternative 1: No Action

The No Action alternative was prepared and evaluated to provide a baseline with which other alternatives can be compared. Under this alternative, no action would be taken to reduce contaminant concentrations in affected Site media.

Effectiveness

This alternative does not remove or provide containment of COCs and will not meet the RAOs. Contaminant concentrations and the existing and future potential for off-site migration of sediment from Red Devil Creek would remain unchanged. Contaminated sediment would continue to discharge through Red Devil Creek and ultimately downstream to the Kuskokwim River.

Overall Protection of Human Health and the Environment: Under this alternative, no engineering or institutional controls will be implemented to address potential exposure pathways or to reduce contaminant concentrations in affected site media. As a result, there will be no measurable contaminant reduction or reduced exposure. Therefore, protection of human health and the environment is not provided.

Compliance with ARARs: ARAR compliance is not applicable to this alternative because chemical-specific ARARs are not evaluated in this EE/CA.

Long-Term Effectiveness and Permanence: This alternative would allow tailings to continue to migrate to the Kuskokwim River. The disposition of tailings within the designated excavation area at the site will not be altered. Therefore, long-term effectiveness and permanence is not provided.

Reduction of Toxicity, Mobility, or Volume through Treatment: This alternative provides no reduction of toxicity, mobility, or volume through treatment.

Short-Term Effectiveness: With no proposed construction activities, there will be no increase associated with exposure to contaminated media. Therefore, there are no short-term risks associated with this alternative.

Implementability

This alternative is readily implementable since there are no administrative or engineering actions to be implemented, administrative coordination is not required, and services or materials are not required.

Cost

There are no costs associated with this alternative.

5.2 Alternative 2: Channelization of Red Devil Creek and Installation of Concrete Cloth Liner

This alternative involves the channelization and installation of a concrete cloth liner along the channel bed for the portion of Red Devil Creek that flows through the Main Processing Area. The installation of the concrete cloth liner will be protective for industrial and/or occasional use by a recreational visitor that could potentially come in contact with contaminated sediment.

Effectiveness

Alternative 2 will not remove contamination from the RDM site but will reduce the potential for continuing migration of highly contaminated sediment to Kuskokwim River and ultimately reduce human and ecological receptor exposure to contaminated tailings observed along Red Devil Creek within the Main Processing Area. By increasing the stability of the creek banks and flow, the concrete cloth will significantly reduce the potential for erosion of the banks and channel bed of Red Devil Creek. Additionally, channelizing the stream will provide improved conveyance of the stream flow, reducing the potential for flooding of the contaminated tailings observed within the Main Processing Area. RAOs will be met under this alternative.

Overall Protection of Human Health and the Environment: Installation of the concrete cloth liner under Alternative 2 will reduce on-site potential risks to human health and the environment through the solidification of stream banks and channel bed of Red Devil Creek. The liner will provide sediment stabilization and reduction of potential erosion through the Main Processing Area, which has been identified as having the highest concentrations of contaminants of potential concern (COPCs) in sediment for RDM. Additionally, the liner would reduce the likelihood of human, animal, and aquatic biota coming in contact with contaminated sediment off site, by mitigating the potential for further sediment transport to the Kuskokwim River. Although the primary exposure pathways will be reduced under this alternative, most of the contaminated sediment identified within Red Devil Creek will remain in place and will be subject to continuing contact with groundwater during periods where high water tables have been observed.

Compliance with ARARs: This alternative can be implemented in compliance with all action-specific and location-specific ARARs.

Long-Term Effectiveness and Permanence: Under this alternative, the concrete cloth liner can remain in place until the full-scale remedy is implemented or approximately 25 years if properly installed. The concrete cloth, once installed, will be effective over the long term in reducing erosion and subsequent migration of Red Devil Creek sediment in the vicinity of the Main Processing Area, but will require annual inspection to determine if liner integrity has been compromised by environmental conditions (i.e., ice flow, beaver dams, etc.). This alternative is not permanent as the concrete liner will need to be removed prior to implementing the final, full-scale remedial action.

Reduction of Toxicity, Mobility, or Volume: Since contaminated sediments would remain in place and not undergo treatment, the toxicity and volume of contaminants would not be reduced under Alternative 2; however, the mobility of contaminated sediment that occurs through erosion and suspension into Red Devil Creek waters would be reduced through the use of the concrete liner. The concrete liner will provide reduced contact between the creek flow and the contaminated sediments, thereby reducing the fluidization of sediments, which also reduces contaminant migration into the Kuskokwim River.

Short-Term Effectiveness: Given RDM's remote location, there is limited short-term risk associated with the local population. The potential for short-term impacts to workers and the surrounding environment would be addressed by engineering controls and BMPs. Workers would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are two ways by which the short-term risks associated with working with metal-laden material can be reduced. Additionally, since there will be a limited amount of earthwork associated with the installation of the concrete cloth, there is reduced exposure to contaminated sediments, which equates to an increase in short-term effectiveness.

Excess excavation material that will result from channelization will require the use of erosion controls. Dewatering the construction areas will also help reduce potential suspension of contaminated sediment during construction. A stormwater pollution plan (SWPPP) will be developed prior to commencing work and will identify ways to prevent surface water runoff from leaching metals with subsequent migration and spreading of contamination. Potential environmental impacts such as erosion and sedimentation and fugitive dust would be addressed by BMPs, which may include bales and limited and temporary diversion channels.

Implementability

Channelization of Red Devil Creek and installation of the concrete cloth would utilize readily available equipment and services. Commonly used earth-moving equipment and site work procedures would be employed to excavate and re-grade the channel and stream banks, install the liner, and stabilize the stockpile storage areas that will be required for excess excavated sediment material. Therefore, Alternative 2 is technically implementable.

Administratively, Alternative 2 is implementable, but mobilization will be a major logistical concern. Heavy construction equipment will be required, including front end loaders, trucks, and other pieces of equipment, which will need to be barged to the site given the remote location of RDM. Additionally, the concrete cloth material will also need to be barged to the site. The majority of this equipment and materials can be obtained in Bethel, Alaska or shipped directly to Bethel, Alaska to be transported up the Kuskokwim River by barge. Barges can only access the site during a very short period of the year (end of May through beginning of September) due to ice cover along the Kuskokwim River from October through mid to late May. All work, including mobilizing and demobilizing equipment and materials to the site, will need to be performed during this three-month construction period. While a relatively small window for construction is available, administrative and logistic efforts can be implemented provided they are planned well in advance of the construction season.

Additional administrative concerns associated with the work performed under this alternative within Red Devil Creek include coordination with BLM, EPA, ADEC, ADHSS, ADF&G, and ADNR. Sources of aggregate material will also need to be identified on site, or off-site sources must be identified, to obtain the necessary material to complete the dissipation pools prior to initiating construction of Alternative 2.

Cost

The estimated cost is $2,090,000 (Table 5-1).

5.3 Alternative 3: Installation of Culvert Liner along Red Devil Creek

Alternative 3 involves installing a culvert liner along the channel bed for the portion of Red Devil Creek that flows through the Main Processing Area. The culvert will be protective for industrial and/or occasional use by a recreational visitor who could potentially come in contact with contaminated sediment.

Effectiveness

Alternative 3 will not remove contamination from the RDM site but will reduce the potential for continuing migration of highly contaminated sediment to the Kuskokwim River and ultimately reduce human and ecological receptors' exposure to contaminated tailings observed along Red Devil Creek within the Main Processing Area.

By breaking the contact between the surface water and contaminated sediments observed within the Main Processing Area, the culvert will significantly reduce the potential for erosion of the banks and channel bed of Red Devil Creek that contains the highest levels of COCs. Additionally, installing the culvert will provide improved conveyance of the stream flow, reducing the potential for flooding of the contaminated tailings observed within the Main Processing Area. Under this alternative, the majority of contaminated sediment within and adjacent to Red Devil Creek will remain in place. RAOs will be met under this alternative.

Overall Protection of Human Health and the Environment: Installation of the culvert liner under Alternative 3 will decrease off-site risks to human health and the environment by reducing the volume of tailings transported to the Kuskokwim River. The contaminated sediment identified within Red Devil Creek will remain in place and will be subject to continuing contact with groundwater; therefore, on-site risks to human health and the environment will remain but are limited.

Compliance with ARARs: This alternative can be implemented in compliance with all action-specific and location-specific ARARs.

Long-Term Effectiveness and Permanence: Under this alternative, the culvert can remain in place until the full-scale remedy is implemented. The culvert, once installed, will be effective over the long term in preventing erosion of Red Devil Creek sediment in the vicinity of the Main Processing Area, but will require annual inspection to evaluate the integrity and flow against impacts from environmental conditions (i.e., ice flow, beaver dams, etc.). This is not a permanent alternative as the culvert will be required to be removed prior to implementing the final full-scale remedial action.

Reduction of Toxicity, Mobility, or Volume: Since contaminated sediments would remain in place and not undergo treatment, the toxicity and volume of contaminants would not be reduced under Alternative 3; however, the mobility of contaminated sediment that occurs through erosion and suspension into Red Devil Creek waters would be significantly reduced through the use of the culvert. The culvert will provide a barrier between the creek flow and the contaminated sediments, thereby reducing the fluidization of sediments, which also reduces tailings migration into the Kuskokwim River.

Short-Term Effectiveness: Given RDM's remote location, there is limited short-term risk associated with the local population. The potential for short-term impacts to workers and the surrounding environment would be addressed by engineering controls and BMPs. Workers would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are two ways by which the short-term risks associated with working with metal-laden material can be reduced. Additionally, since there will be a limited amount of earthwork associated with the installation of the culvert, there is reduced exposure to contaminated sediments, which equates to an increase in its short-term effectiveness.

Any excess excavation material that will result from channelization will be stored on site and will be subject to the use of erosion controls. Dewatering the construction areas will also help reduce potential suspension of contaminated sediment during construction. An SWPPP will be developed prior to commencing work and will identify ways to prevent surface water runoff from leaching metals with subsequent migration and spreading of contamination. Potential environmental impacts such as erosion and sedimentation and fugitive dust would be addressed by BMPs, which may include bales and limited/temporary diversion channels.

Implementability

Installing a culvert along Red Devil Creek will use readily available equipment and services. Commonly used earth-moving equipment and site work procedures would be employed to excavate and re-grade the channel and stream banks as necessary for the culvert base and dissipation pool, install the culvert liner, and stabilize the stockpile storage areas that will be required for any excess excavated sediment material. Therefore, Alternative 3 is technically implementable.

Administratively, Alternative 3 is implementable but mobilization will be a major logistical concern. Heavy construction equipment will be required, including front end loaders, trucks, and other pieces of equipment, which will need to be barged into the site given the remote location of RDM. Additionally, the culvert will also need to be barged to the site. The majority of this equipment and materials can be obtained in Bethel, Alaska or shipped directly to Bethel, Alaska to be transported to the site by barge. Barges can only access the site during a very short period of the year (end of May through beginning of September) due to ice jamming along the Kuskokwim River. All work, including mobilizing and demobilizing equipment and materials to the site, will need to be performed during this three-month construction period. While a relatively small window for construction is available, administrative and logistic efforts can be implemented provided they are planned well in advance of the construction season.

Additional administrative concerns associated with the work performed under Alternative 3 within Red Devil Creek include coordination with BLM, EPA, ADEC, ADHSS, ADF&G, and ADNR. Sources of aggregate material will also need to be identified on site, or off-site sources must be identified, to obtain the necessary material to complete the dissipation pools prior to initiating construction of Alternative 3.

Cost

The estimated cost is $2,110,000 (Table 5-2).

5.4 Alternative 4: Excavation of Actively Eroding Sediment along Red Devil Creek

This alternative involves the excavation of sediment within the portion of Red Devil Creek that extends through the Main Processing Area, which has been identified as actively eroding and containing COCs above cleanup objectives. It also involves regrading tailings on the south side of the creek in the Main Process Area to prevent future erosion. The excavated sediment will be deposited in an on-site stockpile to be included as part of the final, full-scale remedial action. No restoration of the excavated stream is proposed, but the toe of each stream bank of Red Devil Creek will be armored with gabions to prevent further degradation. A sediment trap will also be constructed downstream of the excavation closer to the mouth of Red Devil Creek to help capture remnant material that may find its way into the creek.

Effectiveness

Alternative 4 will not remove contaminated sediment from the RDM site, but it has been designed to mitigate the potential of sediment migration off site into the Kuskokwim River. The alternative provides protection of human health and the environment from active erosion of Red Devil Creek within the Main Processing Area, which has been identified as containing the highest volume of metal-laden sediments along Red Devil Creek. Some contaminated sediment will remain in place but will be protected by regrading and armoring the stream banks to further reduce the potential for erosion. Excavated material from Red Devil Creek will be stored in an on-site stockpile, which will be addressed as part of the full-scale remedy. This alternative meets the early action RAOs.

Overall Protection of Human Health and the Environment: Excavating the tailings within the Main Processing Area that have been observed as actively eroding into Red Devil Creek waters will decrease risks to human health and the environment by reducing the potential for further erosion to surface water.

Although, the primary exposure pathways will be reduced under this alternative, some contaminated sediment within Red Devil Creek will remain in place, and will be subject to continuing contact with groundwater and surface water until a full-scale remedy is implemented.

Compliance with ARARs: This alternative can be implemented in compliance with all action-specific and location-specific ARARs.

Long-Term Effectiveness and Permanence: Under this alternative, excavation of Red Devil Creek will be effective over the long term in preventing erosion of tailings in the Main Processing Area. Annual inspection will be required to evaluate the integrity of the gabion toe armoring to determine whether contaminated sediment has become exposed. Excavation of Red Devil Creek as described for the early action is not designed to be permanent.

Reduction of Toxicity, Mobility, or Volume: The toxicity and volume of contaminants would not be reduced under Alternative 4. A portion of the tailings in the Main Process Area will be redistributed to another on-site location. The mobility of tailings through erosion and suspension into Red Devil Creek would be significantly reduced under this alternative.

Short-Term Effectiveness: Given RDM's remote location, there is limited short-term risk associated with the local population. The potential for short-term impacts to workers and the surrounding environment would be addressed by engineering controls and BMPs. Workers would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are two ways by which the short-term risks associated with working with metal-laden material can be reduced.

Excavated material will be stored on site and will require the use of erosion controls. Dewatering the construction areas will also help reduce potential suspension of contaminated sediment during construction. An SWPPP will be developed prior to commencing work and will identify ways to prevent surface water runoff from leaching metals with subsequent migration and spreading of contamination. Potential environmental impacts such as erosion and sedimentation and fugitive dust would be addressed by BMPs.

Implementability

Excavating Red Devil Creek will use readily available equipment and services. Commonly used earth-moving equipment and site work procedures would be employed to excavate and re-grade the channel and stream banks, as well as the sediment trap, install the gabion toe protection, and stabilize the stockpile storage areas that will be required for excavated sediment material. Administratively, Alternative 4 is implementable, but mobilization will be a major logistical concern. Heavy construction equipment will be required, including front end loaders, trucks, and other pieces of equipment, which will need to be barged into the site given the remote location of RDM. The majority of this equipment and materials can be obtained in Bethel, Alaska, or shipped directly to Bethel, Alaska to be transported by barge. Barges can only access the site during a very short period of the year (end of May through beginning of September) due to ice jamming along the Kuskokwim River. All work, including mobilizing and demobilizing equipment and materials to the site, will need to be performed during this three-month construction period.

Additional administrative concerns associated with the work performed under Alternative 4 within Red Devil Creek include coordination with BLM, EPA, ADEC, ADHSS, ADF&G, and ADNR. Sources of aggregate material will also need to be identified on site, or off-site sources must be identified, to obtain the necessary material to complete the sediment trap prior to initiating construction of Alternative 4.

Cost

The estimated cost is $2,140,000 (Table 5-3).

Table 5-1 Cost Estimate, Alternative 2 – Concrete Channel Construction Red Devil Mine Site, EE/CA Red Devil, Alaska

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DCConCh1	Mobilization/Demobilization	1	lump sum	$675,896	$675,896
DCConCh2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCConCh3	Site Preparation	1	lump sum	$7,902	$7,902
DCConCh5	Excavate Contaminated Materials	1	lump sum	$55,228	$55,228
DCConCh7	Stockpile Construction	1	lump sum	$10,464	$10,464
DCConCh8	Concrete Liner Construction	1	lump sum	$102,862	$102,862
DCConCh9	Construction Completion	1	lump sum	$15,391	$15,391
Total Direct Capital Costs (rounded to nearest $1,000)					***$1,089,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,300,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$65,000
	Administration (5%)				$65,000
	Legal Fees and License/Permit Costs (7%)				$91,000
	3rd Party Construction Oversight (5%)				$65,000
Total Indirect Capital Costs					***$286,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,586,000
	Contingency Allowance (20%)				$317,000
Total Capital Cost (rounded to nearest $10,000)					**$1,900,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Operation and Maintenance Cost	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900
	Insurance, Taxes, Licenses	3%			$540
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,900,000
Present Worth of O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Present Worth Cost for Alternative (Rounded to Nearest $10,000)					**$2,090,000**

Table 5-2 Cost Estimate, Alternative 3 – Culvert Construction Red Devil Mine Site, EECA Red Devil, Alaska

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DCCul1	Mobilization/Demobilization	1	lump sum	$693,415	$693,415
DCCul2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCCul3	Site Preparation	1	lump sum	$5,702	$5,702
DCCul5	Excavated Contaminated Materials	1	lump sum	$49,713	$49,713
DCCul6	Backfill Low Areas	1	lump sum	$471	$471
DCCul7	Stockpile Construction	1	lump sum	$3,890	$3,890
DCCul8	Culvert Liner Installation	1	lump sum	$103,321	$103,321
DCCul9	Construction Completion	1	lump sum	$15,501	$15,501
Total Direct Capital Costs (rounded to nearest $10,000)					***$1,093,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,310,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$66,000
	Administration (5%)				$66,000
	Legal Fees and License/Permit Costs (7%)				$92,000
	3rd Party Construction Oversight (5%)				$66,000
Total Indirect Capital Costs					***$290,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,600,000
	Contingency Allowance (20%)				$320,000
Total Capital Cost (rounded to nearest $10,000)					**$1,920,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Annual Operation and Maintenance Costs	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900.00
	Insurance, Taxes, Licenses	3%			$540.00
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,920,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Cost (Rounded to Nearest $10,000)					**$2,110,000**

Notes

1. Unit costs provided by Means were taken from *RS Means Heavy Construction Cost Data, 27th Ed., 2013.*
2. A 6 month work season and a 6 day work week were assumed.
3. One month for pre-construction and one month for post-construction activities were assumed.
4. A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.

Table 5-3 Cost Estimate, Alternative 4 – Excavation Red Devil Mine Site, EECA Red Devil, Alaska

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DCER1	Mobilization/Demobilization	1	lump sum	$673,853	$673,853
DCER2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCER3	Site Preparation	1	lump sum	$17,108	$17,108
DCER5	Excavation of Contaminated Material	1	lump sum	$90,310	$90,310
DCER7	Stockpile Construction	1	lump sum	$28,588	$28,588
DCER9	Drop Structure/Sediment Trap Construction	1	lump sum	$61,417	$61,417
DCER10	Construction Completion	1	lump sum	$15,831	$15,831
Total Direct Capital Costs (rounded to nearest $10,000)					***$1,110,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,330,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$67,000
	Administration (5%)				$67,000
	Legal Fees and License/Permit Costs (7%)				$93,000
	3rd Party Construction Oversight (5%)				$67,000
Total Indirect Capital Costs					***$294,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,624,000
	Contingency Allowance (20%)				$325,000
Total Capital Cost (rounded to nearest $10,000)					**$1,950,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Annual Operation and Maintenance Costs	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900.00
	Insurance, Taxes, Licenses	3%			$540.00
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,950,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Cost (Rounded to Nearest $10,000)					**$2,140,000**

Notes

1. Unit costs provided by Means were taken from *RS Means Heavy Construction Cost Data, 27th Ed., 2013.*
2. A 6 month work season and a 6 day work week were assumed.
3. One month for pre-construction and one month for post-construction activities were assumed.
4. A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.

