Final
Feasibility Study Supplement
Red Devil Mine
Red Devil, Alaska

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List of Abbreviations and Acronyms

µg/L	micrograms per liter
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AOC	Area of Contamination
ARAR	applicable or relevant and appropriate requirement
BERA	Baseline Ecological Risk Assessment
BLM	U.S. Department of the Interior Bureau of Land Management
BSAF	biota sediment accumulation factor
BTV	background threshold value
CC	confidence coefficient
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
E & E	Ecology and Environment, Inc.
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
FS Report	*Final Feasibility Study, Red Devil Mine, Alaska*
GRA	general response action
Groundwater and Surface Water Report	*Final Red Devil Mine Groundwater and Surface Water Report, Red Devil, Alaska*
HHRA	Human Health Risk Assessment
HQ	hazard quotient
IC	Institutional Control

List of Abbreviations and Acronyms (Cont.)

km	kilometers
LOE	line(s) of evidence
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
MNR	monitored natural recovery
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ng/g	nanograms per gram
NTCRA	non-time-critical removal action
O&M	operation and maintenance
PRB	permeable reactive barrier
Q-Q	quantile-quantile
RAO	remedial action objective
RBCL	risk-based cleanup level
RCRA	Resource Conservation and Recovery Act
RDM	Red Devil Mine site
RG	remedial goal
RI	Remedial Investigation
RI report	*Final Remedial Investigation Report, Red Devil Mine, Alaska*
RI Supplement report	*Final Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska*
RI Supplement Work Plan	*Final Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska*
RI/FS Work Plan	*Work Plan, Remedial Investigation/ Feasibility Study, Red Devil Mine, Alaska*
TBC	to be considered
TCLP	toxicity characteristic leaching procedure

List of Abbreviations and Acronyms (Cont.)

TTF	trophic transfer factor
UPL	upper prediction limit
USL	upper simultaneous limit
UTL	upper tolerance limit
WOE	weight-of-evidence
XRF	X-ray fluorescence spectrometry

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1 Introduction

This Feasibility Study (FS) Supplement report addresses groundwater and Kuskokwim River sediment at the Red Devil Mine site (RDM). The RDM consists of an abandoned mercury mine and ore processing facility located near the village of Red Devil in southwest Alaska (see Figure 1-1). Historical mining activities at the RDM included underground and surface mining. Ore beneficiation and processing at the site included crushing, retorting/furnacing, milling, and flotation. Historical mining operations left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. The RDM encompasses the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of a response action, including public lands managed by the U.S. Department of the Interior Bureau of Land Management (BLM). The BLM initiated a Remedial Investigation (RI)/FS at the RDM in 2009 pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead agency authority.

The RI/FS was performed by Ecology and Environment, Inc. (E & E) on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J. The RI/FS was conducted following the *Work Plan, Remedial Investigation/ Feasibility Study, Red Devil Mine, Alaska* (RI/FS Work Plan; E & E 2011). Data collected during the RI were used to define the physical setting, nature and extent of contamination, and fate and transport of contaminants at the RDM. Results of the RI are presented in the *Final Remedial Investigation Report, Red Devil Mine, Alaska* (RI report; E & E 2014). The RI results were used to assess risk to human health and the environment due to exposure to site contaminants. Results of the final baseline Human Health Risk Assessment (HHRA) and baseline Ecological Risk Assessment (BERA) for the RDM are included in the RI report (E & E 2014).

The FS was performed based on results documented in the 2014 RI report. Results of the FS are presented in the *Final Feasibility Study, Red Devil Mine, Alaska* (FS report; E & E 2016a). The FS addressed contaminated tailings/waste rock, soil, and Red Devil Creek sediments (E & E 2016a).

Neither the 2014 RI nor the 2016 FS fully evaluated possible site impacts to the adjacent Kuskokwim River. The FS did not address remedies for groundwater or Kuskokwim River sediments because the need for, and extent of, cleanup of these media had not yet been completely assessed.

An RI Supplement was conducted to address data gaps associated with soil, groundwater, and Kuskokwim River sediments that were identified as part of the development of site-wide remedial alternatives during the preparation of the FS. The RI Supplement also addressed changes in the groundwater and surface water monitoring network, and possible changes to the groundwater and surface water conditions at the RDM stemming from implementation of a non-time-critical removal action (NTCRA) performed by the BLM at the RDM during the summer of 2014. E & E performed the RI Supplement on behalf of the BLM under BLM National Environmental Services Blanket Purchase Agreement Number L14PA00149 and Delivery Order Number L14PB00938. The RI Supplement was performed per applicable CERCLA statutes, regulations, and guidance following the *Final Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska* (RI Supplement Work Plan; E & E 2015).

As part of the RI Supplement, an HHRA Supplement was performed to address data gaps associated with Kuskokwim River sediments that were not addressed as part of the 2014 RI effort—specifically, to assess the risks and hazards from potential exposure to contaminants of potential concern through direct contact and incidental ingestion of sediment, and consumption of fish from the Middle Kuskokwim River region. In addition, a BERA Supplement was performed to assess potential risks to aquatic-dependent receptors that use the Kuskokwim River near and downstream from the RDM. E & E performed the HHRA and BERA Supplement on behalf of the BLM under BLM National Environmental Services Blanket Purchase Agreement Number L14PA00149 and Delivery Order Number L17PB00236. The HHRA and BERA Supplements are being performed in accordance with the final Proposed Technical Approach for Kuskokwim River Risk Assessment Supplement, Red Devil Mine, Alaska (BLM 2017). The HHERA and BERA were performed following the final *Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement, Red Devil Mine, Alaska* (BLM 2017).

Results of the RI Supplement and HHERA and BERA Supplement are presented in the *Final Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska* report (RI Supplement report; E & E 2018).

The BLM initiated baseline groundwater and surface water monitoring in 2012 to augment the RI results to characterize pre-remedial action conditions and identify seasonal and annual trends in flow, contaminant concentrations, and loading. The 2012 baseline monitoring was performed following the 2012 *Baseline Monitoring Work Plan, Red Devil Mine, Alaska* (E & E 2012), which is generally consistent with the RI/FS Work Plan. Through analysis of 2011 data, it was determined that some data gaps had yet to be adequately addressed, and the overall RI effort was extended. Thus, the 2012 baseline data were appended to the RI report. A second round of baseline monitoring of groundwater and surface water was performed in the spring and fall of 2015. The 2015 baseline monitoring was performed in conjunction with additional groundwater characterization conducted as part of the RI Supplement, following the RI Supplement Work Plan. Results of the 2015 baseline monitoring are presented in the RI Supplement report. After the 2015 monitoring, the BLM performed further baseline monitoring in 2016, 2017, and 2018. E & E performed this baseline monitoring on behalf of the BLM under National Environmental Services Blanket Purchase Agreement Number L14PA00149 and Delivery Order Number L16PB00958. This additional baseline monitoring was conducted following the *Final Work Plan, Groundwater and Surface Water Baseline Monitoring, Red Devil Mine, Alaska* (E & E 2016b). Results of this additional baseline monitoring are presented in the *Final Red Devil Mine Groundwater and Surface Water Report, Red Devil Mine, Alaska* (Groundwater and Surface Water Report; E & E 2019).

Subsequent to the RI Supplement, the BLM performed additional characterization of groundwater and tailings/waste rock at the RDM. The hydrogeologic characterization generated additional information to help facilitate a more detailed hydrologic analysis of the proposed repository and to support the development of a groundwater monitoring network for the repository proposed under 2016 FS Alternatives 3a and 3c. The additional tailings/waste rock characterization generated additional information to assist the design efforts associated with outlining the extent of excavation for tailings/waste rock and impacted soil from the Main Processing Area. E & E performed the additional characterization on behalf of the BLM under National Environmental Services Blanket Purchase Agreement Number L14PA00149 and Delivery Order Number L17PB00325. The additional characterization activities were conducted in accordance with the *Final Work Plan for 2017 Groundwater Monitoring Well Installation and Tailings/Waste Rock Characterization, Red Devil Mine, Alaska* (E & E 2017). Results of the additional characterization are presented in the Groundwater and Surface Water Report.

Like the RI Supplement, this FS Supplement focuses on groundwater and sediment in the Kuskokwim River. Selected results of the RI (E & E 2014), RI Supplement (E & E 2018), and additional characterization and baseline monitoring (E & E 2019) are used to support the development of this FS Supplement. Those results are presented in sections below.

The remedial action alternatives in this FS Supplement report complement those evaluated in the 2016 FS. A preferred site-wide remedial action alternative will incorporate alternatives from both the 2016 FS and this FS Supplement.

All of the primary CERCLA documents developed for the RDM can be accessed online via the Administrative Record quick link presented on the Red Devil Mine

Project page (https://www.blm.gov/programs/public-safety-and-fire/abandoned-mine-lands/regional-information/alaska/projects/red-devil-mine).

1.1 Purpose and Organization of Report

The purpose of the FS Supplement report is to present remedial action objectives (RAOs) and develop and evaluate remedial alternatives to address groundwater and Kuskokwim River sediment contamination as documented in the RI and RI Supplement reports. This FS Supplement report includes a comparative analysis of the remedial alternatives being considered for the site remedy. In accordance with U.S. Environmental Protection Agency (EPA) guidance, the comparative analysis is based on nine criteria to support an informed risk management decision regarding the most appropriate remedy (EPA 1988). The preferred remedial alternative will be identified in a Proposed Plan (separate document) that will be made available for public review and comment.

This FS Supplement report consists of the following sections:

- **Section 1: Introduction –** Provides a summary of background information, including a description of the area investigated, summary of historical activities, overview of the nature and extent of contamination and contaminant fate and transport, and summaries of the baseline HHRA and BERA and a weight-of-evidence (WOE) discussion of potential risks associated with Kuskokwim River fish and sediments.
- **Section 2: Identification and Screening of Technologies –** Presents the RAOs, remedial goals (RGs), general response actions (GRAs), and identification and screening of technology types and process options based on effectiveness, implementability, and cost.
- **Section 3: Development of Alternatives –** Develops and describes the remedial action alternatives and describes the major actions to be undertaken for each alternative.
- **Section 4: Analysis and Evaluation of Alternatives –** Presents a detailed analysis of each alternative and a comparative analysis of the alternatives based on nine evaluation criteria.
- **Section 5: References –** Lists the reports and other documents used in the preparation of this FS Supplement report.
- **Appendix A: Cost Information –** Provides tables presenting FS Supplement cost information.

1.2 Background Information

This section briefly summarizes background information for the RDM presented in the RI report, RI Supplement report, and Groundwater and Surface Water Report.

1.2.1 Site Description

The RDM is approximately 250 air miles west and 1,500 marine/river barge miles from Anchorage, Alaska. The mine site was established on the southwest bank of the Kuskokwim River approximately 2 miles from the village of Red Devil and approximately 8 miles from the village of Sleetmute. The RDM is generally located on the Kuskokwim River in Township 19 North, Range 44 West, within the southwest quarter of section 5, southeast quarter of section 6, northeast quarter of section 7, and northwest quarter of section 8, Sleetmute D-4, Seward Meridian. The site encompasses the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of a response action.

Historical mining operations at the RDM left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. Key areas of the site are described below and illustrated in Figure 1-2:

- The Main Processing Area.
- 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 a network of underground mine workings. The “Dolly Sluice” and “Rice Sluice” and their respective deltas on the bank of the Kuskokwim River are associated with the Surface Mined Area.
- Red Devil Creek, extending from a reservoir upstream of the Main Processing Area to the Red Devil Creek delta at the creek’s confluence with the Kuskokwim River.
- The Red Devil Creek delta, which consists of mixed tailings/waste rock, Red Devil Creek alluvium, and soil located at the confluence of Red Devil Creek and the Kuskokwim River.
- Sediments in the Kuskokwim River. The riverbed sediments are located within submerged lands of the Kuskokwim River owned by the State of Alaska and managed by the Alaska Department of Natural Resources.

The Main Processing Area contains most of the former mine structures and is the location 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 (e.g., housing and warehousing) 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, which contain demolished mine structure 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 aboveground storage tanks, which were used to store fuel for mine operations. The above-ground storage tank area was the subject of a separate investigation and remediation project (Marsh Creek 2010).

1.2.2 Historical Activities

The 2014 RI report provides an in-depth discussion of historical mining operations, ore processing, mining and ore processing wastes, and petroleum-related wastes. That information is not repeated in this FS Supplement report.

1.2.3 Nature and Extent and Fate and Transport of Contamination

As presented in the RI report, background concentrations of inorganic analytes were used to determine chemical concentrations that define the lateral and vertical extents of contamination. Inorganic element concentrations that exceed the recommended background values presented in 2014 RI report Section 4.1 are considered “contamination.” In several instances, the concentrations of a given inorganic element in background samples were below detection limits; in such cases, samples with detected concentrations of those analytes also were treated as contamination in this report. For organic analytes, all positive detections are considered to represent site-related contamination.

As noted above, the 2016 FS addressed contaminated tailings/waste rock, soil, and Red Devil Creek sediments. The soil materials addressed in the 2016 FS include materials located in the upper portion of the Red Devil Creek delta, the surface of which is subaerially exposed when the Kuskokwim River is at low and moderate stages but submerged during flood stages (E & E 2016a). Red Devil Creek surface water was not addressed in the 2016 FS because RI sample results indicate that ambient water just above the mouth of Red Devil Creek does not contain contaminant concentrations above State of Alaska surface water quality criteria. The 2016 FS did not address remedies for groundwater or Kuskokwim River sediments because the need for, and extent of, cleanup of these media had not yet been completely assessed.

Contaminated media addressed in this FS Supplement report are:

- Groundwater.
- Materials in the Red Devil Creek delta below an elevation of 164 feet. The Red Devil Creek delta extends from the Red Devil Creek alluvial area into

the Kuskokwim River. Depending on the stage of the Kuskokwim River, portions of the delta may be subaerially exposed or submerged by the river. For the purpose of the 2016 FS, an elevation of 164 feet was assumed to represent a low river stage elevation at the delta. Contaminated soil addressed under Alternatives 3 and 4 in the 2016 FS include the Red Devil Creek delta materials situated above an elevation of 164 feet. Materials in the portion of the Red Devil Creek delta below an elevation of 164 feet, referred to in this Supplemental FS as the lower delta, are addressed in this FS Supplement.

- Kuskokwim River sediment located downriver of the Red Devil Creek delta.

The need for remediation and exposure controls for these media is evaluated further in Chapter 2 of this FS Supplement report. The nature and extent of contamination in both media is summarized below based on data presented in the RI report, RI Supplement report, and Groundwater and Surface Water Report.

1.2.3.1 Soil and Bedrock

Bedrock and soil, including mine waste, have been characterized as part of the RI, RI Supplement, and 2017 additional characterization activities. Results of these studies that are pertinent to the nature and extent and fate and transport of contamination at the RDM are provided in the RI report, RI Supplement report, and Groundwater and Surface Water Report and briefly summarized below.

1.2.3.1.1 RI Soil Characterization

Seventeen inorganic elements were detected above background values in subsurface soil samples collected during the RI. In addition, semivolatile organic compounds, diesel range organics, and residual range organics were detected in subsurface soil samples. Inorganic elements were detected above background values in all geographic areas of the site. Of the inorganic elements detected, concentrations of antimony, arsenic, and mercury—the primary contaminants of concern (COCs)—were the most highly elevated above background values. The highest concentrations of these inorganic elements were in the tailings and tailings/waste rock soil types in the Pre-1955 and Post-1955 portions of the Main Processing Area. These inorganic elements were also detected at concentrations well above background levels in subsurface soil in parts of the Surface Mined Area. No tailings/waste rock are observed in the Surface Mined Area. At many of those locations, the elevated concentrations were concluded to be likely attributable to naturally mineralized Kuskokwim group bedrock-derived soils (E & E 2014).

In accordance with the RI Work Plan, samples used for background value estimation were collected from locations outside of and upgradient of the areas recognized as potentially impacted by mining, ore processing, waste disposal operations, and potential deposition of emissions from thermal ore processing (E & E

2011). RI soil data and geological information indicated that the areas where background soil samples were collected exhibit little natural mineralization compared to areas where mining activity occurred. The extent of such natural mineralization has not been fully delineated but includes portions of the Main Processing Area and Surface Mined Area that are subject to remediation.

Naturally mineralized soils pre-date mining activities and thus represent pre-mining “background” conditions. Historical mining and ore processing activities, including disposition of the tailings and waste rock, occurred within the Main Processing Area and Surface Mined Area, where naturally mineralized rock and soil are expected to be locally present in the shallow subsurface. Impacts of mine activities throughout most of the Main Processing Area and Surface Mined Area make it difficult to positively identify naturally mineralized conditions. Therefore, it was not possible during the RI to determine the extent and concentration ranges of inorganic elements of naturally mineralized soil (E & E 2014). Consequently, the background levels used to identify contamination in the RI, particularly those for subsurface soil and groundwater, likely locally underestimate pre-mining background concentrations of inorganic elements at parts of the RDM that are subject to remediation.

Results of the RI were used to estimate the depths and volume of tailings/waste rock and contaminated soil proposed for excavation under Alternatives 3 and 4 in the 2016 FS report. Tailings/waste rock and soil with total concentrations of antimony, arsenic, and/or mercury—the primary soil COCs at RDM—exceeding the soil RGs is targeted for excavation under these FS alternatives. This encompasses all surface and subsurface soil containing tailings/waste rock and flotation tailings within the Main Processing Area and the Red Devil Creek downstream alluvial area and delta. It also includes sediment within Red Devil Creek that contains tailings/waste rock, some native soil beneath tailings/waste rock, and some surface soil in or adjacent to the Main Processing Area.

1.2.3.1.2 RI Supplement Soil and Bedrock Characterization

An RI Supplement was conducted to address data gaps associated with soil, river sediment, and groundwater. Results of the RI Supplement are detailed in the Groundwater and Surface Water Report and briefly summarized below.

The objectives of the RI Supplement included characterization of lithology, mineralogy, COC concentrations, depths and thicknesses, and occurrence of saturated conditions of subsurface soils and bedrock in the Main Processing Area, Red Devil Creek downstream alluvial area, and Surface Mined Area. The objectives of the RI Supplement also included additional characterization of naturally mineralized bedrock and soils and the impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations. Results of the soil and bedrock RI Supplement investigation are presented in Chapter 2 of the RI Supplement report.

As noted above, results of the RI (E & E 2014) were used to estimate the depths and volume of tailings/waste rock and contaminated soil proposed for excavation under Alternatives 3 and 4 in the 2016 FS report. Data collected as part of the RI Supplement, which included characterization of soil and bedrock by installing seven boreholes in the Main Processing Area and three boreholes in the Red Devil Creek downstream alluvial area, are useful for refining the estimated depths and volume. Preliminary refined estimated depths of excavation under 2016 FS Alternatives 3 and 4 based on RI Supplement results are presented in Section 1.2.3.1.4.

1.2.3.1.3 2017 Additional Characterization

The BLM performed additional characterization of groundwater and tailings/waste rock at the RDM in 2017. Results of the additional characterization are detailed in the Groundwater and Surface Water Report and briefly summarized below.

The hydrogeologic characterization generated additional information to help facilitate a more detailed hydrologic analysis of the area of the proposed repository and to support the development of a groundwater monitoring network for the repository proposed under 2016 FS Alternatives 3a and 3c. The additional soil and bedrock characterization was performed using a combination of field data collection and laboratory analysis. Additional characterization included installation of 16 additional soil borings/monitoring wells and collection of soil samples for field observations and laboratory analyses for chemical and geotechnical parameters. Results of the additional characterization also are useful for improving understanding of the nature and distribution of naturally mineralized bedrock and the impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and COC concentrations. Results of the additional soil and bedrock characterization and a synthesis of data collected to date are presented in Chapter 2 of the Groundwater and Surface Water Report. Groundwater characterization results are discussed in Section 1.2.3.2, below.

The 2017 additional characterization of tailings/waste rock was performed to address data gaps regarding the lateral and vertical extents of tailings/waste rock in the Post-1955 Main Processing Area expected to have toxicity characteristic leaching procedure (TCLP) concentrations greater than the Resource Conservation and Recovery Act (RCRA) limit for arsenic. FS Alternatives 3a and 3c specified excavation of approximately 210,000 cubic yards of contaminated material for consolidation into the proposed repository. This material includes tailings/waste rock from the Post-1955 Main Processing Area known or expected to have arsenic TCLP concentrations greater than the RCRA limit of 5 milligrams per liter. FS Alternatives 3a and 3c include treatment of the tailings/waste rock by solidification using portland cement as a binding agent prior to consolidation into the proposed repository. RI data include limited TCLP data that indicate arsenic TCLP RCRA exceedances in surface and subsurface soils (mostly tailings/waste rock) within a portion of the Post-1955 Main Processing Area. The FS estimated that approximately 15 percent of the total proposed repository contents (approximately 31,500 cubic yards) would fail TCLP testing for arsenic. Data collected as part of the RI regarding the lateral and vertical extents of materials expected to fail TCLP testing for arsenic were not sufficient for designing the planned excavation.

The 2017 additional tailings/waste rock characterization included characterization of tailings/waste rock, subsurface soils, and depth to bedrock at twenty borehole locations in the Main Processing Area. Field lithological and mineralogical observations were used, in conjunction with X-ray fluorescence spectrometry (XRF) field screening data and laboratory analytical results, to identify tailings/waste rock and soil types and their thicknesses. Results of geologic logging, including interpreted mine waste and soil types identified in the soil borings, are presented in Table 2-3 of the Groundwater and Surface Water Report. Results of laboratory analysis of total arsenic and TCLP arsenic in soil samples are presented in Tables 2-3 and 2-4 of the Groundwater and Surface Water Report, and results of XRF field screening for arsenic, as well as antimony and mercury, are presented in Table 2-3 of the Groundwater and Surface Water Report.

As noted in Section 1.2.3.1.1, results of the RI (E & E 2014) were used to estimate the depths and volume of tailings/waste rock and contaminated soil proposed for excavation under Alternatives 3 and 4 in the 2016 FS report. Data collected as part of the RI Supplement are used to refine the estimated depths and volume, as noted in Section 1.2.3.1.2. The 2017 additional tailings/waste rock characterization results are useful for further refining the estimates of depths and volume. Preliminary refined estimates of depths of excavation under 2016 FS Alternatives 3 and 4 based on the 2017 tailings/waste rock characterization activities are presented in Section 1.2.3.1.4.

1.2.3.1.4 Refined Depths and Volumes of Tailings/Waste Rock and Contaminated Soil

Results of the RI were used to estimate the depths and volume of tailings/waste rock and contaminated soil proposed for excavation under Alternatives 3 and 4 in the 2016 FS report. Tailings/waste rock and soil with total concentrations of antimony, arsenic, and/or mercury exceeding their respective soil RG(s) was targeted for excavation under these FS alternatives. Throughout most of the Main Processing Area, tailings/waste rock was identified in soil borings to varying depths. Underlying native soils with concentrations of one or more or the primary COCs exceeding RGs also were identified. The depth of contaminated soil at each borehole location was estimated based on soil COC concentrations using a combination of laboratory analytical data and XRF field screening data. Bedrock was encountered in some RI soil borings within the areas targeted for remedial action. Where the depth of exceedance of one or more RGs occurs continuously from the surface down to the depth of the top of the bedrock surface, the targeted remedial action depth was set at the depth of top of the bedrock surface.

The depth below the base of tailings/waste rock of soil with concentrations exceeding the RGs was not determined at some RI borehole locations. The borehole depths at most locations were limited, in accordance with the RI/FS Work Plan (E & E 2011), to approximately 3 feet below the base of tailings/waste rock. As a result, limited information on COC concentrations at depths greater than approximately 3 feet below the base of tailings/waste rock was collected at most RI borehole locations. Concentrations of antimony, arsenic, and mercury are commonly elevated above the RGs in soils below tailings/waste rock to at least the depth of the deepest sample collected from a given RI soil boring. At such locations, the depth of soil with concentrations exceeding RGs in some areas with tailings/waste rock was not fully delineated during the RI. For the purpose of the FS, where the depth of exceedance of RGs was not fully defined by the RI data, the depth of RG exceedance was estimated by extrapolating below the depth of the soil boring.

The RI Supplement included characterization of soil and bedrock at seven borehole locations in the Main Processing Area and three boreholes in the Red Devil Creek downstream alluvial area. The 2017 additional tailings/waste rock characterization included characterization of tailings/waste rock, subsurface soils, and depth to bedrock at 20 borehole locations in the Main Processing Area. Locations of RI, RI Supplement, and 2017 boreholes are illustrated in Figure 1-3. The additional data gathered from these boreholes was used to estimate the depth of exceedance of soil RGs at each of the new borehole locations. The additional data also was used to refine the interpretation of depths of soil RG exceedances at nearby RI borehole locations. The results are used to refine the estimated depths of excavation under FS Alternatives 3 and 4, as summarized in Table 1-1. Based on the results of the analysis, it is anticipated that excavation performed under 2016 FS Alternatives 3 and 4 would extend to the top of bedrock throughout most of the Main Processing Area and much of the Red Devil Creek downstream alluvial area.

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Table 1-1 Preliminary Refined Depths of Soil Excavation Under FS Alternatives 3 and 4

General Area	Borehole Information						Bedrock		Estimated Bottom Depth of Soil Excavation Under FS Alternatives 3 and 4			Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88)	
	Year Installed	Borehole ID	2010 Ground Surface Elevation (feet NAVD88)[1]	2015 Ground Surface Elevation (feet NAVD88)[2]	Borehole Total Depth (feet bgs)	Borehole Total Depth Elevation (feet NAVD88)	Depth to Top of Bedrock on Date of Borehole Installation (feet bgs)	Elevation of Top of Bedrock (feet NAVD88)	Original Estimate - 2016 FS[3] (feet bgs)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet bgs)	Basis for Excavation Depth Estimate	2016 FS[3] Estimate (feet NAVD88)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet NAVD88)
Pre-1955 Main Processing Area	2011	MP13	--	271	6	265	28	243	28	--	Top of Bedrock	243	--
	2011	MP50	--	252	6	246	3.5	249	3.5	--	Top of Bedrock	249	--
	2011	MP51	--	246	14	232	10.5	236	10.5	--	Top of Bedrock	236	--
	2011	MP55	--	239	6	233	6	233	6	--	Top of Bedrock	233	--
	2011	MP56	--	237	10	227	8	229	8	--	Top of Bedrock	229	--
	2011	MP60	--	241	33	208	29	212	29	--	Top of Bedrock	212	--
	2011	MP88	--	240	63	177	29	211	29	--	Top of Bedrock	211	--
	2015	MP098	--	239	46	193	35	204	--	35	Top of Bedrock	--	204
	2015	MP099	--	242	26	216	23	219	--	23	Top of Bedrock	--	219
	2017	MP110	--	257	24	233	20	237	--	20	Top of Bedrock	--	237
	2017	MP111	--	251	20	231	18.4	233	--	18.4	Top of Bedrock	--	233
	2017	MP112	--	256	24	232	20	236	--	20	Top of Bedrock	--	236
	2017	MP113	--	258	32	226	28.9	229	--	28.9	Top of Bedrock	--	229
	2017	MP114	--	247	28	219	21.2	226	--	21.2	Top of Bedrock	--	226
	2017	MP115	--	241	28	213	21.1	220	--	21.1	Top of Bedrock	--	220
	2017	MP121	--	219	16	203	10.2	209	--	10.2	Top of Bedrock	--	209
	2000	MW04	--	240	34	206	--	--	30	--	RG Exceedance(s)	210	--
	2011	MP15	--	274	8	266	--	--	10	--	Extrapolated below TD	264	--
	2011	MP48	--	243	14	229	--	--	18	--	Extrapolated below TD	225	--
	2011	MP49	--	243	14	229	--	--	15	--	Extrapolated below TD	228	--
	2011	MP53	--	243	8	235	--	--	14	--	Extrapolated below TD	229	--
	2011	MP54	--	245	8	237	--	--	12	--	Extrapolated below TD	233	--
	2015	MP095	--	227	22	205	16	211	--	15	RG Exceedance(s)	--	212
	2015	MP096	--	239	32	207	28	211	--	21	RG Exceedance(s)	--	218
	2011	MP45	--	243	12	231	--	--	16	--	Extrapolated below TD	227	--
	2011	MP46	--	243	20	223	--	--	24	--	Extrapolated below TD	219	--
	2011	MP47	--	242	26	216	--	--	27	--	Extrapolated below TD	215	--
	2000	MW06	--	215	24	191	--	--	20	--	RG Exceedance(s)	195	--
	2011	MP57	--	232	10	222	--	--	12	--	Extrapolated below TD	220	--
	2011	MP58	--	234	14	220	--	--	16	--	Extrapolated below TD	218	--
	2011	MP59	--	231	16	215	--	--	18	--	Extrapolated below TD	213	--
	2011	MP61	--	229	6	223	--	--	8	--	Extrapolated below TD	221	--
	2011	MP63	--	212	6	206	--	--	8	--	Extrapolated below TD	204	--
	2011	MP52	--	244	42	202	16	228	6	--	RG Exceedance(s)	238	--
	2011	MP62	--	221	29	192	12	209	4	--	RG Exceedance(s)	217	--
	2011	MP66	--	202	28	174	6	196	2	--	RG Exceedance(s)	200	--
	2011	MP89	--	239	41	197	22	217	12	--	RG Exceedance(s)	227	--
	2015	MP100	--	233	37.5	196	36	197	--	21	RG Exceedance(s)	--	212
Post-1955 Main Processing Area	2000	MW07	--	278	21	257	--	--	NA	--	NA (no soil RG exceedances)	NA	--
	2011	MP10	--	279	6	273	2	277	2	--	Top of Bedrock	277	--
	2011	MP12	--	269	22	247	15	254	15	--	Top of Bedrock	254	--
	2011	MP14	--	274	60	214	28	246	28	--	Top of Bedrock	246	--
	2011	MP25	--	243	36	211	36	211	36	--	Top of Bedrock	211	--
	2011	MP34	--	216	22	194	18	198	18	--	Top of Bedrock	198	--
	2011	MP35	--	212	22	190	16	196	16	--	Top of Bedrock	196	--
	2011	MP36	--	214	16	198	10	204	10	--	Top of Bedrock	204	--
	2011	MP37	--	212	22	190	14	198	14	--	Top of Bedrock	198	--
	2011	MP39	--	208	16.5	192	12	196	12	--	Top of Bedrock	196	--
	2011	MP40	--	203	14.5	189	9.5	194	9.5	--	Top of Bedrock	194	--
	2015	MP094	--	227	24	203	20	207	--	20	Top of Bedrock	--	207
	2015	MP097	--	217	16	201	14	203	--	14	Top of Bedrock	--	203
	2015	MP101	--	208	17.5	191	14	194	--	14	Top of Bedrock	--	194
	2017	MP102	--	269	24	245	16	253	--	16	Top of Bedrock	--	253
	2017	MP103	--	271	24	247	18.4	253	--	18.4	Top of Bedrock	--	253

Table 1-1 Preliminary Refined Depths of Soil Excavation Under FS Alternatives 3 and 4

General Area	Borehole Information						Bedrock		Estimated Bottom Depth of Soil Excavation Under FS Alternatives 3 and 4			Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88)	
	Year Installed	Borehole ID	2010 Ground Surface Elevation (feet NAVD88)(1)	2015 Ground Surface Elevation (feet NAVD88)(2)	Borehole Total Depth (feet bgs)	Borehole Total Depth Elevation (feet NAVD88)	Depth to Top of Bedrock on Date of Borehole Installation (feet bgs)	Elevation of Top of Bedrock (feet NAVD88)	Original Estimate - 2016 FS(3) (feet bgs)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet bgs)	Basis for Excavation Depth Estimate	2016 FS(3) Estimate (feet NAVD88)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet NAVD88)
	2017	MP104	--	275	32	243	29.5	246	--	29.5	Top of Bedrock	--	246
	2017	MP105	--	275	32	243	28	247	--	28	Top of Bedrock	--	247
	2017	MP106	--	278	12	266	12	266	--	12	Top of Bedrock	--	266
	2017	MP107	--	265	28	237	20.7	244	--	20.7	Top of Bedrock	--	244
	2017	MP108	--	264	28	236	23	241	--	23	Top of Bedrock	--	241
	2017	MP109	--	261	28	233	25.3	236	--	25.3	Top of Bedrock	--	236
	2017	MP118	--	251	28	223	26	225	--	26	Top of Bedrock	--	225
	2017	MP119	--	235	28	207	27	208	--	27	Top of Bedrock	--	208
	2017	MP120	--	224	20	204	18.3	206	--	18.3	Top of Bedrock	--	206
	2000	MW01	--	254	31	224	--	--	24	--	RG Exceedance(s)	230	--
	2000	MW03	--	228	26	202	--	--	20	--	RG Exceedance(s)	208	--
	2011	MP11	--	267	8	259	--	--	10	--	Extrapolated below TD	257	--
	2011	MP16	--	272	10	262	--	--	14	--	Extrapolated below TD	258	--
	2011	MP18	--	276	22	254	--	--	20	--	RG Exceedance(s)	256	--
	2011	MP22	--	257	16	241	--	--	18	--	Extrapolated below TD	239	--
	2011	MP23	--	253	22	231	--	--	24	--	Extrapolated below TD	229	--
	2011	MP24	--	251	22	229	--	--	25	--	Extrapolated below TD	226	--
	2011	MP26	--	255	18	237	--	--	20	--	Extrapolated below TD	235	--
	2011	MP27	239	245	6	239	--	--	8	--	Extrapolated below TD	231	--
	2011	MP28	243	241	10	231	--	--	14	--	Extrapolated below TD	229	--
	2011	MP29	--	228	26	217	--	--	30	--	Extrapolated below TD	213	--
	2011	MP32	224	231	14	217	--	--	16	--	Extrapolated below TD	208	--
	2011	MP38	--	213	16	197	--	--	17	--	Extrapolated below TD	196	--
	2011	MP17	--	274	32	243	31	243	14	--	RG Exceedance(s)	260	--
	2011	MP30	--	226	24	202	23	203	16	--	RG Exceedance(s)	210	--
	2011	MP91	--	226	51.5	175	23	203	16	--	RG Exceedance(s). See MP30	210	--
	2011	MP21	--	269	16	253	--	--	4	--	RG Exceedance(s)	265	--
	2011	MP19	--	280	32	248	4	276	2	--	RG Exceedance(s)	278	--
	2011	MP20	--	274	31	243	14	260	6	--	RG Exceedance(s)	268	--
Red Devil Creek Downstream Alluvial Area	2015	RD21	--	191	8	183	6	185	--	6	Top of Bedrock	--	185
	2017	MP116	--	236	28	208	22.2	214	--	22.2	Top of Bedrock	--	214
	2017	MP117	--	253	36	217	32	221	--	32	Top of Bedrock	--	221
	2011	RD05	--	194	25	169	14	180	2	--	RG Exceedance(s)	192	--
	2011	RD06	195	194	14	180	10	184	8	--	RG Exceedance(s)	186	--
	2011	RD07	198	197	12	185	10	187	2	--	RG Exceedance(s)	195	--
	2011	RD20	--	177	23	154	16	161	5	--	RG Exceedance(s)	172	--
	2015	RD22	--	195	20	175	17	178	--	3	RG Exceedance(s)	--	192
Red Devil Creek Delta	2011	RD01	173	170	16	154	--	--	NA	--	NA (no soil RG exceedances)	NA	--
	2011	RD02	174	173	14	159	--	--	10	--	RG Exceedance(s)	163	--
	2011	RD03	177	177	16	161	--	--	14	--	RG Exceedance(s)	163	--
	2011	RD04	181	180	14	166	--	--	4	--	RG Exceedance(s)	176	--

Notes

(1) Source: AeroMetric (2012)

(2) Source: QSI (2015)

(3) Source: E & E (2016), Section 2.2.1.

