FINAL
Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization

Supplement to Remedial Investigation
Red Devil Mine, Alaska

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List of Abbreviations and Acronyms

bgs	below ground surface
BLM	Bureau of Land Management
BTEX	benzene, toluene, ethylbenzene, xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	contaminants of concern
COPCs	contaminants of potential concern
DOI	U.S. Department of the Interior
DQO	Data Quality Objective
DRO	diesel range organics
E & E	Ecology and Environment, Inc.
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FCM	food chain multiplier
FS	feasibility study
GRO	gasoline range organics
HHRA	human health risk assessment
mg/kg	milligrams per kilogram
NAVD88	North American Vertical Datum 1988
NTCRA	non-time critical removal action
PCBs	polychlorinated biphenyls
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RDM	Red Devil Mine
RG	remedial goal

List of Acronyms and Abbreviations (cont.)

RI	remedial investigation
RRO	residual range organics
SPLP	synthetic precipitation leaching procedure
SSE	selective sequential extraction
SVOCs	semivolatile organic compounds
TAL	target analyte list
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UCL	upper confidence limit
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
XRF	X-ray fluorescence (spectroscopy)

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Introduction

This document is a supplement to the final Remedial Investigation (RI)/Feasibility Study (FS) Work Plan for the Red Devil Mine (RDM) Site, Red Devil, Alaska (E & E 2011). The RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) in southwest Alaska. The BLM initiated an RI/FS at the RDM in 2009 pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead agency authority. An RI was performed by Ecology and Environment, Inc., (E & E) on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J. Results of the RI are presented in the final Remedial Investigation Report, Red Devil Mine, Alaska (E & E 2014a). An FS for the RDM is under development.

Data collected during the RI were used to define the site physical setting, the nature and extent of contamination, and the fate and transport of contaminants. The RI results were used to assess risk to human health and the environment due to exposure to site contaminants. This work plan supplement addresses data gaps associated with soil, groundwater, and Kuskokwim River sediments that were identified as part of the development of site-wide remedial alternatives during the preparation of the FS. This work plan supplement also addresses changes in the groundwater and surface water monitoring network and possible changes to the groundwater and surface water conditions at the RDM stemming from implementation of a non-time-critical removal action (NTCRA) performed by the BLM at the RDM during the summer of 2014. E & E prepared this work plan supplement on behalf of the BLM under Delivery Order Number L14PB00938 and BLM National Environmental Services Blanket Purchase Agreement Number L14PA00149.

Historical mining activities at the RDM included underground and surface mining. Ore processing included crushing, retorting/furnacing, milling, and flotation. Historical mining operations left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. The final RI/FS work plan and final RI report provide detailed background information on the RDM and information on the regulatory framework for the RI/FS and planned supplemental RI work addressed in this document. That information is not repeated in this work plan supplement.

Existing data and information regarding the RDM are presented in the final RI report and other documents and are summarized in Chapter 2.

1.1 Purpose and Objectives

The purpose of this work plan supplement is to present the supplemental RI activities, procedures, and methods that will be conducted to augment existing data to characterize soil, groundwater, surface water, and Kuskokwim River sediment. The objectives of the planned supplemental RI activities are to address data gaps identified during the development of the FS, address changes to site conditions resulting from the NTCRA, and support the development of site-wide remedial alternatives at the RDM.

1.2 Document Organization

The work plan supplement is organized into the following chapters.

Chapter 1, Introduction – Describes the purpose and objectives of the supplemental RI activities and baseline monitoring.

Chapter 2, Evaluation of Existing Information – Summarizes existing information and identifies data gaps.

Chapter 3, Data Quality Objectives – Identifies the major study questions related to the supplemental RI activities that need to be answered and outlines how the study questions will be addressed through supplemental RI activities.

Chapter 4, Overview of Supplemental RI Study Design – Summarizes the study design concept for the supplemental RI activities and baseline monitoring based on the outputs of the Data Quality Objectives (DQOs) process.

Chapter 5, References – Lists the guidance documents and literature resources cited in this document.

Appendices

A	Field Sampling Plan
B	Quality Assurance Project Plan Addendum
C	Health and Safety Plan

2 Evaluation of Existing Information

Existing data and information regarding the RDM are presented in the final RI report and other documents. Key RI findings and information pertinent to the supplemental RI characterization for soil, groundwater, surface water, and Kuskokwim River sediment are summarized in Sections 2.1 through 2.4. Data gaps identified during the development of the FS are summarized in Section 2.5.

2.1 Red Devil Mine Remedial Investigation

Results of the RI are presented in the final Remedial Investigation Report, Red Devil Mine, Alaska (E & E 2014a).

2.1.1 Soil

Objectives of the surface soil and subsurface soil characterizations are detailed in Chapter 2 of the final RI report and are summarized briefly below:

- Determine the lateral and vertical extent of tailings/waste rock.
- Characterize the nature and extent of contaminants of potential concern (COPCs) in tailings/waste rock and surface and subsurface soil.
- Identify and characterize possible tailings/waste rock at the reservoir dam.
- Characterize the soils within the Surface Mined Area.
- Identify tailings/waste rock within alluvial deposits of Red Devil Creek, including its delta in the Kuskokwim River.
- Identify mining-related material within alluvial deposits of the Dolly Sluice delta and Rice Sluice delta.
- Assess soil characteristics that may affect contaminant fate, transport, bioavailability, and bioaccumulation.
- Characterize chemical and physical characteristics of soils in background areas.
- Provide data for the human health risk assessment (HHRA) and the ecological risk assessment (ERA) to assess potential exposure to COPCs.
- Characterize geotechnical properties of tailings/waste rock and soils that may be subject to excavation and construction activities.

Characterization of surface soil was performed in 2010 and 2011. Characterization of subsurface soil and additional characterization of surface soil were conducted in 2011. Additional subsurface soil characterization was conducted in September 2012 in an attempt to identify and characterize areas of natural mineralization in the Surface Mined Area.

Soil characterization included visual inspection of lithological and mineralogical characteristics; X-ray fluorescence spectroscopy (XRF) field screening for total metals; and laboratory analysis for total target analyte list (TAL) inorganic elements; mercury selective sequential extraction (SSE), arsenic speciation, arsenic bioavailability, synthetic precipitation leaching procedure TAL metals, toxicity characteristic leaching procedure (TCLP) Resource Conservation and Recovery Act (RCRA) metals, semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), diesel range organics (DRO), and residual range organics (RRO). In addition, selected soil samples were analyzed for geotechnical parameters, including grain size/Atterburg limits, moisture content, compaction, direct shear, and permeability.

Results of the RI soil characterization are presented in Chapters 3 through 7 of the final RI report. Locations of RI soil borings are illustrated in Figure 2-1. Key RI results are summarized below.

Soil Types, Characteristics, and Distribution

The distribution and arrangement of soils and mine and ore processing wastes at the site play a significant role in determining the nature and extent of contamination, as well as the fate and transport of contaminants at the RDM. Native soils at the RDM site consist of loess, soils derived from Kuskokwim Group bedrock and alluvial deposits associated with the Kuskokwim River and Red Devil Creek. Non-native materials at the site comprise various types of mining and ore processing wastes and fill. Mining-related waste consists of waste rock, dozed and sluiced overburden, flotation tailings, and tailings (thermally processed ore, also known as calcines, burnt ore, and retorted ore). Tailings and waste rock are typically mixed and are referred to as tailings/waste rock in the final RI report and this document. Native materials have been removed, disturbed, relocated, covered, and/or mixed with other native soils and/or mine waste and tailings and fill locally across the site.

Multiple lines of evidence were used to identify the various mine wastes and soil types and to define their distribution. In conjunction with other information, visual observations of the presence of red porous rock and rock fragments with a distinctive rust-colored rind are shown to be useful to identify the presence of tailings. Visual observations of the presence of primary ore minerals cinnabar (mercury sulfide) and stibnite (antimony sulfide), and related gangue minerals realgar and orpiment (arsenic sulfides), and calcite and quartz veins, combined with other information, are useful to identify waste rock and naturally mineralized bedrock and rock fragments within native soils. Combined with other information, results of mercury SSE analysis is useful to identify the presence of cinnabar and other forms of mercury in soils.

Results of the efforts to delineate the lateral and vertical extents of tailings/waste rock, other mine wastes, and soil types are presented in Chapter 3 of the RI report.

Fate and Transport of Inorganics in Soil

The occurrence of contaminants at the RDM is chiefly dependent on the distribution of mine waste materials, consisting primarily of tailings, waste rock, and flotation tailings. Inorganics also are present in disturbed soils and sluiced overburden from the Surface Mined Area. The present distribution of these materials is explained by historical mining and ore processing activities and subsequent modification by natural surface processes and cleanup actions. The distribution of these materials at the RDM is briefly discussed above.

Migration of contaminants associated with source materials has occurred via physical and chemical processes. Tailings/waste rock have historically been disposed of or eroded into Red Devil Creek within the Main Processing Area and downstream areas. In addition, naturally mineralized soils, particularly from the Surface Mined Area, have been eroded and transported into the Red Devil Creek valley. Tailings/waste rock and natural materials that enter Red Devil Creek by erosion and mass wasting have been in the past, and presently are, subject to surface water transport downstream within Red Devil Creek. Tailings/waste rock and natural materials have been deposited within and transported down the channel of Red Devil Creek to the Kuskokwim River, where they accumulated in a delta. Sluicing of overburden from the Surface Mined Area created the Dolly and Rice Sluice deltas in the Kuskokwim River. Some of these materials also migrated downriver to some extent in the Kuskokwim River.

Contaminants at the RDM presently are transported primarily by the groundwater and surface water pathways. Leaching of inorganics from tailings/waste rock and other sources is one of the primary mechanisms of contamination of groundwater and surface water. Erosion and entrainment of particulates also is an important mechanism. The 2014 NTCRA was completed to address this mechanism (see Section 2.3). Leached contaminants enter groundwater directly where/when groundwater locally immerses these source materials, and by leaching and downward transport toward groundwater where the groundwater levels are locally beneath the base of the source materials. Locally, soils have been impacted by such leaching and migration of contaminants from tailings/waste rock and other contaminant sources. For example, arsenic, mercury, and antimony have leached from tailings/waste rock and have been deposited (e.g., adsorbed or incorporated into minerals) onto soils/alluvium underlying the tailings in the Main Processing Area. This is evident in some RI soil borings that show a profile of decreasing concentrations of these metals below the base of the tailings/waste rock.

Nature and Extent of Contamination in Soil

For the purposes of delineating the extent of RDM-related contamination in soils, concentrations of inorganic analytes in mine wastes and soil were compared to concentrations in soil collected from background locations. In accordance with the RI work plan (E & E 2011), samples used for background value estimation were collected from locations outside and upgradient of the areas recognized as potentially impacted by mining, ore processing, waste disposal operations, and potential deposition of emissions from thermal ore processing. These background areas are located within the Upland Background Area and Red Devil Creek Upstream Alluvial Area for all media except Kuskokwim River sediment. Difficulties associated with the RI efforts to assess background soil concentrations are summarized in Section 4.1.7 of the final RI report.

Thirteen inorganic elements were detected above background values in surface soil samples and seventeen inorganic elements were detected above background values in subsurface soil samples. In addition, SVOCs, DRO, and RRO were detected in surface and/or subsurface soils that may require cleanup. Inorganic elements were detected above background values in all general geographic areas of the site. Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. The highest concentrations of these inorganic elements were in tailings/waste rock located in the Main Processing Area. These inorganic elements also were detected at concentrations above background in native and disturbed native soils, including Red Devil Creek alluvium, in the Main Processing Area, the Surface Mined Area, and other geographic areas of the site. Soil impacted as such by leaching from tailings/waste rock with inorganic element concentrations exceeding background values is considered contaminated. The depth of such deposition of inorganic elements in soils in parts of the Main Processing Area and Red Devil Creek Downstream Alluvial Area is not well known. Existing information on the depth of contamination was used to estimate depths and volumes of soils subject to remediation in the FS, discussed in Section 2.2.

Mercury, antimony, and arsenic were identified in the risk assessment as the primary contaminants of concern (COCs) at the RDM and are present at concentrations above risk-based and regulatory levels in mine wastes and media impacted by mine wastes that are subject to remedial action. One or more of these same metals were detected above risk-based or regulatory levels in RI background soil, sediment, and groundwater samples. Such naturally occurring concentrations represent pre-mining “background” conditions, and are thus not subject to remediation. Discriminating between mining-related contamination and impacts on soil of natural mineralization remains an important objective in developing appropriate and feasible remedial goals and objectives and site-wide remedial alternatives at the RDM.

Natural mineralization at the RDM comprises not only the discrete high grade mercury ore bodies targeted during mining, but also sub-ore grade zones peripheral to the ore bodies. This peripheral mineralization includes not only mercury and antimony sulfide minerals (primarily cinnabar and stibnite, respectively), but also gangue minerals arsenic sulfides (realgar and orpiment). Weathering of these natural sulfides, and possibly other minerals, results in naturally elevated levels of arsenic, mercury, and antimony in groundwater. Bedrock and soil in zones hydraulically downgradient of the mineralized zones also likely contain naturally elevated metals concentrations from deposition of the mobilized metals (e.g., oxidation of arsenic sulfide and adsorption of resulting arsenate onto clay particles or iron oxide/hydroxide).

Organic compounds, including DRO, RRO, SVOCs and PCBs were detected in soil in portions of the Main Processing Area at depths ranging up to 30 feet below ground surface (bgs). Concentrations of DRO in some samples exceeded regulatory criteria.

Risk Assessment
Potential risk to human and ecological receptors exposed to soil was assessed. The primary COCs–antimony, arsenic, and mercury–were identified. Results of the HHRA and the ERA indicated significant risk to these receptors, in part due to direct contact or ingestion of soil. Results of the HHRA and the ERA are presented in Chapter 6 of the final RI report.

2.1.2 Groundwater

Objectives of the groundwater characterizations are detailed in Chapter 2 of the final RI report and are summarized briefly below:

- Characterize the nature and extent of COPCs in groundwater.
- Determine if the monofills are a source of groundwater contamination.
- Assess potential sources and migration patterns of groundwater and COPCs.
- Characterize groundwater depth, flow direction, gradient, and migration patterns of COPCs.
- Assess groundwater–surface water interactions, including the potential for COPCs in groundwater to enter surface water.
- Provide data to support the HHRA.

To date, baseline monitoring of groundwater, as well as surface water, has been performed in the spring and fall 2012. The purpose of the baseline monitoring is to augment the RI results and identify seasonal trends in groundwater and surface water flow and contaminant concentrations and loading. Specific objectives of the baseline monitoring are to:

- Characterize the seasonal variability in groundwater and surface water hydrology and chemistry;
- Characterize the long-term (multiple year) variability in groundwater and surface water hydrology and chemistry; and
- Characterize trends that are present in groundwater and surface water chemistry.

Groundwater samples were variously analyzed for total TAL metals, dissolved TAL metals, total low level mercury, dissolved low level mercury, methylmercury (unfiltered), arsenic speciation, inorganic ions, silicon, total dissolved solids (TDS), total suspended solids (TSS), nitrate and nitrite, carbonate and bicarbonate, SVOCs with tentatively identified compounds, DRO, RRO, gasoline range organics (GRO) and benzene, toluene, ethylbenzene, xylenes (BTEX), and PCBs.

Results of the RI groundwater characterization are presented in Chapters 3 through 7 of the final RI report. Results of the 2012 baseline monitoring were documented in the Final 2012 Baseline Monitoring Report, Red Devil Mine, Alaska, included as Appendix A in the final RI report, and incorporated as appropriate in the RI report. Locations of RI monitoring wells are illustrated in Figure 2-1. Key results of the groundwater characterization and baseline monitoring are summarized below.

Groundwater Occurrence and Flow Patterns

Groundwater occurs in native unconsolidated soil, mine wastes, and bedrock, including underground mine workings. Groundwater within bedrock and the overlying unconsolidated materials is generally hydraulically connected, although there is some hydraulic segregation locally at the site. Groundwater at the site generally flows toward Red Devil Creek and the Kuskokwim River, with groundwater potentiometric surface generally mimicking topography. Groundwater in a portion of the Surface Mined Area flows toward the Main Processing Area and the Red Devil Creek downstream alluvial area. Groundwater in these areas emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than as groundwater. Locally, groundwater flow at the RDM is complicated due primarily to complex modification of the natural hydrogeologic environment at the site. Flow within the unconsolidated materials is complicated by localized hydraulic segregation, variable gaining/losing conditions along Red Devil Creek, localized discharge from the underground mine workings, and seasonal variation in water levels and flow rates. The presence of an extensive network of underground mine workings at the site likely exerts a significant influence over groundwater flow patterns at the RDM. The mine workings likely provide a highly transmissive groundwater flow network that connects a large portion of the Surface Mined Area and the Main Processing Area. Assuming the mine workings are not plugged or caved, the mine workings and associated bedrock fractures likely exert a draining effect where the mine workings locally lie below the water table but above the highest nearby base level, which is the level of Red Devil Creek.

A map illustrating the configuration of the underground mine workings as of 1962 (based on Malone 1962 and MacKevett and Berg 1963) is presented on Figure 2-2. Information from a 1962 mine workings cross section (Alaska Mines and Minerals, Inc. and Decoursey Mountain Mining Co., Inc., 1962) is projected onto RI report geologic cross section B-B’, presented on Figure 2-3 of this document. Information on estimated elevations of key underground mine features is summarized in Table 2-1. The elevation of Red Devil Creek where underground workings approach the surface beneath the creek (near the seep) is approximately 210 feet above mean sea level referenced to the North American Vertical Datum 1988.

Results of a geophysical survey conducted by the United States Geological Survey at the RDM site using surface-based, direct-current resistivity and electromagnetic induction methods, strongly support the presence of near-surface stopes described above. The resistivity results indicated the presence of several anomalies in the subsurface along Red Devil Creek in the Main Processing Area (Burton and Ball 2011). Two of these anomalies appear likely to be associated with underground mine workings.

Anomaly D is interpreted to be an elongate conductive anomaly that underlies Red Devil Creek for a distance of at least approximately 200 feet. Anomaly E is interpreted to be a nearly vertical anomaly that extends to within approximately 6 feet of the surface. Anomaly E is in close proximity to the seep on the left bank of Red Devil Creek (Burton and Ball 2011). The approximate locations of these resistivity anomalies are shown in Figure 2-3.

On a site-wide scale, Red Devil Creek has exhibited predominantly gaining conditions. However, Red Devil Creek exhibited losing conditions locally. Losing conditions have apparently occurred in the vicinity of stations RD04 and RD05 on Red Devil Creek. Below the losing reach, the stream again exhibits gaining conditions (near surface water station RD09). Based on data from two sets of shallow/deep well pairs in the Main Processing Area, it is likely that along the axis of the Red Devil Creek valley, the vertical gradient within bedrock is predominantly upward, although interpretation of the data for one of the well pairs (MW16/MW17) is inconclusive. It is possible that the 2014 NTCRA (see Section 2.3) addressing Red Devil Creek sediment may have locally affected groundwater flow paths and groundwater-surface water interactions in part of the Main Processing Area.

Available data and interpretations of data pertaining to groundwater occurrence and flow patterns are detailed in Chapters 3 and 5 and Appendix A of the final RI report.

Fate and Transport of Inorganic Elements in Groundwater

The flow pathways of groundwater as well as surface water determine the chemical, physical, and biological environments in which leaching and mobilization of inorganic elements may occur. The groundwater flow pathways at the RDM are complex, as discussed above. Groundwater and surface water flow through each of the various environments results in various chemical impacts. Multiple interrelated factors and processes affect the mobility of inorganic elements, impacts on groundwater, and impacts of groundwater on other media. Available data and interpretations of such data are detailed in Chapter 5 of the final RI report.

Nature and Extent of Groundwater Impacts

As with soils, for the purposes of delineating the extent of RDM-related contamination, concentrations of inorganic analytes in groundwater were compared to concentrations in groundwater samples collected from background locations. Samples used for background groundwater value estimation were collected from locations within the Upland Background Area and the Red Devil Creek Upstream Alluvial Area. Efforts to assess background concentrations are detailed in Section 4.1.7 of the final RI report.

Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. Groundwater at the RDM is significantly impacted by leaching of inorganic contaminants from mine wastes, including tailings/waste rock, flotation tailings, and contaminated soils. The greatest impacts, particularly for antimony and arsenic, occur where tailings/waste rock materials within the Main Processing Area are within the saturated zone at least part of the time. Concentrations of total and dissolved antimony and arsenic are highest in the Post-1955 Main Processing Area. Mine waste materials also contribute to mercury groundwater contamination. Some of the groundwater impacts are associated with flow through naturally mineralized soil and bedrock and underground mine workings.

During the RI groundwater sampling effort, it was possible to collect groundwater samples from only one (MW10) of the three monitoring wells (MW09, MW10, and MW11) installed immediately downgradient of Monofill #2. At that time, MW11 was dry, and recharge to MW09 was too slow to allow development or collection of a sample. However, during the subsequent baseline groundwater monitoring, it was possible to develop and sample well MW09. Results of this sampling are summarized in the final RI report Appendix A (Final 2012 Baseline Monitoring Report). No other groundwater sampling data for well MW09 are presently available.

As noted above, mercury, antimony, and arsenic are present at concentrations above risk-based and regulatory levels in mine wastes and media impacted by mine wastes that are subject to remedial action, including groundwater. These same metals occur naturally at concentrations above risk-based and regulatory levels in native bedrock, soil, and sediment, and groundwater and surface water that flow through them. Such naturally occurring concentrations represent pre-mining “background” conditions, and are thus not subject to remediation. Discriminating between mining-related contamination and impacts on groundwater of natural mineralization is an important objective in developing appropriate and feasible remedial goals and objectives and site-wide remedial alternatives at the RDM.

As noted above, weathering of soil and bedrock containing naturally occurring sulfide minerals and possibly other minerals results in naturally elevated levels of arsenic, mercury, and antimony in groundwater. Bedrock and soil in zones hydraulically downgradient of these naturally mineralized materials likely contain naturally elevated metals concentrations from deposition of the mobilized metals (e.g., oxidation of arsenic sulfide and adsorption of resulting arsenate onto clay particles or iron oxide/hydroxide).

Existing data on background groundwater concentrations are from monitoring wells installed outside of the extent of the zone of natural mineralization and are not representative of groundwater affected by naturally mineralized bedrock and soil/alluvium. RI data have shown that groundwater affected by natural mineralization flows into the Main Processing Area.

In addition to inorganic elements, organic compounds were detected in some RI groundwater samples, including DRO, RRO, and several SVOCs. None of the organic compounds detected exceeded comparison criteria in any of the groundwater samples. The extent of organic compounds in groundwater has not been fully delineated.

Risk Assessment

Potential risk to human receptors exposed to groundwater was assessed. Results of the HHRA indicated significant risk to humans via ingestion of groundwater. Results of the HHRA are presented in Chapter 6 of the final RI report.

2.1.3 Surface Water

Objectives of the surface water characterizations are detailed in Chapter 2 of the final RI report and are summarized briefly below:

- Characterize the nature and extent of COPCs of Red Devil Creek and the seep adjacent to the creek in the Main Processing area.
- Assess contribution of COPCs in surface water from groundwater.
- Characterize conditions and factors affecting contaminant fate and transport of COPCs in the surface water Red Devil Creek.
- Provide data to support the HHRA and ERA.

To date, baseline monitoring of surface water and groundwater has been performed in the spring and fall 2012. The purpose of the baseline monitoring is to augment the RI results and identify seasonal trends in groundwater and surface water flow and contaminant concentrations and loading. Specific objectives of the baseline monitoring are to:

- Characterize the seasonal variability in groundwater and surface water hydrology and chemistry;
- Characterize the long-term (multiple year) variability in groundwater and surface water hydrology and chemistry; and

- Characterize trends that are present in groundwater and surface water chemistry.

Results of the RI surface water characterization are presented in Chapters 3 through 7 of the final RI report. Results of the 2012 baseline monitoring were documented in the Final 2012 Baseline Monitoring Report, Red Devil Mine, Alaska, included as Appendix A in the final RI report, and incorporated as appropriate in the RI report. Baseline and RI surface water monitoring locations are illustrated in Figure 2-4. Key results of the surface water characterization and baseline monitoring are summarized below.

Fate and Transport of Inorganic Elements in Surface Water

RI results indicate that transport of contaminants in surface water is occurring presently at the RDM. Contaminant loading (e.g., antimony, arsenic, mercury, and methylmercury) along Red Devil Creek as it flows through the Main Processing Area are attributable to groundwater migration into the stream along gaining reaches and erosion. Groundwater emerges to surface water as baseflow within the Main Processing Area as well as at a seep located adjacent to the creek in the Main Processing Area. Sources of inorganics in groundwater include leaching from mine wastes, as well as naturally mineralized bedrock and native soils. Surface water loading along the creek also is attributable to entrainment of contaminants within or adsorbed to particulates and dissolution/desorption of contaminants from bed and suspended sediment. The 2014 NTCRA was completed to address this mechanism (see Section 2.3).

Multiple, interrelated factors and processes affect the mobility of inorganic elements, impacts on groundwater and surface water, and interactions between groundwater and surface water. Available data and interpretations of such data are detailed in Chapter 5 of the final RI report.

Nature and Extent of Impacts in Surface Water

Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values in Red Devil Creek surface water and surface water sampled at the seep. In Red Devil Creek, starting at the upper end of the Main Processing Area, total and dissolved concentrations of antimony, arsenic, and mercury were significantly elevated above background in Red Devil Creek down to the mouth of Red Devil Creek. The highest arsenic concentrations were detected in the seep samples. Results of surface water characterization and baseline monitoring, including concentration profiles and contaminant loading calculations, are presented in Chapter 4 and Appendix A of the final RI report.

Risk Assessment

Potential risk to human and ecological receptors exposed to surface water was assessed. Results of the HHRA and ERA indicated risk to these receptors. Results of the HHRA and ERA are presented in Chapter 6 of the final RI report.

2.1.4 Kuskokwim River Sediment

During the RI, bed surface sediment samples were collected at 17 locations along the shoreline of the Kuskokwim River in 2010 and 2011, and from 55 offshore locations in 2011 and 2012. RI sediment sample locations are illustrated in Figure 2-5. Objectives of the sampling were to:

- Characterize the nature and extent of CPOCs in river sediment;
- Characterize chemical attributes affecting fate and transport of COPCs;
- Provide data for the HHRA to assess potential exposure to COPCs through direct contact, incidental ingestion, and consumption of fish;
- Provide data for the ERA to assess potential exposure of river biota to COPCs through direct contact and ingestion; and
- Develop an estimate of the amount of material that may require remediation.

Key results of the RI characterization of Kuskokwim River sediment are summarized below.

Fate and Transport of Inorganic Elements in Kuskokwim River Sediment

Materials that enter Red Devil Creek by erosion and mass wasting have been in the past, and presently are, subject to surface water transport downstream within Red Devil Creek. Some of the materials transported down Red Devil Creek to its mouth have been deposited in the Red Devil Creek delta, where they may be subject to further erosion by Red Devil Creek as it flows over the delta, and by the Kuskokwim River. Similarly, sluiced overburden that was historically deposited in the Dolly Sluice and Rice Sluice deltas is presently subject to erosion by the Kuskokwim River. Results of Kuskokwim River bed sediment samples indicate that transportation of materials from Red Devil Creek and its delta, and likely the Dolly and Rice Sluice deltas, has occurred. Detailed discussion of fate and transport of contaminants in Kuskokwim River sediment is presented in Chapter 5 of the final RI report.

Several approaches were taken during the RI to evaluate the potential for methylation of mercury in Kuskokwim River sediments, as discussed below. Several types of data were collected that indicate that a large fraction of total mercury in site soil and sediment is sparingly soluble. For example, mercury SSE data indicate that a small fraction of total mercury in site soil (see final RI report Section 5.3.5.1) and sediment derived in part from site soil (see final RI report Section 5.3.5.2) is water soluble (F1) or stomach acid soluble (F2) and that the proportion of these soluble fractions relative to the total mercury decreases with increasing total mercury concentration. Similarly, synthetic precipitation leaching procedure (final RI report Section 5.3.4.1) data suggest that a small fraction of the total mercury concentration in site soil samples is soluble under slightly acidic conditions. The soluble portion of the total mercury pool is the portion subject to methylation. Kuskokwim River sediment samples were evaluated for methylation potential directly by analyzing methylmercury (see final RI report Section 5.3.6) in 26 bed sediment samples. Methylmercury was detected at concentrations ranging from 0.15 to 3.73 nanograms per gram, and was detected above the background level of 0.49 nanograms per gram in 14 of the 26 samples.

Nature and Extent of Contamination in Kuskokwim River Sediment
In Kuskokwim River sediment samples collected during the RI, antimony, arsenic, and mercury concentrations were the COCs most highly elevated above background values. Methylmercury was detected above the background value in approximately half of the samples analyzed for methylmercury. Concentrations of antimony, arsenic, mercury, and methylmercury generally decrease downriver from the mouth of Red Devil Creek, but not in a regular pattern. The samples collected from some of the locations furthest downriver and distant from the shore exceed one or more of the background values.

The extent of antimony, arsenic, mercury, and methylmercury contamination in river sediments has not been defined by RI sampling in either the downriver or the cross-river directions. Detailed discussion of the nature and extent of contaminants in Kuskokwim River sediment is presented in Chapter 4 of the final RI report.

Baseline human health and ecological risk assessments addressing RDM-related contamination in Kuskokwim River sediment and other media are presented in Chapter 6 of the final RI report. Elements of the risk assessments that pertain to supplemental Kuskokwim River sediment characterization are briefly outlined below.

2.1.4.1 Baseline Human Health Risk Assessment – Sediment

The HHRA addressed potential risk to a future onsite resident, a recreational visitor or subsistence user, and an industrial/mine worker. Of the media and exposure routes assessed, the following pertain to the Kuskokwim River: direct exposure (via dermal contact) to sediment in Red Devil Creek and the near-shore of the Kuskokwim River; and indirect exposure through ingestion of native wild foods, including fish from the Kuskokwim River and potentially, to a lesser extent, from Red Devil Creek.

The HHRA risk characterization results indicated that consumption of fish contributes significantly to the potential risk posed to all receptors at the site. To a lesser degree, direct exposure to sediment also contributed to potential risk to the receptors. Section 6.2.6 of the report identified uncertainties associated with the risk assessment.

Two areas of significant uncertainty associated with the Kuskokwim River are the estimation of concentrations of COCs in fish consumed by receptors and the assumption that all wild food is harvested from the site, discussed further below.

For the HHRA, the concentrations of COCs in game fish were estimated using a health-protective food chain multiplier (FCM) approach and results of a BLM study of Kuskokwim River, Red Devil Creek, and other tributaries to the Kuskokwim River near the RDM site, which included collection and analysis of forage fish (e.g., slimy sculpin [whole fish samples]) for site-related chemicals (BLM 2012). The resulting sculpin whole-fish tissue data from Red Devil Creek were used in the HHRA to estimate concentrations of COCs in game fish consumed by receptors. For methylmercury, an FCM of three was assumed to account for biomagnification (i.e., the game fish concentration of methylmercury is set equal to three times the concentration in sculpin). For inorganic mercury and other metals, an FCM of one was assumed. It was assumed that the game fish of interest—Dolly Varden, sheefish, round whitefish, whitefish (other), burbot, grayling, and Northern pike—are one trophic level above the slimy sculpin, except for grayling, which feed at a slightly lower trophic level than sculpin. This is a health-protective assumption. Further, because sculpin are more resident than the fish taken from the Kuskokwim River, using the Red Devil Creek sculpin data to estimate game fish concentrations in the Kuskokwim River likely overestimates the true concentrations of fish that people are catching and consuming from the Kuskokwim River.

To improve the understanding of fish residence in the Kuskokwim River and tributaries, BLM (2012) conducted fish movement studies on northern pike and burbot. Preliminary results of the telemetric studies show that movements can be highly variable and difficult to predict for a given river system. Based on the BLM fish study data, sedentary fish (slimy sculpin, juvenile Dolly Varden, and juvenile Arctic grayling) and insects from Red Devil Creek and Cinnabar Creek had significantly greater mercury concentrations than the same fish in other tributaries. Northern pike, burbot (lush), and Arctic grayling collected in the rivers sampled had variable mercury levels across the area. Northern pike from the George River had significantly higher mercury concentrations compared to other pike. There were no spatial differences in mercury concentrations in sheefish (BLM 2012).

To evaluate the uncertainties identified above, contaminant concentrations in fish estimated using the FCM approach and Red Devil Creek sculpin data were compared to measured concentrations of antimony, arsenic, and mercury in muscle and liver tissue from northern pike collected by BLM (2012) from the section of the Kuskokwim near Red Devil Creek (Reach C). The measured concentrations of antimony, arsenic, and mercury in northern pike were significantly lower than the concentrations modeled from the sculpin from Red Devil Creek. For example, the 95-percent upper confidence limit (UCL) of measured arsenic in northern pike muscle is 0.626 milligrams per kilogram (mg/kg)-wet, compared to the modeled concentration of 12.98 mg/kg.

To evaluate the impact of assuming that all wild food is harvested from the site, an alternative approach was evaluated in which food intake rates are based instead on data obtained from the Alaska Department of Fish and Game survey of residents of Red Devil Village (Brown et al. 2012).

Using measured arsenic fish concentrations in northern pike (assuming 10 percent of the arsenic is in the inorganic form) and the alternative food intake assumptions, the excess lifetime cancer risk (ELCR) from ingestion of game fish is 6 x 10^{-5} for a recreational/subsistence user or residents in all exposure units, which is several orders of magnitude lower than the ELCR used in the risk assessment.

Ongoing analysis of fish movement study data is expected to further inform discussions about the transfer of mercury, arsenic, and antimony, their various chemical forms, and other trace elements within the middle Kuskokwim River region from cinnabar deposits, Red Devil, and other abandoned mines (BLM 2012).

2.1.4.2 Baseline Ecological Risk Assessment – Sediment

The baseline ecological risk assessment for the RDM site considered vegetation, soil invertebrates, terrestrial and aquatic wildlife, and aquatic biota (e.g., aquatic plants, amphibians, benthos, and fish) in Red Devil Creek and the Kuskokwim River. Four measures or assessment methods were used to evaluate potential risk to the benthic macroinvertebrate community in Red Devil Creek: (1) comparing sediment chemical concentrations to sediment screening levels; (2) benthic community composition in Red Devil Creek compared with nearby reference creeks (BLM 2012); (3) comparing contaminant concentrations in benthic macroinvertebrate composite samples from Red Devil Creek with tissue screening concentrations; and (4) comparing chemical concentrations in surface water with chronic water quality criteria for protection of freshwater aquatic life.
The results of the evaluation are summarized below:

- Measure 1 – Nine contaminants were predicted to be COCs for the benthic community based on comparing sediment contaminant concentrations with screening levels. However, confidence in the COC list and potential risks based on this assessment method is considered low because site-specific bioavailability is not considered.
- Measure 2 – The benthic survey conducted in Red Devil Creek identified no adverse impacts to abundance and diversity of benthic macroinvertebrates in Red Devil Creek compared with nearby reference creeks. The site-specific survey is considered to be a more reliable assessment method and suggests no impacts to the benthic community from site-related contaminants.
- Measure 3 – Comparing contaminant levels in macroinvertebrate tissues samples with critical tissue concentrations identified only a marginal potential risk from methylmercury. This measure also is considered superior to measure 1 because it considers site-specific bioavailability and bioaccumulation.

- Measure 4 – Comparing contaminant levels in surface water from Red Devil Creek and the seep on the bank of the creek identified five COCs for benthic macroinvertebrates and other aquatic biota. The greatest risks were for antimony, arsenic, and mercury in seep water discharging to the creek. Reliability in this assessment method is better than for measure 1, but not as good as measures 2 and 3 because site-specific bioavailability is not considered.

Although adequate data were available to use measures 1 to 4 to evaluate the benthic community in Red Devil Creek, only measure 1 could be used in the Kuskokwim River. No benthic survey data, benthic macroinvertebrate tissue data, or surface-water data were collected from the Kuskokwim River during the RI. Hence, potential risks to the benthic community in the Kuskokwim River are not well understood.

2.2 Red Devil Mine Feasibility Study

An FS for the RDM is under development. The purpose of the FS is to present remedial action objectives (RAOs) and remedial alternatives to address contamination characterized as part of the RI and documented in the RI report. The draft final FS report (E & E 2014b) is based on site characterization information presented in the RDM RI report (E & E 2013). In the draft final FS report, RAOs and remedial goals (RGs) have been identified for the following media of concern at the RDM: tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment. Three media addressed during the RI—Red Devil Creek surface water, groundwater, and Kuskokwim River sediment—are not addressed in the FS. The FS is anticipated to result in an interim Record of Decision for the site. A final Record of Decision will be executed following assessment of the success of source control actions and the associated effect on groundwater and Kuskokwim River sediment quality. Information on the media pertinent to the planned supplemental RI activities is presented below.

2.2.1 Soil

Soil with total concentrations of antimony, arsenic, and/or mercury—the primary soil COCs at RDM—exceeding the soil RGs is targeted for remedial action. This encompasses all surface and subsurface soil containing tailings/waste rock and flotation tailings within the Main Processing Area and the Red Devil Creek Downstream Alluvial Area and Delta. It also includes sediment within Red Devil Creek that contains tailings/waste rock, some native soil beneath tailings/waste rock, and some surface soil in or adjacent to the Main Processing Area. The RGs for antimony, arsenic, and mercury were set at the background values based on RI data.

In general, estimated depths of soil targeted for remedial action are based on the soil boring data presented in the RI. Throughout most of the Main Processing Area, tailings/waste rock was identified in soil borings to varying depths. The tailings/waste rock material in the Main Processing Area is targeted for remedial action. Underlying native soils with concentrations of one or more or the primary COCs exceeding RGs also were identified.

As noted in the final RI report and Section 2.1.1 above, the depths below the base of tailings/waste rock of soil with concentrations exceeding background soil concentrations, and thus RGs, are not known at some soil boring locations. For the purposes of the FS, where the depth of exceedance of RGs is not fully defined by the RI data, the depth of RG exceedance was estimated by extrapolating below the depth of the soil boring.

2.2.2 Groundwater

As stated in the draft final FS report, it is anticipated that future active remediation of tailings/waste rock in the Main Processing Area will reduce contaminant loading to groundwater. It is possible that the NTCRA (see Section 2.3) addressing Red Devil Creek sediment may have affected groundwater flow paths, groundwater-surface water interactions, and contaminant concentrations and loading in part of the Main Processing Area.

The BLM plans to further characterize groundwater before site-wide remedial decision making is completed. The supplemental RI activities are intended to support site-wide remedial decision making.

2.2.3 Surface Water

As stated in the draft final FS report, it is anticipated that future active remediation of tailings/waste rock in the Main Processing Area will reduce contaminant loading to groundwater. Such reductions to groundwater loading would be expected to also reduce contaminant concentrations and loading to surface water. It is possible that the NTCRA (see Section 2.3) addressing Red Devil Creek sediment may have affected groundwater flow paths, groundwater-surface water interactions, and contaminant concentrations and loading in part of the Main Processing Area. Active remedies for Red Devil Creek surface water have not been developed, and RAOs, RGs, and general response actions for Red Devil Creek surface water are not presented in the FS.

2.2.4 Kuskokwim River Sediment

As stated in the draft final FS report, it is anticipated that future active remediation of tailings/waste rock in the Main Processing Area will reduce contaminant loading to the Kuskokwim River. The BLM plans to further characterize Kuskokwim River sediment before site-wide remedial decision making is completed. The supplemental RI activities are intended to support site-wide remedial decision making.

2.3 Non-Time-Critical Removal Action

The RI results indicated that tailings/waste rock located in the Main Processing Area were subject to active erosion along Red Devil Creek and transport to the Kuskokwim River. An Engineering Evaluation/Cost Analysis was prepared by E & E on behalf of the BLM to evaluate removal action alternatives intended to address this erosion and transport (E & E 2014c). The BLM issued a removal action memorandum (BLM 2014a) for an NTCRA at the RDM site in June 2014. Details of the proposed construction activities, as provided in the removal action memorandum, are summarized below.

- Approximately 5,000 cubic yards of tailings and sediment would be excavated along the south side of Red Devil Creek and transported to a designated temporary storage area on site.
- A section of Red Devil Creek would be realigned and a sediment trap constructed downstream of the tailings piles. Depths and distances for excavation would be based on sampling results provided in the draft final RI report and observed geologic characteristics in the vicinity of Red Devil Creek.
- The excavation would extend along Red Devil Creek for approximately 200 feet within the Main Processing Area, limited to the south side of the stream, beginning at the existing centerline of Red Devil Creek below the processing area and proceeding in a straight upstream direction, realigning the creek and maintaining its natural gradient. The excavation would then terminate upstream of the processing area and rejoin the existing creek.
- The excavation would be 12 feet wide at the bottom and extend up at a 3:1 slope (horizontal to vertical) on the south side.
- The realigned channel sidewalls would be lined on each side with 3-foot gabion baskets to maintain the constructed alignment.
- A vertical gabion drop structure would be installed just upstream of the excavated area to act as a transition between the gradient of the excavated channel and the longitudinal gradient in the upstream section of Red Devil Creek.
- A sediment trap would be installed downstream of the realigned channel, immediately upstream of an existing bridge near the mouth of Red Devil Creek. This sediment trap would be sized to allow settling of medium-sized sand (0.50 millimeter) and greater, but would not allow re-suspension of material.
- Standard construction equipment would be used to remove sediment and load the material for transport to a temporary stockpile.
- Side slopes of the temporary stockpile would have a maximum slope of 2:1 (horizontal to vertical). To minimize stormwater infiltration into the sediment stockpile and prevent mobilization of fugitive dust, the stockpile would be covered with a 12-millimeter, ultraviolet-resistant, reinforced polyethylene geomembrane liner with tear-resistant polyester scrim. A soil or vegetation cover would not be required as the stockpile is anticipated to be temporary.
- Erosion and sediment control measures would be installed in the vicinity of the stockpiles as needed to prevent erosion of the excavated sediment.

- Restoration of the stream in the area of excavation would not be part of the proposed action.
- Upon completion of the excavation, the stream would be directed into the realigned channel and then allowed to flow through the current channel downstream of the Main Processing Area before entering the sediment trap.

The BLM performed NTCRA construction during the summer of 2014. The NTCRA activities locally modified the conditions at the RDM that existed at the time of the RI field activities.

Based on the elements identified in the removal action memorandum and post-construction as-built survey data (Marsh Creek 2014), the following key site physical characteristics are expected to have been modified:

- Distribution of tailings/waste rock in part of the Main Processing Area, including an area where tailings/waste rock have been shown to be immersed in groundwater.
- Topographic modifications, including removal and stockpiling of excavated material and regrading.
- Alignment and gradient of Red Devil Creek.
- Nature of substrate and banks of Red Devil Creek.
- Decommissioning of RI monitoring wells MW14, MW15, MW16, and MW17.
- Elimination of RI surface water monitoring stations RD04 and RD07.

Figures 2-1 and 2-4 illustrate the pre-NTCRA topography and Red Devil Creek stream alignment, as well as locations of RI soil borings, monitoring wells, and surface water monitoring stations. Figure 2-6 illustrates the post-NTCRA topography, stream alignment, and RI monitoring well and surface water monitoring locations.

The physical modifications of the site are expected to result in changes to the groundwater and surface water flow paths and interactions and consequently, groundwater and surface water concentrations and loading of inorganic elements.

2.4 Middle Kuskokwim River Investigations

Beginning in 2010, BLM began a study to comprehensively examine mercury, methylmercury, and other metals in the Kuskokwim River basin in proximity to the Red Devil Mine (BLM 2010). Specific objectives of the study were to:

- Estimate levels of metal bioaccumulation within components of the aquatic food web;

- Evaluate macroinvertebrate diversity within several watersheds using a variety of metrics to determine the level of variance between reference and test watersheds; and
- Work with local residents in Stony River, Crooked Creek, and Sleetmute to identify locations of subsistence harvest on the Kuskokwim River within the project area.

The results of this work were published in a several reports prepared by BLM with support from the U.S. Fish and Wildlife Service (USFWS), including:

- *Mercury, Arsenic, and Antimony in Aquatic Biota from the Middle Kuskokwim River Region, Alaska 2010–2011* (USFWS 2012); and
- *Quantification of Fish and Aquatic Insect Tissue Contaminants in the Middle Kuskokwim River, Alaska* (BLM 2012).

As a follow-up to this work, in 2012 and 2013, BLM undertook fish movement studies on northern pike and burbot, and analysis of watershed mercury methylation potential. As indicated in Section 2.1.4, results of this study are expected to provide important information regarding potential impacts of RDM contamination on fish harvested for consumption from the Kuskokwim River.

In 2014, BLM implemented a study to collect additional data that may be used to assess RDM-related impacts on Red Devil Creek and the Kuskokwim River near the RDM. Objectives of the 2014 study are presented in the *Field Operations Plan – 2014, Quantification of Fish and Aquatic Insect Tissue Contaminants in the Middle Kuskokwim River, Alaska* (BLM 2014b) and are summarized below:

- Collect additional data for mercury in slimy sculpin from Red Devil Creek.
- Determine concentrations of mercury in periphyton and/or macroinvertebrates in the near-shore environment of the Kuskokwim River near the RDM.
- Determine if macroinvertebrate assemblages vary upstream and downstream of Red Devil Creek in the Kuskokwim River based on various biotic indices.

Preliminary information regarding the field activities indicates that the attempts to collect periphyton samples were successful, but collection of benthic macroinvertebrates in the Kuskokwim River near the RDM was not successful. Based on visual observations by the BLM biologists at the time of the sampling event, it was decided to not attempt to collect benthic macroinvertebrates because of highly turbid conditions. Locations of periphyton samples are illustrated in Figure 2-5.

2.5 Data Gaps

As indicated above, during the development of the FS, data gaps were identified for several site media. In addition, the NTCRA is expected to have modified site conditions. Key results of the various studies and site activities, including findings pertinent to these data gaps, are presented in the sections above. In addition to the identified data gaps, the BLM plans to continue performing baseline groundwater and surface water monitoring at the site.

Data gaps and baseline groundwater and surface water monitoring to be addressed as part of the supplemental RI activities are discussed below. The approach to address the data gaps is presented in Chapter 3.

2.5.1 Soil

The following data gaps pertaining to soil will be addressed as part of the supplemental RI activities:

1) In parts of the Main Processing Area and Red Devil Creek Area, the depths and total inorganic element concentrations of soil below tailings/waste rock are not well understood.
2) In parts of the Main Processing Area and Red Devil Creek Area, one or more of the following subsurface conditions are not well understood: thickness of tailings/waste rock; lithology, thickness, and inorganic element concentrations of underlying soil/alluvium; depth to bedrock; and depth of the saturated zone(s).
3) Naturally mineralized soil and bedrock likely underlie parts of the Main Processing Area and Red Devil Creek Area that contain tailings/waste rock and contaminated soil that are subject to remediation. The locations and nature of such materials are not well understood.
4) Subsurface conditions in the Surface Mined Area, including thickness of soils and depth of bedrock, presence and thickness of any saturated intervals, and presence of natural mineralization are not well understood.

2.5.2 Groundwater

The following data gaps pertaining to groundwater will be addressed as part of the supplemental RI activities:

1) The impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations in the Surface Mined Area are not well characterized.
2) The impacts of the physical modifications of the site, due to the NTCRA, on groundwater and surface water flow paths and interactions, and consequently, on groundwater inorganic element concentrations, are not known.

3) RI monitoring wells were decommissioned as part of the NTCRA. New wells are necessary to provide ongoing groundwater monitoring data formerly available using these wells.
4) Additional multi-year baseline monitoring of groundwater conditions (including depth, hydraulic gradient, and concentrations of inorganic elements) is needed.
5) The extent of organic compounds in groundwater has not been fully delineated.

2.5.3 Surface Water

The following data gaps pertaining to surface water will be addressed as part of the supplemental RI activities:

1) The impacts of naturally mineralized bedrock and underground mine workings in the Surface Mined Area on groundwater flow paths and inorganic element concentrations, and consequently on surface water concentrations and loading in the Main Processing Area, are not well characterized.
2) The impacts of the physical modifications of the site, due to the NTCRA, on groundwater and surface water flow paths and interactions, and consequently, on surface water inorganic element concentrations and loading, are not known.
3) Additional multi-year baseline monitoring of surface water conditions (including flow rates and concentrations and loading of inorganic elements) is needed.

2.5.4 Kuskokwim River Sediment

The following data gaps pertaining to Kuskokwim River sediment will be addressed as part of the supplemental RI activities:

1) The potential toxicity of contaminated Kuskokwim River sediments is not known.
2) The potential for methylation and bioaccumulation of mercury for Kuskokwim River sediment is not well known.
3) The downriver and cross-river extents of contamination of Kuskokwim River sediment have not been delineated.
4) The turbidity of Kuskokwim River water has not been measured.

Table 2-1 Elevations of Underground Mine Workings

Underground Mine Feature	Approximate Elevation (feet above Mean Sea Level, NAVD88)
503 Crosscut	325
507 Crosscut	275
Dolly No. 7 Crosscut / 1280 Crosscut	210
325 Adit	260
242 Sublevel	240
311 Adit	245
33 Level	210
73 Level	175
150 Level / 200 Level	95
300 Level	-55
450 Level	-205
550 Crosscut	-285
600 Level	-355

Key:

NAVD88 = North American Vertical Datum 1988

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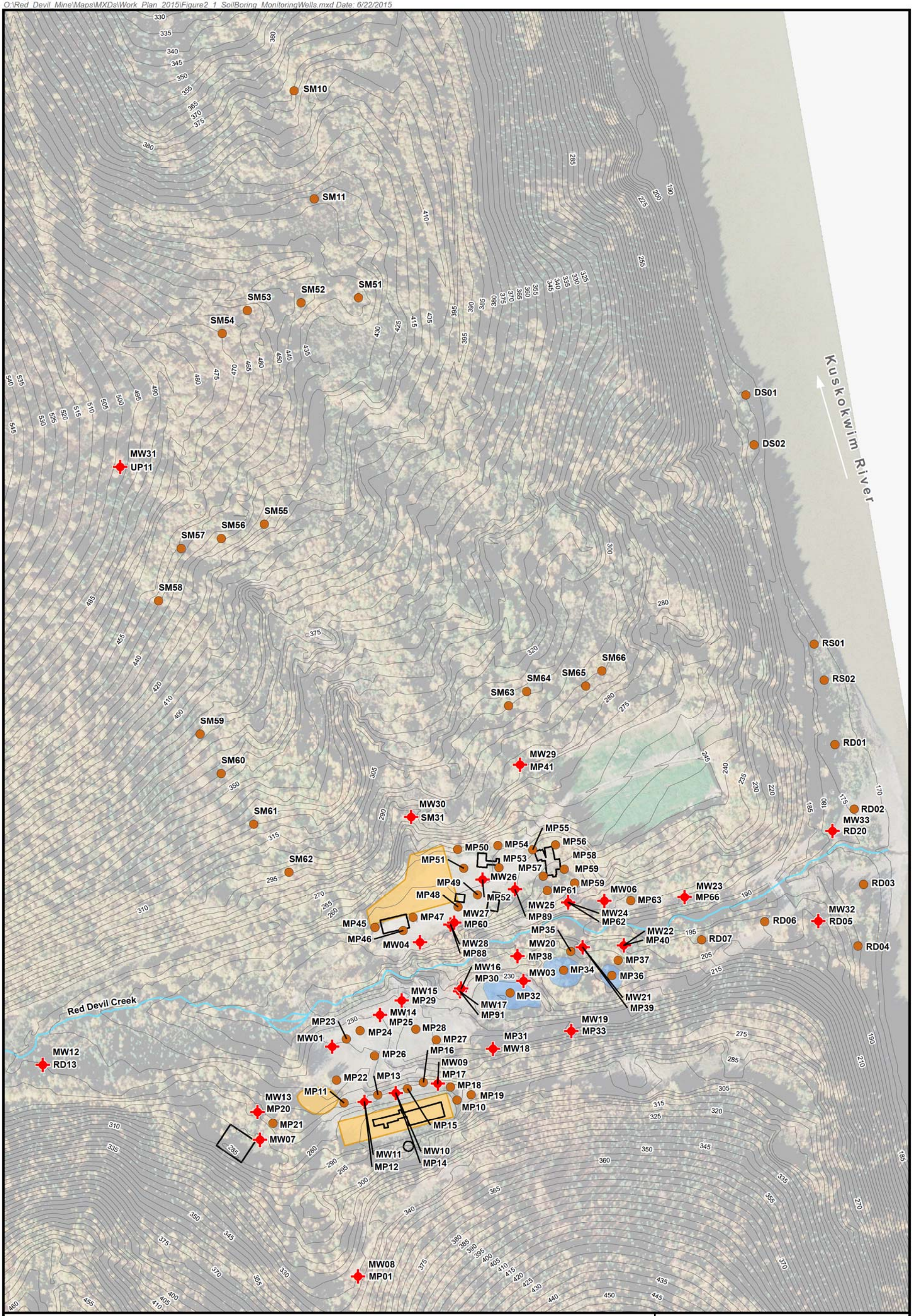

✚	Monitoring Well ID Soil Boring ID
●	Soil Boring
—	2010 5-foot Contour
—	Red Devil Creek
🟦	Settling Pond
🟧	Monofill
☐	Historical Structure

RED DEVIL MINE

Red Devil, Alaska

Figure 2-1
RI Soil Boring and Monitoring Well Locations

Digital aerial orthophotograph taken on September 21, 2010 (AeroMetric 2010)

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

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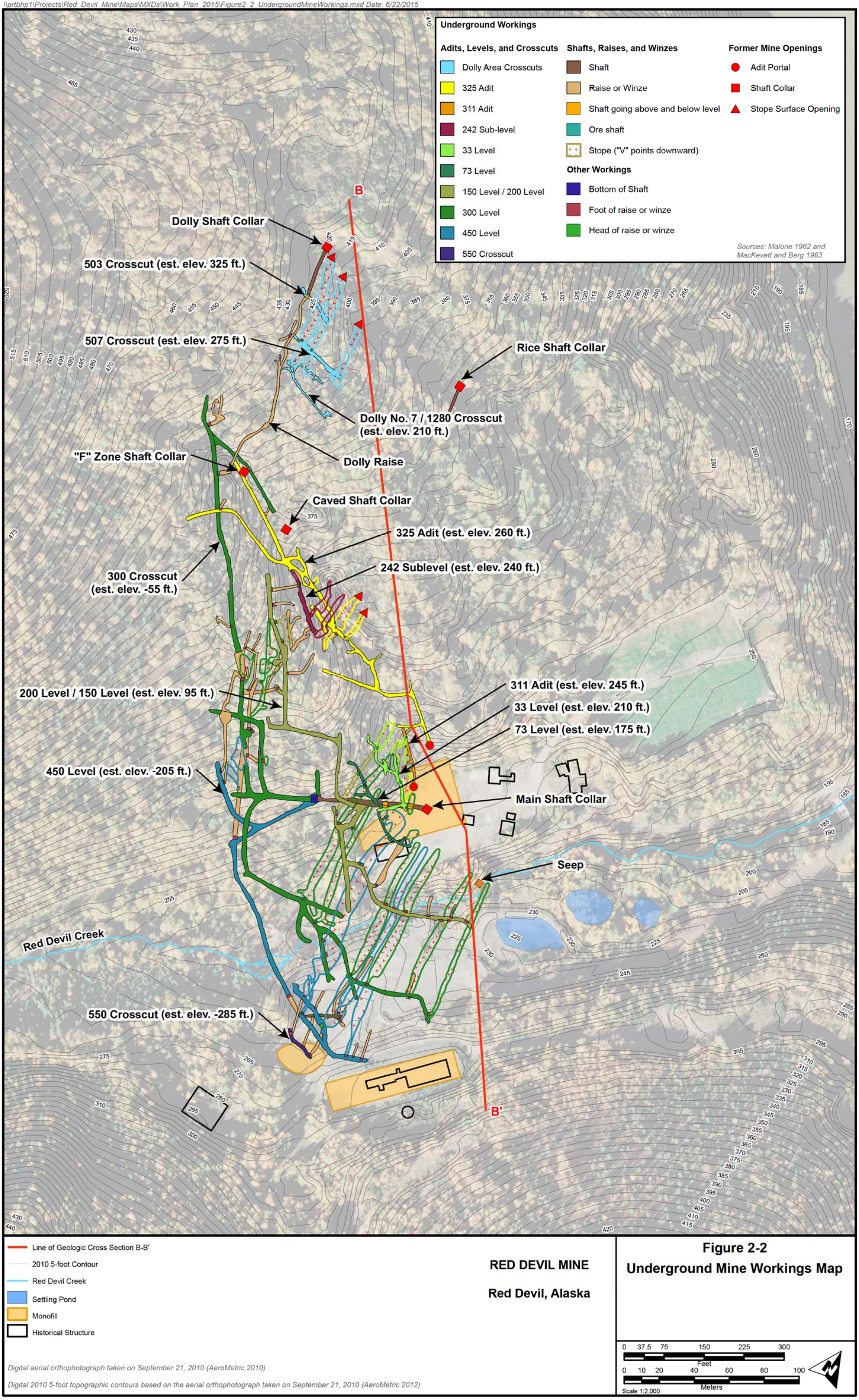

Digital aerial orthophotograph taken on September 21, 2010 (AeroMetric 2010)

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-2
Underground Mine Workings Map

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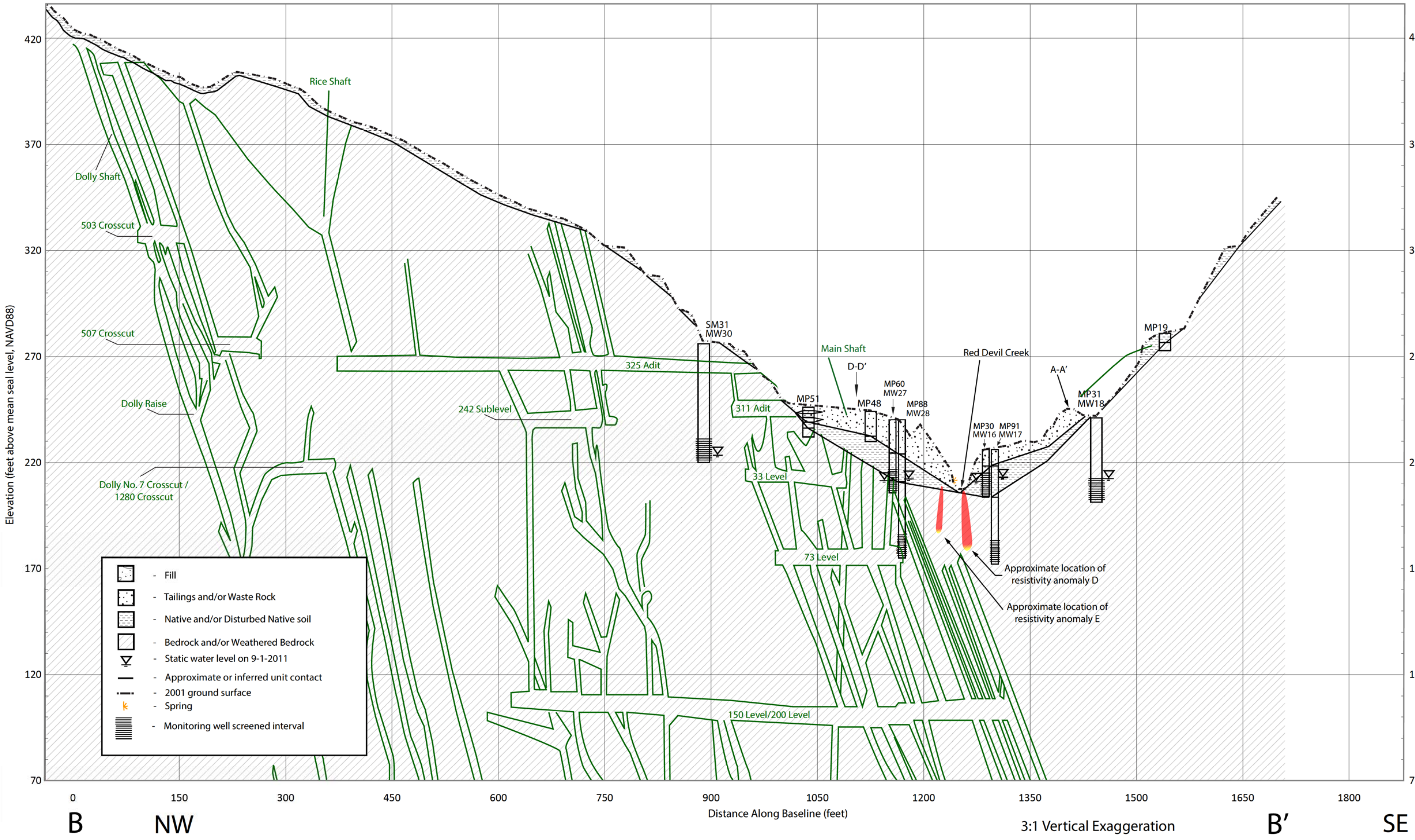

Notes: 1) Surface topography based on 5/27/2001 aerial photograph and topographic map (Aero-Metric, Inc. 2010)
2) Mine workings projected onto geological cross section based on March 1962 longitudinal projection (Alaska Mines and Minerals, Inc. and Decoursey Mountain Mining Co., Inc., 1962)
3) Approximate resistivity anomaly locations based on USGS (2011)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-3
Geologic Cross Section and Underground Mine Workings

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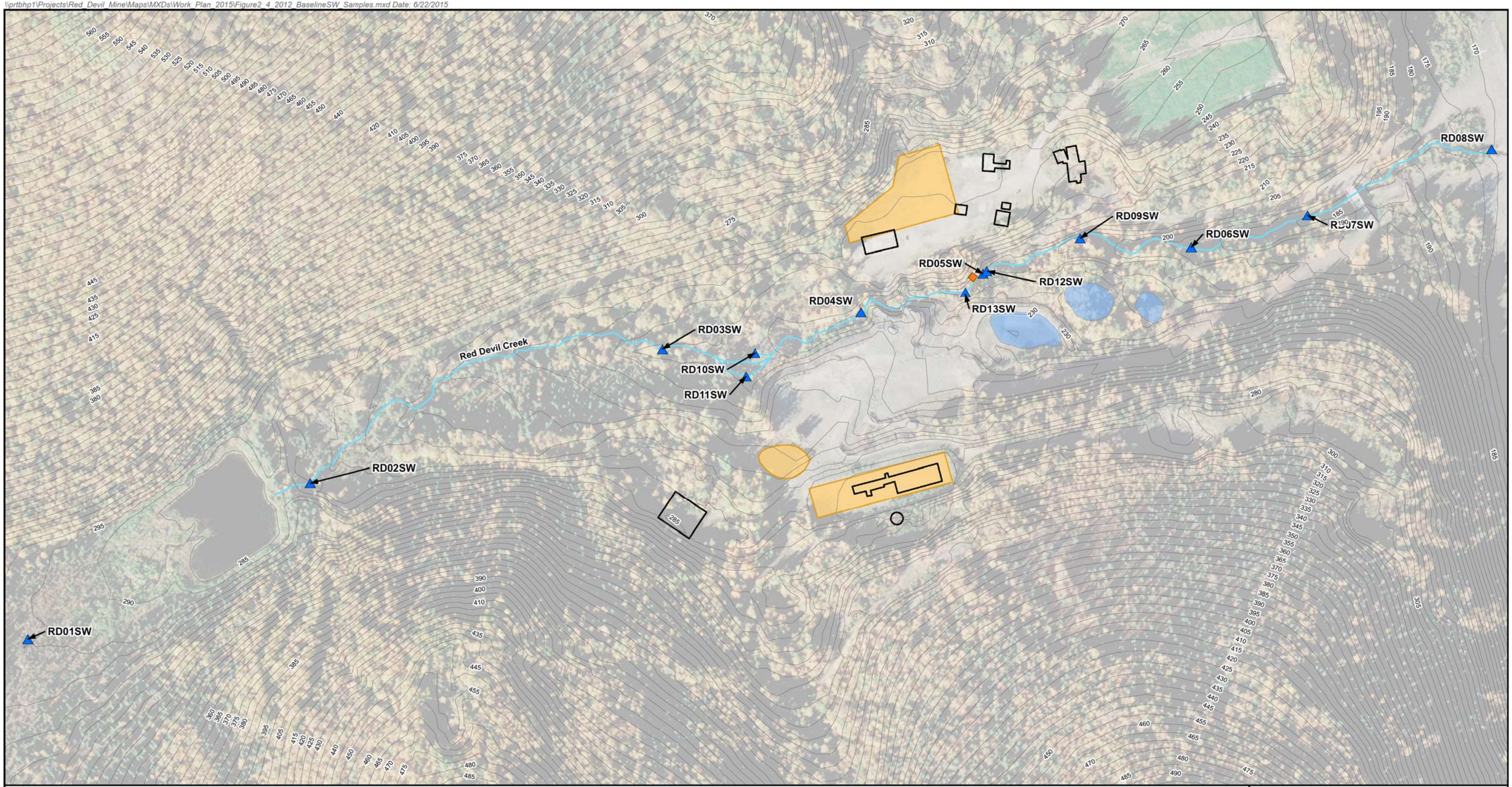

▲ Surface Water Sample Location

✱ Seep Location

— 2010 5-foot Contour

— Red Devil Creek

🟦 Settling Pond

🟧 Monofill

☐ Historical Structure

Digital aerial orthophotograph taken on September 21, 2010 (AeroMetric 2010)

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-4
RI and 2012 Baseline Surface Water Sample Locations

0 37.5 75 150 225 300
Feet
0 12.5 25 50 75 100
Meters
Scale: 1:2,000

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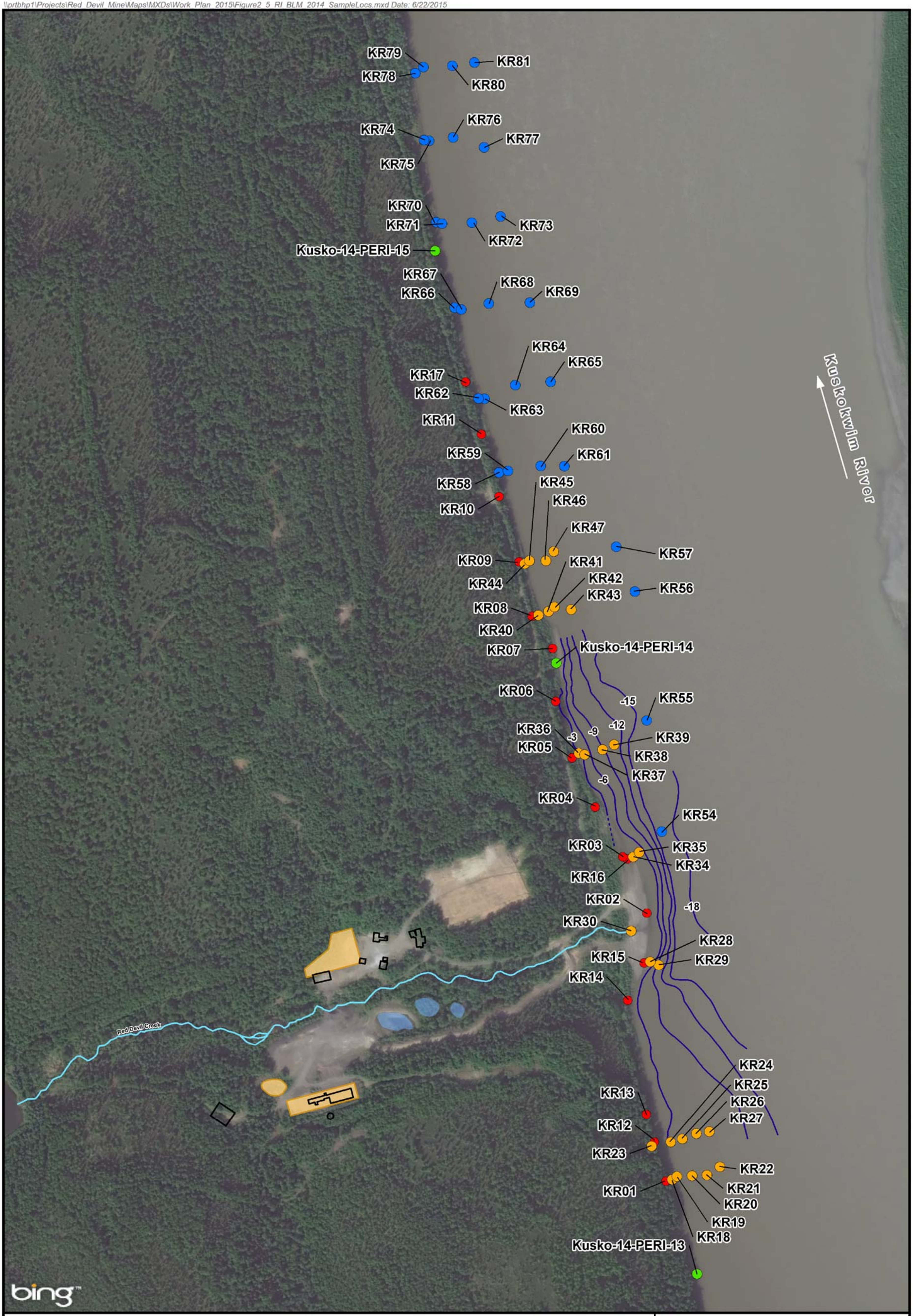

- ● 2014 BLM Periphyton Sample Location
- ● 2012 RI Sediment Sample Location
- ● 2011 RI Sediment Sample Location
- ● 2010 RI Sediment Sample Location
- — Bathymetric contour (feet)
- ▨ Settling Pond
- ▨ Monofill
- ☐ Historical Structure

Bathymetric contours represent approximate depths below river surface on September 25, 2011

RED DEVIL MINE

Red Devil, Alaska

Figure 2-5
Kuskokwim River RI Sediment and BLM Periphyton Sample Locations

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

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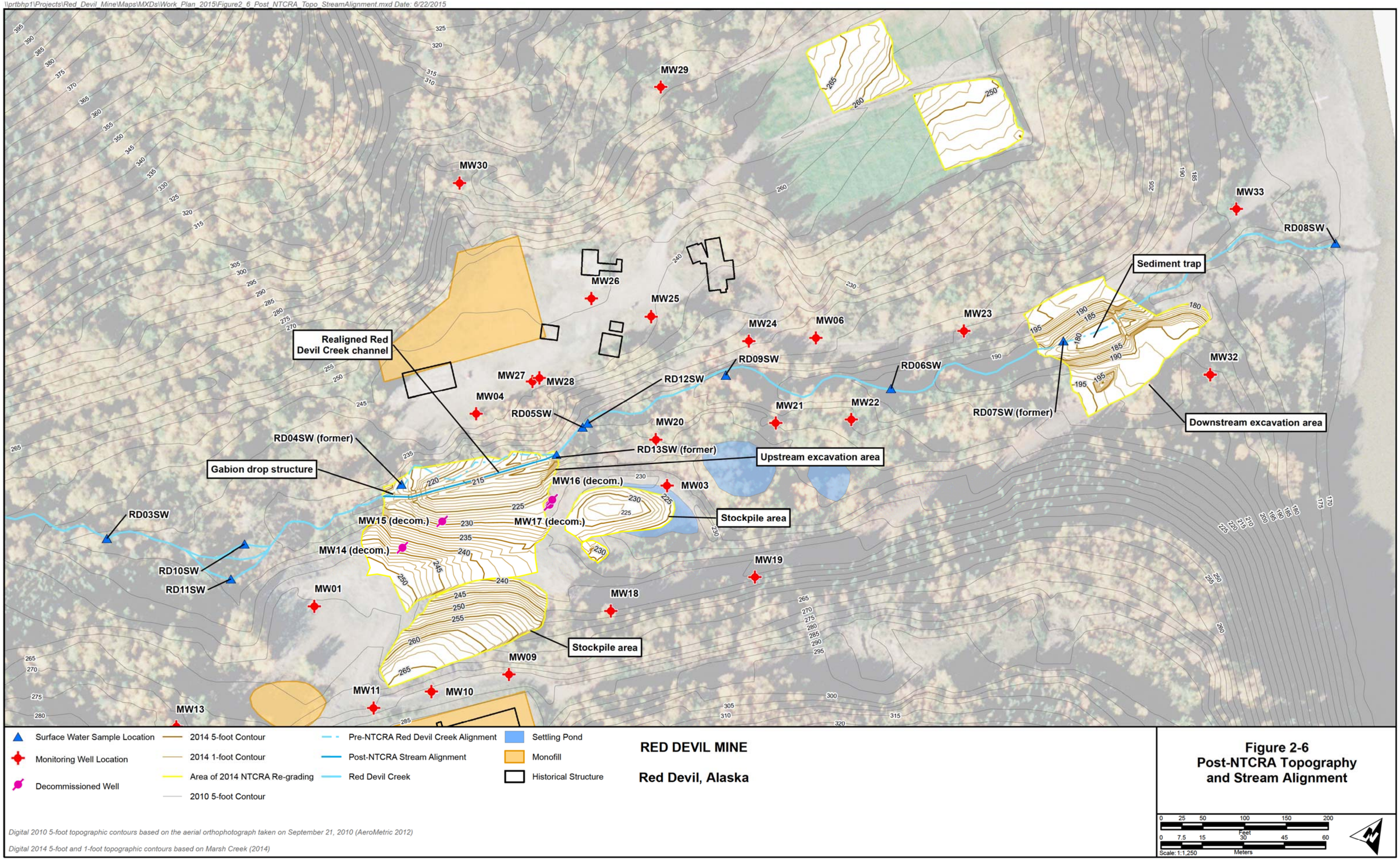

RED DEVIL MINE

Red Devil, Alaska

Figure 2-6
Post-NTCRA Topography and Stream Alignment

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

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3

Data Quality Objectives

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

The DQO steps are as follows.