6 Comparative Analysis of Early Action Alternatives

In Section 5, each early action alternative was analyzed independently, without consideration of the other alternatives. In this section, the alternatives are compared, considering effectiveness, implementability, and cost. This comparative analysis identifies the advantages and disadvantages of each alternative relative to the others. Table 6-1 provides a summary of the comparative analysis.

Alternative 1, the No Action Alternative, is not considered for this comparative analysis because it is not protective of human health and the environment. The remaining alternatives are:

1. Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek
2. Alternative 3 – Installation of Culvert Liner along Red Devil Creek
3. Alternative 4 – Excavation of Actively Eroding Sediment Along Red Devil Creek

6.1 Effectiveness

The subsections below discuss the major components of the effectiveness of the Early Action alternatives.

6.1.1 Overall Protection of Human Health

With the exception of Alternative 1 (No Action), the three early action alternatives all offer varying degrees of protection to human health and the environment to the extent that they prevent tailings from eroding into Red Devil Creek and migrating to the Kuskokwim River. Additionally, upon completion of construction activities, there will be an immediate reduction in the volume of contamination entering the Kuskokwim River for all three of the action alternatives.

The potential short-term risks to the public associated with the alternatives are similar due to the remote location of RDM. BMPs and standard construction practices will be utilized under all alternatives to provide protection of workers implementing the remedy. None of the proposed alternatives will result in contaminant volume reduction. Alternatives 2 and 3 will provide a barrier between contaminated sediment and surface water, reducing exposure pathways identified at the site.

Alternative 3 will direct and contain the stream flow within the culvert, minimizing the potential for overflow and continued erosion of the tailings areas in the Main Process Area and thus would provide greater protection of human health and the environment than Alternative 2.

The relative ranking of the four alternatives with regard to overall protection of human health (most- to least-effective) is as follows:

1. Alternative 3 – Installation of Culvert Liner Along Red Devil Creek
2. Alternative 2 – Channelization and Installation of Concrete Cloth Liner Along Red Devil Creek
3. Alternative 4 – Excavation of Actively Eroding Sediment Along Red Devil Creek
4. Alternative 1 – No Action

6.1.2 Compliance with ARARs/TBC Materials

Alternatives 2, 3, and 4 can be implemented in compliance with action-specific and location-specific ARARs. A greater number of action- and location-specific ARARs would likely apply to Alternative 4 due to the larger extent of disturbance proposed under this alternative. Each of the action alternatives can be implemented such that it is in compliance with ARARs and will allow for the ARARs to be met in full once a full-scale remedy is implemented.

6.1.3 Long-Term Effectiveness and Permanence

Although long-term effectiveness is a criterion under the EE/CA guidance, it should be noted that the early action alternatives presented in this document were developed to provide an interim remedy to the observed erosion of highly contaminated sediment along Red Devil Creek. The alternatives were not designed to be permanent solutions. Alternatives 2, 3, and 4 would require the same post-implementation activities, such annual visual inspections and maintenance to ensure the long-term effectiveness. Additionally, the alternatives will require further remedial actions to be performed during the full-scale remedy in order to address the residual sediment contamination along Red Devil Creek. Finally, Alternatives 2 and 3 would require additional removal/demolition activities under the final remedial action.

Of the three early action alternatives, Alternative 4 provides the most long-term effectiveness. Under this alternative, a portion of the Red Devil Creek sediments will be excavated and stockpiled for later disposition. While Alternatives 2 and 3 are similar to one another, Alternative 2 requires more material be excavated and stockpiled. Therefore, Alternative 2 provides more long-term effectiveness than Alternative 3. With Red Devil Creek remaining in its present state, and contaminated sediments continuing to migrate into the Kuskokwim River unabated, Alternative 1, No Action, provides the least amount of long-term effectiveness.

The relative ranking of the four alternatives with regard to long-term effectiveness (most- to least-effective) is as follows:

1. Alternative 4 – Excavation of Actively Eroding Sediment Along Red Devil Creek
2. Alternative 2 – Channelization and Installation of Concrete Cloth Liner Along Red Devil Creek
3. Alternative 3 – Installation of Culvert Liner Along Red Devil Creek
4. No Action 1 – No Action

6.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 2, 3, and 4 do not provide for a reduction in the volume or toxicity of the actively eroding contaminated sediment observed along Red Devil Creek in the Main Processing Area. While treatment is not associated with the reduction, all the early action alternatives will reduce the mobility associated with the actively eroding and migrating tailings within the Main Processing Area. Alternative 4 provides the most reduction in mobility because contaminated sediments are actually removed from the creek and relocated. Both Alternatives 2 and 3 provide a barrier between the surface waters of Red Devil Creek and the sediment. Therefore, they are considered equal under this evaluation criterion. The No Action Alternative does not provide for a reduction of toxicity, mobility, or volume through treatment.

The relative ranking of the four alternatives with regard to reduction of toxicity, mobility, or volume criteria (most- to least-effective) is as follows (most to least reduction):

1. Alternative 4 – Excavation of Actively Eroding Sediment along Red Devil Creek
2. (tie) Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek
3. (tie) Alternative 3 – Installation of Culvert Liner along Red Devil Creek
4. No Action

6.1.5 Short-Term Effectiveness

No contaminated material is proposed to be transported off site under the proposed RDM Early Action alternatives. Alternative 4 would result in most adverse short-term impacts to construction workers and the environment because a larger quantity of contaminated material would be disturbed during the excavation of Red Devil Creek within the Main Processing Area. However, the potential for such impacts is expected to be minimized by engineering controls and BMPs.

With no work being performed, Alternative 1, No Action, is the most effective in the short term, as no impacts are anticipated. While the installation of the concrete cloth (Alternative 2) is relatively straightforward and does not require excess construction equipment as compared to the installation of a culvert system (Alternative 3), there is more material movement associated with the preparation of the creek bed. Therefore, Alternative 3 provides better short-term effectiveness as compared to Alternative 2.

The relative ranking of the four alternatives with regard to short-term effectiveness (most- to least-effective) is as follows:

1. No Action
2. Alternative 3 – Installation of Culvert Liner along Red Devil Creek
3. Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek
4. Alternative 4 – Excavation of Actively Eroding Sediment along Red Devil Creek

6.2 Implementability

All three alternatives are implementable using common construction equipment and practices. A major concern that will need to be addressed for each of the early action alternatives will be the coordination to obtain and transport equipment to and from the site. It is anticipated that all three active alternatives can be completed within one construction season, which will coincide with the navigation season of Kuskokwim River.

6.2.1 Technical Feasibility

Alternative 2 (Concrete Cloth Liner) will likely require greater technical considerations when compared to the other alternatives due to installation requirements of the concrete cloth.

Although installation is conducted using common site work construction methods and equipment, significant site preparation and planning will be required prior to placement of the cloth. The cloth can only be applied under dry conditions; otherwise, the liner will prematurely set prior to final placement. Additionally, the material only has a working time of 1 to 2 hours after hydration so modifications are not possible once the material has become wet and begins to set.

Of the three action alternatives, Alternative 4 is the most technically feasible. The work associated with Alternative 4 would not have to be repeated during the future full-scale remedial action. Alternatives 2 and 3 are temporary in nature, and less compatible with future final remedial actions.

While the No Action Alternative would appear to be the most technically feasible alternative, it is not. The focus of the Early Action is to reduce contaminated sediment migration into the Kuskokwim River. Alternative 1 does not address this issue; therefore, it is not technically feasible.

On this basis, the alternatives are ranked as follows for the technical feasibility criterion (most- to least-feasible):

1. Alternative 4 – Excavation of Actively Eroding Sediment along Red Devil Creek
2. Alternative 3 – Installation of Culvert Liner along Red Devil Creek
3. Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek
4. Alternative 1 – No Action

6.2.2 Administrative Feasibility
All early action alternatives will require coordination with BLM, EPA, ADEC, ADF&G, and other regulatory authorities to develop mitigation plans to help provide protection of aquatic biota that have been observed within Red Devil Creek prior to the commencement of work. Sources of riprap and fill rock for the gabion toe protection and drop structure under Alternative 4; gabion headwall under Alternative 3; and riprap needed for the dissipation pool as proposed for both Alternatives 2 and 3 will also need to be identified on site, or, alternatively, access agreements for off-site sources will be required prior to initiating construction.

The alternatives are ranked as follows for administrative feasibility (most- to least-feasible based on the extent of disturbance and the quantity of fill/riprap required):

1. Alternative 3 – Installation of Culvert Liner along Red Devil Creek
2. Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek
3. Alternative 4 – Excavation of Actively Eroding Sediment along Red Devil Creek
4. Alternative 1 – No Action

6.2.3 Availability of Service and Materials
Alternative 2 would require more extensive design work and coordination in obtaining materials (e.g., concrete cloth) than Alternatives 3 and 4. Likewise, Alternative 3 would require more design work and coordination when compared to Alternative 4, as Alternative 4 utilizes readily available equipment and personnel without the need to ship additional materials such as culverts or liners to the site. For all three of the action alternatives, an on-site source of riprap will be required or an easement or access agreement will be needed for any off-site sourced material. With no services or materials needed for its implementation, the No Action Alternative ranks ahead of the three action alternatives.

The alternatives are ranked as follows for availability of service and materials (most- to least-available):

1. Alternative 1 – No Action

2. Alternative 4 – Excavation of Actively Eroding Sediment along Red Devil Creek
3. Alternative 3 – Installation of Culvert Liner along Red Devil Creek
4. Alternative 2 – Channelization and Installation of Concrete Cloth Liner along Red Devil Creek

6.3 Cost

While an estimate prepared as part of a detailed design will provide a more accurate cost, this is beyond the scope of an EE/CA. In developing the individual cost estimates, there are a number of uncertainties that must be accounted for. There is a considerable amount of site data; however, data gaps associated with the extent of contamination still exist. Additionally, the designs have not been finalized and assumptions and alternative features provided in this EE/CA are conceptual. Therefore, the volume of material to be excavated was increased by 10% to account for unknowns.

Finally, for all of the action alternatives, a 20% contingency factor was added to address potential unknowns that may increase the cost of implementing the individual alternative.

6.3.1 Cost Evaluation

In evaluating the costs of the early action alternatives, there are three components: capital cost, annual post-construction site controls cost, and total project cost.

For the RDM site, the capital costs of the action alternatives are:

1. Alternative 2 – Channelization and Installation of Concrete Liner, $2,090,000
2. Alternative 3 – Installation of Culvert Liner along Red Devil Creek, $2,110,000
3. Alternative 4 – Excavation of Actively Eroding Sediment, $2,140,000

Each alternative will require post-construction site monitoring to assess the effective-ness and integrity of the early action. Additionally, some minor maintenance, such as debris removal, is also anticipated. The present worth annual O&M costs are estimated to be approximately $23,000 per year for each of the alternatives. A cost summary is provided in Table 6-2.

6.4 Summary of Comparative Analysis

A summary of the comparative analysis for the early action alternatives is presented in Table 6-1.

Table 6-1 Summary of Comparative Analysis, Engineering Evaluation/Cost Analysis, Red Devil Mine

Alternative Description	Qualitative Ranking: Effectiveness	Qualitative Ranking: Implementability	Cost
Alternative 2 **Channelization of Red Devil Creek and Installation of Concrete Liner**	**MODERATE** — Reduces contact between surface water of Red Devil Creek and contaminated sediment observed to be actively eroding. — Would significantly reduce mobility of contaminated sediments; however, volume and toxicity of COCs will not be affected. Contamination will remain in place; excess sediment resulting from excavation will be stored in specified stockpile for further treatment. — ARARs and TBCs will be met.	**LOW** — Readily implementable based on standard construction practices. — However, substantive requirements must be addressed before implementation such as coordination of shipping large quantities of concrete cloth liner to the site by barge. — Will require significant site preparation in areas of contamination prior to installation. Additional site preparation will be needed during the full-scale removal action as the concrete liner will have to be broken up and removed in order to address contaminated sediment at RDM along the creek.	**$2,090,000**
Alternative 3 **Installation of Culvert Liner along Red Devil Creek**	**MODERATE** — Reduces contact between surface water of Red Devil Creek and contaminated sediment observed to be actively eroding. — Would significantly reduce mobility of contaminated sediments; however, volume and toxicity of COCs will not be affected. Contamination will remain in place; excess sediment resulting from excavation will be stored in specified stockpile for further treatment. — ARARs and TBCs will be met.	**MODERATE** — Readily implementable based on standard construction practices. — However, substantive requirements must be addressed before implementation such as coordination of shipping culvert to the site by barge. — Will require additional site preparation during full-scale remedy to remove culvert liner in order to address contaminated sediment at RDM along the creek.	**$2,110,000**
Alternative 4 **Excavation of Actively Eroding Contaminated Sediment along Red Devil Creek**	**MODERATE TO HIGH** — Removes the potential for contact between surface water of Red Devil Creek and contaminated sediment observed to be actively eroding. — Would significantly reduce mobility of contaminated sediments within the Main Processing Area; however, volume and toxicity of COCs will not be affected. Excavated sediments will be stored on site in specified stockpile for further treatment. — ARARs and TBCs will be met.	**HIGH** — Readily implementable based on standard construction practices. — No additional materials will be required to be shipped to the site besides equipment to perform earthwork.	**$2,140,000**

Key:
ARAR = Applicable or relevant and appropriate requirement.
COC = Contaminant of concern.
TBC = To-be-considered material.

Table 6-2 Summary of Individual Alternative Costs

Alternative	Total Capital Cost	Yearly O & M Cost	Present Worth O & M Cost	Total Present Worth Cost
1	-	-	-	-
2	$1,900,000	$23,000	$190,000	$2,090,000
3	$1,920,000	$23,000	$190,000	$2,110,000
4	$1,950,000	$23,000	$190,000	$2,140,000

Key:
O&M = Operation and maintenance.

7 Recommended Early Action Alternative

Based upon the alternative evaluations conducted in Section 6, Alternative 4, Excavation of Actively Eroding Contaminated Sediment, is the recommended early action alternative.

The key advantages of Alternative 4 are that it is the most straightforward and likely least problematic alternative, particularly when the full-scale remedy is implemented. When the full-scale remedy is conducted, Alternative 4 will require the least amount of additional site preparation to address the remaining contaminated sediment at RDM. Although Alternative 4 is not the least expensive to implement, the additional costs would be offset in part by avoiding potential cost increases due to administrative and technical feasibility concerns such as coordination of material shipments to the site. Additionally, Alternative 4 is likely the most adaptable to evolving site-specific conditions that would emerge during cleanup activities under the future full-scale remedy.

8 References

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A Analytical Data Summary Tables, 2013 RI Results

Table A-1 Background Red Devil Creek Surface Water and Sediment Results

Analyte	RD01 10RD01SW	RD01 11RD01SW	RD01 10RD01SD
Total Inorganic Elements (SW=µg/L, SD=mg/kg)			
Aluminum	80	30.5 J	10800
Antimony	1.4	1.52 J	0.54 UJ
Arsenic	0.8	1.1	65
Barium	26.4	23.8	159
Beryllium	0.027 U	0.006 U	0.5
Cadmium	0.022 U	0.005 U	0.3
Calcium	18400	17500	2380
Chromium	0.053 U	0.43	20.4
Cobalt	0.007 U	0.066	12.3
Copper	0.232 U	0.37	21.7
Iron	110	138	32100
Lead	0.2 U	0.021	8
Magnesium	9680	9460	2990
Manganese	10.2	17.5	579
Mercury			0.18
Nickel	0.081 U	0.44	32
Potassium	69.1 U	218 J	1200
Selenium	0.125 U	0.5 J	0.78 U
Silver	0.009 U	0.004 U	0.053 U
Sodium	1580	1470	19.9 U
Thallium	0.003 U	0.005 U	0.33 U
Vanadium	0.3	0.16 J	35.4
Zinc	0.81 U	0.5 J	80
Total Low Level Mercury (SW=ng/L)			
Mercury, Total	3.17	6.37	
Dissolved Inorganic Elements (SW=µg/L)			
Aluminum, Dissolved	14.8 U	11.9 J	
Antimony, Dissolved	1.3	1.4 J	
Arsenic, Dissolved	0.6	0.9	
Barium, Dissolved	24	23	
Beryllium, Dissolved	0.027 U	0.006 U	
Cadmium, Dissolved	0.022 U	0.005 U	
Calcium, Dissolved	19200	17300	
Chromium, Dissolved	0.053 U	0.23	
Cobalt, Dissolved	0.007 U	0.056	
Copper, Dissolved	0.232 U	0.27	
Iron, Dissolved	7.2 U	100	
Lead, Dissolved	0.2 U	0.005 U	
Magnesium, Dissolved	10200	9340	
Manganese, Dissolved	7.2	15.9	
Nickel, Dissolved	0.081 U	0.35	
Potassium, Dissolved	69.1 U	220 J	
Selenium, Dissolved	0.125 U	0.5 J	
Silicon, Dissolved	3.3	3680	
Silver, Dissolved	0.009 U	0.004 U	
Sodium, Dissolved	1610	1450	
Thallium, Dissolved	0.003 U	0.005 U	
Vanadium, Dissolved	0.026 U	0.13 J	
Zinc, Dissolved	0.81 U	0.2 U	
Dissolved Low Level Mercury (SW=ng/L)			
Mercury, Dissolved	1.95	2.63	

Table A-1 Background Red Devil Creek Surface Water and Sediment Results

Analyte	RD01 10RD01SW	RD01 11RD01SW	RD01 10RD01SD
Arsenic Speciation (SW=µg/L, SD=mg/kg)			
Arsenate	0.578	0.774 J	48.7 J
Arsenite	0.102	0.089 J	4.13 J
Inorganic Arsenic	0.68	0.863 J	52.8 J
Mercury Selective Sequential Extraction (sd=ng/g)			
Hg(F0)		3.36 U	
Hg(F1)		1.19 J	
Hg(F2)		0.25 U	
Hg(F3)		57.3 J	
Hg(F4)		17.3 J	
Hg(F5)		24.7	
Hg(F6)		4.98 J	
Methlymercury (SW=ng/L, SD=ng/g)			
Methylmercury	0.074	0.08 J	0.177
Semi-Volatile Organic Compounds (SW=ng/L)			
2-Methylnaphthalene			
Naphthalene			
1-Methylnaphthalene			
2-Methylnaphthalene			
Unknown Hydrocarbon			
Gasoline, Diesel, and Residual Range Organics (SW=mg/L)			
Gasoline Range Organics			
Diesel Range Organics			
Residual Range Organics			
Total Organic Carbon (SD=%)			
Carbon, Total Organic (TOC)		1.47	
General Chemistry (SW=mg/L)			
Bicarbonate	81	74.1	
Carbonate	1 U	3 U	
Hydroxide	1 U		
Hydroxide			
Total Dissolved Solids		74	
Total Suspended Solids		5 U	
Total Dissolved Solids	102		
Total Suspended Solids	2		
Chloride	0.4	0.35 J	
Fluoride	0.022 U	0.05 J	
Sulfate	11.2	9.58	
Nitrate+Nitrite as Nitrogen	0.166	0.208	

Key

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.
µg/L = micrograms per liter mg/kg = milligrams per kilogram mg/L = milligrams per liter
ng/g = nanograms per gram ng/L = nanograms per liter
% = percent
SD = sediment
SW = surface water
U = Analyte was analyzed for but not detected. Value provided is reporting limit.
UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

Table A-2 Background Statistics for Red Devil Creek Sediment and Surface Water Samples