Key

bgs = below ground surface
NA = not applicable
NAVD88 = North American Vertical Datum 1988
TD = total depth

1.2.3.2 Groundwater

Groundwater conditions at the RDM have been characterized as part of the RI, RI Supplement, and 2017 additional characterization activities. Baseline groundwater monitoring activities have been performed at the RDM in 2012, 2015, and between 2016 and 2018. Results of these studies that are pertinent to the nature and extent and fate and transport of contamination in groundwater at the RDM are provided in the RI report, RI Supplement report, and Groundwater and Surface Water Report, and briefly summarized below.

1.2.3.2.1 RI Groundwater Characterization

Seventeen inorganic elements (including both total and dissolved analyses) and methylmercury were detected above the RI background values in the groundwater samples collected during the RI. In addition, semivolatile organic compounds, diesel range organics, and residual range organics were detected in groundwater samples, as well. Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above their background values. Concentrations of total and dissolved antimony and arsenic were found to be highest in the Post-1955 Main Processing Area, particularly where groundwater comes into contact with tailings/waste rock (E & E 2014). For the RI, background groundwater concentrations were proposed based on results of samples collected from two wells—MW12, screened in alluvium located within the Red Devil Creek upstream alluvial area, and MW31, screened in bedrock within the upland area west of the Surface Mined Area. These wells were proposed for background groundwater characterization during the RI based on their location outside of and upgradient of any likely mining-related influence on groundwater COC concentrations. These wells also are located outside of the area of any natural mineralization in bedrock (see Section 1.2.3.1).

1.2.3.2.2 RI Supplement Groundwater Characterization

In 2015, RI Supplement groundwater characterization activities were conducted to address data gaps associated with groundwater in the Main Processing Area, the Red Devil Creek downstream alluvial area, and the Surface Mined Area. As part of the RI Supplement, new monitoring wells were installed in the Surface Mined Area to provide additional information on groundwater conditions in the Surface Mined Area in the vicinity (laterally and vertically) of the underground mine workings (E & E 2018). Results of the RI Supplement groundwater characterization are presented in Chapter 3 of the RI Supplement report. The RI Supplement report includes information regarding the groundwater depths and hydraulic gradients (Section 3.2.2), groundwater quality (Section 3.2.3), and a summary of factors influencing groundwater flow paths and quality in the Surface Mined Area (Section 3.3.1), groundwater conditions in the area of NTCRA regrading (Section 3.3.2) and the area downgradient of Monofill #2 (Section 3.3.3), groundwater organic compounds concentrations (Section 3.3.4), and results of the 2015 baseline groundwater monitoring (Section 3.3.5).

1.2.3.2.3 Baseline Groundwater Monitoring
The BLM performed further baseline groundwater monitoring in the fall of 2016, spring and fall of 2017, and spring of 2018. Results are presented in Chapter 3 of the Groundwater and Surface Water Report.

1.2.3.2.4 2017 Additional Groundwater Characterization
In 2017, the BLM performed additional characterization of groundwater in the vicinity of the proposed repository (see FS Alternatives 3a and 3c) to generate additional information that may be used to inform a more detailed hydrologic analysis of the proposed repository and establishment of a detection groundwater monitoring network for the proposed repository. Results also are useful for further characterizing the impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations at the RDM. Results of the 2017 additional groundwater characterization and a synthesis of groundwater data collected to date are presented in Chapter 3 of the Groundwater and Surface Water Report. The report summarizes information regarding the occurrence and depths to groundwater (Section 3.3); groundwater hydraulic gradients and flow paths (Section 3.4); groundwater quality (Section 3.5); factors influencing groundwater quality, including impacts from mine waste and naturally occurring mineralization (Section 3.6); background groundwater quality (Section 3.7); hydraulic conductivity of soil and bedrock in the Surface Mined Area (Section 3.8); and groundwater discharge and contaminant flux to the Kuskokwim River (Section 3.9).

1.2.3.2.5 Groundwater Characterization Summary
A brief summary of the findings of groundwater characterization and monitoring at the RDM is provided below.

Groundwater occurs at the RDM in bedrock and unconsolidated materials consisting of mine waste (tailings/waste rock) and native soils, including colluvium and alluvium within the Red Devil Creek valley. Groundwater within the Kuskokwim Group bedrock unit appears to occur primarily within fractures. Hydraulic conductivity estimates of the bedrock are consistent with estimates for other aquifers in fractured turbidite sequences. Unconsolidated overburden and bedrock saturated zones appear to be in hydraulic communication on a large scale at the RDM, although some hydrologic segregation exists locally, particularly at the top of weathered bedrock in parts of the site.

Groundwater at the site generally flows toward Red Devil Creek, with groundwater elevations generally mimicking topography over much of the site. Overall, the spatial and temporal variation in water table elevation, estimates of bedrock and soil hydraulic conductivity, and Red Devil Creek discharge data are reflective of a fractured bedrock and alluvial aquifer in a small watershed anchored by a predominantly gaining stream. Of notable exception is the portion of the Surface Mined Area where the system of underground mine workings exerts a draining effect where the mine workings lie below the water table within the host bedrock but above the nearby base level, which is the elevation of Red Devil Creek. The underground workings impart a strong hydraulic gradient toward the portion of the workings that lies below the water table within the host bedrock but above the nearby base level. The mine workings also provide a highly transmissive hydraulic connection between the affected portion of the Surface Mined Area and the Red Devil Creek valley.

The distribution and arrangement of soils and mine wastes at the site play an important role in determining the nature and extent of contamination and fate and transport of contaminants at the RDM. The principal source of the primary COCs—antimony, arsenic, and mercury—in groundwater at the RDM is tailings/waste rock located in the Main Processing Area. Tailings/waste rock also are present, mixed with alluvial and other soils in parts of the Red Devil Creek valley downstream of the Main Processing Area. In general, the highest COC concentrations in groundwater are found where tailings/waste rock lie below the water table. No tailings/waste rock are observed in the Surface Mined Area.

Groundwater at the RDM also is locally impacted by inorganic elements present in naturally mineralized bedrock and native soils. Bedrock is naturally mineralized throughout portions of the Surface Mined Area and Main Processing Area, particularly including the sub-ore grade zones that are peripheral to the ore zones that were targeted by mining. These peripheral mineralized zones currently envelop the present-day system of underground mine workings. Because of the strong hydraulic gradient toward the portion of the workings that lies below the water table within the host bedrock but above the nearby base level, groundwater in much of the Surface Mined Area flows through these zones of peripheral mineralization. Concentrations of COCs in groundwater are locally elevated as a consequence of interaction with this naturally mineralized bedrock.

Much of the groundwater flowing into and through the Main Processing Area and Red Devil Creek valley originates in the Surface Mined Area. Much of this groundwater is impacted by naturally mineralized bedrock, as described above. As such, the quality of groundwater that would emerge from bedrock in the Main Processing Area and Red Devil Creek valley is expected to be impacted by this natural mineralization. Results of the RI Supplement and 2017 additional characterization improved the evaluation of these impacts. Results of the evaluation of these impacts were used to support development of estimates of groundwater quality for groundwater flowing into the Main Processing Area through bedrock. These estimates of groundwater quality are used as groundwater background threshold values (BTVs) to support development of groundwater RGs for this FS Supplement (see Section 2.3.3.2.1, below).

Once groundwater enters into the system of underground mine workings, it may be further impacted by the mine workings themselves. The magnitude of the impacts attributable to natural mineralization versus flow through the mine workings and/or tailings/waste rock cannot be estimated quantitatively.

Groundwater potentiometric surface elevations and stream elevations in Red Devil Creek indicate that some of the groundwater within the Red Devil Creek valley, including groundwater impacted by mine waste in the Main Processing Area and the area downstream of the Main Processing Area, emerges into gaining reaches of Red Devil Creek as baseflow and enters the Kuskokwim River as surface water. Based on the evaluation of surface water discharge and contaminant flux into the Kuskokwim River presented in Section 5.3.9 of the RI Supplement report, the rate of loading of Red Devil Creek surface water contaminants to the Kuskokwim River is too low to measurably affect COC concentrations in the river surface water.

Some shallow groundwater impacted by RDM mine waste in the Red Devil Creek downstream alluvial area does not emerge into Devil Creek surface water, but instead migrates in the subsurface and emerges into the Kuskokwim River as groundwater. Similarly, deeper groundwater, some of which is potentially impacted by flow through mineralized bedrock and underground mine workings emerges into the Kuskokwim River as groundwater. Based on the evaluation of discharge and contaminant flux of such groundwater into the Kuskokwim River, as presented in Section 3.9 of the Groundwater and Surface Water Report, the rate of groundwater flux is too low to measurably affect COC concentrations in the Kuskokwim River surface water.

1.2.3.3 Red Devil Creek Delta

As noted above, the Red Devil Creek delta extends into the Kuskokwim River from the Red Devil Creek alluvial area. Surface and subsurface soil sampling of the delta was performed during the RI. Based on nearshore sediment samples and soil samples collected from soil borings installed on the face of the delta during the RI, the delta consists of mixed tailings/waste rock, Red Devil Creek alluvium, and soil, and contains elevated concentrations of COCs. The extent of these materials is approximated based on a combination of sediment sample data, bathymetry, and data from soil borings installed on the face of the delta and is illustrated in Figures 1-4 and 1-5.

For the purpose of the 2016 FS, an elevation of 164 feet was assumed to represent a low river stage elevation at the delta. Contaminated soil addressed under Alternatives 3 and 4 in the 2016 FS includes the Red Devil Creek delta materials situated above an elevation of 164 feet. Materials within the portion of the Red Devil

Creek delta situated below an elevation of 164 feet are addressed in this FS Supplement report and referred to herein as the lower delta.

Soil and sediment at the Red Devil Creek delta may be subject to future erosion and downriver transport by the Kuskokwim River. Sediment samples collected from the delta are included in the body of data used to evaluate Kuskokwim River sediment, discussed in Section 1.2.3.4.

1.2.3.4 Kuskokwim River Sediment

Kuskokwim River sediment has been characterized as part of the RI and RI Supplement, as described below.

1.2.3.4.1 RI Sediment Characterization

During the RI, bed surface sediment samples were collected at 17 locations along the shoreline of the Kuskokwim River in 2010 and 2011, and from 55 offshore locations in 2011 and 2012. The RI sediment sample results showed relatively low concentrations of COCs in background samples located upriver of the Red Devil Creek delta, and elevated concentrations at the Red Devil Creek delta and downriver locations. Seventeen inorganic elements and methylmercury were detected above background values in the Kuskokwim River RI sediment samples. Antimony, arsenic, and mercury were the most highly elevated contaminants above background values in the Kuskokwim River sediment samples. Concentrations generally decreased downriver from the mouth of Red Devil Creek, but the extent of inorganic element contamination in river sediments was not defined by RI sampling in either the downriver or cross-river direction (E & E 2014).

1.2.3.4.2 RI Supplement Sediment Characterization

In 2015, RI Supplement sediment characterization activities were performed to address data gaps associated with sediment in the Kuskokwim River near and downriver of Red Devil Creek. The RI Supplement sediment characterization was designed to assess the following:

- Cross-river and downriver extents of contamination in Kuskokwim River sediment;
- Turbidity of Kuskokwim River water;
- Toxicity of sediments to benthic macroinvertebrates; and
- Potential for methylation and bioaccumulation of mercury.

RI Supplement sediment characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters of sediment samples collected at 16 offshore sediment sample locations in the Kuskokwim River. Laboratory analyses included the following:

total target analyte list inorganic elements; total organic carbon; grain size distribution; toxicity using a *Hyallela azteca* 28-day test; methylmercury; and mercury selective sequential extraction. In addition to collection of sediment samples, the water column at all RI Supplement sampling locations was analyzed in the field for turbidity. Results of the RI Supplement sediment characterization and BLM studies are presented in Chapter 5 of the RI Supplement report.

1.2.3.4.3 BLM Kuskokwim River Investigations

Beginning in 2010, the BLM began a study to comprehensively examine mercury, methylmercury, and other metals in the Kuskokwim River basin in proximity to the RDM. Studies that are pertinent to the evaluation of Kuskokwim River sediment near the RDM include fish movement and tissue sampling studies, periphyton sampling, and benthic macroinvertebrate sampling. Pertinent results of the BLM investigations are presented in Section 5.2 of the RI Supplement report.

1.2.3.4.4 Kuskokwim River Sediment Characterization Summary

Key findings of the Kuskokwim River characterization pertinent to the nature and extent and fate and transport of contamination at the RDM are summarized below.

Updated Kuskokwim River Sediment Background Levels

The RI report presented background values for Kuskokwim River sediment. The background values were updated in the RI Supplement report to include results of additional background sediment samples collected as part of the RI Supplement. The revised background sediment values for the primary COCs are 0.583 milligrams per kilogram (mg/kg) for total antimony, 13.4 mg/kg for total arsenic, and 0.141 mg/kg (outlier excluded) for total mercury (see Section 5.3.1 of the RI Supplement report).

Cross-River and Downriver Extent of Sediment Contamination

Concentrations of total antimony, arsenic, and mercury decrease with distance from the riverbank near the RDM, and with distance downriver from the Red Devil Creek delta. Maximum COC concentrations in sediment are generally similar to levels measured in tailings/waste rock. Concentrations generally decrease to values near background levels for total antimony, arsenic, and mercury in the most downriver samples collected in the RI Supplement. The distribution of COC concentrations in Kuskokwim River sediment near the RDM suggest that sediment contamination in the river is attributable to a source at the mouth of Red Devil Creek. The general trends toward decreasing concentrations downriver from the Red Devil Creek delta changes to a less regular pattern farther downriver. The change in pattern includes increases in concentrations approximately 1 kilometer (km) downriver from the Red Devil Creek delta and an even more pronounced increase in concentrations approximately 4.4 km downriver from the Red Devil Creek delta. Deviations from the general trend of decreasing concentrations with distance downriver are likely attributable to other non-RDM mineral occurrences, which are discussed below.

Mineral Occurrences near Red Devil Mine

The RDM lies within a mineralized region (e.g., Miller et al. 1989). This regional mineralization influences the concentrations of antimony, arsenic, mercury, and other metals in the environment, including sediment in the Kuskokwim River and some of its tributaries. Section 5.4.2 of the RI Supplement report presents information on mineral occurrences in the area near the RDM. RI Supplement Report Table 5-7 presents information on mineral occurrences in the area near the RDM based on Miller et al. (1989). The table indicates the type of occurrence (i.e., lode or placer); degree of development (e.g., occurrence of mineralization, prospect, mine); production; and minerals present, including cinnabar (mercury sulfide), stibnite (antimony sulfide), and realgar and orpiment (arsenic sulfides), which are the primary sources of mercury, antimony, and arsenic at the RDM. The table also identifies the nearest surface water body hydraulically downgradient of each mineral occurrence. All the surface water bodies drain to the Kuskokwim River. RI Supplement report Figure 5-18 illustrates the locations of the mineral occurrences described by Miller et al. (1989).

Most of the mineral occurrences identified in RI Supplement Section 5.4.2 drain into a reach of the Kuskokwim River that lies within the extent of sediment samples collected during the 2015 Kuskokwim River sediment sampling event. For each mineral occurrence identified in RI Supplement report Table 5-7, the nearest downriver 2015 Kuskokwim River sediment sample is identified.

As indicated in the RI Supplement report, location KR096 is the nearest sediment sample location downriver from the mouth of McCally Creek, which is a watershed containing six mineral occurrences identified by Miller et al. (1989). Location KR103 is the nearest sediment sample location downriver from three mineral occurrences, including the Alice and Bessie claim group (formerly known as the Parks prospect), located near the northeast bank of the river. It is likely that increases in total antimony, arsenic, and mercury concentrations in Kuskokwim River sediment at locations KR096 and KR103 are attributable, in part, to inputs from these other mineral occurrences

Methylmercury in Sediment

Methylmercury was detected in RI samples from 2010 to 2012 at concentrations ranging from 0.15 to 3.73 nanograms per gram (ng/g). Methylmercury was detected in eight of the 14 RI Supplement sediment samples at concentrations ranging up to 0.788 ng/g (estimated). The methylmercury concentration in 14 of 26 of the 2010 to 2012 samples exceeded the recommended RI background level of 0.49 ng/g. Concentrations in three of the RI Supplement samples were greater than the recommended RI background level of 0.49 ng/g for methylmercury.

In general, concentrations of methylmercury in the RI and RI Supplement Kuskokwim River sediment samples are low compared with the national average for rivers (1.6 ng/g) (Scudder 2009). Concentrations in all 14 RI Supplement samples were found to be below the national average, and only four of the 26 RI samples had concentrations above the national average. These results are consistent with the observation that the environmental conditions of the Kuskokwim River near the RDM generally are not conducive to mercury methylation.

Sediment Toxicity

A 28-day growth and survival test with *Hyalella azteca* (freshwater amphipod) was conducted with sediment from 10 locations in the Kuskokwim River downstream from the Red Devil Creek delta and from two upstream reference samples. The following results of this test are noteworthy:

- Seven of 10 samples collected downstream from the Red Devil Creek delta showed no effects on survival or biomass compared with the upstream reference samples or laboratory control sample. The remaining three samples showed a moderate reduction in amphipod survival and biomass compared with reference samples, which was attributed to differences in sediment texture and/or total organic carbon content and/or non-COC metals.
- No effect on growth was observed in nine of 10 samples collected downstream from the Red Devil Creek delta.
- There was no correlation between *Hyalella* survival and sediment concentrations of antimony, arsenic, mercury, or methylmercury.

Kuskokwim River Periphyton

In 2014, the BLM collected periphyton samples from the nearshore environment of the Kuskokwim River at 13 locations downstream from the Red Devil Creek delta and 13 locations upstream form the Red Devil Creek delta. The samples were analyzed for metals, methylmercury, inorganic arsenic, and percent solids. The following results of the analysis are noteworthy:

- Antimony, arsenic, and mercury were elevated in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. The greatest difference was for mercury, which was about 20 times greater on average in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. Inorganic arsenic was not elevated in samples collected downstream from the Red Devil Creek delta.
- Methylmercury was not detected in the periphyton samples. Hence, despite the fact the total mercury levels were elevated in periphyton samples collected downstream from the Red Devil Creek delta, there is no

indication that this pattern of total mercury contamination resulted in greater methylmercury levels at the base of the benthic food web.

Kuskokwim River Fish

Between 2011 and 2014, the BLM Alaska State Office, in cooperation with the U.S. Fish and Wildlife Service and Alaska Department of Fish and Game, measured mercury concentrations in small muscle biopsies from northern pike and burbot equipped with radio transmitters and related the concentrations to fish location and movements in the middle Kuskokwim River region. The study design and methods are described in Matz et al. (2017). Matz et al. (2017) divided the mainstream Kuskokwim River and major tributaries within the study area into eight watersheds or reaches for their investigation. The following results of this study are noteworthy:

- Total mercury levels in pike and burbot from the Kuskokwim River reach that includes the RDM were among the lowest measured in the study.
- Only about 10% of burbot and 40% of pike captured in the Kuskokwim River reach that includes the RDM remained in that river reach. Low fidelity of burbot and pike to this reach has the effect of reducing their exposure to mercury and other contaminants from the RDM.
- Low fidelity of pike to the Kuskokwim River reach near the RDM likely is due to the physical and biological characteristics of the reach. The reach is characterized by strong current, high turbidity, linear shorelines, and low density of shoreline wetlands, which make this reach unattractive to pike.
- The greatest total mercury levels in pike were found in the Takotna, Holitna, and George River watersheds. All three watersheds have extensive areas of oxbows with abundant wetland habitat, ideal habitat for pike and other fish, and important sites for mercury methylation.

Matz et al. (2017) found no relationship between pike total mercury levels and the number of mercury-containing mines or mercury-containing occurrences and prospects in a given watershed.

1.2.4 Baseline Risk Assessment

1.2.4.1 Human Health Risk Assessment

An HHRA was conducted for the RDM as part of the RI in accordance with Alaska State and EPA human health risk assessment guidance (E & E 2014). The following potential receptors were evaluated in the HHRA: future residents, current and future recreational or subsistence users, and future mine workers. As applicable, child receptors were also evaluated. The HHRA was conducted with contaminant data from surface and subsurface soil, nearshore sediment, groundwater, surface water, and biota data.

The potential cancer risks at the site exceed both Alaska Department of Environmental Conservation (ADEC) and EPA criteria for all receptors assessed. In general, exposure to arsenic in soil and groundwater posed the greatest risk. Likewise, the potential hazards at the site exceed both ADEC and EPA criteria for all receptors evaluated in the HHRA. In general, exposure to antimony, arsenic, and mercury in soil, groundwater, and fish from Red Devil Creek posed the greatest hazard. Risks and hazards were the highest for future residents potentially exposed to COCs.

Potential risk-based cleanup levels (RBCLs) were proposed for the COCs and determined in the HHRA. RBCLs were developed for arsenic, antimony, and mercury in a number of media, including soil, groundwater, and biota. RBCLs were also developed for the other COCs at the RDM for the media of concern (see Sections 6.4.1 and 6.4.2 of the 2014 RI report). RBCLs were not developed for Kuskokwim River sediment in the RI.

As part of the RI Supplement, an HHRA Supplement was performed to address data gaps associated with Kuskokwim River sediments that were not addressed as part of the initial RI effort—specifically, to assess the risks and hazards from potential exposure to contaminants of potential concern through direct contact and incidental ingestion of sediment, and consumption of fish from the Middle Kuskokwim River region. Additional results from sediment sampling and fish tissue sampling were used to develop the HHRA Supplement. Results of the HHRA Supplement are detailed in Chapter 6 of the RI Supplement Report, and conclusions are summarized below.

The HHRA Supplement for the Kuskokwim River assessment area indicated that direct exposure (incidental ingestion and dermal exposure) to Kuskokwim River sediment near the RDM results in non-cancer hazards that do not exceed acceptable hazards as defined by EPA and ADEC. Cancer risks from exposure to Kuskokwim River sediment for all receptors are within the acceptable EPA excess cancer risk range of 1 in 10,000 to 1 in 1,000,000. For residents and recreational/subsistence users, the excess cancer risk is slightly above the ADEC standard of 1 in 100,000. Arsenic is the only substance associated with carcinogenic risk at the site. Localized background sediment levels contribute approximately 3% to the overall site cancer risk from direct exposure to sediment and approximately 7% to the overall noncarcinogenic hazard from this pathway.

Potential exposure to methylmercury and arsenic in muscle samples from fish collected from the middle Kuskokwim River region, consisting of the approximately 410-km stretch of the Kuskokwim River from Aniak to just upriver of McGrath, including the reach that contains the RDM, resulted in cancer risk levels above both ADEC and EPA cancer risk and noncancer hazards above ADEC or EPA standards. The cancer risks are primarily driven by consumption of arsenic in northern pike and whitefish. The noncancer hazards are primarily driven by consumption of methylmercury in northern pike, and arsenic and methylmercury in whitefish.

Assessment of potential cancer risks and noncancer hazards from exposure to fish on a regional basis are not specifically tied to the RDM. Northern pike are mobile and migratory. In the BLM study, northern pike tended to stay in tributaries of the mainstem Kuskokwim and had greater mercury concentrations when they were in more mineralized watersheds, although northern pike that stayed in the mainstem Kuskokwim had overall lower mercury concentrations in spite of being in proximity to mercury sources (Matz et al. 2017). The turbid and swift conditions of the Kuskokwim River provide limited habitat for pike and few conditions conducive to mercury methylation (wetlands). There were no spatial differences identified in mercury concentrations in sheefish (inconnu), which are anadromous in the area (Matz et al. 2017).

1.2.4.2 Ecological Risk Assessment

A BERA was conducted for the RDM as part of the RI in accordance with ADEC and EPA ecological risk assessment guidance (E & E 2014). An assortment of ecologically relevant assessment endpoints were evaluated, including terrestrial plants, soil invertebrates, benthic macroinvertebrates, fish and other aquatic biota, terrestrial wildlife, and aquatic-dependent wildlife. The BERA was conducted using contaminant data from two primary sources: (1) surface soil, sediment, surface water, and vegetation data collected for the RI; and (2) fish (slimy sculpin) and benthic macroinvertebrate contaminant data collected from Red Devil Creek by the BLM as part of a larger study examining contaminants in aquatic biota in the Middle Kuskokwim River. Results of the BERA are presented in Chapter 6 of the final RI report.

As part of the RI Supplement, a BERA Supplement was performed to address data gaps associated with Kuskokwim River sediments that were not addressed as part of the initial RI effort. The BERA Supplement is focused on aquatic-dependent receptors that may use the Kuskokwim River near the RDM, including benthos, fish, and wildlife. Since the final RI report was completed, E & E and the BLM have both collected substantial additional data from the Kuskokwim River near the RDM and from the middle Kuskokwim River region in general. These data were used to help understand potential risks to aquatic-dependent receptors that use the Kuskokwim River near and downstream from the RDM (E & E 2018).

Overall, the BERA supplement for the Kuskokwim River assessment area identified only marginal risks to the assessment endpoints evaluated when conservative approaches were used to model bioaccumulation. The following points from this supplemental assessment are noteworthy:

- When using site biota sediment accumulation factors (BSAFs) and trophic transfer factors (TTFs) to model food-chain bioaccumulation, no risks were predicted for herbivorous birds (represented by the green-winged teal), invertivorous birds (represented but the common snipe), piscivorous birds (represented by the belted kingfisher), piscivorous mammals (represented by the mink), forage fish (represented by the slimy sculpin), or benthic macroinvertebrates.
- Because BSAFs often increase with decreasing contaminant concentrations in sediment, BSAFs and TTFs based on data from reference creeks in the middle Kuskokwim River region also were used to model bioaccumulation. When background BSAFs and TTFs were used to model bioaccumulation, marginal potential risks were predicted for invertivorous birds (common snipe) from mercury (hazard quotient [HQ] = 1.2) and selenium (HQ = 1.1), piscivorous birds (kingfisher) from selenium (HQ = 1), piscivorous mammals (mink) from selenium (HQ = 1.2), benthic macroinvertebrates from mercury (HQ = 4.2), and forage fish from mercury (HQ = 1.8). However, as discussed in RI Supplement report Section 7.5.4, selenium risks to the snipe, kingfisher, and mink are from background. And, as noted in RI Supplement report Section 7.6, using only background BSAFs and TTFs to model bioaccumulation likely overestimates risk in the Kuskokwim River assessment area by a factor of two to four.
- By assuming that aquatic-dependent herbivorous birds (green-winged teal) feed only on periphyton from the Kuskokwim River, a potential risk was identified from vanadium (HQ = 8). However, as discussed in RI Supplement report Section 7.5.4, vanadium risks are from background.
- Sediment toxicity testing was the strongest line of evidence used to evaluate potential impacts to the benthic macroinvertebrate community in the Kuskokwim River near the RDM. Low to moderate effects on survival, growth, and/or biomass were identified in three of 10 site samples, but there was no relationship between these effects and sediment concentrations of antimony, arsenic, mercury, and/or methylmercury, the principal site-related contaminants. Instead, the effects appeared to be the result of differences in sediment texture and/or total organic carbon content between the site and reference samples, and/or the result of non-site-related metals (iron, manganese, and nickel) that appear to be naturally elevated in Kuskokwim River sediment.

1.2.5 Weight-of-Evidence Discussion for Potential Risks Associated with Kuskokwim River Fish and Sediments

A WOE evaluation was performed to address RDM-specific and regional risk posed by fish consumption and exposure to contaminated sediment in the Kuskokwim River. The principal objective of this WOE evaluation is to consider all relevant data in addressing important risk questions regarding the RDM site and provide direction to risk managers. By combining the results of multiple lines of evidence (LOEs) relevant to a specific risk questions, it may be possible to reach conclusions that could not be achieved with any single LOE. Results of the WOE evaluation are discussed in Chapter 9 of the RI Supplement report. The RI Supplement report presents a detailed discussion of the findings of a number of factors that are critical to understanding site-specific and regional risk at the RDM and the Kuskokwim River. That discussion is summarized below.

1.2.5.1 Kuskokwim River Fish

A WOE evaluation was developed to consider multiple LOEs relevant to understanding human exposure to methylmercury and arsenic in fish. The WOE evaluation combines the results of the risk assessment with additional LOEs presented in the RI and RI Supplement reports. A principal objective of the WOE evaluation is to consider all relevant data in addressing the primary questions and provide critical information to risk managers. Each individual LOE is considered independently in regard to Kuskokwim River risk, and the LOEs are considered collectively as part of the overall WOE evaluation. In addition to the results of the risk assessment supplements, the other LOEs fall into four groups: (1) site characteristics; (2) contaminant bioavailability; (3) fish movement and local fishing patterns; and (4) effects of recent and planned remediation on potential exposure and risk. The interrelationships between these LOE are illustrated in Figure 9-1 of the RI Supplement report and summarized below.

The LOEs related to RDM and Kuskokwim River characteristics are:

- Kuskokwim River Characteristics near the RDM;
- Regional and Local Background Issues; and
- Kuskokwim River Sediment Data.

The LOEs related to contaminant bioavailability are:

- Sediment Toxicity Tests;
- Periphyton Data;
- Bioaccumulation Factors; and
- Mercury Selective Sequential Extraction Results.

The LOEs related to fish movement and local fishing practices are:

- Telemetry Data;
- Fish Tissue Data; and
- Local Fishing Patterns.

The LOEs related to recent and planned remediation actions to reduce site risks are:

- Previous source control efforts; and
- Planned future remedial actions.

Each LOE is discussed in detail in the RI Supplement report.

Based on the WOE evaluation, the overall evidence supports the conclusion that, although the RDM has contributed mercury and arsenic to the Kuskokwim River, the mercury and arsenic levels measured in pike, burbot, and whitefish reflect primarily regional exposure, and there is no demonstrable RDM-specific increase in fish consumption risk. The mercury and arsenic levels measured in fish from the middle reach of the Kuskokwim and its tributaries are consistent with state-wide levels reported by the ADEC (2017a, 2017b), suggesting that regional levels of mercury and arsenic in the Kuskokwim are not appreciably different than those across the state.