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

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

3.1 Step 1: State the Problem

The key problem statements for the supplemental RI activities for soil groundwater, surface water, and Kuskokwim River sediment are presented below.

Soil

1) In parts of the Main Processing Area and Red Devil Creek Area, soil is locally impacted by migration of inorganic elements from tailings/waste rock. The depths and inorganic element concentrations of such impacted soils are not known well enough to fully inform risk management decisions.

2) In parts of the Main Processing Area and Red Devil Creek Area, one or more of the following subsurface conditions are not well understood: thickness of tailings/waste rock; lithology and mineralogy, thickness, and inorganic element concentrations of underlying soil/alluvium; depth to bedrock; and depth of the saturated zone(s).
3) Although natural mineralization is known to have affected rock and soil present at the site, the presence, locations/depths, and nature of such naturally mineralized materials in soils in the Main Processing Area and Red Devil Creek Area are not understood well enough to support risk management decisions pertaining to soil.
4) In parts of the Surface Mined Area, the following subsurface conditions are not well understood: thickness of soils and depth of bedrock; presence and thickness of any saturated intervals; presence of natural mineralization; and concentrations of inorganic elements.

Groundwater

1) Although flow of groundwater through naturally mineralized soil and bedrock and associated underground mine workings is understood to affect concentrations of inorganic elements in groundwater, the impacts of such processes are not understood well enough to inform risk management decisions.
2) The impacts of the physical modifications of the site, due to the NTCRA, on groundwater and surface water flow paths and interactions, and consequently, on groundwater inorganic element concentrations, are not understood well enough to support future risk management decisions.
3) RI monitoring wells were decommissioned as part of the NTCRA. New wells are necessary to provide ongoing groundwater monitoring data formerly available using these wells.
4) Additional multi-year baseline monitoring of groundwater conditions (including depth, hydraulic gradient, and concentrations of inorganic elements) is needed.
5) The extent of organic compounds in groundwater has not been fully delineated.
6) Additional information on the occurrence, depth, and quality of groundwater in the area downgradient of Monofill #2 is needed.

Surface Water

1) Although naturally mineralized bedrock and underground mine workings in the Surface Mined Area impact groundwater flow paths and inorganic element concentrations, and consequently, surface water concentrations and loading in the Main Processing Area, these impacts are not characterized well enough to support risk management decisions.

2) The impacts of the physical modifications of the site, due to the NTCRA, on groundwater and surface water flow paths and interactions, and consequently, on surface water loading and inorganic element concentrations, are not known.
3) Additional multi-year baseline monitoring of surface water conditions (including flow rates and concentrations and loading of inorganic elements) is needed.

Kuskokwim River Sediment

1) The potential toxicity of contaminated Kuskokwim River sediments is not known.
2) The potential for methylation and bioaccumulation of mercury for Kuskokwim River sediment is not well known.
3) The downriver and cross-river extents of contamination of Kuskokwim River sediment have not been delineated.
4) The turbidity of Kuskokwim River water has not been measured.

3.2 Step 2: Identify the Decision

To accomplish the objectives of the supplemental RI activities, key study questions (data gaps) are presented below for soil groundwater, surface water, and Kuskokwim River sediment.

Soil

The supplemental RI soil characterization addresses the following study questions:

1) In the Main Processing Area and Red Devil Creek Area, what are the depths and inorganic element concentrations of contamination due to deposition of inorganic elements leached from tailings/waste rock?
2) What are the subsurface conditions in parts of the Main Processing Area and Red Devil Creek Area containing tailings/waste rock for the following characteristics: thickness of tailings/waste rock; lithology and mineralogy, thickness, and inorganic element concentrations soil/alluvium; depth to bedrock; and depth of the saturated zone(s)?
3) Are soil and bedrock in parts of the Main Processing Area and Red Devil Creek Area affected by natural mineralization? If so, what are the locations and nature of such materials?
4) What are the subsurface conditions in the parts of the Surface Mined Area for the following characteristics: thickness of soils/depth to bedrock; presence and thickness of any saturated intervals; presence of natural mineralization; and concentrations of inorganic elements?

Groundwater

The supplemental RI groundwater characterization addresses the following study questions:

1) What are the groundwater flow patterns and groundwater quality (including inorganic element concentrations) in parts of the Surface Mined Area potentially impacted by naturally mineralized bedrock and mine workings?
2) What are the groundwater and surface water flow paths and interactions, and groundwater concentrations of inorganic elements in the area affected by the NTCRA?
3) What are the groundwater conditions in the part of the Main Processing Area near the former monitoring wells that were decommissioned as part of the NTCRA?
4) What is the temporal variability (e.g., seasonal and annual) of groundwater conditions (including depth, hydraulic gradient, and concentrations of inorganic elements) at the site?
5) What are the concentrations of organic compounds in groundwater in parts of the site?
6) What are the groundwater conditions in the area downgradient of Monofill #2?

Surface Water

The supplemental RI surface water characterization addresses the following study questions:

1) What is the quality of surface water (including concentration of inorganic elements) at the site, including surface water impacted by flow of groundwater that is impacted by naturally mineralized bedrock and underground mine workings in the Surface Mined Area?
2) What are the groundwater and surface water flow paths and interactions, and surface water quality (including concentrations and loading of inorganic elements) and flow rates in the area affected by the NTCRA?
3) What is the temporal variability (e.g., seasonal and annual) of surface water conditions (including flow rates and concentrations and loading of inorganic elements) at the site?

Kuskokwim River Sediment

The supplemental RI Kuskokwim river sediment characterization addresses the following study questions:

1) What is the potential toxicity of contaminated Kuskokwim River sediments?

2) What is the potential for methylation and bioaccumulation of mercury for Kuskokwim River sediment?
3) What are the downriver and cross-river extents of contamination of Kuskokwim River sediment?
4) What is the turbidity of water in the Kuskokwim River?

3.3 Step 3: Identify the Inputs to the Decision

This section identifies the types of information needed to support resolution of the decisions. The specific types of information needed to address the decisions for soil groundwater, surface water, and Kuskokwim River sediment are presented below.

Soil

1) To address the lack of information in parts of the Main Processing Area and Red Devil Creek Area on depths of contamination and concentrations of inorganic elements in soil below tailings/waste rock that are impacted by deposition of inorganic elements leached from tailings/waste rock, the following types of additional information will be needed:
    a. Subsurface soil lithological, mineralogical, and total inorganic elements concentration data from additional subsurface soil sampling in soil borings to be installed in the Main Processing Area.
2) To address the lack of information in parts of the Main Processing Area and Red Devil Creek Area on subsurface conditions, the following types of additional information will be needed:
    a. Physical and chemical data for soil and bedrock sampled during installation of new soil borings, including: thickness of tailings/waste rock; lithological and mineralogical observations; concentrations of total inorganic elements of soil/alluvium underlying tailings/waste rock; thickness of various soil types; depth to bedrock; and presence, depth, and thickness of saturated interval(s).
3) To assess possible natural mineralization in the Main Processing Area and Red Devil Creek Area, the following types of additional information will be needed:
    a. Physical and chemical data for subsurface soil and bedrock sampled during installation of new soil borings including: lithological and mineralogical observations; total inorganic element concentrations; and results of mercury SSE analyses.
4) To address the lack of information on subsurface conditions in the Surface Mined Area, the following types of additional information will be needed:
    a. Physical and chemical data for subsurface soil and bedrock sampled during installation of new soil borings including:

lithological and mineralogical observations; observations on the presence and depths of saturated intervals; and total inorganic element concentrations.

Groundwater

1) To address the lack of information on groundwater flow patterns and groundwater inorganic element concentrations in parts of the Surface Mined Area potentially impacted by naturally mineralized bedrock and mine workings, the following types of additional data will be needed:

    a. Information on soil and bedrock characteristics to be collected during installation and sampling of new monitoring wells in the Surface Mined Area (see Soil Item 4 above).

    b. Information on groundwater occurrence and depth to be collected during installation of new monitoring wells and static water level measurements in new and existing wells in the Surface Mined Area.

    c. Information on groundwater quality to be obtained by sampling groundwater from new and existing monitoring wells in the Surface Mined Area. Groundwater quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved mercury; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).

    d. Information on groundwater-surface water interactions in the Main Processing Area, and surface water discharge, and surface water quality (see Surface Water Item 1 below).

2) To address the lack of information on the groundwater and surface water flow paths and interactions and groundwater quality in the area affected by the NTCRA, the following types of additional data will be needed:

    a. Information on groundwater occurrence and depth to be collected during installation of new monitoring wells and static water level measurements in new and existing wells in the Main Processing Area.

    b. Information on groundwater quality to be obtained by sampling groundwater from new and existing monitoring wells in the Surface Mined Area. Groundwater quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved mercury; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).

3) To address the elimination of former RI monitoring wells that were decommissioned as part of the NTCRA, new monitoring wells will be installed in the Main Processing Area.
4) To address the lack of information on the temporal variability (e.g., seasonal and annual) of groundwater conditions at the site, the following types of additional baseline groundwater monitoring data will be needed for two baseline monitoring events planned for 2015:
    a. Information on groundwater depth to be collected during static water level measurements in new and existing wells at the site.
    b. Information on groundwater quality to be obtained by sampling groundwater from new and selected existing monitoring wells at the site. Groundwater quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved mercury; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).
5) To address the lack of information regarding organic compounds in groundwater, the following additional types of data will be needed:
    a. Groundwater sample analyses for SVOCs, DRO, GRO, and BTEX from selected monitoring wells.
6) To address lack of information on groundwater conditions downgradient of Monofill #2, additional groundwater monitoring data from wells MW09 and MW10 are needed.

Surface Water

1) To address the lack of information on the quality of surface water at the site, including surface water impacted by flow of groundwater that is impacted by naturally mineralized bedrock and underground mine workings in the Surface Mined Area, the following additional data will be needed:
    a. Information on surface water discharge at locations along Red Devil Creek.
    b. Information on surface water quality at locations along Red Devil Creek. Surface water quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved TAL metals and mercury; total organic carbon (TOC); TSS; TDS; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).

2) To address the lack of information on the groundwater and surface water flow paths and interactions and surface water quality in the area affected by the NTCRA, the following types of additional data will be needed:
    a. Information on surface water discharge at locations along Red Devil Creek.
    b. Information on surface water quality at locations along Red Devil Creek. Surface water quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved TAL metals and mercury; TOC; TSS; TDS; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).
3) To address the lack of information on the temporal variability (e.g., seasonal and annual) of surface water conditions at the site, the following types of additional baseline surface water monitoring data will be needed for two baseline monitoring events planned for 2015:
    a. Information on surface water discharge at locations along Red Devil Creek.
    b. Information on surface water quality at locations along Red Devil Creek. Surface water quality parameters include field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and mercury; dissolved TAL metals and mercury; TOC; TSS; TDS; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate).

Kuskokwim River Sediment

1) To address the question of whether contaminated sediment in the Kuskokwim River is toxic to benthic macroinvertebrates, the following types of additional data will be needed:
    a. Additional sediment characterization data, including results of sediment toxicity testing, analysis for total metals, mercury SSE, grain size, and TOC.
2) To address the lack of information on potential methylation and bioaccumulation of mercury for Kuskokwim River sediment, methylmercury analysis will be performed on selected sediment samples.
3) To address the lack of information on the downriver and cross-river extents of contamination of Kuskokwim River sediment, the following types of additional data will be needed:
    a. Additional sediment characterization data, including results of total metals, grain size, and TOC for samples collected from locations

downriver and outboard of the extent of RI sediment samples collected in 2010, 2011, and 2012.

4) To address the lack of information on turbidity of Kuskokwim River water, the following types of additional data will be needed:
    a. Field turbidity measurement data for selected locations in the Kuskokwim River.

3.4 Step 4: Define the Study Boundaries

The supplemental RI activities will be performed within the upland area of the site (as shown on Figure 1-2 of the final RI report) and in the Kuskokwim River, including the area previously sampled during the RI, as well as from locations further downriver and outboard of the extent of RI sediment samples collected in 2010, 2011, and 2012. Locations of Kuskokwim River sediment samples collected during the RI and periphyton samples collected by the BLM in 2014 are illustrated on Figure 2-5. Planned sampling locations for the supplemental RI activities are presented in Chapter 4.

3.5 Step 5: Develop a Decision Rule

It is anticipated that data collected as part of the supplemental RI activities will be used to support the development of site-wide remedial decisions at the RDM site. Decision rules for employing the results of the supplemental RI characterization to make risk management and cleanup decisions will be developed in consultation with the Alaska Department of Environmental Conservation and the EPA following review of the supplemental RI data and supporting information.

3.6 Step 6: Specify Tolerable Limits on Decision Errors

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

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

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

Quality control samples will be collected and analyzed with environmental samples to assure that data are of known precision and accuracy. Control limits on both precision and accuracy for soil, groundwater, surface water, and sediment samples for planned analyses are addressed in the Quality Assurance Project Plan (QAPP), contained in Appendix C of the RI/FS Work Plan and the QAPP Addendum, presented in Appendix B of this Work Plan Supplement.

3.7 Step 7: Optimize the Design for Obtaining Data

Data gaps were identified for soil, groundwater, surface water, and Kuskokwim River sediments during the development of the FS. These data gaps are presented in Chapter 2 and Section 3.2. Based on these data gaps and Steps 1 through 6 of this DQO process, a study design for the supplemental RI characterization and baseline monitoring has been developed. Details of the study design are presented in Chapter 4 of this work plan supplement.

4 Overview of Study Design

The planned supplemental RI activities presented in this document are intended to augment existing RI and other data to support the development of site-wide risk management decisions encompassing soil, groundwater, surface water, and Kuskokwim River sediment. The planned baseline monitoring activities are intended to provide additional temporal data on groundwater and surface water conditions at the site. The study design presented in this document addresses these needs and was developed following the DQO planning process presented in Chapter 3. An overview of the study design is presented below. Detailed field investigation locations, objectives, rationale, methodologies, and procedures are provided in the field sampling plan, provided as Appendix A of this work plan supplement.

4.1 Soil

Additional soil characterization will be performed to gather the types of additional information identified in Section 3.3. Additional soil characterization will be performed by installing additional soil borings at the site, including:

- Nine soil borings in the Main Processing Area (two of which will be converted to monitoring wells);
- Three soil borings in the Red Devil Creek Area; and
- Five soil borings in the Surface Mined Area (which will be converted to monitoring wells).

Soil and bedrock characterization will be performed using a combination of field observations, results of XRF field screening for total inorganic elements, and laboratory analysis for total TAL metals and mercury SSE. Planned locations of soil borings and details of soil characterization objectives, rationale, methodologies, and procedures are provided in the field sampling plan.

Data generated during the planned 2015 supplemental soil characterization will be presented in an RI report supplement. Soil data collected in the Main Processing Area from depth intervals below the tailings/waste rock will be used to refine the current estimate of depth/volume of material to be remediated through action being assessed under the current FS.

4.2 Groundwater

Additional groundwater characterization will be performed to gather the types of additional information identified in Section 3.3. Additional groundwater characterization will include installing additional monitoring wells at the site and collecting groundwater data from new and selected existing monitoring wells. Planned new monitoring wells are:

- Five new monitoring wells in the Surface Mined Area; and
- Two new monitoring wells in the Main Processing Area.

It is anticipated that one round of groundwater monitoring will be performed using existing RI monitoring wells in the spring/summer 2015. New wells will be installed subsequent to the spring/summer 2015 monitoring, and samples will be collected from these wells following their completion prior to demobilization from the site. A second round of groundwater monitoring of the RI and new wells will be performed during a second mobilization to the site in the fall 2015.

Static water levels will be measured in all existing monitoring wells. Selected wells, including all new monitoring wells, will be sampled for field and laboratory water quality parameters. Locations of planned new monitoring wells and existing monitoring wells planned for monitoring, objectives, rationale, methodologies, and procedures for monitoring well installation and monitoring are provided in the field sampling plan.

Data generated during the planned 2015 supplemental groundwater characterization and baseline groundwater monitoring will be presented in an RI report supplement. Although the planned wells in the Surface Mined Area are intended primarily to assess the potential influence of natural mineralization on groundwater upgradient of the Main Processing area, the resulting information may provide information useful for characterizing groundwater conditions downgradient of the possible on-site repository considered as part of the FS.

After completion of the 2015 baseline monitoring effort, the baseline monitoring results will be reviewed for the purpose of revising the Baseline Monitoring Work Plan for the BLM to use for future baseline monitoring events beginning after 2015. Any trends in groundwater elevation and surface water discharge, groundwater and surface water contaminant concentrations (for arsenic, mercury, and antimony), and surface water contaminant loading identified during preparation of the RI report supplement will be evaluated to guide the selection of monitoring wells, surface water monitoring stations, and analytical parameters appropriate for the BLM's long-term monitoring at the site.

4.3 Surface Water

Additional surface water characterization will be performed to gather the types of additional information identified in Section 3.3. Additional surface water characterization will be performed at eight surface water monitoring stations, including the seep, along Red Devil Creek.

At selected surface water monitoring locations along Red Devil Creek and the seep, discharge rates will be measured and surface water will be sampled for field and laboratory water quality parameters. Locations of planned surface water monitoring stations, objectives, rationale, methodologies, and procedures for surface water characterization and monitoring are provided in the field sampling plan.

It is anticipated that one round of surface water monitoring will be performed in the spring 2015 and a second round will be performed in the fall 2015.

Data generated during the planned 2015 supplemental surface water characterization and baseline surface water monitoring will be presented in an RI report supplement.

After completion of the 2015 baseline monitoring effort, the baseline monitoring results will be reviewed for the purpose of revising the Baseline Monitoring Work Plan for the BLM to use for future baseline monitoring events beginning after 2015. Any trends in groundwater elevation and surface water discharge, groundwater and surface water contaminant concentrations (for arsenic, mercury, and antimony), and surface water contaminant loading identified during preparation of the RI report supplement will be evaluated to guide the selection of monitoring wells, surface water monitoring stations, and analytical parameters appropriate for the BLM's long-term monitoring at the site.

4.4 Kuskokwim River Sediment

The planned supplemental Kuskokwim River sediment characterization addressed in this document is intended to assess whether contaminated Kuskokwim River sediment is toxic to benthic macroinvertebrates, to assess the potential for methylation and bioaccumulation of mercury, to assess the downriver and cross-river extent of contamination, and to evaluate the turbidity of Kuskokwim River water.

Additional sediment characterization will be performed at offshore sediment sample locations in the Kuskokwim River as described below.

- Twelve samples will be collected from the area upriver of, in the vicinity of, and downriver of Red Devil Creek delta. These samples will be analyzed for total TAL metals, TOC, and grain size distribution. These 12 samples also will be analyzed for toxicity using a *Hyallela azteca* 28-day test. Six of the samples also will be analyzed for methylmercury and mercury SSE.
- Twelve samples will be collected from locations cross-river and downriver from the areas of documented elevated concentrations of antimony,

arsenic, and mercury. Each of these samples will be analyzed for total TAL metals, TOC, and grain size distribution. Eleven of these samples also will be analyzed for toxicity using a *Hyallela azteca* 28-day test. In addition, eight of these samples also will be analyzed for methylmercury.

- Four samples will be collected from locations near the right bank of the Kuskokwim River along two previously defined RI sample transects near the Red Devil Creek delta. Two samples will be collected from one transect located upstream of Red Devil Creek, and two samples will be collected from one transect located a short distance downstream of Red Devil Creek. Along each transect, one sample will be collected from shallow water near the shore (approximately 10 to 20 feet from the right bank), and a second sample will be collected approximately 50 feet from the right bank. All four samples will be analyzed for TAL metals only.
- The water column at all sampling locations will be analyzed in the field for turbidity.

Planned sediment sampling locations, objectives, rationale, methodologies, and procedures are provided in the field sampling plan.

Samples planned for sediment toxicity testing will be collected generally from within the footprint of sediment samples collected during the RI and most of the planned locations are collocated with selected RI sample locations. The selected RI sample locations are biased toward locations where, based on RI sampling results:

- Larger proportions of finer grained materials (sand size and smaller) are expected to be present (to facilitate sample collection;
- TOC concentrations are expected to be fairly similar; and
- A wide range of total antimony, arsenic, and mercury concentrations are expected to be present.

A summary of RI Kuskokwim River sediment sample data is presented in Table 4-1. In addition, several of the samples planned for toxicity testing will be collocated with periphyton samples collected by BLM in 2014. Samples intended to assess cross-river and downriver extents of contamination will be collected from outside of the footprint of the RI sediment samples. A subset of these planned samples will be collocated with downriver periphyton samples collected by BLM in 2014.

Results of the supplemental Kuskokwim River sediment characterization will be presented in an RI report supplement. Results of the proposed sediment toxicity testing and other tests will be used in conjunction with results of periphyton sampling performed by BLM in 2014 (BLM 2014) and recent fish tissue and telemetry data for the middle Kuskokwim River region (USFWS 2012) to support the development of site-wide risk management decisions encompassing Kuskokwim River sediment impacted by the site.

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Table 4-1 Summary of RI Kuskokwim River Sediment Sample Data

	Background Screening Criteria	Station ID		KR14	KR15	KR28	KR29	KR30	KR02	KR16	KR03	KR34	KR35	KR54	KR04	KR05	KR36	KR37	KR38	KR39	KR55	KR06	KR07	KR08
		Sample ID		11KR14SD	11KR15SD	11KR28SD	11KR29SD	11KR30SD	10KR02SD	11KR16SD	10KR03SD	11KR34SD	11KR35SD	0912KR54SD	10KR04SD	11KR05SD	11KR36SD	11KR37SD	11KR38SD	11KR39SD	0912KR55SD	11KR06SD	10KR07SD	11KR08SD
		Location Description		Shoreline	Shoreline	Offshore	Offshore	Offshore	Shoreline	Shoreline	Shoreline	Offshore	Offshore	Offshore	Shoreline	Shoreline	Offshore	Offshore	Offshore	Offshore	Offshore	Shoreline	Shoreline	Shoreline
Analyte		Method	Units																					
Total Inorganic Elements																								
Aluminum	12500	SW6010B-Total	mg/kg	**11300 J**	**6810 J**	**7170**	**4340**	**4530**	**9750**	**13500 J**	**17000**	**7050**	**7020**	**4000**	**12600**	**6460 J**	**18400**	**12400**	**6010**	**2050**	**5900**	**7480 J**	**4510**	**9550 J**
Antimony	0.446	SW6010B/SW6020A-Total	mg/kg	**5.41 J**	**272 J**	**589 J**	**360 J**	**894 J**	**1280 J**	**15.2**	**10 J**	**1060 J**	**1420 J**	**4.4**	0.62 U	**99**	**7.72 J**	**5.57 J**	**753**	**149**	**0.18**	**2.1**	**40 J**	**5.48**
Arsenic	15	SW6010B/SW6020A-Total	mg/kg	**12.5 J**	**414 J**	**304 J**	**502 J**	**938 J**	**1790**	**39.2 J**	**60**	**958 J**	**1280 J**	**17**	**30**	**135 J**	**19.2 J**	**19.4 J**	**918**	**79.3**	**8.5**	**17.5 J**	**800**	**52 J**
Barium	168.7	SW6010B/SW6020A-Total	mg/kg	**116 J**	**124 J**	**105**	**187**	**242**	**418**	**152 J**	**227**	**220**	**398**	**57 J**	**161**	**91.6 J**	**131**	**130**	**179 J**	**88.4 J**	**94 J**	**128 J**	**145**	**120 J**
Beryllium	0.505	SW6010B/SW6020A-Total	mg/kg	**0.283**	**0.268**	**0.245**	**0.357**	**0.374**	**0.8**	**0.339**	**0.6**	**0.47**	**0.438**	**0.18**	**0.5**	**0.344**	**0.347**	**0.336**	**0.367**	**0.469**	**0.35**	**0.293**	**0.8**	**0.297**
Cadmium	0.82	SW6010B/SW6020A-Total	mg/kg	**0.251 J**	**0.219 J**	**0.254**	**0.222**	**0.204**	0.058 U	**0.342 J**	**0.6**	**0.301**	**0.294**	**0.1**	**0.4**	**0.27 J**	**0.256**	**0.272**	**0.213 J**	**0.663 J**	**0.22**	**0.281 J**	0.061 U	**0.282 J**
Calcium	4283	SW6010B-Total	mg/kg	**3930 J**	**1550 J**	**19400**	**1960**	**2270**	**2920**	**7480 J**	**6020**	**2770**	**2740**	**1600**	**5920**	**1810 J**	**8550**	**7570**	**2280**	**2060**	**2900**	**6830 J**	**1630**	**5230 J**
Chromium	25.43	SW6010B/SW6020A-Total	mg/kg	**19.7 J**	**11.1 J**	**6.22 J**	**15.1 J**	**19.7 J**	**25**	**21.9 J**	**36**	**16.5 J**	**18.4 J**	**12 J**	**26.7**	**14.2 J**	**22.8 J**	**21.5 J**	**18.9 J**	**11.4 J**	**17 J**	**20.1 J**	**18**	**18.3 J**
Cobalt	14.15	SW6010B/SW6020A-Total	mg/kg	**6.93 J**	**7.69 J**	**9.02**	**11.3**	**8.64**	**14.8**	**8.14 J**	**12.8**	**11.1**	**10.6**	**5.5**	**9.9**	**9.36 J**	**8.54**	**8.16**	**7.3**	**18.2**	**9.1**	**7.14 J**	**18**	**7.78 J**
Copper	37.1	SW6010B/SW6020A-Total	mg/kg	**15**	**20.3**	**13.2 J**	**24.4 J**	**23.5 J**	**37.2 J**	**23.2**	**31 J**	**29.5 J**	**28.2 J**	**8.5 J**	**22 J**	**25.1**	**18.8 J**	**18.7 J**	**23 J**	**87.5 J**	**23 J**	**19**	**56.5 J**	**18.8**
Iron	34626	SW6010B-Total	mg/kg	**24200**	**19800**	**34900**	**25700**	**24400**	**29100**	**29900**	**33900**	**28300**	**31100**	**14000**	**25100**	**33400**	**43300**	**28700**	**19600**	**32300**	**23000**	**25900**	**48100**	**24000**
Lead	13.01	SW6010B/SW6020A-Total	mg/kg	**6.62 J**	**6.06 J**	**5.5**	**5.79**	**5.84**	**7**	**8.82 J**	**10**	**6.88**	**5.94**	**2.2**	**7**	**7.78 J**	**7.03**	**6.7**	**3.94**	**14.1**	**7.2**	**7.32 J**	**10**	**6.71 J**
Magnesium	760.7	SW6010B-Total	mg/kg	**5330**	**2410**	**11400**	**1660**	**3290**	**4530**	**6720**	**6450**	**4890**	**5100**	**2500 J**	**5410**	**2890**	**9370**	**6340**	**3090 J**	**6030 J**	**4000 J**	**6150**	**990**	**4910**
Manganese	760.7	SW6010B-Total	mg/kg	**404**	**5410**	**949**	**522**	**828**	**750**	**586**	**712**	**908**	**666**	**560**	**429**	**708**	**849**	**555**	**466 J**	**1220 J**	**670**	**557**	**684**	**505**
Mercury	0.144	SW7471A-Total	mg/kg	**0.387 J**	**39.2 J**	**33.6 J**	**38.9 J**	**24.2 J**	**56 J**	**2.36 J**	**2.1 J**	**104 J**	**46.1 J**	**0.2**	**0.82 J**	**119 J**	**0.827 J**	**0.208 J**	**19 J**	**1.73 J**	**0.16**	**0.169 J**	**13.2 J**	**1.15 J**
Nickel	40.11	SW6010B/SW6020A-Total	mg/kg	**19.4**	**21**	**21.1**	**31.5**	**29.5**	**48**	**25.3**	**35**	**37.8**	**31.1**	**15**	**28**	**25.7**	**25.6**	**24.3**	**27.5 J**	**65.1 J**	**29**	**23.1**	**55**	**23.8**
Potassium	1134	SW6010B-Total	mg/kg	**1070**	**1070**	**803**	**791**	**1150**	**2190**	**1520**	**1960**	**1590**	**1320**	**480**	**1440**	**749**	**1830**	**1390**	**1500 J**	**1280 J**	**1100**	**1380**	**1120**	**1080**
Selenium	0.773	SW7742-Total	mg/kg	**0.42**	**0.55 J**	**0.33**	**0.22**	**0.19 J**	1.7 U	**0.52**	1.2 U	**0.24**	**0.16 J**	**0.27**	**0.9 U**	**0.39**	**0.39**	**0.35**	0.15 U	**2.11**	**0.65**	**0.39**	1.8 U	**0.31**
Silver	0.127	SW6010B/SW6020A-Total	mg/kg	**0.141**	**0.098**	**0.111**	**0.156**	**0.112**	0.116 U	**0.229**	0.081 U	**0.111**	**0.097**	**0.02**	0.061 U	**0.198**	**0.201**	**0.145**	**0.108**	**0.41**	**0.088**	**0.167**	0.121 U	**0.128**
Sodium	150.9	SW6010B-Total	mg/kg	**143**	**82.5**	**62.6**	**48**	**75.5**	**220**	**200**	**240**	**139**	**125**	**59**	**210**	**77.5**	**262**	**193**	**163**	**56.1**	**120**	**187**	45.7 U	**144**
Thallium	0.144	SW6010B/SW6020A-Total	mg/kg	**0.104**	**0.09**	**0.653**	**0.084**	**0.419**	0.7 U	**0.136**	0.5 U	**0.158**	**0.229**	0.14 U	0.38 U	**0.076**	**0.109**	**0.125**	**0.145**	**0.107**	0.15 U	**0.12**	0.8 U	**0.105**
Vanadium	36.93	SW6010B/SW6020A-Total	mg/kg	**25.5 J**	**16.6 J**	**10.9**	**19.5**	**20.7**	**27.3**	**28.6 J**	**48.5**	**20.7**	**15.1**	**16**	**36.9**	**22.4 J**	**29.5**	**28.3**	**16**	**25.8**	**24**	**26.1 J**	**32.5**	**23.6 J**
Zinc	174	SW6010B/SW6020A-Total	mg/kg	**65.3 J**	**53.8 J**	**50.7 J**	**67.6 J**	**56.7 J**	**83**	**80 J**	**105**	**84.1 J**	**68.6 J**	**32 J**	**80**	**76.6 J**	**72.1 J**	**69.9 J**	**50.8 J**	**132 J**	**62 J**	**71.7 J**	**119**	**67.9 J**
Arsenic Speciation																								
Arsenate		EPA 1632-As-Cryo-S-Speciation	mg/kg	**54.7**	**1710**	-	-	-	**1900 J**	**38.7**	**40.9 J**	-	-	-	**29.1 J**	**184**	-	-	-	-	-	**20.5**	**1020 J**	**47.5**
Arsenite		EPA 1632-As3-CRYO-T	mg/kg	**12.7 J**	**152 J**	-	-	-	**42.5 J**	**31.8 J**	**15.1 J**	-	-	-	**2.63 J**	**47.3 J**	-	-	-	-	-	**5.56 J**	**2.49 J**	**7.49 J**
Inorganic Arsenic		EPA 1632-Total Inorganic As - Solid	mg/kg	**67.4**	**1860**	-	-	-	**1940 J**	**70.5**	**56 J**	-	-	-	**31.7 J**	**231**	-	-	-	-	-	**26**	**1020 J**	**55**
Mercury Selective Sequential Extraction																								
Hg(F0)		EPA 1631	ng/g	-	-	-	-	-	**3.49 U**	-	-	-	-	-	**3.88 U**	-	-	-	-	-	-	-	**6.13**	-
Hg(F1)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**797 J**	-	-	-	-	-	**5.2 J**	-	-	-	-	-	-	-	**93.1 J**	-
Hg(F2)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**38.7 J**	-	-	-	-	-	**0.28 U**	-	-	-	-	-	-	-	**12.5 J**	-
Hg(F3)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**1520 J**	-	-	-	-	-	**572 J**	-	-	-	-	-	-	-	**684 J**	-
Hg(F4)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**10700 J**	-	-	-	-	-	**403 J**	-	-	-	-	-	-	-	**2040 J**	-
Hg(F5)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**175000**	-	-	-	-	-	**4380**	-	-	-	-	-	-	-	**831000**	-
Hg(F6)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	**288 J**	-	-	-	-	-	**91.5 J**	-	-	-	-	-	-	-	**16200 J**	-
Methylmercury																								
Methylmercury	0.49	CAS SOP/EPA 1630	ng/g	**0.20 J**	**2.64**	**1.34 J**		**.64 J**	**0.592**	**1.33**	**0.812**	**1.25 J**	-	-	**0.285**	**0.73**	-	**0.17 J**	-	-	-	**0.24 J**	0.009 U	**0.43 J**
Total Organic Carbon																								
Carbon, Total Organic (TOC)		SW9060M-Total Organic Carbon, Modified for Matrix	%	**0.534**	**0.32**	**0.621**	**0.627**	**0.378**	**0.594**	**1.43**	**1.64**	**0.563**	**0.471**	**0.21**	**0.612**	**0.342**	**0.757**	**0.84**	**0.307**	**2.05**	**0.63**	**0.511**	**0.586**	**0.486**
Percent fines			%	**43.92**	**13.29**	**7.39**	**8.8**	**0.63**	**18**	**98.32**	**92**	**1.34**	**0.42**	2.3	**66.6**	**26.6**	**58.1**	**56.94**	**1.41**	**20.72**	4.4	**70.13**	**21.5**	**50.71**
Sediment Textrure Description			NA	Sandy Silt	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel	Silty Sand	Sandy Silt	Sandy Silt	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Silt	Silty Sand	Sandy Silt	Sandy Silt	Sandy Gravel	Silty Gravel	Sandy Gravel	Sandy Silt	Silty Sand	Silty Sand

Bold = detection

% = percent

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

mg/kg = milligrams per kilogram

ng/g = nanograms per gram

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

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

Table 4-1 Summary of RI Kuskokwim River Sediment Sample Data

	Background Screening Criteria	Station ID		KR40	KR41	KR42	KR43	KR56	KR09	KR44	KR45	KR46	KR47	KR10	KR58	KR59	KR60	KR61	KR11	KR62	KR63	KR64	KR17	KR66
		Sample ID		11KR40SD	11KR41SD	11KR42SD	11KR43SD	0912KR56SD	11KR09SD	11KR44SD	11KR45SD	11KR46SD	11KR47SD	10KR10SD	0912KR58SD	0912KR59SD	0912KR60SD	0912KR61SD	10KR11SD	0912KR62SD	0912KR63SD	0912KR64SD	11KR17SD	0912KR66SD
		Location Description		Offshore	Offshore	Offshore	Offshore	Offshore	Shoreline	Offshore	Offshore	Offshore	Offshore	Shoreline	Offshore	Offshore	Offshore	Offshore	Shoreline	Offshore	Offshore	Offshore	Shoreline	Offshore
Analyte		Method	Units																					
Total Inorganic Elements																								
Aluminum	12500	SW6010B-Total	mg/kg	**9750**	**6390**	**3850**	**9110**	**4600**	**9770 J**	**3450**	**9560**	**7600**	**7380**	**7080**	**4700**	**4300**	**6900**	**5300**	**10600**	**4200**	**340**	**6300**	**8610 J**	**6100**
Antimony	0.446	SW6010B/SW6020A-Total	mg/kg	**57.1 J**	**25 J**	**64.1 J**	**40.2**	**0.19**	**9.51**	**21.6 J**	**0.237 J**	**31.9**	**24.6**	1.2 U	**44**	**13**	**26**	**0.49**	0.56 U	**18 J**	**1.1**	**4.7**	**4.26**	**4.8 J**
Arsenic	15	SW6010B/SW6020A-Total	mg/kg	**123 J**	**54.8 J**	**254 J**	**55**	**6.6**	**20.9 J**	**0.57 J**	**4.41 J**	**87.2**	**77.8**	**160**	**180**	**210**	**66**	**7**	**21**	**40 J**	**3.8**	**18**	**17.5 J**	**34**
Barium	168.7	SW6010B/SW6020A-Total	mg/kg	**132**	**66.6**	**193**	**118 J**	**66 J**	**122 J**	**4.12**	**89.8**	**107 J**	**70.1 J**	**151**	**130**	**110**	**120**	**66 J**	**138**	**67 J**	**7.1**	**50**	**111 J**	**110 J**
Beryllium	0.505	SW6010B/SW6020A-Total	mg/kg	**0.363**	**0.211**	**0.546**	**0.587**	**0.18**	**0.501**	**0.008 J**	**0.505**	**0.411**	**0.289**	**0.6**	**0.79**	**0.45**	**0.56**	**0.16**	**0.4**	**0.34**	**0.046**	**0.37**	**0.334**	**0.54**
Cadmium	0.82	SW6010B/SW6020A-Total	mg/kg	**0.308**	**0.16**	**0.657**	**0.515 J**	**0.11**	**0.338 J**	**0.017 J**	**0.153**	**0.561 J**	**0.202 J**	0.056 U	**0.5**	**0.36**	**1.1**	**0.14**	**0.4**	**0.24 J**	**0.03**	**0.47**	**0.345 J**	**0.38**
Calcium	4283	SW6010B-Total	mg/kg	**4250**	**2000**	**1320**	**2090**	**1700**	**5670 J**	**2110**	**10900**	**1710**	**1950**	**2950**	**2400**	**2000**	**3100**	**1600**	**6440**	**1400**	**160**	**1900**	**4390 J**	**3000**
Chromium	25.43	SW6010B/SW6020A-Total	mg/kg	**17.6 J**	**15.3 J**	**8.78 J**	**27.2 J**	**14 J**	**21.1 J**	**0.65 J**	**18.8 J**	**25 J**	**15 J**	**17**	**20**	**18**	**19**	**14 J**	**23.3**	**15**	**1.7**	**18**	**17.7 J**	**18 J**
Cobalt	14.15	SW6010B/SW6020A-Total	mg/kg	**9.08**	**7.14**	**14.8**	**11.4**	**4.9**	**10.8 J**	**0.369**	**15.8**	**13.9**	**8.44**	**15.1**	**27**	**13**	**17**	**5.6**	**9.2**	**10**	**0.95**	**11**	**10 J**	**9.9**
Copper	37.1	SW6010B/SW6020A-Total	mg/kg	**21.3 J**	**11.6 J**	**40.4 J**	**48.5 J**	**7.7 J**	**26.8**	**.68 J**	**21.5 J**	**41.5 J**	**21.1 J**	**41.9 J**	**63**	**33**	**83**	**10 J**	**19.6 J**	**28 J**	**4.2 J**	**47**	**24.9**	**46 J**
Iron	34626	SW6010B-Total	mg/kg	**26800**	**37900**	**39400**	**31100**	**11000**	**32400**	**55600**	**26200**	**25200**	**22800**	**31200**	**47000**	**29000**	**23000**	**13000**	**23200**	**24000**	**4000**	**29000**	**26000**	**38000**
Lead	13.01	SW6010B/SW6020A-Total	mg/kg	**6.74**	**3.13**	**9.28**	**14.8**	**2.4**	**9.34 J**	**0.05**	**8.97**	**9.78**	**5.95**	**10**	**16**	**8.6**	**18**	**5.5**	**6**	**5.9**	**0.84**	**8.7**	**9.27 J**	**11**
Magnesium	760.7	SW6010B-Total	mg/kg	**4600**	**2910**	**2050**	**4550 J**	**2500 J**	**4800**	**1760**	**4250**	**3770 J**	**3960 J**	**2580**	**1600**	**1700**	**3500**	**2600 J**	**4970**	**1900 J**	**180 J**	**3100**	**4060**	**3400 J**
Manganese	760.7	SW6010B-Total	mg/kg	**567**	**2530**	**1250**	**1220 J**	**400**	**649**	**1170**	**1730**	**1060 J**	**626 J**	**735**	**1200**	**1200**	**700**	**450**	**451**	**550 J**	**53**	**210**	**527**	**740**
Mercury	0.144	SW7471A-Total	mg/kg	**40 J**	**14.2 J**	**4.36 J**	**12 J**	**0.03**	**0.566 J**	**7.19 J**	**.199 J**	**4.75 J**	**7.18 J**	**3.6 J**	**260**	**8.4**	**29000**	**0.027**	**0.52 J**	**1.7 J**	**1.2**	**0.22**	**0.442 J**	**3.1 J**
Nickel	40.11	SW6010B/SW6020A-Total	mg/kg	**25.5**	**21.3**	**39.5**	**48.2 J**	**15**	**30.9**	**0.78**	**31.1**	**50.4 J**	**23.2 J**	**38**	**67**	**31**	**54**	**18**	**27**	**29**	**4**	**36**	**26.1**	**35**
Potassium	1134	SW6010B-Total	mg/kg	**990**	**764**	**964**	**784 J**	**590**	**1280**	**854**	**922**	**824 J**	**1080 J**	**1070**	**1000**	**700**	**1900**	**700**	**1250**	**630**	**61**	**750**	**996**	**1400**
Selenium	0.773	SW7742-Total	mg/kg	**0.36**	**0.3**	**0.36**	**0.87**	**0.29**	**0.5**	**0.61**	**0.17**	**0.58**	**0.46**	1.7 U	**1**	**0.81**	**2.5**	**0.35**	0.81 U	**0.54 J**	**0.075**	**1.3**	**0.39**	**1**
Silver	0.127	SW6010B/SW6020A-Total	mg/kg	**0.127**	**0.118**	**0.099**	**0.122**	**0.032**	**0.172**	**0.106**	**0.086**	**0.153**	**0.087**	0.113 U	**0.13**	**0.078**	**0.57**	**0.037**	0.055 U	**0.043 J**	**0.0072**	**0.12**	**0.15**	**0.14**
Sodium	150.9	SW6010B-Total	mg/kg	**119**	**74.7**	**42.8**	**52.8**	**59**	**145**	**40.4**	**61.6**	**57.7**	**66.2**	42.6 U	**70**	**54**	**110**	**100**	**180**	**72**	**5.8**	**51**	**113**	**120**
Thallium	0.144	SW6010B/SW6020A-Total	mg/kg	**0.107**	**0.056**	**0.128**	**0.096**	0.16 U	**0.123**	**0.011 J**	**0.06**	**0.08**	**0.07**	0.7 U	**0.12**	0.12 U	**0.32**	0.14 U	0.34 U	0.15 U	0.014 U	0.15 U	**0.109**	0.15 U
Vanadium	36.93	SW6010B/SW6020A-Total	mg/kg	**24.1**	**19.5**	**11.4**	**29.3**	**18**	**30.1 J**	**1.72**	**30.8**	**23.5**	**21.2**	**31.4**	**33**	**21**	**30**	**17**	**31.8**	**25**	**3**	**24**	**27.7 J**	**33**
Zinc	174	SW6010B/SW6020A-Total	mg/kg	**65.4 J**	**50.1 J**	**87.6 J**	**19 J**	**31 J**	**93.9 J**	**1.2 J**	**81.8 J**	**92 J**	**54.1 J**	**99**	**140**	**77**	**270**	**40 J**	**75**	**76 J**	**10 J**	**110**	**82.1 J**	**110 J**
Arsenic Speciation																								
Arsenate		EPA 1632-As-Cryo-S-Speciation	mg/kg	-	-	-	-	-	**58.4**	-	-	-	-	**175 J**	-	-	-	-	**23.2 J**	-	-	-	**34.5**	-
Arsenite		EPA 1632-As3-CRYO-T	mg/kg	-	-	-	-	-	**9.75 J**	-	-	-	-	**3.2400 J**	-	-	-	-	**4.595**	-	-	-	**5.48 J**	-
Inorganic Arsenic		EPA 1632-Total Inorganic As - Solid	mg/kg	-	-	-	-	-	**68.2**	-	-	-	-	**178 J**	-	-	-	-	**49.88**	-	-	-	**39.9**	-
Mercury Selective Sequential Extraction																								
Hg(F0)		EPA 1631	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.97 U	-	-	-	-	-
Hg(F1)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**7.34 J**	-	-	-	-	-
Hg(F2)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1.54 J**	-	-	-	-	-
Hg(F3)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**351 J**	-	-	-	-	-
Hg(F4)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**343 J**	-	-	-	-	-
Hg(F5)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**259**	-	-	-	-	-
Hg(F6)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**32.5 J**	-	-	-	-	-
Methylmercury																								
Methylmercury	0.49	CAS SOP/EPA 1630	ng/g	**1.45 J**	-	-	-	-	**0.30 J**	-	**0.15 J**	-	-	**0.654**	**3.73**	-	-	**v**	**0.184**	**0.436**	-	-	**0.32 J**	**2.45**
Total Organic Carbon																								
Carbon, Total Organic (TOC)		SW9060M-Total Organic Carbon, Modified for Matrix	%	**1.16**	**0.274**	**0.313**	**0.643**	**0.091**	**0.538**	**0.379**	**0.326**	**0.722**	**0.567**	**0.513**	**0.43**	**0.25**	**1.1**	**0.21**	**0.426**	**0.4**	**0.5**	**0.63**	**1**	**1.4**
Percent fines			%	**21.34**	**3.09**	**2.47**	**25.82**	-	**52.92**	**4.77**	**41.3**	**5.77**	**11.47**	**23.2**	4.1	4.4	20.5	5.5	**41.7**	7.1	2.1	4.4	**49.41**	12.8
Sediment Textrure Description			NA	Silty Gravel	Sandy Gravel	Sandy Gravel	Silty Gravel	-	Sandy Silt	Sandy Gravel	Silty Sand	Sandy Gravel	Sandy Gravel	Silty Sand	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel	Silty Sand	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Silt	Sandy Gravel

Bold = detection

% = percent

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

mg/kg = milligrams per kilogram

ng/g = nanograms per gram

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

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

Table 4-1 Summary of RI Kuskokwim River Sediment Sample Data

	Background Screening Criteria	Station ID		KR67	KR68	KR69	KR70	KR71	KR72	KR74	KR75	KR76	KR77	KR78	KR79	KR80	KR81
		Sample ID		0912KR67SD	0912KR68SD	0912KR69SD	0912KR70SD	0912KR71SD	0912KR72SD	0912KR74SD	0912KR75SD	0912KR76SD	0912KR77SD	0912KR78SD	0912KR79SD	0912KR80SD	0912KR81SD
		Location Description		Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore
Analyte		Method	Units														
Total Inorganic Elements																	
Aluminum	12500	SW6010B-Total	mg/kg	**7200 J**	**5900**	**5900**	**3900**	**5600**	**4800**	**5800**	**9300**	**3400**	**4900**	**6900**	**6200**	**7200**	**4300**
Antimony	0.446	SW6010B/SW6020A-Total	mg/kg	**9.8**	**42**	**0.17**	**1.9**	**8.3**	**0.7**	**11**	**18**	**11**	**0.62**	**2**	**4.3**	**12**	**0.17**
Arsenic	15	SW6010B/SW6020A-Total	mg/kg	**49 J**	**75**	**7.6**	**26**	**35**	**44**	**17**	**22**	**14**	**9**	**19**	**27**	**12**	**6.2**
Barium	168.7	SW6010B/SW6020A-Total	mg/kg	**160 J**	**73**	**81**	**97**	**100 J**	**93**	**74**	**120**	**70**	**200 J**	**80**	**90 J**	**84 J**	**55**
Beryllium	0.505	SW6010B/SW6020A-Total	mg/kg	**0.39 J**	**0.32**	**0.19**	**0.74**	**0.31**	**0.44**	**0.22**	**0.36**	**0.43**	**0.19**	**0.28**	**0.23**	**0.25**	**0.16**
Cadmium	0.82	SW6010B/SW6020A-Total	mg/kg	**0.26**	**0.21**	**0.13**	**0.68**	**0.28**	**0.46**	**0.17**	**0.33**	**0.25**	**0.11**	**0.16**	**0.17**	**0.21**	**0.11**
Calcium	4283	SW6010B-Total	mg/kg	**2700**	**2200**	**2100**	**11000**	**2500**	**4100**	**1900**	**3400**	**3500**	**1900**	**2000**	**2000**	**3000**	**1700**
Chromium	25.43	SW6010B/SW6020A-Total	mg/kg	**18 J**	**16**	**15**	**18**	**15 J**	**19**	**16**	**23**	**18**	**25 J**	**21**	**17 J**	**21 J**	**12**
Cobalt	14.15	SW6010B/SW6020A-Total	mg/kg	**11**	**8.7**	**6.4**	**8.2**	**8.2**	**23**	**6.2**	**10**	**9.3**	**4.9**	**7.6**	**7.5**	**8**	**4.6**
Copper	37.1	SW6010B/SW6020A-Total	mg/kg	**29 J**	**20 J**	**8.3**	**38 J**	**20 J**	**66**	**14 J**	**23**	**38 J**	**11 J**	**23**	**12 J**	**15 J**	**6.4**
Iron	34626	SW6010B-Total	mg/kg	**30000**	**21000**	**14000**	**42000**	**21000**	**64000**	**15000**	**21000**	**48000**	**10000**	**19000**	**18000**	**14000**	**11000**
Lead	13.01	SW6010B/SW6020A-Total	mg/kg	**7.6 J**	**5.6**	**2.8**	**11**	**5.5**	**13**	**4.1**	**6.4**	**5**	**3.1**	**5.3**	**4.1**	**3.5**	**2.4**
Magnesium	760.7	SW6010B-Total	mg/kg	**3400 J**	**3100 J**	**3300**	**2000 J**	**2700 J**	**8700**	**2900 J**	**4400**	**5200 J**	**2600 J**	**3800**	**3000 J**	**3600 J**	**2300**
Manganese	760.7	SW6010B-Total	mg/kg	**960**	**800**	**510**	**1200**	**1000**	**2800**	**240**	**380**	**2200**	**340**	**250**	**680**	**480**	**410**
Mercury	0.144	SW7471A-Total	mg/kg	**7.6 J**	**3.1**	**0.011**	**0.98**	**0.99**	**2.5**	**7.1**	**1.9**	**0.066**	0.0062 U	**2.4**	**20**	**2.5**	**0.035**
Nickel	40.11	SW6010B/SW6020A-Total	mg/kg	**31**	**26**	**19**	**33**	**22**	**64**	**19**	**28**	**26**	**18**	**21**	**20**	**23**	**13**
Potassium	1134	SW6010B-Total	mg/kg	**1200 J**	**720**	**630**	**940**	**750**	**1800**	**670**	**1100**	**820**	**840**	**820**	**760**	**880**	**470**
Selenium	0.773	SW7742-Total	mg/kg	**.79 J**	**0.5**	**0.36**	**1.1**	**0.58**	**1.5**	**0.4**	**0.83**	**0.78**	**0.34**	**0.56**	**0.47**	**0.67**	**0.35**
Silver	0.127	SW6010B/SW6020A-Total	mg/kg	**0.075 J**	**0.064**	**0.033**	**0.15**	**0.079**	**0.23**	**0.055**	**0.09**	**0.085**	**0.049**	**0.056**	**0.048**	**0.055**	**0.026**
Sodium	150.9	SW6010B-Total	mg/kg	**100 J**	**76**	**83**	**140**	**110**	**67**	**120**	**150**	**75**	**150**	**97**	**83**	**150**	**59**
Thallium	0.144	SW6010B/SW6020A-Total	mg/kg	0.14 U	0.15 U	0.15 U	0.13 U	0.13 U	0.15 U	0.15 U	0.15 U	0.15 U	0.15 U	0.16 U	0.12 U	0.15 U	0.16 U
Vanadium	36.93	SW6010B/SW6020A-Total	mg/kg	**30 J**	**23**	**22**	**38**	**22**	**34**	**23**	**35**	**30**	**22**	**29**	**24**	**29**	**16**
Zinc	174	SW6010B/SW6020A-Total	mg/kg	**80 J**	**59 J**	**42**	**86 J**	**61 J**	**99**	**45 J**	**72**	**67 J**	**37 J**	**54**	**47 J**	**46 J**	**31**
Arsenic Speciation																	
Arsenate		EPA 1632-As-Cryo-S-Speciation	mg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenite		EPA 1632-As3-CRYO-T	mg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inorganic Arsenic		EPA 1632-Total Inorganic As - Solid	mg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury Selective Sequential Extraction																	
Hg(F0)		EPA 1631	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F1)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F2)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F3)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F4)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F5)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg(F6)		BRL SOP No. BR-0013	ng/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylmercury																	
Methylmercury	0.49	CAS SOP/EPA 1630	ng/g	-	-	-	**0.676**	-	-	-	**1.9**	-	-	**0.308**	-	-	-
Total Organic Carbon																	
Carbon, Total Organic (TOC)		SW9060M-Total Organic Carbon, Modified for Matrix	%	**0.54**	**0.47**	**0.11**	**1.1**	**0.26**	**2.3**	**0.8**	**1.3**	**1.6**	**0.1**	**0.49**	**0.34**	**0.86**	**0.086**
Percent fines			%	13	4.8	4.6	5.5	0.8	35.9	11.3	9.7	24.4	10	5	2.9	3.5	3.1
Sediment Textrure Description			NA	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel with Fines	Sandy Gravel	Sandy Gravel	Sandy Gravel with Fines	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel	Sandy Gravel

Bold = detection

% = percent

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

mg/kg = milligrams per kilogram

ng/g = nanograms per gram

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

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

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A

Field Sampling Plan

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FINAL
Field Sampling Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization

Supplement to Remedial Investigation
Red Devil Mine, Alaska

June 2015

Prepared for:

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Figures follow Section 10 References, with the exception of Figure 9-1 in Chapter 9.

Figure

List of Abbreviations and Acronyms

°C	degree Celsius
As	arsenic
ASTM	ASTM International (formerly the American Society of Testing and Materials)
ATV	all-terrain vehicle
bgs	below ground surface
BLM	Bureau of Land Management
BrCl	bromine monochloride
BRL	Brooks Rand Labs
BTEX	benzene, toluene, ethylbenzene, xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
Cl	chlorine
COC	chain-of-custody
COPC	contaminant of potential concern
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DRO	diesel range organics
E & E	Ecology and Environment, Inc.
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FSP	field sampling plan
GPS	Global Positioning System
GRO	gasoline range organics
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
HDPE	high density polyethylene
Hg	mercury

List of Abbreviations and Acronyms (cont.)

HNO_3	nitric acid
IATA	International Air Transportation Association
IDW	investigation-derived waste
L	liter
mL	milliliter
MS	matrix spike
MSD	matrix spike duplicate
NSF	National Sanitation Foundation
NTCRA	non-time-critical removal action
oz	ounce
PCBs	polychlorinated biphenyls
PPE	personal protective equipment
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RDM	Red Devil Mine
RI	remedial investigation
RRO	residual range organics
SOP	standard operating procedure
SPLP	Synthetic Precipitation Leaching Procedure
SSE	selective sequential extraction
SVOC	semivolatile organic compound
TAL	target analyte list
TIC	tentatively identified compounds
TOC	total organic carbon
USGS	U.S. Geological Survey
XRF	X-ray fluorescence (spectroscopy)

1

Introduction

This document is a field sampling plan (FSP) to be used for supplemental site characterization to be conducted during the 2015 field season at the Red Devil Mine (RDM) site, Red Devil, Alaska. The RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) in southwest Alaska. The BLM initiated a remedial investigation (RI)/feasibility study (FS) at the RDM in 2009 pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead agency authority. An RI was performed by Ecology and Environment, Inc., (E & E) on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J. Results of the RI are presented in the final Remedial Investigation Report, Red Devil Mine, Alaska (E & E 2014a). An FS for the RDM is under development.

The 2015 supplemental RI site characterization is being performed to supplement data collected during the RI for several site media. Data collected during the RI were used to define the site physical setting, the nature and extent of contamination, and the fate and transport of contaminants, and to assess risk to human health and the environment. The 2015 supplemental site characterization addresses data gaps associated with soil, groundwater, and Kuskokwim River sediments that were identified as part of the development of site-wide remedial alternatives during the preparation of the FS. The 2015 supplemental site characterization also addresses changes in the groundwater and surface water monitoring network and possible changes to the groundwater and surface water conditions at the RDM stemming from implementation of a non-time-critical removal action (NTCRA) performed by the BLM at the RDM during the summer of 2014.

This FSP is intended to be used in conjunction with the Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska (work plan supplement). E & E prepared the work plan supplement and this FSP on behalf of the BLM under Delivery Order Number L14PB00938 and BLM National Environmental Services Blanket Purchase Agreement Number L14PA00149.

Existing data and information regarding the RDM are presented in the final RI report and other documents. Key RI findings and information pertinent to the supplemental RI characterization for soil, groundwater, surface water, and Kuskokwim River sediment are summarized in the work plan supplement. Information in the work plan supplement is not repeated in the FSP. This FSP is intended to be used as a streamlined guide for the field investigation team.

The purpose of this FSP is to provide specific methodology for the sampling and analysis at the RDM site. The results of the activities performed under this FSP will be used to support the development of site-wide remedial alternatives at the RDM.

2

Sample Locations, Types, and Rationale

This section describes the study design for each component of the 2015 supplemental site characterization activities at the RDM site. The study area for the 2015 supplemental site characterization activities includes the upland area of the site as shown on Figure 1-2 of the final RI report and in Kuskokwim River, including the area previously sampled during the RI, as well as from locations further downriver and outboard of the extent of RI sediment samples collected in 2010, 2011, and 2012. Locations of Kuskokwim River sediment samples collected during the RI are illustrated on Figures 2-5 of the RI work plan supplement.

The work plan supplement and final RI report detail the contaminant sources associated with the site and the contaminants of concern associated with these sources. The planned supplemental RI activities target soil, groundwater, surface water, and Kuskokwim River sediment impacted by these contaminants of concern. Inorganic elements, particularly antimony, arsenic, and mercury are the primary contaminants of concern at the site. In addition to inorganic elements, the following types of organic compounds were detected in one or more media at the site: semivolatile organic compounds (SVOCs), diesel range organics (DRO), residual range organics (RRO), and polychlorinated biphenyls (PCBs).

The study design incorporates both field screening and fixed laboratory analyses. Field screening will provide real-time data to inform selection of samples for laboratory analysis, as well as providing a large dataset to characterize total inorganic element concentrations in soil.

The following sections summarize the sample locations, types, and rationale for the planned 2015 soil, groundwater, surface water and sediment characterization.

2.1 Soil

The 2015 soil characterization activities will address data gaps associated with subsurface soil and bedrock. Additional soil characterization will be performed to gather the types of additional information identified in Section 3.3 of the work plan supplement. Soil characterization will be performed by installing additional soil borings at the site, including:

- Nine soil borings in the Main Processing Area (two of which will be converted to monitoring wells);
- Three soil borings in the Red Devil Creek Area; and
- Five soil borings in the Surface Mined Area (which will be converted to monitoring wells).

Soil and bedrock characterization will be performed using a combination of field observations, results of X-ray fluorescence spectroscopy (XRF) field screening for total inorganic elements, and laboratory analysis for total target analyte list (TAL) metals and mercury selective sequential extraction (SSE). Data gaps and the investigative approach for the subsurface soil investigation are presented in Chapters 3 and 4 of the work plan supplement. General objectives of the soil investigation are summarized below:

- Assess lithologic and mineralogical characteristics of subsurface soils and bedrock.
- Identify mine waste types and soil types.
- Determine thickness and inorganic element concentrations of tailings/waste rock where present.
- Determine concentrations of inorganic elements in tailings/waste rock where present.
- Identify and determine the thickness of types of native soil/alluvium.
- Determine concentrations of inorganic elements in soil/alluvium below tailings/waste rock from the base of tailings/waste rock to the top of bedrock to assess impacts on native soil/alluvium from deposition of inorganic elements leached from tailings/waste rock.
- Determine depth of bedrock.
- Visually assess whether the bedrock is naturally mineralized.
- Determine the presence, depth, and thickness of saturated interval(s).

Available information on the soil type and lithological and mineralogical characteristics and hydrogeologic conditions at the site is presented in the final RI report in Chapter 3 (Physical Characteristics of the Study Area) and Appendices B (Soil Types) and F (Summary of Surface Soil, Subsurface Soil, and Groundwater Data). This information was used in conjunction with information on the distribution of contaminants of potential concern (COPCs) presented in the final RI report in Chapter 4 (Nature and Extent of Contamination) to select the proposed soil boring locations and develop the planned investigative approach. This same information will be used, as appropriate, during the field investigation to guide the refinement of soil boring locations, installation of the soil borings, and interpretation of field lithological, mineralogical, and other observations.

Proposed soil boring locations are illustrated on Figure 2-1. The locations of the proposed soil borings are described in Table 2-1. The proposed positions of these boring locations are approximate. Actual boring locations will be refined during field investigation based on actual conditions encountered in the field.

Soil borings will be installed using a drill rig operated by a subcontracted, Alaska-licensed driller. Soil boring installation and subsurface soil sampling methodologies are discussed in Chapter 4. New monitoring wells will be installed within soil borings as specified in Section 2.2.

At each soil boring, if feasible, soil samples will be collected continuously from the ground surface to the top of bedrock while drilling in unconsolidated materials. While drilling in bedrock, drill cuttings will be collected at minimum intervals of 5 feet. The soil material recovered will be visually characterized and logged by the field geologist and field screened for total inorganic elements using an XRF. Specific field procedures are described in Chapter 4.

In general, if feasible, each soil boring will be advanced to the target depths specified in Table 2-1.

Selected soil samples will be collected for fixed laboratory analysis for total TAL metals and mercury SSE. The proposed frequency and the rationale for selection of soil samples for these laboratory analyses are presented in Table 2-1.

It is anticipated that the soil characterization activities will be performed in the spring/summer of 2015.

2.2 Groundwater

The 2015 groundwater characterization activities will address data gaps associated with groundwater. Additional groundwater characterization will be performed in the spring/summer and fall of 2015 to gather the types of additional information identified in Section 3.3 of the work plan supplement. Additional groundwater characterization includes installing additional monitoring wells at the site and collecting groundwater data from new and selected existing monitoring wells. Planned new monitoring wells are:

- Five new monitoring wells in the Surface Mined Area; and
- Two new monitoring wells in the Main Processing Area.

Additional groundwater characterization will be performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. Data gaps and the investigative approach for the groundwater characterization are presented in Chapters 3 and 4 of the work plan supplement. General objectives of the groundwater characterization are summarized below:

- Assess groundwater occurrence, depth, and quality in the Surface Mined Area.
- Assess groundwater occurrence, depth, and quality in the portions of the RDM site affected by the 2014 NTCRA construction.
- Provide additional information on baseline groundwater conditions at the site.
- Assess groundwater concentrations of SVOCs, DRO, gasoline range organics (GRO), and benzene, toluene, ethylbenzene, xylenes (BTEX) in selected wells.
- Provide additional data on groundwater conditions in the area downgradient of Monofill #2.