Analyte	Sediment					Surface Water - Total					
	10RD01SD Conc.(mg/kg)	Sample Size	Number Detections	Recommended Background Level (mg/kg)	Background Rationale	10RD01SW Conc. (µg/L)	11RD01SW Conc. (µg/L)	Sample Size	Number Detections	Recommended Background Level (µg/L)	Background Rationale
Aluminum	10800	1	1	10800	Single Result	80	30.5 J	2	2	80	Maximum Detection
Antimony	ND	1	0	ND	Single Result	1.4	1.52 J	2	2	1.52 J	Maximum Detection
Arsenic	65	1	1	65	Single Result	0.8	1.1	2	2	1.1	Maximum Detection
Inorganic Arsenic	NA	0	0	NA	Single Result	0.68	0.863	2	2	0.863	Maximum Detection
Barium	159	1	1	159	Single Result	26.4	23.8	2	2	26.4	Maximum Detection
Beryllium	0.5	1	1	0.5	Single Result	ND	ND	2	0	ND	Maximum Detection
Cadmium	0.3	1	1	0.3	Single Result	ND	ND	2	0	ND	Maximum Detection
Calcium	2380	1	1	2380	Single Result	18400	17500	2	2	18400	Maximum Detection
Chromium	20.4	1	1	20.4	Single Result	ND	0.43	2	1	0.43	Maximum Detection
Cobalt	12.3	1	1	12.3	Single Result	ND	0.066	2	1	0.066	Maximum Detection
Copper	21.7	1	1	21.7	Single Result	ND	0.37	2	1	0.37	Maximum Detection
Iron	32100	1	1	32100	Single Result	110	138	2	2	138	Maximum Detection
Lead	8	1	1	8	Single Result	ND	0.021	2	1	0.021	Maximum Detection
Magnesium	2990	1	1	2990	Single Result	9680	9460	2	2	9680	Maximum Detection
Manganese	579	1	1	579	Single Result	10.2	17.5	2	2	17.5	Maximum Detection
Methylmercury	0.000177	1	1	0.000177	Single Result	0.000074	0.00008 J	2	2	0.00008 J	Maximum Detection
Mercury	0.18	1	1	0.18	Single Result	0.00195	0.00263	2	2	0.00263	Maximum Detection
Nickel	32	1	1	32	Single Result	ND	0.44	2	1	0.44	Maximum Detection
Potassium	1200	1	1	1200	Single Result	ND	218 J	2	1	218 J	Maximum Detection
Selenium	ND	1	0	ND	Single Result	ND	0.5 J	2	1	0.5 J	Maximum Detection
Silver	ND	1	0	ND	Single Result	ND	ND	2	0	ND	Maximum Detection
Sodium	ND	1	0	ND	Single Result	1580	1470	2	2	1580	Maximum Detection
Thallium	ND	1	0	ND	Single Result	ND	ND	2	0	ND	Maximum Detection
Vanadium	35.4	1	1	35.4	Single Result	0.3	0.16 J	2	2	0.3	Maximum Detection
Zinc	80	1	1	80	Single Result	ND	0.5 J	2	1	0.5 J	Maximum Detection

Table A-2 Background Statistics for Red Devil Creek Sediment and Surface Water Samples

Analyte	Surface Water - Dissolved					
	10RD01SW Conc. (µg/L)	11RD01SW Conc. (µg/L)	Sample Size	Number Detections	Recommended Background Level (µg/L)	Background Rationale
Aluminum	ND	11.9 J	2	1	11.9 J	Maximum Detection
Antimony	1.3	1.4 J	2	2	1.4 J	Maximum Detection
Arsenic	0.6	0.9	2	2	0.9	Maximum Detection
Inorganic Arsenic	NA	NA	0	0	NA	Maximum Detection
Barium	24	23	2	2	24	Maximum Detection
Beryllium	ND	ND	2	0	ND	Maximum Detection
Cadmium	ND	ND	2	0	ND	Maximum Detection
Calcium	19200	17300	2	2	19200	Maximum Detection
Chromium	ND	0.23	2	1	0.23	Maximum Detection
Cobalt	ND	0.056	2	1	0.056	Maximum Detection
Copper	ND	0.27	2	1	0.27	Maximum Detection
Iron	ND	100	2	1	100	Maximum Detection
Lead	ND	ND	2	0	ND	Maximum Detection
Magnesium	10200	9340	2	2	10200	Maximum Detection
Manganese	7.2	15.9	2	2	15.9	Maximum Detection
Methylmercury	NA	NA	0	0	NA	Maximum Detection
Mercury	0.00317	0.00637	2	2	0.00637	Maximum Detection
Nickel	ND	0.35	2	1	0.35	Maximum Detection
Potassium	ND	220 J	2	1	220 J	Maximum Detection
Selenium	ND	0.5 J	2	1	0.5 J	Maximum Detection
Silver	ND	ND	2	0	ND	Maximum Detection
Sodium	1610	1450	2	2	1610	Maximum Detection
Thallium	ND	ND	2	0	ND	Maximum Detection
Vanadium	ND	0.13 J	2	1	0.13 J	Maximum Detection
Zinc	ND	ND	2	0	ND	Maximum Detection

Key:

µg/L = micrograms per liter

J = Analyte detectedAnalyte detected but relative percent difference was outside control limits; there mg/kg = milligrams per kilogram

NA = Not Available, not analyzed

ND = Not Detected

Table A-3 Red Devil Creek Sediment Results

Analyte	Background Screening Criteria	Station ID	Units	RD01	RD02	RD03	RD11	RD10	RD04
		Sample ID		10RD01SD	10RD02SD	10RD03SD	11RD11SD	11RD10SD	10RD04SD
		Method							
Total Inorganic Elements									
Aluminum	10800	SW6010B-Total	mg/kg	**10800**	**14700**	**9340**	**9930**	**7290**	**9350**
Antimony	ND	SW6010B-Total	mg/kg	0.54 UJ	1.2 UJ	1.2 UJ			**2510 J**
Antimony	ND	SW6020A-Total	mg/kg				**7.39 J**	**5.71 J**	
Arsenic	65	SW6010B-Total	mg/kg	**65**	**50**	**60**			**2290**
Arsenic	65	SW6020A-Total	mg/kg				**32.5**	**62**	
Barium	159	SW6010B-Total	mg/kg	**159**	**278**	**146**			**401**
Barium	159	SW6020A-Total	mg/kg				**130 J**	**119**	
Beryllium	0.5	SW6010B-Total	mg/kg	**0.5**	**0.4**	**0.6**			**0.9**
Beryllium	0.5	SW6020A-Total	mg/kg				**0.311**	**0.417**	
Cadmium	0.3	SW6010B-Total	mg/kg	**0.3**	0.059 U	0.06 U			0.062 U
Cadmium	0.3	SW6020A-Total	mg/kg				**0.163 J**	**0.232**	
Calcium	2380	SW6010B-Total	mg/kg	**2380**	**6170**	**1960**	**2070 J**	**1660 J**	**5530**
Chromium	20.4	SW6010B-Total	mg/kg	**20.4**	**25**	**19**			**29**
Chromium	20.4	SW6020A-Total	mg/kg				**14.9 J**	**11.8 J**	
Cobalt	12.3	SW6010B-Total	mg/kg	**12.3**	**13.7**	**16.5**			**17.8**
Cobalt	12.3	SW6020A-Total	mg/kg				**8.69**	**11.9**	
Copper	21.7	SW6010B-Total	mg/kg	**21.7**	**23.4**	**24.4**			**45.7**
Copper	21.7	SW6020A-Total	mg/kg				**13.2 J**	**14.9 J**	
Iron	32100	SW6010B-Total	mg/kg	**32100**	**29200**	**38300**	**33200**	**36100**	**52000**
Lead	8	SW6010B-Total	mg/kg	**8**	**7**	**8**			**14**
Lead	8	SW6020A-Total	mg/kg				**6.22 J**	**7.99 J**	
Magnesium	2990	SW6010B-Total	mg/kg	**2990**	**4110**	**2710**	**3250 J**	**2780 J**	**8690**
Manganese	579	SW6010B-Total	mg/kg	**579**	**2610**	**1310**	**854**	**1480**	**1350**
Mercury	0.18	SW7471A-Total	mg/kg	**0.18**	**0.55**	**0.42**	**1.57 J**	**0.232 J**	**36**
Nickel	32	SW6010B-Total	mg/kg	**32**	**30**	**38**			**67**
Nickel	32	SW6020A-Total	mg/kg				**22 J**	**26 J**	
Potassium	1200	SW6010B-Total	mg/kg	**1200**	**1300**	**900**	**636 J**	**510 J**	**2660**
Selenium	ND	SW6010B-Total	mg/kg	0.78 U	1.7 U	1.8 U			1.8 U
Selenium	ND	SW7742-Total	mg/kg				**0.39**	**0.33**	
Silver	ND	SW6010B-Total	mg/kg	0.053 U	0.117 U	0.12 U			0.124 U
Silver	ND	SW6020A-Total	mg/kg				**0.062 J**	**0.04**	
Sodium	ND	SW6010B-Total	mg/kg	19.9 U	44.3 U	45.4 U	**39.6**	**21.1**	**240**
Thallium	ND	SW6010B-Total	mg/kg	0.33 U	0.7 U	0.8 U			0.8 U
Thallium	ND	SW6020A-Total	mg/kg				**0.055**	**0.043**	
Vanadium	35.4	SW6010B-Total	mg/kg	**35.4**	**39.3**	**37.9**			**32.2**
Vanadium	35.4	SW6020A-Total	mg/kg				**24.7**	**25.9**	
Zinc	80	SW6010B-Total	mg/kg	**80**	**78**	**91**			**106**
Zinc	80	SW6020A-Total	mg/kg				**51.1 J**	**58.6**	
Arsenic Speciation									
Arsenate		EPA 1632-As-Cryo-S-Speciation	mg/kg	**48.7 J**	**50.4 J**	**53.7 J**		**53.9**	**2480 J**
Arsenite		EPA 1632-As3-CRYO-T	mg/kg	**4.13 J**	**4.39 J**	**1.34 J**		**1.7**	**57.8 J**
Inorganic Arsenic		EPA 1632-Total Inorganic As - Solid	mg/kg	**52.8 J**	**54.8 J**	**55 J**		**55.6**	**2540 J**

Table A-3 Red Devil Creek Sediment Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD01	RD02	RD03	RD11	RD10	RD04
				10RD01SD	10RD02SD	10RD03SD	11RD11SD	11RD10SD	10RD04SD
Mercury Selective Sequential Extraction									
Hg(F0)		EPA 1631	ng/g	3.36 U		2.48 U		**297**	2.92 U
Hg(F1)		BRL SOP No. BR-0013	ng/g	**1.19 J**		**2.55 J**		**3**	**529 J**
Hg(F2)		BRL SOP No. BR-0013	ng/g	0.25 U		**0.39 J**		**1.14 J**	**107 J**
Hg(F3)		BRL SOP No. BR-0013	ng/g	**57.3 J**		**212 J**		**194 J**	**3840 J**
Hg(F4)		BRL SOP No. BR-0013	ng/g	**17.3 J**		**146 J**		**37.3**	**23700 J**
Hg(F5)		BRL SOP No. BR-0013	ng/g	**24.7**		**643**		**166**	**969000**
Hg(F6)		BRL SOP No. BR-0013	ng/g	**4.98 J**		**25.9 J**			**22.9 J**
Methylmercury									
Methylmercury	0.000177	CAS SOP	ng/g					**0.1 J**	
Methylmercury	0.000177	EPA 1630	ng/g	**0.177**	**7.02**	**0.218**			**0.766**
Semi-volatile Organic Compounds									
.gamma.-Sitosterol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**390 J**	**230 J**	
Benzo(b)fluoranthene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**1.5 J**	1.2 U	
Benzoic Acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**220**	96 U	
Benzyl Alcohol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**3.1 J**	2.1 U	
Diethyl Phthalate		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**1.7 J**	1.3 U	
Di-n-butyl Phthalate		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**9 J**	7.9 U	
Docosanoic acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**710 J**	**190 J**	
Heptacosane		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg					**270 J**	
Pentachlorophenol (PCP)		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**22 J**	20 U	
Phenanthrene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**1.9 J**	**2.1 J**	
Phenol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**4.1 J**	2 U	
Unknown		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**700 J**	**180 J**	
Unknown Alkane		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg					**99 J**	
Unknown Alkene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg					**240 J**	
Unknown Carboxylic Acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg				**370 J**	**130 J**	
Total Organic Carbon									
Carbon, Total Organic (TOC)		SW9060M-Total Organic Carbon, Modified for Matrix	%	**1.47**	**8.33**	**0.951**	**1.3**	**0.501**	**1.02**

Key

Bold = detection

Gray shading = exceedance of background

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.

µg/kg = micrograms per kilogram mg/kg = milligrams per kilogram ND = not detected

ng/g = nanograms per gram

% = percent

U = Analyte was analyzed for but not detected. Value provided is reporting limit.

UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

Table A-3 Red Devil Creek Sediment Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD05 10RD05SD	RD12 11RD12SD	RD09 10RD09SD	RD06 10RD06SD	RD07 10RD07SD	RD08 10RD08SD
Total Inorganic Elements									
Aluminum	10800	SW6010B-Total	mg/kg	**910**	**10600**	**11900**	**10200**	**9620**	**8440**
Antimony	ND	SW6010B-Total	mg/kg	**1590 J**	**6360 J**	**3600 J**	**4060 J**	**3430 J**	**1900 J**
Antimony	ND	SW6020A-Total	mg/kg						
Arsenic	65	SW6010B-Total	mg/kg	**130000**	**3610 J**	**2920**	**2950**	**2370**	**1890**
Arsenic	65	SW6020A-Total	mg/kg						
Barium	159	SW6010B-Total	mg/kg	**1990**		**521**	**459**	**542**	**379**
Barium	159	SW6020A-Total	mg/kg		**985 J**				
Beryllium	0.5	SW6010B-Total	mg/kg	1.39 U		**0.9**	**0.8**	**0.8**	**0.7**
Beryllium	0.5	SW6020A-Total	mg/kg		**0.705**				
Cadmium	0.3	SW6010B-Total	mg/kg	1.4 U		0.057 U	0.059 U	0.06 U	0.057 U
Cadmium	0.3	SW6020A-Total	mg/kg		**0.317 J**				
Calcium	2380	SW6010B-Total	mg/kg	**23400**	**3450 J**	**4080**	**3910**	**5000**	**4190**
Chromium	20.4	SW6010B-Total	mg/kg	18.1 U		**29**	**31**	**32**	**25**
Chromium	20.4	SW6020A-Total	mg/kg		**47.4 J**				
Cobalt	12.3	SW6010B-Total	mg/kg	**50**		**20.5**	**21.5**	**22.3**	**14.7**
Cobalt	12.3	SW6020A-Total	mg/kg		**12.5**				
Copper	21.7	SW6010B-Total	mg/kg	**30 J**		**55.6 J**	**58.2 J**	**55.5 J**	**39.9 J**
Copper	21.7	SW6020A-Total	mg/kg		**45.7 J**				
Iron	32100	SW6010B-Total	mg/kg	**344000**	**28900**	**35200**	**39200**	**34000**	**31000**
Lead	8	SW6010B-Total	mg/kg	12.5 U		**12**	**11**	**13**	**7**
Lead	8	SW6020A-Total	mg/kg		**1.72 J**				
Magnesium	2990	SW6010B-Total	mg/kg	**6440**	**5200 J**	**5440**	**5530**	**7700**	**4960**
Manganese	579	SW6010B-Total	mg/kg	**986**	**552**	**1250**	**1560**	**1690**	**784**
Mercury	0.18	SW7471A-Total	mg/kg	**8.6 J**	**77 J**	**46 J**	**63 J**	**60 J**	**79 J**
Nickel	32	SW6010B-Total	mg/kg	**240**		**64**	**61**	**62**	**49**
Nickel	32	SW6020A-Total	mg/kg		**47.2 J**				
Potassium	1200	SW6010B-Total	mg/kg	814 U	**2870 J**	**2850**	**2810**	**2770**	**2320**
Selenium	ND	SW6010B-Total	mg/kg	41 U		1.7 U	1.7 U	1.8 U	1.7 U
Selenium	ND	SW7742-Total	mg/kg		**0.62**				
Silver	ND	SW6010B-Total	mg/kg	2.8 U		0.113 U	0.117 U	0.12 U	0.113 U
Silver	ND	SW6020A-Total	mg/kg		**0.135 J**				
Sodium	ND	SW6010B-Total	mg/kg	1050 U	**225**	**270**	**250**	**230**	**210**
Thallium	ND	SW6010B-Total	mg/kg	17.4 U		0.7 U	0.7 U	0.7 U	0.7 U
Thallium	ND	SW6020A-Total	mg/kg		**0.297**				
Vanadium	35.4	SW6010B-Total	mg/kg	4.2 U		**26.8**	**25**	**27.6**	**25.1**
Vanadium	35.4	SW6020A-Total	mg/kg		**22.8**				
Zinc	80	SW6010B-Total	mg/kg	**120**		**96**	**100**	**91**	**83**
Zinc	80	SW6020A-Total	mg/kg		**65.7 J**				
Arsenic Speciation									
Arsenate		EPA 1632-As-Cryo-S-Speciation	mg/kg	**182000 J**	**2160**	**2930 J**	**4180 J**	**3680 J**	**2330 J**
Arsenite		EPA 1632-As3-CRYO-T	mg/kg	**5960 J**	**333**	**104 J**	**155 J**	**88.2 J**	**63.2 J**
Inorganic Arsenic		EPA 1632-Total Inorganic As - Solid	mg/kg	**188000 J**	**2490**	**3030 J**	**4340 J**	**3770 J**	**2390 J**

Table A-3 Red Devil Creek Sediment Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD05 10RD05SD	RD12 11RD12SD	RD09 10RD09SD	RD06 10RD06SD	RD07 10RD07SD	RD08 10RD08SD
Mercury Selective Sequential Extraction									
Hg(F0)		EPA 1631	ng/g	13.2 U	**41500**		2.36 U		**18.5**
Hg(F1)		BRL SOP No. BR-0013	ng/g	**7.24 J**	**79.4 J**		**640 J**		**1180 J**
Hg(F2)		BRL SOP No. BR-0013	ng/g	**7.09 J**	**4.94 J**		**166 J**		**27.6 J**
Hg(F3)		BRL SOP No. BR-0013	ng/g	**6580 J**	**1890 J**		**5090 J**		**1360 J**
Hg(F4)		BRL SOP No. BR-0013	ng/g	**1280 J**	**4090 J**		**21900 J**		**17700 J**
Hg(F5)		BRL SOP No. BR-0013	ng/g	**2550 M**	**17200 J**		**100000**		**142000**
Hg(F6)		BRL SOP No. BR-0013	ng/g	**63000 J**			**3040 J**		**7550 J**
Methylmercury									
Methylmercury	0.000177	CAS SOP	ng/g		**0.4 J**				
Methylmercury	0.000177	EPA 1630	ng/g	**12.7**		**0.69**	**0.993**	**0.578**	**1**
Semi-volatile Organic Compounds									
.gamma.-Sitosterol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Benzo(b)fluoranthene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Benzoic Acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Benzyl Alcohol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Diethyl Phthalate		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Di-n-butyl Phthalate		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Docosanoic acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Heptacosane		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Pentachlorophenol (PCP)		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Phenanthrene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Phenol		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Unknown		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Unknown Alkane		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Unknown Alkene		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Unknown Carboxylic Acid		SW8270C-Low Level Semivolatile Organics using LVI	µg/kg						
Total Organic Carbon									
Carbon, Total Organic (TOC)		SW9060M-Total Organic Carbon, Modified for Matrix	%	**2.28**	**0.476**	**0.882**	**0.868**	**0.827**	**0.94**

Key

Bold = detection

Gray shading = exceedance of background

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.

µg/kg = micrograms per kilogram mg/kg = milligrams per kilogram ND = not detected

ng/g = nanograms per gram

% = percent

U = Analyte was analyzed for but not detected. Value provided is reporting limit.

UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD02 10RD02SW	RD02 11RD02SW	RD03 10RD03SW	RD03 11RD03SW	RD11 11RD11SW	RD10 11RD10SW	RD04 10RD04SW
Total Inorganic Elements										
Aluminum	80	SW6010B-Total	µg/L	14.8 U	16.6 J	14.8 U	18.4 J	30.9 J	20.1 J	14.8 U
Antimony	1.52	SW6020A-Total	µg/L	1.3	1.42 J	1.5	1.51	8.81	1.95	11
Arsenic	1.1	SW6020A-Total	µg/L	1	1	0.9	0.8	6.7	1	8.2
Barium	26.4	SW6020A-Total	µg/L	25.2	21.6	23.4	21.2	32.1	22.3	24
Beryllium	ND	SW6020A-Total	µg/L	0.027 U	0.006 U	0.027 U	0.006 U	0.006 U	0.006 U	0.027 U
Cadmium	ND	SW6020A-Total	µg/L	0.022 U	0.005 U	0.022 U	0.006 J	0.005 U	0.005 U	0.022 U
Calcium	18400	SW6010B-Total	µg/L	18500	17300	18400	16800	8580	17200	18600
Chromium	0.43	SW6020A-Total	µg/L	0.053 U	0.22	0.053 U	0.23	0.22	0.37	0.053 U
Cobalt	0.066	SW6020A-Total	µg/L	0.007 U	0.061	0.007 U	0.046	0.677	0.06	0.007 U
Copper	0.37	SW6020A-Total	µg/L	0.232 U	0.29	0.232 U	0.28	0.71	0.35	0.232 U
Iron	138	SW6010B-Total	µg/L	190	131	140	118	2470	128	190
Iron	138	SW6020A-Total	µg/L							
Lead	0.021	SW6020A-Total	µg/L	0.2 U	0.008 J	0.2 U	0.013 J	0.021	0.018 J	0.2 U
Magnesium	9680	SW6010B-Total	µg/L	9660	9370	9690	9070	4460	9410	9870
Manganese	17.5	SW6020A-Total	µg/L	29.5	19.1	11.8	11.8	86.4	13.3	15.4
Nickel	0.44	SW6020A-Total	µg/L	0.081 U	0.36	0.081 U	0.39	1.38	0.46	0.081 U
Potassium	218 J	SW6010B-Total	µg/L	69.1 U	233 J	69.1 U	239 J	50 U	214 J	69.1 U
Selenium	0.5 J	SW6020A-Total	µg/L	0.125 U	0.5 J	0.125 U	0.4 J	0.3 U	0.3 U	0.125 U
Silver	ND	SW6020A-Total	µg/L	0.009 U	0.004 U	0.009 U	0.012 J	0.004 U	0.004 U	0.009 U
Sodium	1580	SW6010B-Total	µg/L	1700	1460	1730	1440	2370	1740	1820
Thallium	ND	SW6020A-Total	µg/L	0.003 U	0.005 U	0.003 U	0.007 J	0.005 U	0.005 U	0.003 U
Vanadium	0.3	SW6020A-Total	µg/L	0.026 U	0.1 J	0.026 U	0.16 J	0.22	0.15 J	0.026 U
Zinc	0.5 J	SW6020A-Total	µg/L	0.81 U	0.2 U	0.81 U	0.2 U	2.1	0.4 J	0.81 U
Total Low Level Mercury										
Mercury, Total	2.63	EPA 1631-Total	ng/L	2.83	3.94	2.33	4.5		4.27	15.8
Dissolved Inorganic Elements										
Aluminum, Dissolved	11.9 J	SW6010B-Diss	µg/L	14.8 U	8.7 J	14.8 U			10.2 J	14.8 U
Antimony, Dissolved	1.4 J	SW6020A-Diss	µg/L	1.2	1.41 J	1.4	1.5		1.57	10.4
Arsenic, Dissolved	0.9	SW6020A-Diss	µg/L	0.9	1	0.8	0.9		0.8	7.8
Barium, Dissolved	24	SW6020A-Diss	µg/L	24.3	21	22.8	21.2		20.7	23.6
Beryllium, Dissolved	ND	SW6020A-Diss	µg/L	0.027 U	0.006 U	0.027 U	0.006 U		0.006 U	0.027 U
Cadmium, Dissolved	ND	SW6020A-Diss	µg/L	0.022 U	0.005 U	0.022 U	0.005 U		0.005 U	0.022 U
Calcium, Dissolved	19200	SW6010B-Diss	µg/L	19000	17200	18600			16800	18600
Chromium, Dissolved	0.23	SW6020A-Diss	µg/L	0.053 U	0.2	0.053 U	0.21		0.3	0.053 U
Cobalt, Dissolved	0.056	SW6020A-Diss	µg/L	0.007 U	0.058	0.007 U	0.042		0.044	0.007 U
Copper, Dissolved	0.27	SW6020A-Diss	µg/L	0.232 U	0.36	0.232 U	0.26		0.29	0.232 U
Iron, Dissolved	100	SW6010B-Diss	µg/L	150	105	100			88.8	140
Lead, Dissolved	ND	SW6020A-Diss	µg/L	0.2 U	0.014 J	0.2 U	0.005 U		0.005 U	0.2 U
Magnesium, Dissolved	10200	SW6010B-Diss	µg/L	9990	9280	9870			9440	9930
Manganese, Dissolved	15.9	SW6020A-Diss	µg/L	24.9	18.5	8.2	8.49		9.41	13.6
Nickel, Dissolved	0.35	SW6020A-Diss	µg/L	0.081 U	0.58	0.081 U	0.32		0.37	0.081 U
Potassium, Dissolved	220 J	SW6010B-Diss	µg/L	69.1 U	256 J	69.1 U			215 J	69.1 U
Selenium, Dissolved	0.5 J	SW6020A-Diss	µg/L	0.125 U	0.6 J	0.125 U	0.3 J		0.3 U	0.125 U
Silver, Dissolved	ND	SW6020A-Diss	µg/L	0.009 U	0.004 U	0.009 U	0.004 U		0.004 U	0.009 U
Sodium, Dissolved	1610	SW6010B-Diss	µg/L	1680	1450	1690			1760	1770
Thallium, Dissolved	ND	SW6020A-Diss	µg/L	0.003 U	0.005 U	0.003 U	0.005 U		0.005 U	0.003 U
Vanadium, Dissolved	0.13 J	SW6020A-Diss	µg/L	0.026 U	0.11 J	0.026 U	0.11 J		0.12 J	0.026 U
Zinc, Dissolved	ND	SW6020A-Diss	µg/L	0.81 U	0.2 U	0.81 U	0.2 U		0.2 U	0.81 U
Dissolved Low Level Mercury										
Mercury, Dissolved	6.37	EPA 1631-Diss	ng/L	2.23	2.13	1.92	3.02		3.53	5.6
Arsenic Speciation										
Arsenate		EPA 1632 As-Cryo-W-Speciation	µg/L	0.862	0.828 J				0.595	1.58
Arsenite		EPA 1632 As3-CRYO-W	µg/L	0.122	0.089 J	1			0.227	0.342
Inorganic Arsenic		EPA 1632 Total Inorganic As - Water	µg/L	0.984	0.917 J				0.822	1.92

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD02	RD02	RD03	RD03	RD11	RD10	RD04
				10RD02SW	11RD02SW	10RD03SW	11RD03SW	11RD11SW	11RD10SW	10RD04SW
Methlymercury										
Methylmercury	0.08 J	EPA 1630	ng/L	**0.101**	**0.08 J**	**0.091**	**0.09 J**		**0.08 J**	**0.115**
Semi-Volatile Organic Compounds										
1-Methylnaphthalene		SW8270D	µg/L			0.48 U				0.48 U
2-Methylnaphthalene		SW8270C Base Neutral/Acid Semivolatile Organic compounds	µg/L				0.24 U	0.24 U	0.24 U	
2-Methylnaphthalene		SW8270D	µg/L			0.48 U				0.48 U
Naphthalene		SW8270C Base Neutral/Acid Semivolatile Organic compounds	µg/L				0.37 U	0.37 U	0.37 U	
Unknown Hydrocarbon		SW8270D	µg/L			**2 J**				0 U
Gasoline, Diesel and Residual Range Organics										
Gasoline Range Organics		AK 101	mg/L							
Diesel Range Organics		AK 102	mg/L							
Residual Range Organics		AK 103	mg/L							
General Chemistry										
Bicarbonate		A2320 General Chemistry Parameters	mg/L	**79.5**	**74.2**	**78.9**	**74**		**73.1**	**77.3**
Carbonate		A2320 General Chemistry Parameters	mg/L	1 U	3 U	1 U	1 U		3 U	1 U
Hydroxide		A2320 General Chemistry Parameters	mg/L	1 U		1 U				1 U
Hydroxide		SM 2320	mg/L							
Total Dissolved Solids		A2540C General Chemistry Parameters	mg/L		**76**		**51**		**71**	
Total Suspended Solids		A2540D General Chemistry Parameters	mg/L		5 U		5 U		5 U	
Total Dissolved Solids		EPA 160.1	mg/L	**84**		**81.5**				**87.5**
Total Suspended Solids		EPA 160.2	mg/L	1 U		1.1 U				1.1 U
Chloride		EPA 300.0 General Chemistry Parameters	mg/L	**0.4**	**0.36 J**	**0.5**	**0.39 J**		**0.38 J**	**0.5**
Fluoride		EPA 300.0 General Chemistry Parameters	mg/L	0.022 U	**0.05 J**	0.022 U	**0.08 J**		**0.06 J**	0.022 U
Sulfate			mg/L	**10.8**	**9.55**	**10.1**	**8.63**		**8.69**	**10.3**
Nitrate+Nitrite as Nitrogen		EPA 353.2 Nitrogen, Total Nitrate-Nitrite (Colorimetric, Automated, Cadmium	mg/L	**0.14**	**0.192**	**0.145**	**0.178**		**0.169**	**0.148**
Field Parameters										
Temperature		Field Test	°C	5.84	6.69	5.95	6.38	5.75	5.13	5.66
pH		Field Test	N/A	7.45	7.66	7.39	7.58	7.06	7.08	7.34
ORP		Field Test	mV	101	114	87	94	-26	68	42
Conductance		Field Test	mS/cm	0.194	0.163	0.190	0.161	0.091	0.160	0.190
Turbidity		Field Test	NTU	0.79	0.00	0.00	0.00	60.60	0.00	0.77
Dissolved Oxygen		Field Test	mg/L	14.1	12.11	13.13	10.06	18.68	11.50	16.32
Total Dissolved Solids		Field Test	g/L	0.1	0.106	0.123	0.104	0.059	0.104	0.124

Key

Bold = detection

°C = Degrees Celsius g/L = grams per liter

Gray shading = exceedance of background

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.

µg/L = micrograms per liter mg/L = milligrams per liter

mS/cm = Millisiemens per Centimeter mV = Millivolt

N/A = not applicable

ng/L = nanograms per liter

NTU = Nephelometric Turbidity Unit

ORP = Oxidation reduction potential

U = Analyte was analyzed for but not detected. Value provided is reporting limit.

UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD04 11RD04SW	RD05 10RD05SW	RD05 11RD05SW	RD12 11RD12SW	RD09 10RD09SW	RD09 11RD09SW	RD06 10RD06SW
Total Inorganic Elements										
Aluminum	80	SW6010B-Total	µg/L	14.1 J	14.8 U	6.5 J	18.7 J	14.8 U	22.6 J	14.8 U
Antimony	1.52	SW6020A-Total	µg/L	17.3	26.7	32.6	61.6	108	126 J	141
Arsenic	1.1	SW6020A-Total	µg/L	11.3 J	903	1030	22.5	73.1	73.1	79.6
Barium	26.4	SW6020A-Total	µg/L	22	102	103	22.8	29.2	25.5	29.5
Beryllium	ND	SW6020A-Total	µg/L	0.006 U	0.027 U	0.009 J	0.006 U	0.027 U	0.006 U	0.027 U
Cadmium	ND	SW6020A-Total	µg/L	0.005 U	0.022 U	0.005 U	0.005 U	0.022 U	0.005 U	0.022 U
Calcium	18400	SW6010B-Total	µg/L	16600	34400	36000	17400	18700	17500	19600
Chromium	0.43	SW6020A-Total	µg/L	0.28	0.053 U	0.15 J	0.25	0.053 U	0.57	0.053 U
Cobalt	0.066	SW6020A-Total	µg/L	0.059	5.3	5.24	0.058	0.3	0.244	0.3
Copper	0.37	SW6020A-Total	µg/L	0.33	0.232 U	0.45	0.38	0.232 U	0.47	0.232 U
Iron	138	SW6010B-Total	µg/L	147	2160	2390	137	190	205	180
Iron	138	SW6020A-Total	µg/L							
Lead	0.021	SW6020A-Total	µg/L	0.012 J	0.2 U	0.079	0.013 J	0.2 U	0.024	0.2 U
Magnesium	9680	SW6010B-Total	µg/L	9010	33700	37100	9800	10900	10500	11600
Manganese	17.5	SW6020A-Total	µg/L	14.6	379	354	13.3	26.5	26.4	30.5
Nickel	0.44	SW6020A-Total	µg/L	0.43	19.2	17.1	0.45	1.1	1.25	1.1
Potassium	218 J	SW6010B-Total	µg/L	254 J	1130	1210	225 J	69.1 U	312 J	69.1 U
Selenium	0.5 J	SW6020A-Total	µg/L	0.4 J	0.125 U	0.2 U	0.5 J	0.125 U	0.4 J	0.125 U
Silver	ND	SW6020A-Total	µg/L	0.004 U	0.009 U	0.004 U	0.004 U	0.009 U	0.004 U	0.009 U
Sodium	1580	SW6010B-Total	µg/L	1530	12800	12900	1810	2320	2050	2580
Thallium	ND	SW6020A-Total	µg/L	0.005 U	0.003 U	0.005 U	0.005 U	0.003 U	0.005 U	0.003 U
Vanadium	0.3	SW6020A-Total	µg/L	0.12 J	0.026 U	0.1 J	0.15 J	0.026 U	0.14 J	0.026 U
Zinc	0.5 J	SW6020A-Total	µg/L	0.2 U	0.81 U	1.7	0.3 J	0.81 U	0.5	0.81 U
Total Low Level Mercury										
Mercury, Total	2.63	EPA 1631-Total	ng/L	20.4	43.4	63	71.1	183	312	208
Dissolved Inorganic Elements										
Aluminum, Dissolved	11.9 J	SW6010B-Diss	µg/L	7 J	14.8 U	3.5 J	7 J	14.8 U	11.1 J	14.8 U
Antimony, Dissolved	1.4 J	SW6020A-Diss	µg/L	17.4	3.2	1.37	60.1	101	124 J	130
Arsenic, Dissolved	0.9	SW6020A-Diss	µg/L	10.6	857	856	21.8	67.8	69.8	74.2
Barium, Dissolved	24	SW6020A-Diss	µg/L	21.8	98.7	99.5	22.3	28.2	25.2	28.6
Beryllium, Dissolved	ND	SW6020A-Diss	µg/L	0.006 U	0.027 U	0.012 J	0.006 U	0.027 U	0.006 U	0.027 U
Cadmium, Dissolved	ND	SW6020A-Diss	µg/L	0.005 U	0.022 U	0.005 U	0.005 U	0.022 U	0.005 U	0.022 U
Calcium, Dissolved	19200	SW6010B-Diss	µg/L	16700	35000	36000	16900	19400	17700	19200
Chromium, Dissolved	0.23	SW6020A-Diss	µg/L	0.28	0.053 U	0.16 J	0.21	0.053 U	0.18 J	0.053 U
Cobalt, Dissolved	0.056	SW6020A-Diss	µg/L	0.049	4.9	4.35	0.049	0.2	0.21	0.2
Copper, Dissolved	0.27	SW6020A-Diss	µg/L	0.34	0.232 U	0.15	0.35	0.232 U	0.35	0.232 U
Iron, Dissolved	100	SW6010B-Diss	µg/L	111	2020	2180	89.7	130	149	110
Lead, Dissolved	ND	SW6020A-Diss	µg/L	0.006 J	0.2 U	0.005 J	0.005 U	0.2 U	0.008 J	0.2 U
Magnesium, Dissolved	10200	SW6010B-Diss	µg/L	8930	34800	36400	9460	11400	10600	11500
Manganese, Dissolved	15.9	SW6020A-Diss	µg/L	12.1	380	345	10.8	24.9	23.6	28.8
Nickel, Dissolved	0.35	SW6020A-Diss	µg/L	0.44	17	10.9	0.43	0.8	0.92	1
Potassium, Dissolved	220 J	SW6010B-Diss	µg/L	267 J	1130	1170	230 J	69.1 U	293 J	69.1 U
Selenium, Dissolved	0.5 J	SW6020A-Diss	µg/L	0.4 J	0.125 U	0.2 U	0.4 J	0.125 U	0.3 J	0.125 U
Silver, Dissolved	ND	SW6020A-Diss	µg/L	0.004 U	0.009 U	0.004 U	0.004 U	0.009 U	0.004 U	0.009 U
Sodium, Dissolved	1610	SW6010B-Diss	µg/L	1500	13000	12500 J	1720	2300	2060	2430
Thallium, Dissolved	ND	SW6020A-Diss	µg/L	0.005 U	0.003 U	0.005 U	0.005 U	0.003 U	0.005 U	0.003 U
Vanadium, Dissolved	0.13 J	SW6020A-Diss	µg/L	0.1 J	0.026 U	0.07 J	0.14 J	0.026 U	0.13 J	0.026 U
Zinc, Dissolved	ND	SW6020A-Diss	µg/L	0.2 U	0.81 U	0.2 U	0.3 J	0.81 U	0.5 J	0.81 U
Dissolved Low Level Mercury										
Mercury, Dissolved	6.37	EPA 1631-Diss	ng/L	6.81	3.04	2.42	13.9	14.1	10.9	15.4
Arsenic Speciation										
Arsenate		EPA 1632 As-Cryo-W-Speciation	µg/L	8.36 J	70	234	21.3			51.5
Arsenite		EPA 1632 As3-CRYO-W	µg/L	0.961 J	667	510	0.714			14.7
Inorganic Arsenic		EPA 1632 Total Inorganic As - Water	µg/L	9.32 J	737	745	22			66.2

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD04 11RD04SW	RD05 10RD05SW	RD05 11RD05SW	RD12 11RD12SW	RD09 10RD09SW	RD09 11RD09SW	RD06 10RD06SW
Methlymercury										
Methylmercury	0.08 J	EPA 1630	ng/L	**0.08 J**	**0.491**	**0.62**	**0.09 J**	**0.144**	**0.13**	**0.141**
Semi-Volatile Organic Compounds										
1-Methylnaphthalene		SW8270D	µg/L		**1.5**			0.48 U		0.48 U
2-Methylnaphthalene		SW8270C Base Neutral/Acid Semivolatile	µg/L	0.24 U		**1.2 J**	0.24 U		0.24 U	
2-Methylnaphthalene		SW8270D	µg/L		**1.5**			0.48 U		0.48 U
Naphthalene		SW8270C Base Neutral/Acid Semivolatile	µg/L	0.37 U		**0.68 J**	0.37 U		0.37 U	
Unknown Hydrocarbon		SW8270D	µg/L		0 U			**3 J**		0 U
Gasoline, Diesel and Residual Range Organics										
Gasoline Range Organics		AK 101	mg/L							
Diesel Range Organics		AK 102	mg/L							
Residual Range Organics		AK 103	mg/L							
General Chemistry										
Bicarbonate		A2320 General Chemistry Parameters	mg/L	**72.4**	**229**	**243**	**73.3**	**85.4**	**80.3**	**87.8**
Carbonate		A2320 General Chemistry Parameters	mg/L	3 U	1 U	3 U	3 U	1 U	3 U	1 U
Hydroxide		A2320 General Chemistry Parameters	mg/L		1 U			1 U		1 U
Hydroxide		SM 2320	mg/L							
Total Dissolved Solids		A2540C General Chemistry Parameters	mg/L	**82**		**244**	**72**		**81**	
Total Suspended Solids		A2540D General Chemistry Parameters	mg/L	5 U		5 U	5 U		5 U	
Total Dissolved Solids		EPA 160.1	mg/L		**110**			**116**		**83**
Total Suspended Solids		EPA 160.2	mg/L		**3.6**			1.1 U		1.1 U
Chloride		EPA 300.0 General Chemistry Parameters	mg/L	**0.38 J**	**0.6**	**0.46**	**0.35 J**	**0.5**	**0.36 J**	**0.5**
Fluoride		EPA 300.0 General Chemistry Parameters	mg/L	**0.07 J**	**0.1**	**0.13 J**	**0.07 J**	0.022 U	**0.05 J**	0.022 U
Sulfate		EPA 300.0 General Chemistry Parameters	mg/L	**9.1**	**28.5**	**27.7**	**9.07**	**13**	**11.9**	**13.2**
Nitrate+Nitrite as Nitrogen		EPA 353.2 Nitrogen, Total Nitrate-Nitrite (Colorimetric, Automated, Cadmium	mg/L	**0.185**	0.001 U	0.009 U	**0.156**	**0.116**	**0.192**	**0.127**
Field Parameters										
Temperature		Field Test	°C	5.00	3.79	6.77	5.09	4.84	6.77	4.43
pH		Field Test	N/A	6.66	6.11	5.37	5.97	7.16	7.71	6.98
ORP		Field Test	mV	15	-143	-38	71	57	9	113
Conductance		Field Test	mS/cm	0.162	0.524	0.387	0.177	0.215	0.166	0.072
Turbidity		Field Test	NTU	0.00	2.19	4.63	0.00	0.98	0.00	4.06
Dissolved Oxygen		Field Test	mg/L	16.00	16.29	9.00	13.61	14.55	15.61	15.06
Total Dissolved Solids		Field Test	g/L	0.106	0.335	0.251	0.115	0.14	0.108	0.046

Key

Bold = detection

°C = Degrees Celsius g/L = grams per liter

Gray shading = exceedance of background

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.