Based on full consideration of the multiple LOEs included in this evaluation, several specific risk questions were addressed in the RI Supplement report, as follows:

- Question 1: Are releases of mercury from the RDM a primary contributor to elevated levels of methylmercury in upper trophic level, subsistence fish in the middle reach of the Kuskokwim River?
    - Answer: Although the RDM has been shown to be a source of total mercury to the river, the cumulative evidence does not indicate that the RDM is contributing significantly to methylmercury levels in subsistence fish from the middle Kuskokwim River region.
- Question 2: To what extent are the potential risks associated with exposure to metals, specifically methylmercury and arsenic, in fish from the middle reach of the Kuskokwim River attributable to the RDM versus other sources?
    - Answer: Methylmercury and arsenic levels in fish that live primarily in upgradient tributaries, or that range widely in the Kuskokwim River, are comparable to those collected from the river near the RDM. Furthermore, the fish of interest do not spend much time near the RDM due to poor habitat; hence, their tissue levels reflect bioaccumulation from the locations where they live and eat (i.e., the large tributaries for pike and the entire middle and lower Kuskokwim River for burbot). These results suggest that the RDM, while a historical source of contaminant input to the river, is

not contributing significantly to risks associated with exposure to methylmercury and arsenic in subsistence fish.

1.2.5.2 Kuskokwim River Sediment

This section summarizes the LOEs associated with direct human exposure to sediments in the Kuskokwim River. Non-cancer hazards from exposure to inorganic compounds in Kuskokwim River sediment near the RDM, including the down-river portion, are at levels considered acceptable by the EPA and ADEC. Cancer risks from exposure to inorganic contaminants in Kuskokwim River sediment for all receptors are within the acceptable EPA cancer risk range. For residents and recreational/subsistence users, the cancer risk is slightly above the ADEC acceptable cancer risk level. Arsenic is the only carcinogenic contaminant in sediment at the site.

Alternatives 3 and 4 of the 2016 FS include excavation and removal of the tailings in the Main Processing Area and downstream Red Devil Creek alluvial area. This action is expected to include much of the material in the Red Devil Creek delta, further reducing exposure of human and ecological receptors to site-related contaminants (including arsenic and mercury) in the Kuskokwim River near the RDM. Many of the high concentration sediment samples for arsenic and mercury were collected in the delta directly offshore from the RDM. Remediation and removal of the mine waste at the Red Devil Creek delta is expected to reduce the risk estimates since it will lower the concentrations of arsenic and mercury to which a person may be exposed directly. Given the modest exceedance of the ADEC's cancer risk level, the BLM anticipates that future remedial efforts will remove sufficient waste material to reduce risks to below ADEC standards.

An additional LOE relates to site activity levels assumed to occur at the delta in the HHRA Supplement (E & E 2018). As discussed above, the Kuskokwim River near the RDM does not provide attractive habitat for burbot or northern pike. This stretch of the river is not productive for fishing, and the RDM area lacks road access and boat docks.

Overall, several LOEs suggest that potential risks from sediment exposure are unlikely to be a genuine concern near the RDM currently or in the future. First, the amount of assumed sediment exposure likely was overestimated in the HHRA Supplement. Second, future risks after site remediation are expected to be even lower due to the planned removal of much of the tailings/waste rock material from Red Devil Creek delta.

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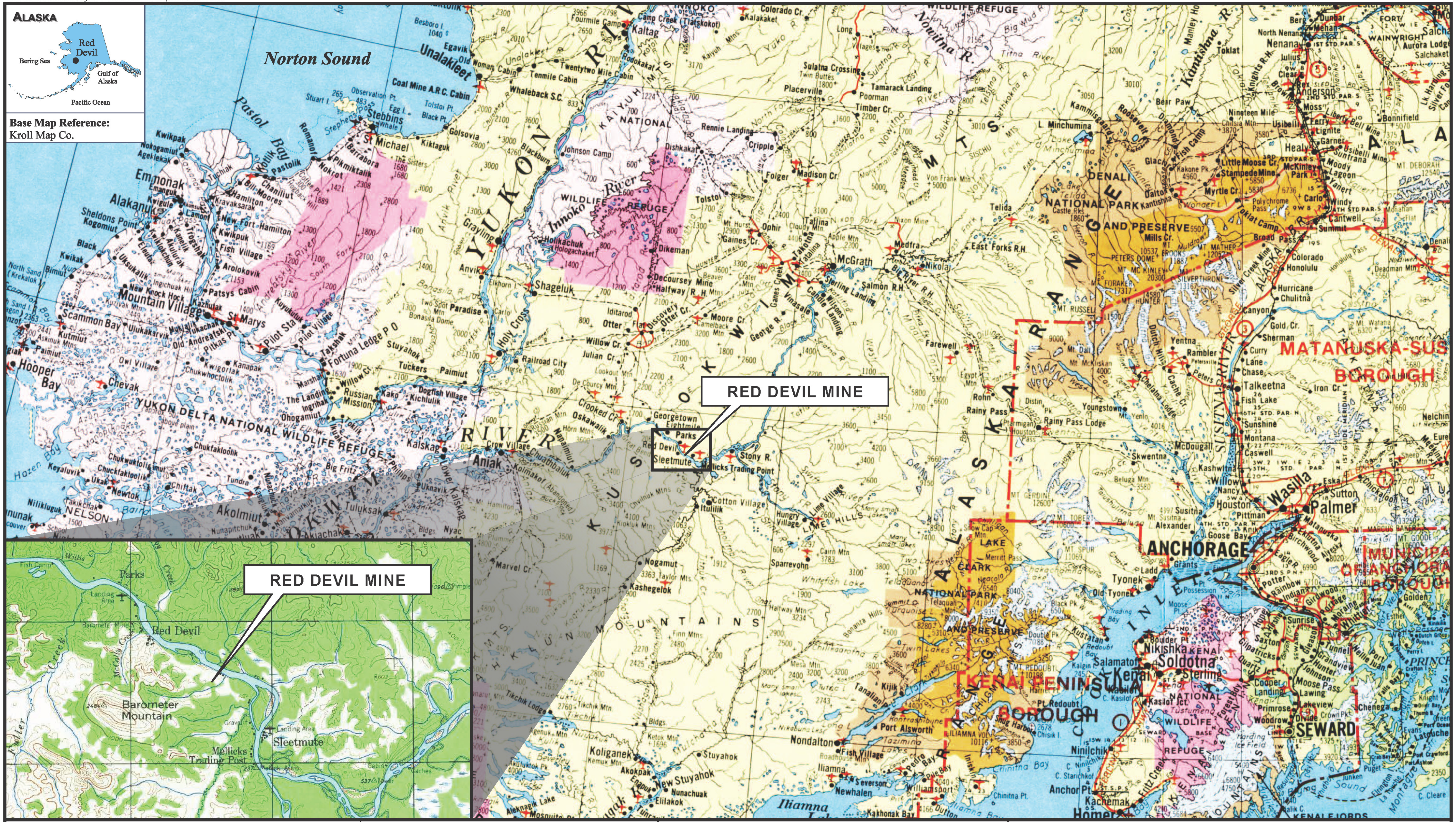
02:EE-001096-0070-08\Figure 1-1 Site Location Map.ai-01/25/13-GRA



ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

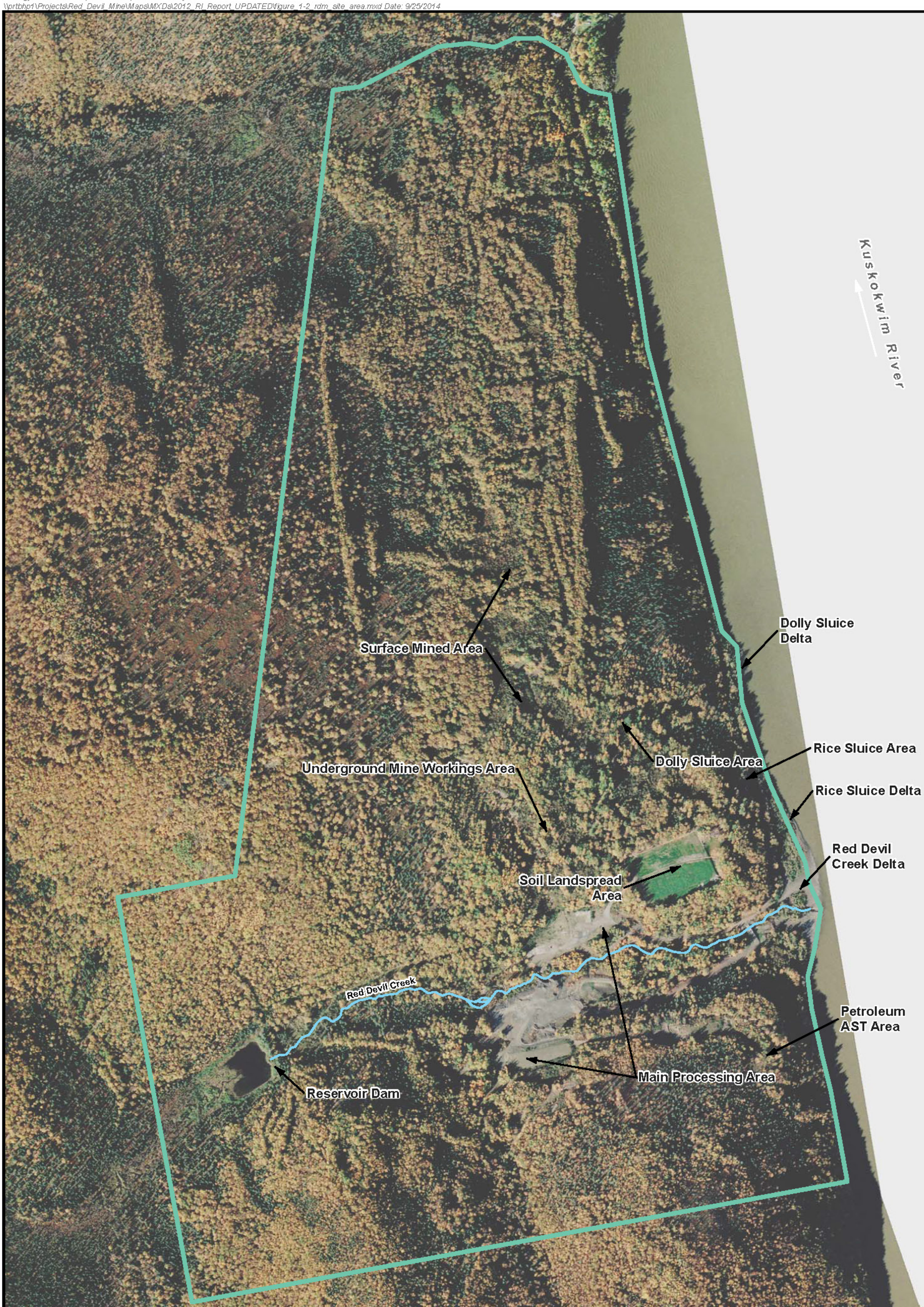
0 40 80
Approximate Scale in Miles

RED DEVIL MINE
Red Devil, Alaska

Figure 1-1
SITE LOCATION MAP

Date: 04/18/13	JSS	02:EE-001096-0070-08

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2012_RI_Report_UPDATED\figure_1-2_rdm_site_area.mxd Date: 9/25/2014



Upland Area Encompassed by Remedial Investigation

RED DEVIL MINE

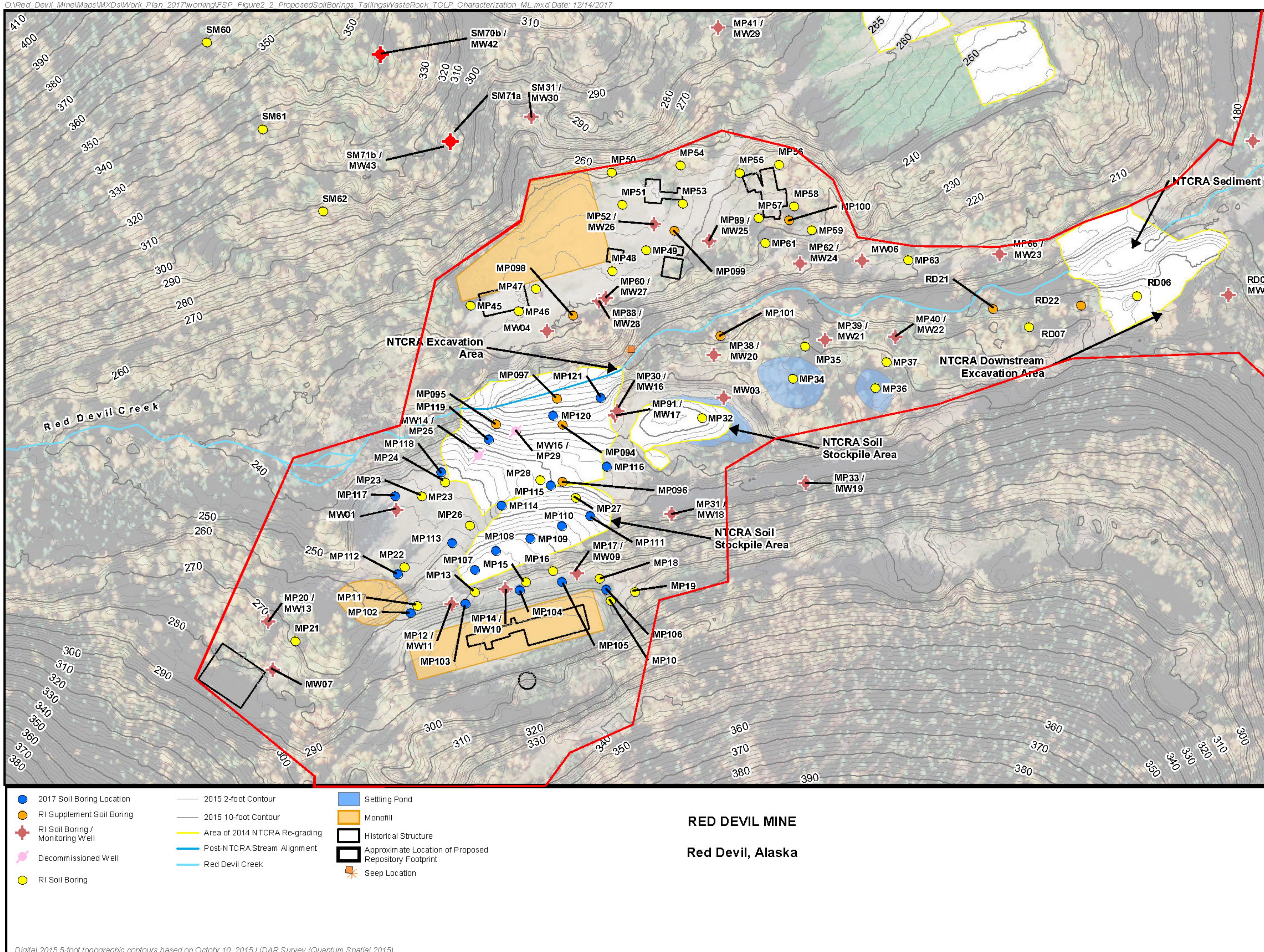
Red Devil, Alaska

Figure 1-2
Upland Area Encompassed by Remedial Investigation

0 75 150 300 450 600 750 Feet
0 37.5 75 150 225 Meters
Scale 1:4,562

Image Source: Aero-Metric, Inc. 2010a

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\Work_Plan_2017\working\FSP_Figure2_2_ProposedSoilBorings_TailingsWasteRock_TCLP_Characterization_ML.mxd Date: 12/14/2017

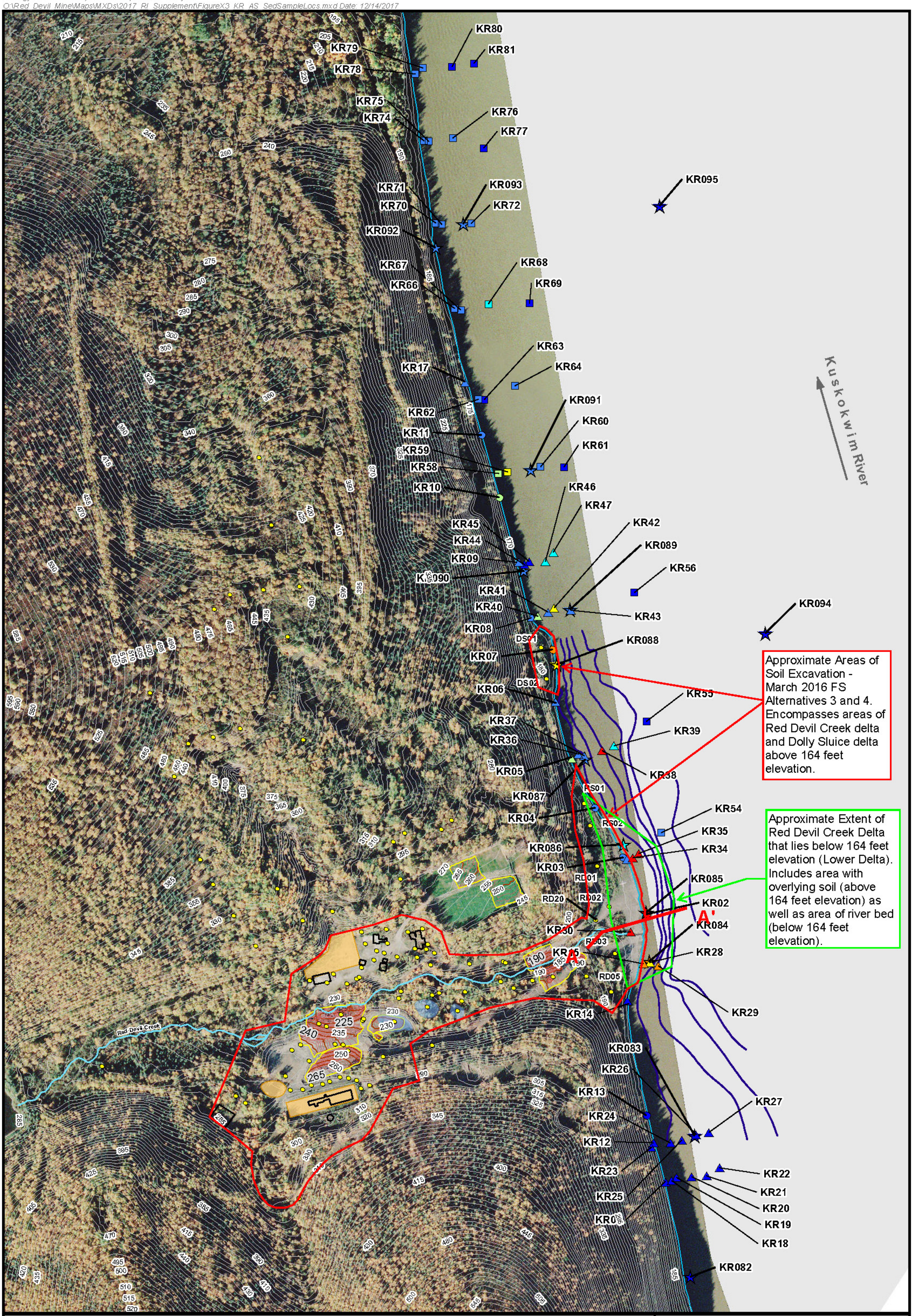


RED DEVIL MINE

Red Devil, Alaska

Figure 1-3
Soil Boring Locations - Main Processing Area and Red Devil Creek Downstream Alluvial Area

0 25 50 100 150 200 Feet
0 7.5 15 30 45 60 75 Meters
Scale 1:1,500



2010 Total Arsenic (mg/kg)	2011 Total Arsenic (mg/kg)	2012 Total Arsenic (mg/kg) AS	2015 Total Arsenic (mg/kg)
> 800	> 800	> 800	> 800
400 to 800	400 to 800	400 to 800	400 to 800
200 to 400	200 to 400	200 to 400	200 to 400
100 to 200	100 to 200	100 to 200	100 to 200
69 to 100	69 to 100	69 to 100	69 to 100
13.4 to 69	13.4 to 69	13.4 to 69	13.4 to 69
≤ 13.4 background	≤ 13.4 background	≤ 13.4 background	≤ 13.4 background

Soil Boring
Bathymetric contour (feet)
2010 5-foot Contour
River level (elevation 165.78 feet) on 9/21/2010
Area of 2014 NTCRA Red Devil Creek Sediment Trap
2014 5-foot Contour
2014 1-foot Contour
Settling Pond
Monofill
Historical Structure

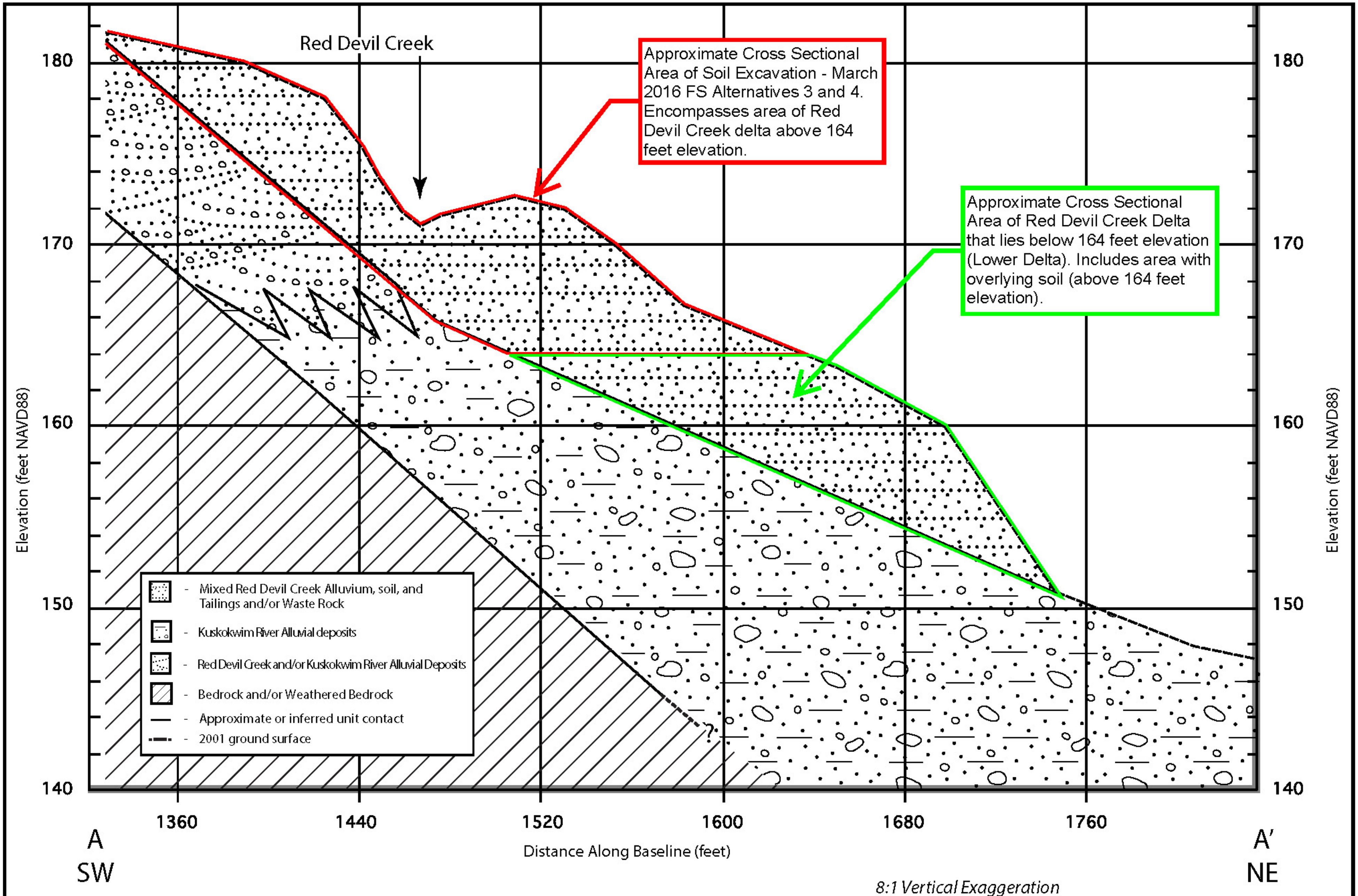
RED DEVIL MINE
Red Devil, Alaska

Figure 1-4

Red Devil Creek Delta Area

0 75 150 300 450 600 Feet
0 15 30 60 90 120 150 Meters
Scale 1:2,500

1. Aerial image collected on 9/21/2010 (Aerometric 2012)
2. Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on 9/21/2010 (AeroMetric 2012)
3. Kuskokwim River elevation on date aerial orthophotographic survey (9/21/2010) was 165.78 feet (Aerometric 2012)
4. Bathymetric contours represent approximate depths below river surface on 9/25/2011
5. Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)



Note: 1. Geologic cross section is modified from final RI report Figure 4-17.
2. Surface topography is based on 5/27/2001 aerial orthophotograph and topographic map (AeroMetric 2010b).

RED DEVIL MINE

Red Devil, Alaska

Figure 1-5
Geologic Cross Section A-A'
Red Devil Creek Delta

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2 Identification and Screening of Remedial Technologies

This chapter presents the RAOs and remedial goals (RGs), applicable or relevant and appropriate requirements (ARARs), GRAs, and identification and screening of remedial technology types and specific process options to address contaminated media that may pose unacceptable risks to human health and the environment. "General response actions" refers to broad categories of remedial actions, "technology types" refers to categories of remedial technologies, and "process options" refers to processes within each technology type (EPA 1988). Remedial technology types and specific process options retained at the conclusion of screening are carried forward and incorporated into Chapter 3 for the development of remedial alternatives.

2.1 Overview

In the 2016 FS report, RAOs, RGs, and site-wide remedial alternatives were identified for tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment (E & E 2016a). On-site groundwater and Kuskokwim River sediment were not addressed in the 2016 FS report because at that time the BLM decided that additional site characterization was necessary to evaluate the need for, and best approaches to remedies for, these media. Since the 2016 FS report was finalized, the BLM has completed additional site characterization to further enhance the development and evaluation of remedies for groundwater and Kuskokwim River sediments.

The risk assessment portion of the RI Supplement focused on human health risks posed by exposure to Kuskokwim River sediments and consumption of fish from the Kuskokwim River, and ecological risks posed by exposure of Kuskokwim River sediments to aquatic-dependent wildlife, benthic organisms, and fish.

The RI baseline risk assessment indicated that on-site groundwater poses potential risks to future human receptors at the RDM (E & E 2014). RAOs, RGs, and remedial alternatives for groundwater are included in this FS Supplement report.

The RI Supplement report details multiple LOEs supporting the conclusion that there is no clear linkage between releases from the RDM and elevated risks associated with consumption of subsistence fish harvested from the Kuskokwim River. The HHRA Supplement concluded that direct exposure to nearshore (areas accessible for wading and fishing) Kuskokwim River sediment near the RDM results in non-cancer hazards that do not exceed acceptable EPA and ADEC standards for all receptors. Cancer risks from exposure to the river sediment for all human receptors are within the acceptable EPA excessive risk range of 1 in 10,000 to 1 in 1,000,000; however, for future residents and recreational/subsistence receptors, arsenic concentrations represent excess cancer risk slightly above the ADEC standard of 1×10^{-5} (1 in 100,000). The BERA Supplement concluded that marginal risks to ecological assessment endpoints are posed by Kuskokwim River sediments (E & E 2018).

The Red Devil Creek delta includes the portion of the delta below an elevation of 164 feet (lower delta). The approximate extent of the Red Devil Creek delta is based on a combination of soil boring, sediment, and bathymetric data collected during the RI, and is depicted in Figures 1-3 and 1-4. The materials within the lower delta may be subject to erosion and migration to downriver locations, potentially including nearshore sediment locations to which human receptors could be exposed.

2.2 Contaminants of Concern

Based on the results of the baseline risk assessment, the COCs identified for groundwater include antimony, arsenic, and inorganic mercury due to human health risks (E & E 2014).

Based on the HHRA Supplement, arsenic is identified as a COC in nearshore Kuskokwim River sediments due to a slight exceedance of ADEC's standard of 1×10^{-5} (1 in 100,000) excess lifetime cancer risk for residential and recreational/subsistence users. All non-carcinogen hazards are at or below 1.0, both EPA and ADEC standards (E & E 2018).

For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints (E & E 2018).

2.3 Remedial Action Objectives and Goals

The overall goal of the remedial action at the RDM is to protect human health and the environment from elevated risks associated with COCs in on-site contaminated media, including groundwater and nearshore Kuskokwim River sediments. RAOs are medium-specific statements for protecting human health and the environment that address specific chemicals, exposure route(s) and receptors. RGs are numeric values that define a chemical concentration that correlates to an acceptable level of risk, generally referred to as cleanup levels.

2.3.1 Groundwater Remedial Action Objectives

To develop site-specific RAOs for groundwater, results of the baseline HHRA were used to identify the receptors requiring protection (see Table 2-1). Accordingly, the RAO for groundwater is:

- Prevent or reduce human future resident exposure (through ingestion, inhalation, or dermal contact) to antimony, arsenic, and mercury in groundwater at concentrations above RGs.

2.3.2 Kuskokwim River Remedial Action Objectives

To develop site-specific RAOs for the Kuskokwim River, results of the HHRA Supplement were used to identify the receptors requiring protection (see Table 2-1). Accordingly, the RAOs for nearshore Kuskokwim River sediment and materials within the lower delta are:

- Reduce human future resident and recreation/subsistence user exposure (through dermal contact and incidental ingestion) to arsenic in materials within the lower delta and nearshore Kuskokwim River sediments at concentrations above RGs.
- Reduce potential migration of materials within the lower delta to downriver locations where human exposure to nearshore sediments at concentrations above RGs could occur.

The BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints (E & E 2018). Therefore, Kuskokwim River sediment RAOs based on protection of ecological receptors were not developed.

Table 2-1 Summary of Media and Receptors of Concern

Exposure Medium	Receptor(s)	Exposure Route(s)	Cancer Risk[1]	Hazard Index[1]
Groundwater	Human – Future Resident	Ingestion Inhalation Dermal Contact	2×10^{-1}	3205
Kuskokwim River Nearshore Sediments and Materials within the Lower Delta	Human – Future Resident and Recreation/Subsistence User	Dermal Contact Incidental Ingestion	4×10^{-5}	1.0

Note:

(1) Cancer Risks and Hazard Indices listed for groundwater exposure are based on a future child resident scenario for the Main Processing Area.

2.3.3 Remedial Goals

Proposed RGs for groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments were developed based on the RAOs listed above. The proposed RGs are identified and discussed below.

- Site-specific RBCLs, in accordance with 18 Alaska Administrative Code (AAC) 75.340;
- Chemical-specific ARARs for groundwater in accordance with18 AAC 75.345, Table C and Safe Drinking Water Act Maximum Contaminant Levels (MCLs); and
- Site-specific background values.

2.3.3.1 Site-Specific Risk-Based Cleanup Levels

2.3.3.1.1 Groundwater Risk-Based Cleanup Levels

Groundwater RBCLs were presented in Section 6.4 of the RI report and are carried forward into this FS Supplement.

2.3.3.1.2 Kuskokwim River Sediment Risk-Based Cleanup Levels

RBCLs were not developed for Kuskokwim River sediment in the RI. As summarized in Section 1.2.4.1, based on the results of the HHRA Supplement for Kuskokwim River sediments (see RI Supplement report Chapter 6), all non-carcinogen hazards are at or below both EPA and ADEC standards. Therefore, an RBCL for non-cancer endpoints was not developed for any chemical. The cancer risk for a residential and recreational/subsistence user was within the EPA's risk range but above the ADEC's cancer risk standard. Arsenic is the only carcinogen in Kuskokwim River sediment. Based on the exposure scenarios for the resident and recreational/subsistence user—a risk-based concentration in Kuskokwim River sediment equivalent to a cancer risk of 1 in 100,000, the ADEC's cancer risk standard—an RBCL for arsenic in sediment has been developed. The Kuskokwim River sediment RBCL for this scenario for arsenic is 69.1 mg/kg. As summarized in Section 1.2.4.2, the BERA Supplement for the Kuskokwim River (see RI Supplement report Chapter 7) identified only marginal risks to the assessment endpoints. Therefore, no RBCLs for Kuskokwim River sediment for ecological receptors were developed.

2.3.3.2 Site-Specific Background Levels

2.3.3.2.1 Groundwater Background Levels

As discussed in Section 1.2.3.2.5, much of the groundwater flowing into and through the Main Processing Area and Red Devil Creek valley originates in the Surface Mined Area, and much of that groundwater is impacted by naturally mineralized bedrock. Therefore, the quality of groundwater that would emerge from bedrock in the Main Processing Area and Red Devil Creek valley is expected to be impacted by this natural mineralization.