Available information on the hydrogeologic conditions at the site is presented in the final RI report in Chapters 3 (Physical Characteristics of the Study Area), 4 (Nature and Extent of Contamination), and 5 (Contaminant Fate and Transport), and Appendices A (Final 2012 Baseline Monitoring Report, Red Devil Mine, Alaska) and F (Summary of Surface Soil, Subsurface Soil, and Groundwater Data). Available information on the 2014 NTCRA construction is summarized in Chapter 2 of the work plan supplement. This information was used to select the proposed monitoring well locations and develop the planned investigative approach. This same information will be used, as appropriate, during the field investigation to guide the refinement of monitoring well locations, installation of the monitoring wells, and interpretation of field observations.

Locations of proposed new monitoring wells are shown on Figure 2-1. The locations of the proposed new monitoring wells are described in Table 2-1. The proposed positions of the new monitoring wells are approximate. Actual boring locations will be refined during field investigation based on actual conditions encountered in the field. Monitoring wells will be installed using a drill rig operated by a subcontracted, Alaska-licensed driller. Monitoring well installation methodologies are discussed in Chapter 4.

Groundwater samples will be collected from the monitoring wells identified in Table 2-2, including all proposed new monitoring wells and selected existing monitoring wells. All groundwater samples will be collected for field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and low-level mercury; dissolved low-level mercury; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; total suspended solids, and alkalinity (as carbonate/bicarbonate). In addition, samples from selected wells will be analyzed for SVOCs, DRO, GRO, and BTEX. Table 2-2 summarizes the proposed numbers of samples to be collected for selected laboratory analyses.

It is anticipated that one round of groundwater monitoring will be performed using existing RI monitoring wells in the spring/summer 2015. New wells will be installed subsequent to the spring/summer 2015 monitoring, and samples will be collected from these wells following their completion prior to demobilization from the site. A second round of groundwater monitoring of the RI and new wells will be performed during a second mobilization to the site in the fall of 2015.

At the beginning of the 2015 groundwater sampling events, a round of static water level measurement will be conducted at all existing wells. Following the completion of groundwater sampling near the end of the sampling event, another round of static water level gauging will be conducted at all new and previously existing monitoring wells. The static water levels will be measured during each round within the shortest time period possible.

Horizontal coordinates and elevations of all existing and newly installed monitoring wells will be surveyed by a subcontracted, Alaska-registered land surveyor. Well elevations will be surveyed to within the nearest 0.1 foot.

2.3 Surface Water

The 2015 surface water characterization activities will address data gaps associated with surface water. Additional surface water characterization will be performed in the spring and fall of 2015 to gather the types of additional information identified in Section 3.3 of the work plan supplement. Additional surface water characterization will be performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. Data gaps and the investigative approach for the surface water characterization are presented in Chapters 3 and 4 of the work plan supplement. General objectives of the surface water characterization are summarized below:

- Assess potential impacts on surface water quality and flow rate by flow of groundwater that is impacted by naturally mineralized bedrock and underground mine workings in the Surface Mined Area.
- Assess groundwater quality and flow rate in the area affected by the 2014 NTCRA construction.
- Provide additional information on baseline surface water conditions at the site.

Available information on the surface water conditions at the site is presented in the final RI report in Chapters 3 (Physical Characteristics of the Study Area), 4 (Nature and Extent of Contamination), and 5 (Contaminant Fate and Transport), and Appendix A (Final 2012 Baseline Monitoring Report, Red Devil Mine, Alaska). Available information on the 2014 NTCRA construction is summarized in Chapter 2 of the work plan supplement. This information was used to select the proposed surface water monitoring well locations and develop the planned investigative approach.

Proposed surface water monitoring locations are shown on Figure 2-2 and are described in Table 2-3.

At the selected surface water monitoring locations along Red Devil Creek and the seep, discharge rate will be measured and surface water will be sampled for field and laboratory water quality parameters. Surface water samples will be collected for field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL metals and low-level mercury; dissolved TAL metals and low-level mercury; total organic carbon (TOC); total suspended solids; total dissolved solids; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate). Table 2-3 summarizes the proposed numbers of samples to be collected for selected laboratory analyses.

It is anticipated that surface water monitoring activities will be performed in the spring and fall of 2015.

A visual survey will be conducted at the site to identify if additional springs or seeps are present. Surface water samples will be collected and discharge will be measured at any new springs identified during the 2015 sampling events.

It is anticipated that the creek will be shallow at most sample locations. To the extent feasible, surface water samples will be collected from mid-depth water in the creek. Specific sampling methodologies are summarized in Chapter 4 of this FSP.

2.4 Kuskokwim River Sediment

The 2015 Kuskokwim River sediment characterization activities will be performed to gather the types of additional information identified in Section 3.3 of the work plan supplement. Sediment characterization will be performed by collecting additional surface sediment samples at the site for various laboratory analyses. Data gaps and the investigative approach for the Kuskokwim River sediment characterization are presented in Chapters 3 and 4 of the work plan supplement. General objectives of the sediment investigation are summarized below:

- Assess the toxicity of sediments to benthic macroinvertebrates.
- Assess the potential for methylation and bioaccumulation of mercury.
- Assess the cross-river and downriver extents of contamination in Kuskokwim River sediment.
- Assess the turbidity of Kuskokwim River water.

Additional sediment characterization will be performed at offshore sediment sample locations in the Kuskokwim River as described below.

- Twelve samples will be collected from the area upriver of, in the vicinity of, and downriver of Red Devil Creek delta. These samples will be analyzed for total TAL metals, TOC, and grain size distribution. Eleven of these samples also will be analyzed for toxicity using a *Hyallela azteca* 28-day test. Six of the samples also will be analyzed for methylmercury and mercury SSE.
- Twelve samples will be collected from locations cross-river and downriver from the areas of documented elevated concentrations of antimony, arsenic, and mercury. Each of these samples will be analyzed for total TAL metals, TOC, and grain size distribution. In addition, eight of these samples also will be analyzed for methylmercury.
- Four samples will be collected from locations near the right bank of the Kuskokwim River along two previously defined RI sample transects near the Red Devil Creek delta. Two samples will be collected from one transect located upstream of Red Devil Creek, and two samples will be collected from one transect located a short distance downstream of Red Devil Creek. Along each transect, one sample will be collected from shallow water near the shore (approximately 10 to 20 feet from the right bank), and a second sample will be collected approximately 50 feet from the right bank. All four samples will be analyzed for TAL metals only.
- The water column at all sampling locations will be analyzed in the field for turbidity.

Sediment samples will be analyzed for the laboratory analyses as summarized in Table 2-4. Proposed 2015 sediment sampling locations are illustrated on Figures 2-3 and 2-4. The locations of the proposed samples are described in Table 2-4. The proposed positions of these sampling locations are approximate. Actual sample locations will be refined during field investigation based on actual conditions encountered in the field.

Available information on the physical and chemical characteristics of Kuskokwim River sediment, including grain size, concentrations of COPCs, and other chemical data, are presented in the final RI report in Chapters 3 (Physical Characteristics of the Study Area) and 4 (Nature and Extent of Contamination). Information on Kuskokwim River sediment pertinent to the physical and chemical fate and transport processes are presented in Chapter 5 (Contaminant Fate and Transport) of the final RI report. Available information regarding other studies pertaining to Kuskokwim River sediment, including periphyton sampling performed by the BLM in 2014, is summarized in Chapter 2 of the work plan supplement. This information was used to select proposed sediment sampling locations and develop the planned investigative approach. This same information will be used, as appropriate, during the field investigation to guide the refinement of sediment sampling locations.

Samples planned for sediment toxicity testing will be collected generally from within the footprint of sediment samples collected during the RI and most of the planned locations are collocated with selected RI sample locations. The selected toxicity sample locations are biased toward locations where, based on RI sampling results:

- Larger proportions of finer grained materials (sand size and smaller) are expected to be present (to facilitate sample collection);
- TOC concentrations are expected to be fairly similar; and
- A wide range of total antimony, arsenic, and mercury concentrations are expected to be present.

In addition, several of the samples planned for toxicity testing will be collocated with periphyton samples collected by BLM in 2014.
Samples planned for sediment toxicity testing will be collected generally from within the footprint of sediment samples collected during the RI and most of the planned locations are collocated with selected RI sample locations. The selected RI sample locations are biased toward locations where, based on RI sampling results:

- Larger proportions of finer grained materials (sand size and smaller) are expected to be present (to facilitate sample collection);
- TOC concentrations are expected to be fairly similar; and
- A wide range of total antimony, arsenic, and mercury concentrations are expected to be present.

A summary of RI Kuskokwim River sediment sample data is presented in Table 4-1 of the work plan supplement. In addition, several of the samples planned for toxicity testing will be collocated with periphyton samples collected by BLM in 2014. Samples intended to assess cross-river and downriver extents of contamination will be collected from outside of the footprint of the RI sediment samples. A subset of these planned samples will be collocated with downriver periphyton samples collected by BLM in 2014.

At the time of the sediment sample collection, field measurement of turbidity of river water will be performed at selected sediment sample locations.

2.5 Quality Control Samples

Following the requirements specified in the RI/FS Quality Assurance Project Plan (QAPP), included in the final RI/FS work plan, field quality control (QC) samples will be collected for all matrices and analytes (except soil samples collected for XRF field screening). QC samples will be:

- **Field Duplicates**: A field duplicate sample is a second sample collected at the same time and location as the original sample. Field duplicate samples are collected simultaneously (an extra volume of one sample, which is then homogenized and split into equal aliquots) or in immediate succession, using identical recovery techniques, and treated in an identical manner during storage, transportation, and analysis. The sample containers are assigned an identification number in the field such that they cannot be identified (blind duplicate) as duplicate samples by laboratory personnel performing the analysis. Duplicate sample results are used to assess precision of the overall sample collection and analysis process. For soil, groundwater, surface water, and sediment, field duplicate samples will be collected at a minimum frequency of one field duplicate for every 10 regular samples for each matrix and sampling method and/or type of equipment used.
- **Matrix Spike**: Matrix spikes (MSs) are used to assess the effect of the sample matrix on analyte recovery. An MS consists of an aliquot of a field sample to which the laboratory adds a known concentration of the analyte(s) of interest. An unspiked aliquot is also analyzed, and the %R for the spiked sample is calculated. Analysis of MSs requires collection of a sufficient volume of sample to accommodate the number of aliquots to be analyzed. The sample(s) chosen for MSs should be representative of the sample matrix but should not contain excessive concentrations of analytes or interfering substances. MSs are analyzed at a frequency of one MS per 20 or fewer samples for each matrix and each sampling event.
- **Rinsate Blanks:** Rinsate blanks are used to assess the effectiveness of equipment decontamination procedures when non-dedicated sampling equipment is used. A rinsate blank is a sample of ASTM Type II reagent grade water or equivalent (i.e., deionized), poured into or over the sampling device or pumped through it, collected in a sample container, and transported to the laboratory for analysis. Rinsate blanks will be collected immediately after the equipment has been decontaminated. The blank will be analyzed for all laboratory analyses requested for the environmental samples collected at the site. A minimum frequency of one rinsate blank per 20 field samples is required for each collection/decontamination method, by matrix and by sample type.
- **Equipment Blanks**: Equipment blanks are used to demonstrate that dedicated sampling equipment is adequately clean if a certificate is not available to demonstrate cleanliness. Equipment blanks will be analyzed for all laboratory analyses requested for the environmental samples collected at the site. One equipment blank sample for dedicated equipment will be collected at a rate of one for each set of dedicated equipment (i.e., bailers and sample tubing) of identical manufacturer’s lot number.
- **Trip Blanks**: One trip blank will be collected for every shipment of samples collected for BTEX analysis.

- **Field Blanks**: Field blanks are laboratory-provided, mercury-free water samples that are processed and treated as a regular sample in all respects, including contact with sampling devices, equipment, sampling site conditions, and analytical procedures. Field blanks are used to determine whether mercury detected in a sample is from the site or can be attributed to contamination. Field blanks will be collected at a rate of one field blank for every 10 regular samples to be analyzed for low-level mercury.

Table 2-1 Summary of Soil Borings, Soil Sampling, and Monitoring Well Installation

						Laboratory Soil Sample Collection			Monitoring Well Installation		
Geographic Area	**Sub Area**	**Location Description**	**Soil Boring ID**	**Targeted Total Drilling Depth Criteria**	**Anticipated Generalized Lithology**	**Total TAL Metals**	**Hg SSE**	**Sample Selection Criteria**	**Monitoring Well ID**	**Screen Interval Selection Target Criteria**	**Planned Screen Length (ft)**
Main Processing Area	Post-1955 Main Processing Area	Near former shallow/deep RI well pair MW16 and MW17	MP092	Drill to minimum of approximately 30 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	MW37	Screen within bedrock. Bottom of screen approximately 25 to 30 feet below top of weathered bedrock/bedrock	10
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near former shallow/deep RI well pair MW16 and MW17	MP093	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	MW38	Screen within unconsolidated materials. Base of screen at top of bedrock	10
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near RI Soil Borings MP29 and MP30	MP094	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near RI Soil Borings MP25 and MP29	MP095	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near RI Soil Borings MP27 and MP28	MP096	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near Red Devil Creek Alignment and RI Soil Borings MP29 and MP30	MP097	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
	Pre-1955-Main Processing Area	Near RI Soil Borings MP45, MP46, MP47, MP48 and MP60	MP098	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near RI Soil Boring MP53	MP099	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
		Near RI Soil Borings MP57 and MP58	MP100	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock	1	1	Select 1 sample of Tailings/Waste Rock from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	4	2	Select 4 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock to the top of bedrock. Select the 4 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 2 samples (a subset of the 4 total TAL metals samples) for Hg SSE with XRF mercury concentrations that are the highest and mid-range for the 4 TAL metals samples.			
					Bedrock	None	None	No laboratory samples			
	Near Red Devil	Near Red Devil Creek			Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium	1	1	Select 1 sample of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium from the base of the interval for total TAL metals and Hg SSE.			

Table 2-1 Summary of Soil Borings, Soil Sampling, and Monitoring Well Installation

						Laboratory Soil Sample Collection			Monitoring Well Installation		
Geographic Area	**Sub Area**	**Location Description**	**Soil Boring ID**	**Targeted Total Drilling Depth Criteria**	**Anticipated Generalized Lithology**	**Total TAL Metals**	**Hg SSE**	**Sample Selection Criteria**	**Monitoring Well ID**	**Screen Interval Selection Target Criteria**	**Planned Screen Length (ft)**
Near Red Devil Creek	Creek Alignment in Main Processing Area	Near Red Devil Creek Alignment and RI Soil Boring MP38	MP101	Drill to approximately 2 feet into weathered bedrock/bedrock	Native Soil/Alluvium	2	1	Select 2 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium to the top of bedrock. Select the 2 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 1 sample (a subset of the 2 total TAL metals samples) for Hg SSE with the higher XRF mercury concentration.	NA		
					Bedrock	None	None	No laboratory samples			
	Near Red Devil Creek in Red Devil Creek Downstream Alluvial Area	Near Red Devil Creek Alignment and RI Soil Borings MP40 and RD07	RD21	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium	1	1	Select 1 sample of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	2	1	Select 2 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium to the top of bedrock. Select the 2 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 1 sample (a subset of the 2 total TAL metals samples) for Hg SSE with the higher XRF mercury concentration.			
					Bedrock	None	None	No laboratory samples			
		Near Red Devil Creek Alignment and RI Soil Borings RD07 and RD06	RD22	Drill to approximately 2 feet into weathered bedrock/bedrock	Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium	1	1	Select 1 sample of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium from the base of the interval for total TAL metals and Hg SSE.	NA		
					Native Soil/Alluvium	2	1	Select 2 samples for total TAL metals from intervals selected to provide data to define concentration gradients of arsenic, mercury, and antimony from the base of Tailings/Waste Rock or Mixed Tailings/Waste Rock and Native Soil/Alluvium to the top of bedrock. Select the 2 samples for total TAL metals with XRF arsenic and antimony concentrations ranging from mid-range to high. Select 1 sample (a subset of the 2 total TAL metals samples) for Hg SSE with the higher XRF mercury concentration.			
					Bedrock	None	None	No laboratory samples			
Surface Mined Area	Surface Mined Area	Northeast of Dolly Shaft and south and assumed downgradient of proposed repository location	SM67	Drill to minimum depth required to meet well installation criteria	Unconsolidated Materials	Up to 1 (see Sample Selection Criteria)	None	Collect a total of 3 samples from amongst the 5 borings installed in the Surface Mined Area for TAL metals. Select samples from the borings/intervals with the highest XRF arsenic, mercury, and antimony concentrations.	MW39	Target groundwater in bedrock, with at least 50% of 20 foot screen submerged under static water level. However, if a saturated zone is encountered above bedrock and continued drilling does not indicate that upper saturated zone is perched, then install well with 10 foot screen within unconsolidated materials.	20
					Bedrock	None	None	No laboratory samples			
		Near Dolly Area Crosscuts	SM68	Drill to minimum depth required to meet well installation criteria	Unconsolidated Materials	Up to 1 (see Sample Selection Criteria)	None	Collect a total of 3 samples from amongst the 5 borings installed in the Surface Mined Area for TAL metals. Select samples from the borings/intervals with the highest XRF arsenic, mercury, and antimony concentrations.	MW40	Target groundwater in bedrock, with at least 50% of 20 foot screen submerged under static water level. However, if a saturated zone is encountered above bedrock and continued drilling does not indicate that upper saturated zone is perched, then install well with 10 foot screen within unconsolidated materials.	20
					Bedrock	None	None	No laboratory samples			
		Near Dolly Area Crosscuts	SM69	Drill to minimum depth required to meet well installation criteria	Unconsolidated Materials	Up to 1 (see Sample Selection Criteria)	None	Collect a total of 3 samples from amongst the 5 borings installed in the Surface Mined Area for TAL metals. Select samples from the borings/intervals with the highest XRF arsenic, mercury, and antimony concentrations.	MW41	Target groundwater in bedrock, with at least 50% of 20 foot screen submerged under static water level. However, if a saturated zone is encountered above bedrock and continued drilling does not indicate that upper saturated zone is perched, then install well with 10 foot screen within unconsolidated materials.	20
					Bedrock	None	None	No laboratory samples			
		Near 325 Adit and 242 Sublevel	SM70	Drill to minimum depth required to meet well installation criteria	Unconsolidated Materials	Up to 1 (see Sample Selection Criteria)	None	Collect a total of 3 samples from amongst the 5 borings installed in the Surface Mined Area for TAL metals. Select samples from the borings/intervals with the highest XRF arsenic, mercury, and antimony concentrations.	MW42	Target groundwater in bedrock, with at least 50% of 20 foot screen submerged under static water level. However, if a saturated zone is encountered above bedrock and continued drilling does not indicate that upper saturated zone is perched, then install well with 10 foot screen within unconsolidated materials.	20
					Bedrock	None	None	No laboratory samples			
		Near 33 Sublevel	SM71	Drill to minimum depth required to meet well installation criteria	Unconsolidated Materials	Up to 1 (see Sample Selection Criteria)	None	Collect a total of 3 samples from amongst the 5 borings installed in the Surface Mined Area for TAL metals. Select samples from the borings/intervals with the highest XRF arsenic, mercury, and antimony concentrations.	MW43	Target groundwater in bedrock, with at least 50% of 20 foot screen submerged under static water level. However, if a saturated zone is encountered above bedrock and continued drilling does not indicate that upper saturated zone is perched, then install well with 10 foot screen within unconsolidated materials.	20
					Bedrock	None	None	No laboratory samples			

Notes

1) At each boring, unconsolidated materials will be collected continuously from the ground surface to the boring total depth using split spoon or continuous core samplers. Weathered bedrock/bedrock material will be collected continuously with split spoon or continuous core samplers, if possible, or by collecting drill cuttings at a minimum frequency of every 1 foot.

2) The material recovered, including unconsolidated materials (e.g., tailings/waste rock, fill, native soil/alluvium) and weathered bedrock/bedrock, will be field screened with an XRF at a minimum frequency of every 1 foot.
3) If possible, each boring will be advanced to the depths specified. For those borings to be converted to monitoring wells, the borings will be advanced to a depth deep enough to install a well as specified based on the site geologist's judgment.

Key:
Hg SSE = Mercury selective sequential extraction
TAL = Target analyte list
XRF = X-ray fluorescence spectroscopy

Table 2-2 Summary of 2015 Groundwater Samples

General Geographic Area	Sub-Area	Location Description	Soil Boring ID	Monitoring Well ID	Number of Samples									
					Total TAL Metals	Total Low-Level Hg	Dissolved Low-Level Hg	Inorganic Ions (chloride, fluoride, sulfate)	Alkalinity as Carbonate, Bicarbonate	Total Suspended Solids	Nitrate/Nitrite as N	SVOCs	DRO	GRO/ BTEX
Main Processing Area	Post-1955 Main Processing Area	Upgradient of Post-1955 Main Processing Area	11MP01	MW08	1	1	1	1	1	1	1	-	-	-
		Downgradient of Monofill #2	11MP17	MW09	1	1	1	1	1	1	1			
		Upgradient of Settling Ponds #2 and #3	11MP33	MW19	1	1	1	1	1	1	1	1	1	1
		Downgradient from Monofill #2 / Post-1955 Retort Building	11MP14	MW10	1	1	1	1	1	1	1	-	-	-
		Gravel Pad / Downgradient from Monofill #3	Pre-RI boring/well previously referred to as MW-1	MW01	1	1	1	1	1	1	1	-	-	-
		Near former shallow/deep RI well pair MW16 and MW17 (decommissioned)	MP092 (proposed 2015 soil boring)	MW37 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
			MP093 (proposed 2015 soil boring)	MW38 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Berm / Downgradient of Settling Pond #3	11MP40	MW22	1	1	1	1	1	1	1	1	1	1
	Pre-1955 Main Processing Area	Pre-1955 Main Processing Area	11MP52	MW26	1	1	1	1	1	1	1	-	-	-
		Shallow/deep well pair near seep on bank of Red Devil Creek / Downgradient of former mine openings / Tailings	11MP88	MW27	1	1	1	1	1	1	1	-	-	-
			11MP60	MW28	1	1	1	1	1	1	1	-	-	-
		Downgradient of Pre-1955 Retort Area	Pre-RI boring/well previously referred to as MW-6	MW06	1	1	1	1	1	1	1	-	-	-
Red Devil Creek Downstream Alluvial Area and Delta	Red Devil Creek Downstream Alluvial Area and Delta	Red Devil Creek Downstream Alluvial Area and Delta	11RD05	MW32	1	1	1	1	1	1	1	-	-	-
		Red Devil Creek Downstream Alluvial Area and Delta	11RD20	MW33	1	1	1	1	1	1	1	-	-	-
Surface Mined Area	Surface Mined Area	Northeast of Dolly Shaft and south and assumed downgradient of proposed repository location	SM67 (proposed 2015 soil boring)	MW39 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Near Dolly Area Crosscuts	SM68 (proposed 2015 soil boring)	MW40 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Near Dolly Area Crosscuts	SM69 (proposed 2015 soil boring)	MW41 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Near 325 Adit and 242 Sublevel	SM70 (proposed 2015 soil boring)	MW42 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Near 33 Sublevel	SM71 (proposed 2015 soil boring)	MW43 (proposed 2015 monitoring well)	1	1	1	1	1	1	1	-	-	-
		Upgradient from Pre-1955 Main Processing Area	11MP41	MW29	1	1	1	1	1	1	1	-	-	-
		Upgradient from Pre-1955 Main Processing Area	11SM31	MW30	1	1	1	1	1	1	1	-	-	-
Upland Area West of Surface Mined Area	Upland Area West of Surface Mined Area	Upland Area West of Surface Mined Area	11UP11	MW31	1	1	1	1	1	1	1	-	-	-

Key:

BTEX = Benzene, toluene, ethylbenzene, and xylenes
DRO = Diesel range organics
GRO = Gasoline range organics
Hg = Mercury
SVOCs = Semivolatile organic compounds
TAL = Target Analyte List

Table 2-3 Summary of 2015 Surface Water Samples

General Geographic Area	Location Description	Sample Location ID	Number of Samples									
			Total TAL Metals	Total Low-Level Hg	Dissolved TAL Metals	Dissolved Low-Level Hg	Total Organic Carbon	Total Suspended Solids	Total Dissolved Solids	Inorganic Ions (chloride, fluoride, sulfate)	Alkalinity as Carbonate, Bicarbonate	Nitrate/Nitrite as N
Red Devil Creek, Main Processing Area	Red Devil Creek, near upstream end of the Main Processing Area	RD10SW	1	1	1	1	1	1	1	1	1	1
	Red Devil Creek, new station immediately upstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former station RD04SW	RD14SW	1	1	1	1	1	1	1	1	1	1
	Red Devil Creek, new station immediately downstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former baseline monitoring station RD13SW	RD15SW	1	1	1	1	1	1	1	1	1	1
	Seep on left bank of Red Devil Creek	RD05SW	1	1	1	1	1	1	1	1	1	1
	Red Devil Creek, new station downstream of seep area between RD12 and RD09	RD16SW	1	1	1	1	1	1	1	1	1	1
	Red Devil Creek, near Settling Pond #2	RD09SW	1	1	1	1	1	1	1	1	1	1
	Red Devil Creek, near Settling Pond #3	RD06SW	1	1	1	1	1	1	1	1	1	1
Red Devil Creek Downstream Alluvial Area and Delta	Red Devil Creek, near confluence of Red Devil Creek and Kuskokwim River, downstream of sediment trap constructed during NTCRA	RD08SW	1	1	1	1	1	1	1	1	1	1

Key:

Hg = mercury
TAL = Target Analyte List

Table 2-4 Summary of 2015 Kuskokwim River Sediment Samples

General Geographic Area	Location Description	Sample Location ID	Total TAL Metals	Grain Size	TOC	Methylmercury	Hg SSE	Sediment Toxicity - *Hyalella azteca* (28 day)
Upriver of Red Devi Creek Delta	Near BLM periphyton sample location Kusko-14-PERI-13	KR082	X	X	X	-	-	X
	Near RI sediment sample location KR26	KR083	X	X	X	-	-	X
Near Right Bank of Kuskokwim River Across from Red Devil Mine Area	Approximately 50 feet from right bank opposite area of RI sample location KR29 upriver from Red Devil Creek	KR106	X	-	-	-	-	-
	Approximately 10 to 20 feet from right bank opposite area of RI sample location KR29 upriver from Red Devil Creek	KR107	X	-	-	-	-	-
	Approximately 50 feet from right bank opposite area of RI sample location KR54 downriver from Red Devil Creek	KR108	X	-	-	-	-	-
	Approximately 10 to 20 feet from right bank opposite area of RI sample location KR54 downriver from Red Devil Creek	KR109	X	-	-	-	-	-
Red Devil Creek Delta Area	Near RI sediment sample location KR29	KR084	X	X	X	X	X	X
	Near RI sediment sample location KR02	KR085	X	X	X	-	-	X
	Near RI sediment sample location KR54	KR086	X	X	X	-	-	-
Downriver of Red Devil Creek Delta	Near RI sediment sample location KR37	KR087	X	X	X	-	-	X
	Near BLM periphyton sample location Kusko-14-PERI-14	KR088	X	X	X	X	X	X
	Near RI sediment sample location KR43	KR089	X	X	X	X	X	X
	Near RI sediment sample location KR45	KR090	X	X	X	-	-	X
	Near RI sediment sample location KR60	KR091	X	X	X	X	X	X
	Near BLM periphyton sample location Kusko-14-PERI-15	KR092	X	X	X	X	X	X
	Near RI sediment sample location KR72	KR093	X	X	X	X	X	X
	Outboard of RI sediment sample locations, near locations KR55 and KR56	KR094	X	X	X	-	-	-
	Outboard of RI sediment sample locations, near location KR73	KR095	X	X	X	-	-	-
	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-16	KR096	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near right bank	KR097	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-26	KR098	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near right bank	KR099	X	X	X	-	-	-
	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-19	KR100	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near right bank	KR101	X	X	X	X	-	X
	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-22	KR102	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near right bank	KR103	X	X	X	-	-	-
	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-27	KR104	X	X	X	X	-	-
	Downriver of RI sediment sample locations, near right bank	KR105	X	X	X	X	-	-
		Planned Number of Samples	**28**	**24**	**24**	**14**	**6**	**12**

Key:
Hg SSE = Mercury selective sequential extraction
TAL = Target Analyte List
TOC = Total organic carbon

3

Sample Identification

Each sample collected during the 2015 supplemental RI characterization will be assigned a unique alphanumeric code. Sample codes will be recorded in field logbooks, on sample containers, and on chain-of-custody (COC) forms. The field team leader will be responsible for maintaining a master database or spreadsheet of samples to be collected and samples obtained to ensure that all planned samples are collected during the field investigation, that sample designation codes are not used twice for different locations, and that the correct analytical parameters are identified on laboratory documentation.

Tables 3-1 through 3-4 describe the sample coding system.

Subsurface Soil

Subsurface soil samples collected for fixed laboratory analysis and XRF field screening will be assigned sample identifiers as specified in Table 3-1. Pre-assigned sample location identifiers for proposed soil borings are presented in Table 2-1 and illustrated on Figure 2-1.

Table 3-1 Sample Identification Coding System: Subsurface Soil

Characters	Purpose	Code	Description
1–2	Sample collection year	15	Last two digits of year
3–4	Geographic area	MP	Main Processing Area
		RD	Red Devil Creek Downstream Alluvial Area
		SM	Surface Mined Area
5–7	Location number	092, 093, etc.	Consecutive number within area/location
8–9	Matrix	SB	Subsurface soil
10–11	Depth	02, 04, 06, etc.	Depth in feet below ground surface as measured at the bottom of the subsurface soil sample interval

Field duplicate samples for subsurface soil samples will be identified by selecting a unique location number not used for the regular sample or any subsequent samples. All samples will be cross-referenced in the field logbooks and in the sample master database to sample locations.

Example sample codes for subsurface soil:

- 15MP092SB06: The regular subsurface soil sample collected from soil boring MP092 in the Main Processing Area, collected from a depth interval of 4 to 6 feet below ground surface (bgs) in 2015.
- 15MP131SB06: The field duplicate subsurface soil sample collected from a soil boring in the Main Processing Area (e.g., MP092), collected from a depth interval of 4 to 6 feet bgs in 2015.

Groundwater

Groundwater samples will be collected for laboratory analyses from existing and new monitoring wells during sampling events in 2015. Groundwater samples will be collected from the wells identified in Table 2-2, and shown on Figure 2-2. Groundwater samples will be assigned sample identifiers as specified in Table 3-2.

Table 3-2 Sample Identification Coding System: Groundwater

Characters	Purpose	Code	Description
1–2	Sample collection month	XX	Numerical month designation (e.g., “05” for May)
3–4	Sample collection year	15	Last two digits of year
5–8	Monitoring well identification number	MW08, etc.	See final RI report for existing monitoring wells. New monitoring wells identification numbers will be assigned identification numbers as specified in Table 2-1.
9–10	Matrix	GW	Groundwater

Field duplicate samples for groundwater samples will be identified by selecting a unique monitoring well identification number not used for any actual monitoring wells. All samples will be cross-referenced in the field logbooks and in the sample master database to monitoring well designations.

Example sample codes for groundwater:

- 0515MW08GW: The regular groundwater sample collected from existing monitoring well MW08 in May 2015.
- 0515MW90GW: The field duplicate groundwater sample collected from existing monitoring well MW08 in May 2015.

Surface Water

Surface water samples will be assigned sample identifiers as specified in Table 3-3. Pre-assigned sample location identifiers for proposed surface water samples are presented in Table 2-3 and on Figure 2-2.

Table 3-3 Sample Identification Coding System: Surface Water

Characters	Purpose	Code	Description
1–2	Sample collection month	XX	Numerical month designation (e.g., “05” for May)
3–4	Sample collection year	15	Last two digits of year
5–8	Surface water monitoring station identification number	RD10, etc.	See Table 2-3 and Figure 2-2 for descriptions and locations of existing and proposed new surface water monitoring stations.
9–10	Matrix	SW	Surface water

Field duplicate samples for surface water samples will be identified by selecting a unique location number not used for any actual samples. All samples will be cross-referenced in the field logbooks and in the sample master database to sample locations.

Example sample codes for surface water:

- 0515RD10SW: The regular surface water sample collected from surface water sampling station RD10 in Red Devil Creek in May 2015.
- 0515RD20SW: The field duplicate surface water sample collected from surface water sampling station RD10 in Red Devil Creek in May 2015.

Kuskokwim River Sediment

Sediment samples will be assigned sample identifiers as specified in Table 3-4. Pre-assigned sample location identifiers for proposed sediment samples are presented in Table 2-4 and on Figures 2-3 and 2-4.

Table 3-4 Sample Identification Coding System: Kuskokwim River Sediment

Characters	Purpose	Code	Description
1–2	Sample collection year	15	Last two digits of year
3–4	Area	KR	Kuskokwim River
5–7	Location number	082, 083, etc.	Consecutive number within area
8–9	Matrix	SD	Sediment

Field duplicate samples for sediment will be identified by selecting a unique location number not used for any actual samples. All samples will be cross-referenced in the field logbooks and in the sample master database to sample locations.

Example sample codes for Kuskokwim River sediment:

- 15KR082SD: The regular sediment sample collected from proposed sampling location KR082 in 2015.
- 15KR150SD: The field duplicate sediment sample collected from proposed sampling location KR082 in 2015.

4

Sampling and Other Field Procedures

This chapter describes the procedures and equipment to be used in the collection of samples and field observations during the 2015 field activities. E & E standard operating procedures (SOPs) are referred to in this chapter and subsequent chapters. Copies of all applicable E & E SOPs will be on site during the implementation of the 2015 field work.

All surface water and groundwater sampling conducted for the 2015 field activities will be conducted using ultraclean sampling methods (U.S. Environmental Protection Agency [EPA] Method 1669). In summary, ultraclean sampling methods involve the following procedures:

- Sampling equipment and containers that have been cleaned using detergent, mineral acids, and reagent water, filled with weak acid solution, and individually double-bagged for storage and shipment are obtained from the laboratory.
- On site, one member of the two-person sampling team is designated as "dirty hands;" the second member is designated as "clean hands." All operations involving contact with the sample container and transfer of the sample from the sample collection device to the sample container are handled by the individual designated as "clean hands."
- A new pair of 8-millimeter nitrile gloves will be worn during each sample collection.
- All sampling equipment and sample containers used will be non-metallic and free from any material that may contain metals.
- Sampling personnel will wear clean, non-talc gloves when handling sampling equipment and sample containers.
- Surface water samples will be collected facing upstream and upwind (when possible) to minimize introduction of contamination.
- Acid preservatives will be placed in sample containers in a clean area prior to sample collection.

4.1 Soil Boring Installation and Subsurface Soil Sampling

Subsurface soil samples will be collected at soil boring locations identified in Section 2.1. Soil borings will be installed using a drill rig operated by a subcontracted, Alaska-licensed driller. A track-mounted drill rig capable of direct push, hollow-stem auger, and air-rotary/down-the-hole hammer drilling techniques will be used to advance the soil borings. The type of drilling method and equipment to be used will depend on the types of subsurface material anticipated and encountered. In general, it is anticipated that direct-push and hollow-stem auger equipment/methods will be used for overburden soils, and air rotary down-the-hole hammer equipment/method will be used for drilling in bedrock. A 2-foot-long split spoon sampler will be used for subsurface soil sampling using direct-push and hollow-stem auger drilling methods. Soil cores will be collected continuously from the ground surface to the base of the unconsolidated materials. While drilling in bedrock, drill cuttings will be collected at a minimum at 5-foot intervals.

Drilling and soil coring will continue at each borehole to the targeted depth if possible. The target depth of each borehole will depend on the specific objective for that borehole and conditions encountered during drilling, as described below. Targeted drilling depth criteria for soil borings are summarized in Table 2-1.

Each borehole will be logged by a project geologist. Observations of soil materials will include the following:

- Soil type (consistent with soil type designations presented in the final RI report);
- Soil group classification (using United Soil Classification System);
- Color;
- Odor;
- Lithology and mineralogical characteristics and grain shape and size of clasts;
- Grain size range and distribution;
- Gradation;
- Soil particle lithology;
- Hardness;
- Plasticity;
- Bedding or sedimentary structures;
- Moisture content;
- Observations of gross contamination, including sheen and elemental mercury;

- Qualitative description of matrix porosity;
- Mineralization, including sulfides and iron staining; and
- Weathering.

In addition to those observations listed above for soil materials, observations will include:

- Lithology and mineralogical characteristics of bedrock; and
- Bedrock fracture characteristics (e.g., dip angle, spacing, smoothness/planarity, void width, weathering, fracture-filling mineralogy, and stain thickness) will be made if feasible (e.g., if the materials can be penetrated and samples with a split spoon sampler).

Following initial visual observation of the recovered soil material, an aliquot of the soil will be collected for possible laboratory analysis for mercury SSE by placing the material directly into the sample container without homogenizing, thereby reducing potential volatilization of any elemental mercury that could be present in the material. Following collection of an aliquot for mercury SSE, sample material will be placed into a clean, dedicated, re-sealable, plastic bag and the bag will be sealed. This material will be homogenized by working the material manually within the sealed bag. This material will then be field screened with an XRF obtain total metals concentration data for the subject interval. This data will be used in the field for the selection of samples for additional analyses as described below.

A subset of subsurface soil samples collected will be selected for laboratory analysis for total TAL metals and mercury SSE. Planned sampling for analytical laboratory analysis and the rationale for selection of samples are summarized in Table 2-1.

After boreholes have been successfully advanced, unless they are converted to monitoring wells, they will be abandoned at the completion of sampling or the end of the day. Soil borings will be abandoned in accordance with State of Alaska regulations. Management of drill cuttings will be performed as specified in Chapter 7. Monitoring wells will be installed as described in Section 4.2.

4.2 Monitoring Well Installation, Construction, and Development

New monitoring wells will be installed within selected soil borings at the locations identified in Section 2.2. Wells will be installed in accordance with State of Alaska regulations and as described below.

The monitoring wells will be constructed of 2-inch inside-diameter, Schedule 40, National Sanitation Foundation (NSF)-approved, PVC flush-threaded joints. The wells will be screened with one 10-foot or 20-foot section of 2-inch, 0.010-inch slot PVC screen, or equivalent. Sections of prefabricated sand pack filter/screen (“pre-pack” screens) may be used for construction of some new monitoring wells. Prefabricated “pre-pack” screens may be used to achieve a consistent sand pack thickness throughout the entire screened interval in wells installed in bedrock or unconsolidated materials. The inner diameter of the “pre-pack” screen section is consistent with the casing sections, and the outer diameter is 4 inches. A 1-foot, 2-inch diameter, schedule 40, matching thread, NSF-approved sump will be attached to the base of the well screen. The monitoring wells will be completed to ground surface using schedule 40 PVC riser. All PVC casing joints will be of matching flush-threaded design with Viton O-rings and will be screwed together without the use of glues, epoxies, or petroleum-based lubricants. All materials will be cleaned and placed in polyethylene bags at the factory; the bags will remain sealed until the time of installation.

The monitoring well screen intervals will be selected at the time of well installation by the project geologist. Selection of screen intervals will be based on the target criteria specified in Table 2-1. For wells screened in bedrock, the screen interval will be selected to straddle an interval that, based on observations made during drilling, is expected to produce water; such intervals are expected to consist of fractured bedrock. If the selected well screen interval lies above the total depth of the boring, the boring will be backfilled with bentonite pellets to a depth corresponding to the base of the sump. A minimum one-hour period will be allotted for hydration of the bentonite prior to well installation.

The annular space between the well screen and borehole will be filled with a uniform sand pack (i.e., conforming to the selected screen size) to serve as a filter media. The top of the sand pack will extend to approximately 2 to 3 feet above the top of the well screen.

A minimum 2-foot-thick bentonite pellet seal will be installed directly above the sand pack. A measured volume of clean water will be added and a specified time period (minimum one hour) will be allotted for maximum hydration. The remaining annulus will be filled with high solids bentonite grout or hydrated bentonite pellets or chips. The bentonite grout will consist of a mixture of powdered bentonite with the recommended volume of water to achieve an optimal seal. The grout will contain at least 30 percent solids by weight and have a density of 11 pounds per gallon or greater. Grout will be emplaced to approximately 3 feet bgs using a tremie pipe from the bottom of the annular space upwards to the surface.

A concrete or cement surface seal will be used to finish grouting the annular space during well completions as discussed below. The monitoring wells will be completed with a 2.5-foot steel riser with locking monument above the ground surface. A locking well cap will secure the well inside the monument.

Prior to well development, grout will be allowed to cure for a minimum of 24 to 72 hours to allow sufficient time for the bentonite seal to cure. For wells installed below the water table, grout will be allowed a minimum of 72 hours curing time prior to development. For wells in which the bentonite seal is above the water table, development may proceed after a minimum of 24 hours.

Well development will be accomplished by a combination of mechanical surging, bailing, and pumping with a submersible pump. The wells will be mechanically surged, depending on the geologic characteristics of the screened interval, to remove fines from inside the screen and casing and to flush the formation around the filter pack throughout the entire screened interval. Fines will be removed from the borehole periodically during the surging process using a bailer to minimize the re-entry of fines into the formation. The monitoring wells will then be pumped with a submersible pump until the measured water quality parameters are stabilized. Water will be removed throughout the entire water column by periodically lowering and raising the pump intake. Development will be considered complete when all water introduced during drilling, if any, plus a minimum of 5 to 10 well-bore volumes have been removed from the well, and the water is chemically stable and as free of sediment as possible. Water produced from the well will be considered chemically stable when field parameters, measured by E & E (pH, temperature, specific conductance, and turbidity) remain within 10 percent of the previous measurement for at least three successive measurements. Water produced from the well will be considered free of sediment when it is clear or turbidity has stabilized for at least three successive borehole measurements. The pump, tubing, and all other equipment used during development will be decontaminated between each use. All development water generated will be collected in 55-gallon drums. The development water will be disposed of as described in Section 7.3.

4.3 Groundwater Sampling

During the 2015 groundwater sampling events, groundwater samples will be collected from existing and new monitoring wells specified in Table 2-2. To the extent practicable, groundwater sampling will occur in a progression from the least to the most contaminated wells, based on existing groundwater sample data.

In general, each well will be sampled following the EPA's Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001 (EPA 2002). The expected sampling approach is specified below.

Prior to groundwater sampling, a round of static water level measurements will be performed at each well. Depth to groundwater will be measured to the nearest 0.01 foot using an electronic water level meter. The locking cover and protective cap will be removed, and the static water level depth will be measured from the surveyed measuring point (usually the north side of the top of the inside well casing). If the casing cap is airtight as evidenced by release or drawing of air upon removal of the well cap, time will be allowed prior to water level measurement for equilibration of pressures after the cap is removed. Measurements will be repeated until the water level is stabilized. The water level meter will be cleaned with an environmental grade non-phosphate detergent before prior to sounding the well. All parts of the water level meter that will contact groundwater will be rinsed with distilled water before placement in the well. Groundwater levels in all monitoring wells will be measured within as short a period of time as feasible, not to exceed one day, in order to provide data representative of the potentiometric surface(s) at the time of the sampling event. The water level measurements will be used to determine groundwater elevation and to estimate the standing water volume contained within the well. The measurement will also be used to determine the depth of the pump intake and to monitor water drawdown during low-flow purging and sampling, as described below.

Groundwater purging and sampling will be performed using a low-flow technique at each well, if feasible. If it is determined that it is not feasible to use a low-flow technique at a given well, the well will be purged utilizing an alternate technique with a pump and/or disposable bailers as described below.

Low-Flow Purging Technique

Low-flow purging/sampling will be performed following the EPA's Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001 (EPA 2002) and Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (Puls and Barcelona, 1996). Low-flow purging and sampling will be performed using a submersible pump, a bladder pump, or a battery-operated peristaltic pump outfitted with dedicated, disposable tubing.

The tubing/pump intake will be carefully lowered into the well to the targeted sample point (e.g., at the middle of the water column within the screen interval). The well will be purged at a target rate of less than 0.5 liter per minute. During purging, the water level will be monitored with the water level indicator to measure well drawdown and to guide the adjustment of purge rate to minimize drawdown while purging. The water level will be monitored continuously during purging and the sampling team will attempt to maintain less than 0.1 meter of drawdown during purging.

During purging, field water quality parameters, including pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity, will be measured to determine when stabilization of the groundwater is achieved. Water quality parameters will be measured using an in-line water quality meter (e.g., Horiba U50 or similar equipment) and recorded in the field logbook. Field parameters will be measured every 3 to 5 minutes during purging. Field parameters will be considered stabilized after all parameters have stabilized for three successive readings. Criteria for stabilization are three successive readings within the following limits include:

- pH: ±0.1 pH units;
- Temperature: ±1 degree Celsius (°C);

- Specific electrical conductance (conductivity): ±3%;
- Turbidity: ±10% (when turbidity is greater than 10 nephelometric turbidity units);
- Dissolved oxygen: ±0.3 milligrams per liter; and
- Oxidation Reduction Potential: ±10 millivolts.

Upon stabilization of field parameters, groundwater samples will be collected directly into the appropriate (pre-preserved, as applicable) sample containers.

The use of peristaltic pumps to collect groundwater samples is limited by the ability of peristaltic pumps to draw water from depths of greater than approximately 25 feet. If it is not possible to collect a groundwater sample from a given well using a peristaltic pump, the sampling team will attempt to use a decontaminated, positive-pressure pump (bladder pump or electric submersible pump) to purge and sample the well using low-flow techniques.

Following successful purging, samples will be collected as described below.

If the drawdown and/or field water quality parameter criteria cannot be met, then the well will be sampled using an alternate purging technique, described below.

Alternate Purging Technique

If low-flow technique is not successful at a given well, purging will be accomplished using a positive pressure pump (e.g., submersible pump) and/or a dedicated, disposable Teflon-lined bailer. A minimum of three casing volumes of water will be purged prior to sample collection unless the well runs out of recoverable water. Field water quality parameters will be measured in the first water extracted from the well and subsequently after each time a casing volume is purged. If a bailer is used, water quality parameters will be measured by pouring a volume of water from a bailer into a container and submerging the water quality meter probe into the container. It may not be possible to achieve the stabilization criteria outlined above using a bailer to purge the well. In this case, sample collection will be performed after six well volumes have been purged from the well.

In the event that the well runs dry during purging, the well will be allowed to recharge for up to 24 hours. Upon resumption of pumping, field water quality parameters will be measured, and samples will be immediately collected.

Sample Collection

Samples will be collected for the parameters specified in Table 2-2. Samples will be collected in bottles provided by the analytical laboratory. Bottle sets will be filled in the following general order: non-filtered, non-preserved aliquots; followed by non-filtered preserved aliquots; followed by filtered, non-preserved aliquots; followed by filtered preserved aliquots. Aliquots for dissolved constituents will be field-filtered using a dedicated 0.45-micrometer filter.

For those wells sampled for BTEX, if a positive-pressure pump is not used to purge and sample the well, the aliquot for BTEX will be collected with a bailer following collection of all other aliquots.

For samples collected using a low-flow purging technique, samples will be collected immediately following stabilization of water quality parameters with the pump still running at the stabilized purge rate. For filtered aliquot collection, the filter will be inserted into the end of the sample tubing while the pump is still running in order to maintain a steady flow of water, minimizing potential disturbance of formation groundwater. Following installation of the filter, water will be allowed to run through the filter for several filter volumes prior to sample collection. The dissolved sample aliquot will then be collected directly into the appropriate sample container.

Samples collected by bailer will be poured directly into the appropriate pre-cleaned sample containers. Filtered aliquots will be collected by pouring water from the bailer into a dedicated transfer container and pumping the water into the sample container using a peristaltic pump outfitted with dedicated tubing and in-line 0.45 micrometer filter.

4.4 Surface Water Sampling

Surface water samples from locations specified in Table 2-3 and illustrated in Figure 2-3, including locations along Red Devil Creek and the seep on the left bank of the creek. Sampling will start at the most downstream location and proceed upstream to avoid disturbing sediments that could impact turbidity and contaminant concentrations in downstream locations.

Samples will be collected for the parameters specified in Table 2-3. Samples will be collected in bottles provided by the analytical laboratory. Bottle sets will be filled in the following general order: non-filtered, non-preserved aliquots; followed by non-filtered preserved aliquots; followed by filtered, non-preserved aliquots; followed by filtered preserved aliquots. Aliquots for dissolved constituents will be field-filtered using a dedicated 0.45-micrometer filter.

Samples will be collected using a battery-operated peristaltic pump outfitted with dedicated silicone tubing. The water sample will be collected from a single location within the middle of the stream channel at the mid-depth water level. Dissolved metals aliquots will be collected following collection of the other aliquots using a dedicated in-line 0.45-micrometer filter.

In the event that it is not possible to collect the water samples using a peristaltic pump, the samples will be collected by hand-dipping the sample container directly into the creek water. For sample containers that have been pre-preserved, a separate dedicated bottle may be used as a transfer container.

Following sample collection at each location, field parameters for pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity will be measured using a calibrated water quality meter and then recorded in the field logbook.

4.5 Stream and Seep Discharge Measurement

Surface water discharge will be measured using the Mid-Section method at each surface water sampling location where the estimated discharge is greater than 2.0 cubic feet per second (cfs) and a portable weir plate will be used for stream sections with smaller discharge rates. Discharge will be measured in accordance with Measurement and Computation of Streamflow: Volume 1, Measurement of Stage and Discharge (Rantz et al. 1982) and Techniques of Water-Resources Investigations Reports (U.S. Geological Survey [USGS] 2011).

4.5.1 Measurement Methods

The following sections detail the methods to be used. Field staff will determine which of the two proposed methods will be applied based on the flow rate during the measurement event.

4.5.1.1 Mid-Section Method

The Mid-Section method involves measuring the channel area and water velocities at a stream cross section. This method will be used where sufficient stream flow is available to allow the channel to be divided into rectangular subsections. After dividing the stream into subsections, the depth, discharge, and distance from the bank will be measured at the center of the stream subsection.

The preferred number of subsections across the width of the stream is 20 to 30, with a minimum of 10. If the stream width is less than 5 feet, the width of the subsections should not be less than 0.5 foot. Not more than 5 percent of stream discharge should occur within a single subsection. Subsections do not have to be the same width. For water depths greater than 2.5 feet, velocity will be measured at two depths, 20 and 80 percent of the total subsection depth, and averaged. For water depths less than 2.5 feet, velocity only will be measured at 60 percent of the total subsection depth.

Appropriate locations for stream cross sections are straight reaches where the streambed is uniform, free of boulders and aquatic vegetation, and where the stream flow is uniform.

4.5.1.2 Portable Weir Plates

Portable weir plates will be used where Red Devil Creek is too small or velocities too low to reliably use the above Mid-Section method. This is typically where stream widths are shallow and flows are less than 2.0 cfs. Weir plates are constructed with a staff gage on the upstream side, far enough away from the notch so it is not impacted by the drawdown of flow through the notch. Once a steady-state discharge through the weir has been reached, the height behind the weir plate is recorded to determine the flow rate through the weir. These are intended to be short-term measurement devices and are removed after each use.

4.5.2 Discharge Calculation

The general equation for calculating discharge is:

Discharge (Q) = Velocity (v) x Cross sectional area of stream channel (A)

For the Mid-Section method, stream discharge will be calculated for each subsection (q) and then summed together to obtain total discharge (Q).

$q_{1,2,3,\text{etc.}} = V_{1,2,3,\text{etc.}} \times \text{Depth at Midpoint}_{1,2,3,\text{etc.}} \times \text{Width of Subsection}_{1,2,3,\text{etc.}}$

and,

$Q = q_1 + q_2 + q_3 + q_{\text{etc.}}$

For the Portable Weir Plate method, the following equation will be used:

Q = Ch^(5/2)

where,

Q = Discharge (cfs);
h = Static head above the bottom of the notch (mean gage height), in feet; and
C = Coefficient of discharge. A standard value of 2.47 will be used for C assuming a 90 degree notched V-weir.

4.5.3 Equipment

Stream discharge measurement will require the following equipment:

Mid-Section Method: A Marsh McBirney or similar flow meter, top-setting wading rod, long tape measure, waders, and calculator.

Portable Weir Plate: Portable weir plate, constructed to USGS standard specifications, shovel, carpenter’s level, rebar to stabilize the weir (as needed), and canvas or similar to prevent downstream undercutting.

4.5.4 Stream Measurements

4.5.4.1 Mid-Section Method

After identifying a suitable location for the stream cross section, a reference point on one bank will be selected. A tape measure will be stretched across the stream, fixing it to the reference point on one bank and another point on the opposite bank, while ensuring that the tape is oriented perpendicular to the stream flow.

Using the measured channel width, the appropriate number of subsections will be determined based on the guidelines in Section 4.5.1.

From the mid-point of each subsection, the stream velocity will be measured at the depths provided in Section 4.5.1. When measuring the stream velocity, the wading rod and flow meter should be located upstream from the field personnel to ensure that stream flow is not disrupted.

Discharge will then be calculated as described in Section 4.5.2 and the velocity of each subsection will be checked to ensure that it is less than 5 percent of the total stream discharge. If any subsection contains more than 5 percent of the stream discharge, additional subsections will be measured.

4.5.4.2 Portable Weir Plate

The weir plate would be pushed into the stream bed perpendicular to the flow, with an effort made to channel all of the stream flow through the weir by using stream bed material to pack around the weir and/or channelize the flow towards the opening of the weir plate. As needed, an estimation of flow around the weir will be made and noted. A carpenter’s level will then be used to ensure that the weir is horizontal after insertion and that the weir is vertical. This will be done to provide an accurate and consistent measurement relative to the water surface. Weir plates will not be submerged on either the up or downstream sides also to increase accurate readings.

Once the pool height has stabilized on the upstream side of the weir, gage readings will be recorded every 30 seconds for three minutes. The mean value of these readings will then be used to compute discharge.

4.6 Kuskokwim River Sediment Sampling

Samples of Kuskokwim River sediment will be collected from offshore locations specified in Table 2-4 and illustrated in Figures 2-3 and 2-4. Samples will be collected for the analyses specified in Table 2-4.

Sediment samples will be collected using a combination of manual van Veen grab sampler and hand coring sediment sampling equipment deployed from a 20-foot, flat-bottomed boat. The sampling vessel will be outfitted with an A-frame and electric winch, fathometer, and Global Positioning System (GPS). The vessel and sampling equipment will be operated by Kinnetic Laboratories, Inc. under subcontract to E & E. An E & E sampler will oversee the operation of the sediment sampling equipment and will perform the collection and handling of sediment samples on board the vessel.

Samples will be collected using methods and equipment similar to those used to collect RI Kuskokwim River offshore sediment samples in 2011 and 2012. During the 2011 and 2012 Kuskokwim River sediment sampling events, sediment samples were collected using a manual van Veen grab sampler or hand coring equipment/method depending on water depth and river bottom substrate encountered at a given location. At many locations, the van Veen sampler was ineffective due to coarse sediment conditions. Where bottom sediment was not dominated by gravel and cobbles, sampling with a van Veen surface sediment grab sampler was attempted. At most locations, a hand auger was used. The sampling methods using these techniques are discussed below.

It is anticipated that sediment bed and river conditions will be similar to those encountered during the 2011 and 2012 sampling events. To collect adequate sediment volume to perform all proposed sediment analyses, including sediment toxicity, a volume of approximately 3 liters of sediment will be required for each sample. Based on RI sediment sampling efforts performed in 2011 and 2012, the sediment texture at some locations is very coarse grained (gravelly and cobbly) and not amenable to sampling or appropriate for the types of analyses planned. Therefore, for those 2015 locations intended to be collocated with previous RI samples, selection of sample locations is biased toward locations where, based on RI sampling results, larger proportions of finer grained materials (sand size and smaller). In addition, the selected locations are biased toward RI sample locations that exhibited fairly similar TOC concentrations and a wide range of total antimony, arsenic, and mercury concentrations. See Section 2.4 for further discussion regarding sample location selection.

Based on past sampling efforts, it may not be possible to collect sufficient sediment from some proposed sample locations due to the swift current and/or the gravel/cobble nature of the river bottom. It is expected that after the first or second deployment of the hand corer or van Veen sampler at a given location, the nature of the bottom conditions (i.e., gravelly/cobbly versus finer grained) will be apparent. In the event that the location is gravelly/cobbly and exceedingly difficult to collect a sample from, the sampling team will relocate, at the discretion of the E & E field team leader, to a secondary nearby location with potentially better bottom conditions. The E & E field team leader will select the new location based on similar location characteristics and using best professional judgment. The process of relocating to a backup location will be repeated up to three times, for a total of four sampling attempts per proposed sample location. In the event that a sediment sample cannot be obtained after such an effort, the station will be abandoned and considered completed.

The vessel will be positioned on the sampling locations using an anchoring system or live-boating.

Surface sediment samples will be collected from the 0- to 10-centimeters (0- to 4-inches) interval. As detailed above, multiple grabs may be required to obtain an adequate sample volume for all analyses. Compositing and homogenization of samples is described below.

For all sampling, field data will be recorded in a logbook and field forms.

Sediment sampling equipment will be decontaminated with phosphate-free detergent and a de-ionized water rinse between uses.

Van Veen Sampler Procedure

For samples collection using a van Veen grab sampler, the steps below will be followed:

1) Position the vessel at the sample location.
2) Set the van Veen sampler jaws in the open position, place the sampler over the edge of the boat, and lower the sampler to the bottom.
3) Trip the sampler to collect the sample.
4) Record the horizontal location coordinates of the sample location using the GPS and record the water depth.
5) Retrieve the sampler and place it securely in the sampling vessel.
6) Examine the sample for the following sample acceptance criteria; if criteria are not achieved, the sample will be rejected and another collection attempt will be made.
    a. The sampler is not overfilled with sample material (to prevent the sediment surface from pressing against the top of the sampler).
    b. The sample does not contain large foreign objects such as trash or debris. A sample that is predominately rock/gravel will be rejected in favor of finer-grained material.
    c. Overlying water is present in the sampler (indicates minimal leakage of material from the sampler).
    d. The overlying water is not excessively turbid (indicates minimal disturbance of the sample).
    e. The sediment surface is relatively flat (indicates minimal disturbance or winnowing of the sample).
    f. The depth of sediment in the sampler is several centimeters greater than the targeted sample depth of 10 centimeters (indicates the desired penetration depth into the bed sediment is achieved).
7) Siphon off any overlying surface water.
8) Measure and collect the top 10 centimeters (4 inches) of sediment with a disposable plastic scoop, avoiding any sediment that is in contact with the inside surface of the grab sampler, then place the sediment into a dedicated, disposable, plastic bowl and cover with aluminum foil.
9) Record the following observations of sediment sample characteristics:
    a. Texture (grain-size distribution)
    b. Color
    c. Biological organisms or structures

   d. Bedding or sedimentary structures
   e. Presence of debris (natural or anthropogenic objects)
   f. Presence of obvious tailings, waste rock, or gross contamination
   g. Lithology of sediment particles
   h. Mineralization, including metal sulfides and iron staining
   i. Odor (for example, hydrogen sulfide or petroleum)

10) If more sample volume is required, repeat steps 1 through 9.
11) Once sufficient sediment volume has been collected, homogenize the sample by mixing with a dedicated, disposable, plastic scoop until a consistent color and texture are achieved. Place sample material in the appropriate, pre-cleaned, labeled sample containers, place in a cooler maintained at 4°Celsius, and prepare for shipment to the analytical laboratory.
12) Confirm all relevant documentation has been completed, entries are accurate, and paperwork has been signed.
13) Wash excess sediment back into the water away from any areas remaining to be sampled.
14) Decontaminate all sampling equipment before proceeding to the next sampling location.

Hand Coring Procedure

For sample collection using hand coring equipment, the steps below will be followed:

1) Position the vessel at the sample location.
2) Lower the hand coring tool from the side of the vessel and collect and retrieve a sediment core.
3) Record the horizontal location coordinates of the sample location using the GPS and record the water depth.
4) Retrieve the sampler and place it securely in the sampling vessel.
5) Examine the sample for the following sample acceptance criteria; if criteria are not achieved, the sample will be rejected and another collection attempt will be made.
   a. The sampler is not overfilled with sample material (to prevent the sediment surface from pressing against the top of the sampler).
   b. The sample does not contain large foreign objects such as trash or debris. A sample that is predominately rock/gravel will be rejected in favor of finer-grained material.
   c. The sediment surface is relatively flat (indicates minimal disturbance or winnowing of the sample).

   d. The depth of sediment in the sampler is several centimeters greater than the targeted sample depth of 10 centimeters (indicates the desired penetration depth into the bed sediment is achieved).

6) Siphon off any overlying surface water.

7) Measure and collect the top 10 centimeters (4 inches) of sediment with a disposable, plastic scoop, then place the sediment into a dedicated, disposable, plastic bowl and cover with aluminum foil.

8) Record the following observations of sediment sample characteristics:
   a. Texture (grain-size distribution)
   b. Color
   c. Biological organisms or structures
   d. Bedding or sedimentary structures
   e. Presence of debris (natural or anthropogenic objects)
   f. Presence of obvious tailings, waste rock, or gross contamination
   g. Lithology of sediment particles
   h. Mineralization, including metal sulfides and iron staining
   i. Odor (for example, hydrogen sulfide or petroleum)

9) If more sample volume is required, repeat steps 1 through 9.

10) Once sufficient sediment volume has been collected, homogenize the sample by mixing with a dedicated, disposable, plastic scoop until a consistent color and texture are achieved. Place sample material in the appropriate, pre-cleaned, labeled sample containers, place in a cooler maintained at 4°Celsius, and prepare for shipment to the analytical laboratory.

11) Confirm all relevant documentation has been completed, entries are accurate, and paperwork has been signed.

12) Wash excess sediment back into the water, away from any areas remaining to be sampled.

13) Decontaminate all sampling equipment before proceeding to the next sampling location.

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5

Sample Analytical Methods

Sample analytical methods, including holding times and method detection limits, are presented in the QAPP, provided as Appendix C of the final RI/FS work plan (E & E 2011). For reference, Table 5-1 summarizes the sample analytical methods.

Table 5-1 Summary of Sample Analytical Methods

Subgroup	Analyte	Analytical Method
Matrix: Soil/Sediment		
Analytical Group: Metals		
Total Metals	■ Mercury	■ EPA 7471A
	■ Mercury (low level)	■ EPA 1631
	■ Aluminum	■ EPA 6010B
	■ Antimony	■ EPA 6020A (mass=121)
		■ EPA 6020A (mass=123)
	■ Arsenic	■ EPA 6010B
	■ Arsenic (low level)	■ EPA 6020A
	■ Barium	■ EPA 6020A (mass=135)
		■ EPA 6020A (mass=137)
	■ Beryllium	■ EPA 6020A
	■ Cadmium	■ EPA 6020A (mass=111)
		■ EPA 6020A (mass=114)
	■ Calcium	■ EPA 6010B
	■ Chromium	■ EPA 6020A (mass=52)
		■ EPA 6020A (mass=53)
	■ Cobalt	■ EPA 6020A
	■ Copper	■ EPA 6020A (mass=63)
		■ EPA 6020A (mass=65)
	■ Iron	■ EPA 6010B (mass=54)
		■ EPA 6010B (mass=57)
	■ Lead	■ EPA 6010B
	■ Magnesium	■ EPA 6010B
	■ Manganese	■ EPA 6020A
	■ Nickel	■ EPA 6020A (mass=60)
		■ EPA 6020A (mass=62)
	■ Potassium	■ EPA 6010B
	■ Selenium	■ EPA 6020A (mass=82)
		■ EPA 6020A (mass=78)
	■ Silver	■ EPA 6020A
	■ Sodium	■ EPA 6010B
	■ Thallium	■ EPA 6020A
	■ Vanadium	■ EPA 6020A
	■ Zinc	■ EPA 6020A (mass=66)
		■ EPA 6020A (mass=67)
		■ EPA 6020A (mass=68)
Methylmercury	■ Methylmercury	■ EPA 1630 Modified
Mercury Selective Sequential Extraction (SSE)	■ Mercury	■ BRL SOP #BR-0013; Hg 5-step SSE and (www.epa.gov/esd/pdf-ecb/542asd95.pdf)
Analytical Group: Conventionals		
	■ Grain Size Analysis	■ ASTM D422
	■ Total Organic Carbon (TOC)	■ EPA 9060 modified
Analytical Group: Toxicity		
***Hyalella Azteca* (28-day)**	Toxicity	■ EPA 100.4

Table 5-1 Summary of Sample Analytical Methods

Subgroup	Analyte	Analytical Method
Matrix: Groundwater/Surface Water		
Analytical Group: Metals		
■ **Total and Dissolved Metals**	■ Mercury (low level)	■ EPA 1631E
	■ Aluminum	■ EPA 6010B
	■ Antimony	■ EPA 6020A (mass=121)
		■ EPA 6020A (mass=123)
	■ Arsenic	■ EPA 6020A
	■ Barium	■ EPA 6020A (mass=135)
		■ EPA 6020A (mass=137)
	■ Beryllium	■ EPA 6020A
	■ Cadmium	■ EPA 6020A (mass=111)
		■ EPA 6020A (mass=114)
	■ Calcium	■ EPA 6010B
	■ Chromium	■ EPA 6020A (mass=52)
		■ EPA 6020A (mass=53)
	■ Cobalt	■ EPA 6020A
	■ Copper	■ EPA 6020A (mass=63)
		■ EPA 6020A (mass=65)
	■ Iron	■ EPA 6010B (mass=54)
		■ EPA 6010B (mass=57)
	■ Lead	■ EPA 6020A
	■ Magnesium	■ EPA 6010B
	■ Manganese	■ EPA 6010B
	■ Nickel	■ EPA 6020A (mass=60)
		■ EPA 6020A (mass=62)
	■ Potassium	■ EPA 6010B
	■ Selenium	■ EPA 6020A (mass=82)
		■ EPA 6020A (mass=78)
	■ Silver	■ EPA 6020A
	■ Sodium	■ EPA 6010B
	■ Thallium	■ EPA 6020A
	■ Vanadium	■ EPA 6020A
	■ Zinc	■ EPA 6020A (mass=66)
		■ EPA 6020A (mass=67)
		■ EPA 6020A (mass=68)
Analytical Group: Petroleum		
	■ Gasoline Range Organics	■ AK 101
	■ Diesel Range Organics	■ AK 102
	■ Benzene	■ EPA 8021B (15.0 mL)
		■ EPA 8021B (5.0 mL)
	■ Toluene	■ EPA 8021B (15.0 mL)
		■ EPA 8021B (5.0 mL)
	■ Ethylbenzene	■ EPA 8021B (15.0 mL)
		■ EPA 8021B (5.0 mL)
	■ m/p-Xylene	■ EPA 8021B (15.0 mL)
		■ EPA 8021B (5.0 mL)
	■ o-Xylene	■ EPA 8021B (15.0 mL)
		■ EPA 8021B (5.0 mL)
Analytical Group: SVOCs		
	■ SVOCs	■ EPA 8270D

Table 5-1 Summary of Sample Analytical Methods

Subgroup	Analyte	Analytical Method
Analytical Group: Conventionals		
	■ Sulfate ■ Chloride ■ Fluoride ■ Nitrate/Nitrite ■ Carbonate/Bicarbonate ■ Total Suspended Solids ■ Total Dissolved Solids ■ Total Organic Carbon	■ EPA 300.0 ■ EPA 300.0 ■ EPA 300.0 ■ EPA 353.2 ■ EPA 310.1/SM2320B ■ EPA 160.2/SM2540D ■ EPA 160.1/SM2540D ■ EPA 9060

Key:

ASTM = ASTM International (formerly American Society of Testing and Materials)
BRL = Brooks Rand Labs
EPA = U.S. Environmental Protection Agency
Hg = mercury
mL = milliliter
SOP = standard operating procedure
SVOCs = semivolatile organic compounds

6

Sample Handling, Preservation, and Shipping

Transportation and handling of samples must be accomplished in a manner that not only protects their integrity, but also prevents any detrimental unnecessary exposure to sample handlers due to the possibly hazardous nature of the samples.

