Engineering Evaluation/Cost Analysis
Kolmakof Mine Site
Napaimute, Alaska

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ACRONYMS

AAC	Alaska Administrative Code
ABS	skin absorption factor
ACM	asbestos-containing materials
ADD	average daily dose
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AF	adherence factor
AHERA	Asbestos Hazard Emergency Response Act
AMEC	AMEC Environment & Infrastructure, Inc.
AOCs	Areas of Concerns
APMC	Alaska Plant Material Center
ARARs	Applicable or Relevant and Appropriate Requirements
As	arsenic
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BCFs	bioconcentration factors
bgs	below ground surface
BLM	Bureau of Land Management
BSAFs	biota-sediment accumulation factors
BTEX	benzene, toluene, ethyl benzene, xylenes
BW	body weight
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF	conversion factor
cm^2	centimeters squared
COCs	contaminants of concern
COPCs	contaminants of potential concern
Cr	chromium
CSIS	Community Subsistence Information System
CSM	Conceptual Site Model
Cu	copper
cy	cubic yards
DAD	dermally absorbed dose
DGGS	Division of Geological and Geophysical Surveys
DI	daily intake
DRO	diesel-range organics
DU	decision unit
E&E	Ecology and Environment, Inc.
ECAO	Environmental Criteria and Assessment Office
ED	Exposure duration
EE/CA	Engineering Evaluation/Cost Analysis
EF	exposure frequency
ELCR	excess lifetime cancer risk
EPCs	Exposure Point Concentrations
ERBSC	ecological risked-based screening concentration
FI	fraction ingested
g/day	grams per day
GI	gastrointestinal

GRO	gasoline range organics
HDPE	high-density polyethylene
HEAST	Health Effects Assessment Summary Tables
Hg	mercury
Hg^0	elemental mercury
HHCSM	human health conceptual site model
HHRA	human health risk assessment
HHSRE	human health screening risk evaluation
HHSSLs	human health risk-based soil screening levels
HI	hazard indices
HQ	hazard quotient
IA	investigation area
IR_{inh}	inhalation rate
IR_{ing}	ingestion rate
IRIS	Integrated Risk Information System
kg	kilogram
kg/mg	kilograms per milligram
KMS	Kolmakof Mine Site
K_{ow}	log of octanol-water partition coefficient
LADD	lifetime average daily dose
LBP	lead-based paint
LDR	land disposal restrictions
LOAEL	lowest-observed adverse effect level
MACTEC	MACTEC Engineering and Consulting, Inc.
m^3/day	cubic meters per day
mg/cm^2	milligrams per square centimeter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/m^3	milligram per cubic meter
MNA	monitored natural attenuation
NCP	National Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
Ni	nickel
ND	non-detect
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	no-observed adverse effect level
NTCRA	Non-Time Critical Removal Action
OEHHA	Office of Environmental Health Hazard Assessment
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PA/SI	preliminary assessment/site investigation
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEC	probable effects concentrations
PEL	probable effects level
PM_{10}	particulate matter less than 10 microns
PPE	personnel protective equipment
RACM	Regulated Asbestos Containing Material

RAGS	Risk Assessment Guidance for Superfund
RAOs	removal action objectives
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RELs	reference exposure levels
RME	reasonable maximum exposure
RRO	residual-range organics
RSI	removal site inspection
RSLs	Regional Screening Levels
SA	surface area
SF	slope factor
SFF	site foraging frequency
SI	Site investigation
SPLP	Synthetic Precipitation Leaching Procedure
SQuiRTs	Screening Quick Reference Tables
SSE	Selective Sequential Extraction
SRE	screening risk evaluation
TBC	To Be Considered Requirement
TCLP	Toxicity Characteristic Leaching Procedure
TKC	The Kuskokwim Corporation
TRVs	toxicity reference values
UCL	upper confidence limit
µg/kg	micrograms per kilogram
$\mu g/m^3$	micrograms of soil per cubic meter of air
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VG	empirical correction factor below ground produce
VOCs	volatile organic compounds
WEFH	Wildlife Exposure Factors Handbook
XRF	X-ray fluorescence

EXECUTIVE SUMMARY

The Bureau of Land Management is exercising its delegated authority to act as lead agency for the completion of this Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Engineering Evaluation/Cost Analysis (EE/CA) of the Kolmakof Mine Site (KMS) to address contaminants of concern (metals, petroleum hydrocarbons, and associated volatile and semi-volatile compounds, lead-based paint, and asbestos) in four areas of concern (Camp Area, Mill Area, Pit Area and Tailings Area) and characterization and disposal of abandoned site-related equipment, structures, and supplies. The Alaska Department of Environmental Conservation (ADEC) is being provided meaningful and substantial participation in the CERCLA process by providing oversight of the project to ensure the State of Alaska's interests are adequately protected.

The KMS is an abandoned cinnabar mine on the North Bank of the Kuskokwim River near the village of Napaimute, Alaska and is scheduled to be conveyed to The Kuskokwim Corporation (TKC) (surface estate) and Calista Corporation (Calista) (subsurface estate) in accordance with the Alaska Native Claims Settlement Act. Based on a preliminary assessment/site investigation (PA/SI) conducted by the United States Environmental Protection Agency (USEPA) and two site inspections and removal actions conducted by the BLM in 2000 and 2006, a Removal Site Inspection (RSI) was performed by Ecology and Environment, Inc (E&E) in 2007 to identify facility features, inventory abandoned mine-related equipment and debris, and identify contaminants requiring possible remediation and or removal prior to transfer of the land to TKC and Calista. The RSI identified mercury as the primary contaminant of concern and identified the need for further investigation to further characterize the site for metals, petroleum hydrocarbons, and explosives, as well as the need for characterization and removal of hazardous and non-hazardous site materials.

MACTEC Engineering and Consulting Inc. (MACTEC) conducted initial investigative removal activities in 2008, including metals background concentration investigation, geophysical survey for a potential monofill location, explosives residue sampling, mercury speciation analysis, and an asbestos and lead-based paint survey. Removal activities included removal and disposal of various hazardous and non-hazardous materials from abandoned waste containers and equipment. In 2011, AMEC Environment & Infrastructure (AMEC, formerly MACTEC) prepared an EE/CA Workplan to complete site characterization activities required to delineate the extent of remaining contamination in each of the AOCs in support of this EE/CA. Field work including investigation of metals, petroleum hydrocarbons, and other contaminants of concern as well as a biological survey was conducted between September 25 and October 1, 2011. The work completed in 2011 identified metals, including mercury, arsenic, and chromium as the primary contaminants of concern in both the Camp Area and the Mill Area, and localized petroleum hydrocarbon contamination in the Mill Area. The results of the site characterization are presented in Appendix A of this document.

As part of the EE/CA, a streamlined human health risk assessment (HHRA) was conducted using a two-tiered approach. Potential health risks were first evaluated by comparing chemicals of potential concern (COPCs) in environmental media at the Site to risk-based screening levels. If a COPC was found to be present at a concentration greater than the defined screening criteria, then the HHRA assessed whether or not the observed concentration is truly likely to constitute a risk to human health given the nature and extent of the constituent Site soils and sediments and other Site specific considerations.

The receptors evaluated in the HHRA included child and adult subsistence/recreational receptor. Mercury and arsenic were determined to be the primary non-cancer hazards for the child receptor from incidental ingestion of soil/sediment and arsenic for the adult receptor from ingestion of above ground produce.

Arsenic was also determined to be the primary cancer risk. The cumulative cancer risks in the Camp and Mill Areas were determined to be above ADECs target cancer risk of 10^{-5}.

A streamlined ecological risk assessment was also completed as part of this EE/CA to identify contaminants of concern in the affected media, contaminant concentrations, and toxicity associated with the contaminants for ecological receptors. Benthic macroinvertebrates were determined to have limited available habitat on the site due to the intermittent nature of the Unnamed Creek in the Mill Area. If it is flowing and benthic macroinvertebrates are growing and reproducing in the sediment, they may be at potential risk of adverse effects from arsenic, copper, and nickel, but likely not mercury since methylmercury, the bioavailable form, is detected at very low concentrations. Benthic macroinvertebrate communities in the Kuskokwim River are not likely to be at true risk of adverse effects to compounds originating in the Tailings Area.

Three animal species were evaluated in the streamlined ecological risk assessment: a semi-aquatic avian invertivore, a terrestrial avian invertivore, and a terrestrial mammalian herbivore. Avian receptors are exposed to the most risk of potential adverse effects from metals in the Camp and Mill areas based on COPCs in the top 6 inches of soil and/or sediment. Mammalian herbivores have less potential of adverse effects because much of their diet is vegetation where COPCs do not accumulate as much as in invertebrates. Arsenic was a COPC posing risk to all receptors in all areas investigated. While mercury is wide-spread, concentrations of the bioavailable fractions were very low and so mercury is thought to pose little or no actual risk to ecological receptors using the site. Total petroleum hydrocarbons as diesel-range organics and residual range organics were detected in a sufficiently small area that it can be considered a negligible exposure likelihood for ecological receptors; constituent polycyclic aromatic hydrocarbons were present at levels that did not pose risk to terrestrial receptors.

Removal action cleanup levels (CULs) were compiled for Site COCs detected in soil and sediment from screening levels protective of human health, ecological receptors, groundwater, and background values. Based on the results of the HHRA and ERA and comparison of soil and sediment data to cleanup levels, there is no surface water or sediment in surface waters that contain COCs at concentrations above cleanup levels. There is one sample location where dry sediment from the former Settling Pond area of the Site contained concentrations of COCs above cleanup levels that is considered soil for the purposes of the removal action because it is in a dry area.

The findings of the EE/CA indicate that approximately 200 cubic yards (cy) of soil containing elevated metal concentrations in two of the four areas of concern (Camp Area and Mill Area) and a limited amount of soil containing Diesel Range Organics [DRO]) in the Mill Area should be addressed in a removal action. In addition, approximately 1,000 cy of debris from site-related equipment and structures remaining at the Site would be demolished and/or removed and disposed as part of site restoration.

The removal action objectives (RAOs) developed to prevent, minimize, or mitigate risks to public health or the environment for the KMS are to evaluate removal actions that will:

- Prevent unacceptable risks to recreational users and ecological receptors that may be exposed to chemicals in soil that contains COCs at concentrations that exceed cleanup levels.

- Remove and properly dispose of abandoned site-related equipment, structures, supplies, and associated materials.

The removal action alternatives identified and analyzed are considered proven remedies because they have been selected and successfully implemented in the past at similar sites and/or for similar contaminants. Remedial options and technologies were screened and assembled into the following four removal action alternatives:

- Alternative 1 - No Action
- Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository
- Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill
- Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

Based on the alternatives evaluation using EE/CA guidance and a comparative analysis of the removal action alternatives, Alternative 2, which involves consolidation of all waste in an onsite repository, is recommended for the KMS. This alternative would meet the threshold criteria of human health and environmental protection and compliance with ARARs, would be effective and implementable pending ADEC approval, and has a significantly lower cost than Alternatives 3 and 4. Although it involves long term monitoring of the repository and deed restrictions, all of the waste would be managed onsite at a significant cost savings compared to offsite disposal, and all of the technical aspects of this alternative are proven and have been implemented at other similar sites.

1.0 INTRODUCTION

The U.S. Bureau of Land Management (BLM) has a requirement to complete a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Engineering Evaluation/Cost Analysis (EE/CA) for Kolmakof Mine Site (KMS) to address contaminants of concern (COCs) which include the metals mercury (Hg), arsenic (As), nickel (Ni), chromium (Cr), copper (Cu) as well as petroleum hydrocarbons and associated volatile and semi-volatile components within four Areas of Concern (AOCs). Other issues to be addressed include characterization and disposal of abandoned site-related equipment, structures, and supplies. The removal site inspection (RSI) conducted by BLM in 2007 (Ecology and Environment, Inc. [E&E], 2008) determined that there were several AOCs at the KMS where Non-Time Critical Removal Actions were warranted under authority of the National Contingency Plan (NCP). Additionally, the BLM has determined that certain hazardous materials needed to be removed from the site and properly disposed.

This EE/CA divides the KMS into separate decision units (DUs) and establishes removal action objectives for each DU. For each DU, this EE/CA identifies Applicable or Relevant and Appropriate Requirements (ARARs), and provides analysis of cost-effective removal alternatives and recommendations for preferred removal actions that best meet the removal objectives.

In support of the preparation of this EE/CA, AMEC Environment & Infrastructure, Inc. (AMEC; formerly MACTEC Engineering and Consulting, Inc. [MACTEC]) prepared the EE/CA Workplan (AMEC, 2011a), which described additional characterization work required to delineate the extent of remaining contamination at each of the AOCs. The tasks outlined in the Workplan were based upon findings of the 2007 RSI, work performed by MACTEC in 2008, and discussions with BLM, Alaska Department of Environmental Conservation (ADEC), and the U.S. Environmental Protection Agency (USEPA). The results of the characterization work performed from September 25 to October 1, 2011 are presented in Appendix A of this document.

This EE/CA presents the results of the investigations performed at the Site as well as the results of the human and ecological risk evaluations and documents the development and screening of removal action alternatives to address any unacceptable risks to human health or the environment associated with the Site.

This EE/CA also presents the removal action objectives (RAOs), the ARARs that will have to be met by the removal action, and the development and evaluation of alternatives to address any identified unacceptable risks at the Site. A range of removal alternatives have been developed and these alternatives have been evaluated against the NCP criteria of effectiveness, implementability and cost for both short term and long term remedies. This EE/CA provides a comparative analysis of the alternatives and defines the removal action alternative which best satisfies the NCP criteria.

1.1 Site Description

The KMS is an abandoned cinnabar mine on the north bank of the Kuskokwim River located within Section 6, Township 17 North, Range 53 West, Seward Meridian. The site, located at approximately 61 degrees 35’ 22.825” north latitude and 158 degrees 55’ 22.438” west longitude, is on public land administered by the BLM. The site is located approximately 19.5 miles east of Aniak, Alaska, and approximately 10 miles west of Napaimute, Alaska (Figure 1), the nearest known inhabited area. A small, unnamed creek passes by portions of the site and flows into the Kuskokwim River. There are no roads to the site or landing strips nearby; access is by boat only.

In the vicinity of KMS, the north bank of the Kuskokwim River is made up chiefly of hard-rock bluffs 100 to 400 feet high. The bluffs consist principally of alternate beds of sandstones and shales that have been intruded by rhyolite dikes and sills. The bluff where the cinnabar mineralization occurs shows sandstone beds two feet to 20 feet in thickness and shale beds from a few inches to two or three feet thick (E&E, 2008). Figure 2 presents an overview of the Site; Figures 3 through 8 show the investigation areas (IAs) and investigation results.

1.2 Site History

Mining of cinnabar at the KMS dates back to approximately 1881, although all of the structures found there are of a more modern age from about the 1940's and newer. The last mining is thought to have occurred in the early 1970's and the claims were determined by BLM to be abandoned and void in 1993. Since the mine closure, the KMS area has become overgrown with vegetation to the extent that roads need to be cleared prior to vehicle travel but are mostly usable as footpaths. The site is located within lands selected for conveyance to an Alaska Native Corporation - The Kuskokwim Corporation (TKC), as part of the Napaimute Village Townsite selection under authority of the Alaska Native Claims Settlement Act (E&E, 2008). Calista, the regional Alaska Native Corporation, will be conveyed the subsurface estate at that time.

A cinnabar deposit within the bluff on the north side of the Kuskokwim River was the only known deposit in the immediate area. From 1969 to 1970, the Bureau of Mines conducted trenching and augering exploration in the area in an attempt to identify extensions of the known cinnabar deposit. The results did not confirm the existence of additional cinnabar ore; however, results were perhaps non-conclusive due to heavy overburden of loess and moss concealing the bedrock (Merrill, 1975). The trenching did result in scars and hummocky topography visible northeast of the Mill Area on (Figure 2). Because this was an exploration that disturbed the topography, but resulted in no production or mining of cinnabar, this area explored by trenching has been ruled out as an area of further concern.

The ore source area for the mining operations is located within the bluff that parallels the Kuskokwim River's north boundary. The bluff is approximately 230 feet high from the base at the river's edge to the top of the slope with a steep grade. From the top of the slope proceeding north for approximately three hundred feet is an area scoured by blasting and bulldozing over the years of operation. This area is identified as the Pit Area (Figure 2). The remnants of a small blast shack, an ore cart, and an air compressor all remain on site in the Pit Area. A 1998, inspection of the site by the Alaska Department of Natural Resources Division of Geological and Geophysical Surveys (DGGS) noted that undisturbed cinnabar remains visible on the slope of the bluff and within the pit area as described in *DGGS Report of Investigation 98-12* (Buntzen, et al., 1999), indicating that at least some of the cinnabar at the base of the bluff is a result of natural erosion, and not a result of mining activities. Erosion of the exposed cinnabar is further documented in a previous report issued in 1947 by the U.S. Department of the Interior, Bureau of Mines "The more promising deposit described by the Geologic Survey in 1914 is not now in evidence and has probably been removed by the rapid erosion to which the bluff is subjected" (Webber, et al., 1947).

From the Pit Area, the blasted fragments with high concentrations of cinnabar were hand sorted and hauled by wooden sled approximately ¼ mile northeast to the Mill Area. The remaining blasted rock with fragments of cinnabar were pushed over the top of the bluff toward the river. This area along the bluff is identified as the Tailings Area, although this may be misleading as the blasted rock might be more accurately described as waste rock, not tailings (E&E, 2008). Waste rock is generally the non-mineralized or low-grade mineralized material removed from above or within the ore during mining activities, whereas tailings are produced during beneficiation activities and are typically fine-grained materials that may still contain low concentrations of the target mineral.

Cinnabar ore collected from the Pit Area was transported approximately ¼ mile northeast to the Mill Area (Figure 2). The mill consisted of an open wooden-framed structure built on a steep slope. The ore deposit area, or chute, was at the top of the slope with a ball mill at the bottom. The structure was protected by a canopy. The ball mill and structure remain on site with a collapsed canopy. Southwest of the chute at the top of the mill, are the burnt remains of a small shed that was formerly used to house blasting supplies.

At the bottom of the mill, a washing system (also identified as a "floatation system" in the 2007 RSI) was likely used to separate the crushed cinnabar from waste rock. A small settling pond was created approximately 200 feet southwest of the ball mill that was used to collect and reuse water from the washing process. Also in the Mill Area, a large shed southeast of the mill was used to house a generator and miscellaneous tools or supplies. Twelve flasks were found in the large shed, some containing small amounts of liquid mercury. A smaller shed south of the large shed was likely used as a tool/work shed. An abandoned pickup truck was found northeast of the mill and shed. Figures 2 and 8 show the location of the Mill Area and the site details.

A road approximately a half-mile long leads southeast from the Mill Area to the Camp Area. The Camp Area (Figures 2 and 7) is located near the Kuskokwim River at a location where the bluff subsides and access is gained from the river. The Camp Area consisted of some outbuildings including two bunkhouses, a cookhouse, a generator shed, a canvas wall tent and a manager's house. One of the bunk houses, the cook house and the manager's house were destroyed sometime after the 2007 field investigation, while the generator shed, and one bunkhouse remain on site mostly intact. Also located in the Camp Area is a mound of earth likely used by the mine operators as a retort facility. Discarded ore-refining equipment including a sewer pipe, retort keg, split drum and a buried half drum remain on the retort mound.

The Tailings Area, Pit Area, Mill Area, and Camp Area have been identified as the four areas of concern to be addressed in the EE/CA (Figure 2).

1.3 Previous Investigations and Removal Actions

This section summarizes investigations and removal actions performed prior to work performed by AMEC in 2011. A detailed description of the 2011 investigation, discussion of results, and a summary of the analytes of concern and associated cleanup criteria is presented in Appendix A.

In 1999, the USEPA performed a preliminary assessment/site investigation (PA/SI) at the site and identified the potential for mercury and other toxic metals contamination from the mining operations. In 2000, in cooperation with USEPA, BLM assumed responsibility for and conducted the site investigation (SI) phase, and determined that removal of hazardous materials was warranted at the Site. In coordination with R&H Mining Company, the last claim owner, the BLM removed several drums of chemicals and razed a shed containing explosives in the Mill Area.

During an August 2006 joint site inspection of the Site with representatives of the Native Village of Napaimute, the BLM concluded that further investigation was warranted. The decision was based on the presence of what appeared to be empty mercury flasks, as well as potential retort operations, a dynamite shed, structures, drums, and debris.

In 2007, E&E conducted a RSI to identify facility features, collect soil, product, sediment, and water samples to identify possible contaminants and concentrations, and to inventory abandoned mine-related structures, equipment, debris, and potentially hazardous materials (E&E, 2008). A summary of the RSI activities in each of the AOCs is presented below.

2007 Removal Site Inspection

Camp Area: During the 2007 RSI, the structures at the Camp Area including a generator shed, bunk house/shop, bunkhouse, cookhouse, manager's house, and canvas wall tent were investigated for the presence of hazardous materials and to evaluate their safety (Figure 7). The retort facility (referred to as "retort mound") in the Camp Area was defined as an earthen mound containing discarded ore refining or processing equipment such as a beer keg, sections of sewer pipe, a firebrick kiln, and a two-part container containing granular material (Figure 7 inset). Results of five soils sampled and analyzed for metals from the retort mound indicate that arsenic, chromium, and mercury concentrations are present above the ADEC Method 2 cleanup criteria (migration to groundwater category) of 3.9 milligrams per kilogram (mg/kg), 25 mg/kg, and 1.4 mg/kg, respectively, as follows:

- Duplicate soil (processed ore) samples collected from the area of the sewer pipe: arsenic (7.1 and 7.6 mg/kg), chromium (78 and 81 mg/kg), and mercury (32 and 43 mg/kg)
- A sample (processed ore) from "two part container": arsenic (8.7 mg/kg), chromium (41 mg/kg) and mercury 18,000 mg/kg). This sample was collected from the granular material contained within the container.
- Soil sample collected near the "two part container" showed arsenic at 7.9 mg/kg, chromium at 26 mg/kg, and mercury at 3.8 mg/kg.
- Soil sample (processed ore) from the area of the beer keg retort: arsenic (7.6 mg/kg), chromium (51 mg/kg) and mercury (32 mg/kg)

A soil sample was also collected in the Camp Area outside the generator shed amongst empty fuel drums and was analyzed for volatile organic compounds (VOCs) and petroleum hydrocarbons. The results indicated the presence of diesel-range organics (DRO) and residual-range organics (RRO), but at levels below the ADEC cleanup criteria.

A surface water sample and sediment sample were collected from within Unnamed Creek, which flows near the Mill Area and empties into the Kuskokwim River at the Camp Area. The sediment sample did not contain metals at concentrations exceeding the National Oceanographic and Atmospheric Administration (NOAA) probable effects levels (PELs). There were no detected metals in the surface water sample.

Mill Area: During the 2007 RSI, 12 surface soil and five sediment samples were collected from various locations at the Ball Mill Area (Figure 8). Four of the soil samples and all five of the sediment samples from these locations contained mercury at levels above the ADEC soil cleanup criteria of 1.4 mg/kg and NOAA PEL of 0.486 mg/kg, respectively:

- Soil sample adjacent to the chute at the top of the mill (690 mg/kg)
- Duplicate soil samples from the floor of the large shed near the 12 mercury flasks (5.4 mg/kg and 9.1 mg/kg)
- Soil sample from between the large shed and the small shed (12 mg/kg)

- Duplicate sediment samples from Unnamed Creek (flowing) at the ball mill (21 mg/kg and 89 mg/kg)

- Sediment sample at the settling pond (48 mg/kg, dry at the time of the RSI)

- Sediment sample near the base of the ball mill (16 mg/kg)

- Sediment sample collected from the drainage ditch north of the ball mill (1.0 mg/kg)

With the exception of one ash sample collected from white powder found at the bottom of the ball mill (which was non-detect), all soil samples collected for metals in the Mill area contained arsenic above the ADEC Method 2 cleanup criteria of 3.9 mg/kg. The highest concentration of arsenic in soil (13 mg/kg) came from the ore chute at the top of the mill. Duplicate samples of ash at the remains of the explosives shed contained arsenic at concentrations of 25 and 30 mg/kg. None of the sediment samples contained arsenic at concentrations exceeding the NOAA PEL. Nickel was also detected in three sediment samples above the PEL of 36mg/kg at concentrations ranging from 40 to 48 mg/kg.

In addition to metals, a soil sample collected from the floor of the large shed at a former generator location contained DRO at a concentration of 16,000 mg/kg, above the ADEC cleanup criteria of 250 mg/kg (migration to groundwater category). RRO was also detected at 3,100 mg/kg, which is below the ADEC cleanup criteria of 11,000 mg/kg.

Tailings Area: The 2007 RSI included an investigation of the tailings area which is approximately 200 to 300 feet wide located along the bluff approximately ¾ miles downriver (west) of the Camp Area (Figure 2). The RSI field team observed that soil at the reported tailings pile appeared to have been placed there, indicating that the slope likely contained either overburden (waste rock) or tailings generated from the mining operation. Three surface soil samples were collected from the toe of the bluff at the reported tailing pile area (Figure 2). Mercury, chromium, and arsenic were detected at levels above ADEC Method 2 cleanup criteria (migration to groundwater category) of 1.4 mg/kg, 25 mg/kg, and 3.9 mg/kg, respectively. Mercury ranged from 22 mg/kg at the east sample location to 99 mg/kg at the center sample location. Chromium ranged from 33 mg/kg to 36 mg/kg and arsenic ranged from 4.5 mg/kg to 9.0 mg/kg.