µg/L = micrograms per liter mg/L = milligrams per liter

mS/cm = Millisiemens per Centimeter mV = Millivolt

N/A = not applicable

ng/L = nanograms per liter

NTU = Nephelometric Turbidity Unit

ORP = Oxidation reduction potential

U = Analyte was analyzed for but not detected. Value provided is reporting limit.

UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD06 11RD06SW	RD07 10RD07SW	RD07 11RD07SW	RD08 10RD08SW	RD08 11RD08SW
Total Inorganic Elements								
Aluminum	80	SW6010B-Total	µg/L	**20.1 J**	14.8 U	**19.3 J**	14.8 U	**19.4 J**
Antimony	1.52	SW6020A-Total	µg/L	**162 J**	**158**	**167 J**	**170**	**184**
Arsenic	1.1	SW6020A-Total	µg/L	**85.3**	**80.5**	**80**	**85.6**	**78.1**
Barium	26.4	SW6020A-Total	µg/L	**28.3**	**29.8**	**26.5**	**30.8**	**26.2**
Beryllium	ND	SW6020A-Total	µg/L	0.006 U	0.027 U	0.006 U	0.027 U	0.006 U
Cadmium	ND	SW6020A-Total	µg/L	0.005 U	0.022 U	**0.005 J**	0.022 U	0.005 U
Calcium	18400	SW6010B-Total	µg/L	**17800**	**18900**	**18000**	**19600**	**17900**
Chromium	0.43	SW6020A-Total	µg/L	**0.27**	0.053 U	**0.28**	0.053 U	**0.52**
Cobalt	0.066	SW6020A-Total	µg/L	**0.274**	**0.2**	**0.23**	**0.2**	**0.23**
Copper	0.37	SW6020A-Total	µg/L	**0.45**	0.232 U	**0.53**	**0.5**	**0.48 J**
Iron	138	SW6010B-Total	µg/L	**199**	**150**	**186**	**140**	**189**
Iron	138	SW6020A-Total	µg/L					
Lead	0.021	SW6020A-Total	µg/L	**0.02 J**	0.2 U	**0.026**	0.2 U	**0.029 J**
Magnesium	9680	SW6010B-Total	µg/L	**10600**	**11300**	**10700**	**11600**	**11000**
Manganese	17.5	SW6020A-Total	µg/L	**32.7**	**27.6**	**28.2**	**24.5**	**32**
Nickel	0.44	SW6020A-Total	µg/L	**1.18**	**1**	**1.13**	**1**	**1.23**
Potassium	218 J	SW6010B-Total	µg/L	**299 J**	69.1 U	**292 J**	69.1 U	**312 J**
Selenium	0.5 J	SW6020A-Total	µg/L	**0.3 J**	0.125 U	**0.4 J**	0.125 U	**0.5 J**
Silver	ND	SW6020A-Total	µg/L	0.004 U	0.009 U	0.004 U	0.009 U	**0.008 J**
Sodium	1580	SW6010B-Total	µg/L	**2130**	**2440**	**2150**	**2590**	**2430**
Thallium	ND	SW6020A-Total	µg/L	0.005 U	0.003 U	0.005 U	0.003 U	0.005 U
Vanadium	0.3	SW6020A-Total	µg/L	**0.15 J**	0.026 U	**0.12 J**	0.026 U	**0.14 J**
Zinc	0.5 J	SW6020A-Total	µg/L	**0.3 J**	0.81 U	**0.3 J**	0.81 U	**0.5 J**
Total Low Level Mercury								
Mercury, Total	2.63	EPA 1631-Total	ng/L	**214**	**233**	**200**	**385**	**239**
Dissolved Inorganic Elements								
Aluminum, Dissolved	11.9 J	SW6010B-Diss	µg/L	**15 J**	14.8 U	**11.1 J**	14.8 U	**19.7 J**
Antimony, Dissolved	1.4 J	SW6020A-Diss	µg/L	**148 J**	**143**	**163 J**	**158**	**184**
Arsenic, Dissolved	0.9	SW6020A-Diss	µg/L	**74.7**	**73.7**	**73.1**	**75.4**	**80.9**
Barium, Dissolved	24	SW6020A-Diss	µg/L	**25.9**	**28.5**	**26.2**	**29.5**	**27.3**
Beryllium, Dissolved	ND	SW6020A-Diss	µg/L	0.006 U	0.027 U	0.006 U	0.027 U	0.006 U
Cadmium, Dissolved	ND	SW6020A-Diss	µg/L	0.005 U	0.022 U	0.005 U	0.022 U	0.005 U
Calcium, Dissolved	19200	SW6010B-Diss	µg/L	**17900**	**19100**	**17800**	**19400**	**17900**
Chromium, Dissolved	0.23	SW6020A-Diss	µg/L	**0.11 J**	0.053 U	**0.33**	0.053 U	**0.39**
Cobalt, Dissolved	0.056	SW6020A-Diss	µg/L	**0.229**	0.007 U	**0.197**	0.007 U	**0.236**
Copper, Dissolved	0.27	SW6020A-Diss	µg/L	**0.32**	0.232 U	**0.32**	0.232 U	**0.5**
Iron, Dissolved	100	SW6010B-Diss	µg/L	**140**	**90**	**104**	**70**	**176**
Lead, Dissolved	ND	SW6020A-Diss	µg/L	0.005 U	0.2 U	0.005 U	0.2 U	**0.037**
Magnesium, Dissolved	10200	SW6010B-Diss	µg/L	**10900**	**11500**	**11000**	**11600**	**11000**
Manganese, Dissolved	15.9	SW6020A-Diss	µg/L	**27.5**	**24.6**	**24.3**	**20.1**	**27.5**
Nickel, Dissolved	0.35	SW6020A-Diss	µg/L	**0.99**	**0.9**	**1**	**0.8**	**1.26**
Potassium, Dissolved	220 J	SW6010B-Diss	µg/L	**287 J**	69.1 U	**286 J**	69.1 U	**382 J**
Selenium, Dissolved	0.5 J	SW6020A-Diss	µg/L	**0.3 J**	0.125 U	**0.3 J**	0.125 U	0.3 U
Silver, Dissolved	ND	SW6020A-Diss	µg/L	0.004 U	0.009 U	0.004 U	0.009 U	**0.009 J**
Sodium, Dissolved	1610	SW6010B-Diss	µg/L	**2180**	**2460**	**2190**	**2490**	**2430**
Thallium, Dissolved	ND	SW6020A-Diss	µg/L	0.005 U	0.003 U	0.005 U	0.003 U	0.005 U
Vanadium, Dissolved	0.13 J	SW6020A-Diss	µg/L	**0.09 J**	0.026 U	**0.09 J**	0.026 U	**0.13 J**
Zinc, Dissolved	ND	SW6020A-Diss	µg/L	0.2 U	0.81 U	0.2 U	0.81 U	**1**
Dissolved Low Level Mercury								
Mercury, Dissolved	6.37	EPA 1631-Diss	ng/L	**13.3**	**16.4**	**13.5**	**15.5**	**12.4**
Arsenic Speciation								
Arsenate		EPA 1632 As-Cryo-W-Speciation	µg/L	**55.7**			**83**	**76.9 J**
Arsenite		EPA 1632 As3-CRYO-W	µg/L	**19.5 J**			**3.76**	**10.2**
Inorganic Arsenic		EPA 1632 Total Inorganic As - Water	µg/L	**75.1**			**86.8**	**87.1 J**

Table A-4 Surface Water Results

Analyte	Background Screening Criteria	Station ID / Sample ID / Method	Units	RD06 11RD06SW	RD07 10RD07SW	RD07 11RD07SW	RD08 10RD08SW	RD08 11RD08SW
Methlymercury								
Methylmercury	0.08 J	EPA 1630	ng/L	**0.14**	**0.123**	**0.14**	**0.129**	**0.12**
Semi-Volatile Organic Compounds								
1-Methylnaphthalene		SW8270D	µg/L		0.48 U		0.48 U	
2-Methylnaphthalene		SW8270C Base Neutral/Acid Semivolatile Organic compounds	µg/L	0.24 U		0.24 U		0.24 U
2-Methylnaphthalene		SW8270D	µg/L		0.48 U		0.48 U	
Naphthalene		SW8270C Base Neutral/Acid Semivolatile Organic compounds	µg/L	0.37 U		0.37 U		0.37 U
Unknown Hydrocarbon		SW8270D	µg/L		0 U		0 U	
Gasoline, Diesel and Residual Range Organics								
Gasoline Range Organics		AK 101	mg/L					
Diesel Range Organics		AK 102	mg/L					
Residual Range Organics		AK 103	mg/L					
General Chemistry								
Bicarbonate		A2320 General Chemistry Parameters	mg/L	**81.2**	**87.8**	**81.3**	**87**	**81.9**
Carbonate		A2320 General Chemistry Parameters	mg/L	3 U	1 U	3 U	1 U	3 U
Hydroxide		A2320 General Chemistry Parameters	mg/L		1 U		1 U	
Hydroxide		SM 2320	mg/L					
Total Dissolved Solids		A2540C General Chemistry Parameters	mg/L	**78**		**84**		**89**
Total Suspended Solids		A2540D General Chemistry Parameters	mg/L	5 U		5 U		5 U
Total Dissolved Solids		EPA 160.1	mg/L		**115**		**220**	
Total Suspended Solids		EPA 160.2	mg/L		1.1 U		1.1 U	
Chloride		EPA 300.0 General Chemistry Parameters	mg/L	**0.37 J**	**0.5**	**0.45**	**0.5**	**0.37 J**
Fluoride		EPA 300.0 General Chemistry Parameters	mg/L	**0.04 J**	0.022 U	**0.09 J**	0.022 U	**0.06 J**
Sulfate		EPA 300.0 General Chemistry Parameters	mg/L	**12.2**	**13.2**	**11.9**	**13.1**	**12.1**
Nitrate+Nitrite as Nitrogen		EPA 353.2 Nitrogen, Total Nitrate-Nitrite (Colorimetric, Automated, Cadmium	mg/L	**0.182**	**0.143**	**0.173**	**0.115**	**0.169**
Field Parameters								
Temperature		Field Test	°C	6.59	4.22	6.31	4.40	5.60
pH		Field Test	N/A	7.62	6.56	7.57	6.27	7.49
ORP		Field Test	mV	86	177	80	2.53	36
Conductance		Field Test	mS/cm	0.168	0.220	0.170	0.229	0.120
Turbidity		Field Test	NTU	0.00	0.21	0.00	0.59	0.00
Dissolved Oxygen		Field Test	mg/L	9.77	16.96	10.75	13.9	11.66
Total Dissolved Solids		Field Test	g/L	0.109	0.143	0.11	0.149	0.077

Key

Bold = detection

°C = Degrees Celsius g/L = grams per liter

Gray shading = exceedance of background

J = Analyte detected but relative percent difference was outside control limits; therefore, concentration is estimated.

µg/L = micrograms per liter mg/L = milligrams per liter

mS/cm = Millisiemens per Centimeter mV = Millivolt

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ng/L = nanograms per liter

NTU = Nephelometric Turbidity Unit

ORP = Oxidation reduction potential

U = Analyte was analyzed for but not detected. Value provided is reporting limit.

UJ = Indicates the compound of analyte was analyzed for but not detected. The sample detection limit is an estimated value.

B RDM Site ARARs and TBCs

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action 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. Department on the Interior to do so.	Applicable to all Alternatives	All alternatives can be imple-mented to be compliant.
Historic Sites, Buildings and Antiques Act, Executive Order 11593	16 USC 461 et seq. 36 CFR 62.1 36 CFR 63 40 CFR Part 6.301(a)	Requires federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts to such landmarks. This Executive Order provides for the inventory and nomination of historical and archaeological sites. There are no buildings remaining at RDM; therefore, this requirement is not an ARAR.	Not applicable, no structures to be addressed.	All alternatives can be imple-mented to be compliant.
National Historic Preservation Act	16 USC 470 et seq. 36 CFR 63 and 800 40 CFR 6.301(b)	Requires federal agencies to take into account the effect of any action on any district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places. Regulates inventory, assessment, and consultation on project impacts and protection measures for cultural properties on federal lands. There are no buildings remaining at RDM; therefore, this requirement is not an ARAR.	Not applicable, no structures to be addressed.	All alternatives can be imple-mented to be compliant.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable only to Alternative 4.	All alternatives can be imple-mented to be compliant.
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable to all alternatives.	All alternatives can be imple-mented to be compliant.

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Appropriate to all alternatives.	All alternatives can be imple-mented to be compliant.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable to all alternatives.	All alternatives can be imple-mented to be compliant.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the US.	Applicable	All alternatives can be imple-mented to be compliant.
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	While appli-cable, no endangered species have been identified within project area.	All alternatives can be imple-mented to be compliant.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable to all alternatives	All alternatives can be imple-mented to be compliant.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Provides for protection of Essential Fish Habitat.	Applicable	All alternatives can be implemented to be compliant.

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
State				
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable, action will reduce contaminant loading to Kuskokwim River.	All alternatives can be implemented to be compliant.
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the US. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable as Early Action does address surface water.	All alternatives can be implemented to be compliant.
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the US, including wetlands. Requires that if there is no practicable alternative to impacting navigable waters of the US, then the impact must be minimized and unavoidable loss must be compensated for through mitigation on-site or off-site.	Applicable to all alternatives.	All alternatives can be implemented to be compliant.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable for all alternatives.	All alternatives can be implemented to be compliant.
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable for all alternatives provided material is removed from the site.	All alternatives can be implemented to be compliant.

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved off the site Area of Contamination.	Relevant and Appropriate for waste removal from site.	All alternatives can be imple-mented to be compliant.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved off the site Area of Contamination.	Applicable for all alternatives provided material is removed from the site.	All alternatives can be imple-mented to be compliant.
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved off the site Area of Contamination.	Relevant and Appropriate provided material is removed from the site.	All alternatives can be imple-mented to be compliant.
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable (if offsite disposal included in the remedial action)	All alternatives can be imple-mented to be compliant.
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable (only if offsite disposal included in the remedial action)	All alternatives can be imple-mented to be compliant.
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable, but no restoration is planned for this site.	All alternatives can be imple-mented to be compliant.

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
State				
Alaska Solid Waste Regulations	18 AAC 60.007 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025(b) 18 AAC 60.210(b)(3),(5),(6),(7) 18 AAC 60.217 18 AAC 60.220(1) 18 AAC 60.225 18 AAC 60.233(1) 18 AAC 60.330 18 AAC 60.410 18 AAC 60.490	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable for all action alter-natives.	All alternatives can be imple-mented to be compliant.
Alaska Anti-Degradation Water Quality Standards	18 AAC 70.015	Specifies that actions may not degrade water that is higher in quality than Ambient Water Quality Criteria unless approval is received from the Alaska Department of Environmental Conservation.	Applicable.	All alternatives can be imple-mented to be compliant.
Alaska Wastewater Disposal Regulations	18 AAC 72.600(c) and (e)	Governs nondomestic wastewater discharges.	Applicable (if wastewater is generated as part of the remedial action), for all alternatives	All alternatives can be imple-mented to be compliant.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.355(b),(c) and (d) 18 AAC 75.360(2),(3),(4)(c),(6),(7),(8) 18 AAC 75.370	Provides operation and reporting requirements for the cleanup of oil or other hazardous substance releases, including standards and guidance for site characterization, cleanup levels, and risk assessment.	Applicable to all alternatives.	All alternatives can be imple-mented to be compliant.

Table B-1 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARAR or TBC	Alternatives Compliance with ARARs
Alaska Pollutant Discharge Elimination System Program	18 AAC 83	Establishes a program for controlling stormwater discharges from inactive mine sites.	Applicable for all alternatives during con-struction activities.	All alternatives can be imple-mented to be compliant.

Key:
AAC = Alaska Administrative Code.
ADEC = Alaska Department of Environmental Conservation.
ARAR = Applicable or Relevant and Appropriate Requirements.
AS = Alaska Statutes.
ATSDR Agency for Toxic Substances and Disease Registry.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
CFR = Code of Federal Regulations.
EPA = U.S. Environmental Protection Agency.
RCRA = Resource Conservation and Recovery Act.
RDM = Red Devil Mine.
TBC = To Be Considered.
USC = United States Code.

C Hydrologic and Hydraulic Report

C Hydrologic and Hydraulic Report

1. Introduction

1.1.Objective

The objective of this engineering analysis is to evaluate the hydrology of Red Devil Creek and examine alternatives to reduce sediment transport in Red Devil Creek. This effort was performed using available data and without a site visit. An array of alternatives that could be pursued at the site were analyzed and an order of magnitude cost was developed.

1.2.Project Description

The Red Devil Mine is in a remote part of western Alaska, on the south side of the Kuskokwim River. It is approximately 250 miles west of Anchorage, 1.5 miles upstream from the village of Red Devil and approximately 8 miles downstream from Sleetmute. The mine occupies approximately 10 acres of BLM managed Land. An airstrip at the village of Red Devil provides access to the area. From the airstrip, the mine can be accessed by boat on the Kuskokwim River or along an unimproved road.

Red Devil Mine started producing mercury in 1933. At times, the mine was one of the largest producers of mercury in the United States. By 1971 the mine had ceased operations and by 1982 the mine was permanently closed.

At the end of its life, the mine consisted of a series of underground workings, open shafts and adits, mine process buildings, a power plant, above-ground fuel tanks, living quarters and a reservoir in the upper reach of Red Devil Creek. Over the last 20+ years, the BLM has closed the shafts and adits, demolished onsite buildings and tanks, and disposed of the demolition debris in onsite repositories. Tailings and waste rock deposited along Red Devil Creek as part of mining operations remain in place, along with extensive surface disturbance in the upper elevations on the northeast side of the mine process area and an old barge landing at the mouth of Red Devil Creek.

2. Hydrologic Analysis

2.1.Methodology

Examination of the site topography allowed the site to be broken up into four drainages for evaluation. Hydrologic analyses were performed to determine the peak flows for various recurrence intervals within the project area. The Soil Conservation Service (SCS) discharge method was applied to all four basins in order to determine the peak flows for the 2, 5, 10, 25, 50 and 100-year events. The SCS method is based upon the United States Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS). Technical Release 55: Urban Hydrology for Small Watersheds (TR-55). The input data required for the SCS Method includes the drainage areas, runoff curve numbers (RCNs), the time of concentration (T_c) and the associated precipitation values. The calculated peak flows were used to determine the shear stress and associated sediment movement with each recurrence interval.