6.1 Sample Documentation

6.1.1 Sample Labels

Sample labels attached to or fixed around the sample container will be used to identify all samples collected in the field. The sample labels will be placed on bottles so as not to obscure any quality assurance/quality control (QA/QC) lot numbers on the bottles, and sample information will be printed legibly. Field identification will be sufficient to enable cross-reference with the project logbook.

To minimize handling of sample containers, labels will be filled out before sample collection. Each sample label will be written in waterproof ink, attached firmly to the sample containers, and protected with Mylar tape. The sample label will contain the following information:

- Sample designation code
- Date and time of collection
- Analysis required
- pH and preservation (when applicable)

6.1.2 Custody Seals

Custody seals are preprinted, adhesive-backed seals with security slots designed to break if the seals are disturbed. Sample shipping containers (e.g., coolers) will be sealed in as many places as necessary to ensure security. Seals will be signed and dated before use. Upon the containers' arrival at the laboratory, the custodian will check (and certify by completing the package receipt log) that seals are intact.

6.1.3 Chain-of-Custody Records

The COC records will be completed fully, at least in duplicate, by the field technician designated by the site manager as responsible for sample shipment. Information in the COC record will contain the same level of detail found in the site logbook, except that the onsite measurement data will not be recorded. The custody record will include, among other things, the following information:

- Name and company or organization of person collecting the samples;
- Date of sample collected;
- Matrix of sample collected (soil/water);
- Location of sampling station (using the sample designation code system described in Chapter 3);
- Number and type of containers shipped;
- Analysis requested;
- Signature of the person relinquishing samples to the transporter, with the date and time of transfer noted, and signature of the designated sample custodian at the receiving facility.

If samples require rapid laboratory turnaround, the person completing the COC record will note these or similar requirements in the remarks section of the custody record.

The relinquishing individual will record pertinent shipping data (e.g., air-bill number, organization, time, and date) on the original custody record, which will be transported with the samples to the laboratory and retained in the laboratory's file. Original and duplicate custody records with the air bill or delivery note constitute a complete custody record. The field team leader will ensure that all records are consistent and that they are made part of the permanent job file.

6.1.4 Field Logbooks and Data Forms

Field logbooks (or daily logs) and data forms are necessary to document daily activities and observations. Documentation will be sufficient to enable reconstruction of events that occurred during the project accurately and objectively at a later time. All daily logs will be kept in a bound notebook containing numbered pages, and all entries will be made in waterproof ink, dated, and signed. No pages will be removed for any reason.

Minimum logbook content requirements are described in E & E's SOPs, *Preparation of Field Activities Logbooks*, a copy of which will be kept on site during the field activities. If corrections are necessary, they will be made by drawing a single line through the original entry (so that the original entry is still legible) and writing the corrected entry alongside it. The correction will be initialed and dated. Corrected errors may require a footnote explaining the correction.

6.1.5 Photographs

Photographs will be taken as directed by the team leader. Documentation of a photograph is crucial to ensure its validity as a representation of an existing situation.

The following information on photographs will be noted in field logbooks:

- Date, time, and location photograph was taken;
- Weather conditions;
- Description of photograph;
- Reasons photograph was taken;
- Sequential number of photograph; and
- Direction.

After the photographs are processed, the information recorded in the field logbook will be summarized in captions in the digital photo log.

6.1.6 Custody Procedures

The primary objective of COC procedures is to provide an accurate written or computerized record that can be used to trace the possession and handling of a sample from collection to completion of all required analyses. A sample is considered to be in custody if it is:

- In someone's physical possession,
- In someone's view,
- Locked up, and
- Kept in a secured area that allows authorized personnel only.

6.1.6.1 Field Custody Procedures

The following guidance will be used to properly control samples during fieldwork:

- As few people as possible will handle samples.
- Coolers or boxes containing cleaned bottles will be sealed with custody tape during transport to the field or while in storage before use. Sample bottles from unsealed coolers or boxes, or bottles that appear to have been tampered with, will not be used.

- The sample collector will be responsible for the care and custody of samples until they are transferred to another person or dispatched properly under COC rules.
- The sample collector will record sample data in the field logbook.
- The site team leader will determine whether proper custody procedures were followed during the fieldwork and decide whether additional samples are required.

When custody is transferred (e.g., samples are released to a shipping agent), the following will apply:

- The coolers in which the samples are packed will be sealed and accompanied by two COC records. When transferring samples, the individuals relinquishing and receiving them must sign, date, and note the time on the COC record. This record documents sample custody transfer.
- Samples will be dispatched to the laboratory for analysis with separate COC records accompanying each shipment. Shipping containers will be sealed with custody seals for shipment to the laboratory. The method of shipment, name of courier, and other pertinent information will be entered in the COC record.
- All shipments will be accompanied by COC records identifying their contents. The original record will accompany the shipment. The other copies will be distributed appropriately to the site team leader and site manager.
- If samples are sent by common carrier, a bill of lading will be used. Freight bills and bills of lading will be retained as part of the permanent documentation.

6.1.6.2 Laboratory Custody Procedures

A designated sample custodian at the laboratory will accept custody of the shipped samples from the carrier and enter preliminary information about the package into a package or sample receipt log, including the initials of the person delivering the package and the status of the custody seals on the coolers (e.g., broken versus unbroken). Additional details on laboratory custody procedures are found in the QAPP.

6.2 Sample Containers and Preservation

Sample aliquots submitted to the analytical laboratories will be placed in commercial certified pre-cleaned sample containers and preserved as identified in Table 6-1.

6.3 Sample Shipping

Due to the remote location of the RDM site, sample shipment to the analytical laboratories will require careful logistical planning to ensure sample holding times are not exceeded and that samples arrive at the laboratories in good condition. In general, sample shipping logistics will involve the following:

- The field team leader will keep records of sample collection dates. Based on the dates of samples being held on site and the number of samples ready for shipment, the field team leader will contact E & E's Anchorage-based sample custodian to notify an aircraft charter service that a sample shipment flight is needed.
- When the sample shipment aircraft arrives at the Red Devil airstrip, the field team leader will relinquish custody of the samples to the pilot.
- When the sample shipment aircraft arrives in Anchorage, E & E's Anchorage-based sample custodian will assume custody of the samples. The custodian will re-pack all sample shipping containers with fresh ice and relinquish custody of the samples to an overnight delivery service that will ship the samples to the analytical laboratories.
- E & E's Anchorage-based sample custodian will confirm with the laboratories that all shipped samples have been received.

Table 6-1 Sample Containers and Preservation

Matrix	Analysis	Maximum Holding Time	Preservation	Sample Containers
Soil/Sediment	Total TAL Inorganic Elements (EPA 6010B/6020A/7471A)	6 months (28 days for Hg)	None, 0–4°C	4-oz glass jar
	Mercury SSE with total Hg	1 year	None, 0–4°C (shipment), ≤ –15°C (in lab)	4-oz glass jar
	Methylmercury	1 year (if aliquoted, weighed, and frozen ≤15°C in lab)	None, 0–4°C (shipment), ≤ –15°C (in lab)	4-oz glass jar
	Total Organic Carbon (EPA 9060)	28 days	None, cool to 4°C ± 2°C	4-oz glass jar
	Grain Size (ASTM D422)	None	None, 0–4°C	16-oz glass or plastic jar
	Toxicity – *Hyalella Azteca (28-day)* (EPA 100.4)	8 weeks	None, 0–4°C	Per laboratory
Water	Total TAL Inorganic Elements	6 months (28 days for Hg)	HNO_3, pH<2, 0–4°C	500-mL plastic bottle
	Dissolved TAL Inorganic Elements	6 months	HNO_3, pH<2, 0–4°C	500-mL plastic bottle
	Total Low-Level Hg	90 days	HNO_3, pH<2, 0–4°C (BrCl in lab within 28 days of collection for low-level Hg)	500-mL (for MS/MSD sample) or 250-mL plastic bottle; pre-tested fluoropolymer or glass bottle w/fluoropolymer-lined lids
	Dissolved Low-Level Hg	90 days	HNO_3, pH<2, 0–4°C (BrCl in lab within 28 days of collection for low-level Hg)	500-mL (for MS/MSD sample) or 250-mL plastic bottle; pre-tested fluoropolymer or glass bottle w/fluoropolymer-lined lids
	Total Organic Carbon	28 days	HCl or H_2SO_4 to pH <2, cool to 4°C ± 2°C	1-L HDPE
	SVOCs	7 days for extraction, 40 days after extraction for analysis	None, 0–4°C	1-L amber bottle
	DRO	7 days for extraction, 40 days after extraction for analysis	None, 0–4°C	1-L amber bottle
	GRO and BTEX	14 days preserved, 7 days unpreserved.	HCl to pH <2, cool to 4°C	Four 40-mL amber glass vials, no headspace
	Total suspended solids	7 days	Cool to 6°C	1-L HDPE
	Total dissolved solids	7 days	Cool to 6°C	1-L HDPE

Table 6-1 Sample Containers and Preservation

Matrix	Analysis	Maximum Holding Time	Preservation	Sample Containers
	Inorganic Ions (chloride, fluoride, sulfate)	28 days	Cool to 4°C	HDPE
	Carbonate/Bicarbonate	14 days	Cool to 6°C	500 mL HDPE
	Nitrate/Nitrite as N	28 days	2 mL H_2SO_4 per liter. Cool to 6°C	500 mL or 1-L HDPE

Key:

°C = degrees Celsius
ASTM = American Society for Testing and Materials
BTEX = benzene, toluene, ethylbenzene, xylenes
BrCl = bromine monochloride
DRO = diesel range organics
GRO = gasoline range organics
HCl = hydrochloric acid
Hg = mercury
HDPE = high density polyethylene
HNO_3 = nitric acid
H_2SO_4 = sulfuric acid
L = liter
mL = milliliter
MS/MSD = matrix spike/matrix spike duplicate
oz = ounce
SSE = selective sequential extraction
SVOC = semivolatile organic compound
TAL = target analyte list

6.3.1 Sample Packaging

Samples will be packaged carefully to avoid breakage or contamination and will be shipped to the laboratory at proper temperatures. The following sample package requirements will be followed:

- Sample bottle lids must never be mixed. All sample lids must stay with the original containers.
- The sample volume level may be marked by placing the edge of the label at the appropriate sample height or by using a grease pencil. This will help the laboratory determine whether any leakage occurred during shipment. The label should not cover any bottle preparation QA/QC lot numbers.
- All sample bottles will be placed in a plastic bag to minimize leakage in case a bottle breaks during shipment.
- The samples will be cooled by placing on ice in sealed plastic bags. Ice is not to be used as a substitute for packing materials.
- Any remaining space in the sample shipping container should be filled with inert packing material. Under no circumstances should material such as sawdust, newspaper, or sand be used.
- The custody record must be sealed in a plastic bag and placed in the shipping container. Custody seals must be affixed to the sample cooler.

6.3.2 Shipping Containers

The appropriate shipping container will be determined by U.S. Department of Transportation (DOT) or International Air Transportation Association (IATA) regulations for the anticipated level of suspected contaminants. For the RDM 2015 field events, it is anticipated that all sample shipping containers will be commercially available coolers.

Shipping containers will be custody-sealed for shipment, as appropriate. The custody seals will be affixed so that access to the container can be gained only by breaking a seal.

Field personnel will arrange transportation of samples to the laboratory. When custody is relinquished to a shipper, field personnel will inform the laboratory sample custodian by telephone of the expected arrival time of the sample shipment and advise him or her of any time constraints on sample analysis.

Suggested guidelines for marking and labeling shipping containers are presented below. In all cases, DOT or IATA regulations will be consulted for appropriate marking and labeling requirements, which include the following:

- Use abbreviations only where specified.

- The words “This End Up” or “This Side Up” must be printed clearly on the top of the outer package. Upward-pointing arrows should be placed on the sides of the package.
- After a shipping container is sealed, two COC seals must be placed on the container, one on the front and one on the back. To protect the seals from accidental damage, clear strapping tape must be placed over them.

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7

Decontamination and Management of Investigation-Derived Waste

7.1 Equipment Decontamination Procedures

Samples will be collected using either dedicated, disposable sampling equipment or non-dedicated equipment as indicated in Chapter 4. Procedures for decontaminating non-dedicated equipment are described below. Detailed information on decontamination procedures is provided in E & E's SOP, Sampling Equipment Decontamination.

Soil Boring Installation, Soil Sampling, and Monitoring Well Installation
Borehole drilling equipment (e.g., auger flights, drill rods, cutting shoe, sampler rods) and other non-dedicated drilling equipment will be decontaminated between sampling locations. Soil sampling equipment that contacts soil materials (e.g., split spoon soil sampler) will be decontaminated between each sample. Drilling equipment will be decontaminated using a high-pressure water washer before the start of work and between each borehole to minimize the potential for cross-contamination between sampling locations. Non-dedicated soil sampling equipment will be decontaminated using the following process:

- Phosphate-free detergent (e.g., Alconox®) and water wash
- Potable water rinse
- 10% nitric acid/water solution rinse
- Distilled water final rinse
- Air dry

Monitoring Well Development and Groundwater Sampling
Non-dedicated well development and sampling equipment (e.g., surge block, submersible pump, water level indicator) will decontaminated between sampling locations using the following steps:

- Physical removal – Remove solid material using a dry brush or paper towels.

- Wash – Scrub with a solution of non-phosphate detergent (e.g., Alconox®) and tap water. A 5-gallon bucket lined with a clean garbage bag or a 3-foot long by 4-inch diameter polyvinylchloride (PVC) pipe will be filled with non-phosphate detergent and tap water. Materials and equipment will be scrubbed with a brush in the solution. The detergent solution will be flushed through the submersible pump.
- Deionized water rinse – A 3-foot long by 4-inch diameter PVC pipe will be filled with deionized water. Equipment will be rinsed by flushing with deionized water.
- Dry: Air dry materials and equipment prior to use.
- Decontamination solutions will be changed out between each sampling location to prevent cross contamination.

Surface Water Sampling
Dedicated, disposable sampling equipment will be used to collect all surface water samples.

Kuskowim River Sediment Sampling
Following the collection of each sediment sample, the sampling device will be thoroughly rinsed with river water. Following this rinse, the device will be cleaned with non-phosphate detergent (e.g., Alconox®) and rinsed with deionized water.

7.2 Vehicle Decontamination Procedures

Vehicles will be used to facilitate completion of the field activities. During the 2015 field events, vehicle use at the site will include all-terrain vehicles (ATVs) used to transport staff and equipment between Red Devil and the site and drill rigs and associated support vehicles. It is not expected that the planned use of the vehicles will result in significant contamination of the ATVs. In the event that the ATVs are subjected to significant contamination, they will be decontaminated by scrubbing with a brush and will be rinsing with potable water.

Equipment will be decontaminated within the site Main Processing Area, away from Red Devil Creek. Gross contamination (e.g., soil, mud) will be removed by washing with potable water and phosphate-free detergent. Any equipment with loose paint chips or that is badly rusted will be scrubbed with a wire brush prior to steam cleaning. Once all visible contaminants are removed, the equipment will be rinsed with potable water.

7.3 Investigation-Derived Waste Management

Investigation-derived waste (IDW) that is expected to be generated during the 2015 sampling events includes the following:

- Used dedicated, disposable sampling equipment;

- Used personal protective equipment (PPE), including gloves and booties;
- Used paper towels;
- Equipment decontamination fluids;
- Soil cuttings from drilling operations;
- Monitoring well development water;
- Monitoring well purge water; and
- Waste sediment (Kuskokwim River).

In general, IDW will be managed in accordance with criteria established in the document, *Management of Investigation-Derived Wastes During Site Inspections* (EPA/540/G-91/009), and guidelines outlined in EPA guidance, *Guide to Management of Investigation-Derived Wastes* (OSWER Publication 9345.3-03FS). IDW will he managed as further described below.

Used dedicated sampling equipment, PPE, and paper towels will be grossly decontaminated if there is visible evidence of contamination (soil), placed in sturdy plastic bags, and shipped offsite at the conclusion of the field activities and disposed of at a sanitary landfill in Anchorage.

Soil Boring Installation, Soil Sampling, and Monitoring Well Installation
The decontamination fluids generated from non-dedicated sampling equipment and the drill rig and related equipment will be allowed to run onto the ground within the boundaries of the site. Disposal of the decontamination fluid will be conducted in such a way that the water fully infiltrates into the ground without ponding and does not enter surface water. Disposal will also be conducted in such a way that it does not transport sediment to surface water.

Soil cuttings from drilling operations will be handled as follows:

- For any soil borings installed in the vicinity of the former ore processing facilities—Pre-1955 Retort, Pre-1955 Furnace, and Post-1955 Retort (Monofill #2)—and the settling ponds, drill cuttings will be temporarily stockpiled between the two “Stockpile Areas” shown in Work Plan Figure 2-5.
- For those soil borings installed at other locations where tailings/waste rock are expected, soil cuttings will be collected by the subcontractor and temporarily stockpiled between the two “Stockpile Areas” shown in Work Plan Figure 2-5.
- For any soil borings in which visible elemental mercury is encountered, drill cuttings will be collected by the subcontractor in 55-gallon drums, sampled for toxicity characteristic leaching procedure (TCLP) TAL metals, and stored on-site pending laboratory analysis.

- For those soil borings installed outside of the Main Processing Area and other locations where tailings/waste rock is not expected, and in which monitoring wells are not installed, drilling cuttings will be returned to the borehole. This is expected to include soil borings in the Surface Mined Area. The soil cuttings will be emplaced starting from the bottom of the hole. If monitoring wells are installed, the soil cuttings will be spread on the ground in the area of the well.

Dedicated, disposable sampling equipment used to collect soil samples will include dedicated, disposable scoops, spoons, and re-sealable plastic bags. These items and used PPE will be managed as described above.

Monitoring Well Development and Groundwater Sampling
Well development and purge water generated at the planned new wells and existing wells targeted for sampling in 2015 will be disposed of onto the ground at the time of sampling. Disposal of this purge water will be conducted in the area of the well following completion of sampling by pouring slowly onto the ground surface in such a way that the water fully infiltrates into the ground without ponding and does not enter surface water. Disposal will also be conducted in such a way that it does not transport sediment to surface water. Based on existing RI and baseline groundwater monitoring data, the potential for comparatively high concentrations of arsenic (greater than the RCRA TCLP limit of 5 milligrams per liter) in these wells is low.

Dedicated, disposable sampling equipment used to collect groundwater samples will include dedicated, disposable sample tubing. These materials and used PPE will be managed as described above.

Surface Water Sampling
Dedicated, disposable sampling equipment used to collect surface water samples will include dedicated, disposable sample tubing. These materials and used PPE will be managed as described above.

Kuskowim River Sediment Sampling
Investigation derived waste that will be generated from the Kuskokwim River off-shore sediment sampling effort will include the following.

- Waste sediment;
- Aqueous decontamination fluids;
- Used dedicated, disposable sampling bowls and scoops/spoons; and
- Used disposable PPE (e.g. gloves).

Waste sediment will be returned to the river by scooping unwanted sediment material from the sampling device into the river at the sample site. Aqueous decontamination fluids (phosphate-free detergent solution) will be containerized and shipped off-site for disposal at a properly licensed facility in Anchorage. Used disposable sampling equipment and PPE and will be managed as described above.

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8

Surveying and Station Positioning

Horizontal coordinates of new soil boring and monitoring well locations will be surveyed using a resource grade GPS device. Coordinates of planned sample locations will be determined prior to mobilization and uploaded into the GPS units to serve as waypoints to facilitate the navigation to planned sample locations in the field. Coordinates will be recorded using a Trimble GeoXT or GeoXH series or equivalent handheld GPS device. Anticipated horizontal accuracy will be contingent on conditions encountered in the field. GPS data will be differentially corrected as necessary to maximize accuracy.

A subcontracted, Alaska-registered land surveyor will survey the vertical and horizontal coordinates of newly installed monitoring wells and new surface water monitoring locations. Elevations will be surveyed to within the nearest 0.1 foot.

A GPS will be used for station positioning for all Kuskokwim River sediment sampling stations. The sampling vessel will have navigation equipment that provides station positioning and water depths measurement and recording. The GPS receiver will be capable of surveying positions accurate to within 3-5 meters. Before sediment sampling is initiated, a control check point will be established that can be accessed by the sampling vessel. At the beginning and end of each day of sampling, the check point will be surveyed from the vessel and compared to the known coordinates. The control check point position as recorded by the vessel should not differ by more than 2 meters from the land-surveyed coordinates. During sampling, the GPS receiver will be placed above the sampling device to record the actual positions of the samples collected. Water depths will be measured at sampling locations directly by lead line. Coordinates of the proposed sediment sampling stations will be uploaded as waypoints into the vessel’s GPS and used to guide the vessel to the appropriate locations.

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9

Deviations from the Field Sampling Plan

Deviations from the FSP are inevitable. Deviations may arise from changed field conditions, adjustment of sampling methods, inability to obtain samples from a planned location, and other circumstances. All deviations to the FSP will be carefully documented by the field team leader using the form presented in Figure 9-1. The nature and reason for FSP deviations will be documented in the RI report.

Red Devil Mine 2015 Sampling Event
FSP Deviation Documentation

Date:	**Name:**
Description of Problem:	
Location of Problem:	
Description of Deviation to Address Problem:	
Other Means Considered but Rejected to Address Problem:	

Figure 9-1 FSP Deviation Documentation Form

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10 References

EPA (U.S. Environmental Protection Agency). 2002. Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001, May 2002.

Puls, Robert W. and Barcelona, Michael J. 1996. Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. EPA/540/S-95/504.

Rantz, S.E. et al. 1982. Measurement and Computation of Streamflow Volume 1. Measurement of Stage and Discharge. USGS Water Supply Paper 2175.

USGS (U.S. Geological Survey). 2011. Techniques of Water-Resources Investigations Reports. http://pubs.usgs.gov/twri. Accessed January 31, 2011.

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Figures

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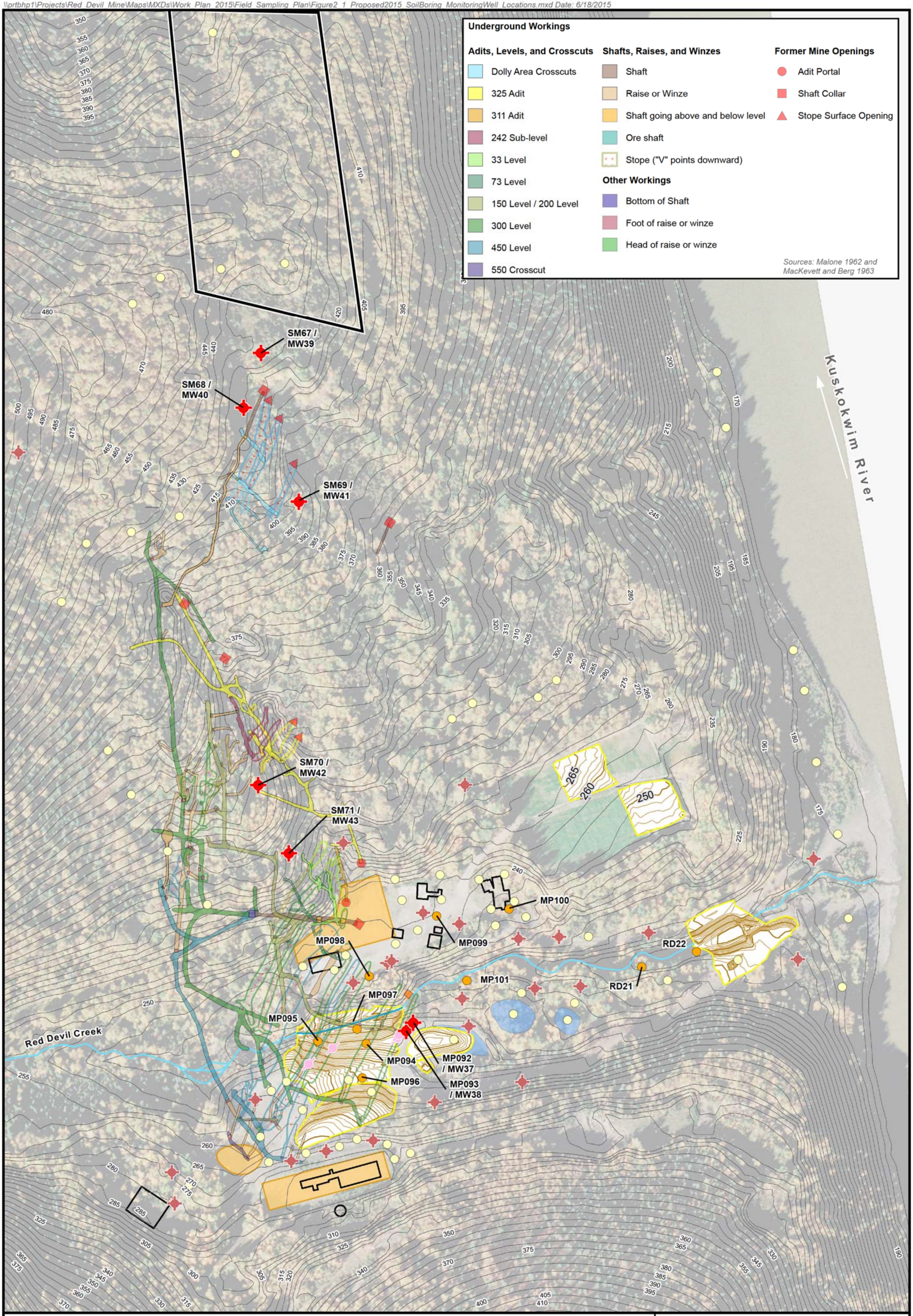

- 🟠 Proposed 2015 Soil Boring
- ✚ Proposed 2015 Soil Boring / Monitoring Well
- ✚ Existing RI Monitoring Well Location
- Decommissioned Well
- ○ Existing RI Soil Boring Location
- Seep Location
- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- 🟦 Settling Pond
- 🟧 Monofill
- ☐ Historical Structure
- ☐ Approximate Location of Repository Footprint

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-1
Proposed 2015 Soil Boring and Monitoring Well Locations

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

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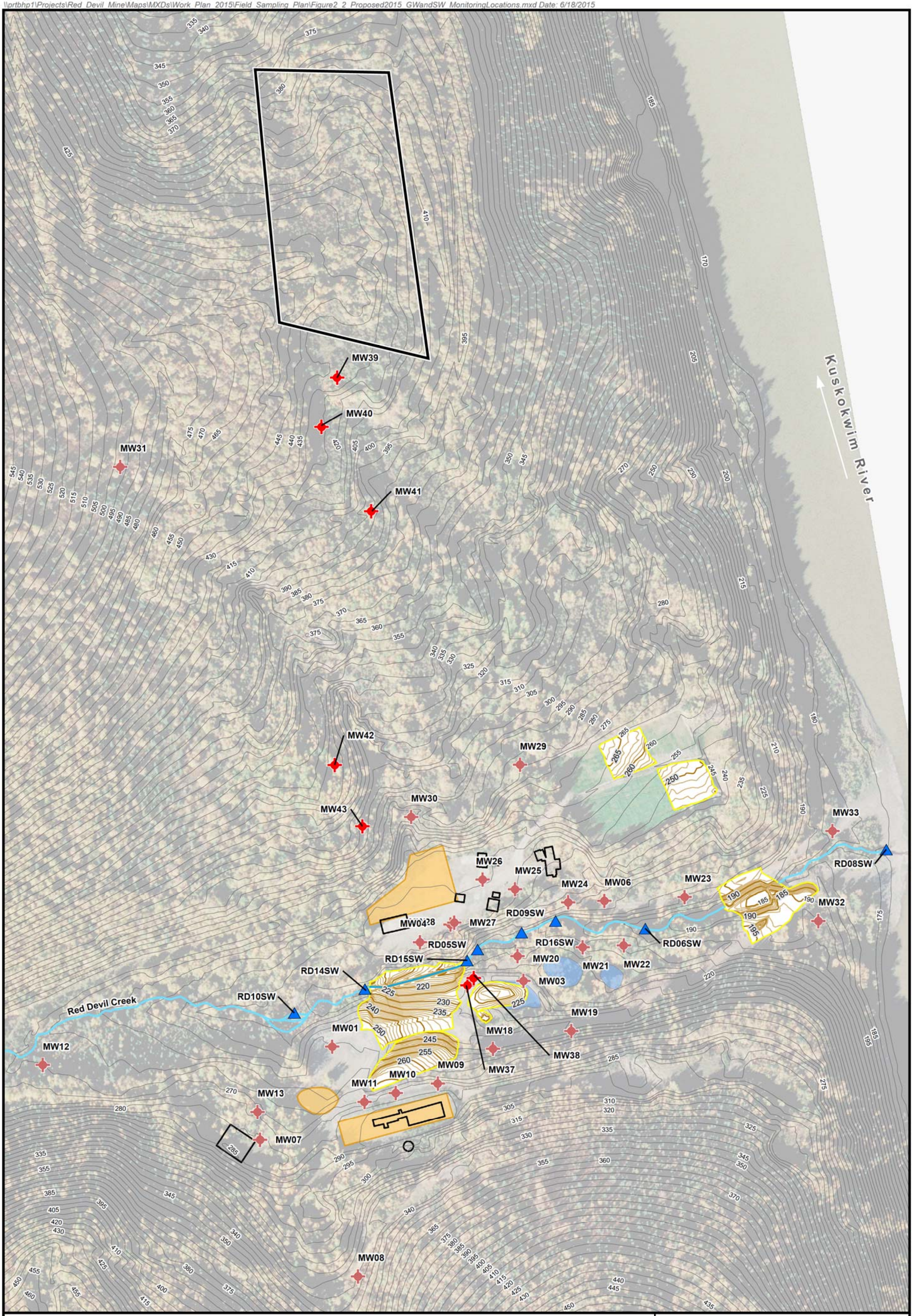

Proposed 2015 Monitoring Locations

- ✚ Proposed New Monitoring Well
- ✚ Existing RI Monitoring Well
- ▲ Surface Water
- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream
- Red Devil Creek
- 🟦 Settling Pond
- 🟧 Monofill
- ☐ Historical Structure
- ☐ Approximate Location of Repository Footprint

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-2
Proposed 2015 Groundwater and Surface Water Monitoring Locations

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

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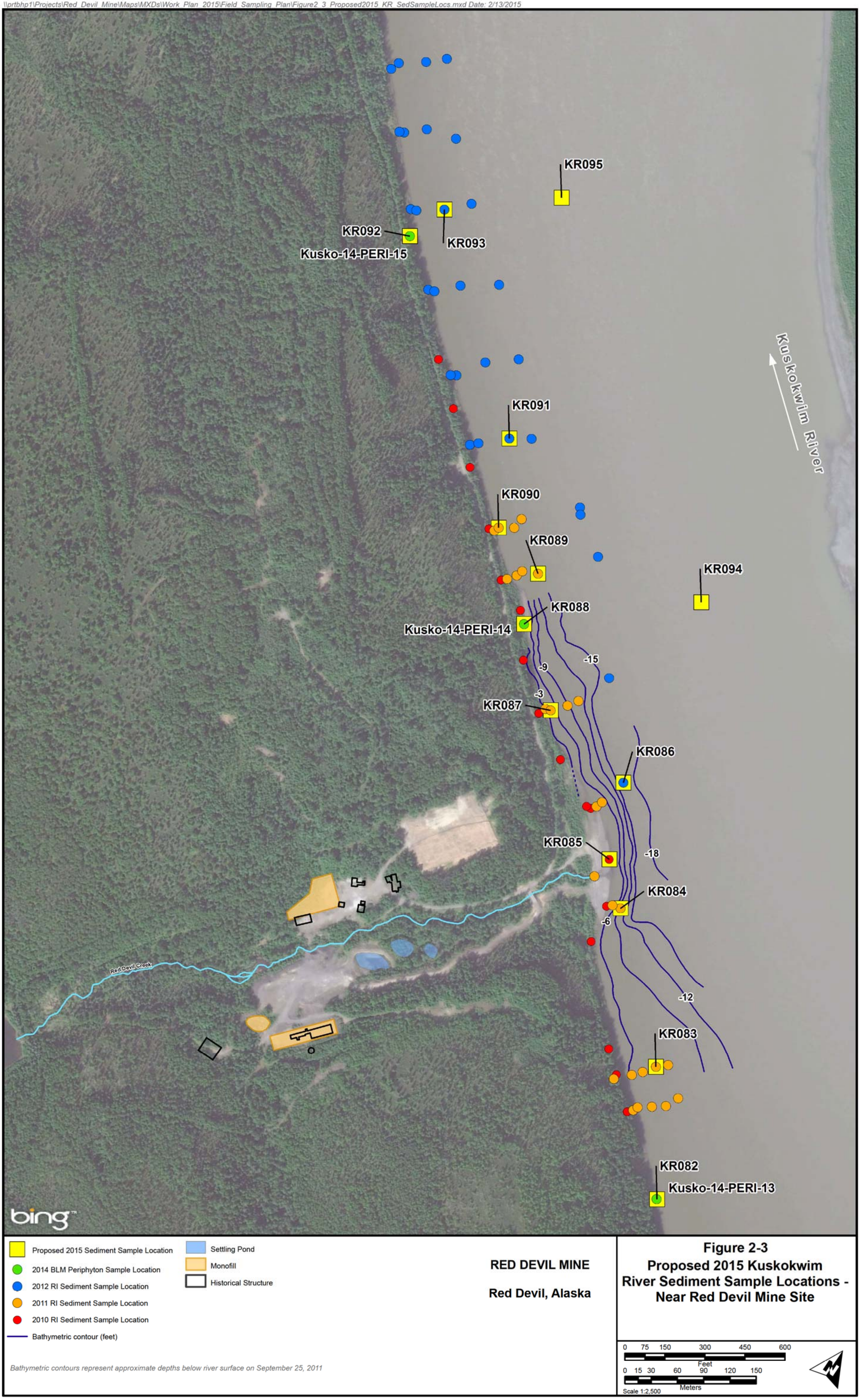

Bathymetric contours represent approximate depths below river surface on September 25, 2011

RED DEVIL MINE

Red Devil, Alaska

Figure 2-3
Proposed 2015 Kuskokwim River Sediment Sample Locations - Near Red Devil Mine Site

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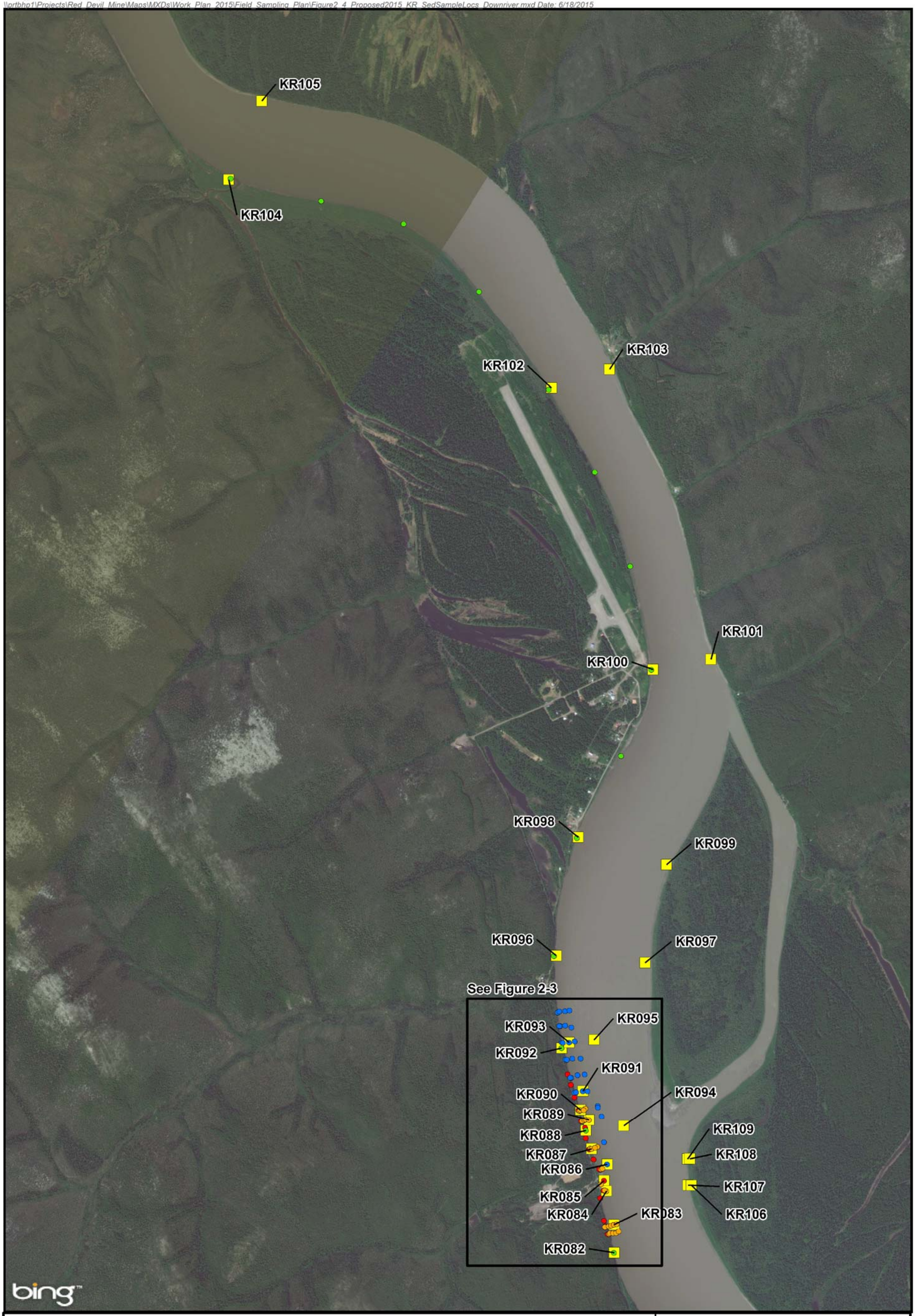
Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\Work_Plan_2015\Field_Sampling_Plan\Figure2_4_Proposed2015_KR_SedSampleLocs_Downriver.mxd Date: 6/18/2015



- 🟨 Proposed 2015 Sediment Sample Locations
- ● 2014 BLM Periphyton Sample Locations
- ● 2012 RI Sediment Sample Locaiton
- ● 2011 RI Sediment Sample Location
- ● 2010 RI Sediment Sample Location

RED DEVIL MINE

Red Devil, Alaska

Figure 2-4
Proposed 2015 Kuskokwim River Sediment Sample Locations - Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500

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B

Quality Assurance Project Plan Addendum

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Quality Assurance Project Plan Addendum for
2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization
Supplement to Remedial Investigation
Red Devil Mine, Alaska

Prepared by Ecology and Environment, Inc., Seattle, WA

Prepared for United States Department of the Interior, Bureau of Land Management (BLM), Anchorage Field Office, Anchorage, AK

June 2015

This Quality Assurance Project Plan (QAPP) addendum was prepared to supplement the Final Quality Assurance Project Plan, Remedial Investigation/Feasibility Study (RI/FS), Red Devil Mine, Alaska (E & E 2011) to address additional site characterization planned for 2015. The QAPP addendum provides updated information needed for the planned 2015 site characterization and is intended to be used in conjunction with the Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska and the Field Sampling Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska.

Specifically, this addendum augments the following elements of the final QAPP:
- Project Organization (QAPP Figure 1-1);
- Contact Information (QAPP Table 1-1);
- Laboratory Reports (QAPP Section 1.6.2);
- Analytes, Analytical Methods, and Related Details (QAPP Table 1-2);
- Sample Handling (QAPP Section 2.3); and
- Laboratory Quality Control (QAPP Section 2.5.2).

These elements are discussed below.

Project Organization (QAPP Figure 1-1)

Figure 1-1 in the final QAPP identifies the key project staff and their roles, as wells as subcontractors retained by E & E to support RI/FS activities at the RDM site. Identities and roles of key E&E project staff and subcontract laboratories are provided in the revised project organization figure (Figure 1).

Contact Information (QAPP Table 1-1)

Table 1-1 in the final QAPP provides contact information for key organizations supporting the RI/FS at the RDM site. The following table augments QAPP Table 1-1 to include subcontract laboratories for the RI supplement.

Table 1-1 Contact Information (supplemental)

Organization	Contact	Title	Telephone	Address
TestAmerica	Kathy Kreps	Client Relations Manager	253-248-4964	5755 8th Street East Tacoma, WA 98424
Brooks Rand Labs	Tiffany Stilwater	Project Manager	206-753-6129	3958 6th Ave NW, Seattle WA 98107
Northwestern Aquatic Sciences	Gerald Irissarri	Director	541-265-7225 tel. 541-265-2799 fax girissarri@nwaquatic.com	3814 Yaquina Bay Rd. P.O. Box 1437, Newport, OR 97365

Laboratory Reports (QAPP Section 1.6.2)

This subsection of the final QAPP was specific to chemical analytical laboratories. The following text augments Section 1.6.2 to cover the sediment toxicity testing report that will be prepared by NAS.

- The bioassay laboratory will submit its standard sediment toxicity testing report to the E & E PM. This deliverables will include the following:
- Case narrative, including any problems encountered, protocol modifications, and corrective actions taken;
- Site and reference sample results for growth, survival, and reproduction;
- Laboratory control results for growth, survival, and reproduction compared with QA/QC limits for these parameters provided in USEPA (2000) for Method 100.4 (28-day *Hyalella azteca* survival and growth);
- Statistical comparison of site sample results with reference and control sample results as per methods described in USEPA (2000);
- All testing protocols used; and
- Sample custody records (including original chain-of-custody forms).

Analytes, Analytical Methods, and Related Details (QAPP Table 1-2)

Table 1-2 in the final QAPP lists analytes, analytical methods, detection limits, and risk-based screening levels for chemical analysis of environmental samples from the RDM site. The following table augments Table 1-2 to cover the sediment bioassays that will be conducted by NAS.

Table 1-2 Analytes, Analytical Methods, Method Detection Limits, Screening Limits, and Risk Assessment Criteria (supplemental)

Analysis Type	Analysis Description	Method	Analyte	Units	Method Detection Limit	Method Reporting Limit
Sediment Toxicity	Toxicity, *Hyalella azteca* (28-day)	EPA 100.4	Survival	%	--	--
			Growth	mg	--	--

Key: -- (dash) = not applicable to bioassay samples

Risk-based screening levels are not applicable to bioassay results and thus are not listed. Survival, growth, and reproduction in site samples are evaluated relative to survival, growth, and reproduction in reference and control samples, not against predetermined values.

Section 2.3 — Sample Handling

Collection, storage, manipulation, and characterization of Kuskokwim River sediment for toxicity testing will be consistent with USEPA (2000) and ASTM (1993), as noted in the Field Sampling Plan addendum for the 2015 RDM site work.

Section 2.5.2 — Laboratory Quality Control

The 28-day *Hyalella azteca* test is conducted with a minimum of four replicates per sediment sample tested. Each replicate is a 300-milliliter (mL) glass beaker with 100 mL of wet sediment and 175 mL of overlying water (culture water typically is used). One day after adding sediment and water to the replicate beakers, ten 7- to 8-day-old amphipods are added to each beaker. The test is conducted at 23 ± 1°C under wide spectrum fluorescent lights with 16 hours of light and 8 hours of darkness per day. The overlying water in each test chamber is renewed every 12 hours. Amphipods are fed daily with a mixture of Yeast, Cerophyll®, and Tetramin (YCT). Hardness, alkalinity, ammonia, and conductivity are measured in the overlying water at the beginning and end of the test (Day 0 and 28). In addition, temperature is measured daily, conductivity is measured weekly, and dissolved oxygen and pH are measured three times per week. Aeration is not used unless dissolved oxygen drops below 2.5 milligrams per liter in overlying water. On Day 28, each replicate beaker is sieved to remove surviving amphipods for growth determinations. Immobile organisms isolated from sieved material are considered dead. Growth or amphipods can be reported as either length or weight; however, additional statistical options are available if length is measured on individual organisms. Additional details regarding testing conditions and procedures are provided in EPA (2000, Table 14.1). A laboratory control sediment sample is tested with site sediment samples. In order for test results to be considered acceptable, average survival of Hyalella in control sediment on Day 28 should be greater than or equal to 80%. Additional test acceptability requirements for the Hyalella test are described in EPA (2000, Table 14.3). EPA (2000, Section 16) describes statistical procedures for comparing survival and growth in site samples with survival and growth in the control sample and/or site-specific background sample.

References

American Society of Testing and Materials (ASTM), 1993. *Guide for Collection, Storage, Manipulation, and Characterization of Sediments for Toxicological Testing,* ASTM Standard E1391-90, *In*: ASTM Standards on Aquatic Toxicology and Hazard Evaluation, ASTM, Philadelphia, PA.

Ecology and Environment, Inc. (E & E). 2011. *Final Quality Assurance Project Plan, Remedial Investigation/Feasibility Study (RI/FS), Red Devil Mine, Alaska.* Prepared for United States Department of the Interior, Bureau of Land Management, Anchorage Field Office, Anchorage, Alaska by E & E, Seattle, Washington.

EPA (United States Environmental Protection Agency). 2000. *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, Second Edition*. Office of Research and Development, Mid-Continental Ecology Division, Duluth, MN and Office of Water, Washington, DC. EPA 600/R-99/064.

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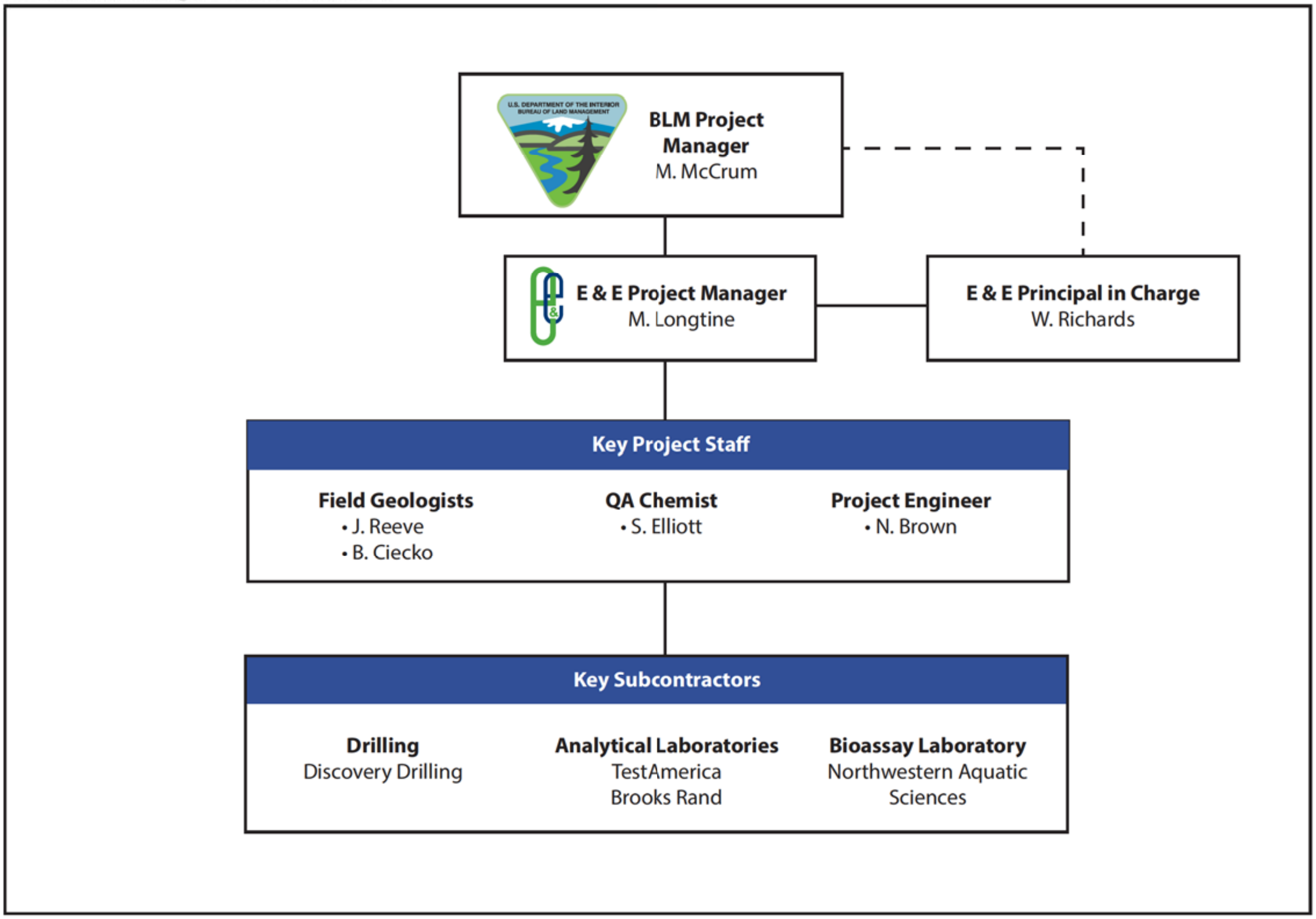

SOURCE: Ecology and Environment, Inc. 2015

Figure 1 **Project Organization**

C

Health and Safety Plan

This appendix is not fully accessible. Portions of this appendix were provided by a third party, as a scanned document. If you need assistance with this appendix, please contact the BLM Alaska Public Information Center 907-271-5960, BLM_AK_AKSO_Public_Room@blm.gov.

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Revision 9
May 2015

ECOLOGY AND ENVIRONMENT, INC.

SITE-SPECIFIC
HEALTH AND SAFETY PLAN

Project: Red Devil Mine Supplemental Remedial Investigation

Project No.: 1001095.0002

Project Location: Red Devil, Alaska

Proposed Date of Field Activities: June – September 2015

Program Manager: Bill Richards

Project Manager: Mark Longtine

Prepared by: Manique Talaia-Murray Date Revised: June 2, 2015

Approved by: Eric Lindeman, RSC Date Approved: June 8, 2015

ACRONYMS/ABBREVIATIONS

ALARA	as low as reasonably achievable
ANSI	American National Safety Institute
ATV	all-terrain vehicle
BLM	Department of the Interior Bureau of Land Management
CHSP	*Corporate Health and Safety Program*
E & E	Ecology & Environment Inc.
LOP	levels of protection
PPE	personal protective equipment
RDM	Red Devil Mine
SHASP	Site-Specific Health and Safety Plan
SOP	Standard operating procedure
SSO	Site Safety Officer
TLD	Thermoluminescent Dosimeter
XRF	x-ray fluorescence

TABLE OF CONTENTS

Section **Page**

Attachments

LIST OF TABLES

Table **Page**

1. INTRODUCTION

1.1 POLICY

It is Ecology and Environment, Inc.'s (E & E) policy to ensure the health and safety of its employees, the public, and the environment during the performance of work it conducts. This site-specific health and safety plan (SHASP) establishes the procedures and requirements to ensure the health and safety of E & E employees for the above-named project. E & E's overall safety and health program is described in *Corporate Health and Safety Program* (CHSP). After reading this plan, applicable E & E employees shall read and sign E & E's SHASP Acceptance form, included as Attachment A. Any changes to this document will be noted on a SHASP Addendum Form, included as Attachment B.

This SHASP has been developed for the sole use of E & E employees and is not intended for use by firms not participating in E & E's training and health and safety programs. Subcontractors are responsible for developing and providing their own safety plans.

This SHASP has been prepared to meet the following applicable regulatory requirements and guidance:

Applicable Regulation/Guidance
29 CFR 1910.120, Hazardous Waste Operations and Emergency Response 29 CFR 1910 General Industry Standards,   29 CFR 1910.151 First Aid
Other: Alaska Physical Agent Data Sheets (PADS) hppt://labor.alaska.gov/lss/pads/pads.htm

1.2 SCOPE OF WORK

Description of Work, Tasks 1, 2, and 7: E&E personnel will collect subsurface soil samples and install groundwater monitoring wells using a track-mounted hollow stem auger and air-rotary drill rig. Additional drilling using a split-spoon sampler will be performed to collect subsurface soil samples. The drilling equipment will be operated by the drilling subcontractor, Discovery Drilling. E&E personnel will be responsible for decontaminating re-usable sampling equipment; the Subcontractor will be responsible for decontaminating drilling and development equipment between sample locations. Where possible, sampling tools will be dedicated to a single sample location and disposed of along with personal protective equipment (PPE); this waste stream will be temporarily collected on-site and then transported off-site for disposal in a regulated municipal landfill.

Description of Work, Task 3: E&E will collect groundwater samples from new and existing monitoring wells on-site with the use of a peristaltic pump, a submersible pump, or a bladder pump. E&E personnel will also collect surface water samples from Red Devil Creek using a peristaltic pump, and measure the flow rate of Red Devil Creek at the surface water sampling locations using a flowmeter. Red Devil Creek is a shallow creek that can be waded with rubber boots.

Description of Work, Task 4: E&E will collect sediment samples from the Kuskokwim River. A small craft operated by a licensed subcontractor will be used to collect sediment samples. The subcontractor, KLI, will collect the sediment samples using a lengthened hand auger or a Van Veen sampler. A combination of anchoring and live boating will be utilized to collect the sample. Once collected by the subcontractor, the sediment will be processed and subsampled by on-board E&E personnel.

Equipment/Supplies: <u>Attachment C contains a checklist of equipment and supplies that will be needed for this work.</u>

The following is a description of each numbered task.

Task Number	Task Description
1	Install groundwater monitoring wells
2	Collect subsurface soil samples from soil borings
3	Collect subsurface and surface water samples from existing monitoring wells and Red Devil Creek
4	Collect sediment samples from Kuskokwim River
7	Investigate the presence of hydrocarbons by collecting subsurface soil samples

1.3 SITE DESCRIPTION

Site Map: See Baseline Monitoring Work Plan Figures 1-1 and 1-2.

Site History/Description (see project work plan for detailed description: The Red Devil Mine (RDM) is a former mercury mine and retort facility that was in operation from the late 1940's through the early 1970's. The Department of the Interior Bureau of Land Management (BLM) began investigation and cleanup efforts at RDM in the late 1980's to the present.

Is the site currently in operation? ☐ Yes ☒ No

Locations of Contaminants/Wastes: Please refer to the Remedial Investigation /Feasibility Study Work Plan Figure 1-3 for specific locations of known and suspected areas of contamination.

Types and Characteristics of Contaminants/Wastes:

☒ Liquid
☒ Flammable/Ignitable
☐ Explosive
☐ Medical/Pathogenic

☒ Solid
☐ Volatile
☐ Reactive

☐ Sludge
☐ Corrosive
☒ Carcinogenic

☒ Gas/Vapor
☐ Acutely Toxic
☐ Radioactive

Other: fine grain size allows for easy wind transportation and inhalation hazard

2. ORGANIZATION AND RESPONSIBILITIES

E & E team personnel shall have on-site responsibilities as described in E & E's standard operating procedure (SOP) for Site Entry Procedures (GENTECH 2.2). The project team, including qualified alternates, is identified below.

Name	Site Role/Responsibility
Jonathan Reeve	Field Team Leader
Bryan Ciecko	Field Team Member
Andy Uhrig	Field Team Member
Manique Talaia-Murray	Field Team Member, Site Safety Officer

3. TRAINING

Prior to work, E & E team personnel shall have received training as indicated below. As applicable, personnel shall have read the Baseline Monitoring Work Plan, Field Sampling Plan, and/or Quality Assurance Project Plan prior to project work.

Training	Required
40-Hour OSHA HAZWOPER Initial Training and Annual Refresher (29 CFR 1910.120)	X
Annual First Aid/CPR	X
Hazard Communication (29 CFR 1910.1200)	X

Training	Required
Fit Test (Task 7 only)	X
Other: XRF 2015 Safety Training	X
CFR – Code of Federal Regulations HAZWOPER - Hazardous Waste Operations and Emergency Response OSHA - Occupational Safety and Health Administration	

4. MEDICAL SURVEILLANCE

4.1 MEDICAL SURVEILLANCE PROGRAM

E & E field personnel shall actively participate in E & E's medical surveillance program as described in the CHSP and shall have received, within the past year, an appropriate physical examination and health rating.

E & E's health and safety record form will be maintained on site by each E & E employee for the duration of his or her work. E & E employees should inform the site safety officer (SSO) of any allergies, medical conditions, or similar situations that are relevant to the safe conduct of the work to which this SHASP applies.

Is there a concern regarding radiation at the site? ☐ Yes ☒ No
If No, go to Section 5.1.

4.2 RADIATION EXPOSURE

4.2.1 External Dosimetry

Thermoluminescent Dosimeter (TLD) Badges: TLD badges are to be worn by all E & E field personnel on certain required sites.

Pocket Dosimeters: ____________________

Other: Innov-X x-ray fluorescence (XRF) instrument is a potential source of exposure when the x-ray is energized and the shutter is open. E & E field personnel should stand as far away as possible from the instrument when measuring samples. This includes propping the XRF with a foot or leg. Field personnel should never expose head, abdomen, eyes, or any sensitive areas to potential exposure from the XRF. See Attachment G for the Innov-X XRF Field Screening Protocol.

4.2.2 Internal Dosimetry

☐ Whole body count ☐ Bioassay ☐ Other

Requirements: ____________________

____

4.2.3 Radiation Dose

Dose Limits: E & E's radiation dose limits are stated in the CHSP. Implementation of these dose limits may be designated on a site-specific basis.

Site-Specific Dose Limits: ____________________

ALARA Policy: Radiation doses to E & E personnel shall be maintained at levels as low as reasonably achievable (ALARA), taking into account the work objective, state of technology available, economics of improvements in dose reduction with respect to overall health and safety, and other societal and socioeconomic considerations.

5. SITE CONTROL

5.1 SITE LAYOUT AND WORK ZONES

Site Work Zones: The site work zone will include all areas delineated in Work Plan Figure 1-2 for upland work. Sediment collection (Task 4) will occur on the Kuskokwim River and will occur between approximately ¼ of a mile upstream of the Red Devil Creek delta and 5 river miles downstream of the village of Red Devil. All sampling and drilling equipment leaving the Red Devil site as delineated in Work Plan Figure 1-3 shall be decontaminated. ATVs and work boots leaving the site on a frequent basis shall have gross contamination removed upon exiting the site.

Site Access Requirements and Special Considerations: There are no roads into the RDM site. Site access will require the use of all-terrain vehicles (ATV). See Attachment D for ATV Use Requirements and SOP.

Illumination Requirements: Work will be performed outdoors during daylight hours.

Sanitary Facilities (e.g., toilet, shower, potable water): To be determined on-site.

On-Site Communications: No cell phone service is available at this remote site. Two way radios will be used where transmission is unobstructed. A satellite phone will be available for use.

Other Site-Control Requirements: None

5.2 SAFE WORK PRACTICES

Daily Safety Meeting: A daily safety meeting will be conducted for all E & E personnel and documented on the Daily Safety Meeting Record Form (Attachment E) and in the field logbook. The information and data obtained from applicable site characterization and analysis will be addressed in the safety meetings and also used to update this SHASP, as necessary.

Work Limitations: Work shall be limited to a maximum of 12 hours per day. If 12 consecutive days are worked, at least one day off shall be provided before work is resumed. Work will be conducted in daylight hours unless prior approval is obtained and the illumination requirements in 29 CFR 1910.120(m) are satisfied.

Weather Limitations: Work shall not be conducted during electrical storms. Work will be suppended for 30 minutes with any visible lighting. Any additional visible lighting will suspend work for an additional 30 minutes. Work conducted in other inclement weather(e.g., rain or snow) will be approved by project management and the regional safety coordinator or designee.

Remote Site Considerations: The Red Devil Mine is located in a remote natural setting that can experience severe weather and sustained wet conditions. Additionally, the site is occasionally frequented by wildlife including black bears and moose, and at some times has noxious insects. Field staff shall prepare for sustained, healthy work in this environment by dressing adequately for the conditions (in warm and waterproof clothing as necessary), wearing bug protection when necessary, and learning how to properly deter wildlife if encountered. Appendix N – Survival Spray, offers further information on how to effectively deter large wildlife using bear spray.

Drilling: Staff shall discuss drill rig safety with the lead driller during the daily safety meeting on any day that drilling will be occurring. Field staff will familiarize themselves with the operation of the drill rig and with the specific mechanical movements and hazards associated with the equipment when it is operating. Field staff will also make an effort to understand work flow patterns around the drill rig, how ancillary activities are associated with the drilling operation, and how to predict and avoid the associated hazards (i.e., positioning and unloading and truck containing drill pipe). Field staff will keep an open safety dialogue with the drill crew and seek clarification about operations if necessary to enhance their own understanding of drilling operations and personal safety. Field staff will make eye contact with the driller and obtain permission to enter within the drill rig work area, including the support truck/vehicle. For additional information about Health and Safety on Drilling Rig Operations, see Attachment H.

Other Work Limitations: Work will not be conducted if wind speeds are sustained above 20 miles per hour.

Buddy System: Field work will be conducted in pairs of team members according to the buddy system.

Line-of-Sight: Each field team member shall remain in the line-of-sight and within verbal communication of at least one other team member.

Eating, Drinking, and Smoking: Eating, drinking, and smoking or other tobacco product use shall be prohibited in the exclusion and contamination reduction areas, at a minimum, and shall only be permitted in designated areas.

Contamination Avoidance: Field personnel shall avoid unnecessary contamination of personnel, equipment, and materials to the extent practicable.

Sample Handling: Protective gloves of a type designated in Section 7 of this form will be worn when containerized samples are handled for labeling, packaging, transportation, and other purposes.

Other Safe Work Practices:

- Transportation to and from the site may involve ATV travel. E & E employees will adhere to the corporate ATV use policy presented in Attachment D.
- No team member will enter any underground mine workings at any time.

6. HAZARD EVALUATION AND CONTROL

6.1 PHYSICAL HAZARD EVALUATION AND CONTROL

Potential physical hazards and their applicable control measures for each task are described in the following table.

Hazard	Task Number	Hazard Control Measures
Biological (flora, fauna, etc.)	1,2,3,4,7	■ Potential hazard: Bear, moose, insect bites ■ Establish site-specific procedures for working around identified hazards. ■ Other: Make noise while in the field. Carry bear spray at all times when away from the Main Processing Area.
Cold Stress	1,2,3,4,7	■ Provide warm break area and adequate breaks. ■ Provide warm, non-caffeinated beverages. ■ Promote cold stress awareness. ■ See *Cold Stress Prevention and Treatment* (Attachment J) if cold stress is a potential hazard.
Compressed Gas Cylinders	3	■ Use caution when moving or storing cylinders. ■ A cylinder is a projectile hazard if it is damaged or its neck is broken. ■ Store cylinders upright, and secure them by chains or other means. ■ Other:
Confined Space	N/A	■ Ensure compliance with 29 CFR 1910.146. ■ See SOP for Confined Space Entry. Additional documentation is required. ■ Other:
Drilling	1,2,7	■ Additional documentation may be required. ■ Landfill caps will not be penetrated without prior discussions with corporate health and safety staff. ■ Other:
Drums and Containers	N/A	■ Ensure compliance with 29 CFR 1910.120(j). ■ Consider unlabeled drums or containers to contain hazardous substances and handle accordingly until the contents are identified. ■ Inspect drums or containers and ensure integrity prior to handling. ■ Move drums or containers only as necessary; use caution and warn nearby personnel of potential hazards. ■ Open, sample, and/or move drums or containers in accordance with established procedures; use approved drum/container-handling equipment. ■ Other:

Hazard	Task Number	Hazard Control Measures
Electrical	1,2,3,4,7	■ Ensure compliance with 29 CFR 1910 Subparts J and S. ■ Locate and mark energized lines. ■ De-energize lines as necessary. ■ Ground all electrical circuits. ■ Guard or isolate temporary wiring to prevent accidental contact. ■ Evaluate potential areas of high moisture or standing water and define special electrical needs. ■ Other:
Excavation and Trenching	N/A	■ Ensure that excavations comply with, and personnel are informed of, the requirements of 29 CFR 1926 Subpart P. ■ Ensure that any required sloping or shoring systems are approved, as per 29 CFR 1926 Subpart P. ■ Identify special PPE (see Section 7) and monitoring (see Section 8) needs if personnel are required to enter approved excavated areas or trenches. ■ Maintain line-of-sight between equipment operators and personnel in excavations/trenches. Such personnel are prohibited from working close to operating machinery. ■ Suspend or shut down operations at signs of cave-in, excessive water, defective shoring, changing weather, or unacceptable monitoring results. ■ Other:
Fire and Explosion	1, 2,3,4,7	■ Inform personnel of the location(s) of potential fire/explosion hazards. ■ Establish site-specific procedures for working around flammables. ■ Ensure that appropriate fire-suppression equipment and systems are available and in good working order. ■ Define requirements for intrinsically safe equipment. ■ Identify special monitoring needs (see Section 8). ■ Remove ignition sources from flammable atmospheres. ■ Coordinate with local fire-fighting groups regarding potential fire/explosion situations. ■ Establish contingency plans and review daily with team members. ■ Other:
Heat Stress	1, 2,3,4,7	■ Provide cool break area and adequate breaks. ■ Provide cool, non-caffeinated beverages. ■ Promote heat stress awareness. ■ Use active cooling devices (e.g., cooling vests) where specified. ■ See *Heat Stress Prevention and Treatment* (attached at the end of this plan if heat stress is a potential hazard).

Hazard	Task Number	Hazard Control Measures
Heavy Equipment Operation	1,2,7	■ Define equipment routes, traffic patterns, and site-specific safety measures. ■ Ensure that operators are properly trained and equipment has been properly inspected and maintained. Verify back-up alarms. ■ Ensure that ground spotters are assigned and informed of proper hand signals and communication protocols. ■ Identify special PPE (Section 7) and monitoring (Section 8) needs. ■ Ensure that field personnel do not work close to operating equipment. ■ Ensure that lifting capacities, load limits, etc., are not exceeded. ■ Other:
Heights (Scaffolding, Ladders, etc.)	NA	■ Ensure compliance with applicable subparts of 29 CFR 1910. ■ Identify special PPE needs (e.g., lanyards, safety nets, etc.) ■ Other:
Noise	1,2,7	■ Establish noise-level standards for on-site equipment/operations. ■ Inform personnel of hearing protection requirements (Section 7). ■ Define site-specific requirements for noise monitoring (Section 8). ■ Other:
Overhead Obstructions	1,2,3,4,7	■ Wear hard hat. ■ Other:
Power Tools	N/A	■ Ensure compliance with 29 CFR 1910 Subpart P. ■ Other:
Sunburn	1,2,3,4,7	■ Apply sunscreen. ■ Wear hats/caps and long sleeves. ■ Other:
Utility Lines	N/A	■ Identify/locate existing utilities prior to work. ■ Ensure that overhead utility lines are at least 25 feet away from project activities. ■ Contact utilities to confirm locations, as necessary. ■ Other:
Weather Extremes	1,2,3,4,7	■ Potential hazards. ■ Establish site-specific contingencies for severe weather situations. ■ Provide for frequent weather broadcasts. ■ Weatherize safety gear, as necessary (e.g., ensure that eye wash units cannot freeze, etc.). ■ Identify special personal protective equipment (Section 7) needs. ■ Discontinue work during severe weather. ■ Other:

6.2 CHEMICAL HAZARD EVALUATION AND CONTROL

6.2.1 Chemical Hazard Evaluation

Potential chemical hazards are described by task number in Table 6-1. Hazard Evaluation Sheets for major known contaminants are provided in Attachment F.

6.2.2 Chemical Hazard Control

An appropriate combination of engineering/administrative controls, work practices, and PPE shall be used to reduce and maintain employee exposures to a level at or below published exposure levels (see Section 6.2.1).

Applicable Engineering/Administrative Control Measures: Spray water on ground to control airborne dust. Limit driving through areas of highest contamination and limit vehicle speeds to decrease generation of dust.

PPE: See Section 7.

6.3 RADIOLOGICAL HAZARD EVALUATION AND CONTROL

6.3.1 Radiological Hazard Evaluation

There are no radiological hazards at RDM. There are non-radiological contaminants at the site. Hazard Evaluation Sheets for major known contaminants are attached at the end of this plan as Attachment F.