Following the 2007 RSI, the BLM identified areas in need of further characterization in order to support the preparation of an EE/CA for the KMS. The following investigations were identified as steps needed to address data gaps in preparation of the EE/CA:

1. Conduct a background metals study where each AOC would be treated as a separate DU with statistically determined background concentrations.

2. Conduct an investigation to determine whether there are potential impacts of contamination in the Tailings Area on the Kuskokwim River.

3. Define the vertical and lateral extent of mercury impacted soils at the Mill Area.

4. Characterize the retort mound soil.

5. Identify on-site locations for potential construction of an ADEC-permitted refuse disposal monofill to be used as an option in the EE/CA.

In addition to these steps, the BLM listed additional tasks to be completed at the KMS:

- Asbestos and lead-based paint survey of selected structures,
- Disposal of mining wastes considered to be hazardous waste,
- Delineate DRO contamination in the large shed,
- Investigate soils under drum piles for petroleum contamination, and
- Determine whether explosives residue remain in soils at the burned explosives shed.

MACTEC 2008 Investigation

Between September and October 2008, MACTEC performed additional investigations in support of the EE/CA, as well as a limited removal action of hazardous waste related to mining operations and ore processing by-products. Investigative activities conducted in 2008 included soil sampling and analysis to establish background metals concentrations, a geophysical survey, residue sampling in the area of the former explosives shed, mercury speciation, and asbestos and lead-based paint surveys. The following paragraphs describe the background metals and mercury speciation sampling, which covered multiple AOCs at the KMS.

Background Study

During the 2008 investigation, MACTEC collected background samples from each of the four AOCs for mercury (Hg), arsenic (As), chromium (Cr), and nickel (Ni) analysis. A total of nine locations were sampled from each AOC. At each location, samples were collected at depth intervals of approximately 0 to 6 inches and 6 to 14 inches below ground surface (bgs). Locations for background samples were selected from areas that were not impacted by the mining operation, but were representative of conditions at the AOC. Background sample locations are designated as “BGS02, BGS03”, etc., and are presented on Figure 5 and all analytical results are presented in Attachment 4. Background concentrations for As, Cr, Ni, and Hg were calculated for each AOC using the USEPA’s Office of Research and Development’s “ProUCL” program as previously described in the EE/CA Workplan (AMEC, 2011a). Documentation of the ProUCL program is included in Attachment 2. The following background levels for metals in soil were calculated for each AOC and are used along with regulatory cleanup levels as part of the risk assessments performed as part of this EECA:

Area of Concern	Arsenic (mg/kg)	Chromium (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)
Camp Area	10.7	29.2	0.522	26.5
Mill Area	12.70	30	1.99	53.9
Pit Area	28	25.3	1.59	24.3
Tailings Area	153	92.1	69.1	155

Determination of Additional Background Values

As described above, soil background values were established at the KMS for arsenic, chromium, mercury, and nickel. As part of the evaluation of analytical results from investigations to date, an analysis of available geochemical data in Alaska was necessary to establish representative background soil and sediment values for the KMS where values were not established. Single site-specific reference samples collected for soil and sediment during the 2007 investigation were not considered in the analysis because they represented single data points for media within a geochemically variable environment. Therefore, results of chemical analyses for soil or sediment ("sediments" representing materials associated with beds underneath surface water bodies) were extracted from the United States Geological Survey's (USGS's) Alaska Geochemical Database (AGDB) (USGS, 2011) for analyses of metals in soils and sediment. Data for samples within a 100 mile radius of the site were used to establish background values for arsenic, chromium, copper, lead, mercury, nickel, and zinc in sediments, and copper and lead in soil.

For comparability to site-specific samples, samples with preparation methods similar to those being used at the site were chosen. Simple plain water leaching and digestion with aggressive acids such as aqua regia or hydrofluoric acid were excluded while sample preparation methods using normal acid digestion were included. Generally, only one analytical method was present for any given sample for a parameter, but in the rare occurrence that a sample was analyzed using more than one analytical method, the highest reported concentration was used. Data generated was then taken into USEPA's ProUCL program (V.4.1.01) to calculate descriptive statistics and suggested background comparison values. Background values for remaining metals, where available, were taken from USGS Paper 1458 (Gough, et.al., 1988), The use of the background values in determining appropriate cleanup criteria for the KMS is discussed in Section 2.2.

Determination of Background Comparison Values for Copper, Lead, and Zinc in Soils and Sediments

Results of chemical analyses for soil or sediment ("sediments" representing materials associated with beds underneath surface water bodies) were extracted from the USGS's Alaska Geochemical Database (AGDB) (USGS, 2011) for analyses of copper, lead, and zinc for samples within a 100 mile radius of the site.

For comparability to site-specific samples, samples with preparation methods similar to those being used at the site were chosen. Simple plain water leaching and digestion with aggressive acids such as aqua regia or hydrofluoric acid were excluded while sample preparation methods using normal acid digestion were included. Generally, only one analytical method was present for any given sample for a parameter, but in the rare occurrence that a sample was analyzed using more than one analytical method, the highest reported concentration was used. Data generated was then taken into USEPA's ProUCL program (V.4.1.01) to calculate descriptive statistics and suggested background comparison values. The following table summarizes the background values identified:

Matrix	Analyte	Suggested Background Comparison Value	Units	Type
Sediment	Copper	70	mg/kg	Nonparametric 95% Upper Prediction Limit
	Lead	20	mg/kg	Nonparametric 95% Upper Prediction Limit
	Zinc	142.9	mg/kg	95% Kaplan-Meier UPL (t)
Soil	Copper	287.1	mg/kg	95% Kaplan-Meier UPL (t)
	Lead	99.01	mg/kg	95% Kaplan-Meier UPL (t)
	Zinc	NA*		

* Note – Zinc had only 2 detections (12 and 1,000 mg/kg) with 236 samples at <200 mg/kg

It is apparent that there has been much soil and sediment sampling in the vicinity of the site. It is expected that, in general, given the number of data points, there should be sufficient confidence in these background comparison values. Zinc in soil has an elevated detection limit relative to the expect values, leading to many non-detect values. Due to this, the value suggested in Gough et al. (1988), USGS PP 1458 will be used. For analytes not found in the USGS geochemical data base (beryllium and thallium in soil and sediment) values from Gough et al. (1988) were also used.

While there were detections of mercury in several of the sediment samples, these likely represent material transported from mercury mineral sources upstream from the site and not the results of site-specific activities. In addition to the known mercury mineralization at the site, there are numerous areas of greater or lesser mercury mineralization known from the surrounding areas. In a description of the Kuskokwim River basin in southwestern Alaska, the USGS noted "Numerous epithermal mercury-rich vein deposits are scattered over several thousand square kilometers" (USGS, 1955; USGS, 1994). Given the sporadic number of samples with elevated concentrations, there is no evidence of systematic, site-activity related contamination.

Mercury Speciation

Soil samples were also collected in 2008 at the KMS for speciation of mercury. Seven of the locations with the highest mercury results reported during the 2007 RSI were sampled: 1) top of the mill at the chute, 2) underneath the base of the ball mill, 3) between the large and small sheds, 4) settling pond, 5) Unnamed Creek sediment, 6) retort mound soil, and 7) tailing area at the toe of the bluff. Samples were collected at approximately two inches bgs and submitted to Frontier Geosciences Inc. laboratory in Seattle, Washington for mercury speciation by Selective Sequential Extraction (SSE). The SSE method was developed to assess the environmental mobility and bioavailability of mercury in contaminated soils, especially those associated with mercury and gold mining.

The speciation is an operational one, based on the solubility of mercury contained in a soil sample to progressively more aggressive solvents. There are seven different fractions (F0 to F6) identified (see following table). These include: F0 – elemental mercury (Hg^0) measured in the headspace above the sample; F1 – plain water soluble mercury (generally inorganic mercury salts); F2 – dilute acid soluble mercury (mercury soluble in stomach acid of vertebrates or forming soluble organic acid complexes);

F3 – weak, generally organically-complexed mercury; F4 – strongly-complexed or adsorbed mercury (generally inorganic complexes or adsorption to crystal active sites); F5 – sulfide, selenide, or amalgam mercury (soluble in aqua regia a mixture of nitric and hydrochloric acid that can dissolve gold and platinum); and F6 – mineral-bound mercury (mercury cations actually incorporated into a mineral's crystal lattice).

Step	Extractant	Description	Typical Compounds
F0	headspace gas	vapor equilibrium	Free elemental Hg^0
F1	De-ionized water	water soluble mercury salts	Mercuric chloride ($HgCl_{2)}$, Mercury (II) Sulfate ($HgSO_{4)}$
F2	pH 2 Hydrochloric (HCl)/Acetic acid	"stomach acid" extractable	Mercury oxide (HgO)
F3	1N Potassium hydroxide (KOH)	organo-complexed	Hg-humics, Mercurous chloride (Hg_2Cl_2)
F4	12N Nitric Acid (HNO_3)	strong-complexed	Hg adsorbed to mineral lattice, Hg_2Cl_2, Hg^0
F5	aqua regia (HCl and HNO_3)	Sulfides, selenides, amalgams	Mercury sulfide (HgS), m-HgS, Mercury selinide (HgSe), Hg gold(Au)
F6	HNO_3/HCl/ Hydrofluoric acid (HF)	mineral-bound	Hg incorporated into crystal lattice

Mobility and bioavailability are high for fractions F0 to F3 while F4 to F6 mercury fractions have low to very low mobility, solubility, or bioavailability. The common mercury ore minerals cinnabar and meta-cinnabar are found almost exclusively in the F5, non-mobile fraction.

The results of the mercury speciation analysis indicated that with the exception of samples collected from the Retort Mound in the Camp Area, the majority of the mercury detected in the collected samples was in the form of cinnabar. The data from the mercury speciation investigation are presented in the 2011 EECA Workplan.

Explosives Sampling

Six soil samples were collected from the area inside the burned explosives shed near the Ball Mill. Samples were collected from the grey to reddish brown silt material at a depth of 2 to 3.5 inches bgs. The soil samples were submitted for analysis of nitroaromatics using USEPA Test Method 8330 to determine if any residual explosives remained after the shed was burned. The samples collected were analyzed by the laboratory one day past the USEPA recommended holding time of 14 days for nitroaromatics in soil. Although there were no reported detected analytes in the samples, AMEC re-sampled this area of the burned explosive shed during the 2011 field program to confirm the non-detect results reported from the 2008 field program. The resampling of the explosive shed indicated that no explosive residue remains in soil at the former explosives shed at concentrations above laboratory detection limits or regulatory action levels. Details of the 2011 resampling of the soils in the explosive shed are presented in Section A2.3.

Asbestos Survey

An asbestos survey was completed in 2008 within buildings at the KMS to determine if asbestos-containing materials (ACM) were present. Thirty bulk samples of potential ACM within the buildings were collected during the 2008 field program and submitted for laboratory analysis. Materials sampled for analysis included rolled roofing, fiberboard, tar paper, and mastic. Prior to the 2008 field activities, three of the buildings in the Camp Area (a bunk house, the cook house, and manager's house) had been burned down and therefore were not screened for asbestos or lead-based paint. None of the samples submitted as part of the 2008 field program contained asbestos. However, insufficient samples (a minimum of three samples of each suspect material is required) to meet National Emission Standards for Hazardous Air Pollutants (NESHAP) criteria were collected for several of the materials tested. Additional samples from materials remaining on site were collected during the 2011 field program to complete the survey in compliance with the NESHAP requirements, and are presented in Section A2.4 of Appendix A of this report. The results of the completed survey indicate that no ACM are present at the site.

Lead-Based Paint Survey

Painted surfaces at the KMS were surveyed in 2008 for lead-based paint using a Niton X-ray fluorescence (XRF) Spectrum Analyzer supplied by BLM. Results from the field screening indicated that the surfaces tested were non-detect (ND) for lead. As part of the 2011 field program, approximately 15 samples from previously tested surfaces were screened in the field using XRF to confirm the original ND results. Samples were collected from the following surfaces:

1. Painted window sills
2. Painted plywood and wall board
3. Shelf supports
4. Painted door frames
5. Various painted interior and perimeter walls

Two samples were collected and submitted to the laboratory to confirm the XRF results; one yellow paint sample from the small shed in the Mill Area and one pink paint sample from the bunk house building in the Camp Area. Laboratory results indicate that only the yellow paint sample from the small shed at a concentration of 35,000 mg/kg was above the ADEC cleanup criteria of 400 mg/kg. Five soil samples located adjacent to the yellow paint samples were collected between the large and small shed and also analyzed for lead with concentrations ranging from 9.8 mg/kg to 28 mg/kg. Findings of the lead survey indicate that a small amount of yellow paint (approximately 80 square feet) remains on site that exceeds ADEC cleanup criteria for lead. The 2011 lead survey results are presented in Section A2.4 of Appendix A.

Hazardous Waste Removal

In addition to the investigation work, AMEC personnel inventoried, prepared, and coordinated the removal of some of the hazardous and non-hazardous wastes from the project site. The Hazardous

Materials Removal report was presented as Appendix D of the EE/CA Workplan. Materials that were removed included processed cinnabar and containers that were packaged from the retort mound in the Camp Area. As part of the evaluation of hazardous wastes, surfaces in the Camp and Mill areas were screened for mercury using an XRF spectrum analyzer. The firebricks, concrete hearth/slab, and other devices in the Camp Area were screened with negative results for elevated mercury or other metals. Surfaces at the Mill Area (wooden and metal beams within the Ball Mill itself, walls of the large and small shed) were also screened using the XRF analyzer, all with negative results. Approximately one cubic yard of hydrocarbon-contaminated soil was removed from the floor of the large shed at the Mill area and disposed offsite.

Pit Area

To support an evaluation of potential on-site locations for construction of an ADEC-permitted monofill as an option in the EE/CA, AMEC conducted a geophysical survey in the Pit Area. In general, the geophysical survey identified a low velocity zone with favorable conditions for a disposal pit. A full discussion of the monofill option for the site is presented in Sections 2.0 and 3.0 of this report. The original geophysical survey report is presented as Attachment 1.

1.4 Sources, Nature and Extent of Contamination

This section discusses the sources, nature, and extent of contamination identified at the KMS based on investigations performed to date, including work performed in 2007 by E&E (E&E, 2008), MACTEC in 2008, and AMEC in 2011. In general, the potential COCs at the KMS include metals, petroleum hydrocarbons and associated volatile and semi-volatile components, explosives, and polychlorinated biphenyls (PCBs).

1.4.1 Metals

This section describes the nature and extent of metals contamination at the Camp, Mill, and Tailings Areas relative to regulatory cleanup levels and background concentrations. Results are discussed relative to the exceedance of ADEC Method 2 Criteria (for soil, protection of groundwater category), NOAA PEL (for sediment), or background level, whichever is greater for each metal. Metals exceedances discussed below are shown on Figures 6, 7, and 8.

Camp Area

In the Camp Area, metals contamination was found to be associated with the Retort Mound and associated processing equipment and containers including a sewer pipe, split-open drum, 55-gallon drum, corrugated sheet metal, and a beer keg retort in the western portion of the Camp Area (E&E, 2008). Processed cinnabar and the majority of the containers were removed and disposed as part of the 2008 field program performed by AMEC. A previously unidentified six-foot long 4-inch metal pipe remains on site at the retort mound.

Investigation Area (IA)-1 (Retort Mound)

A soil sample collected at the surface of the Retort Mound during the 2007 RSI contained mercury and arsenic at concentrations of 3.8 mg/kg and 7.9 mg/kg, respectively, which exceed their respective ADEC Method 2 Criteria of 1.4 and 3.9 mg/kg, respectively. Total chromium was detected at an estimated value (J-qualified) of 26 mg/kg, slightly above the ADEC Method 2 Criteria of 25 mg/kg. Only the mercury concentration exceeds its background value of 0.552mg/kg.

The 2011 soil investigation in the Retort Mound area was completed using random grid-based and biased sampling processes. Locations of sampling points are presented in Figure 7. The grid-based sampling was performed to characterize the soil in the general footprint and perimeter of the Retort Mound. The biased sampling was focused on further characterization of the locations of the former cinnabar containers (split drum), sewage pipe, and the beer keg retort and remaining metal pipe.

The analytical results of the grid-based sampling at the Retort Mound at a depth of 0 to 3 inches bgs indicated the presence of mercury exceeding the ADEC Method 2 Criteria of 1.4 mg/kg in four of six samples at concentrations of ranging from 9.5 to 55.1 mg/kg (Figure 7). Arsenic was detected above the background value of 10.7 mg/kg in two of six samples analyzed at concentrations of 13.4 and 20.6 mg/kg. Chromium was detected above the background value of 29.2 mg/kg in two of six samples analyzed at concentrations of 34.1 and 78.9 mg/kg. Copper, nickel, and hexavalent chromium did not exceed their respective ADEC Method 2 Criteria.

The analytical results of the grid-based sampling at the Retort Mound at a depth of 6 to 12 inches bgs indicated the presence of mercury exceeding the ADEC Method 2 Criteria of 1.4 mg/kg in all three samples analyzed at concentrations of ranging from 3.2 to 22 mg/kg. Chromium was detected slightly above the background value of 29.2 mg/kg in one of three samples analyzed at a concentration 32 mg/kg. Arsenic, copper, nickel, and hexavalent chromium did not exceed their respective ADEC Method 2 Criteria.

The analytical results of the grid-based sampling at the Retort Mound at a depth of 12 to 18 inches bgs indicated the presence of mercury exceeding the ADEC Method 2 Criteria of 1.4 mg/kg in all of three samples analyzed at concentrations of ranging from 20 to 280 mg/kg. Arsenic was detected slightly above the background value of 10.7 mg/kg in two of four samples analyzed at concentrations of 11 and 12 mg/kg. Chromium was detected slightly above the background value of 29.2 mg/kg in one of four samples analyzed at a concentration 31 mg/kg. Copper, nickel, and hexavalent chromium did not exceed their respective ADEC Method 2 Criteria.

The analytical results of the biased sampling at the former cinnabar containers (split drum), sewage pipe, and the beer keg retort from samples collected at depths of 0 to 6 inches, 6 to 12 inches, and 12 to 18 inches bgs had concentrations of mercury equal to, or exceeding the ADEC Method 2 Criteria of 1.4 mg/kg in all samples at concentrations up to 83.4 mg/kg. Arsenic was detected in a 0-to 6-inch sample from the split drum and in a sample from 12 to 18 inches at the sewer pipe at concentrations of 11.1 and 11 mg/kg, respectively, which are slightly above the background value of 10.7 mg/kg. Total chromium was detected in 0 to 6 inch samples at the split drum and sewer pipe at concentrations of 32 and 29.6 mg/kg, respectively, which are slightly above the background value of 29.2 mg/kg.

Two soil samples collected at locations of high mercury concentrations were analyzed for metals using the Synthetic Precipitation Leaching Procedure (SPLP) in order to evaluate whether there is a potential exposure pathway to groundwater through leaching of the soil under normal weathering conditions. Mercury was detected in both samples at concentrations of 0.024 and 0.52 milligrams per liter (mg/L). Copper was detected in one sample at a concentration of 0.024 mg/L.

Drum at Cabin

During the 2011 investigation, an open-topped drum was discovered in the Camp Area containing a reddish colored sandy material, possibly processed ore. A sample was collected and analyzed for metals. Mercury was detected above the ADEC Method 2 Criteria of 1.4 mg/kg at a concentration of 1,400 mg/kg, and total chromium was detected above the background level 29.2 mg/kg at a concentration of 45 mg/kg. Arsenic, copper, and nickel were not present at concentrations above their respective ADEC cleanup levels and/or background.

<u>Mill Area</u>

IA-2 (Ball Mill Building Chute)

During the 2007 RSI, mercury, arsenic, and chromium were detected in a surface sample near the entrance to the Ball Mill chute at concentrations of 690, 13, and 39 mg/kg, respectively, above their respective background values. Arsenic was detected in a surface sample upslope of the entrance to the chute at a concentration of 6.0 mg/kg, which is below background.

During the 2011 field investigation, a total of six soil samples and one duplicate sample from 0 to 6 inches bgs were collected at and near the chute at the top of the Ball Mill. The primary and duplicate sample contained mercury at concentrations of 3.8 and 5.1 mg/kg, respectively, which is above the background value of 1.99 mg/kg. A soil sample collected from the same location at a depth of 6 to 12 inches bgs contained mercury at a concentration of 2.0, which is slightly above background. Arsenic, total chromium, copper, and nickel did not exceed their respective ADEC Method 2 Criteria and/or background value.

IA-3 (Settling Pond)

During the 2007 RSI, a sediment sample collected from the settling pond contained mercury above the NOAA PEL of 0.486 mg/kg at a concentration of 48 mg/kg But was well below the background value of 70.3 mg/kg calculated for the region.

During the 2011 field investigation, a total of six sediment samples and one duplicate sample were collected from a depth of 0 to 6 inches bgs within and adjacent to the settling pond in the Mill Area. Five of the seven sediment samples contained mercury above the background value of 70.3 mg/kg at concentrations ranging from 82.1 to 232 mg/kg. Four of the seven sediment samples contained copper at concentrations above the PEL (197mg/kg) at concentrations ranging from 213 to 297 mg/kg. Concentrations of other metals did not exceed their respective PELs and/or background.

One sediment sample collected at a location of a high mercury concentration was analyzed for metals using the SPLP in order to evaluate whether there is a potential exposure pathway to groundwater through leaching of the soil under normal weathering conditions. Mercury and copper were detected at concentrations of 0.034 and 0.17 mg/L, respectively.

IA-4 (Ditch North of Ball Mill)

During the 2007 RSI, a sediment sample was collected from the ditch north of the Ball Mill; all values were below their respective background and/or PEL values. During the 2011 field investigation, a total of six sediment samples were collected at a depth of 0 to 6 inches bgs from within and adjacent to the ditch in the vicinity of the 2007 sample. No metals were detected at concentrations exceeding their respective PEL and/or background levels.

IA-5 (Between Mill Area Sheds)

During the 2007 RSI, mercury was detected in a surface soil sample collected between the small and large sheds in the Mill Area at a concentration of 12 mg/kg, which is above the background value of 1.99

mg/kg. Arsenic was also reported at concentration of 9 mg/kg, which is above the ADEC Method 2 Criteria of 3.9 mg/kg, but not above the background value of 12.70 mg/kg for the area.

During the 2011 field investigation, a total of six soil samples and one duplicate sample from 0 to 6 inches bgs were collected between the large and small sheds. Three of the six samples and the duplicate sample contained mercury above the background value of 1.998 mg/kg at concentrations ranging from 2.3 to 9.7 mg/kg. Three of the six samples contained arsenic above the background value of 12.70 mg/kg at concentrations ranging from 14.3 to 15.9 mg/kg. Total chromium, copper, and nickel in samples at this depth did not exceed their respective ADEC Method 2 Criteria and /or background values. Soil samples collected from a depth of 6 to 12 inches bgs at selected locations did not contain any of the target metals at concentrations exceeding exceed their respective ADEC Method 2 Criteria and /or background values.

IA-6 (Ditch Under Ball Mill)

During the 2007 RSI, a sediment sample that was collected from the ditch at a location in front of the Ball Mill. No metals were present at concentrations above their respective sediment background and/or PEL values. During the 2011 field investigation, it was noted that the area in front of the Ball Mill (IA-6) did not appear to contain any ditch structure that would contain any sediment deposits. Therefore, a total of six samples, now considered soil samples, were collected in the vicinity of the 2007 sample from a depth of 0 to 6 inches bgs. Five of the six samples contained mercury above the background value of 1.99 mg/kg at concentrations ranging from 2.7 to 63.9 mg/kg. Four of the six samples contained arsenic above the background value of 12.70 mg/kg at concentrations ranging from 13.8 to 68.2 mg/kg. One sample contained total chromium above the background value of 30 mg/kg at a concentration of 35 mg/kg. None of the samples collected from 0 to 6 inches bgs contained copper or nickel above their respective ADEC Method 2 Criteria and/or background values. A total of four soil samples were collected from a depth of 6 to 12 inches bgs to evaluate elevated metals concentrations in the overlying sample. Three of the four samples contained mercury above the background value of 1.998 mg/kg at concentrations ranging from 24 to 730 mg/kg. Arsenic, total chromium, copper, and nickel were not present at concentrations exceeding exceed their respective ADEC Method 2 Criteria and/or background values.

IA-8 (Large Shed)

During the 2007 RSI, duplicate surface soil samples were collected from the floor of the large shed in the vicinity of former mercury flasks. Mercury was present above the background value of 1.99 mg/kg at concentrations of 5.4 and 9.1 mg/kg. Arsenic was reported at concentrations above the ADEC Method 2 Criteria, but were not above the background value of 12.70 mg/kg.

During the 2011 field investigation, a total of six soil samples and one duplicate sample from 0 to 6 inches bgs were collected in the large shed. Four of the six samples and the duplicate sample contained mercury above the background value of 1.99 mg/kg at concentrations ranging from 2.2 to 8.5 mg/kg. One sample contained arsenic above the background value of 12.70 mg/kg at a concentration of 16.5 mg/kg. One sample contained total chromium above the background value of 30 mg/kg at a concentration of 38.6 mg/kg. Copper and nickel in samples at this depth did not exceed their respective ADEC Method 2 Criteria and/or background values. A total of five soil samples from 6 to 12 inches bgs, one sample at 12 to 18 inches bgs, and one sample at 18 to 24 inches bgs were collected beneath the floor of the large shed to further evaluate metals concentrations beneath the overlying samples. None of these samples contained any of the target metals at concentrations exceeding exceed their respective ADEC Method 2 Criteria and/or background values.