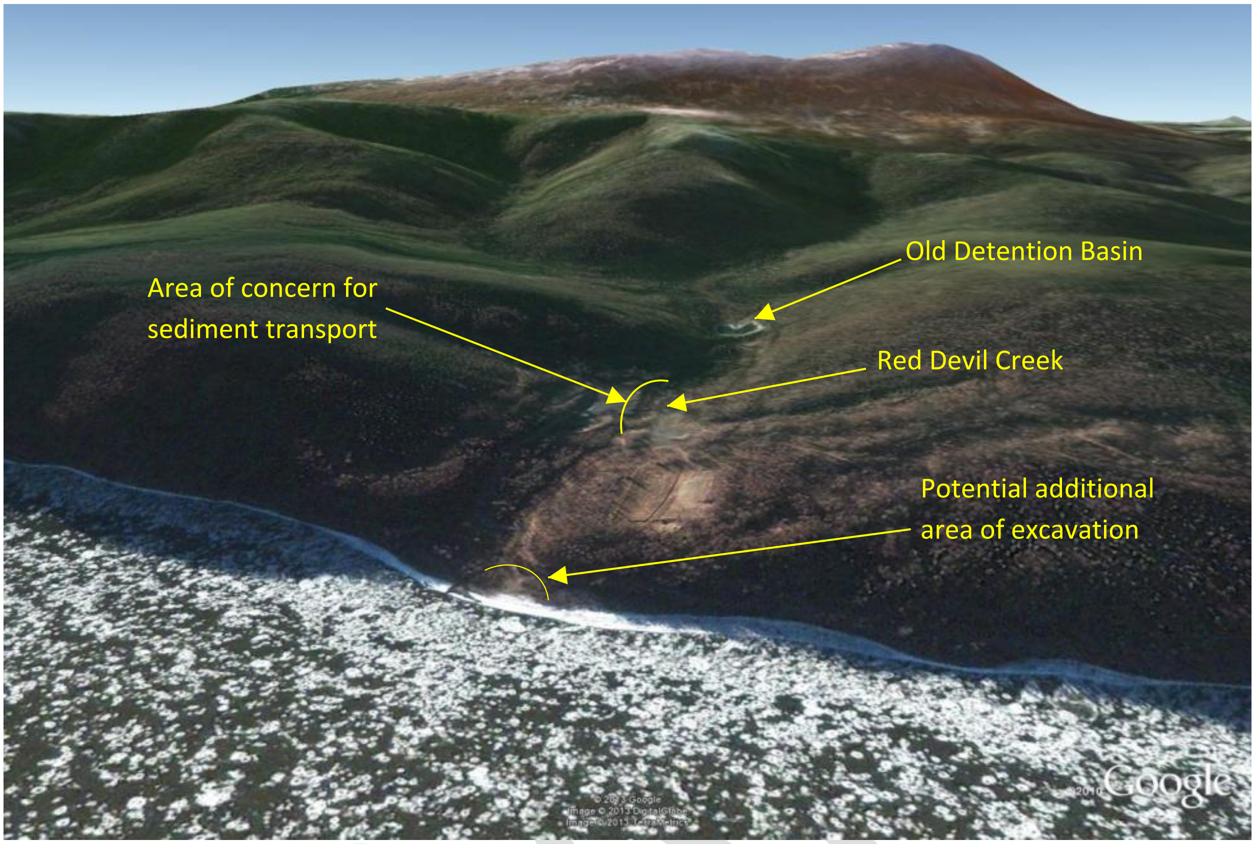

Figure 1 Overview of Red Devil Mine Site and area of concern for this analysis

Precipitation values were acquired from the most recent precipitation frequency estimates published by the National Oceanographic and Atmospheric Administration (NOAA) for the State of Alaska (Perica & al., 2012). Precipitation frequency estimates used for this study are given in Table 1. TR-55 specifies that a Type I storm should be used for Alaska. The type I storm represents the Pacific Maritime climate with wet winters and dry summers. For hydrologic analysis run off for a 24 hour storm was developed using the latest published NWS values.

Table 1: Rainfall for 24-hour Storm Events
NOAA Atlas 14, Volume 7, Version 2
Red Devil, Alaska

Event Year	Rainfall (Inches)
2	1.48
5	1.88
10	2.21
25	2.68
50	3.06
100	3.47

2.2.Drainage Basin Characteristics

Peak runoff generated from storm events is dependent on the area drained, the basin slopes, and the soil characteristics of the contributing drainage basins. Four drainage basins were defined in order to determine flows resulting during the 2-, 10-, 25-, 50- and 100-year storm events. The drainage basins and their acreage were defined based upon existing topographic maps, geographic information systems (GIS) information, and Google Earth. Time of concentration (Tc) was determined for each basin by adding the sheet flow for 100 feet to the shallow concentrated flow, which was subdivided for changes in slope. Travel time for open channel flow was added below the detention basin. The CN number was determined for the basin assuming the vegetation to be brush with soil group C. For the SCS analysis, soils are classified into four hydrologic groups (A,B,C and D) based upon rates of hydraulic conductivity, where Group A soils have the most potential for infiltration and Group D soils have the least potential for infiltration. Soils within the basins have not been characterized, so the soil was assumed to be classified in Group C until further information is available. Group C soils are moderately fine to fine textured, have low infiltration rates when thoroughly wetted, and consist of soils with a layer that impedes downward movement of water. Boring logs from the Red Devil Mine area indicate that most of the upland soils in the area overlie weathered bedrock which would impede the downward movement of water, and without information on the upland soil, it is assumed that it is fine textured with low infiltration. The drainage basin map is shown in Figure 2. The area is undeveloped except for the detention basin and the lower portion of the former mine area. Acreage and values used as input for the SCS analysis are presented in Table 2

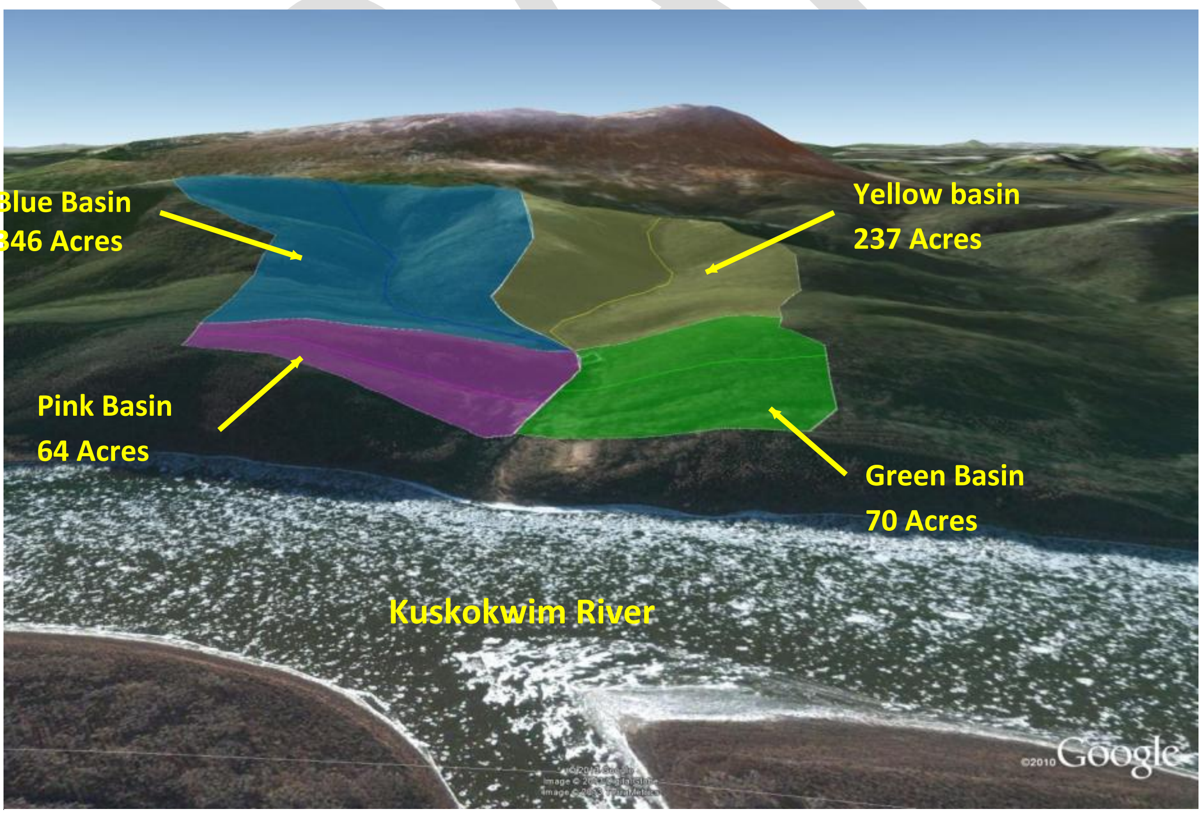

Figure 2 Illustration of Drainage Basin

Table 2 Drainage basin acreage

	Sub-Basin	Area (Acres)	CN	Tc (min)
Red Devil (717 Acres)	Blue	346	70	41
	Yellow	237	70	44
	Pink	64	70	40
	Green	70	70	36

Drainage from the Blue and Yellow basins collect in a channel that drains into the detention basin upstream of the mine site. Channelized flow begins again at the outlet of the detention basin where it continues past the mine site. The Pink and Green basins drain into the channel below the detention basin. The idealized watershed is shown in Figure 3.

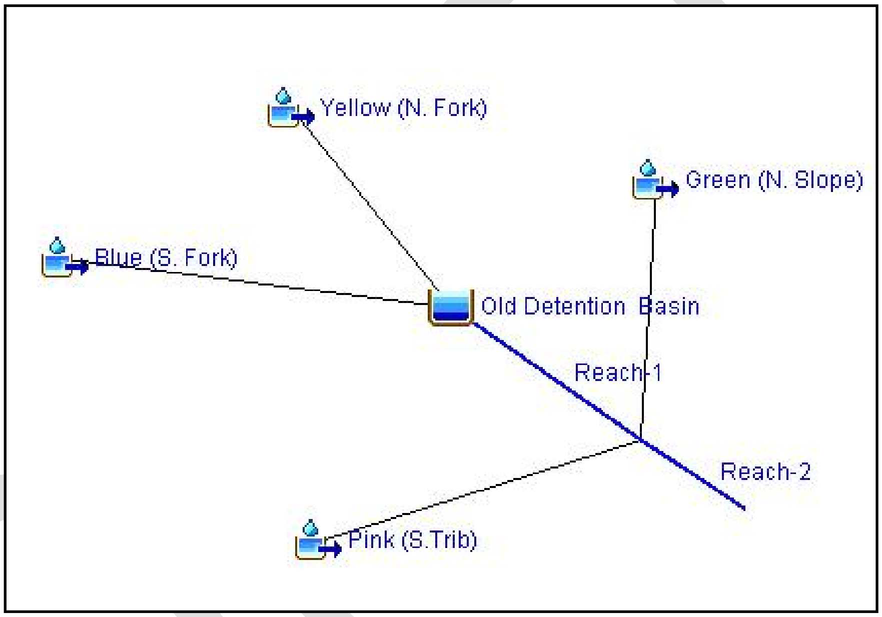

Figure 3 Idealized watershed in HEC-HMS model

2.3.Hydrologic Modeling Results

Table 3 tabulates the peak discharge and related return periods using the SCS method for the area below the mine site tailings piles.

Table 3. Peak Discharge Below the Mine Site for Storm Events using the SCS method.

Location	2 year (cfs)	5 year (cfs)	10 year (cfs)	25 year (cfs)	50 year (cfs)	100 year (cfs)
Red Devil Creek	5.0	12.9	28.2	59.7	87.5	117.6

Results of this analysis were checked against flow measurements made by the BLM's contractor, E&E, in the spring of 2012, and in the fall of 2011 and 2012. Flow results at E&E location RD06 were used for this comparison since it was located close to the bottom of the reach for the hydrologic analysis (Figure 4).

The E&E measurements at RD06 in the fall of 2011 and 2012 were 3.8 cfs and 6.8 cfs, respectively. This flow rate would correspond approximately to a 1-2 year event, and would be representative of the hydrologic cycle totally governed by rain. A flow of 14.5 cfs was measured at RD06 in May of 2012 and is representative of a higher flow due to snowmelt. If this flow rate were solely due to a rainfall event, it would correspond to approximately a 5 year return interval event. Return intervals and associated flows for rain on snow events were not evaluated for this analysis. These discharge measurements appear reasonable when compared to the field measurements.

The depth and velocity associated with the flow rates were calculated using an idealized cross section which set the hydraulic radius equal to the depth of water. This provides reasonable values in lieu of actual data. The idealized cross section was checked with the cross section measurements made by E&E, and compared well with the measurements at RD06. A constant slope of 5% was assumed based on E&E reports of the average creek slope, and a roughness value of 0.043 was used[1]. Using Mannings equation for open channel flow, the depth and velocity were calculated for each measured flow and compared to the measured value. There was some variation between the calculated average depth and velocity and the field measurements, but for this quick engineering study of the site, the values were considered to be adequately representative for determination of incipient sediment movement.

Table 4. Flow depths associated with Storm Events using the SCS method and an idealized cross section.

	August 2011	Spring 2012	Fall 2012
Cross Section Flow [ft^3/s]	6.81	14.47	3.80
E&E measured velocity [ft/s]	2.93	2.33	1.18
Calculated velocity [ft/s]	2.65	3.53	2.2
E&E measured average depth [ft]	0.38	0.55	0.37
Calculated average depth [ft]	0.216	0.31	0.15

[1] Roughness value obtained from Roughness Characteristics of Natural Channels, USGS Water Supply Paper 1849, Harry H. Barnes

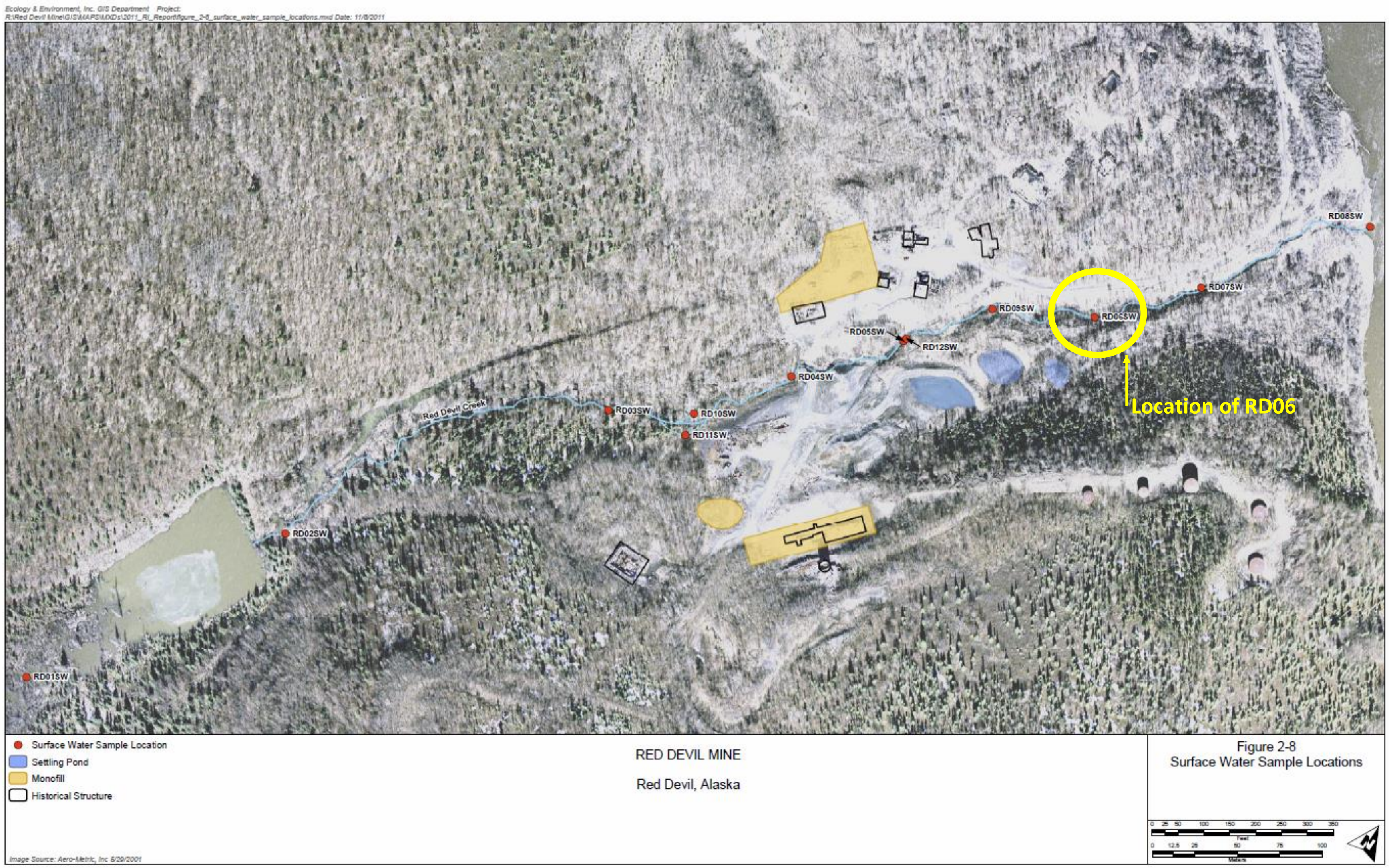

Figure 4 Location of RD06 from E&E's Remedial Investigation Report

Figure 5 Red Devil Creek in September 2012

The calculated depths were used as input to use Shields Diagram to determine sediment size for incipient transport and corresponding velocities. The creek flow rate and calculated velocity, depth, and sediment size that could be transported are shown in Table 5. Table 6 shows the sediment classification with the associated grain size.

Table 5. Flow depths associated with Storm Events using the SCS method and an idealized cross section.

	2 year (5.0 cfs)	5 year (12.9 cfs)	10 year (28.2 cfs)	25 year (59.7 cfs)	50 year (87.5 cfs)	100 year (117.6 cfs)
Red Devil Creek Velocity [ft/s]	2.6	3.6	4.8	6.2	7.32	7.7
Average Red Devil Creek depth [ft]	0.20	0.33	0.51	.72	.92	1.0
Sediment size transported [mm]	≤2.0 Very coarse sand	≤3.0 Very fine gravel	≤4.2 Very fine gravel	≤7.0 Fine gravel	≤9.5* Medium gravel	≤11.0* Medium gravel

*Estimated values beyond use of Shields curve

Table 6 Sediment classification with associated grain size

Table 12-7 Grain Size Classification of Sediment Material

American Geophysical Union

Sediment Material	Grain Diameter Range(mm)	Geometric Median Diameter (mm)
Clay	0.002-0.004	0.003
Very Fine Silt	0.004-0.008	0.006
Fine Silt	0.008-0.016	0.011
Medium Silt	0.016-0.032	0.023
Coarse Silt	0.032-0.0625	0.045
Very Fine Sand	0.0625-0.125	0.088
Fine Sand	0.125-0.250	0.177
Medium Sand	0.250-0.5	0.354
Coarse Sand	0.5-1.0	0.707
Very Coarse Sand	1-2	1.41
Very Fine Gravel	2-4	2.83
Fine Gravel	4-8	5.66
Medium Gravel	8-16	11.3
Coarse Gravel	16-32	22.6
Very Coarse Gravel	32-64	45.3
Small Cobbles	64-128	90.5
Large Cobbles	128-256	181
Small Boulders	256-512	362
Medium Boulders	512-1024	724
Large Boulders	1024-2048	1448

3. Project Alternatives

3.1.Partial Excavation

Excavation to 5 feet

A partial excavation of the tailings pile to 5 feet would remove the sediment that is available for transport from the area of the creek to a depth of five feet or until bedrock is encountered. Depths and distances for excavation were based on information available in the E&E Remedial Investigation Report 2013, and consultation with the Bureau of Land Management. The length of the excavation would extend down the creek for a distance of 500 feet on the north side and 600 feet on the south side in the area of concern (Figure 1).The depth of excavation would extend down five feet or until weathered bedrock is encountered. The width of excavation on the north side of the creek would extend approximately 10 feet back from the creek centerline and then sloped back at a 2 horizontal to 1 vertical slope, and the south side excavation would extend 25 feet from the creek centerline and then slope back into the existing ground on a 3 horizontal to 1 vertical slope (Figure 7). The smaller excavation and steeper slope on the north side was necessary in order to avoid excavation into Monofill 1 (Figure 8). A shallow slope angle was used to prevent erosion from occurring. A cross section of the excavation and the geologic cross section is shown in Figure 7.