Previously, as part of the RI, background groundwater concentrations were proposed based on results of samples collected from two wells—MW12, screened in alluvium located within the Red Devil Creek upstream alluvial area, and MW31, screened in bedrock within the upland area west of the Surface Mined Area. These wells were originally proposed for background groundwater characterization based on their locations outside and upgradient of any likely mining-related influence on groundwater COC concentrations. However, these wells also are located outside of the area of any natural mineralization in bedrock

Results of the RI Supplement and 2017 additional characterization improved the understanding of the impacts of natural mineralization in bedrock in the Surface Mined Area on groundwater quality. Results of the evaluation of these impacts were used to support development of estimates of groundwater quality for groundwater flowing through bedrock into the Main Processing Area. These estimates of groundwater quality are used as groundwater BTVs, as presented in Section 3.7 of the Groundwater and Surface Water Report and summarized in the sections below.

It should be noted that the groundwater sample results for bedrock wells in the Surface Mined Area vary widely between individual wells. As such, results from any given well are not representative of groundwater background levels throughout the watershed. The large variability in groundwater concentrations within the Surface Mined Area is significant for two reasons. First, the background concentrations estimated during the RI using data from wells MW12 and MW31 do not reliably predict what the COC concentrations in background groundwater would be prior to excavation and subsequent re-establishment of equilibrium groundwater conditions. Second, the variability is too great for a single value to represent baseline groundwater conditions within the Surface Mined Area. The BTVs estimated as described in the sections below are presented as RGs to satisfy requirements for the FS Supplement. Alternative methods of establishing baseline groundwater concentrations will be explored at a later phase of the project.

2.3.3.2.1.1 Rationale for Groundwater Background Level Development

As noted above, as part of the RI, background groundwater concentrations were proposed based on results of samples collected from two wells—MW12 and MW31—selected based on their locations outside and upgradient of any likely mining-related influence on groundwater COC concentrations. These wells also are located outside of the area of any natural mineralization in bedrock such as described in Section 2.2.6.2 of the Groundwater and Surface Water Report.

Remedial Alternatives 3 and 4 presented in the 2016 FS include excavation of tailings/waste rock and soil with COC concentrations exceeding one or more soil RGs. It is anticipated that such excavation would extend to the top of bedrock throughout much of the Main Processing Area and Red Devil Creek downstream alluvial area. Where such excavation would extend to the top of bedrock, any groundwater contained within the excavated materials also would be removed. Following such excavation, only small, laterally discontinuous areas of residual uncontaminated soil (i.e., with concentrations of COCs below soil RGs) would remain in place in the Main Processing Area and the downstream Red Devil Creek valley. Some of this residual soil may contain groundwater. Such groundwater would be expected to occur in thin, discontinuous zones within the soil. Some of it could potentially include residual groundwater contaminated by leaching of COCs from the tailings/waste rock and contaminated soil prior to their removal. To evaluate such potentially contaminated groundwater in the FS Supplement, groundwater RGs need to be developed. One or more groundwater RGs may be based on background conditions. For the purposes of the FS Supplement RGs, background groundwater is defined as the groundwater that would flow into the Main Processing Area and Red Devil Creek downstream alluvial valley following excavation. Due to complexities in groundwater flow and contaminant transport at the site, it is not possible to reliably predict what the COC concentrations in such background groundwater would be prior to such excavation and subsequent re-establishment of equilibrium groundwater conditions.

Much of the groundwater presently flowing into and through the Main Processing Area and Red Devil Creek downstream alluvial area originates in the Surface Mined Area northwest of Red Devil Creek and the upland area on the southeast side of Red Devil Creek. It is generally expected that groundwater from these areas would continue to flow into and through the Main Processing Area and Red Devil Creek downstream alluvial area following excavation.

As discussed in Section 3.6 of the Groundwater and Surface Water Report, some of the groundwater presently flowing into the Main Processing Area and Red Devil Creek downstream alluvial area is impacted by naturally mineralized bedrock. As described in Section 2.2.6.2 of the Groundwater and Surface Water Report, as a result of localized hydrothermal mineralization, concentrations of COCs in the Kuskokwim Group bedrock are locally significantly higher than in unmineralized zones of the bedrock unit. Groundwater flowing through these mineralized zones contains COC concentrations significantly higher than groundwater in Kuskokwim Group bedrock that has not undergone the mineralization.

In order to develop appropriate RGs to address the potentially contaminated groundwater that would be present in the Main Processing Area and Red Devil Creek Valley following excavation such as described in FS Alternatives 3 and 4, it is necessary to account for the influence of natural mineralization on the groundwater COC concentrations. As discussed in Section 3.6 of the Groundwater and Surface Water Report, some of the wells installed in the Surface Mined Area reflect impacts of natural bedrock mineralization on COC groundwater concentrations. Therefore, groundwater data from these wells provide an opportunity to estimate COC concentrations impacted by natural mineralization using presently available empirical data.

In coordination with the ADEC and EPA, an approach was developed to estimate such background groundwater levels to inform development of groundwater RGs for the FS Supplement. The approach is presented in Section 3.7.2 of the Groundwater and Surface Water Report and summarized below.

2.3.3.2.1.2 Development of Groundwater Background Threshold Values

The approach and results of the groundwater BTV analysis are summarized below.

Well Selection

The observations used in the derivation of the groundwater BTVs were collected from monitoring wells believed to represent groundwater conditions in bedrock upgradient of the Main Processing Area and Red Devil Creek downstream alluvial area. Wells were selected for the groundwater BTV analysis if they met all of the following criteria:

1) The well is screened in Kuskokwim Group bedrock;
2) The well screen is in a position demonstrably hydraulically upgradient of groundwater that flows into the Main Processing Area or Red Devil Creek downstream alluvial area; and
3) The well has been sampled more than one time (through May 2018).

Eight wells meet all three criteria. These wells were installed during the RI, the RI Supplement, and the 2017 additional groundwater characterization activities (see Groundwater and Surface Water Report Table 3-12). Groundwater samples were collected from the wells between August 2011 and May 2018. Table 3-13 of the Groundwater and Surface Water Report shows the sampling events by well.

As discussed in Groundwater and Surface Water Report Section 3.7.1, concentrations of COCs in the Kuskokwim Group bedrock are locally significantly higher than in unmineralized zones of the bedrock unit, and concentrations of COCs in groundwater flowing through these mineralized zones contains significantly higher COC concentrations than groundwater in the bedrock that has not undergone the mineralization. Three of the selected wells—MW40, MW42, and MW43—are installed in zones of mineralized bedrock in close proximity to the underground mine workings, and groundwater COC concentrations in these wells are accordingly higher than in other the other five wells. Observations of natural mineralization and elevated COC concentrations in groundwater in other wells not included in the list of wells used in the BTV analysis (e.g., MW50) are consistent with this relationship.

It should be noted that several other wells installed in 2017 in the Surface Mined Area meet selection criteria 1 and 2, but as of the date of the BTV analysis presented in this report, the wells had been sampled only once and were therefore not selected for the BTV analysis. The rationale for selection criterion 3 stems from the observation that some wells that have been sampled multiple times exhibit significant variability in concentrations of COCs, particularly mercury. Such variability is especially evident in some bedrock wells installed relatively high in the watershed. Possible explanations for such variability include factors and processes described in the RI report, Section 5.4. For the wells installed in 2017, which are limited to one sampling event for all wells except MW59, evaluation of such variability in COC concentrations is therefore not possible using existing data.

Derivation of Background Threshold Values

As indicated in Groundwater and Surface Water Report Table 3-13, the numbers of samples collected from each of the selected wells vary based on their date of installation. To maintain equal weighting of COC concentrations among the wells, the average of all sample results for a given well was calculated and used in the BTV analysis. For averaging purposes, non-detect observations were replaced by one-half of the sample detection limit. If any of the values contributing to an average concentration was a detected value, the average value also was considered detected.

The data were evaluated and BTVs derived using EPA's ProUCL software version 5.1.002 (EPA 2017). The data were first arranged in the format required for input into ProUCL. The ProUCL input format uses two fields to describe each input value, the first being a numerical concentration value and the second a flag indicating whether the numerical value was a detected (1) or non-detected (0) value.

The analytical parameters evaluated are:

- Antimony, total;
- Arsenic, total; and
- Mercury, dissolved and total by Method 1631 and total by Method 7470.

Concentrations of dissolved antimony and arsenic were also measured in four of the wells included in the background well data set. However, for these analyses, there are too few observations to support reliable statistics, so these parameters were not included in the BTV calculations.

Outlier Analysis

Based on the analysis presented in Groundwater and Surface Water Report Section 3.6, groundwater sample results from each of the wells selected for the BTV analysis are considered reasonably representative of naturally occurring conditions upgradient of the Main Processing Area and Red Devil Creek downstream alluvial area. This list of wells includes wells installed in bedrock exhibiting significant natural bedrock mineralization (MW40, MW42, and MW43) and other wells installed in bedrock with no obvious or reported mineralization. As would be expected, the groundwater COC concentrations varied widely as a result of the wide range in mineralization conditions. Nonetheless, an outlier analysis was performed, as described below.

The data sets having sufficient observations were examined for potential outliers by examining quantile-quantile (Q-Q) plots and performing Dixon's Outlier test for both the original and log transformed observations. Datasets that are gamma or lognormally distributed can appear to include high outliers when the high values may actually be from the upper tail of the gamma or lognormal distribution rather than being true outliers. The results of the outlier tests are summarized in Groundwater and Surface Water Report Table 3-14.

Subsequent BTV calculations for all of the datasets were performed with and without the high statistical outlier values identified as described. Both the original and trimmed (minus the high outliers) data sets, the Q-Q plots, and the Dixon's Outlier test results are included the BTV calculation analysis and the ProUCL files provided in Appendix B of the Groundwater and Surface Water Report.

BTV Calculations

BTV calculations were performed for all of the possible statistical distributions included in ProUCL—normal, gamma, lognormal, and nonparametric. ProUCL automatically performs goodness-of-fit tests for each of the parametric distributions and indicates whether the data appear to fit each of the distributions. The candidate BTVs considered for use depended on the outcome of the various goodness-of-fit tests. Sometimes a dataset may appear to fit more than one distribution; in such cases, the distribution used was selected based on the following hierarchy: normal > gamma > lognormal. For each distribution, ProUCL calculates the following upper limit values: the 90^{th}, 95^{th}, and 99^{th} percentile values and the 95% upper prediction limits (UPLs), 95/95% upper tolerance limits (UTLs), and 95% upper simultaneous limits (USLs). The detailed results of the BTV calculations provided by ProUCL are included in the ProUCL files provided in Appendix B of the Groundwater and Surface Water Report. A summary of the ProUCL results is presented in Groundwater and Surface Water Report Table 3-15.

Section 3.1.1 of the ProUCL Technical Guide (EPA 2015) provides a description and interpretation of upper limits and their use to estimate BTVs, as briefly summarized below:

- Upper Percentile, $\underline{x}_{0.95}$: It is expected that an observation coming from the background population (or comparable to the background population) will be $\leq \underline{x}_{0.95}$ with probability 0.95.

- UPL: a 95% UPL represents that statistic such that an independently collected observation (e.g., new/future) from the target population (e.g., background, comparable to background) will be less than or equal to the UPL95 with a confidence coefficient (CC) of 0.95. We are 95% sure that a *single future value (k=1)* from the background population will be less than the UPL95 with a CC= 0.95.
- UTL: a UTL95-95 represents that statistic such that 95% of observations (current and future) from the target population (background, comparable to background) will be less than or equal to the UTL95-95 with a CC of 0.95. A UTL95-95 represents a 95% upper confidence limit of the 95th percentile of the data distribution (population). A UTL95-95 is designed to simultaneously provide coverage for 95% of all potential observations (current and future) from the background population (or comparable to background) with a CC of 0.95. A UTL95-95 can be used when many (unknown) current or future on-site observations need to be compared with a BTV.
- USL: a USL95 represents that statistic such that all observations from the "established" background data set are less than or equal to the USL95 with a CC of 0.95. Since USL represents an upper limit on the largest value in the sample, that largest value should come from the same background population. A parametric USL takes the data variability into account. It is expected that *all* current or future observations coming from the background population (comparable to background population, unimpacted site locations) will be less than or equal to the USL95 with a CC of 0.95. The use of a USL as a BTV estimate is suggested when a large number of on-site observations (current or future) need to be compared with a BTV.

Based on these considerations, parametric USL values appear to be the most appropriate choice of BTVs for groundwater from the set of wells selected for the BTV analysis. The recommended groundwater BTVs are identified in Groundwater and Surface Water Report Table 3-15 and listed below:

- Total antimony – 12.99 micrograms per liter (µg/L)
- Total arsenic – 444.1 µg/L
- Dissolved mercury (EPA method 1631) – 0.00412 µg/L
- Total mercury (EPA method 1631) – 1.628 µg/L
- Total mercury (EPA method 7470) – 0.322 µg/L

Uncertainty

As noted in Groundwater and Surface Water Report Section 3.7.3, it is not possible to reliably predict what the COC concentrations in background groundwater would be prior to excavation and subsequent re-establishment of equilibrium groundwater conditions. Sources of uncertainty include the variability in COC concentrations in bedrock wells described in Groundwater and Surface Water Report Section 3.7.2.1. It is expected that the eight wells selected for the BTV analysis presented in Groundwater and Surface Water Report Section 3.7.2 will be sampled as part of ongoing monitoring at the site. It is expected that other wells, including the wells installed in the Surface Mined Area in 2017, also will be sampled as part of ongoing monitoring. Results of such future monitoring should provide additional information regarding variability of COC concentrations within a given well, as well as spatial variability.

2.3.3.2.2 Kuskokwim River Sediment Background Levels

As discussed in Section 1.2.3.4.4, the Kuskokwim River sediment background values were updated to include results of additional background sediment samples collected as part of the RI Supplement. The revised background sediment value for arsenic is 13.4 mg/kg.

2.3.3.3 Remedial Goal Selection and Remedial Action Objective Conformity

RGs were selected through a process that balances applicable regulatory levels, site-specific RBCLs, and site-specific background levels relevant to the media addressed in this FS Supplement report. The process of RG selection for each COC was conducted as follows:

- If the State of Alaska and federal chemical-specific ARAR concentration values are different, the lower of the concentration values was selected as the chemical-specific ARAR concentration.
- If the background level is higher than the selected chemical-specific ARAR concentration and/or the site-specific RBCL, the background value was selected as the RG.
- If the chemical-specific ARAR concentration and site-specific RBCL are higher than the background level, the lower of the chemical-specific ARAR concentration or RBCL values was selected as the RG.

Table 2-2 summarizes the proposed RG values for groundwater. Table 2-3 summarizes the proposed RG values for Kuskokwim River sediments, including the materials within the lower delta.

Table 2-2 Proposed Groundwater Remedial Goal Values

Groundwater Contaminant of Concern	Groundwater Chemical-Specific ARAR Concentration[1] (µg/L)	Groundwater Human Health RBCL for Future Resident (µg/L)	Groundwater Background Level[2] (µg/L)
Antimony	6	6.0	12.99
Arsenic	0.52	0.27	444.1
Mercury	0.52	4.3	1.628

Notes:

[1] Groundwater chemical-specific ARARs consist of Safe Drinking Water Act MCLs and State of Alaska groundwater cleanup levels identified in 18 AAC 75.345 Table C. The lower of the two chemical-specific ARARs values for each COC is proposed.

[2] Groundwater background levels were estimated based on available data following the approach described in Section 2.3.3.2.1. As noted in Section 2.3.3.2.1.1, it is not possible to reliably predict what the COC concentrations in background groundwater would be prior to excavation and subsequent re-establishment of equilibrium groundwater conditions. Sources of uncertainty include intra-well and spatial variability in COC concentrations. It is expected that future monitoring will provide additional information concerning such variability.

Key:

µg/L = micrograms per liter
ARAR = applicable and relevant or appropriate requirement
COC = contaminants of concern
MCL = maximum contaminant level
RBCL = risk-based cleanup level
RDM = Red Devil Mine Site

Table 2-3 Proposed Kuskokwim River Remedial Goal Values

Kuskokwim River Media of Concern	Kuskokwim River Contaminant of Concern	Kuskokwim River Sediment Human Health RBCL for Future Resident (mg/kg)	Kuskokwim River Sediment Background Level (mg/kg)
Nearshore Sediments and Materials within the Lower Delta	Arsenic	69.1	13.4

Key:

mg/kg = milligrams per kilogram
RBCL = risk-based cleanup level

Table 2-4 presents the selected RGs for groundwater, Kuskokwim River near-shore sediment, and materials within the lower delta and summarizes their ability to achieve the RAOs.

Table 2-4 Selected Remedial Goals and Remedial Action Objective Conformity

Media and Contaminant of Concern	Selected Remedial Goal	RAO Conformity
Groundwater		
Antimony	12.99 µg/L	Selected RG is the background level[1]. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents the naturally occurring background level of antimony in upgradient groundwater, thus making cleanup to the proposed chemical-specific ARAR[1] or RBCL unachievable at the site.**
Arsenic	444.1 µg/L	Selected RG is the background level[1]. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents the naturally occurring background level of arsenic in upgradient groundwater, thus making cleanup to the proposed chemical-specific ARAR[1] or RBCL unachievable at the site.**
Mercury	1.628 µg/L	Selected RG is the background level[1]. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents the naturally occurring background level of mercury in upgradient groundwater, thus making cleanup to the proposed chemical-specific ARAR[1] or RBCL unachievable at the site.**
Nearshore Kuskokwim River Sediments and Materials within the Lower Delta		
Arsenic	69.1 mg/kg	Selected RG is the human health RBCL. **RAO Conformity: Protective of human health.**

Note:
[1] See Table 2-2.

Key:
µg/L = micrograms per liter
ARAR = applicable and relevant or appropriate requirement
mg/kg = milligrams per kilogram
RAO = remedial action objective
RBCL = risk-based cleanup level
RG = remedial goal

2.4 Areas and Volumes of Media to Be Addressed by the Remedial Action

2.4.1 Groundwater

The distribution and arrangement of soils and mine and ore processing wastes at the site play an important role in determining the nature and extent of contamination and fate and transport of contaminants at the RDM. The primary source of the primary COCs—antimony, arsenic, and mercury—in groundwater at the RDM is tailings/waste rock located in the Main Processing Area. Tailings/waste rock also are located in parts of the Red Devil Creek valley downstream of the Main Processing Area. No tailings/waste rock are observed in the Surface

Mined Area. In general, the highest COC concentrations in groundwater are found where tailings/waste rock lie below the water table.

Groundwater at the RDM also is locally impacted by inorganic elements present in naturally mineralized bedrock and native soils. Bedrock is naturally mineralized throughout portions of the Surface Mined Area and Main Processing Area, particularly including the sub-ore grade zones that are peripheral to the ore zones that were targeted by mining. These peripheral mineralized zones currently envelop the present-day system of underground mine workings.

Because the underground mine workings impart a strong hydraulic gradient toward the workings where the workings lie below the water table within the host bedrock but above the nearby base level, groundwater in much of the Surface Mined Area flows through these zones of peripheral mineralization. Concentrations of COCs in groundwater are locally elevated as a consequence of interaction with this naturally mineralized bedrock. As noted in Sections 1.2.3.2 and 2.3.3.2.1, under present conditions, the groundwater that originates in the Surface Mined Area appears to flow into the Main Processing Area and Red Devil Creek valley and mix with the shallow groundwater impacted by tailings/waste rock and contaminated soils. Based on this analysis, any groundwater remedy would be applicable only to the portions of the Main Processing Area and Red Devil Creek downstream alluvial area where groundwater is impacted by tailings/waste rock and contaminated soil.

Based on the results of the analysis presented in Section 1.2.3.1.4, it is anticipated that excavation performed under 2016 FS Alternatives 3 and 4 would extend to the top of bedrock throughout most of the Main Processing Area and much of the Red Devil Creek downstream alluvial area. Where excavation would extend to the top of bedrock, any contaminated groundwater within the excavated materials also would be removed. Following excavation, it is expected that only small, discontinuous areas of residual uncontaminated soil (i.e., with COC concentrations below soil RGs) would remain in place in the Main Processing Area and Red Devil Creek downstream alluvial area following excavation. The expected occurrence and thickness of such residual soil at the RI, RI Supplement, and 2017 soil boring locations are summarized in Table 2-5.

At some locations, groundwater levels under current conditions lie below the top of bedrock; in these areas, any residual uncontaminated soil would likely not be saturated with water table groundwater at the time of excavation. At other locations, the water table lies above the top of bedrock under current conditions; in these areas, any residual soil may contain groundwater at the time of excavation. Such residual groundwater would be expected to occur in thin saturated zones within the discontinuous zones of uncontaminated soil. To evaluate where such potentially saturated conditions in residual soil could occur, information regarding recent groundwater elevations data was analyzed. The highest water levels recorded between 2015 and 2018 in the monitoring wells located in the Main Processing Area and Red Devil Creek downstream alluvial area was identified. The highest water levels were recorded May 18, 2018 (see Groundwater and Surface Water Report Table 3-5). For soil borings, the May 2018 water table elevation was estimated by interpolating the water elevation between the monitoring wells (see Groundwater and Surface Water Report Figure 3-14). The resulting estimated groundwater elevations were compared to the elevation of the anticipated base of any residual soil (i.e., top of bedrock) at each monitoring well and borehole location. Boreholes/wells where residual soil is anticipated to occur, and where some of the residual soil is expected to lie below the May 2018 water elevation, are identified in Table 2-5. It is anticipated that any residual soil at such locations could potentially contain residual groundwater following excavation. The locations identified in this analysis are MP100, located in the Main Processing Area, and RD07, RD22, and RD20/MW33, located in the Red Devil Creek downstream alluvial area (see Figure 1-3). The size and geometry of any areas of residual soil would be determined based on actual excavation limits as determined by confirmation sampling.

Of the potential residual groundwater zones described above, some of them could contain groundwater with COC concentrations above the groundwater RGs (see Table 2-4). The locations and extents of any zones of groundwater with COC concentrations exceeding the RGs in residual soil would depend on the actual excavation limits. Based on existing information regarding anticipated excavation depths, groundwater levels, and groundwater COC concentrations in monitoring wells, such conditions are anticipated to potentially occur in the area of monitoring well MW33, located in the Red Devil Creek downstream alluvial area. This area is illustrated in Figure 2-1.

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Table 2-5 Summary of Anticipated Residual Soil and Groundwater Under FS Alternatives 3 and 4

General Area	Borehole Information					Monitoring Well Information			Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88)		Estimated Thickness of Residual Soil below Bottom Depth of Excavation and Above Top of Bedrock under 2016 FS Alternatives 3 and 4 (feet)		Groundwater Elevation based on May 18, 2018 Measurement in Monitoring Well or Estimated(4) (feet NAVD88)	Estimated Height of May 18, 2018 Water Elevation(4) Relative to Base of Excavation (feet)	If Residual Soil Expected, Is the Soil Below the Estimated May 18, 2018 Water Elevation?	Estimated Saturated Thickness (feet) in Residual Soil Based on May 18, 2018 Water Level	Groundwater Sample Concentrations(5) Above Groundwater RG(s)		
	Borehole ID	2010 Ground Surface Elevation (feet NAVD88)(1)	2015 Ground Surface Elevation (feet NAVD88)(2)	Borehole Total Depth (feet bgs)	Borehole Total Depth Elevation (feet NAVD88)	Monitoring Well ID	Monitoring Well Total Depth (feet bgs)	Monitoring Well Screened Interval (feet bgs)	2016 FS(3) Estimate (feet NAVD88)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet NAVD88)	Calculated Based on Borehole Data	Estimated Based on Nearby Boreholes					Antimony (12.99 μg/L)	Arsenic (444.1 μg/L)	Mercury (2 μg/L)
Pre-1955 Main Processing Area	MP13	--	271	6	265	--	--	--	243	--	0	--	249	6	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP50	--	252	6	246	--	--	--	249	--	0	--	215	-34	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP51	--	246	14	232	--	--	--	236	--	0	--	215	-21	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP55	--	239	6	233	--	--	--	233	--	0	--	212	-21	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP56	--	237	10	227	--	--	--	229	--	0	--	212	-17	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP60	--	241	33	208	MW27	34	23.0 - 33.0	212	--	0	--	218	6	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP88	--	240	63	177	MW28	64	53.0 - 63.0	211	--	0	--	219	8	NA (no residual soil)	NA (no residual soil)	X	--	X
	MP098	--	239	46	193	--	--	--	--	204	0	--	216	12	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP099	--	242	26	216	--	--	--	--	219	0	--	212	-7	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP110	--	257	24	233	--	--	--	--	237	0	--	239	2	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP111	--	251	20	231	--	--	--	--	233	0	--	232	-1	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP112	--	256	24	232	--	--	--	--	236	0	--	245	9	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP113	--	258	32	226	--	--	--	--	229	0	--	243	14	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP114	--	247	28	219	--	--	--	--	226	0	--	239	13	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP115	--	241	28	213	--	--	--	--	220	0	--	232	12	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP121	--	219	16	203	--	--	--	--	209	0	--	217	8	NA (no residual soil)	NA (no residual soil)	--	--	--
	MW04	--	240	34	206	MW04	30.5	20.0 - 30.0	210	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	220	10	NA (assume no residual soil)	NA (assume no residual soil)	X	--	--
	MP15	--	274	8	266	--	--	--	264	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	249	-15	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP48	--	243	14	229	--	--	--	225	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	215	-10	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP49	--	243	14	229	--	--	--	228	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	213	-15	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP53	--	243	8	235	--	--	--	229	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	213	-16	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP54	--	245	8	237	--	--	--	233	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	215	-18	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP095	--	227	22	205	--	--	--	--	212	1	Assume 0 based on nearby boreholes	227	15	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP096	--	239	32	207	--	--	--	--	218	7	Assume 0 based on nearby boreholes	230	12	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP45	--	243	12	231	--	--	--	227	--	NA (TD above top of bedrock)	Not known	225	-2	Not known	Not known	--	--	--
	MP46	--	243	20	223	--	--	--	219	--	NA (TD above top of bedrock)	Not known	223	4	Not known	Not known	--	--	--
	MP47	--	242	26	216	--	--	--	215	--	NA (TD above top of bedrock)	Not known	220	5	Not known	Not known	--	--	--
	MW06	--	215	24	191	MW06	23.5	13.0 - 23.0	195	--	NA (TD above top of bedrock)	Not known	201	6	Not known	Not known	--	--	--
	MP57	--	232	10	222	--	--	--	220	--	NA (TD above top of bedrock)	Not known	208	-12	Not known	Not known	--	--	--
	MP58	--	234	14	220	--	--	--	218	--	NA (TD above top of bedrock)	Not known	208	-10	Not known	Not known	--	--	--
	MP59	--	231	16	215	--	--	--	213	--	NA (TD above top of bedrock)	Not known	204	-9	Not known	Not known	--	--	--
	MP61	--	229	6	223	--	--	--	221	--	NA (TD above top of bedrock)	Not known	208	-13	Not known	Not known	--	--	--
	MP63	--	212	6	206	--	--	--	204	--	NA (TD above top of bedrock)	Not known	198	-6	Not known	Not known	--	--	--
	MP52	--	244	42	202	MW26	43	32.0 - 42.0	238	--	10	--	215	-23	No	NA (water level below base of excavation)	X	X	X
	MP62	--	221	29	192	MW24	30	19.0 - 29.0	217	--	8	--	209	-8	No	NA (water level below base of excavation)	X	--	X
	MP66	--	202	28	174	MW23	29	18.0 - 28.0	200	--	4	--	190	-10	No	NA (water level below base of excavation)	--	--	--

Table 2-5 Summary of Anticipated Residual Soil and Groundwater Under FS Alternatives 3 and 4

General Area	Borehole Information: Borehole ID	Borehole Information: 2010 Ground Surface Elevation (feet NAVD88)[1]	Borehole Information: 2015 Ground Surface Elevation (feet NAVD88)[2]	Borehole Information: Borehole Total Depth (feet bgs)	Borehole Information: Borehole Total Depth Elevation (feet NAVD88)	Monitoring Well Information: Monitoring Well ID	Monitoring Well Information: Monitoring Well Total Depth (feet bgs)	Monitoring Well Information: Monitoring Well Screened Interval (feet bgs)	Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88): 2016 FS[3] Estimate (feet NAVD88)	Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88): Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet NAVD88)	Estimated Thickness of Residual Soil below Bottom Depth of Excavation and Above Top of Bedrock under 2016 FS Alternatives 3 and 4 (feet): Calculated Based on Borehole Data	Estimated Thickness of Residual Soil below Bottom Depth of Excavation and Above Top of Bedrock under 2016 FS Alternatives 3 and 4 (feet): Estimated Based on Nearby Boreholes	Groundwater Elevation based on May 18, 2018 Measurement in Monitoring Well or Estimated[4] (feet NAVD88)	Estimated Height of May 18, 2018 Water Elevation[4] Relative to Base of Excavation (feet)	If Residual Soil Expected, Is the Soil Below the Estimated May 18, 2018 Water Elevation?	Estimated Saturated Thickness (feet) in Residual Soil Based on May 18, 2018 Water Level	Groundwater Sample Concentrations[5] Above Groundwater RG(s): Antimony (12.99 µg/L)	Groundwater Sample Concentrations[5] Above Groundwater RG(s): Arsenic (444.1 µg/L)	Groundwater Sample Concentrations[5] Above Groundwater RG(s): Mercury (2 µg/L)
Post-1955 Main Processing Area	MP89	--	239	41	197	MW25	42	31.0 - 41.0	227	--	10	--	210	-17	No	NA (water level below base of excavation)	X	X	--
	MP100	--	233	37.5	196	--	--	--	--	212	15	--	208	-4	Yes	11	--	--	--
	MW07	--	278	21	257	MW07	21.5	11.0 - 21.0	NA	--	NA	NA	261	NA	NA	NA	--	--	--
	MP10	--	279	6	273	--	--	--	277	--	0	--	257	-20	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP12	--	269	22	247	MW11	23	12.0 - 22.0	254	--	0	--	252	-2	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP14	--	274	60	214	MW10	61	50.0 - 60.0	246	--	0	--	252	6	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP25	--	243	36	211	MW14	36	25.0 - 35.0	211	--	0	--	232	21	NA (no residual soil)	NA (no residual soil)	X	X	--
	MP34	--	216	22	194	--	--	--	198	--	0	--	209	11	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP35	--	212	22	190	--	--	--	196	--	0	--	204	8	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP36	--	214	16	198	--	--	--	204	--	0	--	206	2	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP37	--	212	22	190	--	--	--	198	--	0	--	203	5	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP39	--	208	16.5	192	MW21	17.5	6.5 - 16.5	196	--	0	--	202	6	NA (no residual soil)	NA (no residual soil)	X	X	--
	MP40	--	203	14.5	189	MW22	15.5	4.5 - 14.5	194	--	0	--	199	6	NA (no residual soil)	NA (no residual soil)	X	--	--
	MP094	--	227	24	203	--	--	--	--	207	0	--	223	16	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP097	--	217	16	201	--	--	--	--	203	0	--	220	17	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP101	--	208	17.5	191	--	--	--	--	194	0	--	207	13	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP102	--	269	24	245	--	--	--	--	253	0	--	250	-3	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP103	--	271	24	247	--	--	--	--	253	0	--	250	-3	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP104	--	275	32	243	--	--	--	--	246	0	--	251	6	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP105	--	275	32	243	--	--	--	--	247	0	--	253	6	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP106	--	278	12	266	--	--	--	--	266	0	--	255	-11	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP107	--	265	28	237	--	--	--	--	244	0	--	246	2	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP108	--	264	28	236	--	--	--	--	241	0	--	246	5	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP109	--	261	28	233	--	--	--	--	236	0	--	243	7	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP118	--	251	28	223	--	--	--	--	225	0	--	236	11	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP119	--	235	28	207	--	--	--	--	208	0	--	230	22	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP120	--	224	20	204	--	--	--	--	206	0	--	222	16	NA (no residual soil)	NA (no residual soil)	--	--	--
	MW01	--	254	31	224	MW01	29.5	19.0 - 29.1	230	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	240	10	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MW03	--	228	26	202	MW03	25.5	15.0 - 25.0	208	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	215	7	NA (assume no residual soil)	NA (assume no residual soil)	X	--	--
	MP11	--	267	8	259	--	--	--	257	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	250	-7	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP16	--	272	10	262	--	--	--	258	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	249	-9	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP18	--	276	22	254	--	--	--	256	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	255	-1	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP22	--	257	16	241	--	--	--	239	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	245	6	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP23	--	253	22	231	--	--	--	229	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	238	9	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP24	--	251	22	229	--	--	--	226	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	236	10	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP26	--	255	18	237	--	--	--	235	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	241	6	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP27	239	245	6	239	--	--	--	231	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	230	-1	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP28	243	241	10	231	--	--	--	229	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	232	3	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP29	--	228	26	217	MW15	26	15.0 - 25.0	213	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	227	14	NA (assume no residual soil)	NA (assume no residual soil)	X	X	X
	MP32	224	231	14	217	--	--	--	208	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	215	7	NA (assume no residual soil)	NA (assume no residual soil)	--	--	--
	MP38	--	213	16	197	MW20	15.5	4.5 - 14.5	196	--	NA (TD above top of bedrock)	Assume 0 based on nearby boreholes	210	14	NA (assume no residual soil)	NA (assume no residual soil)	X	X	--
	MP17	--	274	32	243	MW09	31	20.0 - 30.0	260	--	17	Assume 0 based on nearby boreholes	255	-5	NA (assume no residual soil)	NA (assume no residual soil)	X	--	--

Table 2-5 Summary of Anticipated Residual Soil and Groundwater Under FS Alternatives 3 and 4

General Area	Borehole Information					Monitoring Well Information			Estimated Elevation of Bottom of Excavation under 2016 FS Alternatives 3 and 4 (feet NAVD88)		Estimated Thickness of Residual Soil below Bottom Depth of Excavation and Above Top of Bedrock under 2016 FS Alternatives 3 and 4 (feet)		Groundwater Elevation based on May 18, 2018 Measurement in Monitoring Well or Estimated[4] (feet NAVD88)	Estimated Height of May 18, 2018 Water Elevation[4] Relative to Base of Excavation (feet)	If Residual Soil Expected, Is the Soil Below the Estimated May 18, 2018 Water Elevation?	Estimated Saturated Thickness (feet) in Residual Soil Based on May 18, 2018 Water Level	Groundwater Sample Concentrations[5] Above Groundwater RG(s)		
	Borehole ID	2010 Ground Surface Elevation (feet NAVD88)[1]	2015 Ground Surface Elevation (feet NAVD88)[2]	Borehole Total Depth (feet bgs)	Borehole Total Depth Elevation (feet NAVD88)	Monitoring Well ID	Monitoring Well Total Depth (feet bgs)	Monitoring Well Screened Interval (feet bgs)	2016 FS[3] Estimate (feet NAVD88)	Preliminary Estimate Based on FS Supplement and 2017 Additional Characterization (feet NAVD88)	Calculated Based on Borehole Data	Estimated Based on Nearby Boreholes					Antimony (12.99 µg/L)	Arsenic (444.1 µg/L)	Mercury (2 µg/L)
	MP30	--	226	24	202	MW16	22	11.0 - 21.0	210	--	7	Assume 0 based on nearby boreholes	223	13	NA (assume no residual soil)	NA (assume no residual soil)	X	X	--
	MP91	--	226	51.5	175	MW17	52.5	41.5 - 51.5	210	--	7	Assume 0 based on nearby boreholes	221	11	NA (assume no residual soil)	NA (assume no residual soil)	X	--	X
	MP21	--	269	16	253	--	--	--	265	--	NA (TD above top of bedrock)	Not known	255	-10	Not known	Not known	--	--	--
	MP19	--	280	32	248	--	--	--	278	--	2	--	255	-23	No	NA (water level below base of excavation)	--	--	--
	MP20	--	274	31	243	MW13	32	21.0 - 31.0	268	--	8	--	258	-10	No	NA (water level below base of excavation)	X	--	--
Red Devil Creek Downstream Alluvial Area	RD21	--	191	8	183	--	--	--	--	185	0	--	190	5	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP116	--	236	28	208	--	--	--	--	214	0	--	225	11	NA (no residual soil)	NA (no residual soil)	--	--	--
	MP117	--	253	36	217	--	--	--	--	221	0	--	237	16	NA (no residual soil)	NA (no residual soil)	--	--	--
	RD05	--	194	25	169	MW32	25	14.0 - 24.0	192	--	12	--	179	-13	No	NA (water level below base of excavation)	--	--	--
	RD06	195	194	14	180	--	--	--	186	--	2	--	184	-2	No	NA (water level below base of excavation)	--	--	--
	RD07	198	197	12	185	--	--	--	195	--	8	--	191	-4	Yes	4	--	--	--
	RD20	--	177	23	154	MW33	23	12.0 - 22.0	172	--	11	--	175	3	Yes	11	**X**	--	--
	RD22	--	195	20	175	--	--	--	--	192	14	--	186	-6	Yes	8	--	--	--
Red Devil Creek Delta	RD01	173	170	16	154	--	--	--	NA	--	NA (TD above top of bedrock)	NA	261	NA	NA	NA	--	--	--
	RD02	174	173	14	159	--	--	--	163	--	NA (TD above top of bedrock)	NA (Red Devil Creek delta)	178	15	NA (Red Devil Creek delta)	NA (Red Devil Creek delta)	--	--	--
	RD03	177	177	16	161	--	--	--	163	--	NA (TD above top of bedrock)	NA (Red Devil Creek delta)	175	12	NA (Red Devil Creek delta)	NA (Red Devil Creek delta)	--	--	--
	RD04	181	180	14	166	--	--	--	176	--	NA (TD above top of bedrock)	NA (Red Devil Creek delta)	178	2	NA (Red Devil Creek delta)	NA (Red Devil Creek delta)	--	--	--

Notes

(1) Source: AeroMetric (2012)

(2) Source: QSI (2015)

(3) Source: E & E (2016), Section 2.2.1.