6.3.2 Radiological Hazard Control

Engineering/administrative controls and work practices shall be instituted to reduce and maintain employee exposures to a level at or below the permissible exposure/dose limits (see Sections 4.2.3 and 6.3.1). Whenever engineering/administrative controls and work practices are not feasible or effective, any reasonable combination of engineering/administrative controls, work practices, and PPE shall be used to reduce and maintain employee exposures to a level at or below permissible exposure/dose limits.

Applicable Engineering/Administrative Control Measures: ________________________

PPE: See Section 7.

Table 6-1

CHEMICAL HAZARD EVALUATION

Task Number	Compound	Exposure Limits (TWA)			Dermal Hazard (Y/N)	Route(s) of Exposure[b]	Acute Symptoms	Odor Threshold/ Description	FID/PID	
		OSHA PEL	NIOSH REL[a]	ACGIH TLV					Relative Response	Ionization Potential (eV)
1,2,3,4,7	PAHs	0.2 mg/m^3	0.1 mg/m^3	NA	Y	DA, IH, IN, SC	Irritation to skin, warts	Aromatic		
1,2,3,4,7	Antimony	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3	Y	E, IH, IN, SC	Irritation to eyes, skin, nose, throat, mouth; cough, dizziness, headache, nausea, vomiting, diarrhea, stomach cramps, loss of sense of smell	Silver-white, lustrous solid		
1,2,3,4,7	Arsenic	0.01 mg/m^3	0.002 mg/m^3	0.01 mg/m^3	Y	DA, E, IH, IN, SC	Ulceration of nasal septum, respiratory irritation, dermatitis, gastrointestinal disturbances, peripheral neuropathy, hyperpigmentation	Garlic odor		
1,2,3,4,7	Asbestos	0.1 fibers/ cc air	0.1 fibers/ cc air	0.1 fibers/ cc air	Y	E, IH, IN, SC	Difficulty breathing, eye irritation	White or greenish, blue, or gray-green fibrous, odorless solid		
1,2,3,4,7	Chromium	1 mg/m^3	0.5 mg/m^3	0.5 mg/m^3	Y	E, IH, IN, SC	Irritation to the eyes, skin; lung fibrosis (histological)	Blue white/ steel gray odorless solid		
1,2,3,4,7	Cobalt	0.1 mg/m^3	0.05 mg/m^3	0.02 mg/m^3	Y	E, IH, IN, SC	Cough, difficulty breathing, wheezing decreased pulmonary function, weight loss, dermatitis, asthma	Odorless silvery-gray/black solid		
1,2,3,4,7	Lead	0.05 mg/m^3	0.05 mg/m^3	0.05 mg/m^3	Y	E, IH, IN, SC	Lassitude, insomnia, weight loss, abdominal pain	Heavy, ductile, soft gray solid		
1,2,3,4,7	Mercury	0.1 mg/m^3	0.05 mg/m^3	0.025 mg/m^3	Y	DA, E, IH, IN, SC	Eye and skin irritation; coughing, chest pain, dyspnea, bronchitis, irritability, indecision, headache, lassitude, stomatitis, and salivation,	Silver white odorless liquid		
1,2,3,4,7	Nickel	1 mg/m^3	0.015 mg/m^3	1.5 mg/m^3	Y	E, IH, IN, SC	Irritation to skin, nasal cavities, lungs, allergic asthma.	Odorless Solid		

Table 6-1

CHEMICAL HAZARD EVALUATION

Task Number	Compound	Exposure Limits (TWA)			Dermal Hazard (Y/N)	Route(s) of Exposure[b]	Acute Symptoms	Odor Threshold/ Description	FID/PID	
		OSHA PEL	NIOSH REL[a]	ACGIH TLV					Relative Response	Ionization Potential (eV)
1,2,3,4,7	PCBs (42%/54% chlorine)	0.5 mg/m^3 / 1 mg/m^3	0.001 mg/m^3 / 0.001 mg/m3http://www.cdc.gov/niosh/npg/nengapdxa.html	1 mg/m^3 / 0.5 mg/m3	Y	E, IH, IN, SC	Eye irritation, chloracne,	Colorless to light colored liquid with hydrocarbon odor		
1,2,3,4,7	Thallium	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3	Y	E, IH, IN, SC	Nausea, diarrhea, abdominal pain, vomiting, tremor, chest pain, convulsions, green tongue	Varies		
1,2,3,4,7	Zinc	5 mg/m^3	5 mg/m^3	2 mg/m^3	N	IH	Chills, aches, nausea, fever, cough, dry throat, headache, blurred vision, vomit, fatigue	Odorless Solid		

Key:
ACGIH – American Conference of Governmental Industrial Hygienists
CC – cubic centimeter
DA – dermal absorption
E – eye contact
FID – flame ionizing detector
IH – inhalation
IN – ingestion
mg/m3 – milligram per cubic meter
NIOSH – National Institute for Occupational Health and Safety
OSHA – Occupational Safety and Health Administration
PAH – polyaromatic hydrocarbon
PCB – polycholorinated hydrocarbon
PEL – permissible exposure level
PID – photo ionization detector
REL – reasonable exposure level
SC – skin contact
TLV – threshold limit value
TWA – time-weighted average

7. LEVEL OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT

7.1 LEVEL OF PROTECTION

The following levels of protection (LOPs) have been selected for each work task based on an evaluation of the potential or known hazards, the routes of potential hazard, and the performance specifications of the PPE. On-site monitoring results and other information obtained from on-site activities will be used to modify these LOPs and the PPE, as necessary, to ensure sufficient personnel protection. The authorized LOP and PPE shall only be changed with the approval of the regional safety coordinator or designee. Level A is not included below because Level A activities, which are performed infrequently, will require special planning and addenda to this SHASP.

Task Number	B	C	D	Modifications Allowed
1		(X)	X	
2		(X)	X	
3		(X)	X	
4		(X)	X	
7		(X)	X	

Note: Use "X" for initial levels of protection. Use "(X)" to indicate levels of protection that may be used as site conditions warrant.

7.2 PERSONAL PROTECTIVE EQUIPMENT

7.2.1 Respiratory Plan

Task #	Respirator	Cartridge Type*	Cartridge Replacement Schedule			Chemical	Action Level
	None						
1,4,5,7	APR	815180	[redacted]	[redacted]	PRN	Multi-Purpose	>5 ppm over Background
1,4,5,7	APR	815186	[redacted]	[redacted]	PRN	Mercury	>0.05 mg/m^3
	PAPR		4 hrs	8 hrs	PRN		
	SCBA	NA					

MSA Cartridges	Ultra-Twin Description
815186	Mercury/Chlorine/P100 w/ESLI
815180	Organic Vapor/Acid Gases/Multipurpose/P100(GMC)
464031	Organic Vapors (GMA)
815178	Organic Vapors/P100 (GMA)
815175	Particulates, P100

The PPE selected for each task is indicated below. E & E's PPE program complies with 29 CFR 1910.120 and 29 CFR 1910 Subpart I and is described in detail in the CHSP. Refer to 29 CFR 1910 for the minimum PPE required for each LOP.

PPE	Task 1	Task 2	Task 3	Task 4	Task 7
Full-face APR	(X)	(X)			(X)
PAPR					
Cartridges:					
P100	(X)	(X)			(X)
GMC-P100					
GME-P100					
Other: Mersorb/Particulate combo cartridge					
Positive-pressure, full-face SCBA					
Spare air tanks (Grade D air)					
Positive-pressure, full-face, supplied-air system					
Cascade system (Grade D air)					
Manifold system					
5-Minute escape mask					
Safety glasses	X	X	X		X
Monogoggles					
Coveralls	(X)	(X)			(X)
Protective clothing:					
Tyvek	(X)	(X)	(X)	(X)	(X)
Saranex					
Other:					
Splash apron					
Inner gloves:					
Cotton					
Nitrile	X	X	X	X	X
Latex					
Other:					
Outer gloves:					
Viton					
Rubber					
Neoprene					

PPE	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 7**
Nitrile			(X)		
Other:					
Work gloves	(X)	(X)	(X)	(X)	(X)
Safety boots (as per ANSI Z41)	X	X			X
Neoprene safety boots (as per ANSI Z41)			(X)	(X)	
Boot covers (type: ____________________________________)					
Hearing protection (type: Foam Ear Plugs NRR 29-33_________)	X	X			X
Hard hat	X	X			X
Face shield					
Other: Bear Spray	(X)	(X)	(X)		(X)
Other: 2 way radio	(X)	(X)	(X)		(X)
Key: ANSI – American National Standards Institute APR – air-purifying respirator PAPR – powered air-purifying respirator SCBA – self-contained breathing apparatus					

8. HEALTH AND SAFETY MONITORING

Health and safety monitoring will be conducted to ensure proper selection of engineering/administrative controls, work practices, and/or PPE so that employees are not exposed to hazardous substances at levels that exceed permissible exposure/dose limits or published exposure levels. Health and safety monitoring will be conducted using the instruments, frequency, and action levels described in Table 8-1. Health and safety monitoring instruments shall have been appropriately calibrated and/or performance-checked prior to use. The medical surveillance table below is for general guidance for when to provide medical monitoring for field personnel.

Medical Monitoring Protocol Selection

Table G-1	Medical Monitoring Protocol Selection				
					Modifications
Circle the Appropriate Level:		Level I	Level II	Level III	Use the highest level (with level III being the highest) of any one of the three parameters to initially evaluate personnel on the work site. Down or upgrade based upon the criteria provided in the level of medical monitoring. The SSO should use site specific evaluation for this determination.
Parameter	Values				
Ambient Temperature	>60.8°F to <80°F	X			
	<60.8°F to >80°F		X		
	<40°F to >90°F			X	
Level of Protection	Level D	X			
	Level C		X		
	Level B			X	
Work Load	Light	X			
	Moderate		X		
	Heavy			X	

What level of monitoring take place at the site?	√ None	☐ Level 1	☐ Level 2	☐ Level 3	☐ TBD

9. DECONTAMINATION PROCEDURES

All equipment, materials, and personnel will be evaluated for contamination upon leaving the exclusion area. Equipment and materials will be decontaminated and/or disposed of, and personnel will be decontaminated, as necessary. Decontamination will be performed in the contamination reduction area or any designated area such that the exposure of uncontaminated employees, equipment, and materials will be minimized. Specific procedures are described below.

Equipment/Material Decontamination Procedures (specified by Work Plan): Where possible, dedicated sampling equipment will be used. Other non-dedicated sampling equipment will be decontaminated with a water/Alconox wash and then rinsed with distilled water. Subcontractors will use a heavy bristle broom or brush to knock soil particles from cars and equipment.

Ventilation: All decontamination procedures will be conducted in a well-ventilated area.

Personnel Decontamination Procedures: Remove and discard all disposable PPE, wipe down safety goggles and hard hats with alcohol-free swabs, boot wash, and hand and face wash with warm soapy water prior to leaving site

PPE Requirements for Personnel Performing Decontamination: Level D. To facilitate better footing and foot comfort, heavy, high-top, non-steel-toed boots may be substituted for steel-toed safety boots during field activities when no heavy equipment, tools, or other crushing type equipment will be in use. This substitution needs to be documented for the specific tasks to be completed that day in the daily safety briefing by the SSO.

Personnel Decontamination in General: Following appropriate decontamination procedures, all field personnel will wash their hands and faces with soap and potable water. Personnel should shower at the end of each work shift.

Disposition of Disposable PPE: Disposable PPE must be rendered unusable and disposed as indicated in the work plan. PPE will be transported off site and disposed of in a municipal landfill upon return to Anchorage, Alaska.

Disposition of Decontamination Wastes (e.g., dry wastes, decontamination fluids, etc.): Disposable PPE must be rendered unusable and disposed of as indicated in the work plan.

Table 8-1

HEALTH AND SAFETY MONITORING

Instrument	Task Number	Contaminant(s)	Monitoring Location	Monitoring Frequency	Action Levels[a]	
☑ PID (e.g., RAE mini RAE) ☐ FID (e.g., OVA 128-) ☐ TVA 1000	7	PAHs	Work Spaces, Spit-spoon Sampler, & Breathing Zone.	Continuous while drilling	**Unknown Vapors** Background to 1 ppm above background: Level D 1 to 5 ppm above background: Level C 5 to 500 ppm above background: Level B >500 ppm above background: Level A	**Contaminant-Specific** **PID may detect a wide range of air contaminates, including engine exhausts. If PID readings are elevated at the spit-spoon sampler, well opening, or ground level, let monitor clear and then monitor in the breathing zone to document any potential field personnel exposure. If above 5 ppm, upgrade to level C.**
Oxygen Meter/Explosimeter					**Oxygen** <19.5% or >22.0%: Evacuate area; eliminate ignition sources; reassess conditions. 19.5 to 22.0%: Continue work in accordance with action levels for other instruments.	**Explosivity** $\leq$10% LEL: Continue work in accordance with action levels for other instruments; monitor continuously for combustible atmospheres. >10% LEL: Evacuate area; eliminate ignition sources; reassess conditions.
Radiation Alert Monitor (Rad-mini or RAM-4)					<0.1 mR/hr: Continue work in accordance with action levels for other instruments. $\geq$0.1 mR/hr: Evacuate area; reassess work plan, and contact radiation safety specialist.	
Mini-Ram Particulate Monitor		Arsenic Dust	With Field Teams	Continuous	**General/Unknown** Evaluate health and safety measures when dust levels exceed 2.5 mg/m^3.	**Contaminant-Specific** **Arsenic** = 0.28 mg/m3 in areas with enriched concentrations-tailings impoundments.
HCN/H_2S (Monitox)					$\geq$4 ppm: Leave area and consult with SSO.	
Draeger Colorimetric Tubes					**Tube** **Action Level**	**Action**
Air Monitor/Sampler Type: ________________ Sampling medium: ______________________					**Action Level**	**Action**
Personal Sampling Pump Type: ________________ Sampling medium: ______________________					**Action Level**	**Action**

Table 8-1

HEALTH AND SAFETY MONITORING

Instrument	Task Number	Contaminant(s)	Monitoring Location	Monitoring Frequency	Action Levels[a]
Micro R Meter					<2 mR/hr: Continue work in accordance with action levels for other instruments. 2 to 5 mR/hr: In conjunction with a radiation safety specialist, continue work and perform stay-time calculations to ensure compliance with dose limits and ALARA policy. >5 mR/hr: Evacuate area to reassess work plan, and evaluate options to maintain personnel exposures ALARA and within dose limits.
Ion Chamber					See micro R meter action levels above.
Radiation Survey Ratemeter/Scaler with External Detector(s)					**Detector** **Action Level** **Action**
Noise Dosimeter (Sound Level Meter)					≤85 dBA as measured, using the A-weighed network (dBA): Use hearing protection if exposure will be sustained throughout work shift. >85 dBA: Use hearing protection. >120 dBA: Leave area and consult with safety personnel.
Other: XRF	1-4, 7	Arsenic, Hg, Pb	Split-spoon Sampler	As needed	The XRF is only being used as an analytic tool, not valid for H & S purposes under these conditions..
Other: Jerome 413 X Mercury Meter	1- 4,7	Mercury vapor	Work Zones	Continuous	Action level: Any instantaneous (not TWA) reading at or above 0.05 mg/m^3 requires upgrade to level C.

Table 8-1

HEALTH AND SAFETY MONITORING

Instrument	Task Number	Contaminant(s)	Monitoring Location	Monitoring Frequency	Action Levels[a]

[a] Unless stated otherwise, airborne contaminant concentrations are measured as a time-weighted average in the worker's breathing zone. Acceptable concentrations for known airborne contaminants will be determined based on OSHA/NIOSH/ACGIH and/or NRC exposure limits. As a guideline, 1/2 the PEL/REL/TLV, whichever is lowest, should be used.

ALARA – as low as reasonably achievable
dBA - decibels
FID – flame ionization detector
H_2S – hydrogen sulfide
HCN – Hydrogen Cyanide
LEL – Lower Explosive Limit
mg/m^3 – milligram per cubic meter
PID – photo ionization detector
OVA – Organic Vapor Analyzer
RAE - Rae Systems of monitoring equipment
ppm – parts per million
SSO – Site Safety Officer
TVA – Toxic Vapor Analyzer
TWA – time-weighted average
mR/hr - millirem per hour

10. EMERGENCY RESPONSE

This section contains additional information pertaining to on-site emergency response and does not duplicate pertinent emergency response information contained in earlier sections of this plan (e.g., site layout, monitoring equipment, etc.). Emergency response procedures will be rehearsed regularly, as applicable, during project activities.

10.1 EMERGENCY RESPONSIBILITIES

All Personnel: All personnel shall be alert to the possibility of an on-site emergency; report potential or actual emergency situations to the team leader and SSO and notify appropriate emergency resources, as necessary. All field personnel will have the right of refusal and any field personnel may call out any emergency and stop work immediately if necessary.

Team Leader: The team leader will determine the emergency actions to be performed by E & E personnel and will direct these actions. The team leader will also ensure that applicable incidents are reported to appropriate E & E and client project personnel and government agencies.

SSO: The SSO will recommend health/safety and protective measures appropriate to the emergency.

Other:

10.2 LOCAL AND SITE RESOURCES (including phone numbers)

Ambulance: Request emergency air transportation from Vanderpool's Flying Service, Red Devil Alaska to hospital or clinic.

Hospital: Clara Morgan Sub-regional Clinic. 269 Morgan's Road, Aniak, Alaska 907-675-4556.
Also, Providence Alaska Medical Center. 3200 Providence Dr., Anchorage Alaska 907-562-2211 (See Attachment L for direction and maps.)

Directions to Hospital: Air flight.

Poison Control: 907- 261-3193 (Anchorage)

Police Department: N/A

Fire Department: N/A

Client Contact: Mike McCrum, BLM Project Manager: 907- 271-4426; Larry Beck, BLM Inspector: 907- 267-1226

Site Contact: N/A

On-Site Telephone Number: None. In case of emergency, E & E personnel will use telephone at Red Devil Lodge or satellite phone to call for help.

Cellular Telephone Number: No cell service available on site.

Radios Available: Two Motorola hand-held radios for on-site communication

Other: Red Devil Lodge 907-447-3225, only means of communication in Red Devil, Alaska

10.3 E & E EMERGENCY CONTACTS

E & E Emergency Operations Center (24 Hours):	716-684-8060
Corporate Health and Safety Director: Dr. Paul Jonmaire	716-684-8060 (office) 716-655-1260 (home)
Assistant Corporate Safety Director: Tom Siener, CIH	716-684-8060 (office) 716-662-4740 (home)

Regional Office Contact:

Carl Overpeck, ANC Office	907-257-5000 (office)
Eric Lindeman, Seattle Office	206-419-3422 (Cell)

10.4 OTHER EMERGENCY RESPONSE PROCEDURES

On-Site Evacuation Signal/Alarm (must be audible and perceptible above ambient noise and light levels): Three repeated Rapid Whistle blasts means come to provide assistance. Long whistle blasts means move to the on-site assembly point as reviewed in the daily safety briefing. This signal/alarm method needs to be evaluated once on-site to confirm that it is effective.

On-Site Assembly Area: To be determined in field. To be identified at the first daily safety briefing and documented in the Daily Safety Meeting Form (Attachment E).

Emergency Egress Route to leave site: To be determined in field. To be identified at the first daily safety briefing and documented in the Daily Safety Meeting Form (Attachment E).

Off-Site Assembly Area: To be determined in field. To be identified at the first daily safety briefing and documented in the Daily Safety Meeting Form (Attachment E).

Preferred Means of Reporting Emergencies: Request in-person Vanderpool Flying Service for transportation to Aniak, if necessary, then contact William Richards, then contact Paul Jonmaire, then contact client.

Site Security and Control: In an emergency situation, personnel will attempt to secure the affected area and control site access.

Spill Control Procedures: N/A

Emergency Decontamination Procedures: Douse with copious amounts of water. Remove contaminated clothing and/or PPE.

PPE: Personnel will don appropriate PPE when responding to an emergency situation. The SSO and Section 7 of this plan will provide guidance regarding appropriate PPE.

Emergency Equipment: Appropriate emergency equipment is listed in Attachment C. Adequate supplies of this equipment shall be maintained in the support area or other approved work location.

Incident Reporting Procedures: Notify appropriate local emergency services, notify E & E Regional Health and Safety Officer (Eric Lindeman), notify E & E Corporate Health and Safety Office (Paul Jonmaire). If an accident is narrowly avoided, personnel involved will report the incident on the Near Miss Form (Attachment K), and submit a copy to the E & E Regional Health and Safety Officer (Eric Lindeman).

ATTACHMENT A SITE-SPECIFIC HEALTH AND SAFETY PLAN ACCEPTANCE

Ecology and Environment, Inc.

SITE-SPECIFIC HEALTH AND SAFETY PLAN ACCEPTANCE

Project: Red Devil Mine RI/FS

Project No.: TDD/PAN No.:

Project Location: Red Devil Mine, Alaska

Program Manager: William Richards Project Manager: Mark Longtine

Initial Project Safety Checklist

1. Emergency information reviewed? ___ and made familiar to all team members?
2. Transportation to nearest hospital known? __ and its method to all team members?
3. Health and safety plan readily available and its location known to all team members?

The undersigned acknowledge that they have read and understood and agree to abide by the health and safety plan.

Name (Printed)	Name (Signature)	Date

ATTACHMENT B EXISTING SITE SAFETY PLAN ADDENDUM FORM

Ecology and Environment, Inc.

EXISTING SITE SAFETY PLAN ADDENDUM FORM

Site Name:

Date of original SSP:

Date of amendment:

Date of proposed new work:

Added activities and hazard evaluations:

Added monitoring activities:

Level of protection: 9A 9B 9C 9D

Reason for up/downgrading:

PPE:

Decon:

Team Members	**Responsibility**

Equipment	**Quantity**	**Equipment**	**Quantity**

The terms of the original SSP shall be in effect except as noted on this form.

Prepared by:	**Date:**
Reviewed by:	**Date:**

ATTACHMENT C EQUIPMENT/SUPPLIES CHECKLIST

Ecology and Environment, Inc.
EQUIPMENT/SUPPLIES CHECKLIST

Instrumentation	No.
TVA 1000 (Probe: eV)	
MultiRAE Probe (Probe: 10.8 eV)	1
OVA	
HNu (Probe: eV)	
Thermal Desorber	
O$_2$/Explosimeter with Calibration Kit	
Photovac Tip	
Magnetometer	
Pipe Locator	
Weather Station	
Draeger Tube Kit (Tubes:)	
Brunton Compass	
Real-Time Cyanide Monitor	
Real-Time H$_2$S Monitor	
Heat Stress Monitor	
Noise Equipment	
Personal Sampling Pumps and Supplies	
Mini Ram Dust Monitor	
Mercury Monitor	1
Spare batteries (Type:)	
XRF	1
Radiation Equipment/Supplies	
Documentation Forms	
Portable Ratemeter	
Scaler/Ratemeter	
1” NaI Gamma Probe	
2” NaI Gamma Probe	
ZnS Alpha Probe	
GM Pancake Probe	
Tungsten-Shielded GM Probe	
Micro R Meter	
Ion Chamber	
Alert Monitor	
Pocket Dosimeter	
Dosimeter Charger	
Radiation Warning Tape	
Radiation Decontamination Supplies	
Spare Batteries (Type:)	
Sampling Equipment	
8-oz Bottles	X
Half-Gallon Bottles	
VOA Bottles	X
String	X
Hand Bailers	
Thieving Rods with Bulbs	
Spoons	X
Knives	
Filter Paper	
Bottle Labels	X

Emergency Equipment	No.
First Aid Kit	1
Stretcher	
Portable Eye Wash	
Blood Pressure Monitor	
Fire Blanket	
Fire Extinguisher	
Thermometer (Medical)	
Spill Kit	
Decontamination Equipment	
Wash Tubs	2
Buckets	2
Scrub Brushes	4
Pressurized Sprayer	1
Spray Bottle	2
Detergent (Type: Alconox)	1
Solvent (Type: DENATURED ALCOHOL)	
Plastic Sheeting	
Tarps and Poles	
Trash Bags	X
Trash Cans	
Masking Tape	
Duct Tape	X
Paper Towels	X
Face Mask	X
Face Mask Sanitizer	
Step Ladders	
Distilled Water	X
Deionized Water	
Miscellaneous	
Pump	
Surveyor’s Tape	
100’ Fiberglass Tape	
300’ Nylon Rope	
Nylon String	
Surveying Flags	
Camera	2
Film	
Bung Wrench	
Soil Auger	
Pick	
Shovel	X
Catalytic Heater	
Propane Gas	
Banner Tape	
Surveying Meter Stick	
Chaining Pins and Ring	
Logbooks (2 Large, 2 Small)	X
Required MSDSs	X
Intrinsically Safe Flashlight	

Ecology and Environment, Inc.
EQUIPMENT/SUPPLIES CHECKLIST

Instrumentation	No.	**Emergency Equipment**	No.
Shipping Equipment		Potable Water	X
Coolers	X	Gatorade or Equivalent	
Paint Cans with Lids, Seven Clips Each		Tables	1
Vermiculite		Chairs	2
Shipping Labels		Weather Radio	
DOT Labels:		Two-Way Radios	
“Up”		Binoculars	1
“Danger”		Megaphone	
“Inside Container Complies...”		Cooling Vest	
“Hazard Group”		First Aid Kit	1
Strapping Tape	X	Satellite Phone	1
Baggies	X	Cellular Phones	X
Custody Seals	X	PFD	2
Chain-of-Custody Forms	X		
FedEx Forms	X		
Clear Packing Tape	X		
Permanent Markers	X		

ATTACHMENT D ALL TERRAIN VEHICLES USE REQUIREMENTS STANDARD OPERATING PROCEDURE

For more information contact:

ATV Safety Institute
A Division of the Specialty Vehicle Institute of America

2 Jenner Street, Suite 150
Irvine, California 92618-3806
(949) 727-3727
www.atvsafety.org

For the rider training location
nearest you call: (800) 887-2887

Tips and Practice Guide for the All-Terrain Vehicle Rider

ATV Safety Institute

A Division of the Specialty Vehicle Institute of America

Foreword

It is important to carefully read and follow the instructions and warnings in the owner's manual and on labels. ATVs handle differently from other vehicles such as motorcycles and cars. Proper instruction and practice are important.

ATVs can be hazardous to operate. For your safety, always wear a helmet, eye protection and protective clothing. Always avoid paved surfaces. Never ride on public roads. Never carry passengers or engage in stunt riding. Avoid excessive speeds. Riding and alcohol or other drugs don't mix. Be extra careful on difficult terrain.

The ATV Safety Institute is a division of the Specialty Vehicle Institute of America, a national not-for-profit association representing U.S. distributors of all-terrain vehicles. Supporting members are AlphaSports, Arctic Cat, Bombardier, Cannondale, Honda, Kawasaki, KTM, Suzuki, and Yamaha.
For more information contact:

ATV Safety Institute
A Division of the Specialty Vehicle Institute of America

2 Jenner Street, Suite 150
Irvine, California 92618-3806
(949) 727-3727 • www.atvsafety.org

For the rider training location
nearest you call: (800) 887-2887

U.S. Version • Revision 5/2002
50M/.30/WT

Be Cautious

ATVs are not toys. Serious injury can result from improper use of ATVs, but with preparation and practice, you can safely develop and expand your riding skills. Riding ATVs can be an enjoyable form of outdoor recreation when done properly. ATVs can also be used for agricultural or utility use.

In addition to the information provided in this booklet, it is important to read and follow the instructions and warnings contained in the ATV owner's manual and on labels.

ATVs handle differently from other vehicle, such as motorcycles and cars. Proper instruction and practice are important. The ATV *RiderCourse*^{SM}, a half-day hands-on training program is available nationwide. If you purchased a new ATV, you may be eligible for free training. Once training is completed, you may also be eligible to receive an incentive. To find out if you are eligible for free training and to register for classes, contact the ATV Enrollment Express. Call toll-free (800) 887-2887 for the rider training location nearest you. Those not eligible for free training may take the course for a nominal fee. We recommend you take advantage of the free training program, and perform the exercises in this booklet.

Remember that riders under 16 years of age must be supervised by an adult. In addition, follow the ATV Model Size and Minimum Age information listed on page iii.

Do not ride an ATV that is not recommended for your age group.

If you have a youngster who is about ready to ride an ATV, there are special considerations that you should keep in mind. Although a child may be the recommended age to ride a particular size ATV, not all youngsters have the strength, skills, or judgment needed to operate an ATV. You should supervise your youngster's operation of the ATV at all times, and should permit continued use only if you determine that your youngster has the ability and judgment to operate the ATV safely. You should read *Parents, Youngsters and All-Terrain Vehicles* available from the ASI (see page 62 for more information).

For more information about ATV safety, call the Consumer Product Safety Commission at (800) 638-2772 or the Distributors' ATV Safety Hotline at (800) 852-5344.

RIDER AGE & ENGINE SIZE

ATV Size	Minimum Age
Under 70cc.	6 years and older
70-90cc.	12 years and older
Over 90cc.	16 years and older

Table Of Contents

Tips For The ATV Rider

Table Of Contents

ATV Off-Road Practice Guide

Introduction Part 1

The purpose of this booklet is to answer your questions about All-Terrain Vehicles (ATVs) and help you increase your knowledge of their operation and use. It will help you to learn and respect the capabilities of your ATV.

If you are new to ATVs, you can look forward to lots of fun and excitement. An ATV can be ridden in many types of off-road conditions, but its capabilities depend on your riding experience and ability.

All ATV riders, regardless of what type of riding they do, should read this booklet thoroughly to learn tips that may be helpful in future riding experiences.

This booklet should not be used as a replacement for a training program.

You should consider taking the ATV *RiderCourse*℠, available nationwide. Call toll-free, (800) 887-2887, for information about this course.

The All-Terrain Vehicle (ATV)

Knowing all you can about your ATV and the places you can ride is good preparation for safe and enjoyable riding.

Remember, ATVs are intended for off-road use only. Never operate an ATV on public roads, and always avoid paved surfaces. ATVs are not designed to be used on paved surfaces because pavement may seriously affect handling and control.

ATVs are different from other vehicles, as well as from one another. The following is a list of some differences among ATVs:

- Handling characteristics among ATVs vary depending upon their basic design and how they are equipped.
- Most ATVs have front and rear brakes, while some may have linked brakes. Be sure to learn the recommended stopping techniques for your machine.
- There are ATVs with electric starters, kick-starters, and pull starters.
- There are liquid-cooled ATVs and air-cooled ATVs.
- Some ATV transmissions have automatic clutches; some have hand-operated clutches; some transmissions are fully automatic.
- Some ATVs have a reverse gear.
- Most ATVs have solid drive axles and some have differentials.
- Some ATVs have two-wheel drive, and some have four-wheel drive.
- Some ATVs have chain drives, others have shaft drives.
- Most throttles are controlled by pushing a thumb lever next to the handgrip; others may be controlled by twisting a handgrip.
- Controls and their locations differ from one ATV model to another.

Be Prepared

You may be anxious to take a test run, but before you do, be sure you and your machine are ready. If you are not, the results can range from embarrassment to severe injuries.

Be sure to follow the age and ATV model size recommendations for young riders (see page iii). A safety booklet called *Parents, Youngsters and All-Terrain Vehicles* is available from the ATV Safety Institute.

This easy-to-read booklet is designed to assist parents in determining whether a youngster is ready to ride an ATV. It contains readiness guidelines and checklists for parents to review with their youngsters. It also includes important safety tips and information for youngsters who are learning to ride an ATV.

Protective Gear

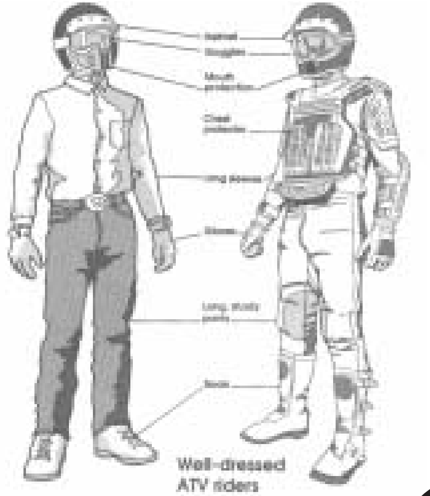
The nature of ATV riding demands that you wear protective clothing. Although complete protection is not possible, knowing what to wear and how to wear it can make you feel more comfortable when you ride and reduce the chance of injury.

Never operate an ATV without an approved motorcycle helmet, eye protection, boots, gloves, long pants, and a long-sleeved shirt or jacket.

Clothing

Good gloves can help keep your hands from getting sore, tired, or cold, as well as offer protection in the event of a spill. Off-highway style gloves, available at ATV dealerships, are padded over the knuckles to help prevent bruising, and provide the best combination of protection and comfort.

The recommended protective footwear is a pair of strong, over-the-ankle boots with low heels to help prevent your feet from slipping off the footrests. Off-highway style boots offer the best protection for feet, ankles, and lower legs.



Well-dressed ATV riders

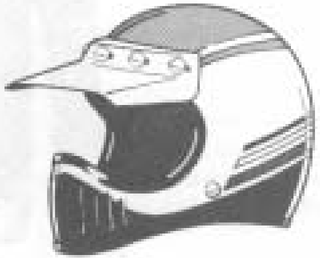
It is important to protect your skin from scratches. A long-sleeved shirt or jersey and long pants are minimum requirements for rider protection. Off-highway riding gear such as off-highway pants with kneepads, jersey, and chest/shoulder protectors provides better protection. You can look stylish and ready for action, and still be well-protected.

Helmets

Your helmet is the most important piece of protective gear for safe riding. A helmet can help prevent a serious head injury.

There are a few basic tips to keep in mind when selecting a helmet. Selecting an approved helmet that meets or exceeds your state's safety standards and carries either the Department of Transportation (DOT) label, the American National Standards Institute label (ANSI z90.1), or the Snell Memorial Foundation label.

Your helmet should fit snugly and fasten securely. Full-face helmets help protect your face as well as your head. Open-face helmets are lighter and may be cooler, but should



be used with mouth protection. Eye protection should be used with both types of helmets.

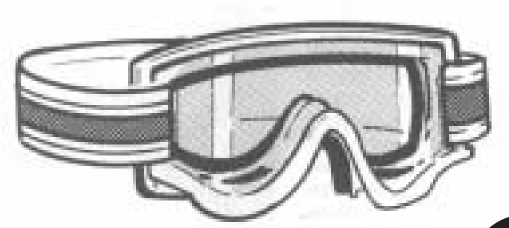
There is also a special time not to wear a helmet. When you stop to talk with landowners or other people you meet on the trails, always take your helmet off. To some people your helmet is a mask and can be intimidating.

Eye Protection

You must be able to see clearly to ride safely. An object such as a rock, branch, or even a bug that hits you in the face can distract you. If you are hit in the eyes without proper protection, you can be blinded. Regular sunglasses do not provide proper protection while riding an ATV. A face shield or goggles will provide you with more protection and should be:

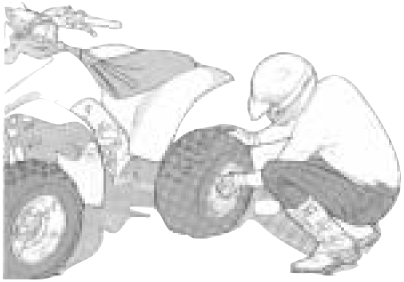
- Free from scratches and bear the standard marking VESC8 (or V-8) or z87.1 in one corner, or should be made of a hard-coated polycarbonate
- Fastened securely
- Well ventilated to prevent fogging

In addition, you may wish to use gray tinted eye protection for riding on bright days or yellow for overcast days. Always use clear eye protection for riding at night.



Pre-Ride Inspection

Inspecting the mechanical condition of your ATV before each ride is important to minimize the chance of being injured or stranded. This also ensures long enjoyment of your ATV. Remember, you can ride farther in one hour than you can walk in a day. Your owner's manual will show you what equipment to check on your particular machine. Listed are the most common items to check:



Tires and Wheels

1. **Air pressure** – Always maintain the recommended tire pressure. Be sure that all tires are inflated to proper pressure. Check that tires on the left side of your ATV are inflated to the same pressure as the corresponding tires on the right side. If the tire pressure on one side is higher than the other side, the vehicle may pull to one side. Under-inflated tires may also cause wheel damage when riding over bumpy terrain. Over-inflation may damage the tires. If the tires are over- or under-inflated, your ATV may not steer or handle properly. To measure pressure accurately (usually 2 to 6 psi), you will need a low-pressure gauge; automotive tire gauges are not accurate for use on ATVs.

2. **Condition** – Check for cuts or gouges that could cause air leakage.
3. **Wheels** – To avoid loss of control or injury, make sure axle nuts are tight and secured by cotter pins, and make sure wheel nuts are tightened properly. Grasp the tire at the front and the rear and try to rock it on its axle to detect worn-out bearings or loose nuts. There should be no free play or slip as you rock the wheel.

Controls

1. **Throttle and other cables** – Make sure the throttle moves smoothly and snaps closed with the handlebars in any position. Check throttle operation while moving the handlebars from fully left to fully right. If your ATV is equipped with an adjustable throttle limiter, check to make sure the adjustment is appropriate for the rider, and that the adjustment is securely set. Check cables and controls for damage from a spill or accumulated dirt and mud, which may restrict full operation.
2. **Brakes** – Make sure the controls operate smoothly and are adjusted according to the instructions in the owner's manual. The controls should be positioned for your easy reach. Your brakes are a crucial part of riding and they must always be in excellent working condition.
3. **Footshifter** – Make sure the footshifter is firmly attached and positioned for safe operation. It should not be so low that your toes are pointed downward at the ground or so high that shifting is awkward.

Lights and Switches

1. **Ignition switch** (if equipped) – Check the condition of the switch and make sure it works properly by switching it off and on during your warm-up period.
2. **Engine stop switch** – Be sure it turns off the engine.
3. **Lights** (if equipped) – Be sure all lights are working.

Oil and Fuel

1. Check oil level while the engine is off. You could get stranded because you are out of oil or fuel.
2. Always start your ride with a full tank of gasoline to give you the best chance of getting home from a long ride.
3. Check for fuel or oil leaks.

Chain/Driveshaft and Chassis

1. **Chain** – Inspect your chain for proper adjustment and adequate lubrication. Check for wear.
2. **Driveshaft** – If your ATV is equipped with a driveshaft rather than a chain, check for oil leaks. Maintain the oil supply as outlined in your owner’s manual.
3. **Nuts ‘n bolts** – Rough terrain will loosen parts. Look and feel for loose parts while the engine is off. Shake handlebars, footrests, etc., before each ride, and periodically check major fasteners with a wrench.

Tool Kit

After completing the pre-ride inspection, check to make sure you have an adequate tool kit in case you encounter any mechanical problems.

Carrying the right tools and equipment with you when you go riding is important for the safe enjoyment of your ATV riding experience. Examine the tool kit that came with your machine. You may want to add a few spare parts — a spark plug or two, perhaps some wire and tape, maybe a headlight bulb. Prepare for the unexpected, and carry what you need to handle any emergencies. Consider carrying a good strong tow rope.

Also remember that off-road riding is hard on your ATV, so it is especially important to perform periodic maintenance as outlined in your owner's manual. Do not risk injury or vehicle breakdown due to lack of proper maintenance.

Let's Prepare To Ride

Riding Area

Be sure you have a large, flat, open practice area, free of obstacles and hazards, to use while you practice. Take a few minutes to review the rest of the riding tips in this booklet before you start your engine.

Starting Procedure

Consult your owner's manual for the correct starting procedure.

- Check that the transmission is in NEUTRAL or PARK (if equipped).
- Set PARKING BRAKE.
- Turn the FUEL valve on.
- Check that the engine stop switch is in the RUN or ON position.
- If the engine is cold, put the CHOKE in the ON position.
- Start the engine.

Posture

The correct riding posture will help you to easily operate the controls and help you react more quickly when shifting your body weight. Proper straight line riding posture includes:

- Head and eyes up, looking well ahead
- Shoulders relaxed, elbows bent slightly out, away from your body
- Hands on the handlebars
- Knees in toward the gas tank
- Feet on the footrests, toes pointing straight ahead

Always keep both hands on the handlebars and both feet on the footrests of your ATV during operation. Removing even one hand or foot can reduce your ability to control the ATV, or could cause you to lose your balance and fall off. If you remove a foot from a footrest, your foot or leg may come into contact with the rear wheels, which could injure you or cause an accident.

ATVs are rider-active; to enhance the performance capabilities of the ATV, you must shift your body weight. This is especially true in maneuvers such as turning, negotiating hills, and crossing obstacles.

Let's Start Riding

Get Moving

- Always keep your feet on the footrests while riding to help prevent injury.
- Be sure that the engine is sufficiently warmed up before you start riding.
- Apply the rear brake and shift into first gear.
- Release the parking brake and apply the throttle slowly.
- If the vehicle has a manual clutch, release it slowly. If the clutch is engaged too quickly, the ATV may move suddenly, causing you to lose control or fall off the ATV.

Shifting Gears

See your owner's manual for instructions on shifting your model of ATV. There are several types of transmissions on ATVs.

Be certain you know how to operate the transmission of the ATV you are riding.

- Always close the throttle while shifting to prevent the front wheels from lifting.
- Learn the sounds of your engine so you can shift to keep the engine speed in the most efficient range.
- If your ATV has a manual clutch, learn where the engagement zone is to prevent stalling, and to allow for smooth shifting.

Braking

Your owner's manual describes your ATV's braking system. You may have both front and rear brake, or linked brakes. Of course, your braking technique will depend upon your ATV's braking system and the type of terrain you are riding on.

Many ATVs are available with four-wheel drive. When operating in four-wheel-drive mode, keep in mind:

- Using only the front brake or the rear brake has the effect of braking both the front and rear wheels.
- Abrupt deceleration from shifting to a lower gear (engine braking) will affect both the front and rear wheels.

Consult your owner's manual for more detailed information.

Some tips for braking are:

- Releasing the throttle.
- Shifting to a lower gear to use the engine to slow the vehicle.
- Applying both brakes equally. (if equipped)
- Avoiding excessive braking while cornering.
- Applying brakes lightly on slippery surfaces.
- Shifting to a low gear when descending a hill and not riding the brake for long periods of time.

Parking

When parking your ATV you should:

- Stop the ATV. Place the transmission in neutral or park and apply the parking brake or engage the parking mechanism (if not already activated by placing the transmission in park). If the ATV is equipped with a parking mechanism, allow the drive train to lock.
- Avoid parking on an incline.

Turning Basics

Always check your owner's manual for the recommended turning technique for your ATV.

The following basic turning technique applies to ATVs being ridden at low to moderate speeds.

- Move your body weight forward and to the inside of the turn.
- Turn the handlebars while looking in the direction of the turn.

As you increase speed or turn more sharply, move your body weight farther toward the inside of the turn to maintain your balance.

If your ATV starts to tip while turning, lean your body farther into the turn while gradually reducing the throttle and making the turn wider, if possible.

Riding On Hills

Going Up Hills

Climbing hills improperly could cause loss of control or cause the ATV to overturn. Always follow procedures described in your owner's manual. Remember:

- Some hills are too steep for your abilities. Use your common sense. If the hill you are approaching looks too steep, it probably is.
- Some hills are just too steep for your ATV, regardless of your abilities.
- Never ride past the limit of your visibility; if you cannot see what is on or over the crest of a hill, slow down until you have a clear view.
- The key to being a good hill rider is to keep your weight uphill at all times.

When approaching an uphill climb, you should:

- Keep your feet firmly on the footrests.
- Shift the ATV into a lower gear and speed up BEFORE climbing the hill so you can maintain momentum.
- When approaching the uphill climb, move up on the seat and lean forward, or stand and position your torso over the front wheels.

As you are climbing, you may need to shift to a lower gear to prevent lugging the engine or stalling. To shift into a lower gear on a hill, remember:

- Keep your body weight forward as you prepare to shift gears. For steeper hills, lean forward as much as possible.
- Shift quickly while momentarily releasing the throttle; this will help keep the front wheels from lifting.

If you do not have enough power to reach the top of the hill, but still have forward momentum and enough room to turn around safely:

- Keep your weight uphill.
- Make a U-turn before you lose speed.
- Proceed downhill in a lower gear, keeping your weight to the uphill side.

If you are riding uphill and lose all forward momentum:

- Keep your weight uphill and apply the brakes to come to a stop. Never allow the ATV to roll backward.
- Apply the parking brake while keeping your weight uphill.
- Dismount on the uphill side or to a side if pointed straight uphill, and follow the procedures described in your owner's manual.

Do not attempt to ride backward down a hill. Should you begin rolling backward, do not apply the rear brake abruptly. Using the rear brake only or abruptly could cause the ATV to roll over backward.

If you begin rolling backward follow these steps:

- Keep your weight uphill and apply the front brake. If your ATV has linked brakes, or if you are in four-wheel drive, follow the procedures described in your owner's manual.
- When you have come to a complete stop, apply the rear brake. Then apply the parking brake and dismount on the uphill side. If pointed straight uphill, dismount to either side and follow the procedures described in your owner's manual.
- If the ATV continues to roll backward, dismount to the uphill side immediately.

Going Down Hills

Always check the terrain carefully before you start down any hill. Choose a downhill path as straight as possible, with a minimum of obstacles. Shift your weight to the rear

and use a low gear. Follow the procedures described in your owner's manual for the special braking techniques for going down hills.

When going downhill, remember to:

- Shift your weight to the rear (uphill).
- Keep the speed low.
- Use gradual braking.
- Use a lower gear.
- Look ahead.

Traversing a Slope

When you go across a slope rather than directly up or down, it is called traversing. Sometimes when a hill is steep it is necessary to climb it or descend it by traversing.

Traversing a slope requires additional attention. Avoid traversing slopes with excessively slippery, rough, or loose surfaces.

Here are some of the basic guidelines for traversing:

- Keep both feet firmly on the footrests.
- Lean your upper body uphill.
- When riding on soft terrain, you may need to turn your front wheels gently uphill to keep your ATV on a straight line across the hill.
- If your ATV begins to tip, turn the front wheels downhill if the terrain allows. If the terrain does not permit, dismount on the uphill side immediately.
- Avoid making sudden throttle changes.

Riding Strategies

Reading Terrain

To get the most out of your ride, you have to know the land you are riding on and what your machine can do. Carefully choose the places you ride. Use existing trails. Stay away from terrain where you do not belong, such as dangerous slopes and impassable swamps. Watch carefully for sharp bumps, holes, ruts, or obstacles.

An expert rider stays out of trouble by handling the ATV well and avoiding any risky situation. Learn to read the trail as you ride. An expert rider looks well ahead on the trail. Know what is coming up; be prepared to react long before you get there. Be constantly alert for hazards. Never operate an ATV at excessive speeds. Go at a speed which is proper for the terrain, visibility, operating conditions and your experience. Always be careful when operating an ATV, especially when approaching hills, turns, and obstacles and when operating on unfamiliar terrain.

Choosing Proper Speeds

Always look well ahead and choose a speed that is proper for the terrain, visibility, operating conditions, and your experience.

By scanning far enough down the trail, you will be able to pick the best “lines” (or safest paths of travel) around or over hazards or small obstacles. As you approach a hazard, do not fixate on it. Instead, continue to search for other clues in the environment and adjust your speed well in advance.

Riding Different Terrain

Sand Dunes

Dune riding offers great thrills and fun, but certain safety precautions are necessary to fully enjoy this type of terrain. Remember to:

- Use an antenna flag on your ATV.
- Be prepared for changing sand.
- Avoid wet sand.
- Avoid riding on vegetation.
- Watch for slip faces and razorbacks.
- Be careful when the sun is overhead; lack of shadows make it difficult to see hazards.

Mud and Water

Your ATV is equipped to ride through mud and shallow water, but you should avoid water crossings where you might damage streambeds and fish spawning grounds, or where you might cause erosion to the banks of a stream or creek. This precaution not only adds to your personal safety and fun, but it preserves the environment for others to enjoy. If you are riding through mud or water remember:

- Footrests may become slippery.
- Determine water depth before attempting a crossing; do not exceed the water depth specified in your owner's manual.
- Avoid fast-flowing water.
- If you cross a stream, use an established ford or place where the stream banks have a gradual incline.
- Be prepared to shift your weight in any direction to maintain balance.

- Watch for submerged obstacles.
- Test brakes after leaving water.

Snow

Riding on firm snow can be great fun. However, riding in soft snow, under the wrong conditions, can be damaging to the terrain. Ride only on firm snow or groomed trails and be sure to have the landowner's permission. Remember to:

- Keep alert to weather conditions.
- Know the weather forecasts.
- Check with local law enforcement to be sure that ATVs are allowed on snowmobile trails before using them.
- Dress appropriately for the weather conditions.

Crossing Roads and Highways

ATVs are designed to be used OFF-ROAD ONLY. A leading cause of accidents and fatalities to ATV riders is riding on or crossing a road illegally or improperly. The hazards of crossing roads cannot be over-emphasized, but you may find it necessary on occasion to cross a road or highway. This is particularly true in farming areas where ATVs are used for various work purposes. If you must cross a road, use the following guidelines to reduce risk:

- Make sure you know your state's laws and regulations before you cross any road.
- Before crossing, bring your ATV to a complete stop on the shoulder of the road.
- Yield the right of way to all oncoming traffic. Look both ways.
- Ride cautiously. Your ATV will handle differently on pavement and may be

difficult to maneuver, increasing the danger of collision.

- Cross the road at a 90-degree angle where there are no obstructions and your visibility is good.
- If you are riding in a group, have the first rider (leader) dismount on the shoulder before crossing and watch for traffic as he waves the group across the road. Have the last rider dismount on the shoulder after crossing and watch traffic, to help the group leader across.
- Remember, crossing roads improperly or riding illegally on the road is a major cause of serious accidents and fatalities to ATV users, so use extra caution. Always assume the drivers DO NOT SEE YOU, since most drivers look for cars, not ATVs.

Safe Riding Practices

Don’t Ride Alone

Always make a plan before you ride. Tell someone where you are going and when you expect to be back. Ride in a group of two or more. Each rider should be responsible for keeping track of one of the others. It’s called the “buddy system” and it’s good insurance on any ride.

The Effects of Alcohol, Drugs, and Fatigue

Riding an ATV can be more demanding than driving a car. You have to be in good physical and mental condition to ride safely. Three factors that keep ATV riders from being in top shape for riding are alcohol, drugs, and fatigue. Each of these can affect your ability and your decision-making process.

Alcohol

Drinking and riding can be fatal. Consumer Product Safety Commission studies show that 30 percent of all ATV riders killed in ATV accidents had been drinking. Fourteen percent of all reported accidents with injuries indicated alcohol consumption by the operator.

Alcohol affects all the skills you need to ride safely. The amount of alcohol in your body is referred to the “Blood Alcohol Concentration” or “BAC.” Most states consider people intoxicated at a BAC of .08 percent. Physical and mental reactions usually became impaired at a BAC of .05 percent. ALCOHOL AND ATVs DO NOT MIX.

Other Drugs

Almost any drug puts an ATV rider at risk. Many over-the-counter prescription and illegal drugs have side effects much like alcohol, which affect the skills you need to ride safely. Depressant drugs such as tranquilizers and barbiturates have effects similar to alcohol on the body systems. Even cold tablets and allergy pills can make you feel weak, dizzy, and drowsy as well as affecting your vision, coordination, and judgment.

Marijuana decreases your ability to see at night and recover from headlight glare. Marijuana users cannot react as quickly as usual, nor operate the ATV as well. Amphetamines or cocaine, while they may increase your attentiveness temporarily, bring on extreme fatigue once they wear off. Furthermore, they produce a mild euphoria, which often causes riders to take foolish risks. Never consume drugs before or while operating an ATV.

Fatigue

Riding an ATV is more tiring than driving a car. Remember that fatigue can affect your ability to control your ATV. Here are some things you can do to keep from getting too tired:

- Protect yourself from the elements. Wind, cold, rain, and heat make you tire quickly. Dress appropriately for the conditions.
- Limit your distance and riding time until you know your limits.
- Take frequent rest breaks. Stop and get off the ATV. No one should go more than one hour without pulling over, stopping, getting off the ATV, and walking around.

Know the Laws

The laws and regulations that control how and where to use your ATV are important for you to be aware of and to follow. They are established for your protection as well as everyone else's. By controlling less responsible riders, the laws and regulations allow others to enjoy the sport. They also help protect the land you ride on and the people who own it. Dealers and ATV clubs can often provide you with a summary of local laws, or direct you to park rangers, game wardens, or other sources who will be glad to help you.

Registration

In many states the laws require that you register your ATV as part of the state's off-highway vehicle registration program. ATV used for agricultural or utility purposes may be subject to different provisions than recreational vehicles. You should check this out when you buy your ATV—your dealer should know the law, and can often help you with registering your vehicle. Fines for riding an unregistered vehicle can be expensive, and you also take the risk of having your ATV impounded. Some states use registration fees to develop riding trails and facilities. So by registering your ATV, you and your friends may be helping to secure and maintain places to ride.

You and the Rest of the World

There is one fundamental factor that controls your riding — access to land. Developing and maintaining riding opportunities means getting along with the rest of the world - private landowners, public land managers, and people you meet on the trails. The better you get along with these people, the easier it will be to locate and preserve good riding areas.

TREAD Lightly!

Riding behavior that harms the land is self-defeating and irresponsible. Learn to protect and preserve your riding areas. In other words, TREAD Lightly!

- Travel only where the motorized vehicles are permitted.
- Respect the rights of hikers, skiers, campers and others to enjoy their activities undisturbed.
- Educate yourself by obtaining travel maps and regulations from public agencies; comply with signs and barriers; and ask owners' permission to cross private property.
- Avoid streams, lake shores, meadows, muddy roads and trails, steep hillsides, and wildlife and livestock.
- Drive (ride) responsibly to protect the environment and preserve opportunities to enjoy your vehicle on wild lands.

Here some tips to help you TREAD Lightly!

- Obtain a travel map from the Forest Service or from other public land agencies. Learn the rules and follow them.
- Keep your ATV quiet. Do not make your exhaust system noisier–there is nothing people dislike more than a loud off-highway vehicle. Do not tamper with the spark arrester.
- Avoid running over young trees, shrubs, and grasses. You will damage or kill them.
- Stay off soft, wet roads and trails readily torn up by vehicles (particularly during hunting seasons). Repairing the damage is expensive.
- Travel around meadows, steep hillsides, stream banks, and lake shores. They are easily scarred by spinning wheels.

- Resist the urge to blaze a new road or trail, or to cut across switchbacks.
- Be courteous when you meet others on the trail. Pull to the side and yield to horseback riders and hikers. It is best to shut off the engine whenever you are near horses — a panicked horse is a danger to you and its rider.
- Stay away from wild animals that are rearing their young or suffering from food shortage.
- Obey gate closures and regulatory signs. Remember, vandalism is costly.
- Stay out of designated wilderness areas. They are closed to all vehicles, even bicycles. Know where your boundaries are.
- Get permission to travel across private land and respect the rights of the landowners.

Future opportunities for exciting travel with your ATV are in your hands, so — TREAD Lightly!

Expanding Your Horizons

How do you find good places to ride?

You can start by talking to you dealer and asking questions such as:

- Where do other customers ride?
- Who owns riding land?
- What are the regulations for use?

ATV clubs provide a way of working together to find good riding areas.

If you are working on your own, topographic maps can be a good way to find open land with suitable trails.

Find out who owns the land and whether they mind you using it. In this way, you can develop a network of good riding areas.

Introduction Part 2

This Practice Guide has several exercises that will help you develop the fundamental skills you need to safely and enjoyably operate your ATV. However, you will need many additional hours of riding before you consider yourself an experienced ATV rider.

Do not attempt these exercises until you have read your owner’s manual and “Part I - Tips for the ATV Rider” portion of this booklet thoroughly. These exercises are designed for unmodified machines with low-pressure knobby tires. Read this guide completely before you start practicing.

This guide contains exercises which should be done by only one rider at a time. Keep practicing until you can do each exercise at least five times in a row without a problem. Be sure to take a break when you get tired. Do not push yourself; when you get tired you can make mistakes. These exercises should take about three to four hours to complete.

About Your ATV And Skills Exercises

Handling characteristics of ATVs vary depending upon basic design and how they are equipped. The exercises in this Practice Guide apply to most ATVs with one exception: ATVs with unlocked differentials. If your ATV has a differential, be sure to lock the rear axle before practicing the exercises in this guide. Refer to your owner's manual for instructions.

ATVs with solid rear axles (and those with locked differentials) turn both rear wheels at the same speed. The technique to use when turning is described on page 19 under "Turning Basics." ATVs with unlocked differentials allow the rear wheels to turn at different speeds. If a rear wheel leaves the ground, it will spin freely. Then when it touches the ground again, it may grab and cause you to lose some control.

Some ATVs are equipped with four-wheel drive. When operating in a four-wheel-drive mode, keep in mind:

- Use of only the front brake or only the rear brake has the effect of braking both the front and rear wheels.
- Abrupt deceleration from shifting to a lower gear (engine braking) will affect both the front and rear wheels.

Consult your owner's manual for more detailed information.

Preparation

Choosing a Practice Area

Choose an open, off-road area (about 100 feet x 200 feet) away from other riders and free of obstructions. The terrain should be flat for Exercises 1, 2, 3, 4, 5, 6, and 9. For Exercises 7 and 8 you will need a hill. The hill should not be very steep and should be easy to climb on foot! Practicing on a hard dirt surface will make it easier for you to learn the basic maneuvers. If you are riding on private property, be sure you have permission from the owner. Do not do these exercises on public roads or paved surfaces. ATVs are designed for off-road use only.

What to Bring

Bring five objects that you can use as markers. Milk cartons or plastic bottles with sand in them work well. Do not use glass bottles or other breakable items. You should also bring a tape measure to mark distances; or at least measure your stride so you can pace off the distances. (One hundred feet is approximately 35 to 40 paces.)

Safety Rules

The practice exercises in this guide can be hazardous if you do not follow the instructions provided. Also follow these safety rules:

- Wear proper protective clothing. This includes an approved motorcycle helmet, over-the-ankle boots, gloves, eye protection, a long-sleeved shirt, and long pants.
- Inspect your ATV before you begin. Consult your owner's manual.
- Check the practice area for potential hazards.
- Bring an experienced friend along to help if anything goes wrong, and to critique your progress.
- Do not mix alcohol or other drugs with ATV riding.
- DO NOT carry passengers.
- Pay attention to additional safety tips found throughout this guide.

How To Use This Guide

This guide is divided into three levels:

Level 1 – Basics of ATV Riding
Level 2 – Elementary Maneuvers
Level 3 – Intermediate Maneuvers

Even if you have been an ATV rider for more than three months, be sure you have mastered the Level 1 drills before you move on to the other levels.

Level 1 – Drills

Level 1 drills cover the basics of ATV riding. (If the terrain you are riding on has ruts or other obstacles, do Exercise 9 following Exercise 3.)

Exercise 1 – Controls

- Location and operation

Exercise 2 – Braking

- Straight path
- In a turn

Exercise 3 – Turning

- Large oval
- Small circles
- Figure 8

Level 2 Drills

Level 2 drills are for practicing elementary maneuvers. All ATV riders should practice these drills before going on to Level 3.

Exercise 4 – Sharp Turns

Exercise 5 – Quicker Turns

Exercise 6 – Quick Stops

- Straight path
- In a turn

Exercise 7 – Hills

- Climbing, turning, and descending
- Stopping while descending

Level 3 Drills

Level 3 drills are for practicing intermediate maneuvers.

Exercise 8 – Traversing Hills

Exercise 9 – Riding Over Obstacles

Exercise 1 – Controls

Objective: To mount and sit on the ATV correctly, locate and operate the controls, and dismount.

Skills: Familiarization and operation of controls.

Directions

Drill 1: Take out your owner's manual and locate your ATV's parking brake. Set the parking brake (if equipped). ATV controls may vary from vehicle to vehicle.

Your ATV may not have all of the following controls, but familiarize yourself with the controls it does have. Locate the following controls as you consult your owner's manual:

- Parking brake
- Throttle (full, half, quarter)
- Engine stop switch
- Choke
- Reverse gear lever (if equipped)
- Hand brake, foot brake
- Ignition switch
- Fuel supply valve
- Transmission hi/lo lever (if equipped)
- Starter (pull, kick, electric)
- Clutch lever
- Shift lever

Drill 2: Mount the ATV, taking care not to step on the shifter. Maintain proper posture and identify and operate each control. Without looking down, try mounting your ATV while remembering to keep your head and eyes looking straight ahead. Be sure you learn the shift pattern for your ATV. Consult your owner's manual.

Tips

- Make sure all the controls work properly. Use your owner's manual and the Pre-Ride Inspection section in this booklet to help you check out your ATV.
- Remember that controls may vary from model to model and you should do this exercise whenever you ride a different ATV.

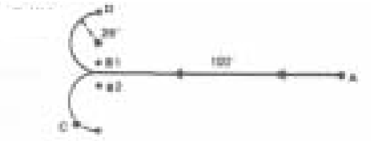
Watch For

- Using the left brake lever as a clutch.
- Shifting to a lower gear instead of to a higher gear and vice versa.
- Trouble changing the hi/lo lever or finding reverse.
- Awkwardness in reaching controls.

Suggestions

- Motorcyclists must modify old reflexes for controls and turning.
- Shift patterns vary among ATVs. Be sure you know the shift pattern of your ATV.
- Consult the owner's manual. Try rocking the ATV slightly while moving the lever.
- Reposition handlebars or controls for ease of operation and check adjustment as stated in the owner's manual.

Exercise 2 – Braking



Objective: To use the brakes properly to bring your ATV to a smooth, safe stop.

Skills: Starting out, shifting, stopping, turning.

Directions

Drill 1: Braking – Straight path

Put marker A down to indicate your starting point. Then place markers B1 and B2 100 feet down a straight path. Start your ATV and ride straight toward the second markers. Begin to slow down before you reach markers B1-B2. Come to a smooth, non-skidding stop with your front tires between markers B1 and B2. Practice this a few times in first gear. Then try it in second gear. Ride straight toward B1-B2, accelerate and shift into second. Begin to slow down and shift back to first gear BEFORE you reach markers B1 and B2. Come to a smooth, non-skidding stop with your front tires between markers B1 and B2.

Drill 2: Braking – In a turn

Place markers C and D as indicated in the diagram. Start at marker A and ride toward B1-B2. Accelerate and shift into second. Begin to slow down and shift back to first gear as you go through markers B1-B2. Once through the markers, turn the handlebars to the left so that you make a gradual turn and come to a smooth, non-skidding stop with your front tires next to marker C. Practice this to the right with your front tires stopping next to marker D. As in Drill 1, practice a few times in second gear; then practice in higher gears until you can stop smoothly and consistently at markers C and D.

Tips

- Keep your feet on the footrests at all times.
- Keep your head and eyes up.
- Look straight ahead when stopping in a straight line. Look around the turn as you slow down in the curve.
- Shift to a lower gear as you decelerate.

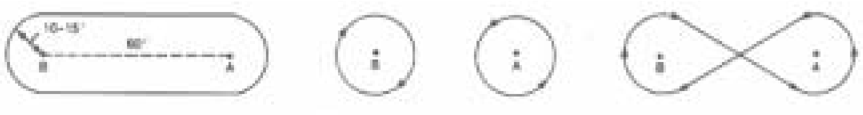
Watch For

- Overshooting the final marker.
- ATV turning to one side during braking in a straight line.
- Rear end sliding or skidding.
- ATV turning too wide in the curve.
- Rough or inconsistent shifting.

Suggestions

- Begin to slow down earlier.
- Keep the handlebars straight and look ahead.
- Begin to slow down earlier. Apply brake pressure more gradually.
- Steer with the handlebars. Move forward and lean in slightly. Begin to slow down earlier.
- Move foot clear of the shift pedal after each shift. Release the throttle before each shift.

Exercise 3 – Turning



Objective: To demonstrate basic turning skills by shifting your weight properly to maintain balance and avoid the possibility of losing control of your ATV.

Skills: Throttle control, shifting weight, turning, braking.

Directions

Drill 1: Turning – Large oval

Place markers A and B 60 feet apart as indicated in the diagram. Ride around the outside of the markers so that you have made a large oval. Ride to the left a few times and then ride around to the right. Do not shift gears during the exercise.

Drill 2: Turning – Small circles

Now use those same markers as the center of two large circles. Ride around marker A to the left. Continue riding around to the left and decrease the radius of the circle so that you are making tighter turns, then ride around marker B to the right and practice decreasing your turning radius.

Drill 3: Turning – Figure 8

Combine the circles around marker A and marker B so that you are doing a large figure 8. As your skills increase, move the marker closer together (25 feet apart) so that the figure 8 becomes smaller.

Tips

- Keep your feet on the footrests at all times.
- Look ahead, concentrating on your intended path of travel.
- Slow down before the turn and gently increase the throttle as you exit the turn.
- Use body positioning (leaning in) to help maintain balance during turns.
- Move your body weight forward and to the inside of the turn.
- Turn the handlebars while looking in the direction of the turn.

Watch For

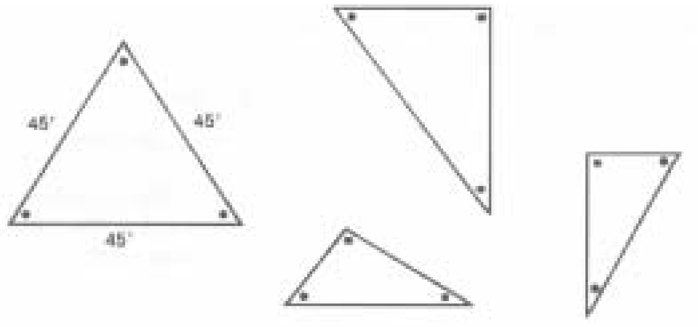
- ATV tipping.
- ATV turning wide.

Suggestions

- Lean your body farther into the turn.
- Slow down. Put more weight up front, use more effort to turn the handlebars, and look in the direction of the turn.

NOTE: If the terrain you are using has ruts or other obstacles, include Exercise 9 after Exercise 3.

Exercise 4 – Sharp Turns



Objective: To make sharp turns without tipping the ATV by coordinating braking, weight shifting, and throttle control to maneuver the ATV in tighter turns.

Skills: Shifting weight, turning, throttle control, braking.

Directions

Drill: Place three markers down to create a triangle with sides of equal length. The sides should be at least 45 feet long. Ride around the outside of the triangle going to the left. Stay within three feet of the triangular path. After this is mastered, ride the triangle to the right. Then change the sides and angles of the triangle and practice with each new triangle.

Tips

- Keep your feet on the footrests at all times.
- Slow down before the turn.
- Look through the turn at your intended path of travel.
- Gently increase the throttle as you exit the turn.
- Lean in and turn the handlebars in the direction of the turn.

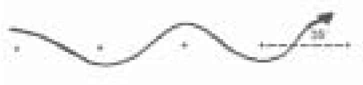
Watch For

- ATV turning wide.

Suggestions

- Slow down more prior to the turn.
- Lean into the turn more.
- Apply throttle gradually to avoid unweighting the front end.
- Bend your elbows and lean forward a bit to maintain weight on the front wheels.

Exercise 5 – Quicker Turns



Objective: To make quicker turns to avoid an obstacle by coordinating speed, body position, and weight shift to help you make quick directional changes.

Skills: Shifting weight, steering with the throttle, changing direction.

Directions

Drill: Put five markers down at 35-foot intervals. Travel to the left of the first marker and then to the right of the second and continue until you reach the last marker. At first, practice at slow speeds, then gradually increase your speed. Do not exceed second gear. After you have mastered this, move the markers closer together. Do not move them closer than 18 feet apart.

Tips

- Keep your feet on the footrests at all times.
- Shift your weight quickly to initiate the turn. To shift your weight effectively, rise up slightly standing on the footrests, quickly move your hips, lean your body to the inside of each turn.
- To go left, apply a slight left turn to the front wheels, quickly lean left, and apply a short burst of throttle. To go right, do the opposite.
- Do not look at the next marker you are approaching. Look ahead; do not fixate on a marker.