IA-9 (Unnamed Creek)

The Unnamed Creek flows from the Mill Area to the Camp Area where it empties into the Kuskokwim River (Figure 2). One sediment sample and a duplicate where collected from the Unnamed Creek in the Mill Area during the 2007 RSI. The sediment and duplicate samples from the Mill Area contained mercury above the NOAA PEL (0.486 mg/kg) and background (1.998 mg/kg) at concentrations of 21 and 89 mg/kg.

During the 2011 investigation, three surface water samples and seven sediment samples and one duplicate were collected from Unnamed Creek in the Mill Area at locations shown on Figure 5. None of the surface water samples contained detectable concentrations of target dissolved metals. One sediment sample collected from the creek in the Mill area contained arsenic at 65.2 mg/kg, above the background level of 12.7 mg/kg. No other detections above NOAA PEL and/or background concentrations for target metals were reported for the Unnamed Creek samples.

IA-16 (Explosives Shed)

As described in the 2007 RSI, the sampled ash collected at the burned explosives shed in the Mill Area (IA-16) was later suspected to contain quicklime or similar material that was spread on the ground or partially consumed in the fire, possibly leaving explosives residue in the footprint of the burned shed under the applied material. In addition to analysis for explosives, the duplicate surface samples collected in the vicinity of the shed were also analyzed for metals. Arsenic was detected at levels above the background value of 12.7 mg/kg at concentrations of 25 and 30 mg/kg.

Tailings Area

In the Tailings Area, elevated concentrations of mercury, arsenic, or chromium in surface soil were detected in the three samples collected at the base of the tailing (waste rock) slope during the 2007 RSI. Based on the RSI results, the 2011 field investigation included sediment sampling in the Kuskokwim River adjacent to the base of the tailings area, and at upstream and downstream locations. A series of three samples were collected and analyzed for selected metals and methylmercury from each location: 1) at the shore, 2) five feet from the shore, and 3) 10 feet from the shore.

IA-7 (Tailings Area)

All three samples adjacent to the Tailings Area contained methylmercury at concentrations well below the ADEC Method 3 criteria of 12.4 micrograms per kilogram (µg/kg). The sediment samples collected from the river adjacent to the tailings area at distances of five feet and ten feet from shore did not contain any target metals concentrations exceeding their respective NOAA PEL and/or background values. No metals values are available for the sediment sample collected at the shore (0 feet) at that location because the container broke in transit to the laboratory and analysis was not performed.

IA-17 (Tailings Area, Upstream)

None of the three sediment samples from the area upriver from the Tailings Area contained methylmercury or the other target metals and concentrations exceeding their respective NOAA PEL and/or background values.

IA-18 (Tailings Area, Downstream)

None of the three sediment samples from the area downriver from the Tailings Area contained methylmercury or the other target metals and concentrations exceeding their respective NOAA PEL and/or background values.

1.4.2 Petroleum Hydrocarbons, PAH, and PCBs

Seven petroleum hydrocarbon IAs were identified within the Camp, Mill, and Pit areas for further characterization of specific petroleum hydrocarbons and associated volatile and semi-volatile components. The IAs selected for petroleum hydrocarbon investigation were based on the findings of the 2007 RSI. Samples collected during the 2011 field investigation that contained detectable concentrations of petroleum hydrocarbons were also analyzed for polynuclear aromatic hydrocarbons (PAHs) because of their possible association with petroleum hydrocarbons and heating fuels. Because routine analytical testing prior to disposal of mercury waste soil during the 2008 removal program identified the presence of PCBs in soil excavated from the Large Shed, analysis for PCBs were added as COCs at the Large Shed. Identified IAs and detected concentrations are described below. Results are presented in Attachment 4 and shown on Figures 5 and 8.

AMEC also conducted additional visual inspections for evidence of petroleum spills in the areas within the sheds where potential stoves and fuel lines may have existed, but found no evidence indicating any spills had occurred.

Camp Area

IA-10 (Drum Area 1)

During the 2007 RSI, duplicate surface soil samples were collected from Drum Area 1. Both samples contained DRO and RRO well below their respective ADEC Method 2 Criteria (migration to groundwater category) for DRO (250 mg/kg) and RRO (11,000 mg/kg) at estimated (J-qualified) concentrations of 65 and 75 mg/kg, and 250 and 270 mg/kg, respectively.

During the 2011 investigation, three samples were collected at IA-10 (Drum Area 1) at a depth interval of 0 to 6 inches bgs and were submitted for laboratory analysis for gasoline range organics (GRO)/benzene, toluene, ethyl benzene, xylenes (BTEX), DRO, and RRO. DRO and RRO were detected in one sample at concentrations of 47.6 mg/kg and 85.2 mg/kg, respectively, and RRO was detected in one sample at a concentration of 83.6 mg/kg, all of which are well below the ADEC Method 2 Criteria for DRO (250 mg/kg) and RRO (11,000 mg/kg).

IA-11 (Drum Area 2)

IA-11 (Drum Area 2) was not investigated during the 2007 RSI, but was identified as an area requiring investigation in the EE/CA Workplan (AMEC, 2011a).

During the 2011 field investigation, three samples were collected at Drum Area 2 at a depth interval of 0 to 6 inches bgs and were submitted for laboratory analysis for GRO/BTEX, DRO, and RRO. DRO and RRO were detected in one sample at concentrations of 42.3 mg/kg and 148 mg/kg, respectively, which are well below the ADEC Method 2 Criteria for DRO (250 mg/kg) and RRO (11,000 mg/kg).

IA-12 (Drum Area 3)

IA-12 (Drum Area 3) was not investigated during the 2007 RSI, but was identified as an area requiring investigation in the EE/CA Workplan (AMEC, 2011a).

Three primary soil samples and one duplicate soil were collected from Drum Area 3 at a depth interval of 0 to 6 inches bgs and were submitted for laboratory analysis for GRO/BTEX, DRO, and RRO. No GRO/BTEX, DRO, or RRO were detected.

<u>Mill Area</u>

IA-8 (Large Shed)

One surface soil sample was collected from the floor of the Large Shed during the 2007 RSI and was submitted for laboratory analysis for GRO/BTEX, DRO, and RRO. GRO was detected at a concentration of 4 mg/kg and DRO and RRO were detected at estimated concentrations of 16,000 mg/kg and 3,100 mg/kg, respectively. Only the DRO was present at a concentration above its ADEC Method 2 Criteria of 250 mg/kg.

During the 2011 field investigation, a total of six soil samples from 0 to 6 inches bgs, three soil samples from 6 to 12 inches bgs, one sample from 12 to 18 inches bgs, and one sample from 18 to 24 inches bgs were collected from the floor of the Large Shed and submitted for laboratory analysis for DRO, and RRO. DRO was detected in three of the six samples in the 0- to 6-inch bgs interval at concentrations ranging from 111 mg/kg to 3,500 mg/kg; in two of the three samples in the 6- to 12-inch bgs interval at concentrations of 1,710 mg/kg and 4680 mg/kg; in the 12- to 18-inch bgs sample at 2,940 mg/kg; and in the 18- to 24-inch bgs sample at 479 mg/kg. All but two of the detected concentrations of DRO were above the ADEC Method 2 Criteria for DRO (250 mg/kg). RRO was detected in two samples from 0 to 6 inches bgs at concentrations of 104 mg/kg and 107 mg/kg, both of which are below the ADEC Method 2 Criteria for RRO (11,000 mg/kg). Each of the samples that tested positive for petroleum hydrocarbons were also tested for PAHs; however, all results were below action levels.

Based on the past detection of PCBs in waste soil removed from the Large Shed in 2008, the 2011 investigation included analysis for PCBs in surface soil samples. No PCBs were detected in six surface samples collected from the Large Shed at 0 to 6 inches bgs.

IA-13 (Drum Area 4)

During the 2007 RSI, a surface soil sample was collected from Drum Area 4 and analyzed for GRO/BTEX, DRO, and RRO. RRO was detected at an estimated (J-qualified) value of 73 mg/kg, well below the ADEC Method 2 Criteria for RRO (11,000 mg/kg). No GRO/BTEX or DRO were detected.

During the 2011 field investigation, three soil samples were collected from Drum Area 4 at a depth interval of 0 to 6 inches bgs and were submitted for laboratory analysis for GRO/BTEX, DRO, and RRO. DRO and RRO were detected in one sample at concentrations of 37.4 and 161 mg/kg, respectively, which are well below the ADEC Method 2 Criteria for DRO (250 mg/kg) and RRO (11,000 mg/kg).

IA-14 (Pickup Truck)

One soil sample was collected from beneath the abandoned pickup truck at a depth interval of 0 to 6 inches bgs during the 2011 field investigation. No GRO/BTEX, DRO, or RRO were detected.

Pit Area

IA-15 (Compressor Area)

One primary soil sample and one duplicate soil sample were collected at a depth of 0 to 6 inches bgs from the vicinity of the compressor at the Pit Area during the 2011 field investigation and were analyzed for GRO/BTEX, DRO, and RRO. None of the target analytes were detected.

1.4.3 Explosives

As described in the 2007 RSI, the sampled ash collected at the burned explosives shed in the Mill Area (IA-16) was later suspected to contain quicklime or similar material that was spread on the ground or partially consumed in the fire, possibly leaving explosives residue in the footprint of the burned shed under the applied material. Duplicate surface samples collected in the vicinity of the shed were analyzed for nitroaromatic compounds; no detectable concentrations were found.

In 2008, MACTEC collected six surface soil samples from 2 to 3.5 inches bgs at the burned shed and analyzed them for explosive residues. While no detections of nitroaromatic compounds were reported above the laboratory reporting limits, the analysis was performed one day outside of holding time.

During the 2011 field investigation, AMEC collected confirmation samples at the former explosives shed at depths of 0 to 6 inches bgs and 6 to 12 inches bgs, and also collected soil samples at a depth of 0 to 6 inches bgs under and adjacent to a box at the base of the Ball Mill that contained white material (possibly quicklime) for explosives analysis. No detectable concentrations of explosive compounds were present.

1.4.4 Asbestos and Lead-Based Paint

MACTEC conducted ACM and lead-based paint (LBP) surveys in the remaining buildings in the Camp and Mill Area during the 2008 field program as described Appendix A and C of the EECA Workplan. Samples were collected from a variety of materials contained in on-site buildings as part of the asbestos survey, which was conducted in general accordance with the Asbestos Hazard Emergency Response Act (AHERA), NESHAP and Occupational Safety and Health Administration (OSHA) protocols. Laboratory reports from the 2008 field investigation indicated that the presence of asbestos was not identified in the samples submitted for analyses; however, an insufficient number of samples to meet NESHAP criteria were collected from several of the materials. As a result, AMEC collected additional samples from the materials identified in Appendix A and C of the EECA Workplan as part of the 2011 field program. No ACM materials were identified as remaining on site from either investigation. The asbestos survey results are presented in Section A2.4 and Attachment 4 of Appendix A.

Painted surfaces were screened for lead-based paint by MACTEC personnel during the 2008 field program using a Nitron XRF Spectrum Analyzer. Results of the field screening did not identify the presence of lead-based paint in the materials analyzed; however samples were not submitted to the laboratory to confirm the non-detected results. As part of the 2011 field program, AMEC performed XRF screening for lead on a variety of painted surfaces remaining on site. Based on the results of the XRF screening, two samples were collected and submitted to the laboratory for lead analysis. While the paint sample submitted from the pink building in the Camp Area was below the ADEC cleanup level of 400 mg/kg, the paint sample collected from the small shed in the mill area contained lead at 35,000 mg/kg, Five soil samples adjacent to the lead containing paint sample were collected in the area between the two shed in the mill area to evaluate lead contamination in nearby soil. The concentration of lead in the five soil samples ranged from 9.8 to 28 mg/kg, well below the ADEC cleanup level of 400 mg/kg. Results from the 2011 lead-based paint survey are presented in Section A2.4 of Appendix A.

1.5 Streamlined Risk Evaluation

Streamlined human health and ecological risk assessments have been completed in order to address contaminants from the abandoned cinnabar mine. The streamlined risk assessment identifies contaminants of potential concern (COPCs) in the affected media, contaminant concentrations, and toxicity associated with the contaminants. Exposure pathways that indicate an obvious threat to human health and the environment have been identified through comparison with chemical-specific screening levels.

1.5.1 Human Health Risk Assessment

The human health risk assessment (HHRA) was evaluated using a two-tiered approach. Potential health risks were first evaluated by comparing the concentration of constituents in environmental media at the Site to risk-based screening levels. If a constituent was found to be present at a concentration greater than the defined screening criteria, then the HHRA assessed whether or not the observed concentration is truly likely to constitute a risk to human health given the nature and extent of the constituent Site soils and sediments and other Site specific considerations.

1.5.1.1 Human Health Screening Risk Evaluation

The human health screening risk evaluation (HHSRE) consisted of comparing the concentrations of inorganic and organic constituents detected in soil and sediment to the ADEC's *Cumulative Risk Guidance* human health risk-based soil screening levels (HHSSLs) for sites located in climate zone below 40 (ADEC, 2008a) and presented on Tables 1 and 2, respectively. These values correspond to the non-carcinogenic risk (hazard quotient [HQ]) of 1 and carcinogenic risk level of 1 x 10^{-05}, therefore, for risk screening purposes, these levels were adjusted to the HQ of 0.1 and carcinogenic risk level of 1 x 10^{-06} (ADEC, 2010). For constituents for which ADEC human health risk-based soil screening levels have not been developed, soil screening levels were obtained from USEPA's Region 9 Regional Screening Levels (RSLs) and adjusted to a HQ of 0.1 and to a carcinogenic risk level of 1 x 10^{-06} (ADEC, 2010). Inorganic constituents detected in surface water were compared to Alaska's drinking water quality values (ADEC, 2008b). Screening levels are developed to be very conservative such that if the concentration of a constituent in an environmental media is below the screening level for that constituent, then the probability is very low that there would be any unacceptable risks associated with exposure to that environmental media. The HHSRE for each media is discussed below and the soil HHSRE is presented on Table 1 and Table 2 for sediment. Data collected in 2007 and 2011 was used in the HHSRE. Samples collected from the Mill Area in the large shed in 2007 were not included in the HHSRE because the soil was removed. For samples and field duplicate pairs, the following criteria were used to select the results to be applied in the HHSRE: 1) where results for the pair of duplicate samples were reported as non-detect, the lowest detection limit was used in the HHSRE; 2) where results for the pair of duplicate samples were reported as detected, the maximum the result was used in the HHSRE; and 3) where one result was reported as non-detect and the other as detected, the detected result was used in the HHSRE.

Soil

Soil samples were collected at the Site in August 2007 and September 2011 from the Tailings Area, Camp Area, and the Mill Area, and were evaluated based ADEC's HHSSLs and background concentrations by area (Figure 6).

Tailings Area – Soil samples were collected in the Tailings Area during the August 2007 sampling event. With the exception of mercury, the maximum concentrations of detected metals were below ADEC's HHSSLs. The maximum mercury concentration exceeded ADEC's HHSSL and the Tailings Area specific background concentration. Therefore, mercury was retained as a COPC in the Tailings Area and further evaluated in the HHRA.

Camp Area – The maximum concentrations of beryllium, chromium VI, copper, lead, nickel, zinc, DRO, and RRO in soil were below ADEC's HHSSLs. The maximum concentration for arsenic, chromium, and mercury exceeded ADEC's HHSSLs and the Camp Area specific background concentrations. Therefore, arsenic, chromium, and mercury were retained as COPCs in the Camp Area and further evaluated in the HHRA.

Select soil samples collected at the Camp Area were also analyzed for BTEX and GRO, but were ND at laboratory reporting limits which were below ADEC's HHSSLs.

Mill Area –The maximum concentrations of beryllium, chromium VI, copper, lead, nickel, zinc, PAHs, aroclor 1254, aroclor 1260, DRO, RRO, and 1,3,5-trinitrobenzene in soil were below ADEC's HHSSLs. The maximum concentration for arsenic, chromium, and mercury exceeded ADEC's HHSSLs and the Mill Area specific background concentrations. Therefore, arsenic, chromium, and mercury were retained as COPCs and further evaluated in the HHRA. Since the Site in the future may be used to gather wild food, ADEC recommends retaining bioaccumulative compounds as COPCs, which include the PAHs, aroclor 1254, and aroclor 1260. Therefore, all detected PAHs, aroclor 1254, and aroclor 1260 were retained as COPCs in the Mill Area and further evaluated in the HHRA.

Select soil samples collected at the Mill and Camp Areas were analyzed for BTEX and GRO, but were not detected in any of the samples. The reporting limits for BTEX and GRO were below ADEC's HHSSLs. Explosive chemicals and PCBs were not detected in any of the samples. The reporting limits for these chemicals were below ADEC's HHSSLs.

Sediment

Sediment samples were collected at the Site in August 2007 and September 2011 from the Tailings Area, Camp Area, and the Mill Area were compared to soil human health screening levels and sediment background concentrations. Since human health screening levels for sediment are not available, ADEC's HHSSLs were used for the sediment (ADEC, 2010).

Tailings Area – As discussed in Section 1.4.1, sediment samples associated with the Tailings Area were collected along the bank of the Kuskokwim River. The maximum concentrations of chromium, copper, methyl mercury, and nickel in sediment were below ADEC's HHSSLs. Arsenic and mercury maximum concentrations exceeded the ADEC's HHSSLs, but they were below the background concentrations. Therefore, the constituents detected in the sediment samples collected from the Tailings Area were not further evaluated in the HHRA.

Camp Area – As discussed in Section 1.4.1 sediment samples associated with the Camp Area were collected along the bank of the Kuskokwim River. The maximum concentrations of chromium, copper, mercury, methylmercury, and nickel in sediment were below ADEC's HHSSLs and the background concentrations. Therefore, the constituents detected in the sediment samples collected from the Camp Area were not further evaluated in the HHRA.

Mill Area – As discussed in Section 1.4.1 sediment samples associated with the Mill Area were collected along the unnamed creek and from the settling pond. The maximum concentrations of antimony, beryllium, copper, lead, methylmercury, and zinc in sediment were below ADEC's HHSSLs. The maximum concentration for mercury and nickel exceeded the ADEC's HHSSLs and the background concentrations. Therefore, mercury and nickel were retained as COPCs in the Mill Area and further evaluated in the HHRA.

In August 2007, cadmium, selenium, silver, and thallium were also analyzed, but were not detected in any of the sediment samples. The reporting limit for cadmium, selenium, and silver were below ADEC's HHSSLs. The reporting limit for thallium was above the adjusted ADEC's HHSSLs but below the unadjusted ADEC's HHSSLs. Although the reporting limit for thallium was above the adjusted ADEC's HHSSLs, it was not further evaluated.

Surface Water

Surface water was collected at the Site during the August 2007 and September 2011 investigations for metals analysis. The surface water results were evaluated using Alaska's drinking water quality values (ADEC, 2008b). Although target metals were not detected in any of the samples from the two investigations, the reporting limits for arsenic, antimony, beryllium, cadmium, lead, nickel, selenium, and thallium from the August 2007 investigation were above the ADEC drinking water quality values. Although the reporting limits for several metals were above the drinking water quality values, they were not further evaluated in the HHRA because they were either not detected in soil and sediment samples or detected below the soil and sediment screening levels. Reporting limits for non-detect results for target metals from the 2011 investigation were below the ADEC drinking water quality values, and were not further evaluated in the HHRA

COPCs

The following chemicals were selected as COPCs for each data set and further evaluated in this HHRA:

- Soil
  - Tailings Area
    - Metals – mercury
  - Camp Area
    - Metals – arsenic, chromium, and mercury
  - Mill Area
    - Metals – arsenic, chromium, and mercury
    - PAHs – acenaphthene, banzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene

    - PCBs – aroclor 1254 and aroclor 1260
- Sediment
  - Mill Area
    - Metals – mercury and nickel.

1.5.1.2 Exposure Assessment

This section describes the potential receptors and exposure pathways selected for quantitative risk characterization, exposure assumptions (or factors), equations used to estimate dose for the selected receptors, and methods used to derive exposure point concentrations.

1.5.1.2.1 Human Health Conceptual Site Model

A human health conceptual site model (HHCSM) was developed to facilitate the analysis of potentially complete exposure pathways at the Site. The HHCSM schematically represents the relationship between chemical sources and receptors at a site, and identifies potentially complete and significant pathways through which receptors may be exposed to the COPCs. The HHCSM is presented as Figure 3.

A complete exposure pathway consists of four components (USEPA, 1989):

- A source and mechanism of chemical release (e.g., release to the subsurface);
- A retention or transport medium (e.g., dust);
- A receptor at a point of potential exposure to a contaminated medium (e.g., resident); and
- An exposure route at the exposure point (e.g., inhalation of particulates).

As described by the USEPA (1989), if any of these four components are not present, then an exposure pathway is considered incomplete and is not evaluated further. If all four components are present, a pathway is considered complete. In addition to the distinction between complete and incomplete pathways, complete exposure pathways can be further delineated into those expected to be insignificant and those that may be significant. The two types of potentially complete pathways (USEPA, 1989) are discussed below:

- Potentially Complete but Insignificant Exposure Pathways. Exposure pathways in this category meet all four requirements to be considered complete. However, these pathways are not expected to contribute significantly to the overall exposure for a receptor, due to the nature of the particular fate and transport mechanisms that comprise the pathway. For this reason, the potential health impacts associated with these types of pathways are evaluated qualitatively but not quantified in this risk assessment.

- Potentially Complete and Significant Exposure Pathways. A potentially complete and significant exposure pathway is comprised of fate and transport mechanisms and exposure characteristics that tend to result in more substantial exposures than complete but insignificant pathways. These pathways comprise the majority of exposure, and as such potential health risks associated with these pathways are quantified in the risk assessment.

The potential receptors and potentially complete exposure pathways for the site are discussed in the sections below.

Potential Receptors

The receptors quantitatively evaluated at the Site were identified on the basis of the anticipated future land use. The anticipated future land use for the Site is primarily subsistence hunting and gathering, with some recreational use, which includes camping, hiking, hunting large game, and foraging for wild food (i.e., Eskimo potatoes, blueberries, lowbush cranberry).

Receptors evaluated in the HHRA include:

- Future adult subsistence/recreational use visitor; and
- Future child subsistence/recreational use visitor.

The HHCSM (Figure 3) illustrates the selected receptors for the HHRA.

Exposure Pathways

Chemicals present in soil and sediment may be absorbed through direct exposure pathways such as inadvertent soil ingestion and dermal contact with soil and sediment during subsistence/recreational activities. Additionally, soil particulates can be suspended in air and inhaled by receptors. Chemicals present in soil and sediment may also be absorbed by plants that may be used for subsistence purposes. Accordingly, the exposure pathways identified as potentially complete at the Site are as follows:

- Future Child/Adult Subsistence/Recreational User:
    - Incidental soil ingestion,
    - Dermal exposure to soil,
    - Inhalation of suspended soil particulates,
- Future Child/Adult Subsistence User:
    - Ingestion of below ground produces (i.e., Eskimo potato), and
    - Ingestion of above ground produces (i.e., Labrador tea, blueberry, lowbush cranberry, etc.).

Although the Site has wildlife present that may comprise subsistence food items such as moose, ruffed grouse, and black bear, this pathway was not evaluated in the HHRA. The ingestion of wildlife present at the Site was considered an insignificant source of COPCs due to the large roaming areas of the wildlife present, which is further discussed in the ecological risk evaluation in Section 1.5.2. The potential exposure pathways for each receptor are illustrated in the HHCSM (Figure 3).

1.5.1.2.2 Exposure Point Concentrations

Exposure Point Concentrations (EPCs) were developed for each location at the Site, for ingestion and dermal contact soil exposures, inhalation of particulates in outdoor air, and ingestion of below ground and above ground produce. The USEPA defines EPCs as the representative chemical concentrations a receptor may contact in an exposure area over the exposure period (USEPA, 1989). The typical concept of human exposure at a site or within a defined exposure area is that individuals contact the contaminated medium on a periodic and random basis. Because of the repeated nature of such contact, the human exposure does not really occur at a fixed point but rather at a variety of points with equal likelihood that any given point within the exposure area will be the contact location on any given day. Thus, the EPCs should be the arithmetic averages of the chemical concentrations within the exposure area. To account for uncertainty in estimating the arithmetic mean concentration from samples, the USEPA (1989) recommends that an upper confidence limit (UCL) on the arithmetic mean or the maximum observed concentration, whichever is less, be used to represent the EPC.

The soil and sediment EPCs were calculated using USEPA's ProUCL Version 4.1. The maximum concentration was used as the EPC for chemicals that had an insufficient number of samples to calculate an UCL. The UCL ProUCL outputs are provided in Attachment 3, Table 1, and the soil and sediment EPCs are summarized on Tables 1 and 2, respectively. Soil and sediment EPCs were calculated to evaluate the ingestion and dermal contact exposure pathways. EPCs for airborne dust in outdoor air and for ingestion of below ground and above ground produce were calculated from the soil and sediment EPCs and discussed further below.

<u>Air Exposure Point Concentrations from Airborne Dust</u>

EPCs for COPCs sorbed to airborne dust were derived by multiplying the EPCs in soil and sediment (mg/kg) by the 24 hour concentration of respirable particles with a mean diameter of less than or equal to 10 microns (PM_{10}) for the USEPA Standard in micrograms of soil per cubic meter of air (i.e., 150 micrograms per cubic meter [$\mu g/m^3$]) and a unit conversion factor in kilograms per microgram (ADEC, 2011). EPCs associated with soil particulates in air are provided in Attachment 3, Table 2.