(4) Source: E & E (2019), Table 3-5 and Figure 3-14.

(5) Source: E & E (2019), Table 3-11.

Key

bgs = below ground surface
NA = not applicable
NAVD88 = North American Vertical Datum 1988
RG = remedial goal
TD = total depth

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2.4.2 Materials within the Lower Delta

Based on RI soil characterization results, materials within the upper portion of the Red Devil Creek delta include tailings/waste rock materials and alluvium. It is expected that materials within the lower delta are similar to those in the upper portion of the delta. The extent of the Red Devil Creek delta is approximated based on a combination of sediment sample data, bathymetry, and data from soil borings installed on the face of the delta (see Figures 1-4 and 2-2).

The volume of unconsolidated materials within the lower delta is estimated to be approximately 18,000 cubic yards.

2.4.3 Nearshore Kuskokwim River Sediments

The estimated volume of nearshore Kuskokwim River sediments targeted for remedial action is 300 cubic yards. This volume estimate is based on delineations of two separate areas where contamination exceeds the RG for arsenic (see Figure 2-2).

2.5 Applicable or Relevant and Appropriate Requirements

This section identifies ARARs and other standards and guidance "to be considered" (TBC) for remedial activities pertaining to groundwater, materials within the lower delta, and Kuskokwim River nearshore sediment. Identification of ARARs and TBCs is used in assessing the feasibility of remedial action alternatives; however, ARARs and TBCs are identified iteratively throughout the RI/FS process leading up to the Record of Decision.

ARARs are defined by the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300.5). Applicable requirements are cleanup and control standards, as well as other substantive requirements or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be considered applicable.

Relevant and appropriate requirements, while not applicable requirements, do address problems or situations sufficiently similar to those encountered at a particular CERCLA site that their use is well suited to that site.

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

ARARs and TBCs are divided into three categories:

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

Chemical-, location-, and action-specific ARARs and TBCs for groundwater, materials within the lower delta, and nearshore Kuskokwim River sediment remedies at the RDM were identified based on existing site data and are presented in Tables 2-6, 2-7, and 2-8. If both federal and state laws address the same issues that are applicable, appropriate, and relevant, the more stringent or specific one is cited below to reduce redundancy. In addition, many regulations refer to other regulations for specific guidance. In these cases, the substantive guidance has been cited.

Table 2-6 Chemical-Specific Applicable or Relevant and Appropriate Requirements

Medium	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Federal					
Groundwater	Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater used as public drinking water supplies.	MCLs would be used as potential groundwater cleanup levels for the site.	Applicable
Kuskokwim River	Clean Water Act	42 USC 402, 40 CFR Part 122	Established NPDES requirements for remedial activities affecting greater than 1 acre. Substantive requirements of the construction stormwater permit may be applicable.	Requirements would prescribe how stormwater is managed during remedy implementation.	Relevant and Appropriate
Kuskokwim River	Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Criteria would be used to manage surface water quality during remedy implementation.	Relevant and Appropriate
Lower Delta Material and Kuskokwim River Sediments	Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	Guidelines would be used to manage sediment quality during remedy implementation.	TBC

Table 2-6 Chemical-Specific Applicable or Relevant and Appropriate Requirements

Medium	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
State					
Groundwater	Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Numeric water quality standards would be used as potential groundwater cleanup levels for the site.	Applicable
Groundwater	Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Would be used to develop potential groundwater and surface water cleanup levels based on risk to human health.	Applicable
Groundwater and Surface Water	Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	If a point of compliance is used in the overall approach to groundwater cleanup, these regulations establish procedures for establishing a point of compliance.	Applicable

Key:
AAC = Alaska Administrative Code
CFR = Code of Federal Regulations
MCL = maximum contaminant level
NPDES = National Pollutant Discharge Elimination System
TBC = to be considered
USC = United States Code

Table 2-7 Location-Specific Applicable or Relevant and Appropriate Requirements

Location	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Federal					
Archaeological or Historically Sensitive Areas.	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 of the Interior to do so.	Establishes requirements for reporting and preservation of archaeological or historic artifacts/resources that might be encountered during remedy implementation.	Applicable
Archaeological or Historically Sensitive Areas.	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.	Establishes procedures for handling and preservation of any archaeological artifacts encountered during remedy implementation.	Applicable
Wetland Areas and/or Waters of the United States.	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.	Establishes rules and procedures for filling or draining wetlands during remedy implementation.	Applicable
Flood Plains	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.	Establishes rules for construction of permanent features in flood plains or other floodplain modifications that could increase flood hazards during remedy implementation.	Applicable

Table 2-7 Location-Specific Applicable or Relevant and Appropriate Requirements

Location	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Streams, rivers, riparian areas, and ponds.	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 U.S.	Establishes protocols and process for coordinating with the U.S. Fish and Wildlife Service if water bodies are impacted by cleanup activities.	Applicable
Bird Migration Corridors	Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Establishes rules for preservation of migratory bird habitat during remedy implementation.	Applicable
Critical ESA Habitat and other locations where ESA-listed species are present	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.	Establishes rules for preservation of ESA-listed species habitat during remedy implementation.	Applicable
Bald and Golden Eagle Habitat	Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Establishes rules for preservation of Bald and Golden eagle habitat during remedy implementation.	Applicable

Table 2-7 Location-Specific Applicable or Relevant and Appropriate Requirements

Location	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Fish-bearing streams and rivers.	Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Establishes rules for preservation of essential fish habitat during remedy implementation.	Relevant and Appropriate
State					
Historically Sensitive Areas.	Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Establishes rules for preservation of historic artifacts or structures during remedy implementation.	Applicable
Fish-bearing streams and rivers.	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.	Establishes procedures for coordinating with Alaska Department of Fish and Game if cleanup activities affect an anadromous water body.	Applicable

Key:
AAC = Alaska Administrative Code
AS = Alaska Statutes
CFR = Code of Federal Regulations
ESA = Endangered Species Act
TBC = to be considered
USC = United States Code

Table 2-8 Action-Specific Applicable or Relevant and Appropriate Requirements

Action	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Federal					
Work in Waters of the United States	Clean Water Act – NPDES	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 EPA gives states the authority to implement the NPDES program.	Establishes criteria for stormwater management during remedy implementation.	Applicable
Work in Waters of the United States	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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Establishes procedures and mitigation requirements for work affecting wetlands and surface water bodies during remedy implementation.	Applicable
Work in Waters of the United States	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.	Establishes water quality criteria for surface waters affected by remedy implementation.	Applicable
Work in Waters of the United States	Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Establishes rules for dredging operations during remedy implementation.	Applicable
On-Site Disposal of Mine Waste	RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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	Establishes standards and operational criteria for on-site disposal of mine waste.	Applicable

Table 2-8 Action-Specific Applicable or Relevant and Appropriate Requirements

Action	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
			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.		
Disturbed Areas	Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Establishes procedures for control of invasive species during remedy implementation.	Applicable
State					
On-site Disposal of Mine Waste	Alaska Solid Waste Regulations	18 AAC 60.010(a) 18 AAC 60.015	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Establishes operational criteria if remedy implementation involves excavation and on-site disposal of delta material or dredged sediments and other site-related waste.	Applicable
On-site Disposal of Mine Waste	Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Establishes requirements for remedy implementation involving excavation and on-site disposal of delta material or dredged sediments and other site-related waste.	Applicable
Monofill Construction or Relocation	Alaska Solid Waste Regulations	18 AAC 60.410	Location standards for monofills.	Establishes standards for monofill siting.	Applicable
Cleanup Confirmation Activities	Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.355(b) 18 AAC 75.355 (c) 18 AAC 75.355(d)	Provides requirements of cleanup confirmation sampling procedures and methods	Establishes procedures and standards for cleanup confirmation following remedy implementation	Applicable

Table 2-8 Action-Specific Applicable or Relevant and Appropriate Requirements

Action	Standard, Requirement, or Criteria	Citation	Description	Remedy Use	Applicable, Relevant and Appropriate, or TBC
Cleanup Operations	Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.360	Provides requirements for cleanup operations	Establishes requirements for cleanup plans prior to remedy implementation	Applicable
Post-cleanup Activities	Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.375(c)	Provides requirements for long-term maintenance of institutional controls	Establishes requirements on future property owners to maintain institutional controls if part of the selected remedy	Applicable

Key:
AAC = Alaska Administrative Code
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
USC = United States Code

2.6 General Response Actions

GRAs are broad categories of remedial actions that may, either individually or in combination, achieve the RAOs established in Section 2.3.1 and, like RAOs, are medium-specific. The identification of GRAs is the first step in the identification of remedial technology types and specific process options.

The following GRAs are applicable for addressing groundwater, materials within the lower delta, and nearshore Kuskokwim River sediment at the RDM:

- The *No Action Alternative* is included as a baseline for comparing other potential response actions. Consideration of a no action approach is required by the NCP (40 CFR 300.430).
- *Institutional Controls (ICs)* may restrict access to and uses of land and contaminated material, thereby limiting exposure. ICs may include administrative and/or legal controls, public awareness efforts, or a combination of these to minimize the potential for exposure to contaminants.
- *Access Controls (ACs)* may limit direct contact with contaminated material, thereby limiting exposure. ACs may include physical barriers, such as fencing and gates, and warning signs.
- *Stabilization/Containment* limits contaminant mobility via technologies such as sediment capping or pumping for groundwater capture, thus substantially reducing pathways of potential exposure.
- *Treatment* addresses the toxicity, mobility, or volume of contaminants through physical, chemical, or biological processes. Treatment of contaminated material includes remedial actions that can be conducted in situ or ex situ.
- *Removal/Disposal* limits exposure by addressing the mobility and volume of contaminants by removal (via extraction, excavation, dredging, or other technology) and containment in an approved disposal facility (on site or off site).

2.7 Identification, Screening, and Evaluation of Remedial Technology Types and Process Options

This section further refines the GRAs into potentially applicable remedial technology types and specific process options to address groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments at the RDM. A description is provided for each remedial technology type and process option, followed by the rationale for retaining or eliminating it from further consideration.

The goal of screening is to identify one process option to represent each technology type to further refine the development of alternatives (Chapter 3). In some cases, more than one process option may be selected per technology type provided two or more process options are sufficiently different in their performance that one would not adequately represent the other.

Remedial technology types and specific process options were identified based on the current understanding of site conditions, previous mine site and FS experience, a review of literature, and vendor information. The following guidance documents were reviewed to aid in the identification of potentially applicable remedial technology types:

- Mining Waste Treatment Technology Selection, Web-Based Technical and Regulatory Guidance Document (ITRC 2011).
- Abandoned Mine Site Characterization and Cleanup Handbook (EPA 2000).
- Arsenic Treatment Technologies for Soil, Waste, and Water (EPA 2002).
- Treatment Technologies for Mercury in Soil, Waste, and Water (EPA 2007).
- Technical Guide: Monitored Natural Recovery at Contaminated Sediment Sites (ESTCP 2009).
- Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites (EPA 1999).
- Guidance for Evaluation the Technical Impracticability of Ground-Water Restoration (EPA 1993).

Three evaluation criteria are used to screen remedial technologies and specific process options:

- Effectiveness – The degree to which the technology or process option is (1) capable of handling the estimated areas or volumes of contaminated media and meeting the RGs identified in the RAOs (i.e., reduces the toxicity, mobility, or volume of contaminants); (2) protective of human health and the environment during the construction and implementation phase (i.e., minimizes short-term impacts); and (3) proven and reliable with respect to site-specific contaminants and conditions.
- Implementability – The technical feasibility (i.e., the applicability in regard to the areas and volumes of contaminated media and the types of contaminants) and administrative feasibility (i.e., the ability to comply with ARARs; the availability and capacity of treatment, storage, and disposal services; and the availability of necessary equipment and skilled workers) of implementing the technology or process option.

- Cost – The cost (capital and operation and maintenance) of the technology or process option.

GRAs, remedial technology types, and specific process options that do not satisfy RAOs and/or are inconsistent with the three evaluation criteria listed above were not retained for further consideration.

Remedy technologies for addressing groundwater, materials within the lower delta and nearshore Kuskokwim River sediments focus on conditions that are likely to exist following removal of tailings/waste rock, contaminated soil, and contaminated creek sediment as described in Remedial Alternatives 3 and 4 of the 2016 FS Report. This is not considered presumptive since source material removal Alternatives 3 and 4 are the only alternatives that meet threshold criteria in the 2016 FS report. Section 2.7.1 describes remedial technology types and process options that are relevant to the media addressed in this FS Supplement report (i.e., groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments). Section 2.7.2 describes remedial technology types and process options that are specific to groundwater. Section 2.7.3 describes remedial technology types and process options that are specific to materials within the lower delta and nearshore Kuskokwim River sediments.

2.7.1 Remedial Technology Types and Process Options for Groundwater, Materials within the Lower Delta, and Nearshore Kuskokwim River Sediments

The following remedial technology types and process options were considered potentially applicable for all media addressed within this FS Supplement Report (groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments). Table 2-9 summarizes the screening and evaluation of these remedial technologies and process options and identifies which remedial technologies and process options were retained for further consideration.

2.7.1.1 Institutional Controls

ICs are non-engineered controls intended to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy by limiting land or resource use. ICs do not actively address contamination, but rather attempt to meet the RAOs by reducing the potential for exposure to contamination. ICs are often used in conjunction with an active technology and/or ACs (e.g., fencing or warning signs). Technologies considered under this GRA include administrative and/or legal controls and public awareness.

Administrative and/or Legal ICs

Administrative and/or legal controls use the regulatory authority of a government entity to impose restrictions on citizens or property under its jurisdiction, custody, or control to ensure long-term protection of contaminated or remediated sites.

Process options include land use restrictions, zoning restrictions, and special permits, as described below:

- Land Use Restrictions – Restrictions that may impose a variety of limitations and conditions on the use of property (e.g., limit future land uses, sediment management, groundwater use, etc.).
- Zoning Restrictions – Restrictions that specify land uses for particular areas (e.g., a local government could prohibit residential development in a contaminated or remediated area).
- Special Permits – Permits that outline specific requirements that must be met before an activity can be authorized (e.g., building, groundwater use, etc.).

These process options would provide limitations on future land use. They would not reduce contaminant mobility, toxicity, or volume of mine waste or other contaminated media that would remain on site but could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options, capital costs are considered to be low, and operation and maintenance (O&M) costs are considered to be negligible to low. This alternative would not address ecological risks.

Public Awareness ICs

Public awareness process options include deed notices, public advisories, and public outreach, which inform landowners and the public about potential risks at a site, as described below:

- Deed Notices – Non-enforceable, informational documents filed in public land records to alert anyone searching the records to important information about the property.
- Public Advisories – Warnings, usually issued by public health agencies, either at the federal, state, or local level, that provide notice to potential users of land, surface water, or groundwater of potential risks associated with their use (e.g., fish consumption advisories).
- Public Outreach – Informational meetings, programs, or pamphlets that alert potential users of land, surface water, or groundwater of potential risks associated with their use.

These process options may educate potential land users regarding potential risks associated with the site. They would not reduce contaminant mobility, toxicity, or volume of mine waste or other contaminated media that would remain on site but could meet RAOs when combined with other remedial actions. Furthermore, there are few effective means for ensuring that public awareness efforts will result in reduced exposure to mine waste. No technical or administrative issues are known that would adversely affect the implementation of these process options. Capital and O&M costs associated with these process options are considered to be low.

2.7.1.2 Access Controls

ACs are physical controls put in place to prevent human and ecological receptor exposure to contamination and/or to protect the integrity of a remedy by limiting direct contact with particular areas of concern. Similar to ICs, ACs do not actively address contamination but rather attempt to address the intent of RAOs by reducing the potential for exposure to contamination. ACs are often used in conjunction with an active remedy and/or ICs. ACs considered under this GRA include physical barriers, such as fencing and gates, and warning signs.

Physical barriers and warning signs can be readily installed with minimal disturbance of existing contaminated material, but ongoing O&M would be required. Physical barriers may prevent exposure of both humans and large ecological receptors but would not likely be effective in reducing contaminant exposure to smaller ecological receptors. Warning signs would not be effective in preventing ecological receptors from exposure to mine-contaminated material. These process options would not reduce contaminant mobility, toxicity, or volume of mine waste or other contaminated media that would remain on site but could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options. Physical barriers and warning signs were addressed and costed in the 2016 FS, and therefore were not retained for further consideration in this FS Supplement in order to eliminate potential duplication of cost.

2.7.2 Remedial Technology Types and Process Options for Groundwater

As noted in Section 2.4.1, COC concentrations in the bedrock aquifer are elevated as a result of interaction with naturally mineralized bedrock. Therefore, any groundwater remedy would be applicable only in the portions of the Main Processing Area and Red Devil Creek downstream alluvial area where groundwater is impacted by tailings/waste rock and contaminated soil. As also noted in Section 2.4.1, source removal as described under FS Alternatives 3 and 4 would result in excavation of tailings/waste rock and contaminated soil, and it is preliminarily anticipated that the excavation would extend to the top of bedrock throughout much of the Main Processing Area and Red Devil Creek downstream alluvial area. Following excavation, it is expected that only small, discontinuous areas of residual uncontaminated soil would remain in place. Under current conditions, the groundwater level lies above the expected depth of excavation in some locations in the Main Processing Area and Red Devil Creek downstream alluvial area. At these locations, the residual soil may contain residual groundwater in thin saturated zones. Some of this groundwater could have antimony, arsenic, and/or mercury concentrations above the groundwater RGs.

In general, technologies associated with reducing antimony, arsenic, and mercury concentrations in groundwater include monitored natural attenuation (MNA), passive treatment, and active treatment. The following sections summarize the remedial technology types and process options that were considered to address groundwater contamination at the RDM. Table 2-10 summarizes the screening and evaluation of these remedial technologies and process options.

2.7.2.1 Monitored Natural Attenuation

In general, MNA is a remedial technology that makes use of naturally occurring physical, chemical, and biological processes to reduce contaminant concentrations, which then reduces the associated risks to receptors and ultimately meets site-specific RAOs. MNA processes can reduce risk to human and ecological receptors by reducing their toxicity, or otherwise limiting access and exposure pathways. Examples of natural attenuation processes include sorption, dilution, and chemical reactions. Monitoring is necessary to assess the rate and magnitude of contaminant reduction through natural recovery processes. MNA is most likely to be effective after source removal has been completed. Due to the slow rate at which natural processes reduce contaminant levels, MNA is unlikely to be effective where source materials continue to contribute to ongoing releases. Capital and O&M costs associated with MNA are generally low.

Groundwater and surface water data collected as part of the RI and RI Supplement indicate that the baseflow (i.e., groundwater to surface water flow) contribution to Red Devil Creek accounts for some of the elevated COC concentrations observed near and downstream of the tailings/waste rock. The tailings/waste rock are immediately adjacent to the creek. As such, shallow groundwater impacted by the tailings/waste rock discharges directly from source materials as surface water into Red Devil Creek rather than flowing through non-source aquifer materials as groundwater. Groundwater and surface water COC concentrations observed during the RI, RI Supplement, and baseline groundwater and surface water monitoring indicate a fairly steady-state condition reflective of this process. Because impacted groundwater discharges directly from source materials into surface water under current conditions, there is little or no potential for natural attenuation processes to reduce COC concentrations in the shallow groundwater. Therefore, MNA would not be a viable approach to managing groundwater if remedial action were based on either FS Alternative 1 or 2.

Under FS Alternatives 3 or 4, the tailings/waste rock and much of the alluvial material in the Main Processing Area and Red Devil Creek downstream alluvial area would be removed, and the excavation would extend to the top of bedrock in much of the Main Processing Area. An MNA approach would not be a viable way to manage groundwater should remedial action involve FS Alternatives 3 or 4. As discussed in Sections 1.2.3.1.4 and 2.4.1, it is expected anticipated that the only portion of the existing shallow alluvial aquifer that would remain after excavation would occur in small, discontinuous, remnant zones of soil left in place following excavation. Because these remnant zones would be small, any elevated groundwater COC concentrations would likely decrease relatively quickly after excavation as a result of flushing from infiltrating precipitation and/or throughflow from the bedrock aquifer.

FS Alternatives 1 through 4 are the only options for remediating tailings/waste rock and soil under consideration at the RDM. Based on the current understanding of groundwater conditions and groundwater-surface water interaction at the RDM, MNA would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs. Therefore, MNA is omitted from further consideration.

2.7.2.2 Treatment

Groundwater treatment technologies considered for the RDM under the groundwater treatment GRA are ex situ and in situ chemical and physical treatment of contaminated groundwater. No potentially applicable biological treatment methods were identified. The technologies considered use physical or chemical processes to reduce contaminant mobility, toxicity, and volume to meet RAOs. Process options for treatment are passive treatment (no electrical input needed) or active treatment (electricity required for running process equipment). Both passive and active treatment process options were considered for the RDM.

Passive treatment technologies rely on natural chemical processes to remove contaminants from solution without a power supply. One passive in-situ groundwater treatment system considered for the RDM is a permeable reactive barrier (PRB). PRBs allow contaminated groundwater to naturally flow through a buried, porous reactive medium that either precipitates, degrades, or adsorbs the contaminants. Capital costs for a PRB are moderate to high, depending on the depth and volume of media required, while O&M costs would be low. The success of a PRB depends on adequate design inputs and an understanding of hydrogeological conditions.

Active treatment systems typically depend on electrical and mechanical processes that require regular professional staff and dedicated control systems. An active system for treating groundwater at the RDM would consist of a series of extraction wells to pump contaminated groundwater to a central treatment system. Active treatment technologies for groundwater include precipitation/ coprecipitation, membrane filtration, adsorption, and ion exchange.

Each of these types of active treatment systems would require a constant and reliable power supply, which does not currently exist at the RDM. Capital and O&M costs associated with each of the active treatment options are high.

As noted in Section 2.7.2.1, because tailings/waste rock are located immediately adjacent to Red Devil Creek, shallow groundwater impacted by the tailings/waste rock discharges directly from source materials as surface water into the creek rather than flowing through non-source aquifer materials as groundwater. Because impacted groundwater discharges directly from source materials into surface water, any attempt to treat the groundwater would be impractical. Therefore, treatment would not be a viable approach to managing groundwater if remedial action were based on either FS Alternative 1 or 2.

Should remedial action involve FS Alternatives 3 or 4, the tailings/waste rock and most of the alluvial material in the Main Processing Area and Red Devil Creek downstream alluvial area would be removed, and only small, laterally discontinuous remnants of the present shallow alluvial aquifer remain after excavation (see Section 2.4.1). Because these zones would be small, groundwater COC concentrations would likely decrease relatively quickly via flushing from infiltrating precipitation and/or throughflow from the bedrock aquifer. Because of the small size of such remnant zones, any attempt to treat the groundwater would be impractical and would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs. Therefore, treatment is omitted from further consideration.

2.7.3 Remedial Technology Types and Process Options for Materials within the Lower Delta and Nearshore Kuskokwim River Sediments

The following remedial technology types and process options were considered potentially applicable for materials within the lower delta and nearshore Kuskokwim River sediments. Table 2-11 summarizes the screening and evaluation of these remedial technologies and process options and identifies which remedial technologies and process options were retained for further consideration.

2.7.3.1 Stabilization/Containment

Sediment capping serves to stabilize and contain contaminated sediment by burying with a sufficiently thick layer of clean material to withstand erosive and scour forces. Multiple process options for sediment capping exist, including gravel, sand, and geotextile caps. Due to site-specific conditions, sediment capping was determined to be unlikely to be effective—scour from ice flow and high velocity currents could remove gravel or sediment caps or undermine geotextile layers. Sediment capping has been omitted from further evaluation.

2.7.3.2 Monitored Natural Recovery

Monitored natural recovery (MNR) is a remedial technology that makes use of naturally occurring physical, chemical, and biological processes to reduce risks to receptors and meet site-specific RAOs. MNR processes reduce risk to human and ecological receptors by destroying or transforming contaminants, reducing their toxicity, or otherwise limiting access and exposure pathways. In general, examples of natural recovery processes include biodegradation, dispersion, and burial with clean sediment. The Red Devil Creek delta and the locations of contaminated sediment downriver from the Red Devil Creek delta are situated on a cut bank of the Kuskokwim River and are thus likely subject to net erosion at most locations. Although net sedimentation could potentially occur locally, it is expected that the primary MNR processes at the RDM would be sediment mixing and dispersion. Monitoring is necessary to assess the rate and magnitude of contaminant reduction through natural recovery processes.

MNR will likely be effective only after source control actions have been completed. Due to the slow rate at which natural processes reduce contaminant levels, MNR is likely to be less effective where source materials continue to contribute to ongoing releases.

This technology is expected to reduce contaminant concentrations in sediment through naturally occurring processes to meet RAOs. One technical issue that could impact the effectiveness of this technology is the status of source control actions (Remedial Alternatives 3 and 4 of the 2016 FS). Capital and O&M costs associated with this process option are considered to be low.

2.7.3.3 Removal

Nearshore sediments would be removed by dredging. Delineation of materials to be removed by dredging would be prepared beforehand by mapping or established by in-field measurements. Off-site disposal would entail loading dredged material onto barges and transporting to an approved disposal facility. On-site disposal would entail consolidation of material within the repository using heavy equipment such as loaders, dozers, and compactors. On-site repository and off-site disposal remedial technologies are discussed in detail in the 2016 FS report.

Process options considered for dredging (i.e., hydraulic and mechanical dredging) are described in the following sections.

2.7.3.4 Hydraulic Dredging

Hydraulic dredging uses a pump to generate suction to fluidize bed material with the surrounding water, enabling it to be transported or removed. A slurry of dredged bed material and water is discharged via the suction pipe to a staging area for dewatering. Suction pipe ends may be plain or equipped with a cutter-head to excavate resistant bed materials such as gravel and bedrock.

Hydraulic dredging using suction allows for more targeted removal of contaminated materials than typical mechanical dredging. Technical limitations may include:

- Dewatering of dredged sediment slurry;
- Access challenges for barge-mounted dredging rigs due to fast moving river currents; and
- Difficulty removing oversized, well armored, and/or cemented bed materials.

This process option would meet RAOs for materials within the lower delta, and nearshore Kuskokwim River sediments by reducing contaminant volume through removal. Capital and O&M cost associated with this process option is considered moderate to high. Costs could be further increased if cobbles, boulders, or large woody debris were encountered, as hydraulic dredging is not well suited to handling large material. Cobbly river bed conditions were encountered locally during Kuskokwim River sediment sampling during the RI and RI Supplement. For these reasons, hydraulic dredging would be considered a “maximum effort alternative” and has not been retained for further analysis.

2.7.3.5 Mechanical Dredging

Mechanical dredging (also referred to as “grab dredging”) involves the removal of sediments with a mechanical apparatus equipped with a bucket or clamshell that is operated via a mechanical arm or cable system. Mechanical dredging rigs may be shore- or barge-mounted.

Mechanical dredging is capable of removing large or cemented bed materials. Technical limitations may include:

- Access challenges for barge-mounted dredging rigs due to high river currents; and
- Difficulty reaching deep or horizontally distant materials with a shore-mounted dredging rig.

This process option would meet RAOs by reducing contaminant volume through removal. Mechanical dredging is a commonly used technology that can be readily implemented. This technology has a high potential of achieving RAOs for materials within the lower delta and sediments. Mechanical dredging would require infrastructure such as docks and offloading areas. Capital costs associated with this process option are considered moderate to high. This technology was retained for removal of materials within the lower delta materials and Kuskokwim River sediments.