Restoration of the stream in the area of excavation is not part of this proposed action. Once excavation is complete, the stream will be allowed to meander through the excavated area. In order to prevent the stream from meandering and eroding the toe of the cut slope, protection will be placed at the toe up to two feet (>100 year return interval depth using an idealized cross section). For this assessment, it is assumed that the toe protection would be a single layer of small mesh gabions with imported fill. It is assumed that drainage down the face of the slope will be minimal. Any erosion associated with drainage down the face of the slope will be caught by the toe protection.

Diversion of Red Devil Creek will be an aspect of the construction that will need to be developed along with the BLM during preparation of plans and specifications. Several approaches are possible ranging from putting the burden on the contractor to address all flow (least risky $), to placing an upper flow limit on the time that the contractor can work (moderately risky $$), to allowing the contractor to work during summer months, assuming low flow conditions (very risky $$$).

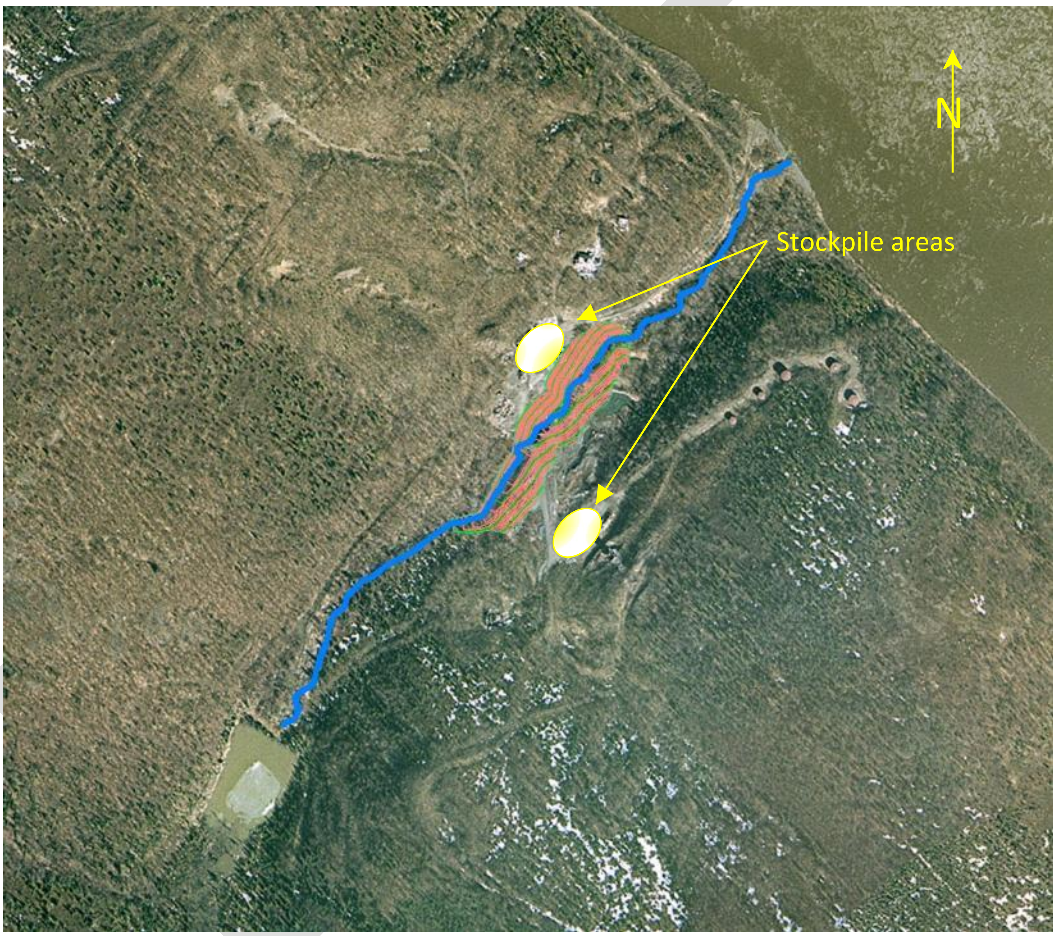

Figure 6 Plan view of 5 foot deep excavation

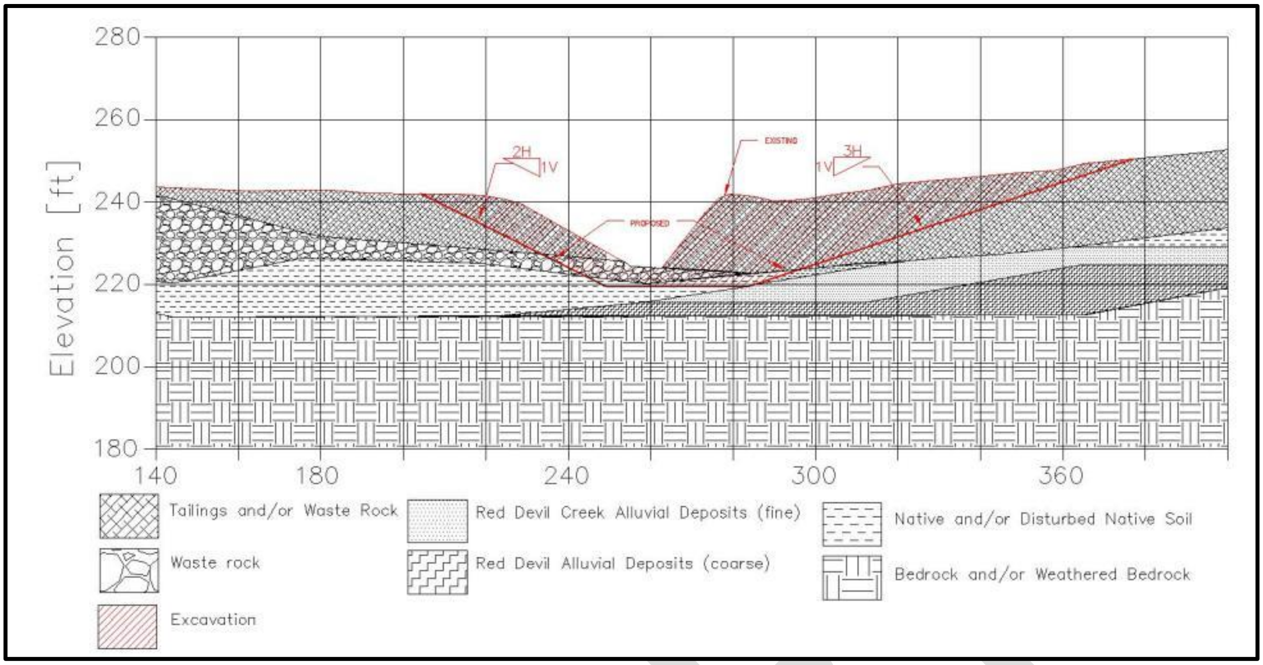

Figure 7 Cross section of excavation to 5 feet with geologic data extracted from E&E Remedial Investigation Report (2013)

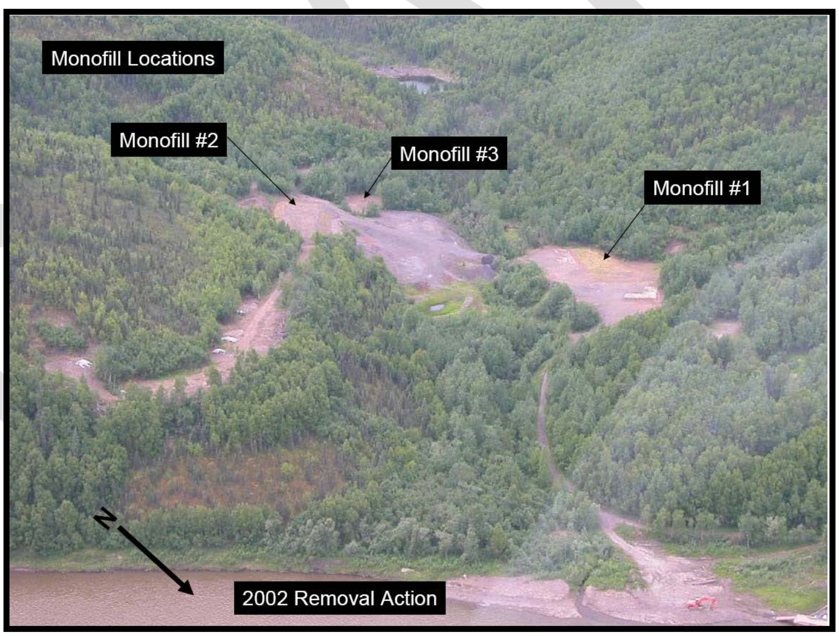

Figure 8 Location of Monofills

Excavation to 10 feet

A partial excavation of the tailings pile to 10 feet would remove the sediment that is available for transport from the area of the creek to a depth of 10 feet or until bedrock is encountered. Depths and distances for excavation were based on information available in the E&E Remedial Investigation Report 2013, and consultation with the Bureau of Land Management. The length of the excavation would extend down the creek for a distance of 500 feet on the north side and 600 feet on the south side in the area of concern (Figure 1).The depth of excavation would extend down ten feet or until weathered bedrock is encountered. The width of excavation on the north and south sides of the creek would extend approximately 10 feet back from the creek centerline and then sloped back at a 2 horizontal to 1 vertical slope (Figure 10).   The smaller excavation on the south side of the creek was an attempt to minimize the volume increase from excavating deeper (Figure 9).

Restoration of the stream in the area of excavation is not part of this proposed action. Once excavation is complete, the stream will be allowed to meander through the excavated area. In order to prevent the stream from meandering and eroding the toe of the cut slope, protection will be placed at the toe up to two feet (>100 year return interval depth using an idealized cross section). For this assessment, it is assumed that the toe protection would be a single layer of small mesh gabions with imported fill. It is assumed that drainage down the face of the slope will be minimal. Any erosion associated with drainage down the face of the slope will be caught by the toe protection.

Diversion of Red Devil Creek will be an aspect of the construction that will need to be developed along with the BLM during preparation of plans and specifications. Several approaches are possible ranging from putting the burden on the contractor to address all flow (least risky $), to placing an upper flow limit on the time that the contractor can work (moderately risky $$), to allowing the contractor to work during summer months, assuming low flow conditions (very risky $$$).

Another risk to be considered with this alternative is the location of the groundwater table. The deeper excavation estimate did not include any costs for dewatering the excavated area. According to the E& E RI, this excavation will extend below the water table. The groundwater hydrology was not evaluated for this exercise, so it has not been determined if the water table is seasonal and may be minimal during construction, or if extra measures such as dewatering will be needed to pursue this alternative. This would need to be evaluated further if this is the selected alternative.

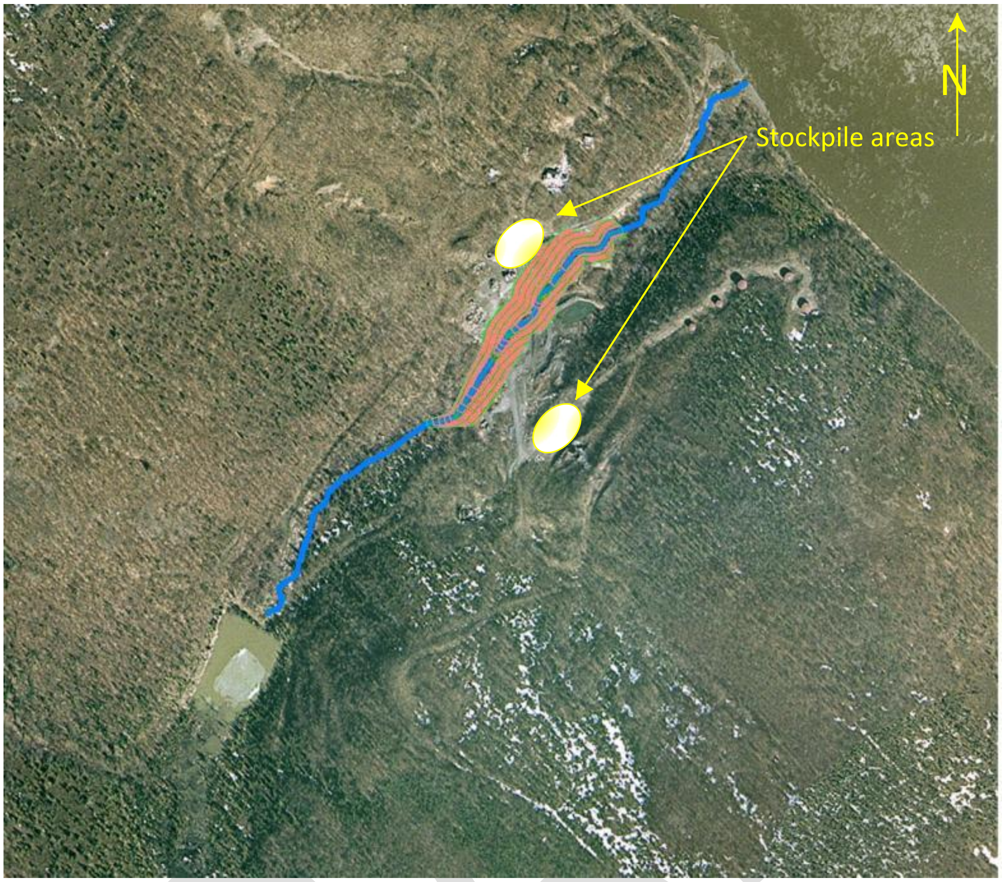

Figure 9 Plan view of the 10 foot deep excavation

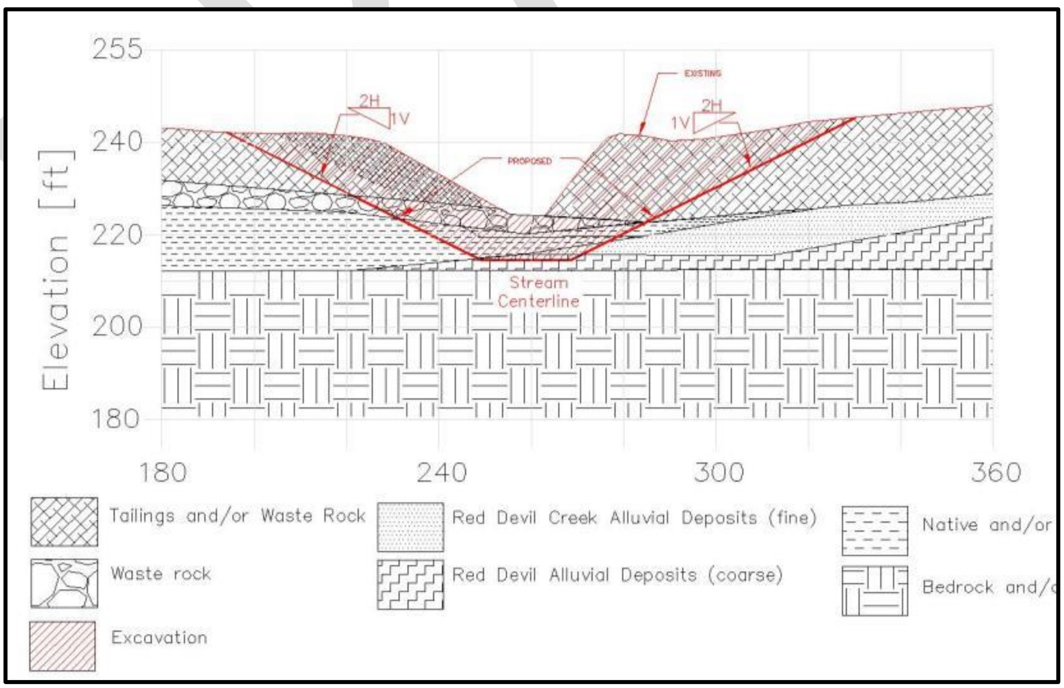

Figure 10 Cross section of excavation to 10 feet with geologic data extracted from E&E Remedial Investigation Report (2013)

Cost: This alternative is estimated to cost between $3,750,000 to $4,430,000 depending on where the gravel for the gabion baskets is obtained. The excavation quantity did not vary much between the 5 foot and the 10 foot excavation. This is because the prism was changed to minimize any increases in excavation.

Risks: Need to make sure that Monofill 1 is left undisturbed. Need to address streamflow during construction. Will likely leave some amount of fine sediment in excavated area that will be transported. Water table could increase difficulty of excavation.

3.2. Line Creek with Culvert

This alternative would entail lining 800 feet of the creek in the area of the tailings pile with a 6 foot diameter culvert (Figure 11). This alternative would break the contact between the creek and the tailings pile, allow for ice buildup in the winter months, prevent tailings from eroding into the stream, and allow easy access for performance inspection. Typically a culvert of this size is buried; however, this culvert will not be buried, so it is anticipated that it will be held in place with a series of straps anchored into the soil or bedrock. The spacing of the straps was estimated to be every 25 feet. Confirmation of the strap spacing would need to be performed if this is the chosen alternative. Excavation of the creek bed would be required in order to provide a uniform grade. The excavated material will be used where fill is required to construct the uniform grade or stockpiled on the tailings pile.

In addition to grading and laying the culvert, a headwall would be required at the upper end of the culvert to train the stream into the culvert. It is assumed that the headwall would be constructed of sheet pile or lined gabions. The headwall would also provide a location to establish control over the stream flow for future cleanup efforts at the site. A cross section of the culvert is shown in Figure 12

Annual inspection would be required for this alternative to check the culvert for beaver dams, damage from ice, abrasion from sediment, and performance of the straps. It is anticipated that inspection would be a visual inspection only.

The depth of water in the culvert was calculated for the 6 foot diameter pipe in six inch increments. The corresponding flows for the depths are shown in Table 7. For estimating purposes the culvert at the site was assumed to be a bolt up culvert that requires assembly on site. Further evaluation could also be performed to determine if the closed pipe culvert is necessary, or if a half pipe culvert (similar to a flume or ditch lining) would be adequate. Examples of half pipe ditch liners and trapezoidal ditch liners is shown in Figure 14.

Diversion of Red Devil Creek will be an aspect of the construction that will need to be developed along with the BLM during preparation of plans and specifications. Several approaches are possible ranging from putting the burden on the contractor to address all flow (least risky $), to placing an upper flow limit on the time that the contractor can work (moderately risky $$), to allowing the contractor to work during summer months, assuming low flow conditions (very risky $$$).

Table 7. Peak Discharge for Storm Events using the SCS method.