<u>Plant Exposure Point Concentrations from Foraging Fruits and Vegetables</u>

EPCs for COPCs in fruits and vegetables due to direct uptake (i.e., root) were developed for below ground produce (i.e., Eskimo potato) and above ground produce (i.e., Labrador tea, blueberry, lowbush cranberry, etc.). The below ground produce EPC was calculated according to the following equation:

$$C_{pr-b} = EPC_s \times BR_{bg} \times VG$$

where:

C_{pr-b} = Exposure point concentration of COPC in below ground produce (mg/kg);

EPC_s = Exposure point concentration of COPC in soil or sediment (mg/kg);

BR_{bg} = Plant-to-soil bioconcentration factor for below ground produce (unitless); and

VG = Empirical correction factor for below ground produce (unitless).

The above ground produce EPC was calculated according to the following equation:

$$C_{pr-a} = EPC_s \times BR_{ag}$$

where:

$C_{pr\text{-}a}$ = Exposure point concentration of COPC in above ground produce (mg/kg);

EPC_s = Exposure point concentration of COPC in soil or sediment (mg/kg); and

BR_{ag} = Plant-to-soil bioconcentration factor for above ground produce (unitless).

The plant-to-soil bioconcentration factor for both below and above ground produce are chemical specific values which accounts for the uptake from soil to the root and the subsequent transport of contaminants through the roots to the above ground plant parts. The values were obtained from the Human Health Risk Assessment Protocol companion database (USEPA, 2011c) and presented in Attachment 3 Table 3. An empirical correction factor for below ground produce was applied because transfer of COPCs with a log of octanol-water partition coefficient (K_{ow}) greater than 4 isn't likely due to the protective outer skin, size, and shape of bulky produce (USEPA, 2005b). A value of 0.01 for COPCs with a K_{ow} greater than 4 were used, and a value of 1 used for COPCs with a K_{ow} less than 4. EPCs for below and above ground produce are provided in Attachment 3, Table 3.

1.5.1.2.3 Exposure Assumptions

The HHRA used single point estimates for each of the input exposure assumptions to develop single point dose estimates for each scenario. Daily intake values were calculated using exposure factors associated with the reasonable maximum exposure (RME) scenario. An RME, as defined by USEPA, is the "highest exposure that is reasonably expected to occur" and is estimated using a combination of average and upper bound values of human exposure factors (USEPA, 1989). Exposure assumptions are provided in Attachment 3, Table 4.

Body Weight, Exposure Time, Exposure Frequency, and Exposure Duration Parameters

The adult receptors were assumed to weigh (BW) 70 kilograms (kg) and child receptor 15 kg (ADEC, 2010; USEPA, 1991).

The exposure frequency (EF) parameter for the subsistence/recreational use receptors with direct contact with soil/sediment is 120 days/year (AMEC, 2011b), which assumes these receptors would access the Site May through October. Assuming that the foraged fruits and vegetables would be eaten every day of the year, the EF parameter for ingestion of foraged fruits and vegetables is 365 days/year (ADEC, 2010). An exposure duration (ED) of six years for the child recreational receptor and 30 years for an adult recreational receptor were used in accordance with ADEC guidelines (ADEC, 2010).

Soil/Sediment Ingestion Factors

The following sections provide a description of the exposure factors specific to the incidental soil/sediment ingestion pathway.

Soil/Sediment Ingestion Rate. The soil ingestion rate (IR_{ing}) values identified for assessing child and adult subsistence/recreational receptor exposures are 200 milligrams per day (mg/day) and 100 mg/day, respectively (ADEC, 2010).

Fraction of Soil/Sediment Ingested. A fraction of soil ingested (FI) parameter of 1 was applied to the HHRA, which assumes that receptors may or may not be directly exposed to contaminated soil/sediment.

Dermal Contact Factors

The following sections provide a description of the exposure factors specific to the dermal contact pathway.

Soil-to-Skin Adherence Factor. The recommended soil-to-skin adherence factor (AF) for the child subsistence/recreational receptor is 0.2 milligrams per centimeter squared (mg/cm^2), which is based on a child playing in wet soil (ADEC, 2010). The AF for the adult subsistence/recreational receptor is 0.07 mg/cm^2, which is based on a residential gardener (ADEC, 2010).

Dermal Surface Area. The dermal surface area (SA) for child and adult subsistence/recreational receptors is based on a residential scenario. This corresponds to a SA of 2,800 and 5,700 centimeters squared (cm^2), respectively (ADEC, 2010).

Skin Absorption Factor. Chemical-specific dermal absorption factors (ABS) were obtained from ADEC, 2008 for PAHs and PCBs, USEPA, 2004 for arsenic, and DTSC, 2005 for other metals in soil and sediment for the evaluation of dermal contact exposures.

Inhalation Factors

The following sections provide a description of the exposure factors specific to the inhalation of suspended soil and sediment particles.

Inhalation Rate. An inhalation rate (IR_{inh}) of 12 cubic meters per day (m^3/day) is recommended for the child subsistence/recreational receptor and IR_{inh} of 20 m^3/day is recommended for the adult subsistence/recreational receptor, which is based on residential receptor (ADEC, 2010).

Ingestion Factors for Foraged Fruits and Vegetables

The following sections provide a description of the exposure factors specific to the ingestion of foraged fruits and vegetables pathway.

Produce Ingestion Rate. The produce ingestion rates were developed from Alaska Department of Fish and Game (ADF&G) Community Subsistence Information System (CSIS) harvest information (ADF&G, 2011). Harvest information was obtained by selecting resource category (Plants/Greens/Mushrooms), then statewide for the community, and then by 2006 and 2007, which were the two most current years available. The harvest data provided in the CSIS did not indicate whether or not children were included in calculating how many per capita pounds were harvested per year; therefore, the ingestion rate calculated using per capita pounds harvested per year was for a child receptor. It was assumed that the adult receptor ingestion rate would be double that of a child receptor. The maximum per capita pounds harvested per year for Eskimo potatoes of 0.2 pounds per year collected by the Kiana Community in 2006 was used to develop the below ground produce ingestion rate, which equals 0.25 grams per day (g/day). An ingestion rate for a child receptor of 0.25 g/day and 0.5 g/day for an adult receptor were used for below ground produce. The maximum per capita pounds harvested per year for vegetation, which includes berries, plants, greens, and mushrooms, of 48.24 pounds per year (60 g/day) collected by the Lime Village Community in 2007 was used to develop the above ground produce ingestion rate. An ingestion rate for a child receptor of 60 g/day and 120 g/day for an adult receptor were used for above ground produce.

Fraction of Soil Ingested. A fraction of foraged fruits and vegetables ingested (FI) parameter of 1 was applied to the HHRA, which assumes that receptors may or may not be directly exposed to contaminated soil.

1.5.1.2.4 Intake Estimates

USEPA and ADEC recommended procedures and exposure assumptions were used to estimate the daily intake (DI) or average daily dose for each COPC in each soil pathway evaluated in the HHRA. A DI represents an estimate of a chemical dose that a receptor might receive on a daily basis. DI was calculated for each COPC and each exposure pathway. DI is defined as the average intake of chemical by the body per day. For noncarcinogenic effects, the DI is averaged over the period of exposure and is referred to as the average daily dose (ADD). For carcinogenic effects, the DI is averaged over a lifetime and is referred to as the lifetime average daily dose (LADD). The general equations employed to estimate the doses for each exposure pathway considered in the HHRA are described in the following sections. Standard exposure factors discussed in Section 1.5.1.2.3 were used to estimate the DIs.

Intake Estimates for Soil and Sediment Ingestion

The chronic DI for soil ingestion exposure pathway was calculated according to the following equation:

$$DI = \frac{EPC \times CF \times IR_{ing} \times FI \times EF \times ED}{BW \times AT}$$

where:

DI = Daily intake (milligrams per kilogram per day [mg/kg-day]);
EPC = Exposure point concentration of COPC in soil or sediment (mg/kg);
CF = Conversion factor (kilograms per milligram [kg/mg]);
IR_{ing} = Ingestion rate (mg/day);
FI = Fraction ingested (unitless);
EF = Exposure frequency (days/year);
ED = Exposure duration (years);
BW = Body weight (kg); and
AT = Averaging time (days; toxic effect assessment-determined variable, ED x 365 for noncarcinogens; 70 years x 365 for carcinogens).

The estimated DIs for soil and sediment ingestion for each COPC are presented in Attachment 3, Tables 5 and 6, respectively, and are discussed in Section 1.5.1.4.

Intake Estimates for Dermal Contact with Soil and Sediment

The chronic DI for dermal contact with soil exposure pathway was calculated according to the following equation:

$$DI = \frac{EPC \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

DI = Daily intake (mg/kg-day);

EPC = Exposure point concentration of COPC in soil or sediment (mg/kg);

CF = Conversion factor (kg/mg);

SA = Skin surface area (cm^2);

AF = Soil to skin adherence factor (mg/cm^2);

ABS = Absorption factor (unitless);

EF = Exposure frequency (days/year);

ED = Exposure duration (years);

BW = Body weight (kg);

AT = Averaging time (days; toxic effect assessment-determined variable, ED x 365 for noncarcinogens; 70 years x 365 for carcinogens).

The estimated DIs for dermal contact with soil and sediment for each COPC are presented in Attachment 3, Tables 7 and 8, respectively, and are discussed in Section 1.5.1.4.

Intake Estimates for Inhalation of Airborne Dust

The chronic DI for the inhalation of airborne dust exposure pathway was calculated according to the following equation:

$$DI = \frac{EPC \times IR_{inh} \times ET \times EF \times ED}{BW \times AT}$$

where:

DI = Daily intake (mg/kg-day);

EPC = Exposure point concentration of COPC in air (milligrams per cubic meter [mg/m^3]);

IR_{inh} = Inhalation rate (m^3/day);

EF = Exposure frequency (days/year);

ED = Exposure duration (years);

BW = Body weight (kg);

AT = Averaging time (days; toxic effect assessment-determined variable, ED x 365 for noncarcinogens; 70 years x 365 for carcinogens).

The estimated DIs for inhalation of airborne dust for each COPC are presented in Attachment 3, Tables 9 for soil and Table 10 for sediment and are discussed in Section 1.5.1.4.

Intake Estimates for Ingestion of Foraged Fruits and Vegetables

The chronic DI for ingestion of foraged fruits and vegetables exposure pathway was calculated according to the following equation:

$$DI = \frac{EPC \times CF \times IR_{wf} \times FI_{wf} \times EF \times ED}{BW \times AT}$$

where:

DI = Daily intake (mg/kg-day);
EPC = Exposure point concentration of COPC in foraged fruits and vegetables (mg/kg);
CF = Conversion factor (kg/g);
IR_{wf} = Ingestion rate (g/day);
FI_{wf} = Fraction ingested (unitless);
EF = Exposure frequency (days/year);
ED = Exposure duration (years);
BW = Body weight (kg);
AT = Averaging time (days; toxic effect assessment-determined variable, ED x 365 for noncarcinogens; 70 years x 365 for carcinogens).

The estimated DIs for ingestion of foraged fruits and vegetables grown in soil and sediment for each COPC are presented in Attachment 3, Tables 11 and 12, respectively, and are discussed in Section 1.5.1.4.

1.5.1.3 Toxicity Assessment

Toxicity assessment is the process of using the existing toxicity information from human and/or animal studies to identify potential health risks at various dose levels in exposure populations (USEPA, 1989). To estimate these potential health risks, the relationship between exposure to a chemical (in terms of chronic daily intake for individuals) and an adverse effect (in terms of bodily response to a specific intake dose level) must be quantified. The methodologies used to develop toxicity factors differ, depending on whether the COPC is a potential carcinogen (i.e., has the potential to cause cancer) and/or has noncancer adverse effects.

USEPA-derived toxicity values were compiled for the HHRA from USEPA’s Integrated Risk Information System (IRIS), an online database (USEPA, 2011b). If values were not published in IRIS, values were obtained from California’s Environmental Protection Agency Office of Environmental Health Hazard Assessment (OEHHA) online toxicity database (OEHHA, 2011) and from USEPA’s RSLs tables (USEPA, 2011a), which include values from the Agency for Toxic Substances and Disease Registry (ATSDR), Health Effects Assessment Summary Tables (HEAST), and Environmental Criteria and Assessment Office (ECAO). These sources are updated regularly based on toxicity and exposure studies. The toxicity values for the COPCs are discussed below and presented in Attachment 3, Table 13.

1.5.1.3.1 Noncancer Reference Doses

In deriving dose-response criteria for assessing the potential for noncancer health effects from exposure to chemicals, it is assumed by regulatory agencies that noncancer health effects occur only after a threshold dose is reached. This threshold dose is usually estimated by regulatory agencies from the no-observed adverse effect level (NOAEL) or the lowest-observed adverse effect level (LOAEL) determined from chronic (i.e., long-term) animal studies or human epidemiological studies. The NOAEL is defined as the highest dose at which no adverse effects are observed, while the LOAEL is defined as the lowest dose at which adverse effects are observed.

Uncertainty factors or safety factors are applied to the NOAEL or LOAEL observed in animal studies or human epidemiologic studies to establish inhalation “reference exposure levels” (RELs) expressed in units of $\mu g/m^3$, “reference concentrations” (RfCs) in units of mg/m^3, and “reference doses” (RfDs) in units of mg/kg-day. Chronic REL or RfC and RfD are an estimate of an exposure level that is not expected to result in adverse health effects in persons exposed for a lifetime, even among the most sensitive members of the population (e.g., children and the aged). Use of these uncertainty and modifying factors add conservatism into the derivation of the REL or RfC and RfD.

The oral RfDs compiled for the COPCs are presented in Attachment 3, Table 13. In the absence of dermal toxicity factors, USEPA recommends using oral RfDs with an adjustment to chemicals that have gastrointestinal tract absorption of less than 50% and no adjustment for chemicals with absorption of greater than or equal to 50% to evaluate the dermal exposure pathways for the COPCs evaluated in this HHRA. This is because organic chemicals are generally well absorbed (>50%) across the gastrointestinal (GI) tract (USEPA, 2004). A cutoff of 50% GI absorption is recommended by USEPA (2004) to reflect the intrinsic variability in the analysis of absorption studies. This cutoff level obviates the need to make comparatively small adjustments in the toxicity value that would otherwise impart on the process a level of accuracy that is not supported by the scientific literature (USEPA, 2004). Risk Assessment Guidance for Superfund (RAGS) Part E Exhibit 4-1 identifies the chemicals that need to be adjusted and provides the percent absorbed in the gastrointestinal tract (USEPA, 2004).

USEPA’s RfC and California Environmental Protection Agency’s (CalEPA) OEHHA chronic REL were converted to the inhalation RfD, expressed as mg/kg-day (the equation and assumptions are provided in Attachment 3 Table 13).

1.5.1.3.2 Cancer Slope Factors

Several chemicals have been shown (and many more are assumed) to be potential human carcinogens. To be health protective, the USEPA (1989) assumes that a relatively small number of molecular events can elicit changes in a cell, ultimately resulting in uncontrolled cell proliferation and cancer. Based on this theory, the USEPA uses a two-part process in evaluating the potential cancer risk of contaminants: (1) assigning a weight-of-evidence classification, and (2) calculating a cancer slope factor (SF) for oral exposures and inhalation exposures.

The USEPA (2005a) weight-of-evidence classification system for carcinogenicity is as follows:

- A Known human carcinogen;
- B1 or B2 Probable human carcinogen;
- C Possible human carcinogen;
- D Not classifiable as to human carcinogenicity; and
- E Evidence of noncarcinogenicity in humans.

The weight-of-evidence classification is based on the source of the data (human epidemiology study or animal bioassay) and whether cancer has been observed in more than one animal species. These alphanumeric classifications are currently being phased out by USEPA as toxicity data are reviewed and revised under the Guidelines for Carcinogenic Risk Assessment (USEPA, 2005a). Under the revised guidelines, a greater emphasis is placed on the conditions under which the observed effects may be expressed, such as whether the potential for carcinogenicity appears limited to a specific route of exposure, or whether carcinogenic activity may be secondary to another toxic effect. The current weight-of-evidence system is a narrative classification, as follows (USEPA, 2005a):

- Carcinogenic to humans;
- Likely to be carcinogenic to humans;
- Suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential;
- Data are inadequate for an assessment of human carcinogenic potential; and
- Not likely to be carcinogenic to humans.

Historically, SFs have been calculated and are available for potential carcinogens in Groups A, B1, and B2, but are calculated only on a case-by-case basis for Group C (USEPA, 1989). The SF is defined as a plausible upper-bound estimate on the probability of a response per unit intake of a chemical over a lifetime, and is typically based on an assumption of continuous exposure and a linear nonthreshold extrapolation model. The SF is expressed as risk per mg/kg-day, or (mg/kg-day)-1. Because the SF is often an upper 95th percentile confidence limit on the probability of response based on experimental animal data used in the linearized multistage model, the cancer risk estimate will generally be an upper-bound estimate. Thus, one can be reasonably confident that the true risk will not exceed the risk estimate derived using this model. USEPA has stated that the true risk is likely to be less than what was predicted or may even be zero (USEPA, 1989).

The oral SFs compiled for the COPCs are presented in Attachment 3 Table 13. In the absence of dermal toxicity factors, USEPA recommends using oral SFs, with an applied adjustment to chemicals that have gastrointestinal tract absorption of less than 50%, which include chromium and nickel, and no adjustment for chemicals with absorption of greater than or equal to 50% to evaluate the dermal exposure pathways for the COPCs evaluated in this HHRA. This is because organic chemicals are generally well absorbed (>50%) across the GI tract (USEPA, 2004). A cutoff of 50% GI absorption is recommended by USEPA (2004) to reflect the intrinsic variability in the analysis of absorption studies. This cutoff level obviates the need to make comparatively small adjustments in the toxicity value that would otherwise impart on the process a level of accuracy that is not supported by the scientific literature (USEPA, 2004). RAGS Part E Exhibit 4-1 identifies the chemicals that need to be adjusted and provides the percent absorbed in the gastrointestinal tract (USEPA, 2004).

1.5.1.4 Human Health Risk Characterization

The risk characterization integrates the COPC selection, exposure assessment, and toxicity assessment to describe the risks to individuals in terms of the nature and likelihood of potential adverse health risks to occur. The risk characterization process involved integrating the exposure intakes and toxicity values to estimate both noncancer hazards and cancer risk to potential subsistence/recreational receptors from exposure to COPCs in soil and sediment at the site. Because cancer risk and noncancer effects are quantified differently, separate methods were used to evaluate these effects, as described below. Chemical specific noncancer hazards are presented in Attachment 3, Tables 14 and 15 for subsistence/recreational child and adult receptors exposed to soil, respectively, and Attachment 3, Tables 16 and 17 for subsistence/recreational child and adult receptors exposed to sediment, respectively.

Chemical specific cancer risks are presented in Attachment 3, Tables 18 and 19 for subsistence/recreational child and adult receptors exposed to soil, respectively, and Attachment 3, Tables 20 and 21 for subsistence/recreational child and adult receptors exposed to sediment, respectively. Noncancer hazard indices (HI) and cancer risks are summarized in Table 3.

1.5.1.4.1 Noncancer Effects Characterization Methodology

The potential for noncancer effects was evaluated by comparing the average daily dose with the chronic RfD to arrive at a ratio called the HQ. For a given COPC and data set, the HQ associated with exposure to the COPC in soil, outdoor air (dust), or indoor air was estimated by dividing the DI by the RfD, according to the following equation (USEPA, 1989):

$$\mathrm{HQ} = \frac{(\mathrm{ADD\ or\ DAD})}{\mathrm{RfD}}$$

where:

HQ = Hazard quotient (unitless);
ADD = Average daily dose (mg/kg-day);
DAD = Dermally absorbed dose (mg/kg-day); and
RfD = Chronic reference dose (mg/kg-day).

The HQ is the ratio of the exposure level to the noncancer toxicity factor. The HQ approach assumes that there is a level of exposure (e.g., RfD) at which it is unlikely that even sensitive populations would experience adverse health effects. If the exposure level exceeds the threshold (i.e., if HQ exceeds one or unity), there may be concern for potential noncancer effects.

The potential additivity of noncancer hazard due to exposure to multiple substances is quantified as a screening HI, which is the sum of chemical-specific HQs for the data set (USEPA, 1989). Usually, if the total screening HI is greater than one, a potential for adverse noncancer health effects may exist. If the HI is equal to or less than one, exposures to the COPCs are not expected to result in a systemic toxic response. It should be noted that HQs and HIs are not statistical probabilities, such as excess cancer risks, and the level of concern does not increase linearly as the RfD is approached or exceeded. If the route-specific or cumulative exposure screening HI is greater than one, segregation of the HI, based on the type of effects, target organ specificity, or mechanisms of action, can be considered (USEPA, 1989). This approach is used to segregate chemicals by mechanism of action and to avoid the overestimation of hazard that may result from assuming that all potential effects are additive.

The chemical- and pathway-specific HQs and HI estimates for the data sets are presented in Attachment 3, Tables 14 and 15 for residential child and adult visitors exposed to the soil, respectively, and Attachment 3, Tables 16 and 17 for residential child and adult visitors exposed to the sediment, respectively. Table 3 summarizes the cumulative HI estimates from all exposure pathways for each data set. The noncancer HI estimates are discussed below in Section 1.5.1.4.3.

1.5.1.4.2 Cancer Risk Characterization Methodology

Cancer risk is expressed as an increased probability of developing cancer as a result of exposure. The USEPA cancer risk characterization methodology has historically assumed, for most carcinogens, that cancer induction does not have a threshold, and any dose, no matter how small, is associated with some incremental or excess cancer risk.

For a given COPC and data set, the excess lifetime cancer risk (ECLR) associated with exposure to the COPC in soil, outdoor air (dust), and indoor air was estimated per pathway by multiplying the LADD by the SF, according to the following equation (USEPA, 1989):

$$\text{ECLR} = (\text{LADD or DAD}) \text{ x SF}$$

where:

ECLR = Excess lifetime cancer risk (unitless);

LADD = Lifetime average daily dose, averaged over a lifetime of 70 years (mg/kg-day);

DAD = Dermally absorbed dose (mg/kg-day); and

SF = Cancer slope factor $(\text{mg/kg-day})^{-1}$.

The ECLR values are expressed in terms such as one-in-ten-thousand (10^{-4}) or one-in-one-million (10^{-6}). An excess cancer risk of 10^{-6} means that an exposed individual may have an added one-in-one million chance of developing cancer as a result of the exposure under evaluation.

To address exposure to multiple chemicals and exposure pathways for each receptor, chemical-specific and pathway specific risks were summed to provide a total receptor ELCR. The chemical- and pathway-specific ECLR estimates for the data sets are presented in Attachment 3, Tables 18 and 19 for residential child and adult visitors exposed to the soil, respectively, and Attachment 3, Tables 20 and 21 for residential child and adult visitors exposed to the sediment, respectively. Table 3 summarizes the cumulative ECLR estimates from all exposure pathways for each data set**.** The cancer risk estimates are discussed below in Section 1.5.1.4.3.

1.5.1.4.3 Summary of Estimated Noncancer Hazards and Cancer Risks

This section provides a summary and discussion of the estimated cancer risks and noncancer hazards with respect to soil and sediment related risk.

Summary of Estimated Noncancer Hazards

For regulatory purposes, an HI of one or less is considered to be an acceptable noncancer hazard level (USEPA, 1989). Attachment 3, Tables 14 and 15 summarizes the total noncancer hazards estimated by child and adult receptors, respectively, for all soil exposure pathways evaluated in the HHRA (i.e., dermal contact, incidental ingestion, inhalation of airborne dust, and ingestion of foraged fruits and vegetables) and Attachment 3, Tables 16 and 17 summarizes the total noncancer hazards estimated by child and adult receptors, respectively, for all sediment exposure pathways evaluated. Table 3 summarizes the cumulative noncancer hazard estimates by receptor.

As discussed in Section 1.5.1.4.1, to avoid the overestimation of hazard that may result from assuming that all potential effects are additive, the HI based on the type of effects, target organ specificity, or mechanisms of action, can be considered. Therefore, HIs for arsenic and mercury were evaluated separately because the critical health effects for mercury include hand tremors, increases in memory disturbances, and slight subjective and objective evidence of autonomic dysfunction (dysautonomia), and for arsenic include hyperpigmentation, keratosis, and possible vascular complications. The other COPCs that were evaluated as one because the total HI for the COPCs are insignificant compared to arsenic and mercury. The critical health effects for all COPCs are listed on Table 3 and Attachment 3, Tables 14 through 17. The cumulative arsenic noncancer hazard for a child receptor ranged from 5 at the Camp Area to 9 at the Mill Area, and for adults 2 at the Camp Area to 4 at the Mill Area. The cumulative mercury noncancer hazard for a child receptor ranged from 3 at the Camp Area to 13 at the Mill Area, and for adults 0.3 at the Camp Area to 2 at the Mill Area. Mercury and arsenic are the COPCs that are driving the noncancer hazards for the child receptor and arsenic for the adult receptor. The incidental ingestion of soil/sediment is the pathway that is driving the mercury hazard, and ingestion of above ground produce pathway for arsenic. The other COPCs that were evaluated are not present at concentrations that pose a noncancer hazard to human health.

Summary of Estimated Cancer Risks

USEPA's cancer risk management range is 10^{-6} to 10^{-4}. According to USEPA, where the cumulative carcinogenic site risk to an individual is less than 10^{-4}, remedial action is generally not warranted unless there are other adverse environmental impacts or an ARAR is exceeded. The ADEC's point of departure for risk management is 10^{-5}, below which, further action is not warranted as that value is considered protective of the intended land use evaluated (i.e. recreational use). If the risk exceeds 10^{-5}, ADEC requires further evaluation or discussion of the risk so that appropriate risk management decisions can be made.