Table 2-9 Evaluation of Remedial Technology Types and Process Options Applicable to All Site Media: Groundwater, Materials within the Lower Delta, and Nearshore Kuskokwim River Sediments

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
No Action	NA	NA	Does not meet RAOs or reduce toxicity, mobility, or volume of contaminants	Implementable	Negligible to low	Retained as required by NCP
Institutional Controls	Administrative and/or Legal Controls	Land Use Restrictions	Depends on continued future use at the site; does not reduce contamination	Implementable. All processes and methods are established.	Low capital costs; negligible to low O&M costs	Potentially applicable in combination with other remedial actions
		Zoning Restrictions				
		Special Permits				
	Public Awareness	Deed Notices	Difficult to ensure that information reaches parties or ensure that the parties will heed the notice; does not reduce contamination	Implementable. All processes and methods are established.	Low capital and O&M costs	Potentially applicable in combination with other remedial actions
		Public Advisories				
		Public Outreach				
Access Controls	Physical Barriers	Fences and Gates	Depends on continued future implementation; does not reduce contamination	Implementable although effectiveness for groundwater and in/near Kuskokwim River is low.	Low capital and O&M costs, unable to maintain fencing in/near Kuskokwim River due to ice flow	Not retained
	Warning Signs	NA	Difficult to ensure that the parties will heed the notice	Implementable	Low capital and O&M costs	Retained

Key:
NA = not applicable
NCP = National Oil and Hazardous Substance Pollution Contingency Plan
O&M = operations and maintenance
RAO = remedial action objective

Table 2-10 Evaluation of Remedial Technology Types and Process Options Applicable to Groundwater

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
Monitored Natural Attenuation	NA	NA	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. All processes and methods are established.	Low capital and O&M cost	Not Retained
Treatment	Passive Treatment	Permeable Reactive Barrier	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. Sizing and media selection are challenging.	Moderate to high capital costs; low O&M costs	Not Retained
	Active Treatment	Precipitation/ Coprecipitation	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. All processes and methods are established.	High capital and O&M cost	Not retained
		Membrane Filtration	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. All processes and methods are established.	High capital and O&M cost	Not retained
		Adsorption	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. All processes and methods are established.	High capital and O&M cost	Not retained
		Ion Exchange	Would not prevent or significantly reduce human future resident exposure to COCs in groundwater at concentrations above RGs.	Implementable. All processes and methods are established.	High capital and O&M cost	Not retained

Key:
NA = not applicable
COCs = contaminants of concern
O&M = operations and maintenance
RG = remedial goal

Table 2-11 Evaluation of Remedial Technology Types and Process Options Applicable to Materials within the Lower Delta and Nearshore Kuskokwim River Sediments

General Response Actions	Remedial Technology Type	Process Option/Material	Effectiveness	Implementability	Cost	Screening Comments
Stabilization / Containment	Capping	Rock	Reduces mobility of contaminants but not toxicity or volume.	Not easily implemented or maintained	Low to moderate capital cost; high O&M costs	Not retained. Unlikely to result in a stable, long-term remedy due to ice scour.
		Synthetic Material (e.g., concrete mat)	Reduces mobility of contaminants but not toxicity or volume.	Not easily implemented or maintained	Moderate to high capital cost; moderate O&M costs	Not retained. Unlikely to result in a stable, long-term remedy due to ice scour.
Monitored Natural Recovery	NA	NA	Considered most effective after source control actions.	Implementable. All processes and methods are established.	Low capital and O&M cost	Potentially applicable in combination with other remedial actions.
Removal	Dredging	Hydraulic Dredging	Reduces mobility of contaminants, considered a maximum effort alternative.	Not implementable due to potential for oversized materials	Moderate to high capital cost	Not retained for further analysis due to implementation issues.
		Mechanical Dredging	Can meet RAOs; reduces mobility of contaminants.	Implementable. All processes and methods are established.	Moderate to high capital cost	Retained for further analysis.

Key:
NA = not applicable
O&M = operations and maintenance
RAO = remedial action objective

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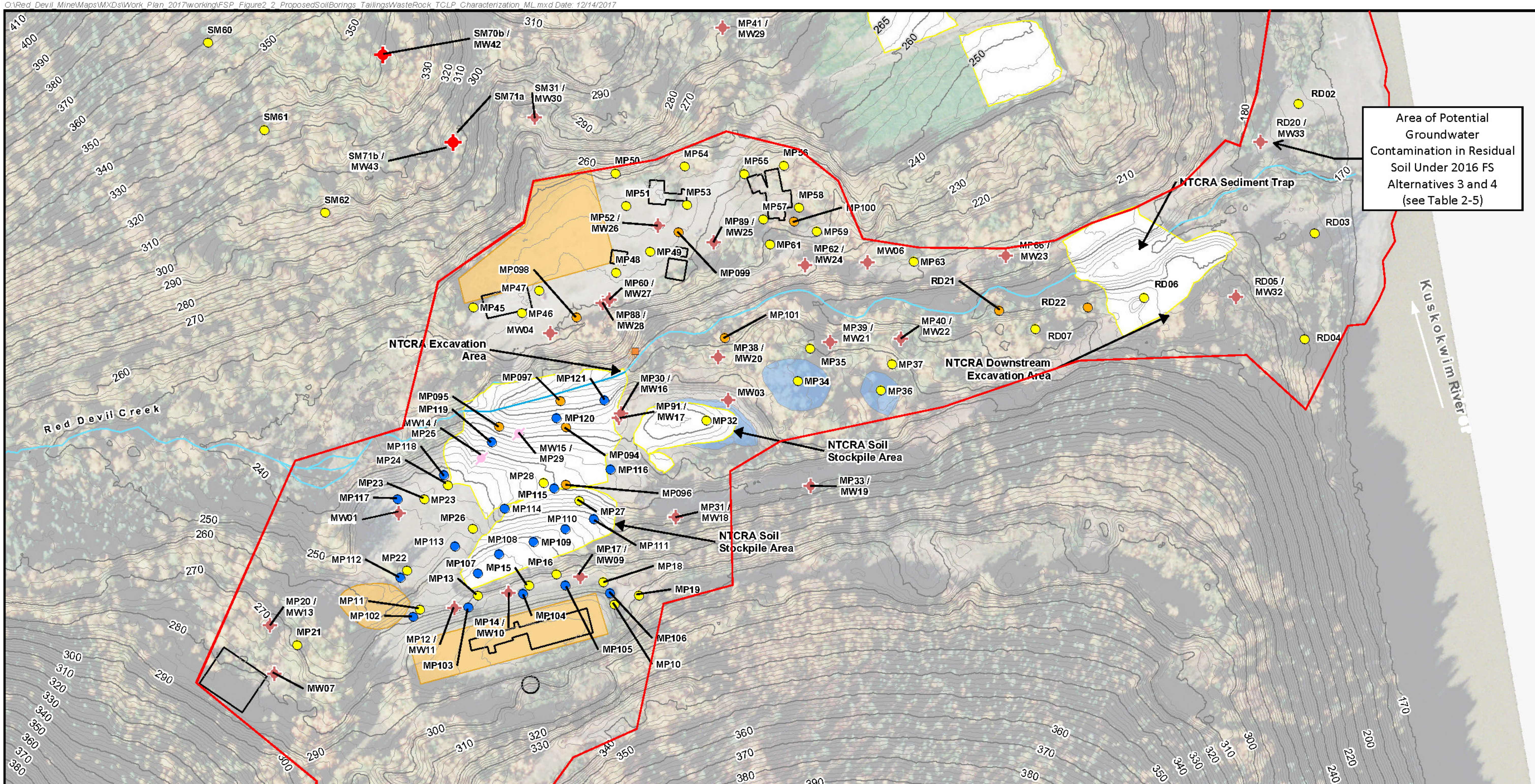

2017 Soil Boring Location	2015 2-foot Contour	Settling Pond
RI Supplement Soil Boring	2015 10-foot Contour	Monofill
RI Soil Boring / Monitoring Well	Area of 2014 NTCRA Re-grading	Historical Structure
Decommissioned Well	Post-NTCRA Stream Alignment	Approximate Location of Proposed Repository Footprint
RI Soil Boring	Red Devil Creek	Seep Location

Digital 2015 5-foot topographic contours based on Octobr 10, 2015 LiDAR Survey (Quantum Spatial 2015).

RED DEVIL MINE

Red Devil, Alaska

Figure 2-1

Area of Potential Groundwater Contamination in Residual Soil Under 2016 FS Alternatives 3 and 4

0 25 50 100 150 200 Feet
0 7.5 15 30 45 60 75 Meters
Scale 1:1,500

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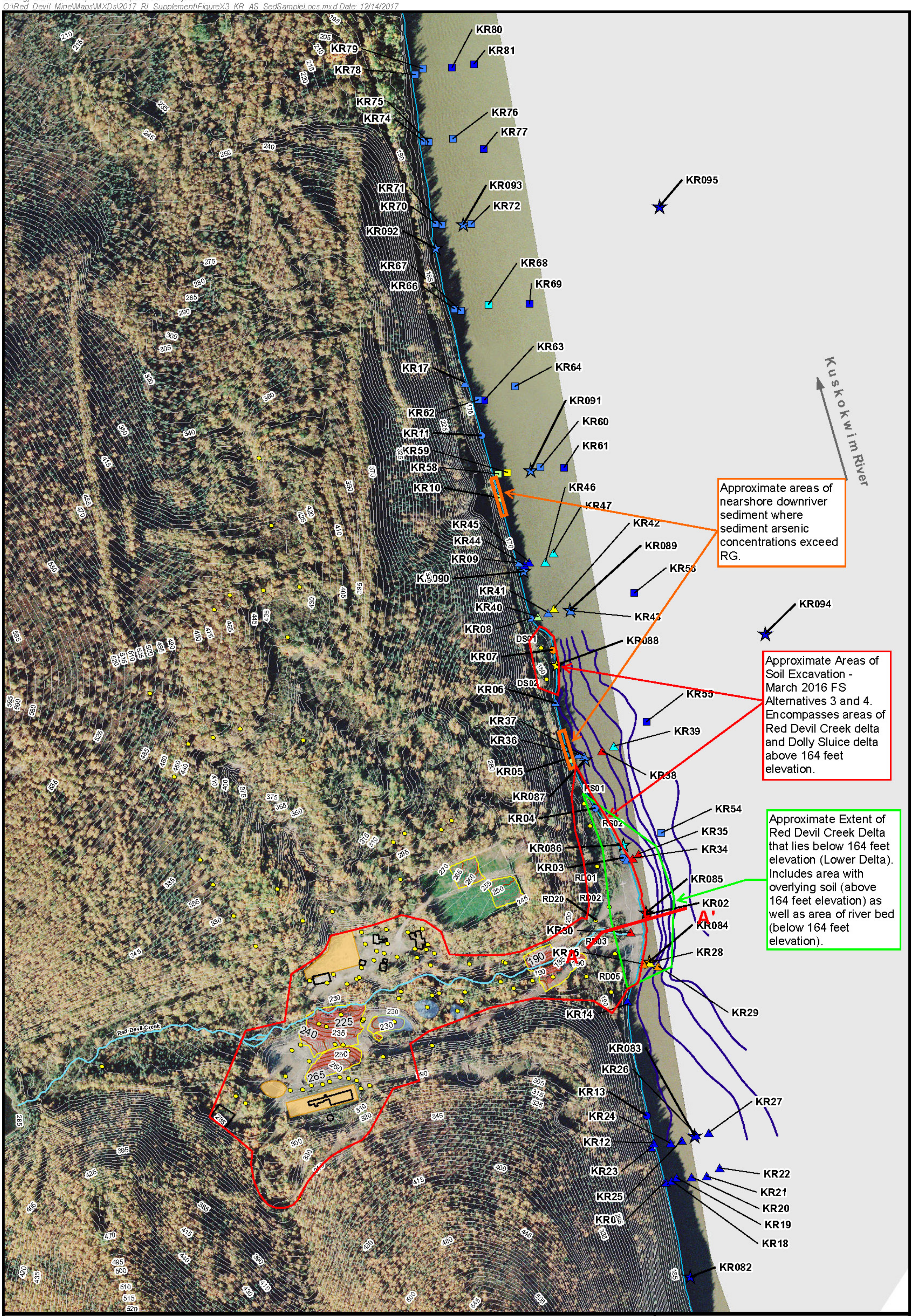

2010 Total Arsenic (mg/kg)	2011 Total Arsenic (mg/kg)	2012 Total Arsenic (mg/kg)	2015 Total Arsenic (mg/kg)
> 800	> 800	> 800	> 800
400 to 800	400 to 800	400 to 800	400 to 800
200 to 400	200 to 400	200 to 400	200 to 400
100 to 200	100 to 200	100 to 200	100 to 200
69 to 100	69 to 100	69 to 100	69 to 100
13.4 to 69	13.4 to 69	13.4 to 69	13.4 to 69
≤ 13.4 background	≤ 13.4 background	≤ 13.4 background	≤ 13.4 background

Soil Boring
Bathymetric contour (feet)
2010 5-foot Contour
River level (elevation 165.78 feet) on 9/21/2010
Area of 2014 NTCRA Red Devil Creek Sediment Trap
2014 5-foot Contour
2014 1-foot Contour
Settling Pond
Monofill
Historical Structure

RED DEVIL MINE
Red Devil, Alaska

Figure 2-2

Red Devil Creek Delta and Areas of Kuskokwim River Nearshore Sediment Exceeding Arsenic Remedial Goal

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500

1. Aerial image collected on 9/21/2010 (Aerometric 2012)
2. Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on 9/21/2010 (AeroMetric 2012)
3. Kuskokwim River elevation on date aerial orthophotographic survey (9/21/2010) was 165.78 feet (Aerometric 2012)
4. Bathymetric contours represent approximate depths below river surface on 9/25/2011
5. Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

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3 Identification of Remedial Alternatives

In this chapter, medium-specific remedial technology types and process options retained for further consideration in Chapter 2 are combined to form remedial alternatives for groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments at the RDM. The primary objective of this phase of the FS Supplement is to develop an appropriate range of remedial alternatives for groundwater and the Kuskokwim River that will contribute to achieving the project's RAOs. The alternatives were developed based on their capacity to achieve media-specific protectiveness, combining different remedial technology types to address different volumes of media and/or areas of the site. They were further refined in regard to process option details (i.e., containment or treatment system sizing, remediation timeframe, spatial requirements, transportation distances, required permits, etc.).

This chapter describes each alternative in detail. Due to the setting of the site, the type of contamination (i.e., COCs and media listed in Table 2-4), and the volume of material to be addressed, a limited number of technology types and process options were retained for discussion in Chapter 2. Therefore, a screening of alternatives was not required in order to select a reasonable number of alternatives for detailed analysis.

Alternatives for addressing groundwater, materials within the lower delta, and nearshore Kuskokwim River sediments focus on conditions that are likely to exist following removal of tailings/waste rock, contaminated soil, and contaminated creek sediment as described in Remedial Alternatives 3 and 4 of the 2016 FS report. This is not considered presumptive since source material removal Alternatives 3 and 4 are the only alternatives that meet threshold criteria in the 2016 FS report.

3.1 Development of Remedial Alternatives for Groundwater

The following remedial alternatives were developed to address residual groundwater contamination following source removal actions that would be performed under 2016 FS Alternatives 3 and 4:

- Alternative GW 1: No Action
- Alternative GW 2: Institutional and Access Controls

3.1.1 Alternative GW 1 – No Action

The No Action alternative is included as a requirement of the NCP. This alternative is a baseline against which other alternatives are measured and is included for comparative purposes.

Under the No Action alternative, contaminated groundwater at the site would remain and no action would be taken to reduce the potential for human or ecological receptor exposure to COCs or to reduce migration. Maintenance or monitoring would not be performed under this alternative.

3.1.2 Alternative GW 2 – Institutional and Access Controls

Under Alternative GW 2, implementation of ICs in the form of a Notice of Environmental Contamination would be performed. Groundwater contamination would be left in place, and no active remediation would be initiated. An Area of Contamination (AOC) would be established with warning signs installed along the perimeter at intervals of approximately 100 yards. Signs would require annual inspections and maintenance to ensure effectiveness. ICs in the form of land use restrictions would be established at the site to restrict future human exposure by limiting activity, use, and access to the property. The long-term retention or disposal of the site lands by the government will involve development of a site management strategy separate from the CERCLA process.

With contaminated groundwater being left in place, five-year reviews meeting the requirements in Section 121 of CERCLA would need to be performed. The intent of five-year review is to assess the protectiveness of the remedy (i.e., alternative) by evaluating whether it is functioning as intended, exposure assumptions are still valid, and new data have been obtained that could alter its effectiveness. If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the BLM will review such action no less often than every five years after the initiation of the selected remedial action.

3.2 Development of Remedial Alternatives for Sediment

A range of remedial alternatives was developed to address the media of concern. The following alternatives were developed for materials within the lower delta and nearshore Kuskokwim River sediment:

- Alternative KR 1: No Action
- Alternative KR 2: Institutional and Access Controls

- Alternative KR 3: Monitored Natural Recovery
- Alternative KR 4a: Limited Dredging of Materials within the Lower Delta for Disposal in an On-Site Repository
- Alternative KR 4b: Limited Dredging of Materials within the Lower Delta for Off-Site Disposal
- Alternative KR 5a: Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediment for Disposal in an On-Site Repository
- Alternative KR 5b: Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediment for Off-Site Disposal

3.2.1 Alternative KR 1 – No Action

The No Action alternative is included as a requirement of the NCP. This alternative is a baseline against which other alternatives are measured and is included for comparative purposes.

Under the No Action alternative, contaminated sediments and materials within the lower delta at the site would remain at their current location and in their current condition. No action would be taken to reduce the potential for human or ecological receptor exposure to COCs or to prevent their off-site migration. Maintenance and monitoring would not be performed under this alternative.

3.2.2 Alternative KR 2 – Institutional and Access Controls

Under Alternative KR 2, contaminated sediments and materials within the lower delta would be left in place, and active remediation would be limited to erecting warning signs to reduce the potential for human receptors to become exposed to on-site COCs.

Alternative KR 2 requires implementation of ICs in the form of a Notice of Environmental Contamination and ACs (signage) to warn human receptors. Establishing ICs and ACs that may restrict future land use has implications for long-term management of the land. Under the 2016 FS, an AOC would be established for the entire signed zone. Warning signs would be installed along the Kuskokwim River shoreline at intervals of approximately 100 yards at the RDM. Since no fence would be located along the river, the signs would be mounted on posts. Sign locations would be selected to avoid areas subject to high river flow forces and ice scour while remaining visible. ICs in the form of land use restrictions would be established at the site to restrict future human exposure by limiting activity, use, and access to the property. The long-term retention or disposal of the site lands by the government will involve development of a site management strategy separate from the CERCLA process.

With contaminated sediments and materials within the lower delta being left in place, five-year reviews meeting the requirements in Section 121 of CERCLA would need to be performed. The intent of five-year review is to assess the protectiveness of the remedy (i.e., alternative) by evaluating whether the remedy is functioning as intended, exposure assumptions are still valid, and new data have been obtained that could alter its effectiveness. If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the BLM will review such action no less often than every five years after the initiation of the selected remedial action.

3.2.3 Alternative KR 3 - Monitored Natural Recovery

Under Alternative KR 3, contaminated sediments and materials within the lower delta would be left undisturbed in place, and naturally occurring processes in the Kuskokwim River and Red Devil Creek delta are expected to reduce the COC concentrations in sediments and materials within the lower delta over time. The Red Devil Creek delta and the contaminated downriver sediments are situated on a cut bank of the Kuskokwim River, and are thus likely subject to net erosion at most locations. Although net sedimentation could potentially occur locally, the primary MNR processes would be sediment mixing and dispersion.

Based on information developed in the HHRA Supplement (E & E 2018), the primary exposure pathway of concern is human exposure through direct contact with and incidental ingestion of nearshore sediments. It is expected that, over time, natural recovery mechanisms can effectively reduce the potential for human receptors to come in contact with contaminated sediments. Alternative KR 3 would be implemented in conjunction with Alternative KR 2 to mitigate residual risk during monitored natural recovery.

The effectiveness of Alternative KR 3 is also related to source removal actions within the RDM. Interim actions performed as a part of the 2014 NTCRA included grading to remove actively eroding tailings piles, and the construction of a sediment trap to prevent further transport of contaminated materials to the Red Devil Creek delta and Kuskokwim River. Removal of tailings/waste rock and contaminated soil in the upland portions of the site, as described by remedial Alternatives 3 and 4 in the 2016 FS report, would further eliminate sources of contaminant transport into the delta and downriver areas. Due to the decrease in source deposition as a result of these completed and proposed remedial actions, it is expected that natural recovery mechanisms will result in decreased potential for exposure over time.

Active remediation under Alternative KR 3 is limited to development and implementation of the site-specific monitoring plan. The site-specific monitoring plan will entail periodic monitoring of sediment COC concentrations and other chemical and physical parameters will be developed. Data collected per the monitoring plan will be analyzed to assess trends in contaminant reduction and assist in the development of the five-year review. The monitoring plan should include provisions for triggering contingency actions such as additional monitoring or development of an appropriate response, as needed. Detailed development of the monitoring plan and associated contingency plan will take place during engineering design.

With contaminated sediments being left in place, five-year reviews meeting the requirements in Section 121 of CERCLA would need to be performed. The intent of five-year review is to assess the protectiveness of the remedy (i.e., alternative) by evaluating whether the remedy is functioning as intended, exposure assumptions are still valid, and new data have been obtained that could alter its effectiveness. If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the BLM will review such action no less often than every five years after the initiation of the selected remedial action.

3.2.4 Alternative KR 4 (a and b) – Limited Dredging of Materials within the Lower Delta

This alternative involves dredging approximately 18,000 cubic yards of material in the lower delta (see Figures 1-4 and 2-2) with options for on-site disposal (Alternative KR 4a) and off-site disposal (Alternative KR 4b). A proposed sequence of dredging operations is as follows:

1. Excavate and grade as needed to create a material handling area adjacent to the delta.
2. Excavate delta sediments from shore to the extent possible, using a long-reach excavator to remove target sediments within approximately 100 feet horizontally from shore down to a depth of approximately 5 feet, as needed.
3. Excavate deep sediments using an excavator on an anchored barge.
4. Dredged spoils would be passively dewatered within the material handling area using site controls to minimize the potential for erosion and transport of dredged sediments back into Red Devil Creek and the Kuskokwim River. Water emerging from the dewatering area will be monitored to ensure compliance with water quality criteria prior to discharging to the Kuskokwim River.
5. Dispose of dewatered dredged spoils in accordance with the selected alternative as presented in the 2016 FS report. Estimated costs are included in this FS Supplement report for disposal of the spoils in an on-

site repository (Alternative KR 4a) and at an approved off-site landfill (Alternative KR 4b).

As part of the remedial design for the RDM, the BLM will work in coordination with agency stakeholders to develop a comprehensive multimedia sampling plan to obtain data of sufficient quality to allow for a determination as to whether a specific area meets cleanup requirements. Based on RI sample results, dredged sediments are not expected to be classified as a hazardous waste. The sampling plan will outline the methods for sampling and classifying material prior to disposal.

Costs associated with mechanical dredging are expected to be moderate to high and would also require the construction of infrastructure such as docks and offloading areas.

3.2.5 Alternative KR 5 (a and b) – Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments

This alternative includes the work described in Alternative KR 4 with the addition of approximately 300 cubic yards of nearshore Kuskokwim River sediments downriver of the delta (see Figures 1-4 and 2-2) with options for on-site disposal (Alternative KR 5a) and off-site disposal (Alternative KR 5b). A proposed sequence of dredging operations is as follows:

1. Excavate and grade as needed to create a material handling area adjacent to the delta.
2. Excavate target nearshore sediments with a long-reach excavator, operating from shore to the extent possible, within approximately 100 feet horizontally from shore down to a depth of approximately 5 feet as needed. Dredged spoils will be transported to a dewatering pad within the material handling area
3. Excavate deep sediments and downriver sediments using an excavator on an anchored barge. Dredged spoils would be temporarily loaded on a second barge and transported to shore for offloading to a dewatering pad within the material handling area.
4. Dredged spoils would be passively dewatered within the material handling area using site controls to minimize the potential for erosion and transport of dredged sediments back into Red Devil Creek and the Kuskokwim River. Water emerging from the dewatering area will be monitored to ensure compliance with water quality criteria prior to discharging to the Kuskokwim River.
5. Dewatered dredged spoils will be disposed of in accordance with the selected alternative as presented in the 2016 FS. Estimated costs are

included in this FS Supplement report for disposal of the spoils in an on-site repository (Alternative KR 5a) and at an approved off-site landfill (Alternative KR 5b).

Costs associated with mechanical dredging are expected to be moderate to high and would require the construction of infrastructure such as docks and offloading areas.

As part of the remedial design for the RDM, the BLM will work in coordination with agency stakeholders to develop a comprehensive multimedia sampling plan to obtain data of sufficient quality to allow for a determination as to whether a specific area meets cleanup requirements. Based on RI sample results, dredged sediments are not expected to be classified as a hazardous waste. The sampling plan will outline the methods for sampling and classifying material prior to disposal.

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4 Detailed Analysis of Remedial Alternatives

This chapter presents the NCP evaluation criteria and provides detailed individual and comparative analyses of the remedial alternatives.

4.1 Evaluation Criteria

The NCP specifies nine evaluation criteria. The first two relate to statutory requirements and are considered threshold criteria, which each remedial alternative must satisfy in order to be eligible for selection. The next five are referred to as primary or balancing criteria and are used to evaluate the technical aspects of a remedial alternative. The final two criteria are considered modifying criteria and are addressed in the Record of Decision after comments are received on the RI and RI Supplement and FS and FS Supplement reports and the Proposed Plan.

The nine NCP evaluation criteria are:

Threshold Criteria:

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs

Primary Criteria:

3. Long-term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, and Volume through Treatment
5. Short-term Effectiveness
6. Implementability
7. Cost

Modifying Criteria:

8. State Acceptance
9. Community Acceptance.

The following sections describe each evaluation criterion.

4.1.1 Overall Protection of Human Health and the Environment

This criterion is used to assess the ability of a remedial alternative to protect human health and the environment from identified risks. The overall assessment of protection draws on the assessments conducted under other evaluation criteria and describes how site risks posed through each pathway addressed by the FS are eliminated, reduced, or controlled through treatment, engineering controls, or ICs. Based on findings from the HHRAs and BERAs and the development of site-specific background concentrations, protectiveness of human health and the environment is evaluated based on the remedial alternative's ability to reduce contaminant concentrations to meet the RAOs and/or reduce or eliminate exposure pathways.

4.1.2 Compliance with ARARs

This criterion is used to determine whether a remedial alternative would meet the federal and state ARARs identified in Chapter 2, Tables 2-6 through 2-8. This section also includes tables identifying whether and/or how each alternative, except the No Action alternative, complies with the pertinent individual ARARs.

The ability of a remedial alternative to comply with certain ARARs that have been identified for the remedial action can depend entirely on the manner in which the remedy is implemented. For evaluation purposes, it is assumed that any action remedy selected would be implemented in a manner that would meet these ARARs.

4.1.3 Long-Term Effectiveness and Permanence

This criterion is used to assess the long-term ability of the remedial alternative to address the threshold criteria by (1) assessing the risk remaining at the site after implementation of the remedial alternative, and (2) evaluating the long-term adequacy and reliability of the remedial alternative, including requirements for management and monitoring.

4.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This criterion is used to assess the ability of a remedial alternative to reduce the inherent risk of the waste material through treatment. Treatment technologies that permanently and significantly reduce toxicity, mobility, or volume are preferred over alternatives that manage untreated waste.

4.1.5 Short-Term Effectiveness

This criterion is used to assess the risks posed to the community, workers, and the environment during implementation of the remedial action. Measures that would be taken to mitigate these risks are addressed under this criterion. This criterion also considers the time required to achieve RGs.

4.1.6 Implementability

The implementability criterion addresses the constructability of a given remedy, including the presence of the necessary support infrastructure and the permitting requirements. This criterion involves analysis of the technical feasibility, administrative feasibility, and availability of services and materials.

4.1.7 Cost

This criterion is used to assess the anticipated capital and annual O&M and monitoring costs associated with a remedial alternative over a 30-year period. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Capital and annual costs in this FS Supplement report are presented in 2017 dollars, shown as net present worth costs calculated with a 3.5% discount factor. Detailed cost estimates are provided in Appendix A. A summary of capital and annual costs is provided in the detailed evaluation for each alternative.

4.1.8 State Acceptance

This assessment evaluates technical and administrative issues and concerns that the State (or support agency) may have regarding each of the remedial alternatives. State acceptance is not part of the evaluation process provided within this document. Following the issuance of a Proposed Plan for the RDM, this criterion would then be evaluated.

4.1.9 Community Acceptance

This assessment evaluates issues and concerns the public may have regarding each of the remedial alternatives. Community acceptance is not part of the evaluation process provided within this document. As with State acceptance, this criterion would then be evaluated following the issuance of a Proposed Plan for the RDM.

4.2 Individual Analysis of Groundwater Remedial Alternatives

Each evaluation criterion is broken down into sub-criteria to evaluate each alternative. The following sections summarize the major components of each remedial alternative and, where necessary, provide additional information pertinent to the analysis. It is important to note that the groundwater remedies outlined below pertain to a scenario in which a source removal action has been selected and executed, such as described in Alternatives 3 and 4 in the 2016 FS. This scenario recognizes that some residual contamination may be present in the groundwater immediately following the removal action. The remedies detailed in this FS Supplement report do not address groundwater in the event that source materials remain in place. Details of each remedial alternative were presented in Chapter 3.

4.2.1 Alternative GW 1 – No Action

Under Alternative GW 1, a groundwater remedy would not be implemented; therefore, groundwater at the RDM would remain in its current state. The evaluation of Alternative GW 1 is provided below.

4.2.1.1 Overall Protection of Human Health and the Environment

Since no action would be implemented, this alternative offers no protection of human health. The baseline risk assessment did not identify risk to ecological receptors. To a degree, some human risks identified in the RI would remain, albeit significantly reduced over time following source removal.

4.2.1.2 Compliance with ARARs

Because no action is being taken, this alternative would not meet water quality standards. Since this alternative provides no controls, current and potential site risks would remain, with no mechanism for tracking contaminant concentrations over time. It should be noted that under any alternative, cleanup to chemical-specific ARARs is not achievable at the site.

4.2.1.3 Long-Term Effectiveness and Permanence

The No Action alternative does not offer any mechanism for determining long-term effectiveness or permanence.

4.2.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no reduction in mobility and volume, nor any mechanism for determining toxicity, under this alternative. In time, contaminant concentrations may be reduced through naturally occurring processes.

4.2.1.5 Short-Term Effectiveness

With no action being taken, there are no short-term risks associated with construction activities under this alternative.

4.2.1.6 Implementability

While technically implementable in the sense that no action would be taken, Alternative GW 1 is not considered to be administratively implementable.

4.2.1.7 Cost

Since no action would be taken, no construction or O&M costs are associated with Alternative GW 1.

4.2.2 Alternative GW 2 – Institutional and Access Controls

Under Alternative GW 2, posted warning signs would be installed along the perimeter of the site and ICs would be implemented.

4.2.2.1 Overall Protection of Human Health and the Environment

The use of warning signs would reduce potential human contact with contaminated groundwater. Land use restrictions could be crafted such that public access to the site would be limited and performed in a manner that reduced the potential for exposure. Consequently, intrusive activities resulting in ingestion, inhalation, and dermal contact from potential human receptors would be prevented. Therefore, Alternative GW 2 provides a limited amount of additional protection for human health. The baseline risk assessment did not identify risk to ecological receptors.

4.2.2.2 Compliance with ARARs

ICs could be implemented and warning signs posted in a way that achieves compliance with action- and location-specific ARARs (see Table 4-1). An AOC would be established within the signed zone. Land use restrictions could be crafted such that public access to the site would be limited and performed in a manner that reduced the potential for exposure. However, compliance with chemical-specific ARARs would not be achieved—specifically, the Safe Drinking Water Act, Alaska Water Quality Standards, and Clean Water Act Water Quality Standards. It should be noted that under any alternative, cleanup to chemical-specific ARARs is not achievable at the site and ICs will be required.

4.2.2.3 Long-Term Effectiveness and Permanence

Once implemented, the risk of human exposure to groundwater containing concentrations of contaminants above the RGs would be reduced. Provided that warning signs are maintained and land use is restricted to reduce potential exposure to contaminated groundwater, Alternative GW 2 does offer a long-term effective and permanent solution for human exposure. This alternative would not be effective in reducing contaminant migration from the site; however, contaminant concentrations in residual groundwater following excavation under FS Alternatives 3 and 4 would gradually decrease until they were fully flushed from the system. Therefore, overall permanence is provided for under this alternative.

4.2.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Under Alternative GW 2, there would be no reduction of toxicity, mobility, or volume through treatment. In time, contaminant concentrations may be reduced through naturally occurring processes.

4.2.2.5 Short-Term Effectiveness

Given that the installation of signage does not require heavy equipment, and installation is limited to installation of signposts, with post installation requiring the use of hand tools to dig approximately 4 feet below ground surface, Alternative GW 2 would pose minimal risks to the community, workers, and the environment during its implementation.

4.2.2.6 Implementability
Technically, Alternative GW 2 is implementable. Deed restrictions are established and have well-documented procedural methods. Fence installation and sign preparation are straightforward and common construction activities. Even with the remote nature of the RDM, no problems are anticipated in obtaining and transporting the materials, labor, and equipment to the site.

4.2.2.7 Cost
ICs and ACs would be implemented as described in the 2016 FS. Although this alternative may require additional signage specific to groundwater in locations away from the soil AOCs established per the 2016 FS, the costs of such additional signage are assumed to be negligible.

4.3 Individual Analysis of Kuskokwim River Remedial Alternatives

Each evaluation criterion is broken down into sub-criteria to evaluate each alternative. The following sections summarize the major components of each remedial alternative and, where necessary, provide additional information pertinent to the analysis. Details of each remedial alternative are presented in Chapter 3, above.