Red Devil Creek Six Foot Culvert						
Flow [cfs]	3.5	14.9	33.9	58.7	89.6	123.5
Water depth in culvert[ft]	0.5	1.0	1.5	2.0	2.5	3.0

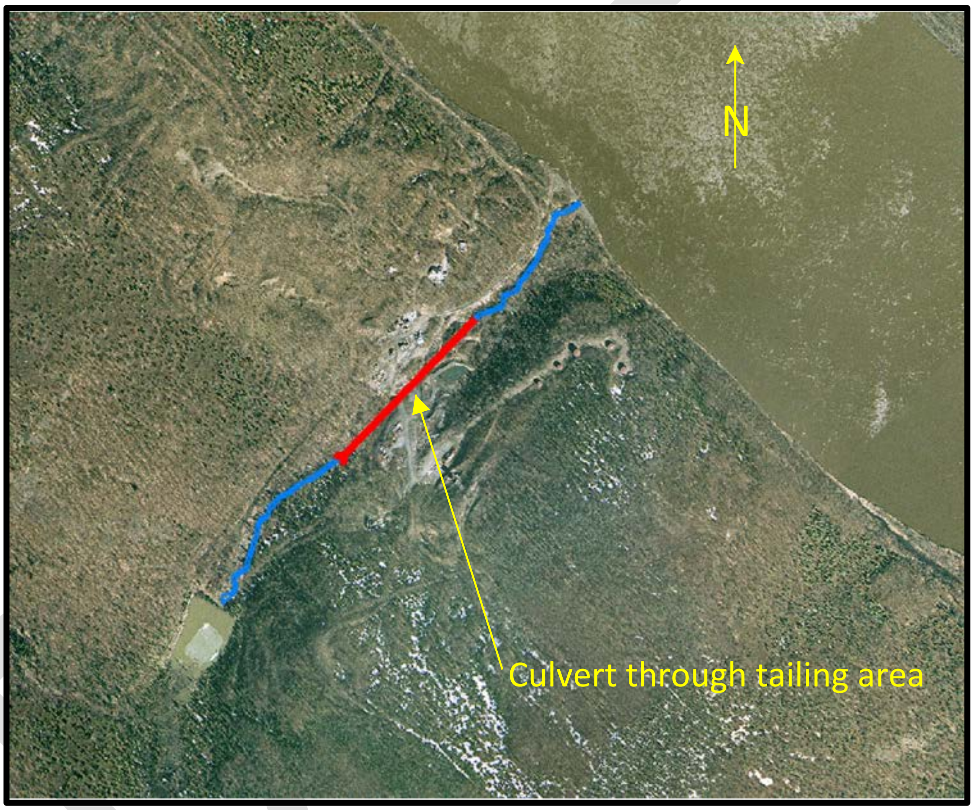

Figure 11 Plan view of the culvert alternative

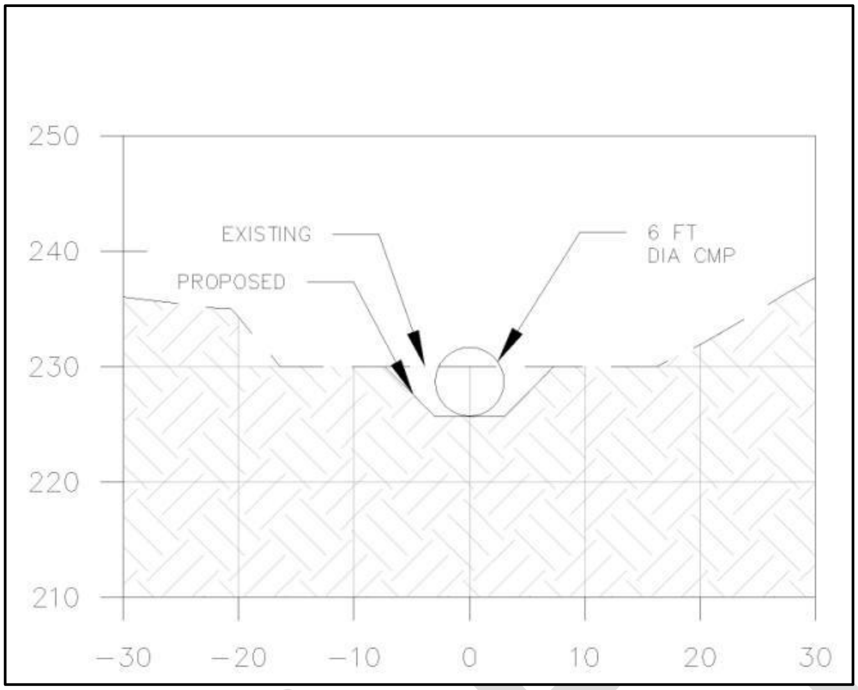

Figure 12 Idealized culvert cross section

Figure 13 Example of a ditch lined with a half pipe

Figure 14 Example of a trapazoidal lining

Cost: This alternative is estimated to cost $4,000,000. Material costs could be reduced if the half culvert option is pursued.

Risks: Annual inspection and possible maintenance associated with this alternative.

3.3. Modify/Upgrade Detention Pond

This alternative would make use of a previously constructed detention pond that has been filling and revegetating. This alternative would reduce the stream flow during high rainfall events by increasing the detention capacity of the pond. In order to evaluate the effect of the detention pond on the downstream flow the US Army Corps of Engineers Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS) was used. The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of watershed systems.

The idealized water shed model shown in Figure 3 was used for this analysis. The existing water storage capacity of the detention pond was determined using the topography generated from 2010 aerial photography. The detention pond was then expanded and lowered to impound 5 feet of water. The extent and depth of the pond expansion was limited in order to keep the pond from becoming classified as a dam. The BLM definition of a dam is: *any human-made structure erected for the purpose of retention, detention, or diversion of water. Structures less than 6 feet high (hydraulic height)—regardless of impoundment capacity—or structures with an impoundment capacity of less than 15 acre-feet—regardless of height—are not considered to be dams.*

The outlet of the pond would be modified in order to control the water surface. For estimation purposes a sheet pile notched weir was assumed to be the control structure. Other alternatives for weir construction include lined gabions or a grout filled mattress.

This alternative would not prevent the flow of water down Red Devil Creek, but it would reduce high flow events by detaining the water. Reducing high flow events would reduce the stream velocity limiting the transport of sediment downstream. The HEC-HMS model evaluated the peak flow in the stream during a 2, 5, 10, 25, 50, and 100 year rain event without the expanded detention basin. The model was then used to determine the effect of the expanded detention basin on peak flow. Results of that evaluation are shown in Table 8.

Diversion of Red Devil Creek will be an aspect of the construction that will need to be developed along with the BLM during preparation of plans and specifications. Several approaches are possible ranging from putting the burden on the contractor to address all flow (least risky $), to placing an upper flow limit on the time that the contractor can work (moderately risky $$), to allowing the contractor to work during summer months, assuming low flow conditions (very risky $$$).

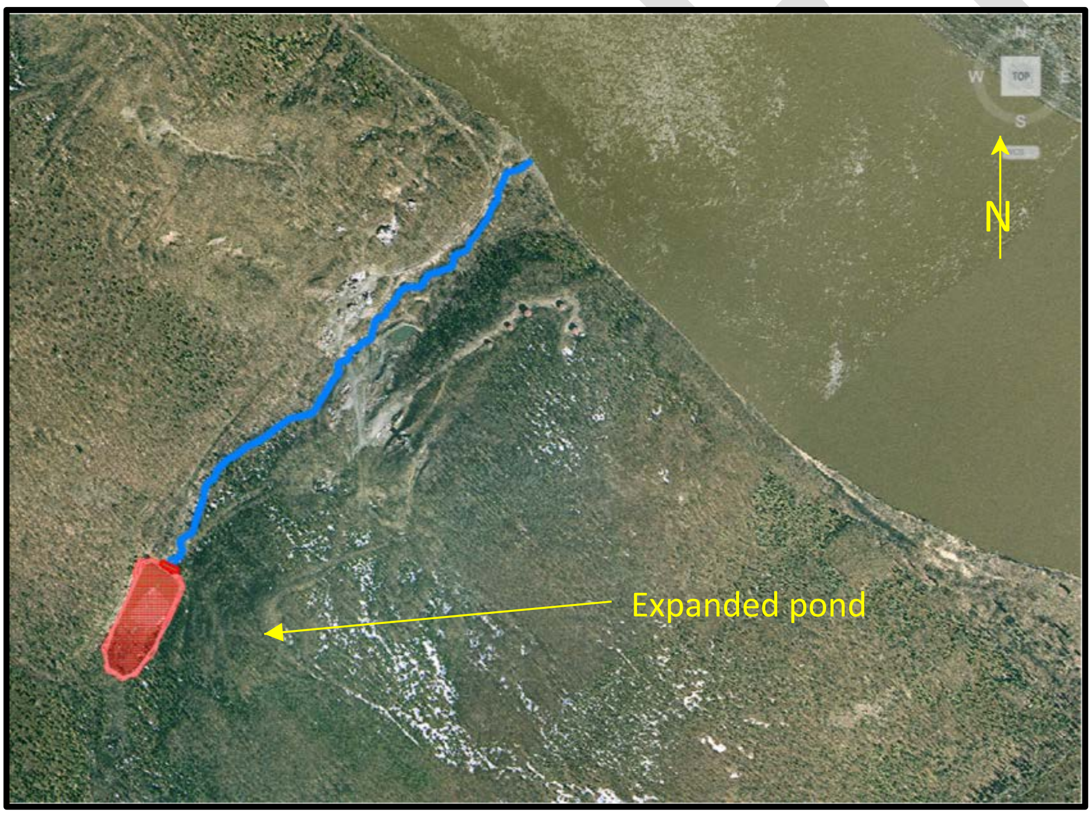

Figure 15 Plan view of detention pond alternative

Table 8. Peak Discharge Below the Mine Site with and without a modified detention pond.

Location	2 year (cfs)	5 year (cfs)	10 year (cfs)	25 year (cfs)	50 year (cfs)	100 year (cfs)
Red Devil Creek Unmodified	5.0	12.9	28.2	59.7	87.5	117.6
Red Devil Creek with Modified Detention Pond	0.9	4.0	13.8	29.3	54.8	84.8
Sediment Size Transported after Modification [mm]	≤0.3	≤2.0	≤3.0	≤4.2	≤7.0	≤9.5*
	Medium sand	Very coarse sand	Very fine gravel	Very fine gravel	Fine gravel	Medium gravel

Cost: This alternative is estimated to cost $7,100,000.

Risks: Depth of bedrock in the area of the weir unknown. Inspection and maintenance will be required if left in place for a period of years. Soil conditions in the area for detention basin are unknown. This could result in unintended difficult excavation (very wet).

3.4.Excavate at Red Devil Creek and Kuskokwim Confluence

This alternative would remove sediment that has been transported down Red Devil Creek to the confluence of Kuskokwim. Sediment would be excavated for a distance of 450 feet downstream and 100 feet upstream from Red Devil Creek and extend from the river bank back 100 feet. The excavation would extend down 5 feet. If an option is included in the contract, the extent of the depth of the excavation could be evaluated at 5 feet and then a determination could be made whether to exercise the option to extend the excavation another 5 feet. The extent of excavation was determined from soil boring data in the Red Devil Mine Remedial Investigation Report (2013). The excavated material would be stockpiled at one of the locations shown in Figure 16.

This alternative contains a high degree of risk. The excavation of the delta area would create a notch along the river bank that could induce erosion of the river bank. The typical method to prevent river erosion is to armor the eroding bank, and typical erosion protection is armor stone. Placement of armor stone in the area used for the barge landing will make the barge landing site unusable. Articulated mat could be used for erosion protection, however; the mat would need to extend beyond the high water line of the Kuskokwim River and extend down to the thalweg of the river, otherwise the river bank material behind the mat risks being removed by the current. An articulated mattress would also be at risk from ice damage during breakup.

Diversion of Red Devil Creek will be an aspect of the construction that will need to be developed along with the BLM during preparation of plans and specifications. Several approaches are possible ranging from putting the burden on the contractor to address all flow (least risky $), to placing an upper flow limit on the time that the contractor can work (moderately risky $$), to allowing the contractor to work during summer months, assuming low flow conditions (very risky $$$).

Cost: This alternative is estimated to cost $2,200,000 (no mobilization included in estimate)

Risks: Unknown potential increase in erosion from currents and ice scour.

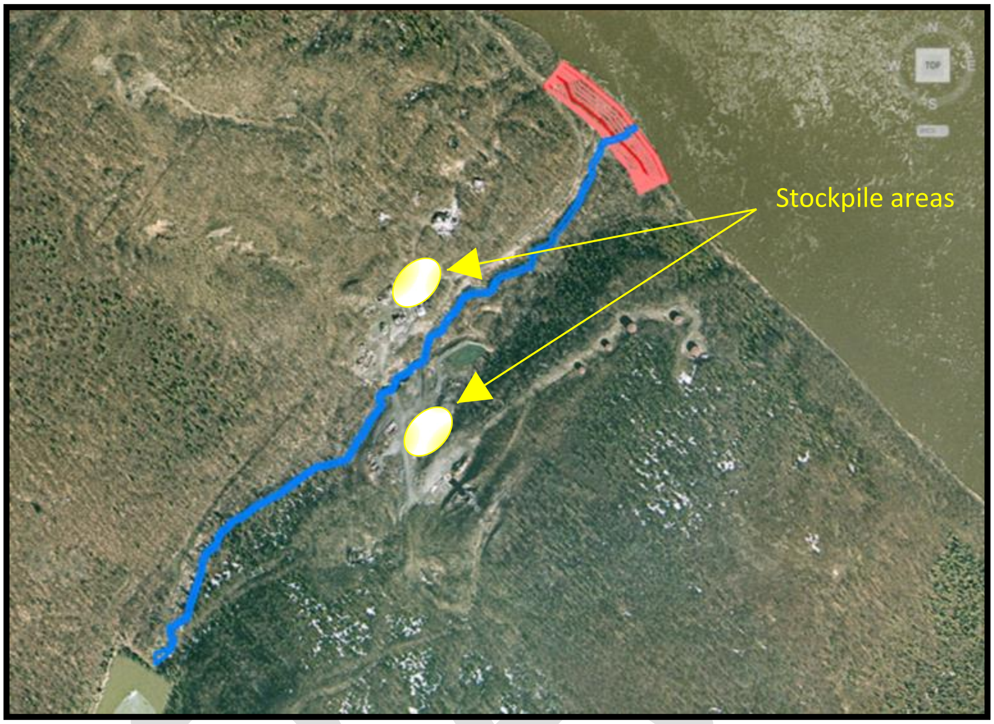

Figure 16 Plan view of delta excavation

4. Conclusions

A variety of solutions are presented in this analysis that can be used to prevent sediment migration at the Red Devil site. They range from removing the contaminated sediment from the creek area, to breaking contact between the creek flow and the tailings pile, to reducing water velocity to minimize the movement of sediment. All alternatives would require a thought out approach to addressing the creek flow during construction. An alternative that provided ability to establish control over the creek flow for future work would be beneficial.

A separate option that was evaluated was the removal of contaminated sediment from the confluence of Red Devil Creek and the Kuskokwim River. This option was viewed as an additional action that could be added to any of the options to limit sediment transport. This option should be approached cautiously since it has to potential to create more problems than it solves.

Table 9 is a qualitative attempt to capture the risk associated with each of the alternative in a table. The classification of low, medium, or high risk was based on the judgment of this evaluator and is presented to help facilitate decision making based on perceived risk.

Table 9 Risk associated with each alternative

Risk				
	Initial cost	Ease of Construction	Maintenance	Project Life
Partial Excavation to 5 feet	Low	Low	Low	Low
Partial Excavation to 10 feet	Low	High	Low	Medium
Line creek with culvert	Low	Low	High	Medium
Modify/Upgrade detention pond	High	High	Medium	Medium

D Cost Estimate

Table D-1 Cost Estimate, Alternative 2 – Concrete Channel Construction Red Devil Mine Site, EECA Red Devil, Alaska

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DCConCh1	Mobilization/Demobilization	1	lump sum	$675,896	$675,896
DCConCh2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCConCh3	Site Preparation	1	lump sum	$7,902	$7,902
DCConCh5	Excavate Contaminated Materials	1	lump sum	$55,228	$55,228
DCConCh7	Stockpile Construction	1	lump sum	$10,464	$10,464
DCConCh8	Concrete Liner Construction	1	lump sum	$102,862	$102,862
DCConCh9	Construction Completion	1	lump sum	$15,391	$15,391
Total Direct Capital Costs (rounded to nearest $1,000)					***$1,089,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,300,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$65,000
	Administration (5%)				$65,000
	Legal Fees and License/Permit Costs (7%)				$91,000
	3rd Party Construction Oversight (5%)				$65,000
Total Indirect Capital Costs					***$286,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,586,000
	Contingency Allowance (20%)				$317,000
Total Capital Cost (rounded to nearest $10,000)					**$1,900,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Operation and Maintenance Cost	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900
	Insurance, Taxes, Licenses	3%			$540
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,900,000
Present Worth of O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Present Worth Cost for Alternative (Rounded to Nearest $10,000)					**$2,090,000**

Table D-2 Cost Estimate, Alternative 3 – Culvert Construction Red Devil Mine Site, EECA Red Devil, Alaska

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DCCul1	Mobilization/Demobilization	1	lump sum	$693,415	$693,415
DCCul2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCCul3	Site Preparation	1	lump sum	$5,702	$5,702
DCCul5	Excavated Contaminated Materials	1	lump sum	$49,713	$49,713
DCCul6	Backfill Low Areas	1	lump sum	$471	$471
DCCul7	Stockpile Construction	1	lump sum	$3,890	$3,890
DCCul8	Culvert Liner Installation	1	lump sum	$103,321	$103,321
DCCul9	Construction Completion	1	lump sum	$15,501	$15,501
Total Direct Capital Costs (rounded to nearest $10,000)					***$1,093,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,310,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$66,000
	Administration (5%)				$66,000
	Legal Fees and License/Permit Costs (7%)				$92,000
	3rd Party Construction Oversight (5%)				$66,000
Total Indirect Capital Costs					***$290,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,600,000
	Contingency Allowance (20%)				$320,000
Total Capital Cost (rounded to nearest $10,000)					**$1,920,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Annual Operation and Maintenance Costs	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900.00
	Insurance, Taxes, Licenses	3%			$540.00
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,920,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Cost (Rounded to Nearest $10,000)					**$2,110,000**

Notes

1. Unit costs provided by Means were taken from *RS Means Heavy Construction Cost Data, 27th Ed., 2013.*
2. A 6 month work season and a 6 day work week were assumed.
3. One month for pre-construction and one month for post-construction activities were assumed.
4. A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.

Table D-3 Cost Estimate, Alternative 4 – Excavation Red Devil Mine Site, EECA Red Devil, Alaska

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DCER1	Mobilization/Demobilization	1	lump sum	$673,853	$673,853
DCER2	Field Overhead and Oversight	3	month	$73,759	$221,277
DCER3	Site Preparation	1	lump sum	$17,108	$17,108
DCER5	Excavation of Contaminated Material	1	lump sum	$90,310	$90,310
DCER7	Stockpile Construction	1	lump sum	$28,588	$28,588
DCER9	Drop Structure/Sediment Trap Construction	1	lump sum	$61,417	$61,417
DCER10	Construction Completion	1	lump sum	$15,831	$15,831
Total Direct Capital Costs (rounded to nearest $10,000)					***$1,110,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$1,330,000***
Indirect Capital Costs					
	Engineering and Design (5%)				$67,000
	Administration (5%)				$67,000
	Legal Fees and License/Permit Costs (7%)				$93,000
	3rd Party Construction Oversight (5%)				$67,000
Total Indirect Capital Costs					***$294,000***
Total Capital Costs					
	Subtotal Capital Costs				$1,624,000
	Contingency Allowance (20%)				$325,000
Total Capital Cost (rounded to nearest $10,000)					**$1,950,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Annual Operation and Maintenance Costs	1	annual	$15,100	$15,100
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$15,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$18,000*
Annual Indirect O&M Costs					
	Administration	5%			$900.00
	Insurance, Taxes, Licenses	3%			$540.00
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$19,000*
	Contingency Allowance	20%			$3,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$23,000
5 Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					1,950,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$190,000
Total Cost (Rounded to Nearest $10,000)					**$2,140,000**

Notes

1. Unit costs provided by Means were taken from *RS Means Heavy Construction Cost Data, 27th Ed., 2013.*
2. A 6 month work season and a 6 day work week were assumed.
3. One month for pre-construction and one month for post-construction activities were assumed.
4. A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.