Attachment 3, Tables 18 and 19 presents the total cancer risks estimated by child and adult receptors, respectively, for all soil exposure pathways evaluated in the HHRA (i.e., dermal contact, incidental ingestion, inhalation of airborne dust, and ingestion of foraged fruits and vegetables) and Attachment 3, Tables 20 and 21 presents the total cancer risks estimated by child and adult receptors, respectively, for all sediment exposure pathways evaluated. Table 3 summarizes cumulative cancer risks estimates by receptor.

The cumulative cancer risk exceeds the cancer risk of 10^{-5} for the Camp and Mill Areas. The cumulative lifetime cancer risk was 2×10^{-4} at the Camp Area and 3×10^{-4} at the Mill Area. Arsenic is the COPC that is driving the cancer risk. The incidental ingestion of soil and ingestion of above ground produce are the pathways that are driving the arsenic cancer risk. The other COPCs that were evaluated are not present at concentrations that pose a cancer risk to human health.

1.5.1.5 Uncertainty Analysis

Uncertainty is inherent in many aspects of the risk assessment process. Because direct measurements are not available for many of the criteria upon which the risk estimates are dependent (e.g., air concentrations, human exposure parameters, and low dose criteria), conservative assumptions and methodologies are employed to evaluate the possibility of underestimating risk. Major factors typically associated with similar Site investigations that may lead to uncertainties in calculating the noncancer hazard and cancer risk are qualitatively discussed below.

1.5.1.5.1 Potential for Presence of Additional Chemicals

The likelihood of additional chemicals present at the Site is low because the Site has undergone much characterization since 2007. A range of laboratory analytical methods has been used to assess the presence of metals, PAHs, PCBs, explosives, BTEX, and petroleum hydrocarbons. These results, combined with available information regarding historical activities at the Site, do not indicate the presence of potentially toxic chemicals that would not have been detected by the investigation methods implemented to date. As such, the uncertainty associated with this potential is low.

1.5.1.5.2 Evaluation of Chemicals That May Not Be Associated with Site Releases

Some of the analytes detected at the Site and evaluated in this HHRA possibly represent natural conditions (e.g., metals). Elevated concentrations of metals in soil and sediment can typically result from naturally occurring (background) rocks and minerals. Although metals were screened against background concentrations in this HHRA, metals further evaluated in this HHRA may represent the background concentration range; therefore, the uncertainty associated with the hazards and risks associated with metals is high. For example, the arsenic EPC in soil (11 mg/kg) at the Camp Area is near the background concentration of 10.74 mg/kg, and is associated with a cumulative cancer risk of 2×10^{-4} for a child receptor and 7×10^{-6} for an adult receptor and a cumulative noncancer hazard of 5 for a child receptor and 2 for an adult receptor.

1.5.1.5.3 Evaluation of Mercury

As discussed in Section 1.3, the mercury speciation analysis indicated that with the exception of samples collected from the Retort Mound in the Camp Area, the majority of the mercury detected at the Site was in the form of cinnabar, which has low bioavailabilty and is a non-mobile fraction. The risk assessment included herein is likely to overestimate the potential direct exposure hazard to subsistence /recreational receptors at the Site; therefore, the uncertainty associated with the hazards from mercury is high.

1.5.1.5.4 Uncertainty of Exposure Pathways and Future Land Uses

The estimation of cancer risks and noncancer hazards are based on the identified future land use. In order to assess the risks from a variety of possible conditions, a number of scenarios were evaluated at the Site. Future recreational and subsistence activities have been evaluated. The exposure scenarios evaluated are consistent with the future land use for the Site. The direct exposure scenarios evaluated in the HHRA assume that each receptor would spend all of their exposure time at the Site. The risk assessment included herein is likely to overestimate the potential direct exposure hazard and risk to recreational receptors at the Site; therefore, the uncertainty associated with this potential is high.

1.5.1.5.5 Uncertainty of Toxicity Factors

Nearly all uncertainties in the toxicity assessment are resolved in a manner that tends to overestimate risk, for example:

- Use of USEPA-recommended toxicological constants which are inherently conservative, e.g.,
  - RfDs are reduced by Uncertainty Factors to account for inadequacies in the available data as well as other factors. All RfDs for COPCs at this site are based on studies of effects in laboratory animals. The RfDs for COPCs in this assessment are 30 to 3000 times less than dose rates that have been shown to cause effects in laboratory animals. The RfDs for arsenic is based on human epidemiologic data and is less uncertain (UF =3), and consequently, less conservative.
  - Cancer Slope Factors represent the upper 95% confidence limit of the actual slope. The actual Cancer Slope Factor is probably less than the value used.
- Six of the Site COPCs have been evaluated under the assumption that they are human carcinogens, when, in fact, only one -- arsenic -- is known to be a human carcinogen. The other

COPCs evaluated as carcinogens are considered by USEPA to be Probable Human Carcinogens because they cause a carcinogenic response in laboratory animals.

All toxicological information available for the COPCs has been developed under laboratory or occupational settings where the receptor was exposed to much higher intake rates than the intakes estimated at this Site, and then results were extrapolated to lower rates.

1.5.1.6 HHRA Summary and Conclusions

This HHRA was developed to evaluate the potential human health hazards and risks associated with exposure to soil, sediment, and foraged fruits and vegetables at the Site. A HHSRE was completed in this HHRA, which identified the COPCs in soil and sediment at each area of the Site. The HHSRE consisted of comparing the concentrations of inorganic and organic constituents detected in soil and sediment to background concentrations or to the ADEC's HHSSLs for sites located in climate zone below 40 and USEPA's RSLs for chemicals that do not have an ADEC HHSSL. If the screening levels were below background concentrations, then background concentrations were used. The screening levels were adjusted to levels were adjusted to the HQ of 0.1 and carcinogenic risk level of 1 x 10^{-06}. The following chemicals were selected as COPCs for each data set and further evaluated in this HHRA:

- Soil
  - Tailings Area
    - Metals – mercury
  - Camp Area
    - Metals – arsenic, chromium, and mercury
  - Mill Area
    - Metals – arsenic, chromium, and mercury
    - PAHs – acenaphthene, banzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene
    - PCBs – aroclor 1254 and aroclor 1260
- Sediment
  - Mill Area
    - Metals – mercury and nickel

The receptors evaluated in the HHRA included child and adult subsistence/recreational receptor. For the subsistence/recreational receptor, the exposure to COPCs via ingestion, inhalation of particulates, and dermal contact with soil/sediment and ingestion of foraged fruits and vegetables were assessed to evaluate potential cancer risks and noncancer health hazards. The estimated daily intake for noncancer hazards and cancer risks are presented in Attachment 3, Tables 5 through 12, and the chemical specific noncancer hazards and cancer risks are presented on Attachment 3, Tables 14 through 21.

As discussed in Section 1.5.1.4, the potential for noncancer effects was evaluated by comparing the average daily dose with the chronic RfD to arrive at a ratio called the HQ, which assumes that there is a level of exposure (e.g., RfD) at which it is unlikely that even sensitive populations would experience adverse health effects. To avoid the overestimation of hazards that may result from assuming that all potential effects are additive, the HI based on the critical effects were considered for arsenic and mercury. Therefore, HIs for arsenic and mercury were evaluated separately. The noncancer HIs for all of the scenarios are above USEPA's threshold (i.e., a HI of 1), with the exception of the adult recreational receptor in the Camp Area and summarized on Table 3.

Cancer risk is expressed as an increased probability of developing cancer as a result of exposure, which assumes, for most carcinogens, that cancer induction does not have a threshold, and any dose, no matter how small, is associated with some incremental or excess cancer risk. Chemical-specific and pathway specific risks were summed to provide a total receptor ELCR in order to address exposure to multiple chemicals and exposure pathways. The cancer risks are above ADEC's target cancer risk of 10^{-5}; these results are summarized on Table 3.

As discussed in Section 1.5.1.5, the uncertainties in the HHRA method would tend to overestimate rather than underestimate risks and hazards.

1.5.2 Ecological Risk Assessment

A streamlined ecological risk assessment (ERA) has been completed to focus on the specific problem the removal action is intended to address (e.g., contaminants from the abandoned cinnabar mine). The streamlined risk assessment identifies contaminants of concern in the affected media, contaminant concentrations, and toxicity associated with the contaminants. Exposure pathways that indicate an obvious threat to the environment have been identified through comparison with chemical-specific ARARs (i.e., maximum contaminant levels).

Initially, an Ecoscoping Form was completed according to ADEC's March 2009 "Ecoscoping Guidance" technical report. When the "Ecoscoping Form" was completed it was determined that a screening-level risk assessment be conducted given the presence of bioaccumulative compounds and the potential use of this site by ecological receptors that are valuable species (Appendix A). The Conceptual Site Model (CSM) was developed according to ADEC's October 2010 "Policy Guidance on Developing Conceptual Site Models." The conceptual site model was developed (Figure 4) to identify pollutant sources, release mechanisms, exposure media and routes, and the potential receptors that should be evaluated further in the screening-level risk assessment.

The KMS currently hosts a variety of habitats that in turn support wildlife. A detailed description of on-site habitats and known or suspected wildlife use is presented in Appendix A. Habitats identified at the site include:

- Spruce-dominated forest
- Paper birch-dominated forest
- Alder-dominated forest

- Willow-dominated bottomlands

- Riparian corridor dominated by herbaceous species.

1.5.2.1 Site Characterization

The Kolmakof site has four areas of concern for wildlife: the mill, tailings, pit, and camp areas. Across most of them, mercury is a primary contaminant due to the elevated concentration of mercury in the cinnabar mineral mined at the site. Arsenic, chromium, copper, nickel, zinc, and diesel and residual range organics are also detected at elevated concentrations. In this section, we discuss the potential for toxicity of the COPCs on-site. Pathways of exposure are illustrated in the CSM (Figure 4).

Antimony is a naturally-occurring, uncommon, non-essential element found naturally in the earth's crust (ATSDR, 1992). It is not readily dissolved in water and is therefore not generally detected in ambient waters, nor is it readily taken up by plants. Laboratory studies with a variety of test animals indicated that it can be lethal at very high concentrations; studies with chronic exposures indicated a reduction in reproduction can occur with prolonged inhalation exposure.

Arsenic is a common, non-essential element found naturally in soil (Eisler, 1988a). Inorganic forms of arsenic are generally more toxic than organic forms, but even then, chronic arsenic poisoning is rare in wildlife. Plants take up arsenic in a solubilized form from the soil. Organisms are exposed to arsenic through ingestion of soil and plants. Vertebrates tend to eliminate arsenic rapidly so concentrations in tissues are generally not high, unless doses are high and acute or subacute poisoning occurs. Arsenic can be bioconcentrated (organism accumulating contaminant from environmental media such as water or soil), but does not biomagnify (increase of contaminant levels at higher trophic levels) in the food chain.

Beryllium is neither essential nor beneficial to plants and animals (Irwin et al., 1997). It is toxic at relatively low concentrations due to inhibition of enzyme activity in cells. However, it is uncommonly found at toxic levels in ambient waters and soils as it is most often found in insoluble forms in the environment.

Chromium is an essential element for many organisms, but is toxic at high concentrations (Eisler, 1986). Hexavalent chromium (Cr^{+6}) is substantially more toxic than trivalent chromium (Cr^{+3}). Plants can uptake both forms, although hexavalent chromium is transported more easily within the plant. Hexavalent chromium is linked to deformities and mutations and while trivalent chromium can cause harm, the concentrations required to cause effects are substantially higher, and the effects are more limited.

Copper is an essential element for metabolism and growth of all organisms, but can be toxic at high concentrations (Eisler, 1998b). Plants are sensitive to high concentrations of copper and aquatic plants in particular can bioconcentrate copper. Studies of toxicity have not been conducted on wild birds or mammals, but effects of copper appear to mainly occur from a reduction in prey species of birds and physiological effects in mammals. Mammals are susceptible to copper toxicosis, but both birds and mammals have higher resistance to copper than do other animals.

Lead is not essential or beneficial to biota (Eisler, 1988b). Plants uptake and bioconcentrate lead with higher concentration in older plant parts and lower concentrations in flowers and shoots. Lead will bioconcentrate in birds and mammals, typically being consumed via the food chain or incidental ingestion of soil through foraging or grooming. Birds exposed to ingested lead may have reductions in reproduction, become weakened, lethargic, and have a loss of appetite, ultimately resulting in death.

Mammals exposed to lead have loss of appetite and coordination, stupor, reduced growth, reproductive effects, many of these ultimately resulting in death.

Mercury is a non-essential metal (Eisler, 1987). It is a neurotoxin which bioaccumulates via the organic, methylated form (methylmercury) and will biomagnify in the food chain. Inorganic forms of mercury, such as cinnabar are generally not harmful to wildlife. Mercury tends to accumulate in roots of plants with low concentrations found in above-ground portions of plants. Methylation of mercury occurs via microbial action and bioaccumulation and biomagnification tends to be greatest via the aquatic food chain due to appropriate conditions for the microbes. Vertebrates ingesting soil, sediment, plant roots, and aquatic organisms such as fish are at greatest risk of exposure.

Nickel is essential for growth for many organisms, but at high concentrations can be toxic (Eisler, 1998a). Plants can take up nickel via the roots and store it in all parts although concentrations in above-ground parts of plants tend to have higher concentrations than roots. While wildlife may consume nickel contaminated media (i.e., plants, soil, other organisms) as part of their diet, for mammals, nickel tends to be more toxic when inhaled or exposed via laboratory techniques not generally experienced during realistic environmental exposures. Nickel is bioaccumulated in vertebrate organisms, but biomagnification does not occur.

Zinc is an essential element that is toxic at high concentrations (Eisler, 1993). Plants will uptake zinc, depending on the type of soil and sensitivity of the plant to concentrations present. Zinc can inhibit growth and has physiological effects on birds, resulting in death at high concentrations. Mammals have a fairly high tolerance to zinc, however at excessive doses zinc is a neurotoxicant.

Naphthalene and Phenanthrene are low molecular weight semi-volatile PAHs common in diesel fuels and heating oils (Irwin et al., 1997). They are mobile in aquatic environments and toxic due to their ability to disrupt proper enzyme functions in animals. Naphthalene is slightly phytotoxic.

1.5.2.2 Selection of Potential Receptors

Notes from the site visit that occurred on September 26 to 27, 2011 (Appendix A) indicate that most of the site is upland habitat. The creek running through the site primarily had a sandy, muddy bottom which is not habitat sufficient to support diverse benthic communities. However, a few short stretches of small cobble were present and juvenile mayflies were noted in one of these stretches on site. A boggy, shrubby wetland area was noted near the Mill Area which may provide habitat for some macroinvertebrate species. Ecological receptors were selected based on observations collected during the site visit and using the *User's Guide for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions* (ADEC, 1999). The receptors reported for the Interior Ecoregion were compared to habitat and species observations from the site and the common snipe, American robin, and tundra vole were selected as appropriate receptors to estimate exposure risk from COPCs on this site.

Ecological receptors commonly used for estimation of risk on a site such as mink and belted kingfisher were not utilized primarily because food resources and habitat at this site were not suitable for these species. Kingfishers typically nest in riverbanks; however the bluffs along the Kuskokwim River are hard-rock sandstone and thus unsuitable nesting habitat. The on-site creek does not provide suitable habitat for fish which are the primary food resource for both kingfishers and mink. The nearby Kuskokwim River may provide food, however without suitable nesting habitat or perches, it is unlikely that kingfishers make use of the site. During the on-site visit, no sign of mink was seen along the creek or river. Without the appropriate food resources in the creek, it is unlikely that mink use the site regularly.

Juvenile mayflies were seen in the onsite creek during the site visit. These invertebrates are exposed to sediments (primary pathway) and surface water.

The common snipe (*Gallinago gallinago*) is a semi-aquatic avian invertivore that consumes freshwater benthic invertebrates by probing in soil and sediments in terrestrial and semi-aquatic habitats. The USEPA's *Wildlife Exposure Factors Handbook* (WEFH): Volume I (USEPA, 1993a) was used to find life history characteristics such as diet composition, food and water ingestion rates, and home ranges. Exposure factors developed for the American woodcock (*Scolopax minor*) were used in this assessment; the American woodcock was identified as a surrogate species for common snipe. The North American summer diet for the woodcock was used (Sperry, 1940, as cited in the WEFH, 1993). It was assumed that 5% of the volume of food ingested was soil and sediment due to the snipe's probing foraging techniques. Since the woodcock's habits are more terrestrial than snipe, the diet was split evenly into terrestrial and aquatic invertebrates, and percent grit was split into soil and sediment. The percent of plants within the diet was not adjusted.

The American robin (*Turdus migratorius*) is a terrestrial avian invertivore that forages in terrestrial areas for soil invertebrates and consumes substantial fruit matter. For this assessment, the summer diet for American robins in the western US was used (Wheelright, 1986, as cited in the WEFH [USEPA, 1993a]). Because many of the invertebrates that robins ingest contain soil, a small percentage of soil was included into the diet.

The tundra vole (*Microtus oeconomus*) is a terrestrial mammalian herbivore that forages primarily on grasses and sedges as they clip roots or rhizomes of plants. They also eat seeds. Accidental ingestion of soil during cleaning is likely to occur with this burrowing mammal, so a small percentage of soil ingestion was included in the assessment. Exposure factors were not available for the tundra vole, however it is in the same genus as the meadow vole (*Microtus pennsylvanicus*) found in the WEFH (USEPA, 1993a). While the tundra vole is usually bigger in body size, it has a similar diet and burrowing behaviors as the meadow vole. Because no site-specific data was available related to tundra vole BW (body weight), no size-weighting factors were applied to adjust meadow vole exposure factors. The summer diet composition from the meadow vole in tallgrass prairie in Illinois was used (Lindroth & Batzli 1984, as cited in the WEFH [USEPA, 1993a) as a surrogate diet for the tundra vole and included soil ingested during grooming.

This risk assessment uses worst-case exposure scenarios that assume 100% of the home range overlaps each study area and that the receptors spend all of the year in this area.

1.5.2.3 Identification of Constituents of Potential Concern

Chemicals were screened by comparing maximum concentrations in media to Soil Ecological Risk-based Screening Concentrations (ERBSCs) (ADEC, 2009b), Sediment PEL Screening Quick Reference Tables (SQuiRTs) (NOAA, 2008), and Freshwater ERBSCs (ADEC, 2009b) to determine COPCs for ecological receptors. Comparison to background concentrations was included in determining COPCs since concentrations of some constituents are naturally elevated in this region. COPCs identified included: antimony, arsenic, beryllium, chromium, copper, lead, mercury (and methylmercury), nickel, zinc, naphthalene, phenanthrene, DRO, and RRO. Analytical results from samples collected from 2007 to 2011 are presented in Attachment 4. Samples collected in 2008 for fractionation are presented on the screening tables using the total to represent inorganic Hg, and fractions F3 and F4 to represent methylmercury (Tables 5 and 6).

1.5.2.3.1 Surface Water

Surface water samples were collected in 2007 from the unnamed creek in the Mill Area and Camp area and at the confluence with the Kuskokwim River (E&E, 2008) and additional surface water samples were collected from the unnamed creek in the Mill Area in 2011. Metals were analyzed in these samples and were undetected or below method detection limit. No COPCs in water were included in the risk assessment.

1.5.2.3.2 Soil

Soil samples were collected in 2007 and 2011 with a few additional samples in 2008 for Hg fractionation. Samples collected in 2011 just below the Ball Mill at IA-6 were categorized as soil for risk assessment purposes since this area was dry and did not appear to have water ponding or flowing through this area. Concentrations in the first six inches bgs were used for exposure point concentrations for avian receptors whereas concentrations at all depths were used for the tundra vole since it will burrow extensively. COPCs identified in the Mill Area included: arsenic, copper, lead, mercury, methylmercury, nickel, zinc, naphthalene, phenanthrene, DRO, and RRO. COPCs identified in the Camp Area included: arsenic, chromium, copper, lead, mercury, methylmercury, nickel, zinc, DRO, and RRO. COPCs identified in the Tailings Area included: copper, lead, mercury, and zinc. Because mercury was identified as a COPC, methylmercury was also included as a COPC, this being the bioavailable form and the form most likely to cause harm to the ecological receptors.

1.5.2.3.3 Sediment

Sediment samples were collected by E&E in 2007 in the dry ditch and flowing creek on-site and at the confluence with the Kuskokwim River. A few samples were collected in 2008 for Hg fractionation analyses, primarily in the Mill Area. Additional sediment samples were taken in 2011 in the “ditch”, in the creek on-site, and in the Kuskokwim River. Three sets of samples were collected in the Kuskokwim River and were assigned to the nearest DU (one to the Camp Area and two to the Tailings Area). COPCs identified for sediments in the Mill Area included: antimony, arsenic, beryllium, copper, mercury, methylmercury, and nickel. The COPC identified in sediments in the Camp Area was beryllium which was carried forward because no screening concentration was available for this element. COPCs identified in sediments in the Tailings Area included: arsenic, mercury, methylmercury, and nickel.

1.5.2.4 Exposure and Toxicity Assessments

BSAFs/BCFs – Biota-sediment accumulation factors (BSAFs) and bioconcentration factors (BCFs) were used to determine concentrations in dietary items based on concentrations of the COPCs in soil and sediment (Table 8). Sources of average BCFs and BSAFs for site COPCs included: *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (Bechtel Jacobs Company Inc., 1998a), *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation* (Bechtel Jacobs Company Inc., 1998b), *Development and Validation of Bioaccumulation Models for Earthworms* (Sample et al., 1998a), *Development and Validation of Bioaccumulation Models for Small Mammals* (Sample et al., 1998b).

Toxicity reference values (TRVs) – Standard scientific references, primarily papers summarized in Sample et al. (1996), were used to identify TRVs for the American robin, common snipe, and tundra vole. No NOAELs were selected for closely related species. In the case of mammalian species, a BW correction factor was applied to adjust between species. These NOAELs were used as the TRVs to calculate the hazard quotient. LOAELs have been included in the TRV summary table (Table 7) for comparison purposes.

1.5.2.5 Risk Characterization

HQs are a screening-level risk assessment tool that are commonly used to identify potential for adverse risk to biota. In this assessment the COPCs, which were identified through the screening process described above, were used to calculate HQs at this site for the American robin, common snipe, and tundra vole (Table 7). For benthic macroinvertebrates, the maximum sediment concentration was compared to the sediment probable effects concentrations (PEC) from MacDonald et al. 2000 (Table 9). A HQ < 1 was assumed to represent no risk of adverse effects to the receptor for the COPC in question. It should be noted that this approach is extremely conservative and likely overestimates the potential for actual risk to wildlife.

DRO and RRO were not included in risk calculations due to: a) the small area in which they were found represents negligible exposure likelihood for ecological receptors; and b) individual organic constituents were evaluated separately.

Tailings Area

Concentrations of total mercury exceeded the PEC, but concentrations of methylmercury, the bioavailable form, were much lower than the PEC. This indicates that benthic macroinvertebrates are not at risk to potentially harmful effects from bioavailable mercury in this portion of the site. Macroinvertebrate habitat in the tailings area is restricted to the Kuskokwim River downstream of the tailings.

Maximum concentrations of arsenic and total mercury posed potential risk to all three terrestrial receptors, however concentrations of methylmercury were not sufficiently high to pose a risk to the tundra vole, indicating that mercury in this area was not bioavailable to voles and thus does not pose a risk to mammalian, terrestrial receptors. Risk from methylmercury was determined for the American robin and common snipe although at a relatively low HQs, suggesting that concentrations in this DU are between NOAEL and LOAEL concentrations and may not pose risk of adverse effects. Further risk calculations based on more realistic exposure assumptions or use of UCL95s or additional targeted soil samples may help resolve this question. Exposure to lead and zinc in soils in this tailings area may cause adverse effects to avian receptors in this DU. Copper and nickel were at soil concentrations sufficiently low to not pose risk of adverse effects to ecological receptors in the tailings area.

Mill Area

In the Mill Area, benthic macroinvertebrates may be exposed to concentrations of copper, nickel, and arsenic that may pose risk of adverse effects. While concentrations of total mercury exceed the PEC, concentrations of methylmercury, the bioavailable form, are much lower than the PEC, indicating that benthic macroinvertebrates are not likely to be at risk to potentially harmful effects from exposure to methylmercury. Because PEC levels are not available for antimony and beryllium, the potential for risk from exposure to these compounds could not be evaluated. While some risk of adverse effects may be posed to benthic macroinvertebrates in the mill area, this stream tends to flow intermittently and does not provide appropriate habitat for most benthic macroinvertebrates.

Neither antimony nor beryllium are generally bioavailable or nor do they bioconcentrate in the food web, so risk to avian or mammalian receptors could not be estimated using BCFs or BSAFs based on soil and sediment concentrations. Phenanthrene, nickel, naphthalene in the soils in the mill area had low HQs and are therefore assumed to not pose risk to ecological receptors. Concentrations of arsenic, copper, and mercury in soils were sufficiently high to pose risk of adverse effects to ecological receptors. However, HQs for methylmercury exposure to tundra vole and common snipe were less than 1, which indicates that bioavailable mercury in the soils does not pose adverse effects to these receptors. The HQ for methylmercury exposure to the American robin barely exceeded 1 which indicates that terrestrial invertevores may be at risk of adverse effects from methylmercury in the Mill Area. Concentrations of lead and zinc in this DU pose risk of adverse effects to avian receptors.

Camp Area

In the Camp Area, no COPC concentrations exceeded the PECs so benthic macroinvertebrates are not expected to be at risk of adverse effects in this area.