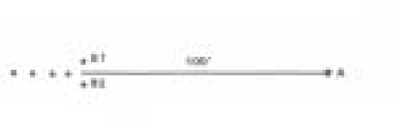
Watch For

- Running over markers as you try to go around.

Suggestions

- Swing wider as you go around the marker, and shift your weight more.
- Use a quicker burst of throttle but not enough to un-weight the front end.

Exercise 6 – Quick Stops



Objective: To make a smooth, safe stop in the shortest possible distance. Practicing these drills will help enable you to stop quickly should an obstacle suddenly appear in your path.

Skills: Shifting gears, stopping, braking while turning.

Directions

Drill 1: Quick Stops – Straight path

Place markers A, B1, and B2 as indicated in the diagram. Start at marker A and ride toward B1-B2 in second gear. Be sure to maintain your speed until you pass B1-B2. When the ATV PASSES markers B1-B2, stop as quickly and as safely as you can. Notice where you stop. Put some sort of marker down there (a small rock perhaps). Do it again and stop smoothly and quickly, but in a shorter distance. Make your first two attempts in second gear. Remember to begin braking and to shift back to first gear only AFTER you have passed markers B1-B2. Shift to higher gears when you have mastered the exercise in second gear.

Drill 2: Quick Stops – In a turn

Place markers C and D as indicated in the diagram. Start at marker A and ride toward B1-B2. When you reach B1-B2, veer left and ride in second gear toward C. When you PASS marker C, stop as quickly and safely as you can. Note where you stop. Put some sort of marker down. Do it repeatedly and stop smoothly and quickly, but in a shorter distance. Make your first two attempts in second gear. Remember to begin braking and to shift back to first gear only AFTER you have passed marker C. Shift to third gear when you have mastered the exercise in second gear. Practice this to the right and stop quickly after you have PASSED marker D.

NOTE: It is best to avoid excessive braking in a turn, but certain conditions may require you to brake while in a turn.

Tips

- Keep your feet on the footrests at all times.
- Keep your head and eyes up.
- If you accidentally lock the wheels, release the brakes momentarily and reapply the brakes more gradually.

Watch For

- ATV swerving to one side.
- Rear end sliding or skidding.
- Front end sliding or skidding.

Suggestions

- Center your body on the ATV. Look where you want to go.
- Apply less rear brake pressure. Shift to a lower gear more smoothly.
- Apply less front brake pressure.

Exercise 7 – Hills

Objective: To ride up, turn around, and ride down a hill by using the proper techniques for safely making a U-turn.

Skills: Maintaining balance, shifting weight, application of brakes, throttle control.

Directions

Make sure your parking brake is in working order before doing this exercise.

Drill 1: Climbing, turning, and descending

For this exercise, select an easy hill, free of obstructions (easy to climb on foot). Start your approach to the hill by accelerating before the base of the hill. Shift into a lower gear at the base of the hill, if necessary, to maintain momentum while climbing the hill. Turn the ATV to the left, in an arc, before you reach the top. Keep turning, using your remaining momentum until you are facing downhill. Descend the hill in a lower gear and as you descend, slow down by applying the brakes. Then practice to the right.

If you are riding uphill and lose all forward momentum:

- Keep your weight uphill, and apply the brakes to come to a stop. Never allow the ATV to roll backward.
- Apply the parking brake while keeping your weight uphill.
- Dismount on the uphill side or to a side if pointed straight uphill, and follow the procedures described in your owner’s manual.

Do not attempt to ride backward down a hill. Should you begin rolling backward, do not apply the rear brake abruptly. Using the rear brake only or abruptly could cause the ATV to roll over backward.

If you begin rolling backward follow these steps:

- Keep your weight uphill, and apply the front brake. If your ATV has linked brakes or if you are in 4WD, follow the procedures described in your owner’s manual.
- When you have come to a complete stop, apply the rear brake. Then apply the parking brake and dismount on the uphill side. If pointed straight uphill, dismount to either side and follow the procedures described in your owner’s manual.
- If the ATV continues to roll backward, dismount to the uphill side immediately.

Drill 2: Stopping while descending

As you descend the hill, slow down by gradually applying the brake(s) and then stop.

Tips: Climbing

- Some hills are too steep for your abilities. Do not exceed your capabilities.
- Some hills are too steep for your ATV regardless of your abilities.
- Keep both feet firmly on the footrests.
- Shift your body weight forward on the seat as you go up the hill. For steeper hills, lean forward more, move up on the seat, or stand and position your torso over the front wheels.
- As you near the top and turn, shift your body weight to the uphill side for balance by leaning into the hill.

Tips: Descending

- To go downhill, shift your weight back. On steeper downward slopes, straighten but do not lock your knees and elbows. Then bend forward sharply at the waist so that your posterior is over the back of the seat.
- Use the brake(s) to slow you down as you descend the hill and always descend in a low gear.
- The key to successfully performing this exercise is to shift your weight smoothly from forward (as you climb) to the uphill side (as you turn) and to the rear

(as you descend). For smooth weight shifts, rise up slightly off the seat.

Watch For

- ATV losing all momentum going up the hill.
- ATV descending too quickly.
- Wheels locking, creating a slide.
- ATV rolling backward while you are on it.

Suggestions

- Approach at a higher speed. Do not attempt to turn your ATV if you do not have the momentumto make the 180-degree turn. Apply the brake(s) before you lose speed. Do not let the ATV roll backward.
- Maintain smooth braking. Use a lower gear. Do not apply the throttle.
- Release brakes and then immediately reapply brakes gradually.
- DO NOT LET THE ATV ROLL BACKWARD ON A HILL. If your ATV has an independent front brake, you can try to stop the ATV by using only the front brake. Move your body weight forward and use the front brake to slow the ATV to a stop. If the front brake does not slow the ATV, dismount to the side immediately. Do not attempt to ride backward down a hill. Using the rear brake only or abruptly could cause you to roll over backward.

Exercise 8 – Traversing Hills

Objective: To use the correct technique to ride across a hill so that you will not lose your balance or directional control.

Skills: Shifting weight, maintaining balance, throttle control.

Directions

Drill: For this exercise, select an easy hill free of obstructions. Start your approach and accelerate before the base of the hill. Shift into a lower gear at the base if necessary to maintain momentum while climbing the hill. Turn the ATV to the left, ride across the slope, and then ride down the hill. Repeat the exercise to the right.

Reminder: Traversing hills is tricky, so practice this carefully. Remember, DO NOT LET THE ATV ROLL BACKWARD.

Tips

- Keep both feet on the footrests.
- Apply the same principles for climbing and descending as you did in the previous exercise.
- Exaggerate your weight shifts.
- If the ATV starts to turn downhill as

you traverse the slope, turn the front wheels slightly uphill to keep the ATV going straight across the hill.

- If the ATV begins to tip, turn the front wheels downhill if the terrain allows you to do so. If the terrain prohibits your turning downhill, and shifting weight into the hill does not help, then dismount on the uphill side immediately.

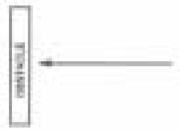
Watch For

- ATV losing momentum going uphill.
- Front wheels lifting as you climb the hill.
- ATV tipping as you traverse the hill or turn.
- Rear end sliding downhill while traversing.
- Excessive jarring as front wheels encounter bumps on descent.

Suggestions

- Approach at a slightly higher speed.
- Lean forward more; move way up on the seat or stand and position your torso over the front wheels. Do not accelerate as quickly up the slope.
- Lean into the hill more. Move off the seat toward the uphill side. Weight the uphill footrest.
- Avoid abrupt changes in throttle position that could cause the rear wheels to lose traction.
- Shift more weight to the rear. Descend more slowly.

Exercise 9 – Riding Over Obstacles



Objective: To use the proper technique to safely ride over obstacles which you cannot avoid.

Skills: Surmounting obstacles, shifting weight.

Directions

Drill: Choose small obstacles for your initial practice. A small rut, mound, or small log will work fine. Approach the obstacle at walking speed and as close to a 90-degree angle as possible. Rise up slightly on the footrests and apply a small amount of throttle as the front wheels reach the obstacle. Lean forward and release the throttle after the front wheels clear the obstacle. Return to your normal riding position after the rear wheels clear the obstacle.

NOTE: If the terrain you are using has ruts or other obstacles, include Exercise 9 after Exercise 3.

Tips

- Be sure to stand on the footrests when performing the exercise.
- Be sure to bend your elbows and knees so that you can use them as shock absorbers.
- Mounds and ruts are considered obstacles.
- If only one front or rear wheel goes over the obstacle, be prepared to shift your weight and maintain balance as the ATV leans to one side.

Watch For

- Excessive jarring from impact.
- ATV failing to continue straight over the obstacle: i.e., as front wheels clear, the ATV turns to one side.
- Front wheels pushing the obstacle rather than crossing over it.
- Rear wheels hitting the obstacle with excessive impact.

Suggestions

- Bend knees and arms more.
- Keep a firm grip on the handlebars (even though your arms are bent) to keep the ATV pointed straight ahead.
- Apply a small amount of throttle as the front wheels meet the obstacle. Release the throttle as soon as the front wheels have gone over the obstacle.
- Lean forward slightly once the front wheels have gone over the obstacle in order to un-weight the rear wheels. The throttle must be released before the rear wheels hit.

From the ATV Safety Institute

Videos, Publications and More

Parents, Youngsters and All-Terrain Vehicles

Especially developed for parents who are teaching their youngsters, this booklet provides important safety information and tips on learning to ride an ATV. *Parents, Youngsters and All-Terrain Vehicles* is designed to help parents determine whether their youngsters are ready to ride an ATV. It contains easy-to-use readiness guidelines and checklists for parents to review with their youngsters. It also covers pre-operating and operating procedures, protective gear, riding techniques, and many other safety points.

"ATV Rally" Interactive Riding Game

Now you can boot up your computer to try your skills in this CD-ROM-based ride that features six different trails in woods, sand, and mountains with surprises and obstacles to test your awareness and reaction time. See what it takes to ride safe from the comfort of your computer station.

Videos, Publications and More

“Ride Safe, Ride Smart” Video

This nine-minute tape is a rider-friendly look at how to get a proper start in ATV riding. It profiles two families: one who rides for recreation only, the other who uses their ATVs first for working the farm, then as camping and trail riding machines. Both sets of parents lead by example, emphasizing riding an ATV that is right for your age, wearing proper protective gear and respecting the environment. They also recommend taking an ATV *RiderCourse*$^{\text{SM}}$ to get the most from your ATV, enjoy the opportunity to meet other enthusiasts, and find out about the best places to ride. Single copies of *Parents, Youngsters and All-Terrain Vehicles* and “Ride Safe, Ride Smart” are available free by contacting:

ATV Safety Institute
2 Jenner Street, Suite 150
Irvine, CA 92618-3806
(949) 727-3727

To purchase large quantities of the publication, contact ASI for prices.
To order the CD-ROM, call (877) 806-7813.

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ATV
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Institute
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Irvine, California 92618-3806

(949) 727-3727

www.atvsafety.org

For the rider training location
nearest you call: (800) 887-2887

U.S. Version

ATTACHMENT E DAILY SAFETY MEETING RECORD FORM

Ecology and Environment, Inc.
DAILY SAFETY MEETING RECORD

General Information

Project: Red Devil Mine Baseline Monitoring

Project No: 001096-070

Project Location: Red Devil Mine, Alaska

Date: Time: Weather:

Specific Location:

Planned Activities:

Safety Topics Presented

Chemical Hazards Update:

Physical Hazards Update:

Radiation Hazards Update:

Review of Previous Monitoring Results:

Protective Clothing/Equipment Modifications:

Special Equipment/Procedures:

Emergency Procedures:

Ecology and Environment, Inc.
DAILY SAFETY MEETING RECORD

ATTENDEES

Meeting shall be attended by all personnel who will be working within the exclusion area. Daily informal update meetings will be held prior to work and when site tasks and/or conditions change.

Name (Printed)	Name (Signature)	Date	Representing (Company/Agency)
Meeting Conducted By:			

Additional Topics/Observations:

Team Members' Comments/Suggestions:

Gasoline (PAHs)

Synonyms & Trade Names
Motor fuel, Motor spirits, Natural gasoline, Petrol [Note: A complex mixture of volatile hydrocarbons (paraffins, cycloparaffins, and aromatics).]

CAS No. 8006-61-9	**RTECS No.** LX3300000	**DOT ID & Guide** 1203 128
	Conversion 1 ppm = 4.5 mg/m^3(approx)	**IDLH** Ca [N.D.] See: IDLH INDEX

Exposure Limits

NIOSH REL
: Ca See Appendix A

OSHA PEL
†: none

Measurement Methods

OSHA PV2028
See: NMAM or OSHA Methods

Physical Description
Clear liquid with a characteristic odor.

MW: 110 (approx)	**BP:** 102°F	**FRZ:** ?	**Sol:** Insoluble	**VP:** 38-300 mmHg	**IP:** ?
Sp.Gr(60°F): 0.72-0.76	**Fl.P:** -45°F	**UEL:** 7.6%	**LEL:** 1.4%		

Class IB Flammable Liquid: Fl.P. below 73°F and BP at or above 100°F.

Incompatibilities & Reactivities
Strong oxidizers such as peroxides, nitric acid & perchlorates

Exposure Routes
inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms
irritation eyes, skin, mucous membrane; dermatitis; headache, lassitude (weakness, exhaustion), blurred vision, dizziness, slurred speech, confusion, convulsions; chemical pneumonitis (aspiration liquid); possible liver, kidney damage; [potential occupational carcinogen]

Target Organs
Eyes, skin, respiratory system, central nervous system, liver, kidneys

Cancer Site
[in animals: liver & kidney cancer]

Personal Protection / Sanitation	**First Aid**
(See protection codes) **Skin:** Prevent skin contact **Eyes:** Prevent eye contact **Wash skin:** When contaminated **Remove:** When wet (flammable) **Change:** No recommendation **Provide:** Eyewash, Quick drench	(See procedures) **Eye:** Irrigate immediately **Skin:** Soap flush immediately **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

NIOSH

At concentrations above the NIOSH REL, or where there is no REL, at any detectable concentration:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister

Any appropriate escape-type, self-contained breathing apparatus

Antimony

Synonyms & Trade Names
Antimony metal, Antimony powder, Stibium

CAS No.	**RTECS No.**	**DOT ID & Guide**
7440-36-0	CC4025000	1549 157 (inorganic compounds, n.o.s.) 2871 170 (powder) 3141 157 (inorganic liquid compounds, n.o.s.)
Formula	**Conversion**	**IDLH**
Sb		50 mg/m^3 (as Sb) See: 7440360

Exposure Limits	**Measurement Methods**
NIOSH REL *: TWA 0.5 mg/m^3 [*Note: The REL also applies to other	**NIOSH** 7301 , 7303 , P&CAM261 (II-4); **OSHA** ID121 , ID125G ,ID206 See: NMAM or OSHA Methods

antimony compounds (as Sb).]

OSHA PEL
*: TWA 0.5 mg/m^3 [*Note: The PEL also applies to other antimony compounds (as Sb).]

Physical Description
Silver-white, lustrous, hard, brittle solid; scale-like crystals; or a dark-gray, lustrous powder.

MW: 121.8	**BP:** 2975°F	MLT: 1166°F	**Sol:** Insoluble	**VP:** 0 mmHg (approx)	**IP:** NA
Sp.Gr: 6.69	**Fl.P:** NA	**UEL:** NA	**LEL:** NA		

Noncombustible Solid in bulk form, but a moderate explosion hazard in the form of dust when exposed to flame.

Incompatibilities & Reactivities
Strong oxidizers, acids, halogenated acids [Note: Stibine is formed when antimony is exposed to nascent (freshly formed) hydrogen.]

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
irritation eyes, skin, nose, throat, mouth; cough; dizziness; headache; nausea, vomiting, diarrhea; stomach cramps; insomnia; anorexia; unable to smell properly

Target Organs
Eyes, skin, respiratory system, cardiovascular system

Personal Protection/Sanitation
(See protection codes)
Skin: Prevent skin contact
Eyes: Prevent eye contact
Wash skin: When contaminated
Remove: When wet or contaminated
Change: Daily

First Aid
(See procedures)
Eye: Irrigate immediately
Skin: Soap wash immediately
Breathing: Respiratory support
Swallow: Medical attention immediately

Respirator Recommendations

NIOSH/OSHA

Up to 5 mg/m^3:

(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering facepieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, P100.

Click here for information on selection of N, R, or P filters.

(APF = 10) Any supplied-air respirator

Up to 12.5 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.

Up to 25 mg/m^3:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 50 mg/m^3:

(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Important additional information about respirator selection

Arsenic (organic compounds, as As)

Synonyms & Trade Names

Synonyms vary depending upon the specific organic arsenic compound.

CAS No.	RTECS No.	DOT ID & Guide
	Conversion	**IDLH** N.D. See: IDLH INDEX

Exposure Limits	**Measurement Methods**
NIOSH REL : none	**NIOSH** 5022 See: NMAM or OSHA Methods

OSHA PEL
: TWA 0.5 mg/m^3

Physical Description
Appearance and odor vary depending upon the specific organic arsenic compound.

Properties vary depending upon the specific organic arsenic compound.

Incompatibilities & Reactivities
Varies

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
In animals: irritation skin, possible dermatitis; resp distress; diarrhea; kidney damage; muscle tremor, convulsions; possible gastrointestinal tract, reproductive effects; possible liver damage

Target Organs
Skin, respiratory system, kidneys, central nervous system, liver, gastrointestinal tract, reproductive system

Personal Protection/Sanitation (See protection codes) Recommendations regarding personal protective clothing vary depending upon the specific compound. Recommendations regarding eye protection vary depending upon the specific compound. Recommendations regarding washing the skin vary depending upon the specific compound. Recommendations regarding the removal of personal protective clothing that becomes wet or contaminated vary depending upon the specific compound. Recommendations regarding the daily changing of personal protective clothing vary depending upon the specific compound. Recommendations regarding the need for eyewash or quick drench facilities vary depending upon the specific compound.	**First Aid** (See procedures) **Eye:** Irrigate immediately **Skin:** Soap wash immediately **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

Not available.

Asbestos

Synonyms & Trade Names
Actinolite, Actinolite asbestos, Amosite (cummingtonite-grunerite), Anthophyllite, Anthophyllite asbestos, Chrysotile, Crocidolite (Riebeckite), Tremolite, Tremolite asbestos

CAS No. 1332-21-4	**RTECS No.** CI6475000	**DOT ID & Guide** 2212 171 (blue, brown) 2590 171 (white)
Formula Hydrated mineral silicates	**Conversion**	**IDLH** Ca [N.D.] See: IDLH INDEX

Exposure Limits

NIOSH REL
: Ca See Appendix A See Appendix C

OSHA PEL
: [1910.1001] [1926.1101] See Appendix C

Measurement Methods

NIOSH 7400 , 7402 ;
OSHA ID160 , ID191
See: NMAM or OSHA Methods

Physical Description
White or greenish (chrysotile), blue (crocidolite), or gray-green (amosite) fibrous, odorless solids.

MW: Varies	**BP:** Decomposes	MLT: 1112°F (Decomposes)	**Sol:** Insoluble	**VP:** 0 mmHg (approx)	**IP:** NA
Sp.Gr: ?	**Fl.P:** NA	**UEL:** NA	**LEL:** NA		

Noncombustible Solids

Incompatibilities & Reactivities
None reported

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
Asbestosis (chronic exposure): dyspnea (breathing difficulty), interstitial fibrosis, restricted pulmonary function, finger clubbing; irritation eyes; [potential occupational carcinogen]

Target Organs
respiratory system, eyes

Cancer Site
[lung cancer]

Personal Protection/Sanitation
(See protection codes)
Skin: Prevent skin contact
Eyes: Prevent eye contact
Wash skin: Daily
Remove: No recommendation
Change: Daily

First Aid
(See procedures)
Eye: Irrigate immediately

Breathing: Fresh air

Respirator Recommendations

(See Appendix E)

NIOSH

At concentrations above the NIOSH REL, or where there is no REL, at any detectable concentration:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Chromium metal

Synonyms & Trade Names
Chrome, Chromium

CAS No. 7440-47-3	**RTECS No.** GB4200000	**DOT ID & Guide**
Formula Cr	**Conversion**	**IDLH** 250 mg/m^3 (as Cr) See: 7440473

Exposure Limits **NIOSH REL** : TWA 0.5 mg/m^3 See Appendix C **OSHA PEL** *: TWA 1 mg/m^3 See Appendix C [*Note: The PEL also applies to insoluble chromium salts.]	**Measurement Methods** **NIOSH** 7024 , 7300 , 7301 , 7303 , 9102 ; **OSHA** ID121 , ID125G See: NMAM or OSHA Methods

Physical Description
Blue-white to steel-gray, lustrous, brittle, hard, odorless solid.

MW: 52.0	**BP:** 4788°F	MLT: 3452°F	**Sol:** Insoluble	**VP:** 0 mmHg (approx)	**IP:** NA
Sp.Gr:	**Fl.P:**	**UEL:**	**LEL:**		

7.14	NA	NA	NA		

Noncombustible Solid in bulk form, but finely divided dust burns rapidly if heated in a flame.

Incompatibilities & Reactivities

Strong oxidizers (such as hydrogen peroxide), alkalis

Exposure Routes

inhalation, ingestion, skin and/or eye contact

Symptoms

irritation eyes, skin; lung fibrosis (histologic)

Target Organs

Eyes, skin, respiratory system

Personal Protection/Sanitation

(See protection codes)

Skin: No recommendation
Eyes: No recommendation
Wash skin: No recommendation
Remove: No recommendation
Change: No recommendation

First Aid

(See procedures)

Eye: Irrigate immediately
Skin: Soap wash
Breathing: Respiratory support
Swallow: Medical attention immediately

Respirator Recommendations

NIOSH

Up to 2.5 mg/m^3:

(APF = 5) Any quarter-mask respirator.

Click here for information on selection of N, R, or P filters.*

Up to 5 mg/m^3:

(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering facepieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, P100.

Click here for information on selection of N, R, or P filters.*

(APF = 10) Any supplied-air respirator*

Up to 12.5 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode*

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.*

Up to 25 mg/m^3:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter*

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 250 mg/m^3:

(APF = 2000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Cobalt metal dust and fume (as Co)

Synonyms & Trade Names
Cobalt metal dust, Cobalt metal fume

CAS No.	**RTECS No.**	**DOT ID & Guide**
7440-48-4	GF8750000	

Formula	**Conversion**	**IDLH**
Co		20 mg/m³ (as Co) See: 7440484

Exposure Limits

NIOSH REL
: TWA 0.05 mg/m³

OSHA PEL
†: TWA 0.1 mg/m³

Measurement Methods

NIOSH 7027, 7300, 7301, 7303, 9102;
OSHA ID121, ID125G, ID213
See: NMAM or OSHA Methods

Physical Description
Odorless, silver-gray to black solid.

MW:	**BP:**	MLT:	**Sol:**	**VP:**	**IP:**
58.9	5612°F	2719°F	Insoluble	0 mmHg (approx)	NA

Sp.Gr:	**Fl.P:**	**UEL:**	**LEL:**
8.92	NA	NA	NA

Noncombustible Solid in bulk form, but finely divided dust will burn at high temperatures.

Incompatibilities & Reactivities

Strong oxidizers, ammonium nitrate

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
Cough, dyspnea (breathing difficulty), wheezing, decreased pulmonary function; weight loss; dermatitis; diffuse nodular fibrosis; resp hypersensitivity, asthma

Target Organs
Skin, respiratory system

Personal Protection/Sanitation	First Aid
(See protection codes) **Skin:** Prevent skin contact **Eyes:** No recommendation **Wash skin:** When contaminated **Remove:** When wet or contaminated **Change:** Daily	(See procedures) **Eye:** Irrigate immediately **Skin:** Soap wash **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

NIOSH

Up to 0.25 mg/m^3:

(APF = 5) Any quarter-mask respirator.

Click here for information on selection of N, R, or P filters.

Up to 0.5 mg/m^3:

(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering facepieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, P100.

Click here for information on selection of N, R, or P filters.*

(APF = 10) Any supplied-air respirator*

Up to 1.25 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode*

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.*

Up to 2.5 mg/m^3:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 20 mg/m^3:

(APF = 2000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Lead

Synonyms & Trade Names
Lead metal, Plumbum

CAS No.	**RTECS No.**	**DOT ID & Guide**
7439-92-1	OF7525000	

Formula	**Conversion**	**IDLH**
Pb		100 mg/m³ (as Pb) See: 7439921

Exposure Limits

NIOSH REL
*: TWA (8-hour) 0.050 mg/m³ See Appendix C [*Note: The REL also applies to other lead compounds (as Pb) -- see Appendix C.]

OSHA PEL
*: [1910.1025] TWA 0.050 mg/m³ See Appendix C [*Note: The PEL also applies to other lead compounds (as Pb) -- see Appendix C.]

Measurement Methods

NIOSH 7082 , 7105 , 7300 ,7301 , 7303 , 7700 , 7701 ,7702 , 9100 , 9102 , 9105 ;
OSHA ID121 , ID125G , ID206
See: NMAM or OSHA Methods

Physical Description
A heavy, ductile, soft, gray solid.

MW:	**BP:**	MLT:	**Sol:**	**VP:**	**IP:**
207.2	3164°F	621°F	Insoluble	0 mmHg (approx)	NA

Sp. Gr:	**Fl. P:**	**UEL:**	**LEL:**		
11.34	NA	NA	NA		

Noncombustible Solid in bulk form.

Incompatibilities & Reactivities
Strong oxidizers, hydrogen peroxide, acids

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
lassitude (weakness, exhaustion), insomnia; facial pallor; anorexia, weight loss, malnutrition; constipation, abdominal pain, colic; anemia; gingival lead line; tremor; paralysis wrist, ankles; encephalopathy; kidney disease; irritation eyes; hypertension

Target Organs
Eyes, gastrointestinal tract, central nervous system, kidneys, blood, gingival tissue

Personal Protection/Sanitation	**First Aid**
(See protection codes) **Skin:** Prevent skin contact **Eyes:** Prevent eye contact **Wash skin:** Daily **Remove:** When wet or contaminated **Change:** Daily	(See procedures) **Eye:** Irrigate immediately **Skin:** Soap flush promptly **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

(See Appendix E)

NIOSH/OSHA

Up to 0.5 mg/m^3:

(APF = 10) Any air-purifying respirator with an N100, R100, or P100 filter (including N100, R100, and P100 filtering facepieces) except quarter-mask respirators.

Click here for information on selection of N, R, or P filters.

(APF = 10) Any supplied-air respirator

Up to 1.25 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.

Up to 2.5 mg/m^3:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 50 mg/m^3:

(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode

Up to 100 mg/m^3:

(APF = 2000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Mercury compounds [except (organo) alkyls] (as Hg)

Synonyms & Trade Names

Mercury metal: Colloidal mercury, Metallic mercury, Quicksilver
Synonyms of "other" Hg compounds vary depending upon the specific compound.

CAS No.	RTECS No.	DOT ID & Guide
7439-97-6 (metal)	OV4550000 (metal)	2809 172 (metal)
Formula	**Conversion**	**IDLH**
Hg (metal)		10 mg/m^3 (as Hg) See: 7439976

Exposure Limits

NIOSH REL
:
Hg Vapor: TWA 0.05 mg/m^3 [skin]

Measurement Methods

NIOSH 6009 ;
OSHA ID140
See: NMAM or OSHA Methods

Other: C 0.1 mg/m^3 [skin]

OSHA PEL
†: TWA 0.1 mg/m^3

Physical Description
Metal: Silver-white, heavy, odorless liquid. [Note: "Other" Hg compounds include all inorganic & aryl Hg compounds except (organo) alkyls.]

MW: 200.6	**BP:** 674°F	**FRZ:** -38°F	**Sol:** Insoluble	**VP:** 0.0012 mmHg	**IP:** ?
Sp.Gr: 13.6 (metal)	**Fl.P:** NA	**UEL:** NA	**LEL:** NA		

Metal: Noncombustible Liquid

Incompatibilities & Reactivities
Acetylene, ammonia, chlorine dioxide, azides, calcium (amalgam formation), sodium carbide, lithium, rubidium, copper

Exposure Routes
inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms
irritation eyes, skin; cough, chest pain, dyspnea (breathing difficulty), bronchitis, pneumonitis; tremor, insomnia, irritability, indecision, headache, lassitude (weakness, exhaustion); stomatitis, salivation; gastrointestinal disturbance, anorexia, weight loss; proteinuria

Target Organs
Eyes, skin, respiratory system, central nervous system, kidneys

Personal Protection/Sanitation (See protection codes) **Skin:** Prevent skin contact **Eyes:** No recommendation **Wash skin:** When contaminated **Remove:** When wet or contaminated **Change:** Daily	**First Aid** (See procedures) **Eye:** Irrigate immediately **Skin:** Soap wash promptly **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

Mercury vapor:

NIOSH

Up to 0.5 mg/m^3:

(APF = 10) Any chemical cartridge respirator with cartridge(s) providing protection against the compound of concern†

(APF = 10) Any supplied-air respirator

Up to 1.25 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with cartridge(s) providing protection against the compound of concern†(canister)

Up to 2.5 mg/m³:

(APF = 50) Any chemical cartridge respirator with a full facepiece and cartridge(s) providing protection against the compound of concern†

(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern†

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and cartridge(s) providing protection against the compound of concern(canister)

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 10 mg/m³:

(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern

Any appropriate escape-type, self-contained breathing apparatus

Other mercury compounds: NIOSH/OSHA

Up to 1 mg/m³:

(APF = 10) Any chemical cartridge respirator with cartridge(s) providing protection against the compound of concern†

(APF = 10) Any supplied-air respirator

Up to 2.5 mg/m³:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with cartridge(s) providing protection against the compound of concern†(canister)

Up to 5 mg/m³:

(APF = 50) Any chemical cartridge respirator with a full facepiece and cartridge(s) providing protection against the compound of concern†

(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern†

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and cartridge(s) providing protection against the compound of concern(canister)
(APF = 50) Any self-contained breathing apparatus with a full facepiece
(APF = 50) Any supplied-air respirator with a full facepiece
Up to 10 mg/m^3:
(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode
Emergency or planned entry into unknown concentrations or IDLH conditions:
(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode
(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus
Escape:
(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern
Any appropriate escape-type, self-contained breathing apparatus

Nickel metal and other compounds (as Ni)

Synonyms & Trade Names
Nickel metal: Elemental nickel, Nickel catalyst
Synonyms of other nickel compounds vary depending upon the specific compound.

CAS No.	**RTECS No.**	**DOT ID & Guide**
7440-02-0 (Metal)	QR5950000 (Metal)	

Formula	**Conversion**	**IDLH**
Ni (Metal)		Ca [10 mg/m^3 (as Ni)] See: 7440020

Exposure Limits

NIOSH REL
*: Ca TWA 0.015 mg/m^3 See Appendix A[*Note: The REL does not apply to Nickel carbonyl.]

OSHA PEL
*†: TWA 1 mg/m^3 [*Note: The PEL does not apply to Nickel carbonyl.]

Measurement Methods

NIOSH 7300 , 7301 , 7303 , 9102 ;
OSHA ID121 , ID125G
See: NMAM or OSHA Methods

Physical Description
Metal: Lustrous, silvery, odorless solid.

MW: 58.7	**BP:** 5139°F	MLT: 2831°F	**Sol:** Insoluble	**VP:** 0 mmHg (approx)	**IP:** NA
Sp.Gr: 8.90 (Metal)	**Fl.P:** NA	**UEL:** NA	**LEL:** NA		

Metal: Combustible Solid; nickel sponge catalyst may ignite SPONTANEOUSLY in air.

Incompatibilities & Reactivities
Strong acids, sulfur, selenium, wood & other combustibles, nickel nitrate

Exposure Routes
inhalation, ingestion, skin and/or eye contact

Symptoms
sensitization dermatitis, allergic asthma, pneumonitis; [potential occupational carcinogen]

Target Organs
Nasal cavities, lungs, skin

Cancer Site
[lung and nasal cancer]

Personal Protection/Sanitation	**First Aid**
(See protection codes) **Skin:** Prevent skin contact **Eyes:** No recommendation **Wash skin:** When contaminated/Daily **Remove:** When wet or contaminated **Change:** Daily	(See procedures) **Skin:** Water flush immediately **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

NIOSH

At concentrations above the NIOSH REL, or where there is no REL, at any detectable concentration:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Thallium (soluble compounds, as Tl)

Synonyms & Trade Names
Synonyms vary depending upon the specific soluble thallium compound.

CAS No.	**RTECS No.**	**DOT ID & Guide** 1707 151 (compounds, n.o.s.)
	Conversion	**IDLH** 15 mg/m^3 (as Tl) See: thallium

Exposure Limits **NIOSH REL** : TWA 0.1 mg/m^3 [skin] **OSHA PEL** : TWA 0.1 mg/m^3 [skin]	**Measurement Methods** **NIOSH** 7300 , 7301 ,7303 , 9102 ; **OSHA** ID121 See: NMAM or OSHA Methods

Physical Description
Appearance and odor vary depending upon the specific soluble thallium compound.

Properties vary depending upon the specific soluble thallium compound.					

Incompatibilities & Reactivities
Varies

Exposure Routes
inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms
nausea, diarrhea, abdominal pain, vomiting; ptosis, strabismus; peri neuritis, tremor; retrosternal (occurring behind the sternum) tightness, chest pain, pulmonary edema; convulsions, chorea, psychosis; liver, kidney damage; alopecia; paresthesia legs

Target Organs
Eyes, respiratory system, central nervous system, liver, kidneys, gastrointestinal tract, body hair

Personal Protection/Sanitation (See protection codes) **Skin:** Prevent skin contact **Eyes:** Prevent eye contact **Wash skin:** When contaminated **Remove:** When wet or contaminated **Change:** Daily	**First Aid** (See procedures) **Eye:** Irrigate immediately **Skin:** Water flush promptly **Breathing:** Respiratory support **Swallow:** Medical attention immediately

Respirator Recommendations

NIOSH/OSHA

Up to 0.5 mg/m³:

(APF = 5) Any quarter-mask respirator.

Click here for information on selection of N, R, or P filters.

Up to 1 mg/m³:

(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering facepieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, P100.

Click here for information on selection of N, R, or P filters.

(APF = 10) Any supplied-air respirator

Up to 2.5 mg/m³:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.

Up to 5 mg/m³:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 15 mg/m³:

(APF = 2000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

Zinc oxide

Synonyms & Trade Names

Zinc peroxide

CAS No. 1314-13-2	**RTECS No.** ZH4810000	**DOT ID & Guide** 1516143
Formula ZnO	**Conversion**	**IDLH** 500 mg/m^3 See: 1314132

Exposure Limits **NIOSH REL** : Dust: TWA 5 mg/m^3 C 15 mg/m^3 Fume: TWA 5 mg/m^3 ST 10 mg/m^3 **OSHA PEL** †: TWA 5 mg/m^3 (fume) TWA 15 mg/m^3 (total dust) TWA 5 mg/m^3 (resp dust)	**Measurement Methods** **NIOSH** 7303 , 7502 ; **OSHA** ID121 , ID143 See: NMAM or OSHA Methods

Physical Description
White, odorless solid.

MW: 81.4	**BP:** ?	MLT: 3587°F	Sol(64°F): 0.0004%	**VP:** 0 mmHg (approx)	**IP:** NA
Sp.Gr: 5.61	**Fl.P:** NA	**UEL:** NA	**LEL:** NA		

Noncombustible Solid

Incompatibilities & Reactivities
Chlorinated rubber (at 419°F), water [Note: Slowly decomposed by water.]

Exposure Routes
inhalation

Symptoms
Metal fume fever: chills, muscle ache, nausea, fever, dry throat, cough; lassitude (weakness, exhaustion); metallic taste; headache; blurred vision; low back pain; vomiting; malaise (vague feeling of discomfort); chest tightness; dyspnea (breathing difficulty), rales, decreased pulmonary function

Target Organs
respiratory system

Personal Protection/Sanitation (See protection codes) **Skin:** No recommendation **Eyes:** No recommendation **Wash skin:** No recommendation **Remove:** No recommendation **Change:** No recommendation	**First Aid** (See procedures) **Breathing:** Respiratory support

Respirator Recommendations

NIOSH/OSHA

Up to 50 mg/m^3:

(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering facepieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, P100.

Click here for information on selection of N, R, or P filters.

(APF = 10) Any supplied-air respirator

Up to 125 mg/m^3:

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter.

Up to 250 mg/m^3:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

(APF = 50) Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode

(APF = 50) Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter

(APF = 50) Any self-contained breathing apparatus with a full facepiece

(APF = 50) Any supplied-air respirator with a full facepiece

Up to 500 mg/m^3:

(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF = 50) Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.

Click here for information on selection of N, R, or P filters.

Any appropriate escape-type, self-contained breathing apparatus

ATTACHMENT G INNOVX-XRF FIELD SCREENING PROTOCOL

DRAFT
Standard Operating Procedure for Innov-X X-Ray Fluorescence Handheld Analyzer For Metals In Soil

September 2010

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List of Tables

List of Abbreviations and Acronyms

Acronym	**Definition**
CSV	Comma separated values
DQO	Data quality objectives
IDW	Investigation-derived waste
LEAP	Light Element Analysis Program
MDL	Method detection limit
mg/kg	Milligrams per kilogram
NIST	National Institute of Science and Technology
r	Correlation coefficient
RPD	Relative percent difference
RSD	Relative standard deviation
XRF	X-ray fluorescence

1

Method Summary

This standard operating procedure (SOP) describes how to use the Innov-X portable X-ray fluorescence (XRF) analyzer to perform EPA Reference Method 6200 for “Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment.” The SOP is intended specifically for the Innov-X XRF devices, although basic principles of XRF soil analysis may be applicable to similar instruments. The SOP is intended to supplement the EPA Reference Method 6200.

The instrument requires daily standardization and calibration of both a reference metal alloy sample, as well as appropriate soil samples for the elements and concentrations of interest. During calibration, a mathematical relationship between the measured element signal and the known quantity of elements introduced to the instrument is generated. An instrument method detection limit (MDL) study is also performed prior to field use.

Instrument standardization is performed by measuring the signal associated with known quantities of metal elements in a 316L stainless steel alloy to verify that the XRF analyzer is operating and performing within manufacturer specifications. A blank analysis is then performed on a block of pure Teflon to ensure that there is no contamination of the analyzer window. Then, a National Institute of Science and Technology (NIST) traceable soil reference sample, with a known quantity of elements, is analyzed. The signal associated with the quantity of the various elements is determined and compared with the known quantity for that reference sample. Concentrations of the elements of interest should be within 20% of the known value, with the exception of chromium (Cr), which can be within 30%. Field samples can then be run to determine concentration of the elements of interest.

Analysis of field samples can either be done in-situ or ex-situ with varying degrees of preparation to achieve higher quality data. Improper sample preparation is the largest source of error associated with XRF field analysis. Proper sampling techniques are discussed in detail in Section 9. Interferences are also a major concern with XRF analysis and can come from: analysis through bagged samples, excess moisture, and soil chemistry. Interferences are discussed in detail in Section 3.

Continuing quality control activities during analysis determine the error associated with the data. These required quality control activities are described in sections 6 and 7.

2

Equipment and Reagents

2.1 Equipment and Setup

The Innov-X field portable XRF spectrometer is assembled in accordance with the appropriate manufacturer's guidance. A summary of these operations is provided:

- Prior to field deployment, the removable lithium ion batteries, as well as the internal battery for the instrument PDA, should be fully charged. See instrument specific manuals and/or quick start guides for information regarding charging, as they vary between analyzers in EPA R10. Once on site, the instrument should be powered on and allowed to warm up in the environment it will be operating in for at least 15 minutes prior to standardization.
- Launch the application software, Innov-X, if it does not launch automatically.
- Choose the "Soil" analysis mode. Unless a new selection is made, the application starts on the most recent mode used. Use of the Light Element Analysis Program (LEAP) will provide the lowest possible detection limit for elements lighter than iron, and specifically for Ti, Cr, and Ba. See instrument manual for information on activating this program mode.
- Attach the standardization clip over the analyzer window and run the standardization procedure. A radiation safety notice will appear on the screen; read the notice and acknowledge that you are a certified user by tapping **START**. Upon successful instrument standardization, the XRF analyzer is now ready to analyze soil reference standards and field test samples. Be aware that once standardization is complete, the X-ray tube will be energized for the next 4 hours, or until the instrument/software is powered off. A solid red light on the analyzers metal snout indicates the X-ray beam is shuttered, while a blinking light warns the operator that X-rays are being emitted from the instrument.

2.2 Additional Reagents and Supplies

Additional supplies and reagents are required for operation of the Innov-X field portable XRF analyzer:

2.2.1 National Institute of Science and Technology Standards

NIST standards for quality control samples. Avoid contamination by keeping these containers sealed. The following standards are assumed available in this SOP:

- NIST 2702 Inorganics in Marine Sediment;

- NIST 2709a San Joaquin Soil;
- NIST 2710 Montana Soil, Highly Elevated Traces; and
- NIST 2711 Montana Soil, Moderately Elevated Traces.

Information on these standards is provided in Appendix A.

2.2.2 Disposable Supplies

Disposable spatulas, mixing bowls, a sieve, and extra sample bags should be packed with the instrument. Before going to a site the operator should check that the quantity of these items is adequate for anticipated tasks.

2.2.3 Personnel Protective Equipment

Gloves and eye protection are not packed with the instrument, but should be readily available in the work area.

These additional required materials and reagents (with the exception of sampling supplies, gloves, and eyewear) are maintained in travel cases ready for shipment or transport.

3 Interferences and Instrument Operation

3.1 Interferences

Generally, instrument precision is the least significant source of error in field portable XRF analysis. User or application related error is generally more significant and varies with each site and method used. Some sources of interferences can be minimized or controlled by the instrument operator, but others cannot. Common sources of user or application related errors are discussed below.

Physical matrix effects result from variations in the physical characteristics of the sample. These variations may include such parameters as particle size, uniformity, homogeneity, and surface condition. For example, if any analyte exists in the form of very fine particles in a coarser-grained matrix, the analyte's concentration will vary depending on how the fine particles are distributed within the coarser-grained matrix. One way to reduce such error is to sieve soil and or grind samples to a uniform particle size reducing the sample-to-sample particle size variability. Every effort should be made to thoroughly mix and homogenize soil samples before analysis, as field studies have shown that sample heterogeneity has the largest impact on comparability with confirmatory samples.

Sample moisture has two effects on XRF results:

- It alters the soil chemistry.
- Moisture impedes the ability to properly prepare samples.

Although the presence of significant moisture does impact soil chemistry, all modern XRF analyzers perform automatic corrections for variations in soil chemistry from site to site. EPA Method 6200 states that "Moisture content above 20% may cause problems, since moisture alters the soil chemistry from which the XRF has been calibrated." Normalization and correction parameters built into the Innov-X instrument will automatically correct results for changes in the soil matrix, without having a significant effect on accuracy, except for the dilution effect that can cause discrepancies with laboratory results.

Innov-X states that "The inability to adequately prepare a wet sample is, we believe, the single biggest contributor to errors when testing wet samples." Wet samples are inherently difficult to properly grind, sieve, and completely homogenize to obtain high quality XRF results. Also, fixed laboratories always dry samples prior to analysis and report percent weight content on a dry sample basis. Portable XRF results are often obtained with a wet sample in the field, and results thus include the moisture content. With all other factors the same, the results for the portable XRF will be lower than those of a fixed laboratory by the amount of moisture in the sample. For example, for a sample with 10% moisture content, the reported XRF concentrations would be 10% lower than the laboratory results reported on a dry weight basis.

Inconsistent positioning of the samples in front of the probe window is a potential source of error because the X-ray signal decreases as the distance from the radioactive source increases. This error is minimized by maintaining the same distance between the window and each sample. For best results, the window of the probe should be in direct contact with the sample, which means that the sample should be flat and smooth to provide a good contact surface.

Lastly, interference can occur when the spectral peak from one element overlaps either partially or completely with the spectral peak of another. Mathematical corrections in the instrument can correct for most of these events, but there are limits to their effectiveness. The following are interference examples relevant to several RCRA metals of interest:

- Lead interferes with arsenic (not vice versa). The net effect is an elevated detection limit and lower level of precision for arsenic. The XRF handles this correction automatically, but the precision is affected. The loss of precision is reported by the XRF.
- Z, Z-1, Z+1 types of interference. These types of interference occur when high levels of an element of atomic number Z are present. This can cause elevated reported levels of elements with atomic number Z-1 and Z+1. Generally, portable XRFs have good correction methods, so this interference only causes problems with very high levels of the element in question. For example, high concentrations of Fe (Z=26) in excess of 10% may cause elevated levels of Mn or Co (Z=25 and Z=27 respectively).

3.2 Instrument Operation

Blanks, quality control standards, and samples are all analyzed using the same general procedure:

- With the instrument warmed up and standardization with the 316L alloy successfully completed, the analyzer is now ready to perform sample analysis. Be sure that the standardization clip is removed prior to sample analysis.
- Ensure the sampling area covers the entire yellow Kapton window. Do not point the unit at yourself or any other person during operation. Do not test small samples in your hand. Place them on a surface for testing.
- Either pull the trigger or tap **Start**. The *Elapsed Time* screen appears. The test time is reported on the *Test Time* screen under Test Condition. Hold analyzer still while analysis is performed.
- After analysis is complete, tap the **Results** tab and the results screen appears.
- Subsequent tests can be started from either the *Results* or *Analysis* screens.

- All analyzer data can be exported to a spreadsheet program by using a comma delimited (comma separated values = CSV) text file format. It is possible to export data for a single day or single mode, or to export all data saved on the analyzer.
- Microsoft ActiveSync software must be installed to export data.
- To export results, tap **Setup**, then Results Management icon, and the export options screen appears.
- Tap the **Export** radio button.
- Tap either the **Results** or **Spectra** radio button.
- Use the Mode down arrow to select: All, Standardization, Analytical, Process Analytical, or Soil Analysis.
- Tap **All** or **Select** in Dates. All exports all stored readings (this can take several minutes). Select allows the selection of an individual date. It is recommended that all data be backed up on a daily basis and all data be backed up prior to deleting some or all old data.
- Either tap the Save or Save As and name the file to be exported. Tap the up arrow folder icon to navigate to the desired folder on the PC and tap OK. The export screen appears.
- Connect the Innov-X supplied USB cable to analyzer and the PC. ActiveSync or Mobile Device should automatically start. If it does not, start the program manually.
- Open Windows Explorer on the target PC and tap the icon resembling the PDA. The directory structure on the analyzer appears.
- Navigate the directory and copy the file(s) to the target PC.
- Readings can be deleted on the analyzer by tapping on **Setup** and then on **Results Management** and the export options screen appears.
- Tap the **Delete** radio button and the delete screen appears. Select desired data to be permanently removed (some or all). Be certain that all data is backed up prior to tapping **Delete Results and Spectra** and confirming.

4 Instrument Calibration

4.1 Standardization and Performance Checks

As described previously, the analyzer must be standardized using the 316L stainless steel alloy clip before the analyzing any samples. The software will not permit analysis of samples until standardization is performed. Standardization of the instrument allows the analyzer to optimize the detector's electrical gain settings, which can drift, especially with temperature fluctuations, and ensures that the instrument hardware and software are performing within the manufacturer tolerances (± 20%). Standardization can be done at any time, but is required by the analyzer if the software is restarted or after 4 hours of continuous use. The recommended standardization intervals are:

- At the start of the work day
- Mid-day
- And at the close of the work day

Once a successful standardization of the analyzer is completed, performance checks with NIST traceable soil standards should be performed before field samples are to be analyzed. While similar to the standardization using 316L stainless steel, the analysis of various elements of interest in the soil matrix with known quantities allows the operator to gauge how the analyzer will perform with field samples. For data to be considered adequately precise the relative standard deviation (RSD) for the analytes of interest should be less than 20% with the exception of chromium, for which RSD values should be less than 30%.

- An acceptable performance check of one or more NIST soil standards must be performed at the beginning of every day in which the instrument is to be used to perform elemental analysis of soil.
- Variations in analyzer response are element-specific and can fluctuate. Additional calibrations may be performed if operating conditions change or if quality control materials dictate.

The general procedure for performing a performance check is the same as described previously in Section 3, Instrument Operation. Exporting the analyzer results for performance checks and comparing them to the known elemental concentration allows the operator to calculate percent differences for the elements of interest. A repeated series of performance checks on a standard will allow the operator to determine the MDL, which is described in detail in Section 9.

5

Field Usage and Sample Preparation

The field portable XRF is generally used in three ways to test for analytes in soils, as described below (adapted from Innov-X instrument manual, Appendix B).

5.1 In-Situ Soil Testing

To perform in-situ soil testing, the XRF is placed directly onto the ground. Operators remove any plant matter and foreign objects so the analyzer probe is flush with the soil material targeted for analysis. A thin sheet of plastic may be used to prevent contamination of the analyzer and possible puncturing of the Kapton window (see note below on analysis through plastic). Precision of in-situ analysis can be improved by averaging multiple readings of the sample area. For example, 4 analyses may be taken within a 4-inch by 4-inch soil surface and averaged. Multiple analysis of the same area can also provide information on the homogeneity of the soil. This information may be used to decide if bagged sampling (see below) is necessary to achieve the desired data quality.

5.2 Bagged Soil Sample Testing

To perform bagged soil sample testing, a sample of soil is collected in a thin plastic bag, mixed for 3 to 5 minutes, and tested directly through the bag. Except for a few elements – namely Cr, V, and Ba – testing through the thin plastic bag has little effect on the test result. Results for Cr, V, and Ba will be 20 to 30% lower than if tested without the presence of the bag. Multiple analyses of a bagged sample may be performed to provide information on the homogeneity of the sample and the effectiveness of mixing within the bag. This information may be used to decide if prepared soil sampling (see below) is necessary to achieve the desired data quality.

5.3 Prepared Soil Sample Testing

Prepared sample testing provides the maximum possible accuracy for XRF soil testing. Prepared sample tests require a sample to be collected, dried if necessary, sieved, and ground into a powder. The prepared sample is them placed into a sample baggie or XRF cup for analysis.

Results for samples with high moisture levels will have a low bias, and will not correlate well with results for samples analyzed at the laboratory. Therefore samples with free water should be drained prior to analysis. Slurries and obviously wet samples should be dried prior to analysis. For any results of wet sample that are between half of an action level and the action level, the test should be re-run after the sample is either air-dried overnight or dried at 60°C until visibly dry (soil is crumbly). Accelerated drying of soils at high temperatures or with high volume air flow will cause loss of mercury from the samples, and should be avoided if mercury may be present. If necessary, a separate sample can be dried rapidly and weighed, and these results can be used to convert results to a dry weight basis.

5.4 Data Quality Objectives

It is important to understand the data quality objectives (DQO) of the project in order to determine the appropriate mix of field screening and prepared sample testing. In-situ testing usually provides only screening-level data. The correlation coefficient (r) for the results should be 0.7 or greater for the field portable XRF data to be considered usable as screening level data. This is because analytical testing always requires a uniform, homogeneous sample matrix. A laboratory achieves this by digesting the sample in hot acid prior to analysis. Testing directly on the ground does not ensure uniformity is met. Preparing a sample provides a uniform sample and likely better analytical data quality, although several minutes of testing time is required. If the r is 0.9 or greater and inferential statistics indicate the field data and confirmatory data are statistically equivalent at a 99% confidence level, the data could potentially meet definitive level data criteria.

XRF operators may use a mixture of in-situ and prepared sample testing. The exact mixture of in-situ and prepared sample testing depends upon the goals of the soil testing.

6 Analysis

The following is a general schedule that describes analysis activities, beginning with the instrument standardization that has already been described. Once standardization has been successfully performed, analysis can begin.

6.1 Calibration

- An energy calibration (standardization) check is performed at the beginning of day.

6.2 Initial Quality Control

- Calibration blank using Teflon block to check for contamination on analyzer window
- Choose a quality control NIST standard(s) with concentrations near the action levels or MDLs for the elements of interest.

6.3 Samples

- Up to 20 samples may be run in a batch
- Refer to the Site Specific Sampling Plan for confirmation sampling criteria as applicable.

6.4 Continuing and Final Quality Control

- An instrument blank for every 20 environmental samples
- Calibration verification check sample with appropriate NIST standard every 20 samples
- Precision sample performed once per day.

6-1 Example Logbook Entry

Sample ID	Time	Arsenic (mg/kg)	Chromium (mg/kg)	Comments
Energy Cal	0800			Pass
Instrument Blank				OK
NIST 2709a				As <20% , Cr <30% diff
1				In-situ
2				In-situ
3				Leaves & twigs removed
4				In-situ
5				In-situ
6				In-situ
7				In-situ
8				In-situ
9				In-situ
10				Bag, split sample for lab
11				In-situ
12				In-situ
13 precision -1				Bag
13 precision – 2				Bag
13 precision – 3				Bag
13 precision – 4				Bag
13 precision – 5				Bag
13 precision – 6				Bag
13 precision – 7				RSD: As<20%, Cr<30%
14				In-situ
15				In-situ
16				In-situ
17				Bag, split sample for lab
18				In-situ
19				In-situ
Energy Cal	1200			4 hrs elapsed, Pass
20				In-situ
Instrument Blank				OK
NIST 2709a				As<20%, Cr<30% diff
Lunch taken	1230			XRF off, put on charger

7 Quality Assurance/Quality Control

Initial and continuing quality control, in the form of the Calibration Blank and the Quality Control Standard, ensure that the instrument is operating at an acceptable limit of accuracy. The results of these analyses should be compared to the following guidelines.

7.1 Quality Assurance

Quality assurance activities are preventive measures taken to ensure the quality of analytical results. The single most important quality assurance activity undertaken in the field laboratory is rigorous attention to the possibility of errors in sample identification and data entry. Organizing the workspace so that only one sample is on the bench at a particular time is one option. Assume that the analytical environment will be chaotic, and that work processes will be interrupted, and organize the workspace to eliminate identification and recording errors.

7.2 Quality Control

Quality control activities are tests performed during analysis to ensure that the analytical error associated with analysis does not become unacceptably large. These quality control activities were introduced in Section 6. In this section the criteria for acceptable quality control results are described. Control activities and acceptance criteria are summarized in Table 7-1.

7-1 Quality Control Samples – Frequency and Acceptance Criteria

Quality Control Material	Frequency	Acceptance Criterion
MDL Study	Performed annually	± 20 % of certified Concentration.
Energy Calibration Check	3 times per day, or every 4 hours	Pass or Fail
Instrument Blank	At start and every 20 samples	Between MDL and the negative of the MDL
Calibration Verification	At start and every 20 samples	± 20 % of certified concentration (± 30 % for Cr)
Precision Sample	Once per day	± 20 % of certified concentration (± 30 % for Cr)

7.2.1 Instrument Blank

This value should be between the MDL and the negative of the MDL.

7.2.2 Calibration Verification

The operator is to perform a two minute test on an appropriate NIST reference standard. The result values should be within 20% of the true value of the standard (± 30 % for Cr).

7.2.3 Precision Verification

A minimum of one precision sample should be run per day by conducting from 7 to 10 replicate measurements of the sample. The precision is assessed by calculating the RSD of the replicate measurements of the analyte. The RSD values should be within 20% for most analytes, with the exception of Cr, for which the value should be less than 30 percent.

7.3 Corrective Actions

Corrective action must be taken when quality control results are not acceptable. Acceptable corrective actions may include, but are not limited to:

- Repetition of the Calibration Blank or Calibration Verification one time. It is not acceptable to re-run calibration blank or calibration verification tests repeatedly in order to achieve an acceptable quality control result.
- Use of a new sample bag as the blank, replacing the Kapton window (if dirty), or use of a new soil standard as the Calibration Verification are acceptable measures. If one of these measures fixes the problem, the problem must be identified so that it does not present problems with subsequent analyses..
- Re-calibration of the instrument is an acceptable corrective action. It should be noted, however, that re-calibration often merely masks other analytical problems.
- If other corrective actions fail, the minimum reporting limit may be raised. This should be done in consultation with subject matter experts.

8 Data Reporting, Qualification and Calculation

8.1 Data Reporting and Qualification

Analytical results above the minimum reporting limit are reported to three significant figures. Analytical results below the minimum reporting limit are reported with two significant figures. Analytical results less than the minimum detection limit are reported as undetectable (U) at the value of the minimum detection limit.

8.2 Calculation

Some calculations must be performed by the operator. These calculations are described below.

8.2.1 Relative Percent Difference

The relative percent difference (RPD) is calculated as follows:

$$\left[\frac{(x_1 - x_2)}{\frac{(x_1 + x_2)}{2}}\right] \times 100 = RPD$$

Where x_1 is a sample result and x_2 is a separate but comparable sample result.

8.2.2 Percentage True Value of Quality Control Standard

The percentage true value of the quality control standard is calculated as follows:

$$\text{Percentage True Value} = \left[\frac{x_1 - x_2}{x_2}\right] \times 100$$

Where x_1 is the Quality Control Standard sample result and x_2 is the true value of the Quality Control Standard.

8.2.3 Percentage of Solids

The percentage of solids in a sample is calculated as follows:

$$\text{Percent Solids} = \frac{\text{dry weight}}{\text{wet weight}} \times 100$$

9 Determination of the Method Detection Limit

The MDL is determined at least yearly or more frequently if changing instrument conditions cause concern about instrument sensitivity. The determination is performed as follows:

- When the Innov-X XRF spectrometer is ready for analysis, perform seven repetitions of a low level sample using the appropriate NIST standard corresponding to the element(s) of interest.
- Determine the mean and standard deviation of the seven repetitions. Many calculators and spreadsheet programs will perform these calculations, but they are included below as a reference:

$$Mean = \frac{\sum measurements}{7}$$

$$Deviation = \frac{\sqrt{\sum \ (individual - mean)^2}}{6}$$

- 3.14 times the standard deviation yields the calculated MDL (The 3.14 value is obtained from the Student's T Test and is based on 7 samples.
- Ten times the standard deviation yields the minimum reporting limit.

10 Health, Safety, and Waste Disposal

10.1 Health and Safety in the Field Laboratory

Laboratory operators should always wear gloves and eye protection during operations, and food and beverages should be excluded from laboratory areas. A further special hazard posed by handheld XRF analyzers is ionizing radiation emitted from the front of the instrument. The XRF should only be used by a trained operator. The instrument should never be pointed toward others. Hands should be held away from the instrument snout while analyzing samples. Personal dosimeter badges are required to be worn; if available, ring style finger dosimeters may also be worn.

Drying of samples that contain high levels of water is advised, but samples that potentially contain mercury should only be air dried (with proper ventilation) and not heated to avoid exposure to mercury vapors.

Covering the analyzer window with a clean bag is advised for in-situ sampling, as to avoid contamination, and cross contamination of the Kapton window.

10.2 Waste Disposal

Excess soil sample material should be returned to the site and the containers emptied. Investigation derived waste (IDW), including empty sample containers, may be disposed of at a solid waste landfill unless it contains high levels of contamination.

11

References

Innov-X Omega XRF Analyzer instrument operating manual.

EPA SW-846 Method 6200, "Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment."

A

National Institute of Science and Technology Standard Reference Material Values

A.1 SRM 2702 Inorganics in Marine Sediment

Table 1. Certified Concentrations for Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Al[b,c,f,G]	8.41 % ± 0.22 %	Ni[A,a,b,c,d,e]	75.4 ± 1.5
As[b,c,d,G]	45.3 ± 1.8	P[b,c,f,H]	0.1552 % ± 0.0066 %
Ba[A,b,e]	397.4 ± 3.2	Pb[A,a,b,c,e]	132.8 ± 1.1
Ce[b,c,e,G]	123.4 ± 5.8	Rb[b,e,G]	127.7 ± 8.8
Cd[A,a,b,d,I]	0.817 ± 0.011	Sb[a,b,e,G]	5.60 ± 0.24
Co[b,c,G]	27.76 ± 0.58	Sc[b,c,G]	25.9 ± 1.1
Cr[a,b,c,e,G]	352 ± 22	Sr[A,b,c,e]	119.7 ± 3.0
Fe[b,c,f,G]	7.91 % ± 0.24 %	Th[b,c,e,G]	20.51 ± 0.96
Hg[A-1,d,H]	0.4474 ± 0.0069	Ti[b,c,f,G]	0.884 % ± 0.082 %
K[b,c,f,G]	2.054 % ± 0.072 %	Tl[A,a]	0.8267 ± 0.0060
La[b,c,e,G]	73.5 ± 4.2	V[b,c,G]	357.6 ± 9.2
Mn[b,c,G]	1757 ± 58	Zn[a,b,c,e,G]	485.3 ± 4.2
Na[b,c,f,G]	0.681 % ± 0.020 %		

Table 2. Reference Values for Concentrations of Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Ag[a,d]	0.622 ± 0.078	Mg[b,c,f]	0.990 % ± 0.074 %
Ca[b,c,f]	0.343 % ± 0.024 %	Mo[b,c,e]	10.8 ± 1.6
Cu[a,b,c,d,e]	117.7 ± 5.6	Se[b,c,e]	4.95 ± 0.46
Ga[b,c,e]	24.3 ± 1.9	Sn[a,c,e]	31.6 ± 2.4

Table 3. Information Values for Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Be[b,c]	3.0	Nb[c,e]	63
C (total)[j]	3.36 %	Nd[G]	56
C (organic)[j]	3.27 %	S[j]	1.5 %
Cs[b,G]	7.1	Sm[G]	10.8
Hf[G]	12.6	U[b,e]	10.4
Li[b,c]	78.2	W[G]	6.2

A.2 SRM 2709a San Joaquin Soil – Baseline Trace Element Concentrations

Table 1. Certified Values[(a)] (Dry-Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (%)	Element	Mass Fraction (mg/kg)
Aluminum	7.37 ± 0.16	Antimony	1.55 ± 0.06
Calcium	1.91 ± 0.09	Barium	979 ± 28
Iron	3.36 ± 0.07	Cadmium	0.371 ± 0.002
Magnesium	1.46 ± 0.02	Chromium	130 ± 9
Phosphorus	0.0688 ± 0.0013	Cobalt	12.8 ± 0.2
Potassium	2.11 ± 0.06	Lead	17.3 ± 0.1
Silicon	30.3 ± 0.4	Manganese	529 ± 18
Sodium	1.22 ± 0.03	Strontium	239 ± 6
Titanium	0.336 ± 0.007	Vanadium	110 ± 11
		Zirconium	195 ± 46

Table 2. Reference Values[(a)] (Dry-Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (mg/kg)
Arsenic	10.5 ± 0.3
Cerium	42 ± 1
Cesium	5.0 ± 0.1
Copper	33.9 ± 0.5
Europium	0.83 ± 0.02
Gadolinium	3.0 ± 0.1
Lanthanum	21.7 ± 0.4
Mercury[(b)]	0.9 ± 0.2
Nickel	85 ± 2
Rubidium	99 ± 3
Scandium	11.1 ± 0.1
Thallium	0.58 ± 0.01

Table 3. Information Values[(a)] (Dry Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (mg/kg)
Boron	74
Dysprosium	3
Hafnium	4
Lutetium	0.3
Neodymium	17
Samarium	4
Selenium	1.5
Tantalum	0.7
Terbium	0.5
Ytterbium	2

A.3 SRM 2710 Montana Soil – Highly Elevated Trace Element Concentrations

Table 1. Certified Values

Element	Mass Fraction (%)			Element	Mass Fraction (mg/kg)		
Aluminum	6.44	±	0.08	Antimony	38.4	±	3
Calcium	1.25	±	0.03	Arsenic	626	±	38
Iron	3.38	±	0.10	Barium	707	±	51
Magnesium	0.853	±	0.042	Cadmium	21.8	±	0.2
Manganese	1.01	±	0.04	Copper	2950	±	130
Phosphorus	0.106	±	0.015	Lead	5532	±	80
Potassium	2.11	±	0.11	Mercury	32.6	±	1.8
Silicon	28.97	±	0.18	Nickel	14.3	±	1.0
Sodium	1.14	±	0.06	Silver	35.3	±	1.5
Sulfur	0.240	±	0.006	Vanadium	76.6	±	2.3
Titanium	0.283	±	0.010	Zinc	6952	±	91

Table 2. Noncertified Values

Element	Mass Fraction (%)
Carbon	3

Element	Mass Fraction (mg/kg)
Bromine	6
Cerium	57
Cesium	107
Chromium	39
Cobalt	10
Dysprosium	5.4
Europium	1
Gallium	34
Gold	0.6
Hafnium	3.2
Holmium	0.6
Indium	5.1
Lanthanum	34
Molybdenum	19
Neodymium	23
Rubidium	120
Samarium	7.8
Scandium	8.7

A.4 SRM 2711 Montana Soil – Moderately Elevated Trace Element Concentrations

Table 1. Certified Values

Element	Mass Fraction (%)		
Aluminum	6.53	±	0.09
Calcium	2.88	±	0.08
Iron	2.89	±	0.06
Magnesium	1.05	±	0.03
Phosphorus	0.086	±	0.007
Potassium	2.45	±	0.08
Silicon	30.44	±	0.19
Sodium	1.14	±	0.03
Sulfur	0.042	±	0.001
Titanium	0.306	±	0.023

Element	Mass Fraction (µg/g)		
Antimony	19.4	±	1.8
Arsenic	105	±	8
Barium	726	±	38
Cadmium	41.70	±	0.25
Copper	114	±	2
Lead	1162	±	31
Manganese	638	±	28
Mercury	6.25	±	0.19
Nickel	20.6	±	1.1
Selenium	1.52	±	0.14
Silver	4.63	±	0.39
Strontium	245.3	±	0.7
Thallium	2.47	±	0.15
Vanadium	81.6	±	2.9
Zinc	350.4	±	4.8

Table 2. Noncertified Values

Element	Mass Fraction (%)
Carbon	2

Element	Mass Fraction (µg/g)
Bromine	5
Cerium	69
Cesium	6.1
Chromium	47
Cobalt	10
Dysprosium	5.6
Europium	1.1
Gallium	15
Gold	.03
Hafnium	7.3
Holmium	1
Indium	1.1
Iodine	3
Lanthanum	40
Molybdenum	1.6

B

Metals of Interest to ERU for Annual MDL Precision Studies

B-1 Metals of Interest

Analytes	Residential Soil RSL (mg/kg)	CAS Registry No.
Arsenic (As)	0.39	7440-38-0
Chromium (Cr)	230	7440-47-3
Copper (Cu)	3100	7440-48-4
Lead (Pb)	400	7439-92-1
Mercury (Hg)	6.7	7439-97-6
Nickel (Ni)	1600	7440-02-0
Silver (Ag)	390	7440-22-4

DRAFT
Standard Operating Procedure for Innov-X X-Ray Fluorescence Handheld Analyzer For Metals In Soil

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List of Tables

List of Abbreviations and Acronyms

Acronym	**Definition**
CSV	Comma separated values
DQO	Data quality objectives
IDW	Investigation-derived waste
LEAP	Light Element Analysis Program
MDL	Method detection limit
mg/kg	Milligrams per kilogram
NIST	National Institute of Science and Technology
r	Correlation coefficient
RPD	Relative percent difference
RSD	Relative standard deviation
XRF	X-ray fluorescence

1

Method Summary

This standard operating procedure (SOP) describes how to use the Innov-X portable X-ray fluorescence (XRF) analyzer to perform EPA Reference Method 6200 for "Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment." The SOP is intended specifically for the Innov-X XRF devices, although basic principles of XRF soil analysis may be applicable to similar instruments. The SOP is intended to supplement the EPA Reference Method 6200.

The instrument requires daily standardization and calibration of both a reference metal alloy sample, as well as appropriate soil samples for the elements and concentrations of interest. During calibration, a mathematical relationship between the measured element signal and the known quantity of elements introduced to the instrument is generated. An instrument method detection limit (MDL) study is also performed prior to field use.

Instrument standardization is performed by measuring the signal associated with known quantities of metal elements in a 316L stainless steel alloy to verify that the XRF analyzer is operating and performing within manufacturer specifications. A blank analysis is then performed on a block of pure Teflon to ensure that there is no contamination of the analyzer window. Then, a National Institute of Science and Technology (NIST) traceable soil reference sample, with a known quantity of elements, is analyzed. The signal associated with the quantity of the various elements is determined and compared with the known quantity for that reference sample. Concentrations of the elements of interest should be within 20% of the known value, with the exception of chromium (Cr), which can be within 30%. Field samples can then be run to determine concentration of the elements of interest.