4.3.1 Alternative KR 1 – No Action
Under Alternative KR 1, no remedy would be implemented; therefore, materials within the lower delta and nearshore sediments would remain in place. The evaluation of Alternative KR 1 is provided below.

4.3.1.1 Overall Protection of Human Health and the Environment
Since no action would be implemented, this alternative offers no protection of human health and the environment. The risks to human receptors identified in the RI would remain. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved. Since this alternative provides no controls, current and potential site risks would remain, with no mechanism for tracking contaminant concentrations over time.

4.3.1.2 Compliance with ARARs
This alternative complies with ARARs.

4.3.1.3 Long-Term Effectiveness and Permanence
The No Action alternative does not offer any mechanism for determining long-term effectiveness or permanence.

4.3.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no reduction in mobility and volume nor any mechanism for determining toxicity under this alternative. In time, contaminant concentrations may be reduced through naturally occurring processes.

4.3.1.5 Short-Term Effectiveness

With no action being taken, there are no short-term risks associated with construction activities under this alternative.

4.3.1.6 Implementability

While technically implementable in the sense that no action would be taken, Alternative KR 1 is not considered to be administratively implementable. It is implementable in the sense that no equipment or materials would be needed.

4.3.1.7 Cost

Given that no action would be taken, there are no construction or O&M costs associated with Alternative KR 1.

4.3.2 Alternative KR 2 – Institutional and Access Controls

Under Alternative KR 2, ICs and ACs intended to restrict site access would be implemented to enhance the effectiveness of this alternative. Warning signs would be installed along the Kuskokwim River shoreline.

4.3.2.1 Overall Protection of Human Health and the Environment

The use of warning signs would reduce potential human exposure associated with direct contact with contaminated sediments. However, warning signs would not reduce migration of contamination. Land use restrictions could be crafted such that public access to the site would be limited and performed in a manner that reduces the potential for exposure. Consequently, the potential for direct contact, intrusive activities, and potential human exposure would be reduced as well. Therefore, Alternative KR 2 provides a limited amount of protection for human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved.

4.3.2.2 Compliance with ARARs

Alternative KR 2 complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-2).

4.3.2.3 Long-Term Effectiveness and Permanence

Once implemented, the risk of human exposure to sediments containing concentrations of contaminants above the RG would be reduced. Provided that the warning signs are maintained, and land use is restricted to reduce potential exposure to contaminated material, Alternative KR 2 does offer a long-term effective and permanent solution for human exposure. However, it offers no reduction with regard to ecological exposure. Additionally, this alternative would not be effective in reducing contaminant migration from the site. Therefore, overall permanence is low for this alternative.

4.3.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Under Alternative KR 2, there would be no reduction of toxicity, mobility, or volume of contaminated sediments through treatment. In time, contaminant concentrations may be reduced through naturally occurring processes.

4.3.2.5 Short-Term Effectiveness

Given that the installation of signage does not require heavy equipment, Alternative KR 2 would pose minimal risks to the community, workers, and the environment during its implementation.

4.3.2.6 Implementability

Technically, Alternative KR 2 is implementable. Deed restrictions are established and have well-documented procedural methods. Sign installation is a straightforward and common construction activity. Even with the remote nature of the RDM, no problems are anticipated in obtaining and transporting the materials, labor, and equipment to the site.

4.3.2.7 Cost

The total capital cost associated with Alternative KR 2 is $18,000. The annual O&M cost is estimated to be $6,000, and the 30-year present worth cost has been estimated to be $130,000. A summary of the key cost components is presented in Table 4-3, with additional supporting information provided in Appendix A.

4.3.3 Alternative KR 3 – Monitored Natural Recovery

Under Alternative KR 3, contaminated sediments and materials within the lower delta would be left in place and naturally occurring processes in the Kuskokwim River and Red Devil Creek delta are expected to reduce the volume of contaminants at the site. Assuming that source reduction is performed, the volume of in-place contaminated sediments will also be reduced. The Red Devil Creek delta and area of contaminated sediments are located on a cut bank of the Kuskokwim River, comprising a scour environment with heavily armored bed sediments. Based on this environment, the primary recovery mechanisms are expected to be surface sediment dilution, consolidation, and bed armoring. A site-specific monitoring plan will be implemented to assess trends in contaminant reduction and trigger contingency actions if necessary. In addition to O&M in the form of monitoring costs, Alternative KR 3 would also require implementation of ICs, signage, and five-year reviews. Surface sediment sampling has been successfully conducted at the RDM using sediment augers from a small vessel.

4.3.3.1 Overall Protection of Human Health and the Environment

Alternative KR 3 does not remove, stabilize, or treat the contaminated sediments. However, a site-specific monitoring program would be developed for this alternative to ascertain the effectiveness of surface sediment dilution, consolidation, and bed armoring, and provide for contingency actions if necessary. This alternative also implements ICs and ACs that would reduce potential human exposure associated with direct contact of contaminated sediments. As a result, this alternative offers limited protection of human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved.

4.3.3.2 Compliance with ARARs

Alternative KR 3 complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-4).

4.3.3.3 Long-Term Effectiveness and Permanence

Alternative KR 3 may provide a long-term and permanent solution if sufficient evidence of contaminant reduction through natural processes is obtained. ICs and ACs would need to be implemented to reduce the risk to human health until the RG is met.

4.3.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative allows for the reduction of residual contaminant concentrations through naturally occurring processes. While the risk associated with the sediment will be reduced under this alternative, there is no reduction of toxicity, mobility, and volume through treatment.

4.3.3.5 Short-Term Effectiveness

The only activities proposed under this alternative are periodic sediment sampling and annual maintenance of ICs and ACs, which do not present a significant increase in short-term risks.

4.3.3.6 Implementability

Alternative KR 3 can be implemented both technically and administratively. Sediment sampling has been successfully performed at the RDM during the RI and RI Supplement, and this alternative provides a means to demonstrate whether contaminant concentration reductions are occurring. It also allows for five-year reviews to assess whether the remedy is effective at meeting the RG.

Implementation of ICs and ACs in conjunction with this alternative would further increase its effectiveness.

4.3.3.7 Cost

The total capital cost associated with Alternative KR 3 is $18,000. The annual O&M cost is estimated to be $91,000, and the 30-year present worth cost has been estimated to be $1,670,000. A summary of the key cost components is presented in Table 4-5, with additional supporting information provided in Appendix A.

4.3.4 Alternative KR 4a – Limited Dredging of Materials within the Lower Delta for Disposal in On-site Repository

Alternative KR 4a includes the excavation of approximately 18,000 cubic yards of materials within the lower Red Devil Creek delta (see Figure 2-2). This alternative does not address the approximately 300 cubic yards of contaminated nearshore river sediments located downriver of the delta. A material handling area would be constructed on shore adjacent to the delta for dewatering and stockpiling dredged spoils. Long-reach excavators would be used to remove target materials within approximately 100 feet horizontally from shore down to a depth of approximately 5 feet. Dredged spoils would be dewatered within the material handling area and allowed to passively drain. Deeper materials would then be excavated from an anchored spud barge and temporarily loaded onto a second barge and transported to shore for offloading to a dewatering pad. Dewatered dredged spoils would be disposed of in accordance with the selected alternative as presented in the 2016 FS. At the time of writing of this FS Supplement report, a disposal alternative for contaminated site materials has not yet been selected. Under this alternative, it is assumed that the dredged materials are consolidated in an on-site repository.

4.3.4.1 Overall Protection of Human Health and the Environment

By excavating materials within the lower delta and consolidating them into a repository, Alternative KR 4a would largely provide protection of human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved.

While this alternative would involve no reduction in the contaminant concentrations, the overall risk would be reduced by consolidating the contaminated sediments in a repository. Repository configurations were evaluated in the 2016 FS.

Approximately 300 cubic yards of contaminated nearshore Kuskokwim River sediment downstream of the delta would require ICs and ACs. Based on removal of the materials within the lower delta, the overall risk posed by nearshore Kuskokwim River sediment is expected to drop to levels protective of human health. For this reason, the remaining downstream nearshore Kuskokwim River sediment would not require removal to reduce potential risk to acceptable levels.

4.3.4.2 Compliance with ARARs

Alternative KR 4a complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-6).

It should be noted that during the remedial design as individual components are developed, ARAR compliance will be a key evaluation criterion. Not only does the final product need to meet its intended goal, it also needs to meet with the appropriate ARAR.

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. Dredging would therefore be designed and implemented in a manner compliant with action- and location-specific ARARs.

4.3.4.3 Long-Term Effectiveness and Permanence

Consolidating materials within the lower delta with concentrations above the RG into a dedicated repository can provide a long-term and permanent solution. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Provided that an appropriate confirmation sampling and analysis plan is implemented as part of the remedy, this alternative would provide a high level of certainty that areas of contamination would be removed to meet the RG.

However, nearshore Kuskokwim River sediments that exceed the RG would be left in place under this alternative. There would be no reduction in contaminant migration of these sediments. While human exposure can be reduced through ICs and ACs, ecological exposure would remain unchanged.

4.3.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no on-site treatment component associated with this alternative. However, the mobility of contaminants would be reduced by removing materials within the lower delta materials above the RG and consolidating them in an on-site repository. Based on RI data, it is not expected that TCLP arsenic concentrations for Kuskokwim River sediments would exceed the RCRA limit for arsenic of 5 mg/L.

4.3.4.5 Short-Term Effectiveness

During dredging operations, contaminated sediments may become mobilized and migrate downstream, which may present a limited short-term risk associated with the local population. Workers involved in remedial action would be subject to health and safety risks associated with heavy construction equipment in a remote setting and exposure to media containing elevated concentrations of arsenic, which may be mitigated through the use of personal protective equipment.

4.3.4.6 Implementability

Alternative KR 4a is both technically and administratively implementable. Mechanical dredging of contaminated sediments is a common and effective practice. Water management may be difficult in and along the Kuskokwim River, which may require water quality monitoring during dredging and dewatering activities. Sediment dewatering times should be carefully considered during the design phase to ensure that dredging activities are completed during the limited construction season.

Given the remote location, mobilization of heavy construction equipment would be a major logistical component that would require barging materials over long distances. However, mobilizing the resources needed to implement Alternative KR 4a is feasible.

Repository configurations are detailed and evaluated in the 2016 FS and have been determined to be both technically and administratively implementable.

4.3.4.7 Cost

The total capital cost associated with Alternative KR 4a is $6,060,000. The annual O&M cost is estimated to be $17,000, and the 30-year present worth cost has been estimated to be $6,370,000. A summary of the key cost components is presented in Table 4-7, with additional supporting information provided in Appendix A.

4.3.5 Alternative KR 4b – Limited Dredging of Materials within the Lower Delta for Off-Site Disposal

Alternative KR 4b includes the excavation of materials within the lower delta as described for Alternative KR 4a, but with disposal at an off-site facility rather than an on-site repository. Contaminated sediments would be containerized and shipped to an approved landfill in the contiguous United States (assumed to be located in Oregon for FS Supplement costing purposes).

4.3.5.1 Overall Protection of Human Health and the Environment

By excavating materials within the lower delta and disposing of them off site, Alternative KR 4b would largely provide protection of human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved.

While this alternative would involve no reduction in contaminant concentrations, the overall risk would be reduced by disposing of them in a secured, permitted landfill.

Approximately 300 cubic yards of contaminated nearshore Kuskokwim River sediment downstream of the delta would require ICs and ACs. Based on removal of the materials within the lower delta, the overall risk posed by nearshore Kuskokwim River sediment is expected to drop to levels protective of human health. For this reason, the remaining downstream nearshore Kuskokwim River sediment would not require removal to reduce potential risk to acceptable levels.

4.3.5.2 Compliance with ARARs

Alternative KR 4b complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-6). With regard to shipping, approximately 18,000 cubic yards of material would be disposed of in the contiguous United States. Based on RI sample results, dredged sediments are not expected to be classified as a hazardous waste, which will be verified through implementation of the sampling plan described in Section 3.2.4.

The remedial design will also outline the specifics associated with U.S. Department of Transportation requirements associated with transport for each state that the material will pass through. As part of the 2016 FS, barges permitted to haul hazardous waste were contacted to obtain price quotes. Once the material has left the RDM and arrived at a modern port (e.g., Anchorage, Seward, Bethel, etc.), it will be handled by port operations that are familiar with and equipped to handle hazardous waste and meet the required safety and shipping protocols.

It should be noted that during the remedial design as individual components are developed, ARAR compliance will be a key evaluation criterion. Not only does the final product need to meet its intended goal, it also needs to meet the pertinent ARAR.

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. Dredging would therefore be designed and implemented in a manner compliant with the ARARs.

4.3.5.3 Long-Term Effectiveness and Permanence

Excavation of materials within the lower delta having contaminant concentrations above the RG and transporting them to an appropriately licensed and maintained landfill located in the contiguous United States could provide a long-term and permanent solution. Removing the contaminated materials from the lower delta would provide an effective means of reducing human and ecological exposure as well as future migration of contaminants from the site. Removal effectiveness would be demonstrated by confirmation sampling and analysis.

Under this alternative, nearshore Kuskokwim River sediments that exceed the RG would be left in place. There would be no reduction in contaminant migration of these sediments. While human exposure can be reduced through ICs and ACs, ecological exposure would remain unchanged.

4.3.5.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no on-site treatment component associated with this alternative. However, the mobility of contaminants would be reduced by disposing of the materials within the lower delta that exceed the RG in a secured, permitted landfill.

4.3.5.5 Short-Term Effectiveness

During dredging operations, some contaminated sediments may be mobilized downstream in the Kuskokwim River, which may present a limited short-term risk associated with the local population. Workers involved in remedial action would be subject to health and safety risks associated with heavy construction equipment in a remote setting and exposure to media containing elevated concentrations of arsenic, which may be mitigated through the use of personal protective equipment.

4.3.5.6 Implementability

Alternative KR 4b is both technically and administratively implementable. Mechanical dredging of contaminated sediments and off-site disposal is a common and effective practice. Water management may be difficult in and along the Kuskokwim River, and may require water quality monitoring during dredging and dewatering activities.

Given the remote location, mobilization of heavy construction equipment would be a major logistical component that would require barging materials over long distances. However, mobilizing the resources needed to implement Alternative KR 4b is feasible.

4.3.5.7 Cost

The total capital cost associated with Alternative KR 4b is $16,650,000. The annual O&M cost is estimated to be $17,000, and the 30-year present worth cost has been estimated to be $16,960,000. A summary of the key cost components is presented in Table 4-8, with additional supporting information provided in Appendix A.

4.3.6 Alternative KR 5a – Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediment for Disposal at an On-site Repository

Alternative KR 5a includes the excavation approximately 18,000 cubic yards of materials within the lower Red Devil Creek delta and 300 cubic yards of contaminated nearshore Kuskokwim River sediments (see Figure 2-2). This alternative would be executed as described for Alternative KR 4a, with the addition of the approximately 300 cubic yards of nearshore sediments located downstream of the Red Devil Creek delta.

4.3.6.1 Overall Protection of Human Health and the Environment

By excavating materials within the lower delta and nearshore, downriver sediments and consolidating them into a repository, Alternative KR 5a would largely provide protection of human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment end-points (E & E 2017a, 2018); therefore, protection of the environment is already achieved.

While this alternative would involve no reduction in the contaminant concentrations, the overall risk would be reduced by consolidating the contaminated sediments in a repository. Repository configurations were evaluated in the 2016 FS.

4.3.6.2 Compliance with ARARs

Alternative KR 5a complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-9). Sediment dredging methods will be evaluated and selected based on their effectiveness and whether they meet the necessary protectiveness established by the pertinent ARARs.

4.3.6.3 Long-Term Effectiveness and Permanence

Consolidating excavated material with concentrations above the RG into a dedicated repository can provide a long-term and permanent solution. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Removal effectiveness would be demonstrated by confirmation sampling and analysis.

4.3.6.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no on-site treatment component associated with this alternative. However, the mobility of contaminants would be reduced by removing materials within the lower delta and nearshore Kuskokwim River sediments above the RG and consolidating them in an on-site repository.

4.3.6.5 Short-Term Effectiveness

During dredging operations, some contaminated sediments may be mobilized downstream in the Kuskokwim River, which may present a limited short-term risk associated with the local population. Workers involved in remedial action would be subject to health and safety risks associated with heavy construction equipment in a remote setting and exposure to media containing elevated concentrations of arsenic, which may be mitigated through the use of personal protective equipment.

4.3.6.6 Implementability

Alternative KR 5a is both technically and administratively implementable. Mechanical dredging of contaminated sediments is a common and effective practice. Water management may be difficult in and along the Kuskokwim River, and may require water quality monitoring during dredging and dewatering activities.

Given the remote location, mobilization of heavy construction equipment would be a major logistical component that would require barging materials over long distances. However, mobilizing the resources needed to implement Alternative KR 5a is feasible.

Repository configurations are detailed and evaluated in the 2016 FS. This disposal method is both technically and administratively implementable.

4.3.6.7 Cost

The total capital cost associated with Alternative KR 5a is $6,160,000, and annual O&M would not be required because no contaminated sediments would remain in the river. A summary of the key cost components is presented in Table 4-10, with additional supporting information provided in Appendix A.

4.3.7 Alternative KR 5b – Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments for Off-site Disposal

Alternative KR 5b includes the excavation of materials within the lower delta and contaminated sediments as described for Alternative KR 5a, but with disposal at an off-site facility. Contaminated sediments would be containerized and shipped to an approved landfill in the contiguous United States (assumed to be located in Oregon for FS Supplement costing purposes).

4.3.7.1 Overall Protection of Human Health and the Environment

By excavating materials within the lower delta and nearshore, downriver sediments and disposing of them off site, Alternative KR 5b would largely provide protection of human health. For ecological receptors, no COCs are identified because the BERA Supplement for the Kuskokwim River identified only marginal risks to the assessment endpoints; therefore, protection of the environment is already achieved.

While this alternative would involve no reduction in the contaminant concentrations, the overall risk would be reduced by consolidating the excavated materials in a repository and eliminating exposure pathways. Human health and the environment are protected from the materials that are consolidated in the repository. Repository configurations were evaluated in the 2016 FS.

4.3.7.2 Compliance with ARARs

Alternative KR 5b complies with chemical-specific ARARs and could be implemented to be compliant with location- and action-specific ARARs (see Table 4-9). As part of the remedial design for the RDM, the BLM will work in coordination with agency stakeholders to develop a sampling and analysis protocol to verify that RAOs are met. Sediment dredging methods will be evaluated and selected based on their effectiveness and whether they meet the necessary protectiveness established by the pertinent ARARs.

With regard to shipping, approximately 18,300 cubic yards of material will be disposed of in the contiguous United States. Based on RI sample results, dredged sediments are not expected to be classified as a hazardous waste, which will be verified through implementation of the sampling plan described in Section 3.2.5.

The remedial design will also outline the specifics associated with United States Department of Transportation requirements associated with transport for each state that the material will pass through. As part of the 2016 FS, barges permitted to haul hazardous waste were contacted to obtain price quotes. Once the material has left the RDM and arrived at a modern port (e.g., Anchorage, Seward, Bethel, etc.), it will be handled by port operations that are familiar with and equipped to handle hazardous waste and meet the required safety and shipping protocols.

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design.

4.3.7.3 Long-Term Effectiveness and Permanence

Excavation of materials within the lower delta and nearshore sediments having contaminant concentrations above the RG and transporting them to an appropriately licensed and maintained landfill located in the contiguous United States could provide a long-term and permanent solution. Removing the contaminated materials from within the lower delta would provide an effective means of reducing human and ecological exposure, as well as future migration of contaminants. Removal effectiveness would be demonstrated by confirmation sampling and analysis.

4.3.7.4 Reduction of Toxicity, Mobility, and Volume through Treatment

There is no on-site treatment component associated with this alternative. However, the mobility of contaminants would be reduced by dredging the contaminated materials and consolidating them in an on-site repository.

4.3.7.5 Short-Term Effectiveness

During dredging operations, some contaminated sediments may be mobilized downstream in the Kuskokwim River, which may present a limited short-term risk associated with the local population. Workers involved in remedial action would be subject to health and safety risks associated with heavy construction equipment in a remote setting and exposure to media containing elevated concentrations of arsenic, which may be mitigated through the use of personal protective equipment.

4.3.7.6 Implementability

Alternative KR 5b is both technically and administratively implementable. Mechanical dredging of contaminated sediments and off-site disposal is a common and effective practice. Water management may be difficult in and along the Kuskokwim River, and may require water quality monitoring during dredging and dewatering activities. Sediment dewatering times should be carefully considered during the design phase to ensure dredging activities are completed during the limited construction season.

Given the remote location, mobilization of heavy construction equipment would be a major logistical component that would require barging materials over long distances. However, mobilizing the resources needed to implement Alternative KR 5b is feasible.

4.3.7.7 Cost

The total capital cost associated with Alternative KR 5b is $16,920,000, and annual O&M would not be required because the contaminated sediments would be removed from the delta and the nearshore area. A summary of the key cost components is presented in Table 4-11, with additional supporting information provided in Appendix A.

4.4 Comparative Analysis of Remedial Alternatives for Groundwater

A comparative analysis of groundwater remedial alternatives is provided in the following sections.

4.4.1 Overall Protection of Human Health and the Environment

Alternative GW 2 offers some reduction in human health risk exposure by reducing the public's ability to access the site. While Alternative GW 2 does not address contaminant migration, it provides more protection than Alternative GW 1, which does not provide any reduction in human exposure and/or risk.

4.4.2 Compliance with ARARs

Alternative GW 2 could be implemented to be compliant with the ARARs even while acknowledging that cleanup to chemical-specific ARARs is not achievable at the site. Alternative GW 1 does not provide compliance with ARARs.

4.4.3 Long-Term Effectiveness and Permanence

Under proper maintenance, Alternative GW 2 offers more long-term effectiveness and permanence than Alternative GW 1, which does not provide any mechanism for determining long-term effectiveness or permanence.

4.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternatives GW 1 and GW 2 do not provide treatment to reduce toxicity, mobility, and volume of contaminated groundwater. Therefore, under these two alternatives, there is still the potential for contaminated groundwater to migrate off site.

4.4.5 Short-Term Effectiveness

No construction activities are proposed under Alternatives GW 1 and GW 2. Site activity under Alternative GW 2 is limited to installation of signposts, with post installation requiring the use of hand tools to dig approximately 4 feet below ground surface. Therefore, Alternative GW 2 would pose minimal risks to the community, workers, and the environment during its implementation.

4.4.6 Implementability

Alternative GW 1 is the easiest alternative to implement since no work would be performed. Alternative GW 2 is also easy to implement. Installing warning signs and deed restrictions are straightforward processes that are commonly implemented at sites undergoing some type of environmental remediation and/or restoration. Even with the remoteness of the RDM, signage material, labor, and installation equipment can be readily obtained and transported to the site.

4.4.7 Cost

There is no cost associated with Alternative GW 1 because no action would be taken. For Alternative GW 2, ICs and ACs would be implemented as described in the 2016 FS. Although this alternative could require additional signage specific to groundwater in locations away from the soil AOCs established per the 2016 FS, the costs of such additional signage are assumed to be negligible.

4.5 Comparative Analysis of Remedial Alternatives for Materials within the Lower Delta Materials and Nearshore Kuskokwim River Sediment

A comparative analysis of remedial alternatives for materials within the lower delta and nearshore Kuskokwim River sediment is provided in the following sections.

4.5.1 Overall Protection of Human Health and the Environment

Of the seven alternatives, Alternative KR 5b offers the most protection of human health and the environment because materials within the lower delta materials and nearshore sediments from the Kuskokwim River are removed and disposed of in a permitted landfill. Although Alternatives KR 4a and KR 4b do not remove the downriver nearshore sediments that exceed the RG, they lower overall risk to levels that are similar to those under Alternative KR 5b.

Monitoring performed under Alternative KR 3 provides information on the rate at which natural processes reduce sediment concentrations. Because Alternative KR 3 provides information needed to assess remedial progress, it is more protective than Alternatives KR 1 and KR 2.

4.5.2 Compliance with ARARs

All six "action" alternatives could be implemented to be fully compliant with the ARARs. While Alternatives KR 2, KR 3, KR 4a, and KR 4b could be implemented in a manner that complies with the ARARs, contaminated sediment would initially remain in certain nearshore locations above the RG.

4.5.3 Long-Term Effectiveness and Permanence

Alternative KR 1 does not provide for long-term effectiveness and/or permanence. Alternatives KR 2 and KR 3 offer slightly more effectiveness and permanence than Alternative KR 1. Of Alternatives KR 1 through KR 3, KR 3 is most effective, but not nearly as effective as Alternatives KR 4 and KR 5.

Alternatives KR 4a and KR 4b provide removal of most of the material containing contaminant concentrations above the RG and consolidating the material in a secured area. However, both alternatives would leave a small amount of contaminated nearshore sediment in the river.

Alternatives KR 5a and KR 5b both involve the removal of materials within the lower delta and nearshore Kuskokwim River sediments above the RG. Alternative KR 5a would employ an on-site repository, while Alternative KR 5b includes disposal at an off-site licensed landfill. With a licensed landfill being continuously monitored and maintained, Alternative KR 5b takes advantage of closure plans and related administrative processes already established for the disposal facility.

While an on-site repository can be designed and implemented in a way that matches the protectiveness of a secure landfill, the RDM's remote location increases the cost and complexity of long-term monitoring and O&M that is typically performed at such a facility. Therefore, an existing landfill provides marginally better long-term effectiveness and permanence than an on-site repository, which requires some level of O&M, as described in the 2016 FS report.

4.5.4 Reduction of Toxicity, Mobility, and Volume through Treatment

None of the alternatives involve treatment of contaminated sediments. However, Alternatives KR 4a, KR 4b, KR 5a, and KR 5b include removal and disposal of contaminated materials into a landfill or repository, which would achieve a considerable reduction in contaminant mobility.

Alternatives KR 1, KR 2, and KR 3 do nothing to prevent surface water from coming into contact with impacted sediments. Therefore, under these alternatives, there is still marginal potential for impact to human health and the environment.

4.5.5 Short-Term Effectiveness

Under Alternative KR 4b and KR 5b, approximately 18,000 cubic yards of material would be transported several thousand miles to a final disposal site. As a result, these two alternatives offer the least short-term effectiveness and generate the most adverse risk. For these alternatives, contaminated material would be loaded and off-loaded multiple times, so there is also an increase in the risk of a release. Material transfers at several ports, and transport over long distances in both brown water and blue water, present the potential for spills and other mishaps.

Of the remaining alternatives, Alternatives KR 4a and KR 5a would generate adverse short-term risk, but considerably less than Alternatives KR 4b and KR 5b. Hauling dried sediment materials and consolidation in a repository could generate dust containing COCs. Water trucks and personal protective equipment could be used to reduce the potential for exposure. Alternative KR 4a would involve slightly less adverse risk than Alternative KR 5a in that there would be less material excavated and hauled associated with leaving the downriver, nearshore sediments in place. It should be noted that these material handling risks also apply to Alternatives KR 4b and KR 5b.

With no action being performed, Alternative KR 1 has the least amount of adverse short-term risk. While there is a finite amount of site work being performed (i.e., sign installation), Alternative KR 2 has slightly more adverse short-term risk than Alternative KR 1 and far less than the previously discussed alternatives. Alternative KR 3 involves slightly more short-term risk due to periodically sampling the sediments.

4.5.6 Implementability

All of the action alternatives can be implemented. In terms of technical, administrative, and logistical concerns, Alternative KR 2 would be the easiest to implement. Installing warning signs and deed restrictions are straightforward processes that are commonly implemented at sites undergoing some type of environmental remediation and/or restoration. Even with the remoteness of the RDM, signage material, labor, and installation equipment can be readily obtained and transported to the site.

Alternatives KR 4a, KR 4b, KR 5a, and KR 5b involve excavation of contaminated sediments. Alternatives KR 4a and KR 5a are considered to be more implementable because they do not require the dredged spoils to be transported thousands of miles by barge and rail.

Given that no work would be performed, Alternative KR 1 is the easiest alternative to implement.

4.5.7 Cost

Alternatives KR 4b and KR 5b, which include off-site disposal of contaminated sediments, are the most expensive alternatives. Alternative KR 4b has the highest present worth cost, at $16,960,000, because it leaves contaminated sediments in place, which requires implementation of ICs and ACs that have annual O&M costs. The present worth for Alternative 5b is $16,920,000, which satisfies RAOs and does not require O&M. Alternatives KR 4a and KR 5a include disposal in an on-site repository and involve present worth costs $6,370,000 and $6,160,000, respectively.

The present worth cost associated with Alternative KR 3 is $1,670,000, Alternative KR 2 is $130,000, and there is no cost associated with Alternative KR 1. Table 4-12 summarizes the individual alternative costs for materials within the lower delta and nearshore Kuskokwim River sediment.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Applicable	Cleanup to MCLs is not achievable at the site. This alternative could place restrictions on the use of groundwater.
Clean Water Act	42 USC 402, 40 CFR Part 122	Establishes NPDES for remedial activities greater than 1 acre in size. Substantive requirements of the construction stormwater permit may be applicable.	Relevant and Appropriate	ARAR not triggered. Alternative does not involve construction.
Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	ARAR not triggered. Groundwater does not contribute contaminants above water quality standards in Red Devil Creek.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	TBC not triggered. Alternative does not address sediment.
State				
Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Applicable	Cleanup to numeric water quality criteria is not achievable at the site. This alternative could place restrictions on the use of groundwater.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Applicable	Cleanup to groundwater cleanup levels is not achievable at the site. This alternative could place restrictions on the use of groundwater.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	Applicable	A point of compliance for groundwater would not be established under this alternative since active groundwater remediation would not be implemented.
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 of the Interior to do so.	Applicable	ARAR not triggered. Alternative would not include any activity that could impact archaeological or historic resources.
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	ARAR not triggered. Alternative would not include any ground disturbing activity.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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.	Applicable	ARAR not triggered. Alternative would not include any ground disturbing activity that could affect wetlands.
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	ARAR not triggered. Alternative would not include development within a floodplain.
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 U.S.	Applicable	ARAR not triggered. No surface waters affected under this alternative.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	ARAR not triggered. No habitat affected under this alternative.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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.	Applicable	ARAR not triggered. No habitat affected under this alternative.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	ARAR not triggered. No habitat affected under this alternative.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	ARAR not triggered. No surface waters affected under this alternative.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	ARAR not triggered. Alternative would not include any activities that could impact archaeological or historic resources.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	ARAR not triggered. No habitat affected under this alternative.
Action-Specific				
Federal				
Clean Water Act – NPDES	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 EPA gives states the authority to implement the NPDES program.	Applicable	ARAR not triggered. Alternative would not involve discharges of wastewater or newly generated stormwater to surface water.
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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Applicable	ARAR not triggered. Alternative would not involve any placement of fill material in surface water or wetlands.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Water Act – Water Quality Standards	40 CFR 131	Sets standards 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	ARAR will not achieve WQSs.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	ARAR not triggered. Alternative would not involve any dredging of creek or river sediments.
RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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 operational 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	ARAR not triggered. Alternative would not involve construction of a solid waste disposal facility.
Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative could be implemented in compliance with this order.

Table 4-1 Alternative GW 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Applicable	ARAR not triggered. No waste would be moved under this alternative.

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
ESA = Endangered Species Act
NPDES = National Pollutant Discharge Elimination System
MCL = maximum contaminant level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = to be considered
USC = United States Code

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Applicable	ARAR not triggered. Kuskokwim River does not exceed MCLs.
Clean Water Act	42 USC 402, 40 CFR Part 122	Establishes NPDES for remedial activities greater than 1 acre in size. Substantive requirements of the construction stormwater permit may be applicable.	Relevant and Appropriate	ARAR not triggered. Alternative does not involve construction.
Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	ARAR not triggered.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative uses site-specific RBCL as RG. Use of TBC not warranted.
State				
Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Applicable	ARAR not triggered. Kuskokwim River does not exceed water quality standards.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Applicable	ARAR not triggered.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	Applicable	ARAR not triggered.
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 of the Interior to do so.	Applicable	ARAR not triggered. Alternative would not include any deep ground disturbing activity or other activities that could impact archaeological or historic resources.
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	ARAR not triggered. Alternative would not include any deep ground disturbing activity.
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.	Applicable	ARAR not triggered. Alternative would not include any ground disturbing activity that could affect wetlands.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	ARAR not triggered. Alternative would not include development within a floodplain.
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 U.S.	Applicable	ARAR not triggered. No surface waters affected under this alternative.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	ARAR not triggered. No habitat affected under this alternative.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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.	Applicable	ARAR not triggered. No habitat affected under this alternative.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	ARAR not triggered. No habitat affected under this alternative.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	ARAR not triggered. No surface waters affected under this alternative.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	ARAR not triggered. Alternative would not include any activities that could impact archaeological or historic resources.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	ARAR not triggered. No habitat affected under this alternative.
Action-Specific				
Federal				
Clean Water Act – NPDES	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 EPA gives states the authority to implement the NPDES program.	Applicable	ARAR not triggered. Alternative would not involve discharges of wastewater or newly generated stormwater to surface water.
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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Applicable	ARAR not triggered. Alternative would not involve any placement of fill material in surface water or wetlands.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	Implementation of Alternative would not affect water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	ARAR not triggered. Alternative would not involve any dredging of creek or river sediments.
RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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 operational 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	ARAR not triggered. Alternative would not involve construction of a solid waste disposal facility.
Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative could be implemented in compliance with this order.