Beryllium is not generally bioavailable and does not readily bioconcentrate in the food web, so risk could not be calculated for avian or mammalian receptors using BCFs or BSAFs based on soil and sediment concentrations. Concentrations of arsenic and total mercury in soil pose risk of adverse effects to all ecological receptors. Bioavailable mercury was also identified as posing a slight risk to the two avian receptors but not to the tundra vole. HQs for methylmercury for the avian receptors indicated that concentrations in this area likely fall between the NOAEL and LOAEL for these ecological receptors indicating that mercury may not pose actual risk. In addition to arsenic and mercury (methylmercury), both avian receptors were likely at risk of adverse effects due to exposure to chromium, lead, and zinc in soils. Nickel and copper posed additional potential of risk of adverse effects to the American robin. However, these concentrations were slightly above an HQ of 1 (1.2 and 1.07, respectively) and may not cause adverse effects since exposure concentrations are just above NOAEL concentrations. The current exposure scenario (worst-case) assumes 100% of the home range overlaps this area and that the receptors spend all of the year in this area. This is unlikely as these receptors have much larger home ranges and do not use the site all year.

A more in-depth risk evaluation where EF and site foraging frequency (SFF) can be adjusted would likely eliminate a number of COPCs as posing risk of adverse effects to ecological receptors. It is possible that arsenic and methylmercury for avian receptors, and nickel, lead, and copper for the robin, and zinc for snipe could be eliminated as posing risk if a more appropriate exposure scenario (rather than worst case) were used to calculate risk.

1.5.2.6 Summary of Risk to Ecological Receptors

Benthic macroinvertebrates have limited available habitat on the site due to the intermittent nature of the stream. If the stream in the Mill Area is flowing and benthic macroinvertebrates are growing and reproducing in the sediment, they may be at potential risk of adverse effects from arsenic, copper, and nickel, but likely not mercury since methylmercury, the bioavailable form, is detected at very low concentrations. Benthic macroinvertebrate communities in the Kuskokwim River are not likely to be at significant risk of adverse effects to compounds originating in the tailings area.

Avian receptors are exposed to the most risk of potential adverse effects from metals in the Camp and Mill areas. The highest concentrations for many COPCs were detected in the top 6 inches of soil or sediment which is where the food for these animals is found. Mammalian herbivores have less potential of adverse effects because much of their diet is vegetation, and the COPCs do not accumulate in plants as much as in invertebrates. Arsenic was a COPC posing risk to all receptors in all DUs. While mercury is wide-spread, concentrations of the bioavailable fractions were very low, and so mercury is thought to pose little or no actual risk to ecological receptors using the site. DRO and RRO were detected in a sufficiently small area that can be considered a negligible exposure likelihood for ecological receptors; constituent PAHs were present at levels that did not pose risk to terrestrial receptors.

1.5.3 Summary of the Human Health and Ecological Risk Assessments

The HHRA and ERA were developed to evaluate the potential human health hazards and risks and ecological hazards associated with impacted soil and sediment at the Site. The following chemicals of concern (COCs) were identified in these risk assessments for each area at the Site:

- Tailings Area
    - Soil
        - HHRA – mercury;
        - ERA – arsenic, lead, mercury, and zinc;
    - Sediment
        - No COCs identified;
- Camp Area
    - Soil
        - HHRA – arsenic and mercury;
        - ERA – arsenic, chromium, copper, lead, mercury, nickel, and zinc;
    - Sediment
        - No COCs identified;
- Mill Area
    - Soil
        - HHRA – arsenic and mercury;
        - ERA – arsenic, copper, lead, mercury, and zinc;
    - Sediment
        - HHRA – mercury.

As discussed above, the hazards and risks associated with the COCs are likely an overestimation based on background concentrations of the metals, bioavailability of mercury, use of the site by human receptors, and available habitat for ecological receptors on the Site.

2.0 REMOVAL ACTION OBJECTIVES

This section identifies the RAOs for conducting a Non-Time Critical Removal Action (NTCRA); identifies potential federal, state, and local regulations with which the selected removal action must comply; presents the development of cleanup levels, and defines the scope of the removal action. The RAOs address (1) COCs present in soil or sediment at concentrations above cleanup levels at the Site; and (2) demolition/disposition of site-related equipment, structures, supplies, containers, and materials.

The human health and ecological screening risk evaluations (SREs) (Section 1.5) identified the media and exposure pathways that should be addressed by the NTCRA, and the cleanup levels that represent residual levels of chemicals in soil and sediment at the site which are protective for the specific exposure pathways and human or ecological receptors evaluated in the SRE. Based on the nature and extent of COCs present above cleanup levels, the scope of the removal action evaluation includes primarily shallow soil in three areas of the Site containing elevated metal concentrations, and in one area (the Large Shed floor in the Mill Area) a small amount of DRO. Site surveys, inventories, and visual observations (Sections 1.3 and 1.4) also identified the site-related equipment, structures, supplies, containers, and materials remaining at the Site that require demolition and/or removal/disposal.

The RAOs were developed to identify the NTCRA to be implemented to prevent, minimize, or mitigate risks to public health or the environment. The RAOs for the KMS are to evaluate removal actions that will:

- Prevent unacceptable risks to recreational users and ecological receptors that may be exposed to chemicals in soil or sediment that contain COCs at concentrations that exceed cleanup levels.

- Remove and properly dispose of abandoned site-related equipment, structures, supplies, and associated materials.

2.1 Identification of Potential ARARs

This section describes potential ARARs identified for the removal action alternatives, which are identified in accordance with NCP and USEPA guidance. Removal actions must achieve potential ARARs to the extent practicable, considering site-specific conditions, including the urgency of the situation, the scope of the removal action, and the impact of potential ARARs on cost and duration of the removal action (40 CFR 300.415(9)(0)).

No federal, state, or local permits are required for remedial actions conducted wholly onsite (CERCLA 121(e), 42 U.S.C. 9621(e) and 40 CFR 300.400(e)(1)). Onsite remedial actions meet only substantive requirements, not administrative requirements, of potential ARARs. Administrative requirements, such as permits, reports, and records, along with substantive requirements, apply only to hazardous materials sent offsite for further management. The substantive requirements identified as potential ARARs for the KMS removal action were based on a review of federal environmental laws and more stringent state environmental and facility siting laws.

Pursuant to Section 300.415(j) of the NCP, to the extent practicable considering the exigencies of the situation, a removal action must attain applicable ARARs. ARARs are promulgated, enforceable federal and state environmental, or public health requirements, which fit into either of two categories: "applicable requirements" or "relevant and appropriate requirements." The term "promulgated" means that the standards are of general applicability and are legally enforceable [40 CFR 300,400(g)(4)].

- Applicable Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, on, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not legally applicable to a hazardous substance, pollutant, contaminant, response action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site or actions at the site.

In addition, USEPA considers certain identified state and federal guidance documents when conducting a removal action. These are known as “to be considered" criteria (TBCs). TBCs are non-promulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of ARARs. Along with ARARs, TBCs may be used to develop the response action parameters necessary to protect human health and the environment. State standards are ARARs if they are "promulgated, are identified by the state in a timely manner, and are more stringent than federal requirements."

The final ARARs and TBCs will be used in the detailed analysis of the effectiveness of removal alternatives and will be factored into the development of performance standards to be included in the NTCRA Scope of Work.

USEPA categorizes ARARs and TBCs into chemical-specific, action-specific, and location-specific. These ARAR categories are described below.

Potential Chemical-Specific ARARs

Chemical-specific ARARs and TBCs are health- or risk-based values that may define acceptable exposure levels and, therefore, may be used to establish remediation goals. In general, chemical-specific ARARs are set for a single chemical or a closely related group of chemicals. ADEC regulations for potential impacts to groundwater from waste materials and soil standards for designated land uses are examples of potential chemical-specific ARARs for the site COCs. Examples of TBCs applied to the KMS include ecological risk-based sediment concentrations, and the use of site-specific background levels.

Some of the soils in the Retort Mound area and in some other areas of the site contain high levels of mercury, and any disposal options will be influenced by whether the soils are classified as hazardous or nonhazardous (solid) waste. The Resource Conservation and Recovery Act (RCRA) states that materials will be classified as solid waste if a representative sample of the material passes a Toxicity Characteristic Leaching Procedure (TCLP). The TCLP entails the analysis of water that is flushed through a material to determine how chemicals will leach from the material. In order for a soil sample to pass, analytical results for mercury must be less than 0.2 mg/L. If the results are higher than 0.2 mg/L, the soils are considered a hazardous waste. Hazardous waste containing mercury over 260 mg/kg are also considered "high level" wastes, and must be retorted/treated before disposal by landfilling to reduce the leachability of the waste to below 0.2 mg/L under current Land Disposal Restrictions. Hazardous wastes are classified as "low level" if they contain 260 mg/kg or less mercury, and must be stabilized before disposal by landfilling. ADEC regulates solid waste under 18 Alaska Administrative Code (AAC) 60, and hazardous waste under 18 AAC 62. Contaminated soils classified as solid waste may be disposed of in a permitted Solid Waste Landfill.

A summary of the types of chemical-specific ARARs and TBCs potentially applicable to the KMS are presented in Table 13.

Specific cleanup levels proposed for use as RAOs in the removal action are presented in Tables 4 through 6 (HHSRE) and Tables 10 through 12 (Ecological SRE), and are also shown on Figures 6 through 8 that show the areal extent of concentrations in site media that exceed these values.

Under 40 CFR 261.4(b)(7), solid waste generated from the extraction, beneficiation, and processing of ores and minerals are excluded from regulation as a hazardous waste and RCRA Subtitle C hazardous waste requirements. Based upon available information, residual mine waste from the KMS meet the RCRA exemption and would not be regulated as a hazardous waste. Although not a hazardous waste, mine waste is generally considered a solid waste and is therefore regulated by Alaska Solid Waste Regulations. Unless it is determined to have the potential to generate acid-rock drainage, waste rock is exempt from the requirements of 18 AAC 60. Surface waters draining from waste rock at the KMS have not been identified as acidic. Based on the available information, waste rock at the site meets this exemption and would not be regulated as a solid waste.

Potential Action-Specific ARARs

Action-specific ARARs and TBCs are technology- or activity-based requirements or limitations on actions taken. These requirements generally focus on actions taken to remove, handle, treat, or dispose of hazardous wastes. These action-specific requirements do not in themselves determine the response action alternative; rather, they indicate how a selected alternative must be achieved. Examples of action-specific ARARs include stockpiling of treated or untreated soil from the site, and discharge of pollutants into surface waters.

A summary of the types of action-specific ARARs and TBCs potentially applicable to the KMS are presented in Table 13.

Potential Location-Specific ARARs

Location-specific ARARs and TBCs are restrictions placed on the conduct of activities solely because they are in specific areas. Potential location-specific ARARs can be triggered for example, if the removal action involved would cause discharge to sensitive locations such as wetlands, floodplains, historic areas, or wildlife refuges. These requirements may limit the type of potential remedial action that can be implemented, or may impose additional constraints on remedial alternatives. Potential location-specific ARARs are requirements that affect the management of hazardous constituents due to the location of the management unit. For construction of an onsite repository to contain demolition and non-hazardous contaminated materials, ADEC allows one-time disposal of inert/non-hazardous waste in a landfill (monofill) under as covered by 18 AAC 60.

A summary of the types of location-specific ARARs and TBCs potentially applicable to the KMS are presented in Table 13.

ARAR Waivers

Under certain circumstances, a removal alternative that does not meet an ARAR may be selected and a waiver of the ARAR may be granted. There are six sets of circumstances described in Section 300.430(f)(1)(ii)(c) of the NCP, for which waivers may be granted:

- If the alternative is an interim measure and will become part of a total remedial action that will attain the ARAR;
- If compliance with the ARAR will result in greater risk to human health and the environment than other alternatives;
- If compliance with the requirement is technically impracticable from an engineering perspective;
- If the alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach;
- If the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other removal actions within the state; or
- For fund-financed actions (i.e., removal actions financed by the federal Superfund), an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the Site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

No ARAR waivers are specifically identified or requested in the EE/CA at this time. Removal action alternatives for which a waiver would be required in order to implement would be identified after public and regulatory agency review of the EE/CA.

2.2 Summary of Cleanup Level Development and Application

Removal action cleanup levels (CULs) were compiled for Site COCs detected in soil and sediment from screening levels protective of human health, ecological receptors, groundwater, and background values. Tables 14 and 15 summarize the screening levels and background concentrations used in the development of cleanup levels for soil and sediment, respectively. The cleanup levels were developed as further discussed below.

Human Health Screening Levels

As discussed in Section 1.5.1.1 the soil and sediment human health screening levels were compiled from ADEC's *Cumulative Risk Guidance* human health risk-based soil screening levels (HHSSLs) for sites located in climate zone below 40 (ADEC, 2008a). The human health screening levels presented in Tables 14 and 15 correspond to the non-carcinogenic risk HQ of 1 and carcinogenic risk level of 1×10^{-05}, therefore, these levels were adjusted to the HQ of 0.1 and carcinogenic risk level of 1×10^{-06} (ADEC, 2010). If constituents for which ADEC human health risk-based soil screening levels have not been developed, then soil screening levels were obtained from USEPA's Region 9 Regional Screening Levels (RSLs) and adjusted to a HQ of 0.1 and to a carcinogenic risk level of 1×10^{-06} (ADEC, 2010). Since human health screening levels for sediment are not available, ADEC's HHSSLs were used for the sediment (ADEC, 2010).

Protection of Groundwater Screening Levels

The soil and sediment protection of groundwater screening levels were compiled from ADEC's Register 188 Table B1. Method Two – Soil Cleanup Levels Table (ADEC, 2009a).

Ecological Screening Levels

Ecological soil screening levels were compiled from ADEC's 2009 Ecoscoping Guidance Technical Report, and sediment screening levels are the PELs from NOAA Screening Quick Reference Tables for Organics – Sediment for Freshwater Sediment (NOAA, 2008).

Background Levels

Background levels were determined as described in Section 1.3. The soil background levels for arsenic, chromium, mercury, and nickel are site specific values that were developed from the soil samples that were collected at the Site in 2008 and presented in AMEC's September 2011 Engineering Evaluation/Cost Analysis Workplan, Kolmakof Mine Site. Background levels for beryllium and thallium in soil and sediment and zinc in soil are from Gough et al. (1988).

The remaining background levels for metals in soil and sediment are calculated from values presented in the USGS Alaska Geochemical Database (2011). Results of chemical analyses for soil and sediment ("sediments" representing materials associated with beds underneath surface water bodies) were extracted from the USGS's Alaska Geochemical Database (AGDB) (USGS, 2011) for samples within a 100 mile radius of the site.

For comparability to site-specific samples, samples with preparation methods similar to those being used at the site were chosen. Simple plain water leaching and digestion with aggressive acids such as aqua regia or hydrofluoric acid were excluded while sample preparation methods using normal acid digestion were included. Generally, only one analytical method was present for any given sample for a parameter, but in the rare occurrence that a sample was analyzed using more than one analytical method, the highest reported concentration was used.

The data generated from the USGS database were analyzed using USEPA's ProUCL program (V.4.1.01) to calculate a background comparison values. There have been many soil and sediment samples collected in the vicinity of the site. It is expected that, given the number of data points, there should be sufficient confidence in these background comparison values.

Additional Considerations Regarding Application of Cleanup Levels

Although there were three sample locations where zinc was detected at concentrations slightly above the background value of 70 mg/kg (83, 86, and 110 mg/kg), because they were isolated detections that occurred outside of any IA or operational area, the ADEC protection of groundwater criteria was selected as the cleanup instead of the background value. ADEC protection of human health criteria were also selected for DRO/RRO because they did not pose a risk to ecological receptors, and there are no background values for these compounds.

Although there were two sample locations where mercury was detected in the Tailings Area at concentrations slightly above the background value of 69.1 mg/kg (74 and 99 mg/kg), because they were isolated detections that occurred in an area (as described in Section 1.2, Site History) containing waste rock from the cliff face that contains native cinnabar that continues to shed through natural processes, the detections of mercury in this area are considered naturally occurring. Therefore, the background level for mercury is not applicable as a removal action cleanup level, and a removal action is not evaluated in the Tailings Area.

2.3 Scope of the Removal Action

Based on the results of the HHRA and ERA and comparison of soil and sediment data to cleanup levels, there is no surface water or sediment in surface waters that contain COCs at concentrations above cleanup levels. There is one sample location where dry sediment from the former Settling Pond area of the Site contained concentrations of COCs above cleanup levels that is considered soil for the purposes of the removal action because it is in a dry area.

The findings of the EE/CA indicate that approximately 200 cubic yards (cy) of soil containing elevated metal concentrations in two of the four areas of concern (Camp Area and Mill Area) and a limited amount of soil containing DRO in the Mill Area should be addressed in a removal action. In addition, approximately 1,000 cy of debris from site-related equipment and structures remaining at the Site would be demolished and/or removed and disposed as part of site restoration.

The goal of the EE/CA is to reduce the environmental risk associated with contaminated surface soils, and the physical hazards associated with the abandoned mine structures and equipment based on the following objectives:

- Remove contaminated surface soil in the Camp and Mill Areas to reduce the environmental risk.
- Treat, contain and/or dispose of the contaminated soil.
- Demolish existing structures and equipment to eliminate the physical hazards.
- Reduce the environmental risk posed by any contaminants in demolition debris through decontamination.
- Dispose of the demolition debris.

The boundaries of the areas of soil where a removal action is necessary to address concentrations of COCs above cleanup levels are approximated by the cross-hatched areas depicted on Figures 9 and 10, which show the proposed excavation areas in the Camp Area and Mill Area, respectively.

The removal action encompasses a total volume of approximately 200 cubic yards (cy) of soil as follows:

Soil

- <u>Camp Area</u>: Approximately 85 cy of soil containing metals at concentrations above cleanup levels from three locations within the former Retort Mound (Figure 9).
- <u>Mill Area</u>: Approximately 115 cy of soil from six locations at IA-2, IA-3, IA-4, IA-5/13, IA-6, and IA-8 containing metals at concentrations above cleanup levels, of which approximately 10 cy also contains DRO at concentrations above the cleanup level that would be handled separately from the soils only containing metals (Figure 10).

The structural removal action encompasses a total volume of approximately 1,000 cy of material as follows, based on updates to the inventory presented in Attachment D of the RSI (E&E, 2008) from previous removals and field observations conducted during the 2011 field investigation:

Structures, Demolition and Construction Debris

- Approximately 700 cy of nonhazardous wood and concrete debris, of which 500 cy is estimated to be wood debris from 11 buildings that could be burned to reduce the total volume to approximately 200 cy.

Equipment, Machinery, and Containers

- Approximately 300 cy of equipment, machinery, and containers.

Waste Handling Assumptions

Soil or Sediment Containing Mercury

Based on the results of the previous investigations and data collected during the 2011 field investigation and under 40 CFR 261.4(b)(7), the removal action materials at the KMS are considered a nonhazardous (solid) waste and are not anticipated to contain concentrations of metals or other chemicals that would be designated as a hazardous waste. As described in Section 2.1, if the results of a TCLP on a representative sample are higher than 0.2 mg/L for mercury, the soils are considered a RCRA hazardous waste and would require pretreatment prior to landfilling. Contaminated soils classified as a nonhazardous or solid waste may be disposed of in a permitted solid waste landfill.

As described in Section 1.4.1, three soil samples collected at locations of high total mercury XRF concentrations during the 2011 field investigation were collected from similar depth intervals as samples for total metals, and were analyzed for metals using the SPLP. Two samples from the Retort Mound portion of the Camp Area and one sample from the Settling Pond in the Mill Area were analyzed for total metals and SPLP. At the Retort Mound, mercury was detected in two samples at concentrations of 0.024 and 0.52 mg/L, and at a concentration of 0.034 mg/L from the Settling Pond at the Mill Area. Although TCLP data for mercury has not been collected for onsite materials, because the SPLP uses a similar leaching procedure, the SPLP results can be used for planning purposes to develop assumptions on the potential leachability of mercury in soil. The SPLP sample from the Retort Mound that contained mercury at 0.52 mg/L is likely due to extraction on a particle of residual retort waste. The retorting process produces a much more soluble/leachable form of mercury, so it is expected that some residual retort waste is present in the Retort Mound that has a much more soluble form of mercury compared to soil and sediment present in other portions of the site.

The results of the other two SPLP samples collected from sediment in the Settling Pond in the Mill Area and soil from the Retort Mound in the Camp Area did not contain elevated levels of mercury. Therefore, because one of the SPLP results from the Retort Mound exceeded the TCLP limit for mercury, and several samples at the site contained total mercury concentrations greater than 260 mg/kg, associated soil and/or sediment could potentially be considered hazardous and/or high level waste that would require pretreatment prior to placement or disposal to reduce its potential mobility when exposed to water. Although SPLP data indicates that some waste materials in the Retort Mound may be readily leachable, available results from previous water sample analyses from the site do not exhibit unacceptable mercury concentrations, so the amount of leachable mercury is apparently small. None of the surface water samples collected at the site contained concentrations of mercury or other metals above screening or cleanup levels evaluated in the SRE.

Structures, Demolition and Construction Debris

Based on the results of previous asbestos and lead-based paint surveys and sampling of building materials, with the exception of a small amount of yellow paint on a small shed in the Mill Area (approximately 80 square feet) that exceeds ADEC cleanup criteria for lead, no potentially hazardous ACM or lead-based paint residues are present in materials to be demolished at the site.

Equipment, Machinery, and Containers

Based on the results of previous surveys and sampling, with the exception of a drum in the Camp Area containing a reddish colored sandy material (possibly residual processed ore) that contained a high level of mercury above the ADEC Method 2 Criteria and total chromium above the background level, no hazardous materials are expected to be contained in the equipment, machinery, and containers surveyed and inventoried at the site. Any equipment or machinery containing potentially hazardous products will be drained and decontaminated prior to disposal, and any batteries will be removed in accordance with 18 AAC 60.

3.0 REMOVAL ACTION TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

This section documents the process of identifying and screening removal technologies that are potentially applicable to removal actions for impacted soil and site structures and equipment at the KMS. Potentially applicable technologies are identified based on available site characterization data and known physical site conditions. Technologies identified are then either retained for further consideration or screened out, based on an evaluation of their ability to effectively address the affected media identified in Section 2.2. The technologies that are retained for further consideration are then assembled into removal action alternatives to address the site-specific RAOs established in Section 2.0.

The following subsections present the results of the technology identification and screening, and descriptions of the removal action alternatives developed. The removal alternatives are evaluated in greater detail in Section 4.0.

3.1 Technology Identification and Screening

In accordance with USEPA guidance on Conducting Non-Time-Critical Actions Under CERCLA (EE/CA Guidance) (USEPA, 1993b), technologies and associated process options having the highest potential for success at the KMS were identified for a preliminary screening evaluation. Technologies and process options identified as potentially applicable at the site are summarized and screened for applicability. The screening determination identifies whether the given process option will be retained for further consideration in assembling potential removal action alternatives. A discussion of the rationale used to retain or eliminate technologies and process options is provided below.

Institutional Controls

No Action: No action is required for consideration and comparison purposes by NCP 40 CFR § 300,430(e)(6). The no action scenario represents a baseline condition against which other removal actions are compared, and is retained for further consideration.

Deed Restrictions: Deed restrictions may include modifying conditions of the current property deed to limit certain types of land uses to supplement the protectiveness of other actions taken as part of an overall site remedy. Deed restrictions remain in effect with property transfers to new owners. Future restrictions on development or intrusive work in certain portions of the site, such as the location of an onsite monofill or solid waste landfill, may be an appropriate type of deed restriction when combined with other site control measures. Deed restrictions would be subject to approval between BLM and ADEC. Proprietary land use or deed restriction agreements may be required between BLM, ADEC, and/or EPA related to title considerations for land used in a removal action. Agreements would specify restrictions on future earthwork or construction of dwellings on or near the site. These restrictions would be enforced by BLM, and would remain in force unless removed by a court order. Legal access restrictions are retained for further consideration because they are potentially applicable if impacted materials remain onsite as part of the removal action.

Site Fencing: Physical access restrictions prevent access for recreational users or other site visitors to impacted areas of the site using fencing, signage, and routine security inspections. Physical access restrictions are eliminated from further consideration because it is the intent of BLM to remediate the individual AOCs and restore the KMS to allow unrestricted reuse by recreational users.

Earthwork/Physical Removal and Handling

Excavation: Excavation techniques are used to physically remove impacted materials to eliminate the potential for receptors to come in contact with them. Excavation technologies typically involve conventional earthmoving construction equipment. Equipment such as backhoes, front end loaders, and bulldozers would be suitable for excavation and movement or placement of soil or other cover materials, and for demolition of structures. Excavation techniques used at the site may require dust control measures in disturbed areas to prevent particulate inhalation. Dust control typically involves spraying water over excavated areas and materials to suppress particulate suspension.

Excavation would be required for removal of impacted soils, as well as for demolition of structures and foundations. Excavated materials would require segregation for separate handling based on (1) the types of COCs and cleanup level exceedances in each area; (2) assumptions on whether certain soils may contain COCs at concentrations that would designate the material as a high level or hazardous waste (e.g., from the Retort Mound); and (3) the presence of demolition materials, equipment, construction debris, etc. Excavation is applicable for removal of impacted soil and demolition of site structures, etc., and is retained for further consideration.

Transportation: Transportation technologies typically involve the use of conventional materials handling equipment, such as excavators, to transport excavated materials either onsite or offsite. Transportation activities would include dust control measures to prevent the suspension of particulates around the site when equipment is in use. Transportation of excavated or demolished materials is applicable for removal of impacted soil and demolition of site structures, etc., and is retained for further consideration.