Analysis of field samples can either be done in-situ or ex-situ with varying degrees of preparation to achieve higher quality data. Improper sample preparation is the largest source of error associated with XRF field analysis. Proper sampling techniques are discussed in detail in Section 9. Interferences are also a major concern with XRF analysis and can come from: analysis through bagged samples, excess moisture, and soil chemistry. Interferences are discussed in detail in Section 3.

Continuing quality control activities during analysis determine the error associated with the data. These required quality control activities are described in sections 6 and 7.

2 Equipment and Reagents

2.1 Equipment and Setup

The Innov-X field portable XRF spectrometer is assembled in accordance with the appropriate manufacturer's guidance. A summary of these operations is provided:

- Prior to field deployment, the removable lithium ion batteries, as well as the internal battery for the instrument PDA, should be fully charged. See instrument specific manuals and/or quick start guides for information regarding charging, as they vary between analyzers in EPA R10. Once on site, the instrument should be powered on and allowed to warm up in the environment it will be operating in for at least 15 minutes prior to standardization.
- Launch the application software, Innov-X, if it does not launch automatically.
- Choose the "Soil" analysis mode. Unless a new selection is made, the application starts on the most recent mode used. Use of the Light Element Analysis Program (LEAP) will provide the lowest possible detection limit for elements lighter than iron, and specifically for Ti, Cr, and Ba. See instrument manual for information on activating this program mode.
- Attach the standardization clip over the analyzer window and run the standardization procedure. A radiation safety notice will appear on the screen; read the notice and acknowledge that you are a certified user by tapping **START**. Upon successful instrument standardization, the XRF analyzer is now ready to analyze soil reference standards and field test samples. Be aware that once standardization is complete, the X-ray tube will be energized for the next 4 hours, or until the instrument/software is powered off. A solid red light on the analyzers metal snout indicates the X-ray beam is shuttered, while a blinking light warns the operator that X-rays are being emitted from the instrument.

2.2 Additional Reagents and Supplies

Additional supplies and reagents are required for operation of the Innov-X field portable XRF analyzer:

2.2.1 National Institute of Science and Technology Standards

NIST standards for quality control samples. Avoid contamination by keeping these containers sealed. The following standards are assumed available in this SOP:

- NIST 2702 Inorganics in Marine Sediment;

- NIST 2709a San Joaquin Soil;
- NIST 2710 Montana Soil, Highly Elevated Traces; and
- NIST 2711 Montana Soil, Moderately Elevated Traces.

Information on these standards is provided in Appendix A.

2.2.2 Disposable Supplies

Disposable spatulas, mixing bowls, a sieve, and extra sample bags should be packed with the instrument. Before going to a site the operator should check that the quantity of these items is adequate for anticipated tasks.

2.2.3 Personnel Protective Equipment

Gloves and eye protection are not packed with the instrument, but should be readily available in the work area.

These additional required materials and reagents (with the exception of sampling supplies, gloves, and eyewear) are maintained in travel cases ready for shipment or transport.

3 Interferences and Instrument Operation

3.1 Interferences

Generally, instrument precision is the least significant source of error in field portable XRF analysis. User or application related error is generally more significant and varies with each site and method used. Some sources of interferences can be minimized or controlled by the instrument operator, but others cannot. Common sources of user or application related errors are discussed below.

Physical matrix effects result from variations in the physical characteristics of the sample. These variations may include such parameters as particle size, uniformity, homogeneity, and surface condition. For example, if any analyte exists in the form of very fine particles in a coarser-grained matrix, the analyte's concentration will vary depending on how the fine particles are distributed within the coarser-grained matrix. One way to reduce such error is to sieve soil and or grind samples to a uniform particle size reducing the sample-to-sample particle size variability. Every effort should be made to thoroughly mix and homogenize soil samples before analysis, as field studies have shown that sample heterogeneity has the largest impact on comparability with confirmatory samples.

Sample moisture has two effects on XRF results:

- It alters the soil chemistry.
- Moisture impedes the ability to properly prepare samples.

Although the presence of significant moisture does impact soil chemistry, all modern XRF analyzers perform automatic corrections for variations in soil chemistry from site to site. EPA Method 6200 states that "Moisture content above 20% may cause problems, since moisture alters the soil chemistry from which the XRF has been calibrated." Normalization and correction parameters built into the Innov-X instrument will automatically correct results for changes in the soil matrix, without having a significant effect on accuracy, except for the dilution effect that can cause discrepancies with laboratory results.

Innov-X states that "The inability to adequately prepare a wet sample is, we believe, the single biggest contributor to errors when testing wet samples." Wet samples are inherently difficult to properly grind, sieve, and completely homogenize to obtain high quality XRF results. Also, fixed laboratories always dry samples prior to analysis and report percent weight content on a dry sample basis. Portable XRF results are often obtained with a wet sample in the field, and results thus include the moisture content. With all other factors the same, the results for the portable XRF will be lower than those of a fixed laboratory by the amount of moisture in the sample. For example, for a sample with 10% moisture content, the reported XRF concentrations would be 10% lower than the laboratory results reported on a dry weight basis.

Inconsistent positioning of the samples in front of the probe window is a potential source of error because the X-ray signal decreases as the distance from the radioactive source increases. This error is minimized by maintaining the same distance between the window and each sample. For best results, the window of the probe should be in direct contact with the sample, which means that the sample should be flat and smooth to provide a good contact surface.

Lastly, interference can occur when the spectral peak from one element overlaps either partially or completely with the spectral peak of another. Mathematical corrections in the instrument can correct for most of these events, but there are limits to their effectiveness. The following are interference examples relevant to several RCRA metals of interest:

- Lead interferes with arsenic (not vice versa). The net effect is an elevated detection limit and lower level of precision for arsenic. The XRF handles this correction automatically, but the precision is affected. The loss of precision is reported by the XRF.
- Z, Z-1, Z+1 types of interference. These types of interference occur when high levels of an element of atomic number Z are present. This can cause elevated reported levels of elements with atomic number Z-1 and Z+1. Generally, portable XRFs have good correction methods, so this interference only causes problems with very high levels of the element in question. For example, high concentrations of Fe (Z=26) in excess of 10% may cause elevated levels of Mn or Co (Z=25 and Z=27 respectively).

3.2 Instrument Operation

Blanks, quality control standards, and samples are all analyzed using the same general procedure:

- With the instrument warmed up and standardization with the 316L alloy successfully completed, the analyzer is now ready to perform sample analysis. Be sure that the standardization clip is removed prior to sample analysis.
- Ensure the sampling area covers the entire yellow Kapton window. Do not point the unit at yourself or any other person during operation. Do not test small samples in your hand. Place them on a surface for testing.
- Either pull the trigger or tap **Start**. The *Elapsed Time* screen appears. The test time is reported on the *Test Time* screen under Test Condition. Hold analyzer still while analysis is performed.
- After analysis is complete, tap the **Results** tab and the results screen appears.
- Subsequent tests can be started from either the *Results* or *Analysis* screens.

- All analyzer data can be exported to a spreadsheet program by using a comma delimited (comma separated values = CSV) text file format. It is possible to export data for a single day or single mode, or to export all data saved on the analyzer.
- Microsoft ActiveSync software must be installed to export data.
- To export results, tap **Setup**, then Results Management icon, and the export options screen appears.
- Tap the **Export** radio button.
- Tap either the **Results** or **Spectra** radio button.
- Use the Mode down arrow to select: All, Standardization, Analytical, Process Analytical, or Soil Analysis.
- Tap **All** or **Select** in Dates. All exports all stored readings (this can take several minutes). Select allows the selection of an individual date. It is recommended that all data be backed up on a daily basis and all data be backed up prior to deleting some or all old data.
- Either tap the Save or Save As and name the file to be exported. Tap the up arrow folder icon to navigate to the desired folder on the PC and tap OK. The export screen appears.
- Connect the Innov-X supplied USB cable to analyzer and the PC. ActiveSync or Mobile Device should automatically start. If it does not, start the program manually.
- Open Windows Explorer on the target PC and tap the icon resembling the PDA. The directory structure on the analyzer appears.
- Navigate the directory and copy the file(s) to the target PC.
- Readings can be deleted on the analyzer by tapping on **Setup** and then on **Results Management** and the export options screen appears.
- Tap the **Delete** radio button and the delete screen appears. Select desired data to be permanently removed (some or all). Be certain that all data is backed up prior to tapping **Delete Results and Spectra** and confirming.

4 Instrument Calibration

4.1 Standardization and Performance Checks

As described previously, the analyzer must be standardized using the 316L stainless steel alloy clip before the analyzing any samples. The software will not permit analysis of samples until standardization is performed. Standardization of the instrument allows the analyzer to optimize the detector's electrical gain settings, which can drift, especially with temperature fluctuations, and ensures that the instrument hardware and software are performing within the manufacturer tolerances (± 20%). Standardization can be done at any time, but is required by the analyzer if the software is restarted or after 4 hours of continuous use. The recommended standardization intervals are:

- At the start of the work day
- Mid-day
- And at the close of the work day

Once a successful standardization of the analyzer is completed, performance checks with NIST traceable soil standards should be performed before field samples are to be analyzed. While similar to the standardization using 316L stainless steel, the analysis of various elements of interest in the soil matrix with known quantities allows the operator to gauge how the analyzer will perform with field samples. For data to be considered adequately precise the relative standard deviation (RSD) for the analytes of interest should be less than 20% with the exception of chromium, for which RSD values should be less than 30%.

- An acceptable performance check of one or more NIST soil standards must be performed at the beginning of every day in which the instrument is to be used to perform elemental analysis of soil.
- Variations in analyzer response are element-specific and can fluctuate. Additional calibrations may be performed if operating conditions change or if quality control materials dictate.

The general procedure for performing a performance check is the same as described previously in Section 3, Instrument Operation. Exporting the analyzer results for performance checks and comparing them to the known elemental concentration allows the operator to calculate percent differences for the elements of interest. A repeated series of performance checks on a standard will allow the operator to determine the MDL, which is described in detail in Section 9.

5

Field Usage and Sample Preparation

The field portable XRF is generally used in three ways to test for analytes in soils, as described below (adapted from Innov-X instrument manual, Appendix B).

5.1 In-Situ Soil Testing

To perform in-situ soil testing, the XRF is placed directly onto the ground. Operators remove any plant matter and foreign objects so the analyzer probe is flush with the soil material targeted for analysis. A thin sheet of plastic may be used to prevent contamination of the analyzer and possible puncturing of the Kapton window (see note below on analysis through plastic). Precision of in-situ analysis can be improved by averaging multiple readings of the sample area. For example, 4 analyses may be taken within a 4-inch by 4-inch soil surface and averaged. Multiple analysis of the same area can also provide information on the homogeneity of the soil. This information may be used to decide if bagged sampling (see below) is necessary to achieve the desired data quality.

5.2 Bagged Soil Sample Testing

To perform bagged soil sample testing, a sample of soil is collected in a thin plastic bag, mixed for 3 to 5 minutes, and tested directly through the bag. Except for a few elements – namely Cr, V, and Ba – testing through the thin plastic bag has little effect on the test result. Results for Cr, V, and Ba will be 20 to 30% lower than if tested without the presence of the bag. Multiple analyses of a bagged sample may be performed to provide information on the homogeneity of the sample and the effectiveness of mixing within the bag. This information may be used to decide if prepared soil sampling (see below) is necessary to achieve the desired data quality.

5.3 Prepared Soil Sample Testing

Prepared sample testing provides the maximum possible accuracy for XRF soil testing. Prepared sample tests require a sample to be collected, dried if necessary, sieved, and ground into a powder. The prepared sample is them placed into a sample baggie or XRF cup for analysis.

Results for samples with high moisture levels will have a low bias, and will not correlate well with results for samples analyzed at the laboratory. Therefore samples with free water should be drained prior to analysis. Slurries and obviously wet samples should be dried prior to analysis. For any results of wet sample that are between half of an action level and the action level, the test should be re-run after the sample is either air-dried overnight or dried at 60°C until visibly dry (soil is crumbly). Accelerated drying of soils at high temperatures or with high volume air flow will cause loss of mercury from the samples, and should be avoided if mercury may be present. If necessary, a separate sample can be dried rapidly and weighed, and these results can be used to convert results to a dry weight basis.

5.4 Data Quality Objectives

It is important to understand the data quality objectives (DQO) of the project in order to determine the appropriate mix of field screening and prepared sample testing. In-situ testing usually provides only screening-level data. The correlation coefficient (r) for the results should be 0.7 or greater for the field portable XRF data to be considered usable as screening level data. This is because analytical testing always requires a uniform, homogeneous sample matrix. A laboratory achieves this by digesting the sample in hot acid prior to analysis. Testing directly on the ground does not ensure uniformity is met. Preparing a sample provides a uniform sample and likely better analytical data quality, although several minutes of testing time is required. If the r is 0.9 or greater and inferential statistics indicate the field data and confirmatory data are statistically equivalent at a 99% confidence level, the data could potentially meet definitive level data criteria.

XRF operators may use a mixture of in-situ and prepared sample testing. The exact mixture of in-situ and prepared sample testing depends upon the goals of the soil testing.

6 Analysis

The following is a general schedule that describes analysis activities, beginning with the instrument standardization that has already been described. Once standardization has been successfully performed, analysis can begin.

6.1 Calibration

- An energy calibration (standardization) check is performed at the beginning of day.

6.2 Initial Quality Control

- Calibration blank using Teflon block to check for contamination on analyzer window
- Choose a quality control NIST standard(s) with concentrations near the action levels or MDLs for the elements of interest.

6.3 Samples

- Up to 20 samples may be run in a batch
- Refer to the Site Specific Sampling Plan for confirmation sampling criteria as applicable.

6.4 Continuing and Final Quality Control

- An instrument blank for every 20 environmental samples
- Calibration verification check sample with appropriate NIST standard every 20 samples
- Precision sample performed once per day.

6-1 Example Logbook Entry

Sample ID	Time	Arsenic (mg/kg)	Chromium (mg/kg)	Comments
Energy Cal	0800			Pass
Instrument Blank				OK
NIST 2709a				As <20% , Cr <30% diff
1				In-situ
2				In-situ
3				Leaves & twigs removed
4				In-situ
5				In-situ
6				In-situ
7				In-situ
8				In-situ
9				In-situ
10				Bag, split sample for lab
11				In-situ
12				In-situ
13 precision -1				Bag
13 precision – 2				Bag
13 precision – 3				Bag
13 precision – 4				Bag
13 precision – 5				Bag
13 precision – 6				Bag
13 precision – 7				RSD: As<20%, Cr<30%
14				In-situ
15				In-situ
16				In-situ
17				Bag, split sample for lab
18				In-situ
19				In-situ
Energy Cal	1200			4 hrs elapsed, Pass
20				In-situ
Instrument Blank				OK
NIST 2709a				As<20%, Cr<30% diff
Lunch taken	1230			XRF off, put on charger

7 Quality Assurance/Quality Control

Initial and continuing quality control, in the form of the Calibration Blank and the Quality Control Standard, ensure that the instrument is operating at an acceptable limit of accuracy. The results of these analyses should be compared to the following guidelines.

7.1 Quality Assurance

Quality assurance activities are preventive measures taken to ensure the quality of analytical results. The single most important quality assurance activity undertaken in the field laboratory is rigorous attention to the possibility of errors in sample identification and data entry. Organizing the workspace so that only one sample is on the bench at a particular time is one option. Assume that the analytical environment will be chaotic, and that work processes will be interrupted, and organize the workspace to eliminate identification and recording errors.

7.2 Quality Control

Quality control activities are tests performed during analysis to ensure that the analytical error associated with analysis does not become unacceptably large. These quality control activities were introduced in Section 6. In this section the criteria for acceptable quality control results are described. Control activities and acceptance criteria are summarized in Table 7-1.

7-1 Quality Control Samples – Frequency and Acceptance Criteria

Quality Control Material	Frequency	Acceptance Criterion
MDL Study	Performed annually	± 20 % of certified Concentration.
Energy Calibration Check	3 times per day, or every 4 hours	Pass or Fail
Instrument Blank	At start and every 20 samples	Between MDL and the negative of the MDL
Calibration Verification	At start and every 20 samples	± 20 % of certified concentration (± 30 % for Cr)
Precision Sample	Once per day	± 20 % of certified concentration (± 30 % for Cr)

7.2.1 Instrument Blank

This value should be between the MDL and the negative of the MDL.

7.2.2 Calibration Verification

The operator is to perform a two minute test on an appropriate NIST reference standard. The result values should be within 20% of the true value of the standard (± 30 % for Cr).

7.2.3 Precision Verification

A minimum of one precision sample should be run per day by conducting from 7 to 10 replicate measurements of the sample. The precision is assessed by calculating the RSD of the replicate measurements of the analyte. The RSD values should be within 20% for most analytes, with the exception of Cr, for which the value should be less than 30 percent.

7.3 Corrective Actions

Corrective action must be taken when quality control results are not acceptable. Acceptable corrective actions may include, but are not limited to:

- Repetition of the Calibration Blank or Calibration Verification one time. It is not acceptable to re-run calibration blank or calibration verification tests repeatedly in order to achieve an acceptable quality control result.
- Use of a new sample bag as the blank, replacing the Kapton window (if dirty), or use of a new soil standard as the Calibration Verification are acceptable measures. If one of these measures fixes the problem, the problem must be identified so that it does not present problems with subsequent analyses..
- Re-calibration of the instrument is an acceptable corrective action. It should be noted, however, that re-calibration often merely masks other analytical problems.
- If other corrective actions fail, the minimum reporting limit may be raised. This should be done in consultation with subject matter experts.

8

Data Reporting, Qualification and Calculation

8.1 Data Reporting and Qualification

Analytical results above the minimum reporting limit are reported to three significant figures. Analytical results below the minimum reporting limit are reported with two significant figures. Analytical results less than the minimum detection limit are reported as undetectable (U) at the value of the minimum detection limit.

8.2 Calculation

Some calculations must be performed by the operator. These calculations are described below.

8.2.1 Relative Percent Difference

The relative percent difference (RPD) is calculated as follows:

$$\left[\frac{(x_1 - x_2)}{\frac{(x_1 + x_2)}{2}}\right] \times 100 = RPD$$

Where x_1 is a sample result and x_2 is a separate but comparable sample result.

8.2.2 Percentage True Value of Quality Control Standard

The percentage true value of the quality control standard is calculated as follows:

$$\text{Percentage True Value} = \left[\frac{x_1 - x_2}{x_2}\right] \times 100$$

Where x_1 is the Quality Control Standard sample result and x_2 is the true value of the Quality Control Standard.

8.2.3 Percentage of Solids

The percentage of solids in a sample is calculated as follows:

$$\text{Percent Solids} = \frac{\text{dry weight}}{\text{wet weight}} \times 100$$

9

Determination of the Method Detection Limit

The MDL is determined at least yearly or more frequently if changing instrument conditions cause concern about instrument sensitivity. The determination is performed as follows:

- When the Innov-X XRF spectrometer is ready for analysis, perform seven repetitions of a low level sample using the appropriate NIST standard corresponding to the element(s) of interest.
- Determine the mean and standard deviation of the seven repetitions. Many calculators and spreadsheet programs will perform these calculations, but they are included below as a reference:

$$Mean = \frac{\sum measurements}{7}$$

$$Deviation = \frac{\sqrt{\sum \ (individual - mean)^2}}{6}$$

- 3.14 times the standard deviation yields the calculated MDL (The 3.14 value is obtained from the Student’s T Test and is based on 7 samples.
- Ten times the standard deviation yields the minimum reporting limit.

10 Health, Safety, and Waste Disposal

10.1 Health and Safety in the Field Laboratory

Laboratory operators should always wear gloves and eye protection during operations, and food and beverages should be excluded from laboratory areas. A further special hazard posed by handheld XRF analyzers is ionizing radiation emitted from the front of the instrument. The XRF should only be used by a trained operator. The instrument should never be pointed toward others. Hands should be held away from the instrument snout while analyzing samples. Personal dosimeter badges are required to be worn; if available, ring style finger dosimeters may also be worn.

Drying of samples that contain high levels of water is advised, but samples that potentially contain mercury should only be air dried (with proper ventilation) and not heated to avoid exposure to mercury vapors.

Covering the analyzer window with a clean bag is advised for in-situ sampling, as to avoid contamination, and cross contamination of the Kapton window.

10.2 Waste Disposal

Excess soil sample material should be returned to the site and the containers emptied. Investigation derived waste (IDW), including empty sample containers, may be disposed of at a solid waste landfill unless it contains high levels of contamination.

11 References

Innov-X Omega XRF Analyzer instrument operating manual.

EPA SW-846 Method 6200, “Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment.”

A

National Institute of Science and Technology Standard Reference Material Values

A.1 SRM 2702 Inorganics in Marine Sediment

Table 1. Certified Concentrations for Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Al [b,c,f,G]	8.41 % ± 0.22 %	Ni [A,a,b,c,d,e]	75.4 ± 1.5
As [b,c,d,G]	45.3 ± 1.8	P [b,c,f,H]	0.1552 % ± 0.0066 %
Ba [A,b,e]	397.4 ± 3.2	Pb [A,a,b,c,e]	132.8 ± 1.1
Ce [b,c,e,G]	123.4 ± 5.8	Rb [b,e,G]	127.7 ± 8.8
Cd [A,a,b,d,I]	0.817 ± 0.011	Sb [a,b,e,G]	5.60 ± 0.24
Co [b,c,G]	27.76 ± 0.58	Sc [b,c,G]	25.9 ± 1.1
Cr [a,b,c,e,G]	352 ± 22	Sr [A,b,c,e]	119.7 ± 3.0
Fe [b,c,f,G]	7.91 % ± 0.24 %	Th [b,c,e,G]	20.51 ± 0.96
Hg [A-1,d,H]	0.4474 ± 0.0069	Ti [b,c,f,G]	0.884 % ± 0.082 %
K [b,c,f,G]	2.054 % ± 0.072 %	Tl [A,a]	0.8267 ± 0.0060
La [b,c,e,G]	73.5 ± 4.2	V [b,c,G]	357.6 ± 9.2
Mn [b,c,G]	1757 ± 58	Zn [a,b,c,e,G]	485.3 ± 4.2
Na [b,c,f,G]	0.681 % ± 0.020 %		

Table 2. Reference Values for Concentrations of Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Ag [a,d]	0.622 ± 0.078	Mg [b,c,f]	0.990 % ± 0.074 %
Ca [b,c,f]	0.343 % ± 0.024 %	Mo [b,c,e]	10.8 ± 1.6
Cu [a,b,c,d,e]	117.7 ± 5.6	Se [b,c,e]	4.95 ± 0.46
Ga [b,c,e]	24.3 ± 1.9	Sn [a,c,e]	31.6 ± 2.4

Table 3. Information Values for Selected Elements

Elements	Mass Fraction mg/kg (unless noted as %)	Elements	Mass Fraction mg/kg (unless noted as %)
Be [b,c]	3.0	Nb [c,e]	63
C (total) [j]	3.36 %	Nd [G]	56
C (organic) [j]	3.27 %	S [j]	1.5 %
Cs [b,G]	7.1	Sm [G]	10.8
Hf [G]	12.6	U [b,e]	10.4
Li [b,c]	78.2	W [G]	6.2

A.2 SRM 2709a San Joaquin Soil – Baseline Trace Element Concentrations

Table 1. Certified Values[(a)] (Dry-Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (%)	Element	Mass Fraction (mg/kg)
Aluminum	7.37 ± 0.16	Antimony	1.55 ± 0.06
Calcium	1.91 ± 0.09	Barium	979 ± 28
Iron	3.36 ± 0.07	Cadmium	0.371 ± 0.002
Magnesium	1.46 ± 0.02	Chromium	130 ± 9
Phosphorus	0.0688 ± 0.0013	Cobalt	12.8 ± 0.2
Potassium	2.11 ± 0.06	Lead	17.3 ± 0.1
Silicon	30.3 ± 0.4	Manganese	529 ± 18
Sodium	1.22 ± 0.03	Strontium	239 ± 6
Titanium	0.336 ± 0.007	Vanadium	110 ± 11
		Zirconium	195 ± 46

Table 2. Reference Values[(a)] (Dry-Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (mg/kg)
Arsenic	10.5 ± 0.3
Cerium	42 ± 1
Cesium	5.0 ± 0.1
Copper	33.9 ± 0.5
Europium	0.83 ± 0.02
Gadolinium	3.0 ± 0.1
Lanthanum	21.7 ± 0.4
Mercury[(b)]	0.9 ± 0.2
Nickel	85 ± 2
Rubidium	99 ± 3
Scandium	11.1 ± 0.1
Thallium	0.58 ± 0.01

Table 3. Information Values[(a)] (Dry Mass Basis) for Selected Elements in SRM 2709a

Element	Mass Fraction (mg/kg)
Boron	74
Dysprosium	3
Hafnium	4
Lutetium	0.3
Neodymium	17
Samarium	4
Selenium	1.5
Tantalum	0.7
Terbium	0.5
Ytterbium	2

A.3 SRM 2710 Montana Soil – Highly Elevated Trace Element Concentrations

Table 1. Certified Values

Element	Mass Fraction (%)			Element	Mass Fraction (mg/kg)		
Aluminum	6.44	±	0.08	Antimony	38.4	±	3
Calcium	1.25	±	0.03	Arsenic	626	±	38
Iron	3.38	±	0.10	Barium	707	±	51
Magnesium	0.853	±	0.042	Cadmium	21.8	±	0.2
Manganese	1.01	±	0.04	Copper	2950	±	130
Phosphorus	0.106	±	0.015	Lead	5532	±	80
Potassium	2.11	±	0.11	Mercury	32.6	±	1.8
Silicon	28.97	±	0.18	Nickel	14.3	±	1.0
Sodium	1.14	±	0.06	Silver	35.3	±	1.5
Sulfur	0.240	±	0.006	Vanadium	76.6	±	2.3
Titanium	0.283	±	0.010	Zinc	6952	±	91

Table 2. Noncertified Values

Element	Mass Fraction (%)	Element	Mass Fraction (mg/kg)
Carbon	3	Bromine	6
		Cerium	57
		Cesium	107
		Chromium	39
		Cobalt	10
		Dysprosium	5.4
		Europium	1
		Gallium	34
		Gold	0.6
		Hafnium	3.2
		Holmium	0.6
		Indium	5.1
		Lanthanum	34
		Molybdenum	19
		Neodymium	23
		Rubidium	120
		Samarium	7.8
		Scandium	8.7

A.4 SRM 2711 Montana Soil – Moderately Elevated Trace Element Concentrations

Table 1. Certified Values

Element	Mass Fraction (%)		
Aluminum	6.53	±	0.09
Calcium	2.88	±	0.08
Iron	2.89	±	0.06
Magnesium	1.05	±	0.03
Phosphorus	0.086	±	0.007
Potassium	2.45	±	0.08
Silicon	30.44	±	0.19
Sodium	1.14	±	0.03
Sulfur	0.042	±	0.001
Titanium	0.306	±	0.023

Element	Mass Fraction (µg/g)		
Antimony	19.4	±	1.8
Arsenic	105	±	8
Barium	726	±	38
Cadmium	41.70	±	0.25
Copper	114	±	2
Lead	1162	±	31
Manganese	638	±	28
Mercury	6.25	±	0.19
Nickel	20.6	±	1.1
Selenium	1.52	±	0.14
Silver	4.63	±	0.39
Strontium	245.3	±	0.7
Thallium	2.47	±	0.15
Vanadium	81.6	±	2.9
Zinc	350.4	±	4.8

Table 2. Noncertified Values

Element	Mass Fraction (%)
Carbon	2

Element	Mass Fraction (µg/g)
Bromine	5
Cerium	69
Cesium	6.1
Chromium	47
Cobalt	10
Dysprosium	5.6
Europium	1.1
Gallium	15
Gold	.03
Hafnium	7.3
Holmium	1
Indium	1.1
Iodine	3
Lanthanum	40
Molybdenum	1.6

B

Metals of Interest to ERU for Annual MDL Precision Studies

B-1 Metals of Interest

Analytes	Residential Soil RSL (mg/kg)	CAS Registry No.
Arsenic (As)	0.39	7440-38-0
Chromium (Cr)	230	7440-47-3
Copper (Cu)	3100	7440-48-4
Lead (Pb)	400	7439-92-1
Mercury (Hg)	6.7	7439-97-6
Nickel (Ni)	1600	7440-02-0
Silver (Ag)	390	7440-22-4

ATTACHMENT H HEALTH AND SAFETY ON DRILLING RIG OPERATIONS

Title:	**HEALTH AND SAFETY ON DRILLING RIG OPERATIONS**
Category:	H&S 5.3
Revised:	September 2008

STANDARD OPERATING PROCEDURE

HEALTH AND SAFETY ON DRILLING RIG OPERATIONS

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TITLE: HEALTH AND SAFETY ON DRILLING RIG OPERATIONS

CATEGORY: H&S 5.3

REVISED: September 2008

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1. Introduction

This document is meant to be used in conjunction with Ecology and Environment, Inc., (E & E) standard operating procedures (SOPs) for field operations and hazardous waste site operations, and incorporates by reference all safety precautions required therein. It specifically addresses the functions and responsibilities of personnel working on or around drilling operations.

E & E personnel are frequently required to oversee a subcontractor's work in the field using drill rigs to take soil and rock samples, and install piezometers and monitoring wells. This document discusses the supervision of subcontract drillers by E & E.

2. Responsibilities and Authority of Subcontract Driller

The subcontract driller has authority to direct its personnel within the area while drilling operations are in progress. Access to the hazardous area around the auger and borehole is restricted by a "super exclusion zone" delineated by a 4-foot by 8-foot sheet of plywood centered over the borehole before drilling. A large hole cut in the plywood allows penetration of the augers. No E & E personnel are allowed in this "super exclusion zone" at any time while drilling is underway.

Housekeeping around the rig is the responsibility of the driller, but all team members should, when necessary, participate in this effort.

2.1 Responsibility and Authority of E & E Personnel

E & E personnel working at a drilling site must act as support to the subcontract drilling team by providing any necessary support functions; however, it is important that E & E personnel are careful not to interfere with the drilling process. Personnel are restricted from approaching the "super exclusion zone" while drilling is underway. If an E & E crew member recognizes an unsafe condition in the work area or on the rig, he should bring it to the attention of the site safety officer (SSO) and team leader if it is not resolved in a timely manner by the subcontractor driller. If conditions are still deemed to be hazardous, team members have the option of contacting their regional safety coordinator (RSC) or Corporate Health and Safety Group in Buffalo.

It is the responsibility of all E & E personnel to have with them on site their issued non-disposable gear, including hard hat, face shield, respirator, steel-toed boots, eyepiece inserts, safety glasses, and appropriate outerwear for the expected weather. It is the E & E employee's responsibility to ensure that all of his/her equipment is in proper working order.

All personnel should be aware of emergency facilities, egress routes, and special medical conditions of their team members. As with all E & E fieldwork, the buddy system is to be enforced.

3. Training Requirements for Site Personnel

3.1 E & E Site Safety Officer

In addition to basic health and safety training, annual health and safety refresher training, first aid, cardiopulmonary resuscitation (CPR), and necessary training in field monitoring of personnel, an SSO should have previous experience as a team member on field drilling projects in order to have a working knowledge of the drill rig and the extreme hazards that can occur with its operation. Where monitoring instrumentation is to be used, the SSO must be properly trained prior to fieldwork. The SSO must have an understanding of the hazards of heat and cold stress, their associated symptoms, and proper work modifications to protect field staff from potential injury.

3.2 Other E & E Personnel

All E & E personnel present on site shall have taken the basic 40-hour health and safety course and annual 8-hour refresher training course. Field personnel also must meet medical and respiratory fitness test requirements established by E & E and Occupational Safety and Health Agency (OSHA).

3.3 Subcontract Driller and Other Subcontract Drilling Personnel

Subcontract drillers and their support personnel on site must, at a minimum, have passed basic 40-hour health and safety training as prescribed by OSHA 29 Code of Federal Regulations (CFR) 1910.120. They shall be medically approved and trained to use the level(s) of respiratory protection required on site. Certification of training by the subcontractor shall be required as a deliverable included in E & E's contractual documentation. This training shall be verbally verified and logged on site by the SSO or team leader before starting work.

4. Supervision of Subcontract Drillers

4.1 Responsibilities and Authority of Site Safety Officer

The responsibilities of the SSO at a drilling site where subcontracted drillers are used include the following: rig inspections, personnel monitoring, and personnel protection.

A rig inspection should begin by verifying the following:

- The mast must be located at least 25 feet from any overhead or underground utility lines;
- The location and operation of operational and unencumbered kill switches must be reiterated to all site personnel;

- Outriggers, stabilizers, or jacks are in place, and the rig is level;
- A geophysical survey (e.g., electromagnetic or ground-penetrating radar) or a reliable site history must be obtained to verify the absence of underground utilities, buried obstacles, tanks, and drums;
- A first aid kit and filled eyewash bottle must be readily available;
- A fire extinguisher should be charged to the proper pressure and placed at the rear of the rig during drilling;
- The condition of ropes, chains, and cables must be checked;
- A lifeline or safety belt must be available if mast climbing is necessary;
- The Site Safety Plan (SSP) must be posted with emergency phone list and map of hospital route; and
- A "super exclusion zone" must be established around the borehole, using traffic cones or a 4-foot by 8-foot sheet of plywood. This defined area will be entered during active drilling only by the subcontract driller and his helper(s), except in emergency situations.

If, upon review, the SSO deems that any material item noted above requires replacement or repair, the SSO must make necessary the arrangements for that repair or replacement, and later verify that repair or replacement is sufficient before actual drilling begins. Similarly, if the conditions listed above are not met, the SSO must request that they be met to his satisfaction before allowing drilling to proceed. Working together, the SSO and the subcontract driller should verify that the rig has been checked against the operator's checklist.

The SSO's monitoring duties include calibration and setup of the appropriate monitoring devices, as specified in the SSP. At a minimum, this generally includes an O_2/explosimeter and real-time organic-vapor monitoring capabilities (e.g., HNU, organic vapor analyzer [OVA]). Noise and heat-stress monitoring are employed where appropriate. If the SSO believes additional monitoring devices beyond the directive of the SSP should be employed (e.g., Rad Mini, Mini Ram), it is his/her responsibility to obtain this equipment from the nearest E & E office through the cooperation of the RSC or the Corporate Health and Safety Group. The SSO is also responsible for ensuring that a trained operator for this additional equipment is on site.

It is the responsibility of the SSO to ensure that all safety equipment is in good working order. Day-to-day operations, as well as calibration data, must be recorded in the equipment log or SSO log. Adequate supplies such as breathing air, drinking liquids, and calibration gas must be maintained.

E & E personnel are forbidden from entering the "super exclusion zone" around the borehole while drilling is underway. The SSO must not attempt to take air readings in or around the auger while it is in use, or from cutting samples while the auger is in motion. If possible, an

O_2/explosimeter should be set up for unmanned (alarmed) operations at the rig, using an extension hose to continuously draw samples from the borehole area during drilling operations.

The SSO has ultimate authority over the subcontractor with regard to whether work practices meet the requirements of the SSP. Shutdown of work or restriction of personnel are options available to the SSO. The SSO should hold informal site safety briefings at the start of both fieldwork and daily work shifts throughout the course of the project. Although E & E contractually requires subcontractors to provide properly trained and outfitted staff, the SSO should verify verbally at the start-up meeting that the field staff has necessary respiratory approval and OSHA-mandated training, especially at hazardous waste sites. Site safety briefing topics, as well as the names of attendees, will be recorded in the site safety log.

If the SSO has reason to believe that either E & E or subcontractor personnel are under the influence of alcohol or drugs, or are otherwise ill before or during work on site, he or she should consider restricting those team members from site work. Personnel who are to perform work that requires Level C protection must be clean-shaven or they may be restricted at the discretion of the SSO.

The following is a list of basic topics to be discussed at site safety meetings:

- Personnel responsibilities;
- Planned investigation and presumed potential hazards;
- Levels of protection, monitoring plan, and equipment;
- Emergency scenario plans, including use of kill switches;
- Location and operation of kill switches, fire extinguisher, and first aid kits;
- Heat and cold stress hazards;
- “Super exclusion zone” around borehole; and
- Warnings to subcontractors about hazards of climbing the mast without proper safety equipment.

Because heat stress is a constant threat during warm weather, the SSO is responsible for determining whether conditions are unsuitable for work. If site conditions require the assistance of work modifications, cooling vests, and other cooling means, the SSO may decide that work should not continue. The need for worker monitoring through blood pressure and oral temperature checks will be determined by the SSO with assistance from the RSC and Corporate Health and Safety Group staff, if necessary.

The SSO will be responsible for shutting down the drilling operation if electrical storms occur in the site area.

No refueling operations will be performed until rig engines are shut down. Motor fuels should be stored and dispensed from spring-loaded, OSHA/Factory Mutual-approved metal or polyethylene gas cans.

The SSO should ensure and document that no boreholes are left open or unfilled after drilling equipment is moved. In instances where a hole must be left open and unattended, suitable barricades or the equivalent will be staged around the hole to prevent personnel and equipment from falling in.

4.2 Responsibilities and Authority of Other E & E Personnel

All E & E personnel on site are required to follow the terms of the SSP and the direction of the SSO. Because the SSO cannot be in all places at all times, the crew should observe the subcontractors and condition of their equipment at all times, and report immediately to the team leader and SSO any safety-related issues that are unresolved. Included are such details as dressout, site functions, and decontamination. It is important that the SSO be involved so that proper log entries can be made.

It is a policy of E & E not to provide safety equipment or monitoring instrumentation to subcontractors. Some projects, however, may be arranged in such a manner that allows E & E personnel and subcontractors to share the same expendable supplies.

E & E personnel are forbidden from approaching augers during drilling. Activities at the borehole, such as sampling, require that the operation of equipment be stopped.

5. Drilling Hazards

5.1 General Drilling Hazards

Drilling operations present numerous health and safety hazards to site personnel, subcontractor drillers, and members of the public who may approach the rigs. Drilling hazards that apply to all drilling methods and possible control methods include:

- Slip/trip/fall hazards;
- Ergonomic hazards;
- Moving objects;
- Unguarded points of operation;
- Heat/cold stress;
- Noise;
- Buried or overhead utilities;

- Radiological hazards;
- Lightning;
- Chemical hazards; and
- Biological hazards.

5.2 Physical Hazards (Slip/Trip/Fall Hazards)

Personnel may be injured if they trip over tools or objects, walk on uneven terrain, fall from heights or into holes, or slip on surfaces.

Controls

- Store all tools and supplies away from the super exclusion zone;
- Personnel should use caution when walking on uneven surfaces so that they do not lose their balance;
- Subcontractor drillers must wear a lifeline or safety belt if mast climbing is necessary;
- Boreholes should be barricaded or marked with flags when drilling has been completed to prevent personnel from stepping in the hole; and
- Soil or sand should be applied to wet or slippery surfaces.

5.3 Ergonomic Hazards

Muscle strains, sprains, and injuries can occur when personnel use improper lifting methods, lift objects that are too heavy, improperly reach for objects, or work in awkward positions.

Controls

- Lift with the back as straight as possible, bend the knees, and keep the object close to the body;
- Use two people to move heavy objects such as augers;
- Avoid excessive stretching of the arms when picking up objects; and
- Avoid sudden twisting of the back or working in awkward positions.

5.4 Moving Objects

Site personnel may be injured if they are struck by debris from the borehole or by drilling machinery or components.

Controls

- Wear the appropriate personal protective equipment such as safety boots, safety glasses, and a hard hat; and
- Adequate inspection and maintenance of the drill rig will reduce the likelihood of worn equipment or parts falling and causing accidents.

5.5 Unguarded Points of Operation

The spinning auger on a drill rig or the V-belt drive on a motor are unguarded points of operation that can pull site personnel into the machinery and cause serious injuries.

Controls

- Mechanical guards cannot be placed around the spinning auger on a drill rig. Site personnel must stay away from the spinning auger and avoid wearing loose clothing that could get caught in the auger; and
- Mechanical guards must be placed over V-belt drives.

5.6 Heat/Cold Stress

Drilling is a strenuous job, and heat stress is a major hazard in hot, humid environments, especially when personnel are wearing protective equipment such as coveralls, gloves, boots, and respirators. Cold injury can occur at low temperatures and when the wind-chill factor is low.

Heat Stress

Controls

- Recognize the signs and symptoms of heat stress;
- Monitor workers who are wearing protective clothing; and
- Provide fluid replacement and schedule rest periods in cool locations.

Cold Stress

Controls

- Recognize the signs and symptoms of cold stress;
- Personnel must wear appropriate clothing during cold weather; and
- A warm rest location and fluid replacement should be provided.

5.7 Noise

Excessive noise can cause hearing damage, distract workers, and interfere with communications.

Controls

- In excessive noise areas, wear the hearing protection recommended by the SSO.

5.8 Buried or Overhead Utilities

Contact of drilling tools with electric, gas, steam, process, or other utility lines can result in fires, explosions, electric shock hazards, burns, etc.

Controls

- The boom on the drill rig must be kept at least 25 feet from overhead and buried utilities;
- After buried utilities have been located using an appropriate geophysical survey, the line locations should be marked with flags. Maps of underground utilities should also be checked, if available, to verify locations; and
- Drilling operations should proceed slowly in areas near buried utilities, as the actual utility location may not exactly correspond to the area identified by a flag or as illustrated on a map.

5.9 Radiological Hazards

5.9.1 Nonionizing Radiation

Nonionizing radiation is radiation that emits photon energy that is not sufficient to produce ionization in biological systems. Radio frequencies (including radar and microwave), infrared, visible light, and ultraviolet regions of the electromagnetic spectrum are considered to be nonionizing. Ultraviolet radiation from the sun is usually the major nonionizing radiation hazard present during drilling operations. Ultraviolet radiation can damage the skin and eyes. Potential effects include, but are not limited to, sunburn, skin cancer, photosensitization, and cataracts.

Controls

- Wear sunscreen on all exposed skin areas; and

- Wear safety glasses that block ultraviolet radiation (or sunglasses worn over safety glasses).

5.9.2 Ionizing Radiation Hazards

Ionizing radiation is electromagnetic or particulate radiation with sufficient energy to ionize atoms. Ionizing radiation may be present on some drilling sites and includes:

- Electromagnetic radiation
  - Gamma rays
  - X-rays

- Particulate radiation
  - Alpha
  - Beta
  - Neutrons

Controls

Site personnel can minimize their exposure to external radiation hazards by:

- Limiting exposure time;

- Increasing the distance from the radiation source; and

- Shielding the radiation source.

Some radiation sources can enter the body through inhalation, ingestion, and/or skin contact. Exposure can be controlled through the wearing of personal protective equipment and thorough washing of skin surfaces with soap and water.

5.10 Lightning Hazard

The elevated mast on a drill rig is a potential target of lightning.

Controls

- The SSO will halt drilling operations when electrical storms approach the drilling location.

5.11 Chemical Hazards

Chemical contaminants may be present in the form of gases, vapors, aerosols, fumes, liquids, or solids. Site personnel may be exposed to these contaminants through one or more of the following pathways: inhalation, ingestion, skin, and/or eye contact.

Controls

- Become familiar with the specific drilling operation being used to identify and avoid chemical discharge locations;
- Wear appropriate personal protective equipment;
- Practice contamination avoidance; and
- Stay upwind during grout mixing (silica inhalation hazard).

5.12 Biological Hazards

Biological hazards that may be present during drilling operations include poisonous plants, animals, and insects, and infectious agents.

Controls

- Wear insect repellant at sites where biting insects are prevalent;
- Learn to identify poisonous plants that cause dermatitis, such as poison ivy and poison oak;
- Wear impervious personal protective clothing (e.g., saranex coveralls, latex booties, nitrile surgical gloves) if work must be conducted in areas where site personnel will contact poisonous plants; and
- Avoid potential animal nesting areas and animal carcasses.

6. Drilling Methods and Hazards

6.1 Solid Flight and Bucket Augers

Solid-flight augers (also referred to as solid-stem augers, continuous flight augers, and disk augers) use solid-stem auger sections, with the flighting (curved corkscrew-like blades) connected end-to-end to the cutting head (see Figure 1). Soil cuttings are moved upward to the ground surface by the flighting as the auger penetrates into the soil. Samples are typically collected by removing an auger section, attaching a split-spoon or thin-wall sampler to the end of a drill rod, and placing this arrangement into the borehole. Split-spoon samples are collected by using a hammer connected to the drill rod and split-spoon. The hammer is operated by wrapping sections of rope around a rotating cathead hoist (a wide metal cylinder). A disk auger is similar to a solid-flight auger except that it is larger in diameter and the flighting goes around the stem once. Bucket augers have a cutting edge on the bottom. Once the bucket auger fills with soil cuttings, it is brought to the surface to be emptied. Figure 1 shows various types of bucket augers.

Auger drill methods are used in unconsolidated material for sampling subsurface media, installing groundwater monitoring wells, and identifying depth to bedrock.

6.2 Hollow-Stem Auger

A drill rig rotates a hollow-stem auger (see Figure 2) and moves it vertically into the soil. The hollow stem allows use of continuous or intermittent soil sampling techniques. Once the required depth has been reached, screens and casing for monitoring wells can be placed in the hollow-stem gravel pack and grout is added as the auger is pulled out of the borehole. Hollow-stem auger drilling is a common method of monitoring well installation.

6.2.1 Auger Drilling Hazards

Physical Hazards

Spinning Auger. The spinning auger is not equipped with a metal guard; therefore, it is imperative that personnel use extreme caution when working near spinning auger, as contact with the auger can cause personnel to be pulled into the auger and crushed between the auger and the drill rig. Only approved drillers will remain in proximity to the borehole during drilling, and an approximate 4- by 8-foot “super exclusion area” will be established by placing a 4- by 8-foot sheet of plywood over the borehole, or by placing flagging or traffic cones around a 4- by 8-foot perimeter. No personnel, except the driller and the driller’s helper, will enter this zone during drilling. The SSO will issue warnings to those personnel not authorized to enter this zone.

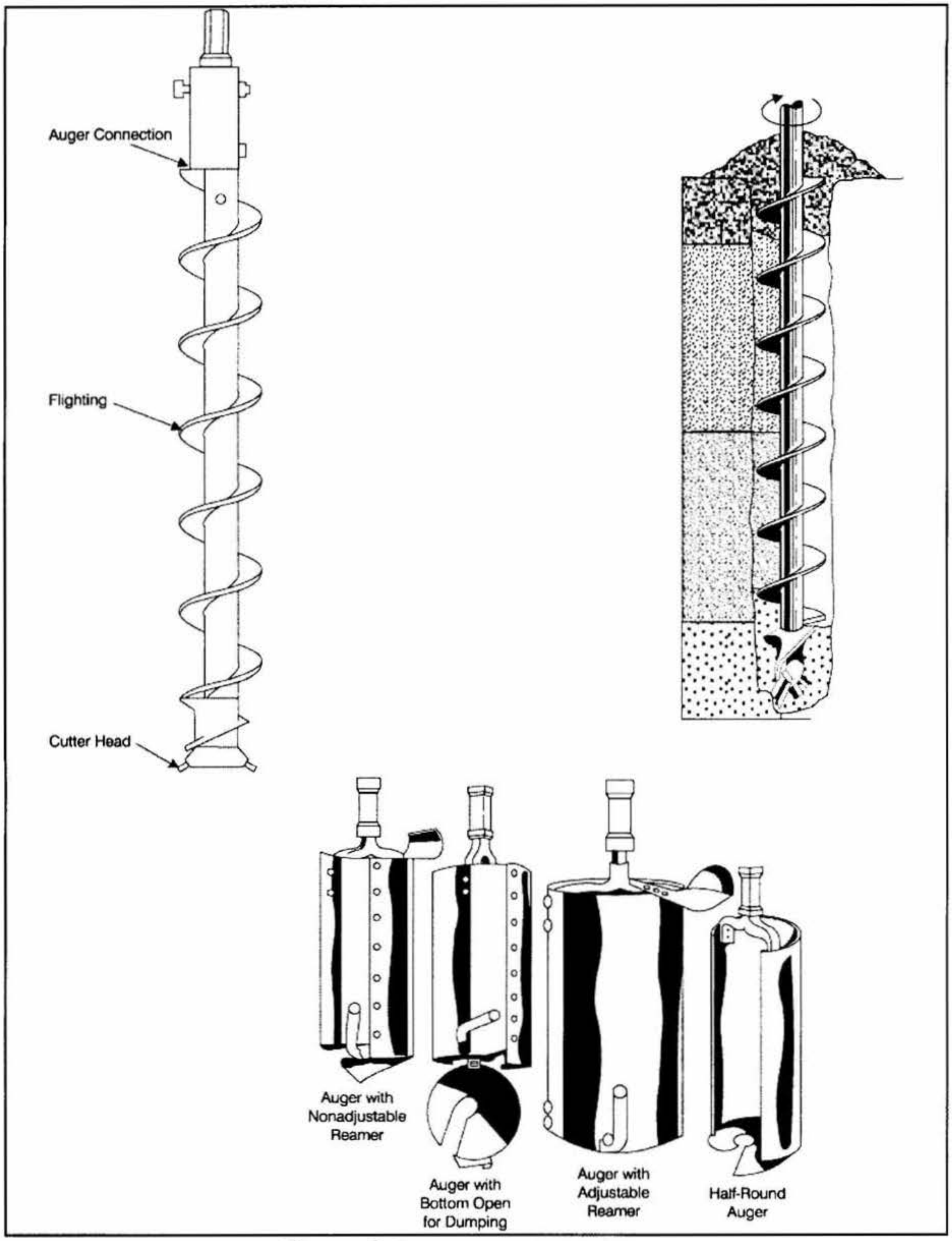

Figure 1 Solid Flight and Bucket Augers

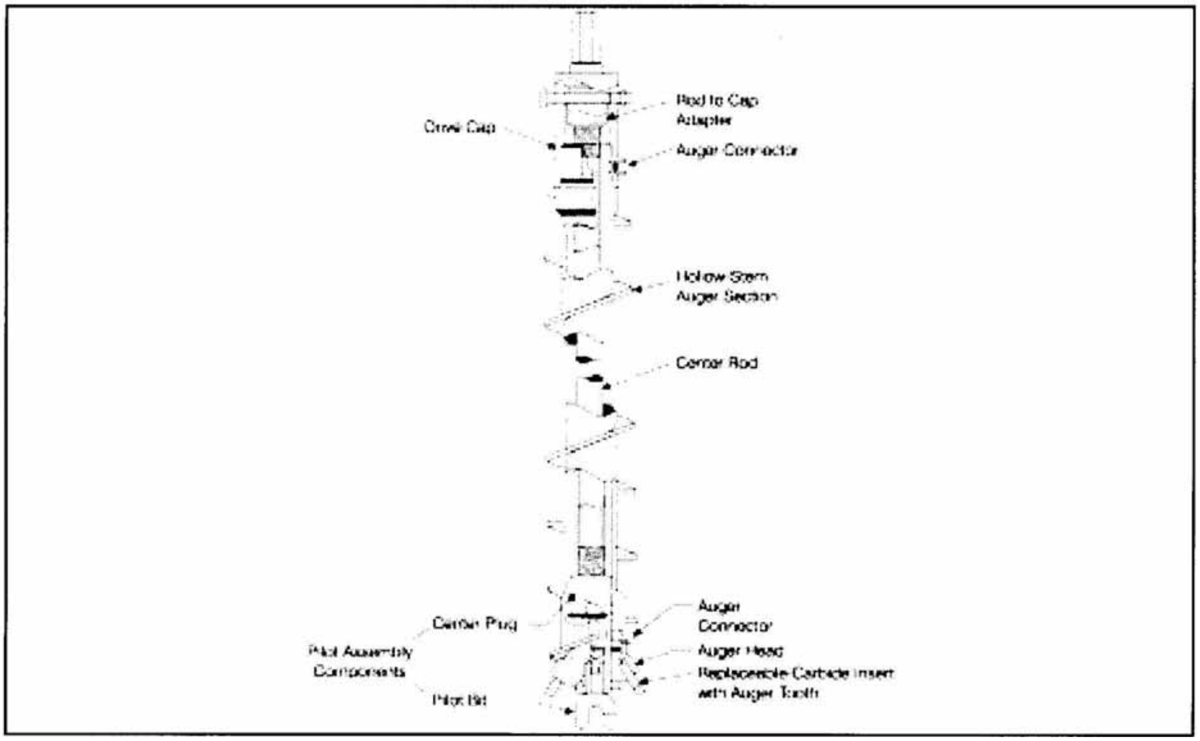

Figure 2 Hollow-Stem Auger

Overhead Equipment. If wire line core sampling is conducted, drill steel and sampling gear will be lifted overhead. Site personnel must conduct the necessary equipment inspections to ensure it is in good condition prior to the start of drilling operations. In addition, drillers must make sure that proper hoisting procedures are used to reduce the likelihood of dropping drill steel or sampling gear.

Drill Rig Lurching. The drill rig has a tendency to lurch and shake when the auger comes into contact with harder materials. This is especially true when hollow-stem auger drilling methods are utilized. The rig can also lurch seriously in hearing sands. Site personnel should be aware of possible drill rig movement and move away from the rig if lurching or shaking occurs.

Noise. If split-spoon sampling is conducted, a hammer is used to drive the spoon into the soil. The hammer generates a loud noise when it contacts a metal surface. Site personnel are required to wear appropriate hearing protection during hammering operations.

6.3 Open-Hole Rotary Methods

A direct mud rotary drilling system (also direct [liquid] rotary, hydraulic rotary, or reverse [circulation] rotary) is shown in Figure 3. Drilling fluid (mud) is pumped through drill rods to a bit. The mud flows back to the surface through the space between the drill rods and the borehole and is discharged at the surface through a pipe into a tank, tub, pond, or pit. After the cuttings settle, a pump recirculates the liquid back through the drill rods. The mud serves to:

- Cool and lubricate the bit;
- Stabilize the borehole well; and
- Prevent the inflow of fluids from formations.

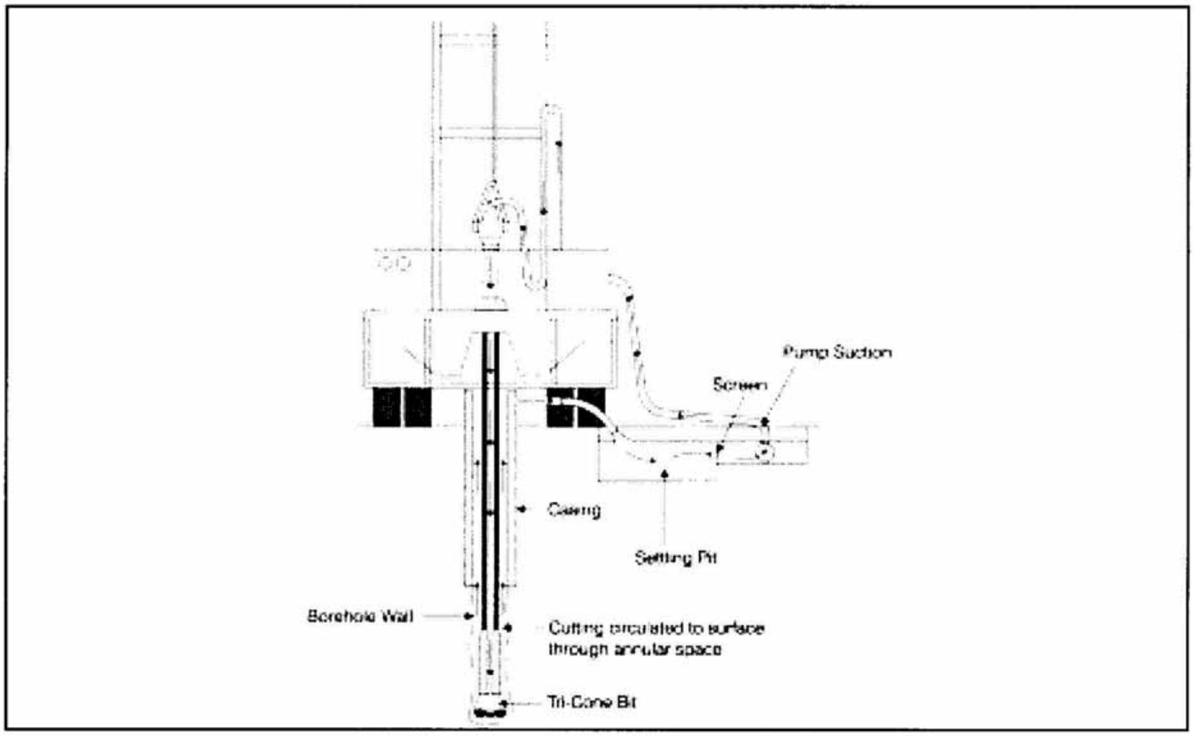

Figure 3 Open-Hole Rotary Method

A shale shaker can collect a sample from the circulated fluid by placing it in the discharge flow before the settling pit. In addition, the drilling fluid flow can be shut off and split-spoon, thing-wall, or consolidated-core samplers can be used to collect a sample by inserting a sampler through the drill rods. Reverse circulation rotary drilling is a variation of mud rotary drilling in that the mud flows from the mud pit down the borehole outside the drill rods, passes up through the bit carrying cuttings into the drill rods, and is then discharged into the mud pit. The equipment used is similar to the direct mud rotary method, except most of the equipment is larger.

Equipment Breaks. A break in support equipment for drill steel could cause equipment to fall and injure site personnel. Equipment inspection is required to ensure it is in good condition prior to the start of drilling operations.

Slippery Conditions. Because the use of drilling mud will create slippery conditions around the drill rig and support area, mud should be contained to the immediate work area. Slippery spots should be dried with sand/dirt to reduce slipping hazards. Gloves should be changed when they become coated with mud.

6.4 Direct Air Rotary with Rotary Bit/Downhole Hammer

Also called an air rotary with roller-cone (tri-cone) bit, down-the-hole hammer, or air percussion rotary, the rig setup for air rotary with a tri-cone or roller-cone bit is similar to direct mud rotary (see Figure 3), except the method uses air instead of water and drilling mud. The main components of a drill string using a tri-cone bit are illustrated in Figure 4. Compressed air is forced down through the drill rods to cool the bit, and cuttings are carried up the open hole to the surface. A cyclone slows down the air velocity, forcing the cuttings into the container. A roller-cone drill bit is used for hard-to-soft consolidated rock and unconsolidated formations. When a downhole hammer is utilized, it replaces the roller-cone bit (see Figure 4). The hammer produces a pounding action as it rotates. Other features are similar to the rotary bit, except small amounts of surfactant and water are used for dust and bit temperature control.

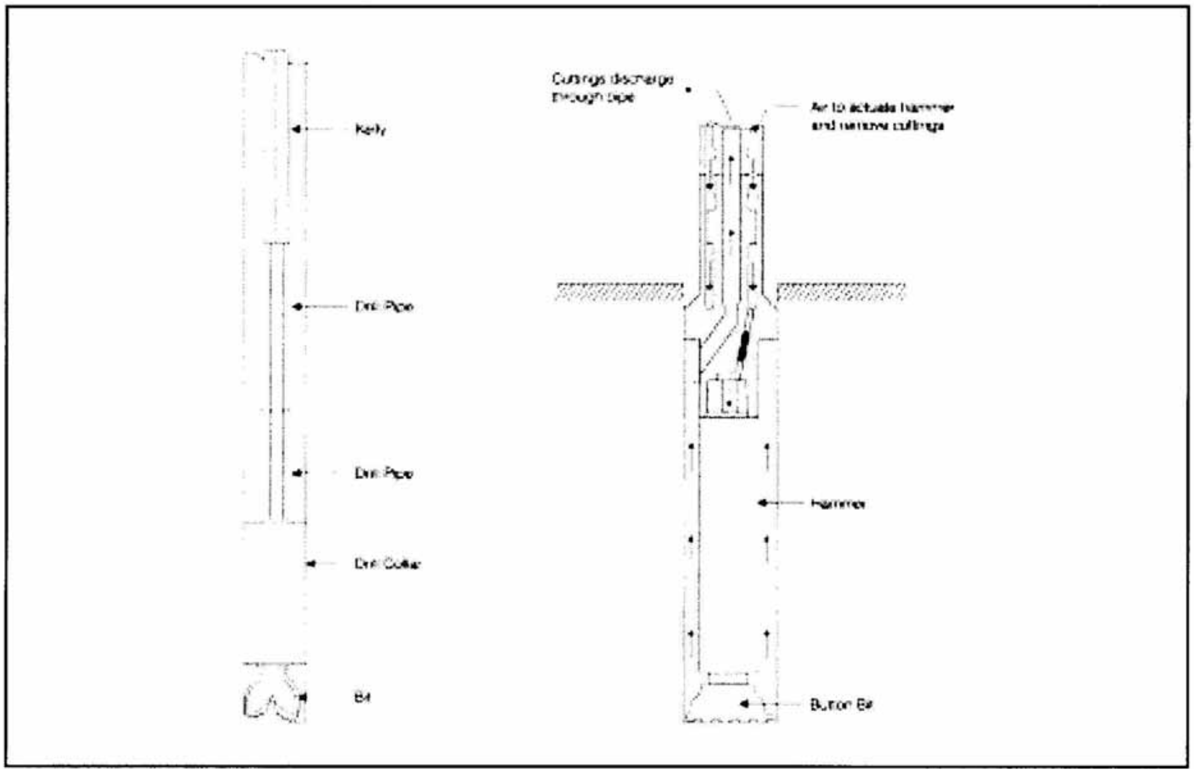

Figure 4 Direct Air Rotary

Physical Hazards

Noise. Excessive noise is generated from the use of air compressors, casing drivers, and downhole hammers. Site personnel are required to wear hearing protection during drilling operations.

Cuttings and Water. Cuttings and water blown from the hole can strike and injure site personnel. Site personnel must stay away from this discharge location and wear appropriate personal protective equipment.

Overhead Equipment. If wire line core sampling is conducted, drill steel and sampling gear will be lifted overhead. Site personnel must conduct the necessary equipment inspections to ensure it is in good condition prior to the start of drilling operations. In addition, drillers must make sure that proper hoisting procedures are followed to reduce the likelihood of falling drill steel or sampling gear.

6.5 Cable Tool

A cable tool drill rig operates by repeatedly lifting and dropping tools attached to a cable into a borehole. Figure 5 shows the components of a cable tool rig. This drilling method crushes rock and a spudding beam mixes the crushed particles with water. The water and debris is removed by a bailer or pump. In unconsolidated formations, a casing is driven into the ground. In consolidated formations, drilling is conducted with the use of a casing.

Physical Hazards

Noise. The spudding beam generates excessive noise. All personnel must wear appropriate hearing protection during drilling operations.

Rig Movement. The drill rig tends to lurch as the drill string is raised and lowered. Site personnel must maintain an adequate distance from the rig during drilling operations.

Overhead Equipment. Drill string and bailers are hoisted during drilling operations and present an overhead hazard to site personnel if a tool falls from a height.

6.6 Casing Advancement: Rotary Drill-Through Methods

6.6.1 Drill-Through Casing Driver and Dual Rotary Method

Casing drivers advancement (also referred to as air [mud] rotary drill or downhole hammer with casing drivers, air rotary casing hammer, and air drilling with casing hammer) involves a driver that moves the casing as drilling occurs (see Figure 6) during the use of conventional direct air (mud) or downhole hammer equipment. Drill cuttings move upward in the space between the drill pipe and the casing. The diameter of the casing is slightly larger than the bit so it can be easily removed.

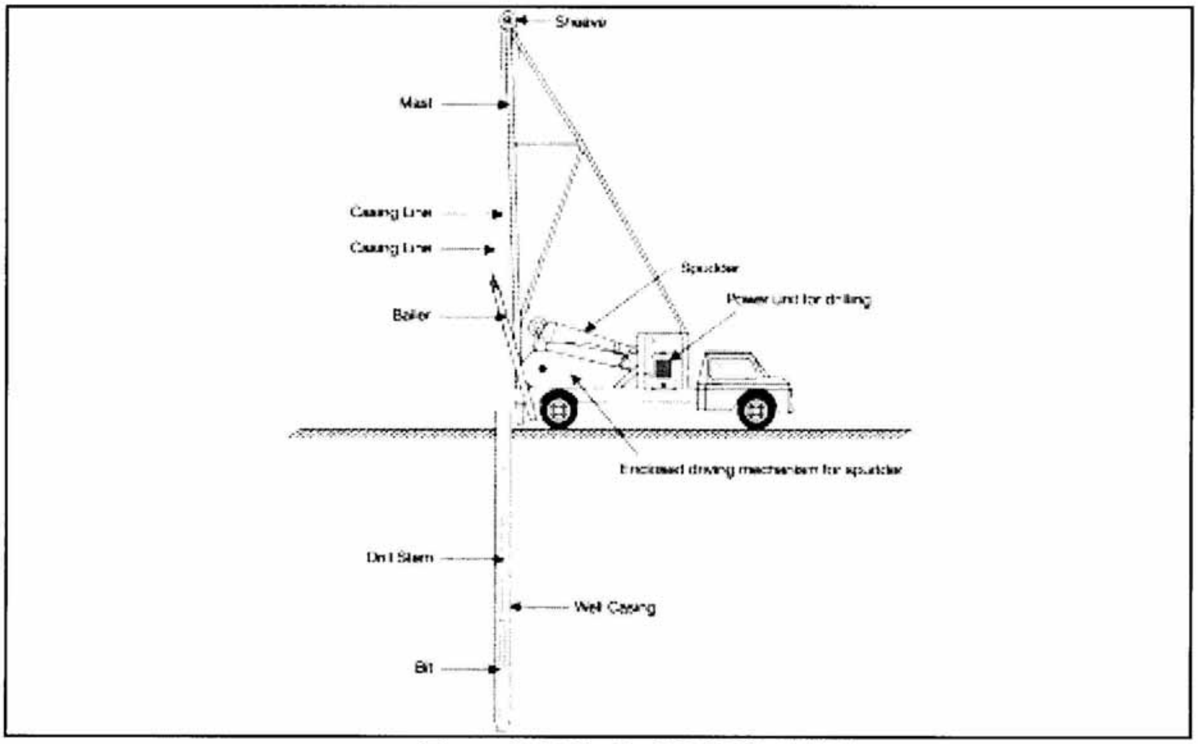

Figure 5 Cable Tool Drill Rig

In dual rotary advancement, the casing is moved by using a rotary steel casing provided with a carbide-studded drive shoe. The carbide ring cuts through the overburden material. Rotary drilling (usually air) takes place at the same time using a downhole hammer or tri-cone bit. Drilling can be conducted either inside or ahead of the casing.

The type of drilling is used to install monitoring wells in unconsolidated formations, where loss of circulation of drilling fluids is a problem, and/or where prevention of cross-contamination of aquifers is important.

6.6.2 Reverse Circulation (Rotary, Percussion Hammer, and Hydraulic Percussion)

The reverse-circulation rotary drilling method can utilize air rotary with a downhole hammer or bit or mud rotary. Two or three casings can be used.

Reverse circulation dual-wall rotary. This method is similar to downhole hammers with a casing driver or air rotary-cone bit, except air is moved down the space between the casing and the drill pipe to the bit, and soil cuttings are pushed to the surface through the drill pipe (see Figure 7).