Table 4-2 Alternative KR 2 (Institutional and Access Controls) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Applicable	ARAR not triggered. No waste would be moved under this alternative.

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
ESA = Endangered Species Act
NPDES = National Pollutant Discharge Elimination System
MCL = maximum contaminant level
RBCL = Risk-Based Cleanup Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = to be considered
USC = United States Code

Table 4-3 Cost Estimate Alternative KR 2 (Institutional and Access Controls)

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DC1	Install Warning Signs	1	lump sum	$14,500	$14,500
Total Direct Capital Costs (rounded to nearest $1,000)					***$15,000***
Indirect Capital Costs					
	Engineering and Design (5%)	5%			$1,000
	Administration (4%)	4%			$1,000
	Legal Fees and License/Permit Costs (4%)	4%			$1,000
	3rd Party Construction Oversight (5%)	5%			$1,000
Subtotal Indirect Capital Costs (rounded to nearest $10,000)					***$0***
Subtotal Capital Costs					$15,000
Contingency Allowance (20%)					$3,000
Total Capital Cost (rounded to nearest $1,000)					**$18,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Operation and Maintenance Cost	1	lump sum	$2,750	$2,750
ES	5-Year Review	1	lump sum	$2,000	$2,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$5,000*
Annual Indirect O&M Costs					
	Administration	5%			$250
	Insurance, Taxes, Licenses	3%			$150
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$0*
	Subtotal Annual O&M Costs				*$5,000*
	Contingency Allowance	20%			$1,000
Total Annual O&M Cost (Rounded to Nearest $1,000)					**$6,000**
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					18,000
Present Worth of O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$110,000
Total Present Worth Cost for Alternative (Rounded to Nearest $10,000)					**$130,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(3) ES stands for Engineer's Estimate.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Applicable	ARAR not triggered. Kuskokwim River does not exceed MCLs.
Clean Water Act	42 USC 402, 40 CFR Part 122	Establishes NPDES for remedial activities greater than 1 acre in size. Substantive requirements of the construction stormwater permit may be applicable.	Relevant and Appropriate	ARAR not triggered. Alternative does not involve construction.
Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	ARAR not triggered.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative uses site-specific RBCL as RG. Use of TBC not warranted.
State				
Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Applicable	ARAR not triggered. Kuskokwim River does not exceed water quality standards.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Applicable	ARAR not triggered.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	Applicable	ARAR not triggered.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 of the Interior to do so.	Applicable	ARAR not triggered. Alternative does not involve construction.
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	ARAR not triggered. Alternative does not involve construction.
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.	Applicable	ARAR not triggered. Alternative does not involve construction.
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	ARAR not triggered. Alternative does not involve construction.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 U.S.	Applicable	Alternative could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative could be implemented in compliance with this act.
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.	Applicable	Alternative could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative could be implemented in compliance with this act.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	ARAR not triggered. Alternative does not involve construction.
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	Alternative could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – NPDES	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 U.S. EPA gives states the authority to implement the NPDES program.	Applicable	ARAR not triggered. Alternative would not involve discharges of wastewater or newly generated stormwater to surface water.
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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Applicable	ARAR not triggered. Alternative would not involve any placement of fill material in surface water or wetlands.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	Alternative could be implemented in compliance with this act.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	ARAR not triggered. Alternative would not involve any dredging of creek or river sediments.
RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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 operational 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	ARAR not triggered. Alternative would not involve construction of a solid waste disposal facility.
Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Applicable	Alternative could be implemented in compliance with these regulations.

Table 4-4 Alternative KR 3 (Monitored Natural Recovery) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
ESA = Endangered Species Act
NPDES = National Pollutant Discharge Elimination System
MCL = maximum contaminant level
RBCL = Risk-Based Cleanup Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = to be considered
USC = United States Code

Table 4-5 Cost Estimate Alternative KR 3 (Monitored Natural Recovery)

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
	No Capital Costs Required	1	lump sum	$0	$0
Total Direct Capital Costs (rounded to nearest $10,000)					***$0***
Indirect Capital Costs					
	Engineering and Design (5%)	5%			$0
	Administration (4%)	4%			$0
	Legal Fees and License/Permit Costs (4%)	4%			$0
	3rd Party Construction Oversight (5%)	5%			$0
Total Indirect Capital Costs					***$0***
Total Capital Costs					
	Subtotal Capital Costs				$0
	Contingency Allowance	20%			$0
Total Capital Cost (rounded to nearest $10,000)					**$0**
Annual Direct Operation & Maintenance Costs					
Item Description		**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Sediment Sampling, Analysis and Reporting (9 events over 30 years)	0.33	lump sum	$137,000	$45,210
ES	5-Year Review	1	lump sum	$25,000	$25,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$70,000*
Annual Indirect O&M Costs					
	Administration	5%			$3,500
	Insurance, Taxes, Licenses	3%			$2,100
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$6,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$76,000*
	Contingency Allowance	20%			$15,200
Total Annual O&M Cost (Rounded to Nearest $1,000)					$91,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					0
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$1,670,000
Total Cost (Rounded to Nearest $10,000)					**$1,670,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(2) ES stands for Engineer's Estimate.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Applicable	ARAR not triggered. Kuskokwim River does not exceed MCLs.
Clean Water Act	42 USC 402, 40 CFR Part 122	Establishes NPDES for remedial activities greater than 1 acre in size. Substantive requirements of the construction stormwater permit may be applicable.	Relevant and Appropriate	Alternative could be implemented in compliance with this act.
Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	ARAR not triggered.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative uses site-specific RBCL as RG. Use of TBC not warranted.
State				
Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Applicable	Alternative could be implemented in compliance with these standards.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Applicable	ARAR not triggered.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	Applicable	ARAR not triggered.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 of the Interior to do so.	Applicable	Alternative could be implemented in compliance with this act.
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	Alternative could be implemented in compliance with this act.
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.	Applicable	ARAR not triggered. Alternative does not involve construction in wetlands.
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	ARAR not triggered. Alternative would not involve development within floodplains.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 U.S.	Applicable	Alternative could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative could be implemented in compliance with this act.
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.	Applicable	Alternative could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative could be implemented in compliance with this act.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative could be implemented in compliance with these requirements.
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	Alternative could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – NPDES	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 EPA gives states the authority to implement the NPDES program.	Applicable	ARAR not triggered. Alternative would not involve discharges of wastewater or newly generated stormwater to surface water.
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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Applicable	Alternative could be implemented in compliance with this act.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	Alternative could be implemented in compliance with this act.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative could be implemented in compliance with this act.
RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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 operational 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	Alternative could be implemented in compliance with this act.
Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Applicable	Alternative could be implemented in compliance with these regulations.

Table 4-6 Alternative KR 4 (Limited Dredging of Materials within the Lower Delta) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
ESA = Endangered Species Act
NPDES = National Pollutant Discharge Elimination System
MCL = maximum contaminant level
RBCL = Risk-Based Cleanup Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = to be considered
USC = United States Code

Table 4-7 Cost Estimate Alternative KR 4a (Limited Dredging of Materials within the Lower Delta for Disposal in an On-Site Repository)

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC2	Mobilization/Demobilization	1	lump sum	$2,513,776	$2,513,776
DC3	Field Overhead and Oversight	3	month	$216,468	$649,403
DC4	Site Preparation	1	lump sum	$446,237	$446,237
DC5	Excavate Contaminated Sediments; Haul and Dispose in Repository	1	lump sum	$463,926	$463,926
DC9	Construction Completion	1	lump sum	$138,302	$138,302
Total Direct Capital Costs (rounded to nearest $10,000)					***$4,210,000***
Indirect Capital Costs					
	Engineering and Design (7%)	7%			$295,000
	Administration (4%)	4%			$168,000
	Legal Fees and License/Permit Costs (4%)	4%			$168,000
	3rd Party Construction Oversight (5%)	5%			$211,000
Total Indirect Capital Costs					***$842,000***
Total Capital Costs					
	Subtotal Capital Costs				$5,052,000
	Contingency Allowance	20%			$1,010,000
Total Capital Cost (rounded to nearest $10,000)					**$6,060,000**
Annual Direct Operation & Maintenance Costs					
Item Description		**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Operation and Maintenance Cost	1	lump sum	$2,750	$2,750
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$13,000*
Annual Indirect O&M Costs					
	Administration	5%			$650
	Insurance, Taxes, Licenses	3%			$390
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$14,000*
	Contingency Allowance	20%			$2,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$17,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					$6,060,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$310,000
Total Cost (Rounded to Nearest $10,000)					**$6,370,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(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) ES stands for Engineer's Estimate.

Table 4-8 Cost Estimate Alternative KR 4b (Limited Dredging of Materials within the Lower Delta for Disposal Off-Site)

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DC2	Mobilization/Demobilization	1	lump sum	$2,513,776	$2,513,776
DC3	Field Overhead and Oversight	3	month	$216,468	$649,403
DC4	Site Preparation	1	lump sum	$446,237	$446,237
DC6	Excavate Contaminated Sediments; Haul and Dispose in Off-Site Landfill	1	lump sum	$7,812,786	$7,812,786
DC9	Construction Completion	1	lump sum	$138,302	$138,302
Total Direct Capital Costs (rounded to nearest $10,000)					***$11,560,000***
Indirect Capital Costs					
	Engineering and Design (7%)	7%			$809,000
	Administration (4%)	4%			$462,000
	Legal Fees and License/Permit Costs (4%)	4%			$462,000
	3rd Party Construction Oversight (5%)	5%			$578,000
Total Indirect Capital Costs					***$2,311,000***
Total Capital Costs					
	Subtotal Capital Costs				$13,871,000
	Contingency Allowance	20%			$2,774,000
Total Capital Cost (rounded to nearest $10,000)					**$16,650,000**
Annual Direct Operation & Maintenance Costs					
Item Description		**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2	Operation and Maintenance Cost	1	lump sum	$2,750	$2,750
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$13,000*
Annual Indirect O&M Costs					
	Administration	5%			$650
	Insurance, Taxes, Licenses	3%			$390
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$1,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$14,000*
	Contingency Allowance	20%			$2,800
Total Annual O&M Cost (Rounded to Nearest $1,000)					$17,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					$16,650,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$310,000
Total Cost (Rounded to Nearest $10,000)					**$16,960,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(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) ES stands for Engineer's Estimate.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Safe Drinking Water Act	42 USC 300f et seq. 40 CFR Part 141 subpart O appendix A, 40 CFR Part 143	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Applicable	ARAR not triggered. Kuskokwim River does not exceed MCLs.
Clean Water Act	42 USC 402, 40 CFR Part 122	Establishes NPDES for remedial activities greater than 1 acre in size. Substantive requirements of the construction stormwater permit may be applicable.	Relevant and Appropriate	Alternative could be implemented in compliance with this act.
Clean Water Act	33 USC 1251 et seq., 40 CFR Part 121	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	ARAR not triggered.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000.	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative uses site-specific RBCL as RG. Use of TBC not warranted.
State				
Alaska Water Quality Standards	18 AAC 70.020	Establishes water quality standards that apply if contaminated water is encountered during remedial actions.	Applicable	Alternative could be implemented in compliance with these standards.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(b)	Establishes groundwater cleanup levels for expected potential future use.	Applicable	ARAR not triggered.
Alaska Oil and Other Hazardous Substances Pollution Control	18 AAC 75.345(g)	Establishes point of compliance for groundwater that is hydrologically connected to surface water.	Applicable	ARAR not triggered.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 of the Interior to do so.	Applicable	Alternative could be implemented in compliance with this act.
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	Alternative could be implemented in compliance with this act.
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.	Applicable	ARAR not triggered. Alternative does not involve construction in wetlands.
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	ARAR not triggered. Alternative would not involve development within floodplains.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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 U.S.	Applicable	Alternative could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative could be implemented in compliance with this act.
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.	Applicable	Alternative could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative could be implemented in compliance with this act.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative could be implemented in compliance with these requirements.
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	Alternative could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – NPDES	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 EPA gives states the authority to implement the NPDES program.	Applicable	ARAR not triggered. Alternative would not involve discharges of wastewater or newly generated stormwater to surface water.
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 U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or off site.	Applicable	Alternative could be implemented in compliance with this act.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
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	Alternative could be implemented in compliance with this act.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative could be implemented in compliance with this act.
RCRA – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides operational 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 operational 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	Alternative could be implemented in compliance with this act.
Invasive Species EO	EO 13112	Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative could be implemented in compliance with this order.

Table 4-9 Alternative KR 5 (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments) ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Applicable	Alternative could be implemented in compliance with these regulations.

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
EO = Executive Order
ESA = Endangered Species Act
NPDES = National Pollutant Discharge Elimination System
MCL = maximum contaminant level
RBCL = Risk-based Cleanup Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = to be considered
USC = United States Code

Table 4-10 Cost Estimate Alternative KR 5a (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments for Disposal in On-Site Repository)

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC2	Mobilization/Demobilization	1	lump sum	$2,513,776	$2,513,776
DC3	Field Overhead and Oversight	3	month	$216,468	$649,403
DC4	Site Preparation	1	lump sum	$446,237	$446,237
DC7	Excavate Contaminated Sediments; Haul and Dispose in Repository	1	lump sum	$531,562	$531,562
DC9	Construction Completion	1	lump sum	$138,302	$138,302
Total Direct Capital Costs (rounded to nearest $10,000)					***$4,280,000***
Indirect Capital Costs					
	Engineering and Design (7%)	7%			$300,000
	Administration (4%)	4%			$171,000
	Legal Fees and License/Permit Costs (4%)	4%			$171,000
	3rd Party Construction Oversight (5%)	5%			$214,000
Total Indirect Capital Costs					***$856,000***
Total Capital Costs					
	Subtotal Capital Costs				$5,136,000
	Contingency Allowance	20%			$1,027,000
Total Capital Cost (rounded to nearest $10,000)					**$6,160,000**
Annual Direct Operation & Maintenance Costs					
Item Description		**Quantity**	**Unit**	**Cost/Unit**	**Cost**
	Operation and Maintenance Cost	1	lump sum	$0	$0
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$0*
Annual Indirect O&M Costs					
	Administration	5%			$0
	Insurance, Taxes, Licenses	3%			$0
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$0*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$0*
	Contingency Allowance	20%			$0
Total Annual O&M Cost (Rounded to Nearest $1,000)					$0
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					6,160,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$0
Total Cost (Rounded to Nearest $10,000)					**$6,160,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(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) ES stands for Engineer's Estimate.

Table 4-11 Cost Estimate Alternative KR 5b (Limited Dredging of Materials within the Lower Delta and Nearshore Kuskokwim River Sediments for Off-Site Disposal)

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC2	Mobilization/Demobilization	1	lump sum	$2,513,776	$2,513,776
DC3	Field Overhead and Oversight	3	month	$216,468	$649,403
DC4	Site Preparation	1	lump sum	$446,237	$446,237
DC8	Excavate Contaminated Sediments; Haul and Dispose in Repository	1	lump sum	$8,002,853	$8,002,853
DC9	Construction Completion	1	lump sum	$138,302	$138,302
Total Direct Capital Costs (rounded to nearest $10,000)					***$11,750,000***
Indirect Capital Costs					
	Engineering and Design (7%)	7%			$823,000
	Administration (4%)	4%			$470,000
	Legal Fees and License/Permit Costs (4%)	4%			$470,000
	3rd Party Construction Oversight (5%)	5%			$588,000
Total Indirect Capital Costs					***$2,351,000***
Total Capital Costs					
	Subtotal Capital Costs				$14,101,000
	Contingency Allowance	20%			$2,820,000
Total Capital Cost (rounded to nearest $10,000)					**$16,920,000**
Annual Direct Operation & Maintenance Costs					
Item Description		**Quantity**	**Unit**	**Cost/Unit**	**Cost**
	Operation and Maintenance Cost	1	lump sum	$0	$0
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$0*
Annual Indirect O&M Costs					
	Administration	5%			$0
	Insurance, Taxes, Licenses	3%			$0
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$0*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$0*
	Contingency Allowance	20%			$0
Total Annual O&M Cost (Rounded to Nearest $1,000)					$0
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					16,920,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$0
Total Cost (Rounded to Nearest $10,000)					**$16,920,000**

Notes:

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 31st Ed., 2017, adjusted for Anchorage, AK.*

(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) ES stands for Engineer's Estimate.

Table 4-12 Summary of Individual Alternative Costs for Materials within the Lower Delta and Kuskokwim River Sediment

Alternative	Total Capital Cost	Yearly O&M Cost	Present Worth O&M Cost	Total Present Worth Cost
KR 1	$0	$0	$0	$0
KR 2	$18,000	$6,000	$110,000	$130,000
KR 3	$18,000	$91,000	$1,670,000	$1,670,000
KR 4a	$6,060,000	$17,000	$310,000	$6,370,000
KR 4b	$16,650,000	$17,000	$310,000	$16,960,000
KR 5a	$6,160,000	$0	$0	$6,160,000
KR 5b	$16,920,000	$0	$0	$16,920,000

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A Cost Information

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Table A-1 Derived Costs for Kuskokwim River Remedial Alternatives

Derived Cost DC1 - Install Access Controls (Alt KR 2)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Mobilization and Demobilization	2	lump sum	$2,000	$4,000	Engineer Estimate	Travel/Lodging/Per Diem
Ship Signs and Post Hole Digger	1	each	$500	$500	Engineer Estimate	-
Install Warning Signs on Posts	20	each	$500	$10,000	Engineer Estimate	Assume one for every 100 feet of shoreline.
			DCIC1 Subtotal	*$14,500*		

Derived Cost DC2 - Mobilization/Demobilization (Alt KR 4 and KR 5)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Backhoe	3	each	$700	$2,100	2017 RSMeans, 01 54 36.50 1300	-
Dozer	1	each	$700	$700	2017 RSMeans, 01 54 36.50 1300	-
Front End Loader	2	each	$700	$1,400	2017 RSMeans, 01 54 36.50 1300	-
Dump Truck	3	each	$700	$2,100	2017 RSMeans, 01 54 36.50 1300	-
Diesel Generator	2	each	$451	$903	2017 RSMeans, 01 54 36.50 1200	-
Boom Crane	1	each	$700	$700	2017 RSMeans, 01 54 36.50 1300	-
Lodging Trailer Transport	1	each	$37,803	$37,803	2013 Vendory Quote, AATCO Structures	
Barge Delivery Cost	2	each	$1,209,600	$2,419,200	2013 Vendor Quote, Crowley Maritime Corp	
Flexifloat Delivery Cost	3	each	$10,000	$30,000	2017 Vendor Quote, Flexifloat	
Flexifloat Excavator Spud Barge Rental	1	each	$14,370	$14,370	2017 Vendor Quote, Flexifloat	
Flexifloat Sediment Barge Rental	3	each	$1,500	$4,500	2017 Vendor Quote, Flexifloat	
			DC2Subtotal	*$2,513,776*		

Derived Cost DC3 - Field Overhead and Oversight (Alt KR 4 and KR 5)

Description	Quantity	Unit	Unit Cost	Cost/Month	Reference	Notes
Superintendent	1	month	$13,800	$13,800	2017 RSMeans, 01 31 13.20 0260	-
Clerk	1	month	$2,920	$2,920	2017 RSMeans, 01 31 13.20 0020	-
Trailer	1	month	$343	$343	2017 RSMeans, 01 52 13.20 0350	-
Porta John (2)	1	month	$396	$396	2017 RSMeans, 01 54 33 40 6410	-
Field Office Expenses	1	month	$282	$282	2017 RSMeans, 01 52 13.40 0100	-
Air Monitoring Instrument Rental	1	month	$8,100	$8,100	2013 Vendor Quote, Field Environmental	Assume four DataRam 4000s @ $1,350/unit/month, and four Personal DataRams @ $675/unit/month
Pressure Washer for Deconning	1	month	$564	$564	2017 RS Means, 01 54 33 5450	
3/4 Ton Pickup Rental	5	each	$3,000	$15,000	2013 Vendor Quote, ABC Motorhome & Car Rentals	Assume 5 trucks required for the site.
Diesel-Engine-Driven Generators	1	month	$4,950	$4,950	2013 Vendor Quote, Craig Taylor Equipment	50-65 kW. $2,475/unit. Assume two generators are needed for duration of field activity.
Diesel Fuel For Generators and Pickup Trucks	1	month	$9,600	$9,600	Engineer Estimate	Estimate based on ~3000 gallons/month @ $3.20/gallon (current average $/gal for diesel in Alaska)
Lodging Trailer Rental	4	each	$4,350	$58,000	Vendor Quote, AATCO	each Unit houses 6 people. 12'x54', 3 moth lease: assume 15 people total
Lodging Trailer Transport	1	each	$37,803	$37,803	Vendory Quote, AATCO	
Propane for Lodging Trailers	1	montth	$810	$810	Engineer Estimate	Assume 225lbs of propane used/trailer/month @ $0.90/lb.
Per Diem	1	month	$63,900	$63,900	Engineer Estimate	Assume $142/person/day. Assume 15 people
			DC2 Subtotal	*$216,468*		

Table A-1 Derived Costs for Kuskokwim River Remedial Alternatives

Derived Cost DC4 - Site Preparation (Alt KR 4 and KR 5)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Silt Fencing	1,000	linear foot	$2.51	$2,510	2017 RS Means, 31 25 14.16 1000	
Hay Bales	1,000	linear foot	$6.96	$6,960	2017 RSMeans, 31 25 14.16 1250	-
Staging Area Geotextile	1,111	square yard	$1.74	$1,933	2017 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Staging Area Aggregate Base	10,000	square foot	$7.99	$79,900	2017 RSMeans, 32 11 23.23 0100	-
Dewatering Pad Geotextile	1,111	square foot	$1.74	$1,933	2017 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Dewatering Pad Aggregate Base	10,000	square foot	$7.99	$79,900	2017 RSMeans, 32 11 23.23 0100	-
Dewatering Pad Liner	10,000	square foot	$2.16	$21,600	2017 RSMeans, 33 47 13.53 1100	30 mil thickness
Temporary Barge Mooring Construction	1	lump sum	$200,000	$200,000	Engineer Estimate	-
River Access Structure Construction	1	lump sum	$51,500	$51,500	Engineer Estimate	-
			DC3a Subtotal	*$446,237*		

Derived Cost DC5 - Excavate Materials within Lower Delta and Dispose of in Repository (Alt KR 4a)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Excavate Contaminated Sediments from Shore for Dewatering	10,800	cubic yard	$1.93	$20,844	2017 RSMeans, 31 23 16.42 0305	Assume 60% sediments removed from shore
Excavate Contaminated Sediments from Spud Barge, Load onto Sediment Barge	7,200	cubic yard	$1.93	$13,896	2017 RSMeans, 31 23 16.42 0305	Assume 40% sediments removed from barge
Excavator Barge Rental	3	month	$14,370.00	$43,110	vendor quote, Flexifloat	
Sediment Barge Rental	3	month	$1,500.00	$4,500	vendor quote, Flexifloat	Assume 3 sediment barges
Transport Sediment Barge to Shore	50	hour	$2,500.00	$125,000	Engineer Estimate	-
Off-Load Sediment Barge to Shore for Dewatering	7,200	cubic yard	$1.93	$13,896	2017 RSMeans, 31 23 16.42 0305	
Load Dewatered Sediments onto Trucks	18,000	cubic yard	$1.74	$31,320	2017 RSMeans, 31 23 16.42 1650	
Haul Sediments to Repository Site	18,000	cubic yard	$5.14	$92,520	2017 RSMeans 31 23 23.20 5000	-
Spread dumped material, by dozer, no compaction	18,000	cubic yard	$2.98	$53,640	2017 RSMeans, 31 23 23.17 0020	-
Compaction- riding, vibrating roller, 12" lifts, 2 passes	18,000	cubic yard	$0.38	$6,840	2017 RSMeans, 31 23 23.23 5060	-
Confirmation Sampling	20	each	$200	$4,000	Engineer Estimate	DEC estimate, includes shipping
Water truck-soil wetting	18,000	cubic yard	$3.02	$54,360	2017 RSMeans, 31 23 23.23 9000	-
			DC4a Subtotal	*$463,926*		

Derived Cost DC6 - Excavate Materials within Lower Delta and Dispose Off-Site (Alt KR 4b)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Excavate Contaminated Sediments from Shore for Dewatering	10,800	cubic yard	$1.93	$20,844	2017 RSMeans, 31 23 16.42 0305	Assume 60% sediments removed from shore
Excavate Contaminated Sediments from Spud Barge, Load onto Sediment Barge	7,200	cubic yard	$1.93	$13,896	2017 RSMeans, 31 23 16.42 0305	Assume 40% sediments removed from barge
Excavator Barge Rental	3	month	$14,370.00	$43,110	vendor quote, Flexifloat	
Sediment Barge Rental	3	month	$1,500.00	$4,500	vendor quote, Flexifloat	Assume 3 sediment barges
Transport Sediment Barge to Shore	50	hour	$2,500.00	$125,000	Engineer Estimate	-
Off-Load Sediment Barge to Shore for Dewatering	7,200	cubic yard	$1.93	$13,896	2017 RSMeans, 31 23 16.42 0305	-
Load Dewatered Sediments into Super Sacks	18,000	cubic yard	$1.74	$31,320	2017 RSMeans, 31 23 16.42 1650	-
Purchase Super Sacks	12,000	each	$14.30	$171,600	2013 Vendor Quote	-
Load Super Sack Containers on to River Barge	18,000	cubic yard	$2.42	$43,560	2017 RSMeans, 31 23 23.14 5400	-
Barge Transport from Red Devil to Seward	18,000	cubic yard	$172	$3,096,000	2013 Vendor Quote, Crowley Maritime Corp	-
Load Super Sack Containers from Barge to Train	18,000	cubic yard	$5	$92,700	2017 RSMeans, 31 23 16.13 1346	-
Train Transport	18,000	cubic yard	$153	$2,745,360	2013 Vendor Quote, Alaska Railroad	-
Non-Hazardous Waste Disposal	23,400	ton	$60	$1,404,000	2017 Vendor Quote, Waste Management	
Confirmation Sampling	20	each	$350	$7,000	Engineer Estimate	DEC estimate, includes shipping
			DC4b Subtotal	*$7,812,786*		

Table A-1 Derived Costs for Kuskokwim River Remedial Alternatives

Derived Cost DC7 - Excavate Materials within Lower Delta and Nearshore Kuskokwim River Sediments and Dispose of in Repository (Alt KR 5a)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Excavate Contaminated Sediments from Shore for Dewatering	10,800	cubic yard	$1.93	$20,844	2017 RSMeans, 31 23 16.42 0305	Assume 60% sediments removed from shore
Excavate Contaminated Sediments from Spud Barge, Load onto Sediment Barge	7,500	cubic yard	$1.93	$14,475	2017 RSMeans, 31 23 16.42 0305	Assume 40% sediments removed from barge
Excavator Barge Rental	3	month	$14,370.00	$43,110	vendor quote, Flexifloat	-
Sediment Barge Rental	3	month	$1,500.00	$4,500	vendor quote, Flexifloat	Assume 3 sediment barges
Transport Sediment Barge to Shore	75	hour	$2,500.00	$187,500	2017 RSMeans, 31 23 16.42 0305	-
Off-Load Sediment Barge to Shore for Dewatering	7,500	cubic yard	$1.93	$14,475	2017 RSMeans, 31 23 16.42 0305	-
Load Dewatered Sediments onto Trucks	18,300	cubic yard	$1.74	$31,842	2017 RSMeans, 31 23 16.42 1650	-
Haul Sediments to Repository Site	18,300	cubic yard	$5.14	$94,062	2017 RSMeans 31 23 23.20 5000	-
Spread dumped material, by dozer, no compaction	18,300	cubic yard	$2.98	$54,534	2017 RSMeans, 31 23 23.17 0020	-
Compaction- riding, vibrating roller, 12" lifts, 2 passes	18,300	cubic yard	$0.38	$6,954	2017 RSMeans, 31 23 23.23 5060	-
Confirmation Sampling	20	each	$200	$4,000	Engineer Estimate	DEC estimate, includes shipping
Water truck-soil wetting	18,300	cubic yard	$3.02	$55,266	2017 RSMeans, 31 23 23.23 9000	-
			DC4a Subtotal	*$531,562*		

Derived Cost DC8 - Excavate Materials within Lower Delta and Nearshore Kuskokwim River Sediments and Dispose of Off-Site (Alt KR 5b)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Excavate Contaminated Sediments from Shore for Dewatering	10,800	cubic yard	$1.93	$20,844	2017 RSMeans, 31 23 16.42 0305	Assume 60% sediments removed from shore
Excavate Contaminated Sediments from Spud Barge, Load onto Sediment Barge	7,500	cubic yard	$1.93	$14,475	2017 RSMeans, 31 23 16.42 0305	Assume 40% sediments removed from barge
Excavator Barge Rental	3	month	$14,370.00	$43,110	vendor quote, Flexifloat	-
Sediment Barge Rental	3	month	$1,500.00	$4,500	vendor quote, Flexifloat	Assume 3 sediment barges
Transport Sediment Barge to Shore	75	hour	$2,500.00	$187,500	Engineer Estimate	-
Off-Load Sediment Barge to Shore for Dewatering	7,500	cubic yard	$1.93	$14,475	2017 RSMeans, 31 23 16.42 0305	-
Load Dewatered Sediments into Super Sacks	18,300	cubic yard	$1.74	$31,842	2017 RSMeans, 31 23 16.42 1650	-
Purchase Super Sacks	12,200	each	$14.30	$174,460	2013 Vendor Quote	-
Load Super Sack Containers on to River Barge	18,300	cubic yard	$2.42	$44,286	2017 RSMeans, 31 23 23.14 5400	-
Barge Transport from Red Devil to Seward	18,300	cubic yard	$172	$3,147,600	2013 Vendor Quote, Crowley Maritime Corp	-
Load Super Sack Containers from Barge to Train	18,300	cubic yard	$5	$94,245	2017 RSMeans, 31 23 16.13 1346	-
Train Transport	18,300	cubic yard	$153	$2,791,116	2013 Vendor Quote, Alaska Railroad	-
Non-Hazardous Waste Disposal	23,790	ton	$60	$1,427,400	2017 Vendor Quote, Waste Management	
Confirmation Sampling	20	each	$350	$7,000	Engineer Estimate	DEC estimate, includes shipping
			DC4b Subtotal	*$8,002,853*		

Table A-1 Derived Costs for Kuskokwim River Remedial Alternatives

Derived Cost DC9 - Construction Completion (Alt KR 4 and KR 5)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Haul Road Removal	1,000	square yard	$12.51	$12,510	2017 RSMeans, 02 41 13.17 5050	-
Staging Area Removal	1,111	square yard	$12.51	$13,900	2017 RSMeans, 02 41 13.17 5050	-
Dewatering Pad Removal	1,111	square yard	$12.51	$13,900	2017 RSMeans, 02 41 13.17 5050	-
Temporary Barge Mooring Removal	1	each	$42,954	$42,954	Engineer Estimate	-
River Access Structure Removal	1	each	$32,216	$32,216	Engineer Estimate	-
Regrade excavated areas to match existing topography	30000	square yard	$0.26	$7,800	2017 RSMeans, 31 22 16.10 3300	
Seeding	270	MSF	$36	$9,842	2017 RSMeans, 32 92 19.14 4600	slope mix, tractor spread
Equipment Decontamination	1	lump sum	$5,180	$5,180	2017 RSMeans, Crew B-1D	1 Laborer + 1 Pressure Washer. Assume 6 days.
			DC13a Subtotal	*$138,302*		

Derived Cost OM1 - Operation and Maintenance Costs (Alt KR 3)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Mobilization and Demobilization	1	lump sum	$2,000	$2,000	Engineer Estimate	Travel/Lodging/Per Diem
Post and Sign Maintenance	1	lump sum	$750	$750	Engineer Estimate	-
			OM1 Subtotal	*$2,750*		

Derived Cost OM2- Sediment Sampling and Analysis (Alt KR 3, KR 4, and KR 5)						
Description	**Quantity**	**Unit**	**Unit Cost**	**Cost**	**Reference**	**Notes**
Mobilized 2 man field crew & expenses	1	lump sum	$5,000	$5,000	Engineer Estimate	Based on actual sediment sampling costs at RDM
Sampling Vessel Operation	1	lump sum	$80,000	$80,000		
Sampling Crew Labor	160	hours	$125	$20,000		
Sampling Analysis	20	each	$350	$7,000		
Reporting	1	lump sum	$25,000	$25,000		includes work plan
			OM3a Subtotal	*$137,000*		