Grading: Grading is used to alter the ground surface contour of an area such that surface water runoff is directed along desired routes. Site plans are developed to establish an overall grading design to optimize surface water conveyance around and away from impacted areas of the site, or in strategic locations across the site. Grading is considered potentially applicable to restore excavated areas and to limit infiltration rates into areas where impacted soil remains onsite, and is retained for further consideration.

Diversion: Diversion may include construction or modification of features such as ditches, channels, and berms used to direct or divert surface water flow downslope, away from impacted soils. Diversion is eliminated from further consideration since surface water is not impacted at the site, and erosion can be adequately controlled in excavated areas as part of post-excavation grading, compaction and revegetation.

Surface Water Collection: Surface water storage in a surface impoundment or reservoir in a desired location is used to equalize surface water runoff from a site in conjunction with diversion structures (e.g., ditches or channels). The surface water collection process is eliminated from further consideration since surface water is not impacted at the site, and runoff can be adequately conveyed in excavated areas as part of post-excavation grading and revegetation.

Offsite Disposal: Offsite disposal involves transportation and placement of material in a permitted, engineered containment facility located outside of the site boundaries. Offsite disposal facilities provide a long term solution to containment of waste and elimination of the exposure pathways, and also typically offer pretreatment of the waste if necessary to meet land disposal restrictions (LDRs). Offsite disposal is retained for further consideration.

Revegetation: Replacing vegetation following disturbance of the ground surface will mitigate soil erosion and surface water infiltration and runoff. Roots from cover plants hold the soil in place, preventing wind and water erosion. Revegetation can also reduce infiltration of water into surface materials through interception of water by plant root systems and transpiration mechanisms.

Revegetation is typically performed in conjunction with placement of clean fill and soil covers. For this site, revegetation includes topsoil replacement and planting native ground cover. Establishing vegetation can also be effective in enhancing the stability and permanence of cover systems. Revegetation is retained for further consideration.

Containment/Monitoring

High-density polyethylene (HDPE) Liner and Cover: This type of plastic is used as a liner material and a cover for stockpiled impacted materials. Placement of an HDPE liner and cover would prevent direct exposure of the materials to the environment or receptors, and significantly reduce the potential for leaching of COCs. Therefore, HDPE liners and covers are retained for further consideration in conjunction with other actions such as excavation as part of an overall site remedy.

Soil and Waste Rock Cover: Onsite soil and waste rock can be used as cover material to prevent direct contact with impacted materials by human and ecological receptors, reduce erosion, and provide a suitable foundation for revegetation. Soil and waste rock covers are retained for further consideration.

Clay Cover: A clay cover consists of low permeability clay layers used as cover material to prevent direct contact with impacted materials by human and ecological receptors, and are typically used in place of soil or waste rock covers to further minimize surface water infiltration. Clay covers are typically used in landfill cover designs where significant control of surface water leaching into materials that contain highly mobile COCs in the subsurface environment is desired. Metals are the primary COCs at the site, and are not highly mobile and have not impacted groundwater at the site. In addition, clay is not locally available and would have to be imported to the remote location of the site. Adequate infiltration control could be achieved by other means; therefore, clay covers are eliminated from further consideration.

Clean Fill: Clean fill material is used to perform grading activities, construct soil cover, and place in excavated areas. Onsite soil and waste rock are available for use as clean fill for these purposes; therefore, this option is retained for further consideration.

Onsite Consolidation: Consolidation of excavated and/or demolished materials in an onsite repository, monofill, or landfill would allow all waste to be managed in one location. They are typically capped with an engineered low-permeability cover system, and may also be revegetated. Consolidation in an onsite would allow demolition and/or impacted materials to be maintained in a controlled environment and with an appropriate cover can minimize or eliminate exposure pathways to potential human and ecological receptors. Consolidation in an onsite monofill for a single waste (demolition debris) and in a repository (demolition debris and impacted soil) are retained for further consideration.

Capping in Place: Capping involves placement of a cover over the contaminated materials in place, without excavating and transporting or consolidating materials. Capping is typically applicable when the contaminants are of low to moderate toxicity and mobility and the volume of contamination is widespread, and costs to remediate or remove it and/or environmental impacts are very high. After the cap system is constructed, deed restrictions would be implemented to prevent future development or intrusive work in the capped portions of the site. Capping in place is eliminated from further consideration because contamination is not widespread, and it is the intent of BLM to remediate the individual AOCs and restore the KMS to allow unrestricted reuse by recreational users.

Monitored Natural Attenuation: Natural attenuation processes are commonly used for remediation of contaminated sites. A variety of natural processes occur without human intervention at all sites at varying rates and degrees of effectiveness to attenuate (i.e., decrease) the mass, toxicity, mobility, volume, or concentrations of organic and inorganic contaminants in soil, groundwater, and surface water systems. Monitored natural attenuation (MNA) requires more complex and costly site characterization prior to implementation, long term monitoring, and potential of continued migration, and/or cross-media transfer of contaminants. Metals do not typically degrade over time and natural attenuation is not expected to occur to a significant degree in the future. Therefore, MNA is eliminated from further consideration.

Treatment

Stabilization/Encapsulation: Stabilization and encapsulation techniques reduce or eliminate the mobility of metal constituents in soil by chemically and physically binding the metals within the soil matrix into a stable mass. Stabilization techniques commonly use Portland cement or other pozzolanic materials as the primary stabilization agent. Encapsulation techniques are typically proprietary processes that utilize polymers or other resin-like encapsulants to bind the metals to the soil particles. These technologies can be applied to soils either after excavation (ex situ) or in place (in situ); however, only ex situ and/or offsite treatment would be applicable for the KMS soils because, as with capping in place, it is the intent of BLM to remediate the individual AOCs and restore the KMS to allow unrestricted reuse by recreational users. These techniques may be combined with a consolidation and cover option to further reduce potential exposure pathways and leachability of metals in the waste. In fact, because stabilized/encapsulated materials are subject to weathering, these techniques would only be considered in conjunction with placement beneath a cover system/in a landfill.

The ratio of stabilization material or encapsulant required to effectively treat waste materials would be determined through predesign laboratory treatability testing. Most metals are treatable by cement-based stabilization, which tends to form insoluble metal hydroxides in the basic pH ranges commonly found in cement. However, mercury is widespread in impacted soils at the site and is not as treatable by cement-based stabilization. It is possible that a unique formula could be designed that uses a sulfide-based cement that in effect would convert the soluble mercury from the retort processed materials back into a less soluble material, similar to the makeup of the naturally occurring cinnabar deposits at the site. However, because the volume of material is low, it would not be cost effective to design and develop an innovative technology for small-scale treatment, so stabilization is eliminated from further consideration. Encapsulation using a commercially available technology such as MT2 that is effective for mercury-containing soils and metal-containing materials is retained for further consideration prior to placement in an onsite landfill.

Metals Recovery: Metals recovery from mine waste materials may be achieved using various reprocessing techniques including pyrometallurgical and hydrometallurgical processes. However, metals recovery from site waste materials is not retained for further consideration because the volume of material is low/small scale treatment would not be cost effective, and metals concentrations in the impacted soils are below concentrations necessary for cost-effective use of the technology.

Soil Washing: Soil washing is an ex-situ soil remediation technique combining aqueous extraction and constituent separation to reduce residual metal concentrations in treated materials to specified levels. The process uses mechanical and/or chemical scrubbing to remove metals by dissolving or suspending them in a wash solution, or by concentrating them into a smaller volume of soil through particle size separation techniques. However, soil washing is not retained for further consideration because the volume of material is low/small scale treatment would not be cost effective, and metals concentrations in the impacted soils are below concentrations necessary for cost-effective use of the technology.

3.2 Development of Removal Action Alternatives

Based on the analysis of the nature and extent of contamination presented in Section 1.0 and on the RAOs developed in Section 2.0, this section identifies and assesses a limited number of alternatives that are either appropriate for meeting RAOs, or are provided for comparative analysis purposes as required by the NCP. The alternatives identified and analyzed in the following subsections are considered proven remedies because they have been selected in the past at similar sites and/or for similar contaminants. Remedial options and technologies were screened and assembled into the following four removal action alternatives identified and evaluated in this section:

- Alternative 1 - No Action
- Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository
- Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill
- Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

The four removal action alternatives retained for consideration are summarized in Table 16 and are described below.

3.2.1 Alternative 1 - No Action

The no action alternative as required by the NCP is retained throughout the evaluation process and represents a baseline condition against which other removal action alternatives are compared. The No Action Alternative consists of allowing the site to remain in its present condition, with no actions or measures taken to reduce or monitor contaminant concentrations. Contaminant levels would not be reduced and no short term risk reduction would be achieved. Long term risk reduction would occur only through natural attenuation mechanisms, but metals do not typically degrade over time and the extent of natural attenuation would be unknown since no monitoring would occur. This alternative would not meet the RAOs identified for the removal action.

3.2.2 Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository

This alternative involves excavation and pretreatment of soil containing metals via encapsulation, demolition of site structures and associated equipment, burning of wood building materials and decontamination as necessary of equipment, and placement of all materials in an onsite repository under an engineered cover system. The limited amount of soil (approximately 10 cy) that contains DRO at concentrations above the cleanup level from the floor of the Large Shed (IA-8) would be segregated from the metals-containing soils, and would be handled separately and transported offsite for pretreatment and disposal at an offsite thermal treatment facility.

Implementation of this alternative is based on the following assumptions:

- The soil is a solid waste rather than a hazardous waste.
- A suitable location for a repository exists at the KMS and is managed by the BLM. The BLM would implement deed restrictions for future land use at the site. The repository would be designed in accordance with 18 AAC 60 to contain solid or inert waste.
- By encapsulating the impacted soil the long term risk associated with the soil is reduced and could, if approved by ADEC, eliminate the requirement for post-closure monitoring of the repository.

- The quantity of encapsulant required to immobilize mercury in soil and metal-containing materials would be established by performing a small-scale bench test before field application.

As described in Section 2.2 and shown on Figures 6, 9, and 10, approximately 200 cy of soil in the vicinity of the Camp and Mill Areas would be excavated, pretreated with an encapsulant, and consolidated and covered in an onsite repository, along with approximately 500 cy of demolition debris that has been reduced in volume (from 1,000 cy) by burning wood building materials.

A total of approximately 200 cy of impacted soil is estimated to require removal based on the results of the site investigations and SRE, and would be pretreated with an encapsulant, and placed in the repository. Approximately 500 cy of demolition material would be placed in the repository from demolition of all site structures, equipment, machinery, and containers, and burning of segregated wood debris from building demolitions that may be burned onsite. The small amount of yellow paint on a small shed in the Mill Area (approximately 80 square feet) that exceeds ADEC cleanup criteria for lead would also be pretreated to reduce the leachable lead components with MT2 stabilizer encapsulant or similar commercially available product prior to placement in the repository.

The following materials if they could not be pretreated via an encapsulant to reduce the mobility of metals, or are potentially hazardous materials, would be handled separately and disposed offsite:

- Soil from the floor of the large shed at a former generator location that contained DRO at a concentration that exceeds ADEC cleanup criteria for DRO;

- A drum in the Camp Area containing a reddish colored sandy material (possibly residual processed ore) that contained a high level of mercury above the ADEC cleanup criteria;

- Any decontamination materials from draining lubricants or fuels if present in engines, equipment, or machinery, and batteries.

Standard excavation technologies using conventional earthmoving construction equipment such as backhoes, front end loaders, and bulldozers would be suitable for excavation and movement or placement of soil or other cover materials, and for demolition of structures. This equipment would be mobilized to the site via barge on the river and offloaded at the bottom of the access road that ends at the river.

Removal Action Sequence

The removal action is anticipated to be implemented under the following sequence of tasks:

Demolition

- Demolish 11 wooden structures and remove and segregate any equipment, machinery, or vehicles; segregate wood material; apply encapsulant to lead-based paint surface on wood from small shed and stockpile with non-wood debris; burn remaining wood debris; decontaminate/drain any equipment, machinery, or vehicles and collect red sand drum and potentially hazardous waste in drums for offsite disposal.

Excavation and Pretreatment

- Prepare stockpile staging area;

- Excavate shallow soils from Camp and Mill Areas and stockpile;

- Conduct confirmation sampling in excavation bottoms; overexcavate as necessary until confirmation sample results indicate all soils remaining within excavation areas contain concentrations of COCs below cleanup levels;

- Apply encapsulant to excavated soil and mechanically mix with a backhoe or suitable equipment; stockpile.

Repository Construction

- Clear vegetation from the existing access road (approximately 1.3 aces) that is partially grown over but reported to be level and intact;

- Clear and grub an approximate 0.25 acre area for excavation of the repository;

- Prepare stockpile storage area for excavated material that will later be used as cover;

- Excavate a 30 foot by 100 foot rectangular excavation (bottom dimensions) with 1:2 sloped sidewalls;

- Stockpile material for backfill;

- Backfill excavation with 1,000 cy of stockpiled encapsulated soil and demolition debris from the removal action;

- Construct a cover with stockpiled material and revegetate.

Predesign

A predesign study would be conducted on a sample of mercury-containing soil from the Retort Mound to verify treatment via an encapsulant such as MT2 would reduce the leachable concentration of mercury to below the TCLP limit prior to placement in an onsite repository. The encapsulant technology was proven effective for reducing the mobility of mercury in mined materials and lead-based paint on building materials and was implemented at the Red Devil Mine Site, another cinnabar mine site near KMS owned by BLM, prior to placement in an onsite repository. The encapsulant would be applied to all contaminated soil (approximately 200 cy) prior to placement in the repository via addition of a chemical agent and mechanical mixing with a backhoe or suitable equipment which converts leachable metals to nonleachable minerals.

The removal action would begin by identifying a suitable repository site. An area located at the end of an existing access road that leads from the riverbank where construction equipment would be offloaded by barge, to the top of the former Pit Area is being considered for a repository site. Figure 11 presents a conceptual plan for a proposed location and cross-section showing the approximate dimensions for the repository that would have sufficient capacity to hold all the waste. This area is relatively level with lower elevations in the depression of the larger pit area, and is heavily vegetated with some trees and dense underbrush of vegetation. It is not located near creeks or streams and can be developed so that final grades allow for drainage away from the repository. To accommodate the total volume of approximately 1,000 cy, the repository would require a footprint of approximately 30 feet wide by 100 feet long, and would extend to a maximum of 15 feet deep. The total volume of 1,000 cy is estimated to include 200 cy or soil, 200 cy of building demolition and construction debris, 300 cy of equipment and machinery, and a contingency volume of 300 cy to account for: (a) possible overexcavation of soil if post-excavation confirmation samples or visual observations indicate additional excavation is necessary to achieve cleanup levels; (b) a soil fluff factor of 1.5; and (c) the possibility that building foundations/footing materials extend deeper into the subsurface than estimated in the RSI inventory (E&E, 2008).

The onsite repository would be designed to accomplish the following objectives:

- Prevent exposure by dermal contact, inhalation, or incidental ingestion of impacted/encapsulated soils;
- Contain demolition and construction debris;
- Prevent access from burrowing animals;
- Provide stability against slope failure and resist erosion; and
- Limit infiltration and migration of water through the materials.

18 AAC 60 also requires that a landfill meet certain technical requirements, including the following:

- The bottom of the disposal site must be at least 4 feet above groundwater.
- The site must not be closer than 200 feet to any source of drinking water, including wells or surface water.
- The facility must be surrounded by a berm or natural barrier.
- The facility must be fenced.
- Daily cover material must be placed over the waste.
- At least two feet of final soil cover must be placed over the completed landfill.
- At least six inches of soil must be placed over the final cover to promote successful revegetation. Plant species used for revegetation of the site must be as recommended by the Alaska Plant Material Center (APMC).
- Final grades must promote surface water runoff without erosion or ponding and minimize the amount of water entering the waste cell.

Regulatory Requirements

The ADEC allows one-time disposal of inert/nonhazardous solid waste in a landfill as covered by 18 AAC 60 under the following conditions (from the State's *Application for Authorization For One-Time Disposal of Inert Waste;* Version 09-2010 [the Application]):

- Waste must be generated locally (within 25 miles of disposal site);
- Waste must consist solely of inert waste, including building debris, non-RACM (Regulated Asbestos Containing Material), scrap metal, and other construction and demolition waste;
- Waste must be generated from a single project;
- Total volume of waste may not exceed 1,000 cy;

- The landfill must be located in a remote area with no year-round ground access to a major road system (a system of connected roads with a total length of 100 miles or more);
- The landfill must be in a location where there is no reasonable access to an existing permitted landfill (all permitted landfills are more than 25 road miles away or have refused, in writing, to accept the waste);
- Active disposal at the site may not exceed one year in duration.

A repository could be constructed at the KMS to consolidate and dispose of removal action waste that would meet all the conditions listed above. The final design of the repository (e.g., whether a HDPE liner would be required beneath the waste and post-closure monitoring would be required) would be developed after results of the encapsulant bench scale testing were evaluated and it was determined whether the encapsulated soils could be handled as a solid (nonhazardous) waste.

The following section describes a conceptual plan that would meet the technical requirements of 18 AAC 60 for inert waste. Actual authorization by the State would require satisfactory completion and submittal of the design and application by the BLM and approval by ADEC.

Location

The location is proposed for the area shown on Figure 11. This location has several favorable characteristics:

- The location is near dirt roads that would be convenient for transporting waste from other locations at KMS to the monofill. Yet the entire KMS has no connection to a public road system and is only accessible by the Kuskokwim River.
- The location is in a cleared, formerly mined area, and surrounded by heavy forest vegetation that would provide visual screening.
- In the higher ground to the west, several elongated mounds or ridges help divert surface water from rainfall and snow melt around the location.
- The location is on top of a 150-foot-high bluff, at approximately a 500 feet distance from the Kuskokwim River. It is also located more than 500 feet distance from the nearest creek. In this location, groundwater is expected to be much deeper than four feet below the ground surface.
- The 2008 geophysical survey of this location indicated it was underlain by 15 to 20 feet of earth materials that can be readily excavated (Attachment A). Visual observations indicate that the upper materials are silty soils, with rock fragments, and probably deeply-weathered materials related to the underlying meta-sandstone bedrock. Excavation to create the necessary monofill volume below grade should yield suitable materials for both daily and final soil cover and for constructing a perimeter berm around the area.

Construction

A concept plan and details are shown on Figure 11. Material from an excavation approximately 30 feet wide, 100 feet long and a maximum 15 feet deep would be removed to create the necessary repository volume to dispose of no more than 1,000 cy of nonhazardous waste. The initial soil excavated would be stockpiled for later use in the final soil cover and topsoil layers. Further excavations would yield materials for construction of the perimeter berm and for stockpiling and reuse as daily cover material. The location would be fenced and gated to prevent intruders during operation and post-closure.

Operation

Waste material would be placed on the bottom of the excavation in lifts of relatively uniform thickness and compacted by trackwalking with a bulldozer to reduce post-closure settlement of the final cover. At the end of each day, the waste fill lift would be covered by at least six inches of compacted soil. All nonhazardous waste from the KMS would be placed in the monofill during a single summer construction season. All operations would be documented with monitoring records to be kept in a permanent location upon completion.

Closure

After all wastes have been placed, a final soil cover, at least two feet thick, would be placed such that the final ground surface is at least three feet above the original site grades. This should accommodate some future settlement of the final cover, keeping it well above the surrounding ground and maintaining drainage away from the monofill. The surface of the final cover would be higher in the center of the monofill to promote drainage off the cover. The cover layer would be capped with at least six inches of topsoil for seeding and revegetation in accordance with recommendations of the APMC. A closure report documenting the monofill construction, operation and closure would be submitted to ADEC within 180 days of final waste placement. Land use restrictions would be implemented at the repository to prevent activities that could compromise the soil cover. Prohibited activities would include: excavation, spreading, or disturbance of surface and subsurface soils and would be specified in deed restrictions at the KMS. Periodic monitoring and maintenance may be required to verify that the cover remains intact and performs as intended, unless if approved by ADEC, the potential long term environmental risks associated with the mobility of metals in impacted soil is reduced by encapsulation and could eliminate the requirement for post-closure monitoring.

3.2.3 Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill

This alternative involves excavation and offsite transportation and disposal of contaminated soil at a permitted landfill facility, and demolition of site structures and associated equipment and placement of demolition materials in an onsite monofill under an engineered cover system.

Implementation of this alternative is based on the following assumptions:

- The impacted soil cannot be appropriately pretreated onsite to reduce the potential mobility of metals and/or ADEC approval of onsite disposal in a repository as a solid waste (Alternative 2) could not be obtained.
- A suitable location for a “single waste” (inert solid waste constituting only demolition debris) monofill exists at the KMS and is managed by the BLM. The BLM would implement deed restrictions for future land use at the site. The monofill would be designed in accordance with 18 AAC 60.

Because the impacted soil would be excavated and removed from the site, institutional controls, such as fencing or deed restrictions would not be needed except for the demolition debris monofill, and long term monitoring and maintenance would not be required.

The components and descriptions of the technical aspects of this alternative are basically the same as under Alternative 2, which the exception of: (1) offsite disposal of impacted soil (instead of pretreatment with an encapsulant and placement in an onsite repository); and (2) only demolition debris would be placed in an onsite monofill without attempting to reduce the volume by burning wood building material. Additional capacity for onsite consolidation would be available for wood material without soil placement under this alternative, while still keeping the total volume of material from exceeding the 1,000 cy limit under 18 AAC 60. The limited amount of soil (approximately 10 cy) that contains DRO at concentrations above the cleanup level from the floor of the Large Shed (IA-8) would be segregated from the metals-containing soils, and would be handled separately and transported offsite for pretreatment and disposal at an offsite thermal treatment facility.

As described in Section 2.2 and shown on Figures 6, 9, and 10, approximately 200 cy of soil in the vicinity of the Camp and Mill Areas would be excavated, containerized, and transported offsite for disposal at a permitted landfill facility. Excavated material stockpiles would be sampled in accordance with disposal facility acceptance criteria, and would be segregated and disposed at an appropriate landfill (Class I, Class 2) depending on waste characterization results. Approximately 700 cy of demolition material would be placed in the monofill from demolition of all site structures, and approximately 300 cy of equipment and machinery would be decontaminated, drained, or cleaned as necessary to remove any potentially hazardous components and render them solid waste from demolition.

The following materials that may potentially be hazardous, would be handled separately and disposed offsite:

- The small amount of yellow paint on a small shed in the Mill Area (approximately 80 square feet) that exceeds ADEC cleanup criteria for lead;
- A drum in the Camp Area containing a reddish colored sandy material (possibly residual processed ore) that contained a high level of mercury above the ADEC cleanup criteria;
- Any decontamination materials from draining lubricants or fuels if present in engines, equipment, or machinery, and batteries.

Standard excavation technologies using conventional earthmoving construction equipment such as backhoes, front end loaders, and bulldozers would be suitable for excavation and movement or placement of soil or other cover materials, and for demolition of structures. This equipment and shipping containers would be mobilized to and from the site via barge on the river and offloaded/onloaded at the bottom of the access road that ends at the river.

During excavation and offsite disposal of impacted soil, shipping containers would be used to transport the material from the KMS to the disposal facilities. The shipping containers would be lined with visqueen and covered. The containers would be designed to transport the excavated material without the need for secondary containment in drams or other smaller containment vessels.

Prior to transporting excavated materials to the disposal site, composite samples would be collected for TCLP analysis. Prior to shipment, a waste characterization profile would be conducted. Both U.S. and Canadian manifests would be required to accompany the waste during transport through Intemational and Canadian waters en route to Seattle, Washington. From Seattle, the material would then be transported by rail or truck to a suitable landfill depending on its waste characterization profile. The landfill identified for disposal of hazardous materials is in Arlington, Oregon, and nonhazardous soils and debris is in Seattle.

Techniques and proposed handling and management during the removal action excavation, demolition, and construction of the monofill activities otherwise are the same as described under Alternative 2.

Removal Action Sequence

The removal action is anticipated to be implemented under the following sequence of tasks:

Demolition

- Demolish 11 wooden structures and remove and segregate any equipment, machinery, or vehicles; decontaminate/drain any equipment, machinery, or vehicles; collect red sand in drum and any other potentially hazardous waste in drums for offsite disposal.

Excavation

- Prepare stockpile staging area;
- Excavate shallow soils from Camp and Mill Areas and stockpile;
- Conduct confirmation sampling in excavation bottoms; overexcavate as necessary until laboratory confirmation sample results indicate all soils remaining within excavation areas contain concentrations of COCs below cleanup levels;
- Regrade and shape the shallow excavation areas as necessary, to ensure positive drainage and minimize erosion.

Monofill Construction

- Clear vegetation from the existing access road (approximately 1.3 aces) that is partially grown over but reported to be level and intact;
- Clear and grub an approximate 0.25 acre area for excavation of the repository;
- Prepare stockpile storage area for excavated material that will later be used as cover;
- Excavate a 30 foot by 100 foot rectangular excavation (bottom dimensions) with 1:2 sloped sidewalls;
- Stockpile material for backfill;
- Backfill excavation with 1,000 cy of stockpiled demolition debris from the removal action;
- Construct a cover with stockpiled material and revegetate;
- Install perimeter fencing posted with signage.

3.2.4 Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

This alternative involves excavating the impacted soil, demolishing site structures and equipment, and transporting all material to permitted offsite disposal facilities. Because all of the impacted materials and demolition debris would be removed from the site, institutional controls, such as fencing or deed restrictions would not be needed. Confirmatory sampling would be performed to verify complete removal of materials exceeding cleanup levels, and long term monitoring and maintenance would not be required.