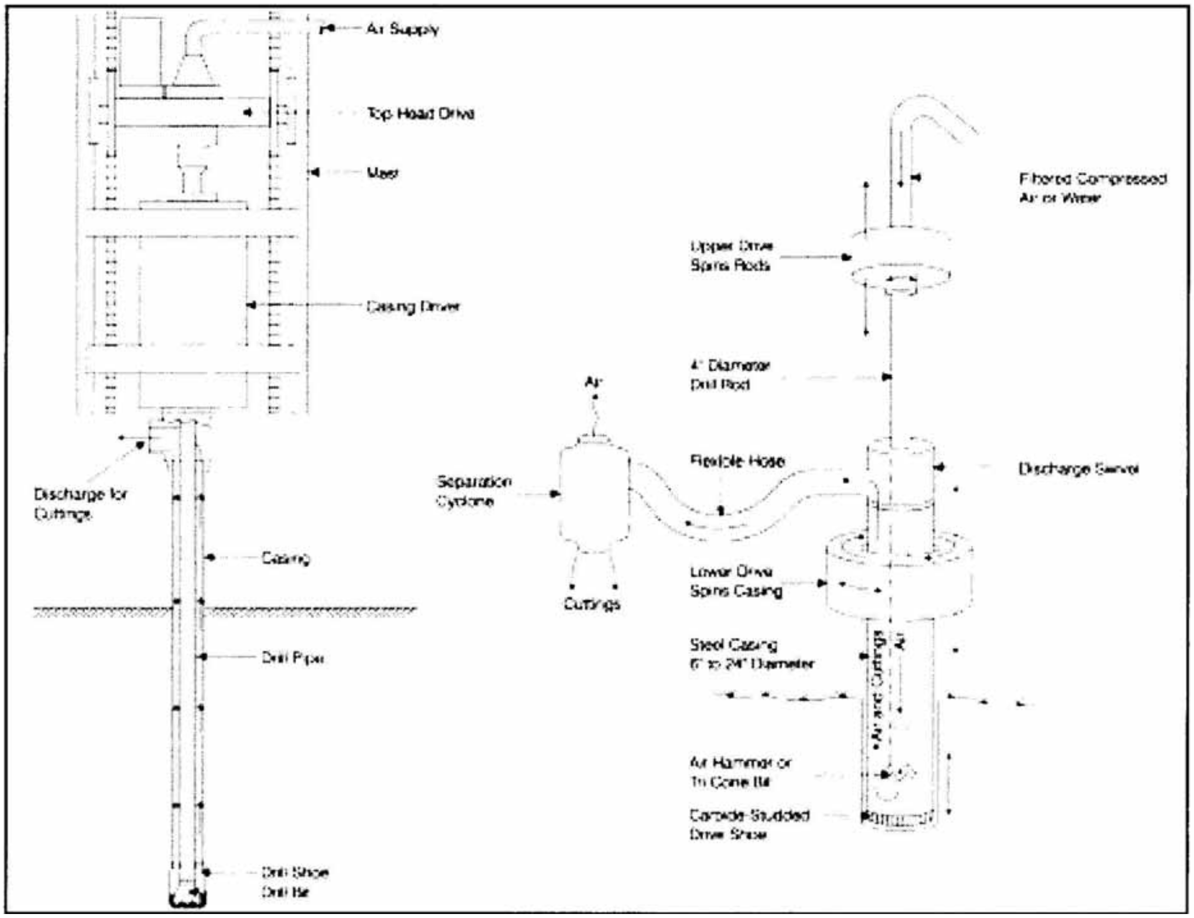

Figure 6 Casings

Reverse circulation dual-wall percussion hammer. The percussion hammer operates in a similar manner of reverse circulation as the dual-wall rotary method, except the drive method is different. Either two or three casings are used. Compressed air is moved into the space between the outer and inner pipes, and soil cuttings are discharged from the inner pipe to a cyclone. A percussion hammer on the most of the drill rig strikes an anvil on the top of the drive assembly. Two or three casings are driven, and the bit does not rotate.

Physical Hazards – Reverse Circulation Dual-Wall Rotary

Noise. Excessive noise is generated from the use of air compressors, casing drivers, and downhole hammers. Site personnel are required to wear hearing protection during drilling operations.

Cuttings. Cuttings and debris discharged from the hole can strike and injure site personnel. Site personnel must stay away from the discharge point and wear appropriate personal protective equipment.

Overhead Equipment. If wire line core sampling is conducted, drill steel and sampling gear will be lifted overhead. Site personnel must conduct the necessary equipment inspections to ensure it is in good condition prior to the start of drilling operations. In addition, drillers must make sure that proper hoisting procedures are followed to reduce the likelihood of dropping drill steel or sampling gear.

Physical Hazards – Hydraulic Percussion

Slips/Falls. Site personnel can slip on wet ground around the drill rig or fall into the water tank. Site personnel must keep the drilling location clear of debris and contain spillage prior to and during drilling operation.

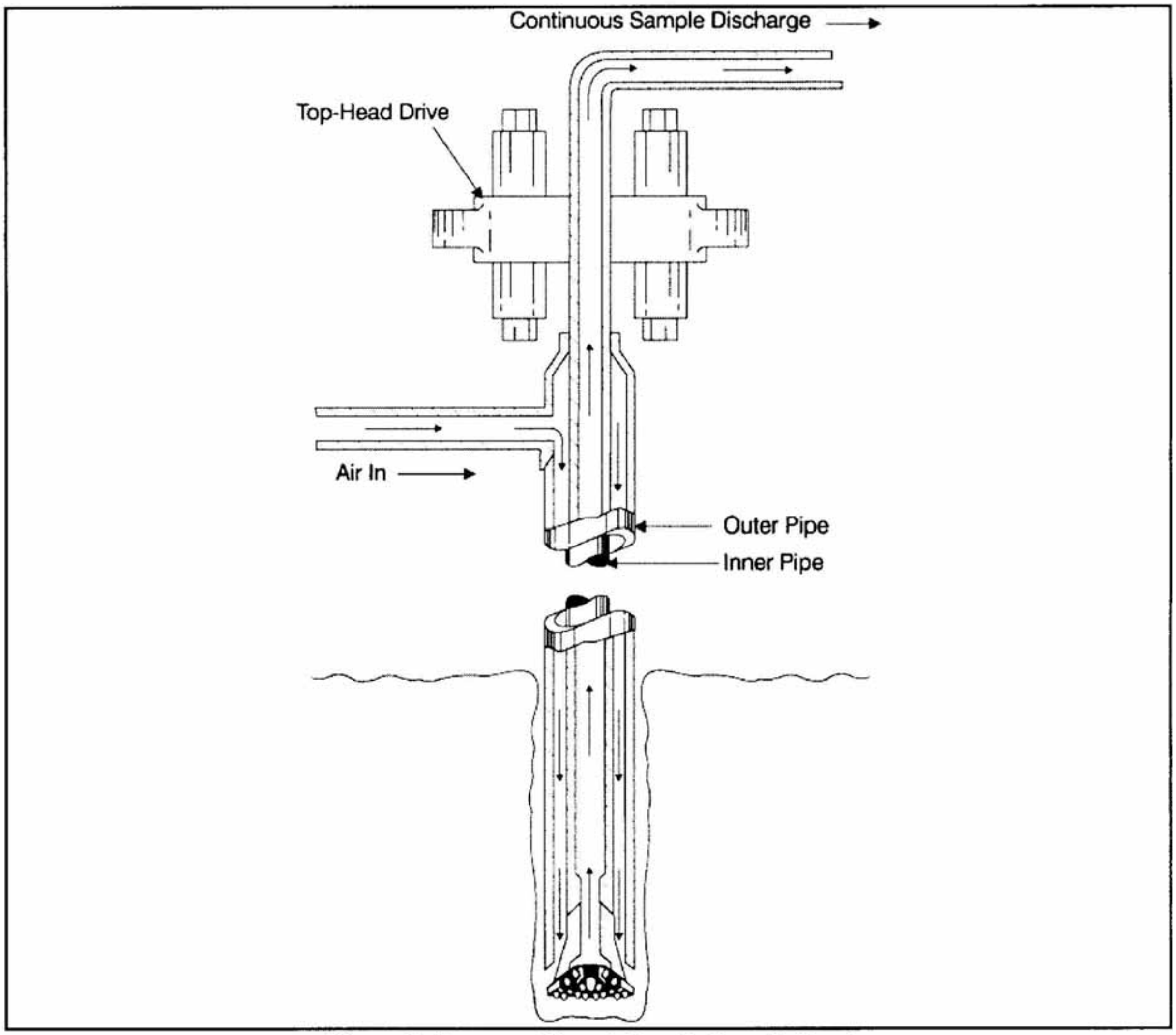

Figure 7 Reverse Circulation Rotary Method

6.7 Sonic Drilling

The sonic drill rig is similar to other drilling rigs in that it is a machine attached to a frame mounted on some type of vehicle. Sonic drilling is the use of high frequency vibration used in conjunction with down pressure and rotation to advance drilling tools through subsurface formations (see Figure 8). The use of high frequency vibration through the drilling tools causes the formation materials to vibrate at their natural frequencies allowing the drilling tool (casing) to advance by fracturing, shearing or displacing formation material. Most sonic drilling is utilized for drilling in unconsolidated material. However, sonic drilling can also be used for drilling and sampling of rock formations.

During drilling, unconsolidated samples are collected using a sample (or core) barrel. Core barrels are either solid tubes or split barrels of various diameters and lengths generally sized to match the inside diameter of the drill casing being utilized. Typical core barrels are 10 to 20 feet in length and casing sizes range from 0.5 inches to 12 inches, although 4 to 6 inch casing is typical. The core barrel is fitted with a drill bit/cutting shoe, and the sampler is placed within the outer casing material and attached to the rig by drilling rods. As the borehole is advanced, formation material is collected within the core barrel.

Following the sampling run (typically 10 to 20 feet), the core barrel is extracted from the well casing. Formation material is then extracted from the core barrel. Typically, sample material is extracted into a plastic sleeve, which is separated into convenient lengths for logging. The process of sonic drilling and sample collection will cause the sample to be distorted due to vibration, but generally will be intact. In the case of rock drilling, the vibration may create mechanical fractures that can affect the structural analysis for permeability and thereby not reflect the true *in-situ* condition.

The advantages to using sonic drilling technology includes reducing the amount of drill cutting generated, providing rapid formation penetration, and the recovery of a continuous core sample.

Physical Hazards

Noise. Excessive noise is generated from the use of oscillating drill head. Site personnel are required to wear hearing protection during drilling operations.

Overhead Equipment. During drilling operations steel casing (up to 20 foot lengths), core barrels, and drill rods may be hoisted in the air. Site personnel must conduct the necessary equipment inspections to ensure it is in good condition prior to the start of drilling operations. In addition, drillers must make sure that proper hoisting procedures are followed to reduce the likelihood of falling drill steel or sampling gear.

Slips/Falls. Site personnel can slip on wet ground around the drill rig or trip over drilling equipment (e.g. wrenches, etc.). Site personnel must keep the drilling location clear of debris and contain spillage prior to and during drilling operation.

Drill Rig Lurching. The drill rig may have a tendency to lurch and shake when the drill casing comes into contact with harder materials. Site personnel should be aware of possible drill rig movement and move away from the rig if lurching or shaking occurs.

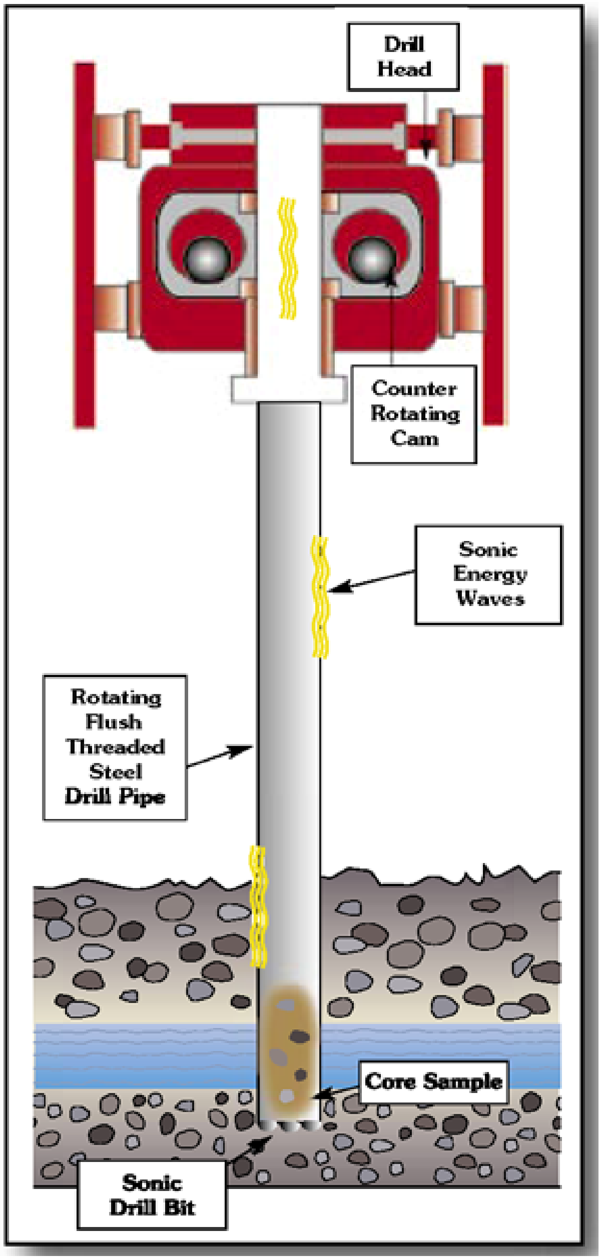

Figure 8 Sonic Drilling Method

ATTACHMENT I HEALTH AND SAFETY PLAN FOR BOATING

Health and Safety Plan Attachment for Safe Boating

Introduction

For many of E & E's activities, it is necessary to use conventional boats or airboats to transport personnel and conduct work tasks. These tasks can be accomplished safely with the right combination of equipment, safety awareness and common sense.

Equipment Required for Boat Operations

1. Personal Flotation Devices (PFD)

All boats must carry one wearable PFD (Type I, II, III or Type V PFD) for each person aboard. A Type V PFD provides performance of a Type I, II, or III PFD (as marked on its label) and must be used according to the label requirements. Any vessel 16 ft and longer (except canoes and kayaks) must also carry one throwable PFD (Type IV PFD).

PFDs must be

- Coast Guard approved,
- in good and serviceable condition, and
- the appropriate size for the intended user.

Accessibility

- A PFD should be worn at all times when the vessel is underway. A wearable PFD can save your life, but only if you wear it.
- They should not be stowed in plastic bags, in locked or closed compartments or have other gear stowed on top of them.
- The best PFD is the one you will wear.
- Throwable devices must be immediately available for use.

2. Visual Distress Signals

All vessels used on coastal waters, the Great Lakes, territorial seas, and those waters connected directly to them, up to a point where a body of water is less than two miles wide, must be equipped with U.S.C.G. Approved visual distress signals. Vessels owned in the United States operating on the high seas must be equipped with U.S.C.G. Approved visual distress signals.

Pyrotechnic Devices

Pyrotechnic Visual Distress Signals must be Coast Guard Approved, in serviceable condition, and readily accessible.

- They are marked with an expiration date. Expired signals may be carried as extra equipment, but can not be counted toward meeting the visual distress signal requirement, since they may be unreliable.
- If pyrotechnic devices are selected a minimum of three are required. That is, three signals for day use and three signals for night. Some pyrotechnic signals meet both day and night use requirements.
- Pyrotechnic devices should be stored in a cool, dry location, if possible.
- A watertight container painted red or orange and prominently marked "DISTRESS SIGNALS" or "FLARES" is recommended.

3. Fire Extinguishers

Coast Guard Approved fire extinguishers are required on boats where a fire hazard could be expected from the motors or the fuel system. Extinguishers are classified by a letter and number symbol. The letter indicates the type fire the unit is designed to extinguish (Type B for example are designed to extinguish flammable liquids such as gasoline, oil and grease fires). The number indicates the relative size of the extinguisher. The higher the number, the larger the extinguisher.

Coast Guard approved extinguishers required for boats are hand portable, either B-I or B-II classification and have a specific marine type mounting bracket. It is recommended the extinguishers be mounted in a readily accessible position, away from the areas where a fire could likely start such as the galley or the engine compartment.

Extinguisher markings can be confusing because extinguishers can be approved for several different types of hazards. For instance, an extinguisher marked "Type A, Size II, Type B:C, Size I" is a B-I extinguisher.

Look for the part of the label that says **"Marine Type USCG"**

- Make sure Type B is indicated
- Portable extinguishers will be either size I or II. Size III and larger are too big for use on most recreational boats.

4. Ventilation

A powered ventilation system is required for each compartment in a boat that has a permanently installed gasoline engine with a cranking motor for remote starting.

5. Sound Producing Devices

Any vessel less than 39.4 feet/12 meters in length may carry a whistle or horn, or some other means to make an efficient sound signal to signal your intentions and to signal your position in periods of reduced visibility.

6. Navigation Lights

Recreational vessels are required to display navigation lights between sunset and sunrise and other periods of reduced visibility (fog, rain, haze, etc.).

7. Communication

Cell phones should be fully charged prior to leaving the dock

8. Additional Safety Equipment

- First Aid Kit
- Marine Radio, As applicable
- Dewatering Device & Backup bilge pump operable, alternative bailing device available
- Anchor and Line for Area
- Capacity/Certification of Compliance
- Charts of the area and compasses
- Mooring lines - bow, stern, and spring lines
- Bright flashlight or searchlight
- Alternate propulsion - paddle or oar
- Compass, As applicable
- Sunscreen and sunhat
- Drinking water

Weather conditions

On a warm sunny day there is nothing better than being in a boat on the water enjoying the elements while working. Slight changes in weather conditions, however, can adversely affect a body of water in a relatively short time period. If a boat and crew are in an exposed position this change could seriously jeopardize their safety. A boat operator should be knowledgeable relative to the weather patterns typical of the area in which work is to be done, and able to identify rapidly approaching frontal systems that could place the boat and crew in danger.

1. Wind

Heavy wind is one of the greatest hazards to a small boat on a large body of water. Wind can quickly whip the water surface into a severe chop with breaking white-capped waves. The greater the fetch (upwind distance over water) from the boat's position the worse the wind driven surface waves can be. If the boat is located in a shallow area downwind from deeper water the height of the wind driven waves can be expected to increase dramatically as they enter the shallows. Wind blowing in opposition to the direction of flow can create large swells and threaten the safety of boat and crew.

A boat operator must carefully assess wind conditions upon arrival to work in an area and determine if a significant hazard exists that could be avoided on a calmer day. A rule-of-thumb for estimating wind speed is to look for white caps which generally begin to appear at wind speeds approaching 20 miles per hour over calm water.

If possible, working with the bow into the wind is the safest position for the boat in windy conditions. However, working in a river requires that the bow be held against the direction of flow. If the wind opposes the current this could place the boat and crew in jeopardy as the steep wind driven swell will impact the boat's stern. This situation could potentially swamp the boat if the waves increase in size and begin to break over the transom.

2. Rain

Aside from personal discomfort, light rain does not present an extreme hazard to crews in small boats. Heavy rain over long durations can constitute a significant hazard if allowed to accumulate in the bottom of the boat. If the boat is transporting a load near maximum for its hull configuration the weight of the accumulated rain water could adversely effect stability or significantly reduce freeboard (distance from the waterline to the gunwale). Either of these could result in swamping or capsizing. Lightning storms are common in some locations and must be considered as a serious threat to the safety of boat and crew.

Again it is the operator's responsibility to assess the severity of the situation and react to protect the safety of the boat and crew. This action could be nothing more than pumping the excess rain water overboard on a periodic basis or may require that the work effort be temporarily aborted until the rain or lightning dissipates to a non-threatening level.

3. Extreme Conditions

Weather extremes range from hot temperatures and sun exposure to cold temperatures and freezing conditions. Most often small work boats do not provide protection from the elements. Working in the middle of a body of water almost always means complete exposure to the existing weather extremes.

The hazards here may be health risks as well as some potential for physical injury. In the case of extreme heat and sun exposure, the crew should always carry drinking water to help minimize the potential for dehydration. Some form of protection from the sun is essential and will aid in reducing the potential for dehydration in addition to minimizing the harmful effects of ultraviolet rays on human skin. Extreme heat combined with high wind can increase the rate of dehydration.

Extreme cold and freezing conditions may be more hazardous than heat. In addition to the more obvious concerns about hypothermia, dehydration is still a potential problem. Protective clothing is essential to minimize the effects of hypothermia. An accidental fall overboard could prove fatal if the victim is not properly clothed. Water robs the body of heat 25 times faster than air so the immediate problem is rescuing the overboard victim. Remember the 50/50 rule (i.e., an unprotected overboard victim in water less than or equal to 50 degrees Fahrenheit has a 50 percent chance of surviving for 50 minutes). In addition to these potential health risks a boat operator working in extreme cold and freezing conditions must watch for ice build-up on the boat's hull. Even though ice floats its mass above the waterline adds to the weight of the boat and its load. If ice is allowed to accumulate above the waterline as a result of splash from the wake or spray from wind blown waves the boat can become overloaded and settle in the water to a point where an otherwise insignificant volume of water could swamp and sink the boat.

3. Restricted Visibility

The most common cause of restricted visibility is fog. Heavy rain and snow, or in some areas, blowing dust can reduce visibility in the extreme as well. Operation during periods of extreme restricted visibility is not advised particularly in areas frequented by large commercial vessel traffic. When operation is essential during periods of restricted visibility standard navigation lights must be displayed. If the small work boat is not equipped with navigation lights it should not be used in these conditions. Also, proper horn or bell signals should be given as required by inland or international navigation rules for the size of vessel underway or anchored during periods of restricted visibility.

Navigation

1. Tidal Reaches

Streams in coastal areas present the boat operator with flow conditions generally unknown or inexperienced by most inland boat operators. The lower reaches of nearly all coastal streams are tidally affected. Changes in flow characteristics associated with daily tidal variations include some or all of the following: rise and fall of stage; increase and decrease in flow velocity; sudden appearance of breaking waves and turbulence; and possible reversals in flow direction. Boat operators working in tidal affected areas must understand these flow characteristics. Consulting tide and current tables, and navigation charts is essential to planning daily activities and minimizing potential hazards. Basic rules-of-thumb to operating in tidal reaches include: moving through shallows during rising (flood) tides to provide the greatest margin for error in the event of grounding the boat; timing of bar crossings from riverine into marine conditions during flood tides and never during the maximum ebb currents; and timing of sampling and measuring activities relative to tidal effects when flow reversals are common.

2. Flow Around Fixed Structures

Fixed structures including bridges, and dams are of particular concern to operators and crews working from boats. Boat operators should always familiarize themselves with any in-channel structure that could ultimately threaten the safety of their vessel and crew. Charts or maps of an area can provide valuable information related to the size and location of a structure across the channel. Regulatory agencies such as the State Department of Transportation, Corps of Engineers, Bureau of Reclamation, etc. can generally provide more detailed local information.

- **Bridges**

  Bridges may constitute major hazards to the boating public by restricting overhead clearance, generating extreme turbulence in the vicinity of piers located in the flow, or trapping debris and reducing the opening available between piers. During high stages, overhead clearance may be minimal for the passage of river traffic. In this case, if work must be done downstream of the bridge, one of two courses of action are necessary to protect the safety of vessel and crew: find an alternate location for launching the boat below the bridge; or call the bridge tender and request an opening of the lift or swing span if so equipped. The following list of actions will help to ensure the safety of vessel and crew when working in the vicinity of bridges.

- Never work from a boat in close proximity to and upstream of an excessively submerged bridge structure.
- If it is necessary to work from a boat upstream from a bridge during high flow or anytime the structure presents a threat to safety, two sources of power (main engine plus auxiliary or twin engines) should be onboard and running in the event the backup is immediately needed.
- Always carry an anchor of adequate size and design securely attached to a length of chain equal to one boat length, and a length of nylon line equal to three to five times the anticipated depth, to stop the vessel and hold it against the flow. This equipment must be ready to deploy in an instant with the end of the line attached to the boat.
- Cutting devices adequate to clear any line that becomes fouled on the boat and threatens its safety must be at the ready. These should include but are not limited to garden loppers, bolt cutters, cable shears, and a hatchet or machete.
- Avoid working in close proximity to bridge piers if possible.
- If it is necessary to work close to a bridge pier, approach the pier in the tail-wake from downstream keeping a sharp lookout for debris caught on the pier. Carefully work along side the pier and inside the wake or eddy line generated by its upstream face.
- Never put the boat across the upstream face of the pier where it could become trapped by the force of the current.

- **Dams**

  Dams impounding the flow are another source of hazards to boats operating in their vicinity. Dams are generally of two types which present different hazards to boat operators and crews. The first to consider is the large structure tens or possibly hundreds of feet high, and impounding a large reservoir for the purpose of power generation and/or flood control. These structures may have a lock channel to allow passage of vessels from one pool level to the next in the upstream or downstream direction. Boat operation in the vicinity of these large structures should be limited to the approaches to the navigation lock. Operation near any intake structure or in the tail race channel should be avoided as flow volumes, stream velocities, river stages, and associated turbulence can change unexpectedly. As an example, a small boat can be easily swamped or capsized by an unexpected wave surging from the outflow as the gates are reset to increase power generation or flows are increased to pass storm runoff.

  Low-head dams are the second type to consider. These structures may constitute the most dangerous man-made obstruction a boat operator might encounter. Most low-head dams span the entire width of the channel usually to pool the flow for diversion into an irrigation system or for some other purpose requiring a low hydraulic head as the driving force. Water passing over the face of these structures appears as a smooth even flow across the entire stream width usually falling ten feet or less. To the uninitiated there doesn't seem to be any hazard because the flow appears to be benign and almost tranquil in nature. The danger here is real and extreme. The plunging water creates a turbulent zone of reverse current (a hydraulic) at the downstream base of the dam. A boat can be drawn into the falling water and easily swamped. The tumbling action will then roll the boat over, submerge it, and push it away from the dam below the surface only to pull it and its occupants back into the falling water as they reach the surface. This continuous action can easily trap the boat and crew at the face of the dam with no hope of escape. The following list of actions will help to ensure the safety of vessel and crew when working in the vicinity of low-head dams. If possible avoid working above, below, or otherwise in close proximity to a low- head dam. This may not be appropriate either.

3. Canals

Canals are normally highly regulated man-made waterways. Any operator using a boat to transit these conduits of flow must understand the flow system and its hazards. Typically the water in any given canal system is allocated for some specific use. Regulation may be seasonal or associated with storm runoff. The system may consist of a series of diversions conveying flow to various points of use, and may include flow through tunnels or large diameter pipes, in addition to open channel conveyances. In short, use of boats in these types of flow systems should be avoided if at all possible and only undertaken after the operator and crew have contacted the agency responsible for management and regulation to become familiar with potential hazards built into the system.

Carbon Monoxide

CO - When docked, or rafted with another boat, be aware of exhaust emissions from the other boat.

Seasickness

Seasickness is caused when the minute inner ear organs that enable a human to balance are disturbed by the motion of the boat swaying and pitching. This movement sets off alarm signals to the brain causing nausea, headache, dizziness, and sometimes vomiting. This condition can be intensified by the lack of fresh air and inactivity. It can also be a person's worst nightmare at sea.

Fortunately, several remedies can be taken before setting sail. Pills can be obtained over the counter which help most people by sedating the balancing organs. The pills can cause drowsiness and should be taken with care. Some people find special wrist bands effective. There are also stick-on patches that can be worn on the skin behind the ear, but these are obtained by doctor's prescription only.

You can often avoid seasickness by staying busy and keeping your mind occupied by taking over the helm or any other activity that will keep you above decks. Look at the distant horizon rather than the water close at hand. Take deep breaths and drink plenty of water. The worst thing that a person can do is go below decks with no land or horizon to look at. Reading or staring at an object will assuredly bring on the affects of seasickness. If you are seasick and can't bear it anymore, lie down on your back with your eyes closed. This will greatly reduce the affects.

References:

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Florida Boating Safety Course
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http://www.commanderbob.com/

Nautical Know How
http://www.boatsafe.com/nauticalknowhow/seasick.htm

ATTACHMENT J COLD STRESS PREVENTION AND TREATMENT

COLD STRESS PREVENTION AND TREATMENT

Cold temperatures are potentially hazardous, especially when work is conducted without appropriate precautions. The following sections describe cold stress prevention and the recognition and treatment of cold stress emergencies.

Preventing Emergencies Due to Cold Stress

When working in situations where the ambient temperature is low, especially if low temperatures are accompanied by windy conditions, personnel should use the following cold-stress prevention measures:

X Wear warm, dry, loose-fitting clothing that is preferably worn in layers. Outer clothing should be waterproof and windproof. Inner clothing should be capable of retaining warmth even when it is wet (e.g., wool or polypropylene) or have wicking capabilities (to draw moisture and perspiration away from the skin).

X Wear lined and insulated footwear and warm gloves or mittens.

X Alternately remove and don clothing layers as necessary to regulate body temperature and reduce excess perspiration.

X Drink warm fluids as often as desired.

X Take frequent breaks to provide for cold stress monitoring.

Cold Stress Emergencies

Hypothermia. Exposure to cold can cause the body's internal temperature to drop to a dangerously low level. Hypothermia occurs when a person's body loses heat faster than it can be produced. The body's normal deep-body temperature is approximately 98.6 degrees Fahrenheit. If body temperature drops to 95 degrees Fahrenheit, uncontrollable shivering may occur. If cooling continues, these other symptoms may occur:

∃ Vague, slow, slurred speech;

∃ Forgetfulness, memory lapses;

∃ Inability to use hands;

∃ Frequent stumbling;

∃ Drowsiness;

∃ Exhaustion, collapse;

∃ Unconsciousness; and

∃ Death.

Hypothermia impairs the judgment of the victim. Hypothermia is possible even in temperatures above freezing and can be prevented by remaining warm and dry and avoiding overexposure to the cold.

If a person shows symptoms of hypothermia, perform the following:

∃ Remove the victim from exposure to wet and cold weather.

∃ Remove wet clothing.

∃ If the victim is only mildly affected, provide warm drinks and dry clothing.

∃ If the victim is more seriously affected (clumsy, confused, unable to shiver), begin safe-warming procedures such as hugging, wrapping in dry blankets, and the use of warm objects such as hot water bottles or heat packs, and arrange for evacuation. Do not give the victim warm drinks until he or she exhibits a clear level of consciousness and appears to be warming up.

Frostbite. Frostbite occurs when body tissue freezes. Severe frostbite can lead to reduced circulation and the possible need for amputation. To prevent frostbite, maintain good circulation and keep extremities warm and dry. In extreme cold, it is important to prevent heat loss from as many areas of the body as possible. Exposed limbs and the head are major areas of heat loss.

Tall, thin people; those in poor physical condition; people with chronic diseases; heavy smokers; children; the elderly; and those who have been drinking alcohol are more susceptible to frostbite than other people due to poor circulation, poor production of body heat, or both.

There may be no pain or numbness experienced with gradual freezing of body tissues. While in the cold, it is important to test extremities for sensation and ensure that clothing is loose-fitting and warm. Exposed parts of the body should be inspected routinely. Just before freezing, skin becomes bright red. As freezing continues, small white patches will appear and the skin will become less elastic, often remaining pitted after it is touched or squeezed.

Serious freezing is most common in the feet because people are less aware of them, circulation and sensation are poorer, and warm footwear is difficult to obtain. Hands are usually the next to freeze. Exposed parts of the head will freeze less rapidly because they are conditioned to exposure and have a better blood supply.

In very cold weather, avoid touching cold metal with bare body parts. In the event that this happens, release the skin gently using heat, warm water, or urine. Avoid handling gasoline, kerosene, or similar liquids which, when handled in cold weather, can cause immediate frostbite.

If a person shows symptoms of frostbite, consult a medical professional, if possible, and perform the following:

- Initiate rewarming only if subsequent refreezing is not a possibility (thawing and refreezing should always be avoided because this is very injurious to tissue). Rewarm body parts in water that is approximately 100 to 105 degrees Fahrenheit. Do not try to thaw the body parts using cold water, snow, or intense heat from fires or stoves. The whole body may be immersed in warm water if necessary.

- If a large portion of an extremity is frozen when rewarming is initiated, the deep body temperature may drop as cooled blood begins to circulate throughout the body. Provide warm liquids to alleviate this situation.

- Move the afflicted part gently and voluntarily during rewarming.

- Use pain medication if it is available. Rewarming can be acutely painful. After thawing is completed, a deep pain may persist for several days, depending on the severity of the frostbite. Pain may be a good sign as it indicates that nerve function is present.

- A dull purple color, swelling, or blisters indicate serious injury and the need for medical attention. Consult a medical professional.

ATTACHMENT K NEAR MISS/NEAR HIT FORM

ECOLOGY AND ENVIRONMENT, INC. EMPLOYEE EXPOSURE/INJURY/INCIDENT REPORT/NEAR MISS

A separate report is to be completed for each incident and submitted immediately to the CHSD (Paul Jonmaire) for consideration.

CC: Office Safety and Health Coordinator, Office Manager

Reason for report:
☐ *Possible Exposure*
☐ *Exposure*
☐ *Personal Injury*
☐ *Potential Near Miss*

Completed By: Click here to enter name.
Job Title: Click here to enter Job Title.
Today's Date: Click here to enter date.
Case Number: Click here to enter Case Number.
Project/OVH #: Click here to enter Project/OVH #.
Location of Event: Click here to enter Location.
Date of Event: Click here to enter date.
Time of Event: Click here to enter time. ☐ AM ☐ PM
☐ Check if time cannot be determined.

- ✓ Was the client notified? ☐ Yes ☐ No
- ✓ Was your office notified? ☐ Yes ☐ No
- ✓ Was headquarters notified? ☐ Yes ☐ No
- ✓ Was medical treatment sought? ☐ Yes ☐ No
- ✓ Did the employee miss any work? ☐ Yes ☐ No
- ✓ Has the employee returned to work? ☐ Yes ☐ No
- ✓ Was a site-specific health and safety plan for this specific activity prepared? ☐ Yes ☐ No
  (If yes, please attach – No? Please explain)
  Click here to enter text.

Employee Information

Full Name: Click here to enter text.
Employee #: Click here to enter employee #.
Home Address:
Street: Click here to enter Street.
City: Click here to enter City.
State: Click here to enter State.
Zip Code: Click here to enter Zip Code.
Phone: Click here to enter Phone.
Date of Birth: Click here to enter a date.
Gender: ☐ Male ☐ Female
Date Hired: Click here to enter a date.
Office: Click here to enter Office.
Job Title: Click here to enter Job Title.

Information about the physician or other health care professional

1. Date of treatment: Click here to enter a date.
2. Name of physician or other health care professional who provided assistance, if any:
   Click here to enter text.
3. If treatment was given away from the worksite, where was it given and by whom?
   Click here to enter text.
4. Was employee treated in an emergency room/ urgent care facility?
   ☐ Yes
   ☐ No
5. Was employee hospitalized overnight as an in-patient?
   ☐ Yes
   ☐ No

Information about the incident

1. Date of Incident: Click here to enter date.
2. Weather conditions at time of incident:
   Click here to enter text.
3. Time employee began work:
   Click here to enter text. ☐ AM ☐ PM

4. What was the employee doing just before the incident occurred? Describe the activity, as well as the tools, equipment, or material the employee was using. Be specific.
   Click here to enter text.
5. Where did the incident occur?
   Click here to enter text.
6. What happened? Tell us how the incident occurred.
   Click here to enter text.
7. What was the injury? Tell us the part of the body that was affected and how it was affected; be more specific than “hurt”, “pain”, or “sore”.
   Click here to enter text.
8. Were proper PPE and clothing being used the employee? If so, please describe.
   Click here to enter text.
9. Please list the names of those employees or contractors who witnessed the incident.
   Click here to enter text.
10. Please list the names of those employees or contractors who were also affected by this incident.
    Click here to enter text.
11. What object or substance directly harmed the employee, if applicable?
    Click here to enter text.
    ☐ Check if no harm to employee.
12. If the employee died, when did the death occur?
    Date of death:
    Click here to enter a date.

ADDITIONAL COMMENTS:

Click here to enter text.

EMPLOYEE SIGNATURE:

____
Signature

____
Date

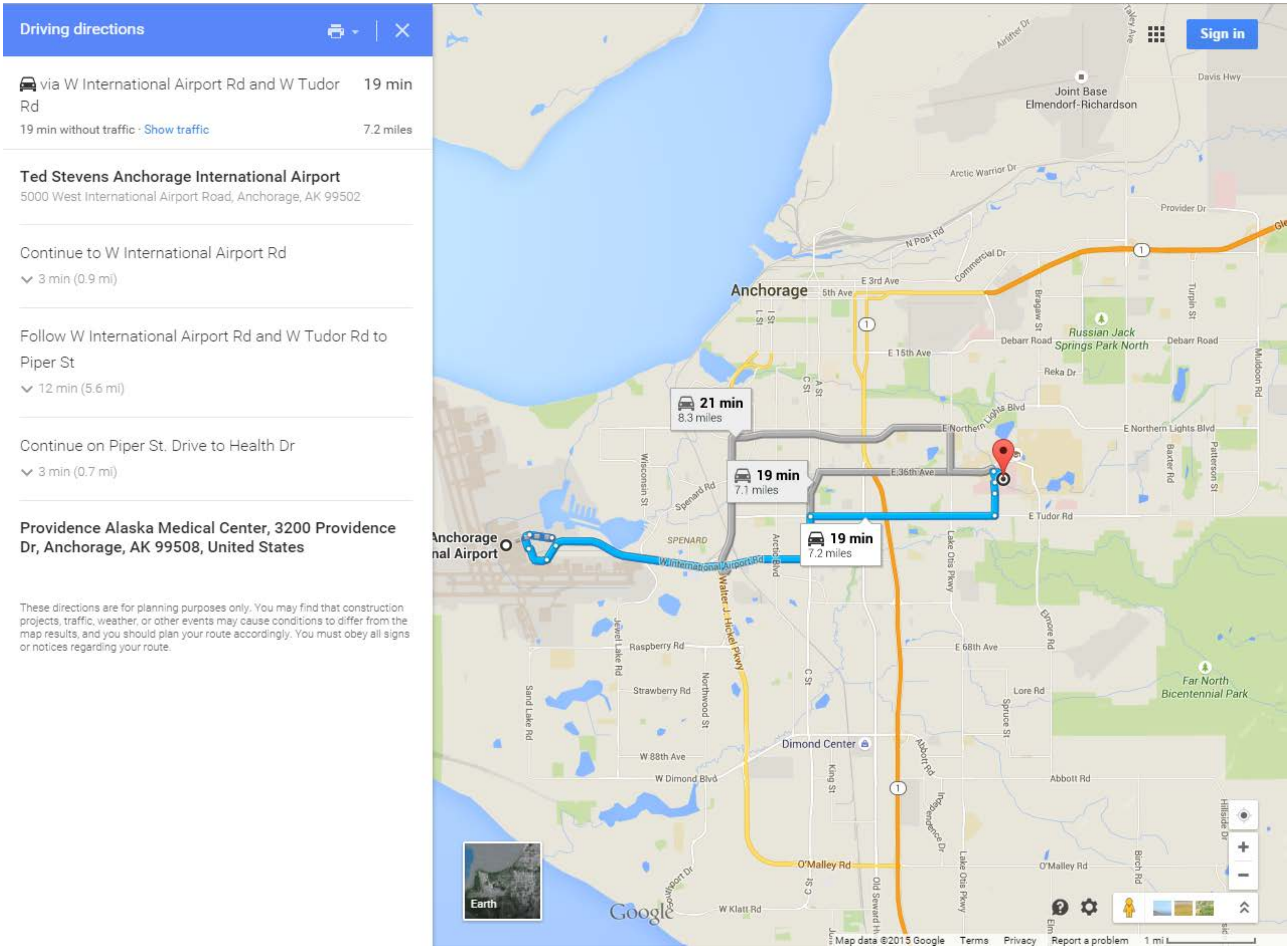
FIELD TEAM LEADER OR SUPERVISOR SIGNATURE:

____
Signature

____
Date

ATTACHMENT L MAP TO HOSPITAL AND SITE MAP

Providence Alaska Medical Center



Driving directions

via W International Airport Rd and W Tudor Rd 19 min

19 min without traffic · Show traffic 7.2 miles

Ted Stevens Anchorage International Airport

5000 West International Airport Road, Anchorage, AK 99502

Continue to W International Airport Rd

3 min (0.9 mi)

Follow W International Airport Rd and W Tudor Rd to Piper St

12 min (5.6 mi)

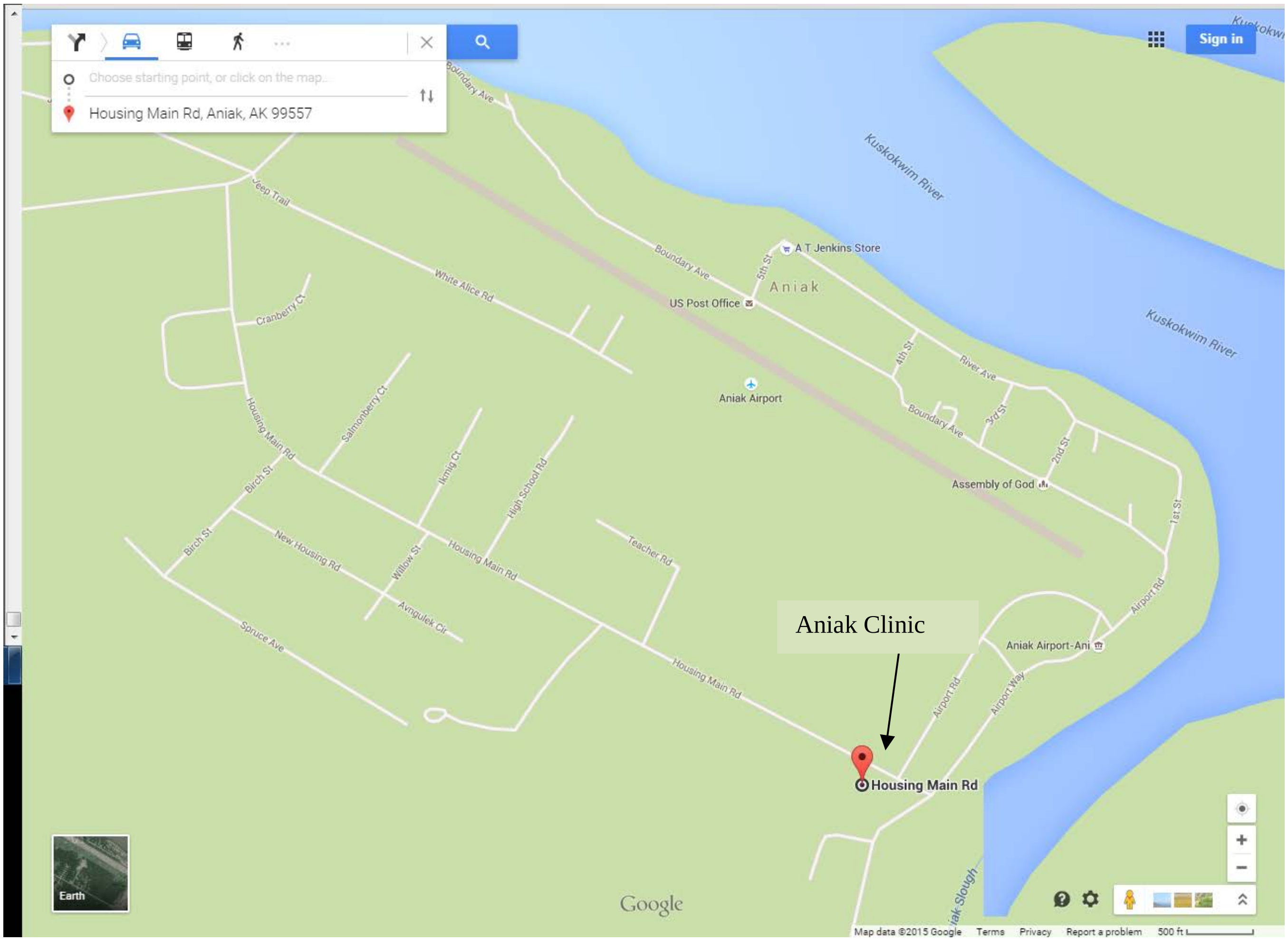
Continue on Piper St. Drive to Health Dr

3 min (0.7 mi)

Providence Alaska Medical Center, 3200 Providence Dr, Anchorage, AK 99508, United States

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

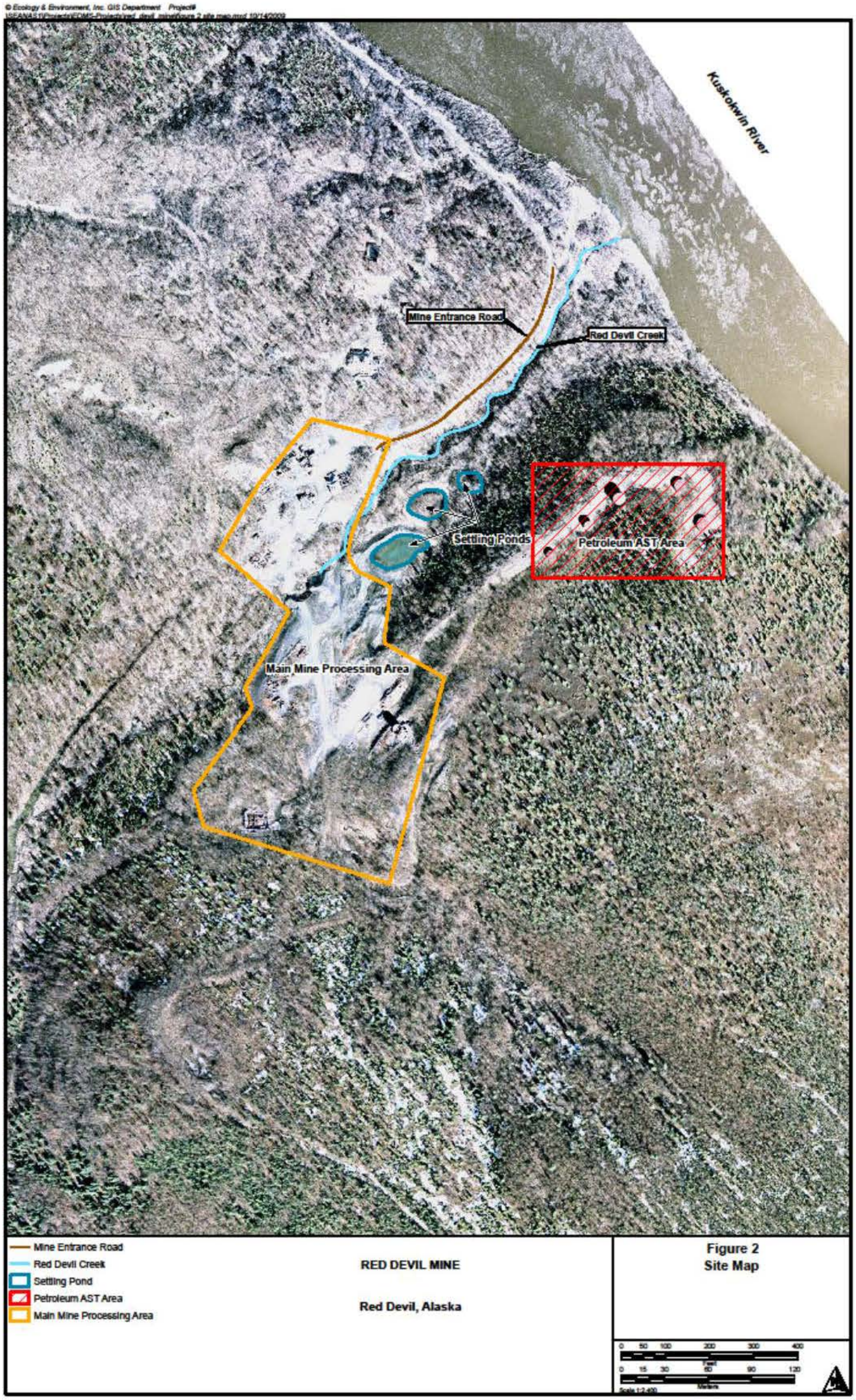
Clara-Morgan Sub-Regional Clinic



Choose starting point, or click on the map...

Housing Main Rd, Aniak, AK 99557

\\SEANAS1\Projects\EDMS-Projects\red_devil_mine\figure 2 site map.mxd 10/14/2009



RED DEVIL MINE

Red Devil, Alaska

Figure 2
Site Map

ATTACHMENT M USE OF SAFETY SPRAY

TONYBYNUM.COM

SURVIVAL SPRAY

by Christine Paige

Want to live through a bear attack? Add a chemical weapon to your arsenal.

On one of the last days of deer season in Wyoming's high country, Skyler Atkins had just shot a mule deer while hunting with his friend, Don Hoard. Leaning down to dress it out, Atkins opened his blade and happened to glance up over Hoard's shoulder. "Oh my God, there's a bear!" A sow grizzly was in full charge, barreling toward them.

The two had set off into the backcountry near Togwotee Pass hoping to fill Atkins's freezer. It's high, wild country—open mountain meadows and conifer glades with sweeping views of the Teton, Absaroka and Gros Ventre ranges. Hoard, with years of hunting the area and many bear sightings under his belt, knew the country well and the two were on alert for bears.

They had seen fresh grizzly prints on the trail in—a large male, Hoard thought, and where the trail split they chose the path away from the tracks. Once up on the ridgetop, they saw a grizzly sow with two cubs feeding in a meadow. She began to move toward them, but Hoard

Shot low in front of a charging bear, as this staged photo illustrates, bear spray billows up into a bruin-stopping cloud that has proven by far the best defense for surviving an attack unharmed.

and Atkins yelled and waved their arms, and she turned with her cubs and moved off.

"Let's get a deer and get out of here," Hoard told Atkins. It was midday, and the two began hunting back toward their truck. As they glassed an open meadow, they spotted a small group of mulies near a creek in the meadow bottom. A young buck moved up out of the creek, and Atkins killed it with one shot at 150 yards. Atkins grabbed his pack and the men worked their way down to the deer. "Let's get this done quick," Hoard urged.

"I pulled my bear spray out, took off the safety and placed it next to me, ready to go." Hoard recalls. "My buddy had taken out his knife, I grabbed a leg, and then he looked over my shoulder. When he saw the bear, I had my back to it and at first thought he was joking. But then I saw his eyes."

"You want me to shoot her?" yelled Atkins. "No, no, no!" hollered Hoard as he spun around with the bear spray. "She was at 22 steps—22 steps—at full charge with a cub. I squeezed the trigger on the bear spray. She hit that cloud and stopped in her tracks. Then she turned around and ran back up the hill with her cub. It was a short spray, and I yelled and screamed at her."

The grizzly and cub sat and watched the hunters from the hill as they gutted the deer. As Atkins dragged the carcass away, Hoard trailed, facing the bears with his bear spray at the ready, walking backwards out to the truck. Once the hunters started moving away, the bears went down to the gut pile.

"This was a different bear from the sow with two cubs we saw earlier," Hoard relates. "As quick as it took us to get to that deer she was there. The bears in that area—I think they hear a gunshot and it's like ringing a dinner bell."

Not-so-Chance Encounters

Throughout bear country, people and bears are bumping into one another more often. Both bear and human populations are on the rise, and bear encounters are becoming more frequent. Black bear populations are stable or increasing nationwide, and the recovering grizzly population in the Rocky Mountains is three times what it was in 1975.

According to Chris Servheen, Grizzly Bear Recovery Coordinator with the U.S. Fish and Wildlife Service, in 2011 alone there were 83 incidents in the northern Rockies of grizzlies charging people—31 instances (37 percent) involved hunters and 29 (35 percent) involved hikers. Fourteen (17 percent) resulted in human injuries and 2 were fatal.

In a landscape with more bears, the very nature of hunting increases the chance of an encounter. By stalking quietly, moving at dawn and dusk, traveling off-trail, hunting alone, bugling, cow-calling, raking brush or rattling antlers, using cover scents including elk urine, and releasing the aromas of rumen and freshly killed meat onto the breeze, hunters do just about everything "wrong" in bear country.

Hunters are also out at the peak of bears' season of "hyperphagia" when bears become big furry eating machines, focused on piling on the calories before hibernation. "They are amped up and in competition with one another for resources," says Kevin Frey, bear management specialist for Montana Fish, Wildlife and Parks (FWP) in the Greater Yellowstone. "If a bear comes upon a carcass or gut pile, it's an enormous protein and calorie reward."

It's essential that hunters be keenly aware of bear sign, understand bear behavior and, should an encounter happen, be prepared with a good defense, Frey says. Most hunters are well-trained to rely on their firearm, but the numbers in favor of bear spray are stacking up. Talk to anyone who has used bear spray in an encounter, and you're talking to a convert. So is it time to add a chemical weapon to your arsenal?

Talk to anyone who's used bear spray in a griz encounter and you're talking to a convert. They're alive and well. And every bear that has a negative encounter with bear spray learns something positive.

Bear Spray or Bullets?

In two research papers, presented at the 4th International Human-Bear Conflicts Workshop in Missoula, Montana, in March, bear biologists Tom Smith of Brigham Young University, Stephen Herrero of the University of Calgary and several co-authors crunched the numbers on the effectiveness of bear spray and firearms in bear encounters.

The researchers collected every incident they could find of bear encounters in Alaska where people had used bear spray to defend themselves—72 cases in all, from 1985 to 2006, including black bears, brown bears/grizzlies and polar bears. In short, bear spray packs a punch: it stopped undesirable behavior more than 90 percent of the time (66 of 72 cases), and in only three cases were humans injured when bear spray was used—all relatively minor injuries.

In 13 incidents, brown and black bears resumed threatening behavior after the first spraying, but repeated spraying finally deterred the bear so that the human could escape. In the three cases where people were injured, all involved charging brown bears, and none required hospitalization. In those three instances, the bears were in full charge when the spray was triggered, explains Smith, and the momentum of the charge carried the bear through the fog. But the spray did dissuade the bear, leaving the victims with only minor lacerations.

"I am almost shocked and amazed at the track record of bear spray," says Herrero.

Smith and Herrero followed up with a study of firearms in bear encounters. They collected 269 cases in Alaska that occurred between 1883 and 2009, across all three bear species. The bottom line: discharging a firearm usually stopped encounters—84 percent of incidents (31 of 37) for handgun users and 76 percent (134 of 176) for long gun users.

But another finding was sobering: bears inflicted injuries on humans in 56 percent (151 of 269) of the incidents involving firearms, and people suffered the same rate of bear-inflicted injuries whether they discharged their firearm or not. In the study, there was no statistical difference in the outcomes between those who discharged their firearm and those who did not, whether that outcome was a fatality, an injury or no injury at all.

Further, once a bear charged, the odds of successfully deterring an attack dropped seven-fold. Try to aim at a bounding, lurching bruin hurtling toward you at 44 feet per second and hit it with a projectile a half-inch or less in diameter, shooting accurately at high speed as your body floods with adrenaline and your brain clangs in alarm. "If you're at a target range, you're pretty good," says Smith, but in a sudden bear charge, "it can be combat shooting. It's easy to miss or worse, make a bad hit."

Firearms may fail as a defense for a variety of reasons, including jamming, having the safety engaged or no round in the chamber, inability to reload, a bear being too close, and people stumbling and falling. In the study, the most common (in 21 percent of cases) was simply a lack of time to respond. Some people also have very real concerns about using lethal force, either for fear of shooting another person being attacked or the legal or emotional ramifications of killing a bear, even in self defense. That hesitation can be critical.

As yet, there is no record of a human fatality in an encounter where bear spray was used. However, Smith and Herrero recorded 17 human fatalities in cases when firearms were used as defense, whether the victim was killed by the bear or by human partners trying to defend against the attack. Only last year, tragedy unfolded for two black bear hunters in Idaho when one mistakenly shot a grizzly. After tracking the wounded bear into brush, the grizzly attacked one man and the other fired at the bear to halt the attack—but the bullet killed both his partner and the bear.

"If you're an average person with average skills, the odds are stacked against you using a firearm," asserts Smith. "If you're proficient, you have a good chance of defending yourself. But there are a lot of situations when you're not in a good position to use a firearm, so why wouldn't you carry bear spray? It's another tool in the toolbox."

In addition to a far better record for human safety, clearly another advantage of bear spray is that it leaves bears alive and healthy. In Smith and Herrero's study, bears were killed in 61 percent (162 of 269) of incidents when firearms were used as defense. Very often encounters involve females with cubs, and a dead sow means orphaned cubs. No one knows how many of those encounters were bluff charges where the bear would have pulled up short of an actual attack. As for bullets that hit without killing, a wounded bear is a recipe for disaster—once injured, it's natural for bears to go after the threat. As Frey points out, "A wounded bear is a danger to others, and it's not fun for managers to go in to take care of a wounded bear."

Firing off a warning shot may not get a bear to move—many bears simply don't associate a loud gunshot with danger to themselves. A nose full of bear spray, on the other hand, is strong aversive conditioning and teaches a bear it's a bad idea to mess around with people. "Bears learn quickly," says Mike Madel, Montana Fish Wildlife and Parks (FWP) bear management specialist on the Rocky Mountain Front. "They remember those encounters and experiences." Frey concurs: "Every bear that has a negative encounter with bear spray learns something. It's a positive gain for others in bear country."

"He had me by the back of my suspenders"

On a windy day in 1995, Frank Vitale and some friends were horse packing along Tuchuck Ridge in the Whitefish Range of northwestern Montana. Vitale, a farrier and long-time hunter, horse-packer and outdoorsman has spent decades exploring the backcountry of the Northern Continental Divide—home to the densest population of grizzlies in the lower 48.

It was a narrow, steep and rocky ridgeline trail, a stringer of subalpine fir trees on the uphill side. The group had four riders, five horses and a cattle dog. "One of the fellows riding with me had run into a huge boar grizzly the week before," recalls Vitale. "So he decided to bring a can of bear spray along. It wasn't common—it had only been available to the public for a few years."

Vitale, riding lead, suddenly saw a large dark hump in the trail 40 to 50 feet away. A grizzly was sound asleep, bedded down in the ridge saddle. Vitale realized they couldn't turn the horses and slip away without a lot of clatter and possible disaster, and made a quick decision to dismount and snub

STAY SAFE

Always keep your bear spray immediately accessible and ready to deploy.

Practice with an old canister or inert training canister (available online from bear spray manufacturers).

Direct the spray slightly downward—the spray will billow upward.

Spray a warning blast at 40 to 50 feet. If the bear continues to charge, keep spraying.

Don't worry about wind direction—just spray the bear.

Leave the area promptly, but do not run.

If you get spray on you, flush for 30 minutes with cool, clear water.

Store canister in a cool place, in an ammo can or bear spray tote—never leave it in a hot car.

Note the expiration date. When you purchase bear spray, weigh the canister, note the weight on the can, and weigh it annually to check if it has lost propellant.

For a video on how to use bear spray and a wealth of bear safety information, visit *www.BeBearAware.org.*

the horses to the trees.

"The wind, a crosswind, was in our favor." says Vitale. "I yelled at the bear and woke it from its nap. It sprang up, and two cubs of the year popped up bawling. Just then the dog ran past us straight at the bear, and the horses started freaking out. The bear charged, the dog disappeared above us into the trees and circled around behind us with the bear after it. Now I think we're really in for it, if we're between the sow and her cubs."

Grizzly charges usually involve surprise encounters or incidents where food is involved. "When you surprise a bear at close range," says Smith, "the grizzly's response seems to be that the best defense is a good offense."

Fortunately, the grizzly broke off chasing the dog and headed back to her cubs. "Then," Vitale continues, "she came down on all fours and charged right for us." Vitale's buddy passed him the bear spray. "He had me by the back of my suspenders, and at 15 or 20 yards I started spraying and just kept spraying. The bear ran into the big cloud and it stopped her cold—she turned around and took off with the cubs."

There was a little blowback, their eyes were watering, but they were alive and well.

"I'm a lifelong hunter, and now I always have bear spray right there, real close," Vitale says. "I don't see a big deal to carrying it in a holster on your hip—it's readily available and you can shoot it from your hip if you have to. As a hunter I feel you have a responsibility not only to protect yourself but also to protect the bears."

Bold Bears & Wary Bears

Most bear attacks involve grizzlies—studies of bear encounters confirm that the grizzly is the most aggressive of North America's bear species. Black bears are far more numerous than grizzlies and are involved in more human conflicts (these typically involve attractants such as food, garbage and bird feeders), but grizzlies are responsible for most human injuries and fatalities. Grizzly charges usually involve surprise encounters or incidents where food is involved. "When you surprise a bear at close range," says Smith, "the grizzly's response seems to be that the best defense is a good offense."

Fatal attacks on humans by black bears on the other hand, while extremely rare, are overwhelmingly predatory attacks rather than surprise encounters. In another recent study, Smith, Herrero and their co-authors found 59 incidents of fatal black bear attacks in Canada and the U.S. between 1900 and 2009. Most involved predatory behavior (49 of 56 cases; 88 percent), and of the predatory attacks where the sex was known, 92 percent (33 of 36) involved male bears. Nearly 50 percent (28 of 59) of these fatalities occurred in the last two decades, but in no case were people carrying bear spray.

Remarkably, most bear encounters leave humans unscathed. Bears are generally cautious, giving humans a wide berth. Surprised, they may bluff charge. "It's how they deal with other species," explains Frey. "They're trying to figure out the situation and get you to leave."

Madel agrees: "In most cases grizzly bears are bluff charging—they're trying to push you off. It's heart-pounding." Before the development of bear spray, Madel relied on a shotgun for defense in management work, and he got good at climbing trees. "I started carrying bear spray 10 years ago—it's way easier than a shotgun." Although Madel has been charged on more than a few occasions during management work, he has only had to use his bear spray three times—all three instances turned charging grizzlies.

No two bears are the same—each is an individual personality, each a product of its experiences. Some bears are more tolerant than others, some more timid, some more bold. "The most surprising part, perhaps, is how many encounters there *aren't*, even in a bad conflict year," comments Frey. "They're pretty tolerant of us, given a warning that we're there. Bears get to be old bears by being cautious."

Wyoming's Free-Trial Project

Mike Boyce, bear management specialist with the Wyoming Game and Fish Department in Jackson, is concerned about the growing potential for hunter conflicts with the expanding grizzly population in the Jackson Hole area. With a grant from the Jackson Hole Wildlife Foundation, Boyce started an experimental program to offer bear spray free of charge to hunters, and distributed a total of 200 canisters during the last two seasons.

"We focus on hunters because we feel that it's a demographic that tends to have a lot of encounters with grizzly bears in the field, whether they surprise a bear while hunting, or as soon as they get game on the ground," says Boyce. "We approach people one-on-one at trailheads and campgrounds and ask them if they'd like to participate in the project. Most people are very receptive."

GOOD READING

Bear Attacks: Their Causes and Avoidance (2002 Revised Edition) by Stephen Herrero.

Grizzly Country (1967) by Andy Russell

Learning to Talk Bear (1997) by Roland Cheek

Living with Bears (2006) by Linda Masterson

Mark of the Grizzly (1998) by Scott McMillion

The biologists also provide bear safety tips, demonstrate how to carry and deploy bear spray, and ask hunters to fill out a questionnaire. Boyce hopes to continue the program this year and plans to follow up with a phone survey to track hunters' experiences.

"Our department feels that firearms are an effective way to deal with aggressive encounters with bears, but there are limitations to using a firearm, obviously. Bear spray is a lot more user-friendly; it's easier to use in stressful situations. It's another tool that people should have in their tool kit. I think this is a good effort to try to help people protect themselves and to decrease some of the bear mortalities we've had in the last few years.

"There are numerous encounters we don't hear about," Boyce continues. "Some of the outfitters have encounters almost on a daily basis—as they're hunting, sneaking through the woods, or when they have a carcass on the ground. I carry bear spray every day. I've never had to use it on a bear, but I've used it effectively on moose! It's a good deterrent for all large carnivores and all aggressive wildlife."

Third Time's the Charm

In the last rosy light of evening, bowhunter Michael Wallover was on his way back to his Jeep after hunting mule deer all day up Mount Leidy, north of Wyoming's Gros Ventre Wilderness. "I was tired," Wallover recalls, "and was about 30 feet from the car when I heard huffing. I walked another five feet and out came a grizzly."

Wallover sprinted to the car, turned and let fly with his bear spray. "It came around the car and I sprayed it again. It backed into the tree line and came back out a third time."

He sprayed the grizzly three times before it took off, and ended up covered in the bear spray himself, his skin on fire but otherwise unharmed. "It was a big bear—its shoulder was as high as my '07 Wrangler, and the whole encounter was over in maybe a minute. I was shouting and cursing, and if I had used my .45 I wouldn't be talking to you right now," says Wallover. He packs the bear spray in a holster on his left hip, his .45 pistol on his right hip. "I had no problems deploying it—it was faster than a pistol.

"I grew up hunting in black bear country, worked for an archery company in Pennsylvania, and I took my first bull elk with a bow," says Wallover. "Now I'm sold on bear spray. I just recommend always keeping it in a very accessible place."

Use the Right Spray & Use It Right

Bear spray shouldn't be confused with mace or any other "pepper spray" sold for personal defense in human encounters. Bear spray contains nearly twice the irritant as personal-defense pepper spray, and has greater distance, duration and volume. The active ingredient, capsaicin, affects the mucus membranes, flooding the nose, mouth and eyes—painful, but with no lasting damage. A bear senses the world primarily through smell, and bear spray sends an explosion of irritant that overwhelms a bear's nasal membranes and hotwires its brain from fight to flight. Although only tested on bears, anecdotes from the field show it's been effective fending off a variety of aggressive animals—moose, wild boars, mountain lions and even elephants.

Bear spray creates a wall of defense—a cloud about the size of a sheet of plywood. If you have to deploy your spray, direct it slightly downward as the cloud will expand upward. Often, people shoot too high. By directing the spray downward, a charging bear will run into the fog of spray as it billows up. Typically, bear spray contains enough propellant for 6 to 7 seconds. In some situations, a person may need to spray two or three bursts to deter an aggressive attack.

Like any weapon, bear spray is useless buried inside a pack. It should be carried so it's immediately accessible and can be deployed within seconds—in a hip holster, chest holster, a trouser cargo pocket, on a pack belt, or tucked into the front of your jacket. Madel suggests rifle hunters use a safari-sling for their guns, "You have to get used to it, but you can drop your rifle and immediately grab your bear spray." Even with a two-handed rifle carry, it's possible to cradle your rifle and deploy the spray from your hip.

Wayde Cooperider, outdoors skills and safety supervisor for FWP, asserts, "We fight like we train. Practice how you would deal with a bear conflict, so you don't need to think in a confrontation. Under stress, you become half the person you are—you lose fine motor skill and mental acuity. You have to take in the situation, process it and execute a plan.

With practice, you don't have to go through all that. Always carry your spray on your body in the same place, and learn how to use it."

That includes practicing with the bear spray, as you would with any weapon. Practice slipping off the safety and removing the canister from the holster. With any new canister, test it with a single, brief shot. Practice deploying spray with an old canister, or with an inert training canister (these can be purchased online from bear spray manufacturers.) It helps to feel the slight kickback of the canister, know how far the spray carries, and how it expands.

Bear spray should *never* be applied like an insect repellent on tents, gear, people or sprayed around campsites. Because it contains food-grade pepper extracts, the spray applied to surfaces can actually attract bears! It's the difference between spicing your food vs. getting pepper blown up your nose. If you have to use your spray in an encounter, leave the area.

Perhaps the most vulnerable time for hunters is once they have game on the ground.

Whether or not some bears associate gunshots with carcasses, they do tune in to human hunting activity and the prevalence of gut piles on the landscape. With their keen sense of smell, bears readily find carcasses and will naturally want to claim and defend such a haul.

Boyce urges hunters to gut the animal quickly and move the gut pile well away from the meat or carcass—bears typically go for the entrails first. If you can't carry the meat out in one load, be prepared to hang it as high off the ground as you can. If that's not possible, leave it in an open area with wide visibility so when you return you can assess any scavenger activity from a distance. If a bear is not immediately on the carcass, it may be close by. Look for sign, make lots of noise and come in so your scent blows downwind to the carcass area. And if a bear appears, don't argue over the meat.

Although no deterrent is 100 percent effective, bear spray has racked up an impressive track record for human safety and as a nonlethal deterrent.

"Bear spray provides a way to smack 'em without worrying about the aftermath," says bear biologist Smith. Consider that nature is full of creatures that successfully deploy chemical weapons as self-defense—skunks being the obvious example. With bear spray, you can "go skunk," and both you and the bear will likely walk away—you with a great campfire story, the bear with a good lesson learned.

Christine Paige, a wildlife biologist and writer, lives in Wyoming among a whole lot of elk, bears and wild country.