Implementation of this alternative is based on the following assumptions:

- The impacted soil could not be appropriately pretreated onsite to reduce the potential mobility of metals and/or ADEC approval of onsite disposal in a repository as a solid waste (Alternative 2) could not be obtained.
- A suitable location for an onsite demolition debris monofill does not exist at the KMS and/or ADEC approval to leave the debris onsite (Alternative 3) could not be obtained.

Because the impacted soil would be excavated and removed from the site, institutional controls, such as fencing or deed restrictions would not be needed. Confirmatory sampling would be performed to verify complete removal of materials exceeding the RAOs, and long term monitoring and maintenance would not be required.

The components and descriptions of the technical aspects of this alternative are basically the same as under Alternative 3, which the exception of offsite disposal of demolition debris (instead of placement in an onsite monofill). The limited amount of soil (approximately 10 cy) that contains DRO at concentrations above the cleanup level from the floor of the Large Shed (IA-8) would be segregated from the metals-containing soils, and would be handled separately and transported offsite for pretreatment and disposal at an offsite thermal treatment facility.

As described in Section 2.2 and shown on Figures 6, 9, and 10, approximately 200 cy of soil in the vicinity of the Camp and Mill Areas would be excavated, containerized, and transported offsite for disposal at a permitted landfill facility. Excavated material stockpiles would be sampled in accordance with disposal facility acceptance criteria, and would be segregated and disposed at an appropriate landfill (Class I, Class 2) depending on waste characterization results. Approximately 1,000 cy of demolition debris would also be containerized, and transported offsite for disposal at a permitted landfill facility: 700 cy of demolition material from demolition of all site structures, and approximately 300 cy of equipment and machinery that would be decontaminated, drained, or cleaned as necessary to remove any potentially hazardous components and render them solid waste from demolition.

The following materials that may potentially be hazardous, would be handled separately and disposed offsite at an appropriate landfill facility:

- The small amount of yellow paint on a small shed in the Mill Area (approximately 80 square feet) that exceeds ADEC cleanup criteria for lead;
- A drum in the Camp Area containing a reddish colored sandy material (possibly residual processed ore) that contained a high level of mercury above the ADEC cleanup criteria;
- Any decontamination materials from draining lubricants or fuels if present in engines, equipment, or machinery, and batteries.

Standard excavation technologies using conventional earthmoving construction equipment such as backhoes, front end loaders, and bulldozers would be suitable for excavation and movement of soil, and for demolition of structures. This equipment and shipping containers would be mobilized to and from the site via barge on the river and offloaded/onloaded at the bottom of the access road that ends at the river.

Prior to transporting excavated materials to the disposal site, composite samples from impacted soil would be collected for TCLP analysis. Prior to shipment, a waste characterization profile would be conducted. Both U.S. and Canadian manifests would be required to accompany the waste during transport through Intemational and Canadian waters en route to Seattle. From Seattle, the material would then be transported by rail or truck to a suitable landfill depending on its waste characterization profile. The landfill identified for disposal of hazardous materials is in Arlington, Oregon, and nonhazardous soils and debris is in Seattle.

Techniques and proposed handling and management during the removal action excavation and demolition activities otherwise are the same as described under Alternatives 2 and 3.

Removal Action Sequence

The removal action is anticipated to be implemented under the following sequence of tasks:

Demolition

- Demolish 11 wooden structures and remove and segregate any equipment, machinery, or vehicles; decontaminate/drain any equipment, machinery, or vehicles; collect red sand in drum and any other potentially hazardous waste in drums for offsite disposal.

Excavation

- Prepare stockpile staging area;
- Excavate shallow soils from Camp and Mill Areas and stockpile;
- Conduct confirmation sampling in excavation bottoms; overexcavate as necessary until laboratory confirmation sample results indicate all soils remaining within excavation areas contain concentrations of COCs below cleanup levels;
- Regrade and shape the shallow excavation areas as necessary, to ensure positive drainage and minimize erosion.

Offsite Disposal

- Conduct waste characterization profile sampling of stockpiled soil;
- Mobilize shipping containers to the site;
- Load soil and demolition debris into separate containers from the stockpile staging area;
- Transport and dispose soil and demolition debris to appropriate permitted landfill facilities.

4.0 ANALYSIS OF ALTERNATIVES

This section presents the analysis and comparison of each of the removal action alternatives based on the evaluation criteria described in the EE/CA Guidance (USEPA, 1993b). The purpose of the analysis is to assess each alternative relative to the evaluation criteria presented in the EE/CA Guidance, so that a comparison of each alternative's performance can be made to support the selection of the preferred alternative recommended for implementation as the NTCRA in Section 5.0.

4.1 Evaluation Criteria

The four removal action alternatives are evaluated and compared below with respect to effectiveness, implementability, and cost following these three evaluation criteria provided in the EE/CA Guidance (USEPA, 1993b):

Effectiveness

- Overall protection of human health and the environment
- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Compliance with ARARs

Implementability

- Technical feasibility
- Availability of services and materials
- Administrative feasibility

Cost

- Direct capital costs
- Indirect capital costs
- Annual post-removal site control or Operations and Maintenance (O&M) costs

4.2 Detailed Analysis of Removal Action Alternatives

As specified in EE/CA guidance, the purpose of the detailed analysis in the EE/CA is to evaluate each alternative for their effectiveness, implementability, and cost and ability to achieve the RAOs identified in Section 2.0. The four alternatives under consideration are:

- Alternative 1 - No Action

- Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository
- Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill
- Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

Results of the alternatives evaluation using the criteria identified in Section 4.1 are summarized in Table 16. Capital costs and annual O&M costs are summarized in Appendix B. The evaluation and comparison of alternatives are presented in the following subsections.

4.2.1 Alternative 1 - No Action

Effectiveness

The No Action Alternative was retained for comparison purposes, pursuant to the NCP. The short- and long-term effectiveness of this alternative is low. Taking no action to remove impacted soils would mean that the site remains in its present condition, with no reduction in contaminant concentrations. Alternative 1 would not be effective because it would not achieve RAOs and thus is not protective of human health or the environment. Alternative 1 does not comply with ARARs. In the short term, the No Action Alternative would likely pose no additional threats to human health or the environment compared to current site conditions because the site is remote, unoccupied, and has been in its current condition for a number of years. Long term risk reduction would only occur through natural attenuation mechanisms, which are not expected to be significant and would be unknown under this alternative since no monitoring would occur.

Implementability

This alternative is technically feasible to implement and would not be dependent on the availability of services and materials. The No Action Alternative is not administratively feasible, and would be unacceptable because it would not achieve RAOs.

Cost

Neither monitoring nor operations and maintenance would be implemented under Alternative 1; therefore, there are no costs associated with this alternative.

Uncertainties and Assumptions

With the exception of unknown degree to which natural attenuation of COCs may occur, there are no significant uncertainties or assumptions associated with the performance of this alternative.

4.2.2 Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository

Effectiveness

This alternative would meet site-specific RAOs, and comply with the potential ARARs identified. This alternative would provide protection of human health and the environment and generally achieve RAOs, because the risks associated with the COCs and complete exposure pathways are mitigated by physically isolating the soils in a properly constructed and maintained capped repository. There would be no reduction in the mass or toxicity of COCs, however, since the impacted materials would still remain onsite but consolidated in a repository. This alternative would effectively reduce contaminant mobility at the site by removing impacted soil and disposing of the waste in a lined and capped repository along with demolition debris. Confirmation samples would be collected and submitted for laboratory analysis to document that all impacted materials have been removed and remaining soil does not contain concentrations of COCs above cleanup levels. Long term monitoring and control programs would be established to ensure continued effectiveness.

This alternative involves limited shallow excavation in three areas of the site, and construction of the repository in another area, all of which are accessible from existing site roads. Although there would be some short term risks from removal of impacted soils and demolition of site structures that would have to be handled and relocated, these risks can be controlled. Risks to workers during construction would be managed using standard health and safety practices such as dust suppression to protect workers from incidental inhalation and ingestion of dust particulates. Short-term effectiveness would be achieved through typical dust control and other best management practices identified and implemented as required, as well as the use of appropriate personnel protective equipment (PPE) to reduce exposure to impacted materials and demolition debris.

No significant risks to members of the community during removal actions have been identified. No environmental long term impacts would result from the implementation of the removal action.

This alternative would provide a high degree of effectiveness and would achieve RAOs and ARARs. The long-term effectiveness would depend on an O&M plan ensuring the integrity of the repository and its cover.

The use of signs and deed restrictions to prevent future excavation at the repository would be effective in managing the risks posed by contaminants remaining onsite. Inspection and maintenance of the cap will be required on a regular basis to meet this criterion over the long term. The repository area would be fenced off to prevent access and signage posted.

Implementability

This alternative is both technically and administratively feasible. Soil capping technologies are reliable, and the effectiveness of this remedy can be monitored easily. The removal action work could implemented using conventional construction practices. Cap construction materials would be available from an onsite borrow source.

This alternative involves limited shallow excavation in three areas of the site, and construction of the repository in another area, all of which are accessible from existing site roads. It is anticipated that construction could be completed and RAOs achieved within a single construction season.

Although some difficulty would be involved in transporting the required equipment, material, and personnel to this remote site, all the required services and materials are available. The Kuskokwim River is navigable by barges and shallow-draft boats.

Some minor road clearing and site preparation work, including construction of staging, loading, and decontamination areas would be required to prepare the site for the removal action. Temporary stockpiles of contaminated materials would be created prior to placement in the onsite repository. The stockpile area would be prepared by placing visqueen under removed materials, and the area bermed to contain runoff and soil.

Periodic inspections and maintenance, as needed, would ensure the long term integrity and effectiveness of the cap.

Cost

The total estimated cost for Alternative 2 is approximately $1,642,000 (Appendix B; Table B-2). This includes equipment and materials mobilization, onsite earthwork to excavate soil and demolish site structures, treat soil, prepare the staging and repository areas, construction of the repository, fencing, post-removal confirmatory sampling, and demobilization. Annual O&M costs are estimated to be approximately $5,000, and include inspection of the site to ensure the integrity of the security features and cap, and preparation of a brief summary report documenting the results.

Uncertainties and Assumptions

There is some uncertainty whether material to be excavated from the Retort Mound may contain mercury in a more mobile form than materials from other portions of the site; therefore, a pretreatment bench scale study on a sample of material using a commercially available encapsulant would need to be conducted.

There is limited uncertainty regarding selection of a suitable repository area. Previous investigations and surveys indicate the proposed repository site at the former Pit Area would be suitable.

The cover would be designed to minimize surface water intrusion. The design would also consider stresses imposed by snow loads and freezing ground conditions. Cover design depends on the physical and hydraulic properties of the cover material. The availability of suitable cover material at the site has been preliminarily assessed, and soil from the repository excavation in the Pit Area could be used as cover material.

There is limited uncertainty associated with this alternative relating to the amount of post-removal residual contamination that would remain. The site has been adequately characterized and the results of the SRE indicates post-removal risks would be reduced to acceptable ranges if all cleanup levels are met in excavation areas, which will be verified based on the results of confirmation sampling.

There is limited uncertainty regarding the volume of materials within the removal areas, based on results of previous investigations and sample density.

Conceptual cap designs would be evaluated in detail during remedial design, including cap requirements to limit movement of COCs. The cover would be designed of material that would not degrade the quality of runoff water as it flows from the repository.

The most significant uncertainty is in the cost estimate. Without a visit to assess site-specific conditions such as site access and transportation of equipment, physical conditions of the proposed repository, availability of suitable staging areas, and the amount of site preparation necessary, vendors and contractors cannot provide a detailed estimate of the tasks, equipment, labor and costs involved to implement the alternative.

Once a removal action is selected, a detailed cost estimate would need to be prepared.

4.2.3 Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill

Effectiveness

This alternative would meet site-specific RAOs, and comply with the potential ARARs identified. This alternative would provide protection of human health and the environment, because it would effectively reduce contaminant mobility at the site by removing impacted soil and disposing of the waste offsite, and demolition debris would be consolidated onsite in a monofill. Contaminant toxicity and volume at the site would be reduced by transferring the risk to a managed offsite disposal facility.

Confirmation samples would be collected and submitted for laboratory analysis to document that all impacted materials have been removed to cleanup levels. Excavation and offsite disposal protects human health and the environment by removing impacted materials with metals concentrations above RAOs, and disposing of them in a licensed and properly managed disposal facility.

This alternative involves limited shallow excavation in three areas of the site, and construction of the monofill in another area, all of which are accessible from existing site roads. Although there would be some short term risks from removal of impacted soils and demolition of site structures that would have to be handled and transported offsite or relocated, these risks can be controlled. Risks to workers during construction would be managed using standard health and safety practices such as dust suppression to protect workers from incidental inhalation and ingestion of dust particulates. Short term risks of exposure to the contaminated material may occur during excavation and transport of materials to the disposal facility. Short-term effectiveness would be achieved through typical dust control and other best management practices identified and implemented as required, as well as the use of appropriate PPE to reduce exposure to impacted materials and demolition debris.

No significant risks to members of the community during removal actions have been identified. No environmental long-term impacts would result from the implementation of the removal action. Long-term effectiveness and permanence would be achieved through removal of impacted materials.

This alternative would provide a high degree of effectiveness and would achieve RAOs and ARARs.

The use of signs and deed restrictions to prevent future excavation at the monofill would be effective in managing the demolition debris. The monofill area would be fenced off to prevent access and signage posted.

Implementability

This alternative is technically feasible and readily implementable since the equipment and labor resources necessary for excavation, removal, transportation and disposal would be available in the region. Conventional earth moving equipment would be used for excavation and placement of materials within prepared containers. Both U.S. and Canadian manifests would be required prior to transport to Seattle via cargo vessel.

This alternative involves limited shallow excavation in three areas of the site, and construction of the monofill in another area, all of which are accessible from existing site roads. It is anticipated that construction could be completed and RAOs achieved within a single construction season.

Although some difficulty would be involved in transporting the required equipment, material, and personnel to this remote site, all the required services and materials are available. The Kuskokwim River is navigable by barges and shallow-draft boats.

Some minor road clearing and site preparation work, including construction of staging, loading, and decontamination areas would be required to prepare the site for the removal action. Temporary stockpiles of contaminated materials would be created prior to placement in containers and transportation to an offsite landfill. The stockpile area would be prepared by placing visqueen under removed materials, and the area bermed to contain runoff and soil.

Cost

The total estimated cost for this alternative is approximately $2,708,000 (Appendix B; Table B-3). This includes equipment and materials mobilization, onsite earthwork to prepare the staging and monofill areas, excavation of soil and demolition of site structures and equipment, construction of the monofill, fencing, post-removal confirmatory sampling, offsite disposal of impacted materials, and demobilization. Annual O&M costs are estimated to be approximately $5,000, and include inspection of the site to ensure the integrity of the security features and cap, and preparation of a brief summary report documenting the results.

Uncertainties and Assumptions

There is some uncertainty whether material to be excavated from the Retort Mound may contain mercury in a more mobile form than materials from other portions of the site; therefore, waste characterization sampling prior to offsite disposal would need to be conducted to determine the type of landfill that could accept the waste and any pretreatment requirements.

There is limited uncertainty regarding selection of a suitable monofill area. Previous investigations and surveys indicate the proposed monofill site at the former Pit Area would be suitable.

The cover would be designed to minimize surface water intrusion. The design would also consider stresses imposed by snow loads and freezing ground conditions. Cover design depends on the physical and hydraulic properties of the cover material. The availability of suitable cover material at the site has been preliminarily assessed, and soil from the repository excavation in the Pit Area could be used as cover material.

There is limited uncertainty associated with this alternative relating to the amount of post-removal residual contamination that would remain. The site has been adequately characterized and the results of the SRE indicates post-removal risks would be reduced to acceptable ranges if all cleanup levels are met in excavation areas, which will be verified based on the results of confirmation sampling.

There is limited uncertainty regarding the volume of materials within the removal areas, based on results of previous investigations and sample density.

The most significant uncertainty is in the cost estimate. Without a visit to assess site-specific conditions such as site access and transportation of equipment, physical conditions of the proposed monofill, availability of suitable staging areas, and the amount of site preparation necessary, vendors and contractors cannot provide a detailed estimate of the tasks, equipment, labor and costs involved to implement the alternative.

Once a removal action is selected, a detailed cost estimate would need to be prepared.

4.2.4 Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

Effectiveness

This alternative would meet site-specific RAOs, and comply with the potential ARARs identified. This alternative would provide protection of human health and the environment, because it would effectively reduce contaminant mobility at the site by removing impacted soil and site structures and equipment, and disposing of the waste offsite. Contaminant toxicity and volume at the site would be reduced by transferring the risk to a managed offsite disposal facility.

Confirmation samples would be collected and submitted for laboratory analysis to document that all impacted materials have been removed to cleanup levels. Excavation and offsite disposal protects human health and the environment by removing impacted materials with metals concentrations above RAOs, and disposing of them in a licensed and properly managed disposal facility.

This alternative involves limited shallow excavation in three areas of the site, which are accessible from existing site roads. Although there would be some short term risks from removal of impacted soils and demolition of site structures that would have to be handled and transported offsite, these risks can be controlled. Risks to workers during construction would be managed using standard health and safety practices such as dust suppression to protect workers from incidental inhalation and ingestion of dust particulates. Short term risks of exposure to the contaminated material may occur during excavation and transport of materials to the disposal facility. Short-term effectiveness would be achieved through typical dust control and other best management practices identified and implemented as required, as well as the use of appropriate PPE to reduce exposure to impacted materials and demolition debris.

No significant risks to members of the community during removal actions have been identified. No environmental long term impacts would result from the implementation of the removal action. Long-term effectiveness and permanence would be achieved through removal of impacted materials.

This alternative would provide a high degree of effectiveness and would achieve RAOs and ARARs.

Implementability

This alternative is technically feasible and readily implementable since the equipment and labor resources necessary for excavation, removal, transportation and disposal would be available in the region. Conventional earth moving equipment would be used for excavation and placement of materials within prepared containers. Both U.S. and Canadian manifests would be required prior to transport to Seattle via cargo vessel.

This alternative involves limited shallow excavation in three areas of the site, which are accessible from existing site roads. It is anticipated that construction could be completed and RAOs achieved within a single construction season.

Although some difficulty would be involved in transporting the required equipment, material, and personnel to this remote site, all the required services and materials are available. The Kuskokwim River is navigable by barges and shallow-draft boats.

Some minor road clearing and site preparation work, including construction of staging, loading, and decontamination areas would be required to prepare the site for the removal action. Temporary stockpiles of contaminated materials would be created prior to placement in containers and transportation to an offsite landfill. The stockpile area would be prepared by placing visqueen under removed materials, and the area bermed to contain runoff and soil.

Cost

The total estimated cost for this alternative is approximately $2,815,000 (Appendix B; Table B-4). This includes equipment and materials mobilization, excavation of soil and demolition of site structures and equipment, post-removal confirmatory sampling, offsite disposal of impacted materials, and demobilization.

Uncertainties and Assumptions

There is some uncertainty whether material to be excavated from the Retort Mound may contain mercury in a more mobile form than materials from other portions of the site; therefore, waste characterization sampling prior to offsite disposal would need to be conducted to determine the type of landfill that could accept the waste and any pretreatment requirements.

There is limited uncertainty associated with this alternative relating to the amount of post-removal residual contamination that would remain. The site has been adequately characterized and the results of the SRE indicates post-removal risks would be reduced to acceptable ranges if all cleanup levels are met in excavation areas, which will be verified based on the results of confirmation sampling.

There is limited uncertainty regarding the volume of materials within the removal areas, based on results of previous investigations and sample density.

The most significant uncertainty is in the cost estimate. Without a visit to assess site-specific conditions such as site access and transportation of equipment, availability of suitable staging areas, and the amount of site preparation necessary, vendors and contractors cannot provide a detailed estimate of the tasks, equipment, labor and costs involved to implement the alternative.

Once a removal action is selected, a detailed cost estimate would need to be prepared.

4.3 Comparative Analysis of Removal Action Alternatives

This section presents a comparative analysis of alternatives to identify the relative advantages and disadvantages of each alternative based on their effectiveness, implementability, and cost. Although Alternative 1, the No Action Alternative, would not meet the threshold criteria of protection of human health and compliance with ARARs, this alternative is used as a baseline for comparison to the other alternatives.

4.3.1 Effectiveness

Alternative 1 would be the least effective alternative in reducing potential risks to human health and the environment, and would not meet RAOs or comply with ARARs. Alternatives 2, 3, and 4 would all be more effective than Alternative 1, because they would physically isolate or remove contaminants from receptor contact and would comply with potential ARARs. Exposure pathways to receptors would be eliminated by reducing direct contact with, and mobility of, the COCs. Alternative 4 would provide the highest level of protection of human health and the environment and long term effectiveness, because it is the only alternative that completely removes all of the contamination and site structures and equipment from the site, and would not require any long term monitoring or O&M. Both Alternatives 2 and 3 create a new material disposal site with their own long-tem management requirements. Alternative 4 would comply with all ARARs. Alternatives 2, 3 and 4 present the same short term risks to workers and the environment from airborne dust and material contact with site workers during excavation and material transfer activities. Alternatives 3 and 4 which involve offsite transportation and disposal, would pose some short term risks to the community during transport.

Alternatives 2, 3, and 4 could all be completed within a single construction season. Under Alternative 2, toxicity and volume onsite are not reduced; rather, they are consolidated onsite and isolated. Under Alternatives 3 and 4, they are reduced onsite through removal and disposal in a permitted, managed disposal facility offsite, but there would be no reduction in toxicity or volume of the original material. Alternatives 2, 3, and 4 would reduce or eliminate potential exposure pathways to human and ecological receptors.

4.3.2 Implementability

Alternative 1 would be feasible from a technical and administrative perspective and would be easily implemented in general, because no actions would be taken. Of the three remaining alternatives, Alternative 2 would be the easiest to implement technically because all of the tasks would be conducted and completed onsite; Alternatives 3 and 4 would require an additional level of effort associated with offsite transportation and disposal of waste. Alternative 4 requires the least construction activities of any of the alternatives, except for Alternative 1, because it would not involve onsite construction and placement of waste in a repository or monofill. Alternatives 2 and 3 are administratively feasible with deed restrictions on land use associated with the repository or monofill, and Alternative 4 is administratively feasible with no deed restrictions.

Alternatives 2, 3, and 4 are all implementable, and the construction methods to be used rely on available technologies for which experienced contractors are available within the region. Under Alternatives 3 and 4, impacted soils could easily be transported offsite to a permitted disposal facility.

Under Alternatives 2 and 3, there appears to be sufficient space and conditions would be acceptable to construct a repository or monofill in the Pit Area. Technical feasibility challenges exist in transporting equipment and materials to and from the KMS due to its remote location; however, based on preliminary research during preparation of cost estimates, the materials, services, and equipment could be procured locally and regionally.

Alternative 4 poses similar technical transportation challenges to Alternative 3 with regard to transporting the number of containers required to transfer materials offsite. A staging area would have to be created to store containers, excavated material, and equipment necessary to excavate materials and load them into the containers. Limited numbers of containers can be transported to the site and stored there at any one time. Alternative 4 would be slightly more difficult to implement than Alternative 3 because the volume of material would be higher associated with transporting equipment and containers to and from the site.

Alternative 4 would be the most difficult to implement, followed by Alternative 3 due to the additional level of effort and costs associated with offsite disposal.

4.3.3 Cost

There are no associated costs with Alternative 1, since there are no activities associated with its implementation. Costs for implementation of Alternatives 2 through 4 are estimated as follows:

Alternative 2 – Excavation and Onsite Consolidation of Soil and Debris in a Repository

- Total Cost: $1,642,000
- Capital Cost: $1,617,000
- O&M Cost: $25,000

Alternative 3 – Excavation and Offsite Disposal of Soil and Onsite Consolidation of Debris in a Monofill

- Total Cost: $2,708,000
- Capital Cost: $2,683,000
- O&M Cost: $25,000

Alternative 4 - Excavation and Offsite Disposal of Soil and Debris

- Total Cost: $2,815,000
- Capital Cost: $2,815,000
- O&M Cost: $0

5.0 RECOMMENDED REMOVAL ACTION ALTERNATIVE

Based on the alternatives evaluation using EE/CA guidance, and from the comparative analysis of the removal action alternatives, Alternative 2, which involves consolidation of all waste in an onsite repository, is recommended for the KMS. This alternative would meet the threshold criteria of human health and environmental protection and compliance with ARARs, would be effective and implementable pending ADEC approval, and has a significantly lower cost than Alternatives 3 and 4. Although it involves long term monitoring of the repository and deed restrictions, all of the waste would be managed onsite at a significant cost savings compared to offsite disposal, and all of the technical aspects of this alternative are proven and have been implemented at other similar sites.

The following steps would be required to implement Alternative 2:

- Perform a bench scale study on encapsulation of Retort Mound soils
- Select a staging area for equipment and stockpiles
- Evaluate and refine the repository design
- Prepare design drawings and specifications for the selected repository design
- Address deed restrictions, land use agreements, regulatory approvals
- Conduct a site visit for prospective contractors
- Complete a detailed cost estimate
- Contract for construction.

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TABLES

FIGURES

APPENDIX A

SUMMARY OF 2011 FIELD INVESTIGATION RESULTS

APPENDIX B

REMOVAL ACTION ALTERNATIVE COST ESTIMATES

ATTACHMENT 1

GEOPHYISCAL TEST RESULTS

ATTACHMENT 2

ProUCL DOCUMENTATION

ATTACHMENT 3

HUMAN HEALTH RISK ASSESSMENT DOCUMENTATION

ATTACHMENT 4

KOLMAKOF SITE DATA SUMMARY 2007-2011