ROUX

Feasibility Study Report

CFAC Facility
2000 Aluminum Drive
Columbia Falls, Montana

June 16, 2021

Prepared for:
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Acronym List

Acronym	Definition
%	Percent
°C	Degrees Celsius
°F	Degrees Fahrenheit
$95UCL_{mean}$	95 Percent Upper Confidence Limit of the Mean
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirement
ATV	All-Terrain Vehicle
ARM	Administrative Rules of Montana
BCY	Bulk Cubic Yard
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BSSA	Backwater Seep Sampling Area
BTV	Background Threshold Value
CCC	Criterion Continuous Concentration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFAC	Columbia Falls Aluminum Company, LLC
CFR	Code of Federal Regulations
CN	Cyanide
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
COPEC	Constituent of Potential Ecological Concern
CQA	Construction Quality Assurance
CQC	Construction Quality Control
CSM	Conceptual Site Model
CY	Cubic Yard
DEQ-7	MDEQ Circular DEQ-7
DOE	Department of Energy
DU	Decision Unit
EC	Engineering Control
ELCR	Excess Lifetime Cancer Risk
EPC	Exposure Point Concentration
ER/IP	Electrical Resistivity/Induced Polarization
ERAGS	Ecological Risk Assessment Guidance for Superfund
F	Fluoride
FR	Federal Register
FS	Feasibility Study
FT-AMSL	Feet Above Mean Sea Level
FT-BLS	Feet Below Land Surface
FWS	Free-Water Surface
GAC	Granular Activated Carbon

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Acronym	Definition
GCL	Geosynthetic Clay Liner
GPM	Gallons Per Minute
GRA	General Response Action
GW	Groundwater
HASP	Health and Safety Plan
HDPE	High-Density Polyethylene
HI	Hazard Index
HMW	High Molecular Weight
HQ	Hazard Quotient
IC	Institutional Control
ISCO	*In Situ* Chemical Oxidation
ISM	Incremental Sampling Methodology
ITRC	Interstate Technology & Regulatory Council
KG/DAY	Kilograms Per Day
LCS	Leachate Collection System
LMW	Low Molecular Weight
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
LTTD	Low Temperature Thermal Desorption
MCA	Montana Code Annotated
MCL	Maximum Contaminant Level
MDEQ	Montana Department of Environmental Quality
MDL	Method Detection Limit
MDNR	Montana Department of Natural Resources
MG/KG	Milligrams Per Kilogram
MNA	Monitored Natural Attenuation
MPDES	Montana Pollutant Discharge Elimination System
NCP	National Contingency Plan
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NRWQC	National Recommended Water Quality Criteria
O&M	Operations and Maintenance
OM&M	Operations, Maintenance, and Monitoring
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PPE	Personal Protective Equipment
PRAO	Preliminary Remedial Action Objective
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goal
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective

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Acronym	Definition
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SC	Site Characterization
SLERA	Screening Level Ecological Risk Assessment
SPL	Spent Potliner
SW	Surface Water
TBC	"To Be Considered" Criteria
TSDF	Treatment, Storage, and Disposal Facility
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
UG/L	Micrograms Per Liter
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USNRC	United States Nuclear Regulatory Commission
VEB	Vertical Engineered Barriers
VOC	Volatile Organic Compound
WMU	Waste Management Unit
WP	Work Plan
WSSP	Wet Scrubber Sludge Pond
WWTP	Wastewater Treatment Plant
ZVI	Zero-Valent Iron

1. Introduction

On behalf of Columbia Falls Aluminum Company, LLC (CFAC), Roux Environmental Engineering and Geology, D.P.C. (Roux), has prepared this Feasibility Study Report ("FS Report") as part of the on-going Remedial Investigation/Feasibility Study (RI/FS) of the Superfund Site referred to as Anaconda Aluminum Co. Columbia Falls Reduction Plant, located two miles northeast of Columbia Falls in Flathead County, Montana (hereinafter, "the Site"). The RI/FS is being conducted pursuant to the Administrative Settlement Agreement and Order on Consent dated November 30, 2015, between CFAC and the United States Environmental Protection Agency (USEPA) (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Docket No. 08-2016-0002).

1.1 RI/FS Objectives

As described in Section 1 of the RI/FS Work Plan (Roux, 2015a), the RI/FS was designed to meet the following study objectives:

- Objective 1: Identify and characterize sources of contaminants of potential concern (COPCs);
- Objective 2: Determine the nature and extent of Site-related COPCs in environmental media at the Site (i.e., soil, groundwater, surface water, sediment, and sediment porewater);
- Objective 3: Understand the fate and transport of COPCs in environmental media at the Site;
- Objective 4: Identify any complete or potentially complete exposure pathways (considering current and also potential future land use);
- Objective 5: Evaluate current and potential future human health and ecological risks posed by the COPCs present at the Site; and
- Objective 6: Conduct an evaluation of remedial alternatives for the Site.

Objectives 1 through 5 have been achieved through the performance of the RI, as documented in the Remedial Investigation Report (Roux, 2020a; "RI Report") and summarized in Section 1.2 below. Objective 6 is the focus of this FS, for which an FS Work Plan (Roux, 2020b; "FSWP") has been prepared.

1.2 Remedial Investigation Activities Summary

The following provides an overview of environmental investigations performed at the Site related to the RI/FS and the associated RI/FS reports documenting those investigations. A detailed description of the results of the investigations are provided in their respective reports and are summarized together in the Phase II Site Characterization (SC) Data Summary Report (Roux, 2019). The results of the Baseline Human Health Risk Assessment (BHHRA; EHS Support, 2019d) and Baseline Ecological Risk Assessment (BERA; EHS Support, 2019e) are also described in their respective reports. The overall scope of work and results of the Site characterization, BHHRA, and BERA are presented collectively within the RI Report.

Phase I SC Data Summary Report – 2017

CFAC and Roux completed a Phase I SC from April 2016 through July 2017, which included the collection and laboratory analysis of soil, sediment, groundwater, and surface water samples from within and around Site features. The Phase I SC activities were performed in accordance with the USEPA-approved Phase I

Sampling and Analysis Plan (SAP) and SAP Addendum (Roux, 2015b; 2016a). The results of these field activities are provided in the Phase I SC Data Summary Report (Roux, 2017a).

Screening Level Ecological Risk Assessment (SLERA) – 2017

The SLERA, completed by Roux, provided an assessment of potential risks to ecological receptors that might be exposed to constituents from the Site (Roux, 2017b). The SLERA evaluated the aspects of the Site that could influence potential exposures and risks to ecological receptors.

Based on the review of the historical processes and data collected during the SLERA, preliminary constituents of potential ecological concern (COPECs) were identified in surface water, sediment, and surface soil to which ecological receptors could potentially be exposed. Based on these results, it was determined the conclusions of the SLERA were insufficient to dismiss potential ecological risk, and further data gathering or data analyses was recommended to better understand the risk.

Groundwater and Surface Water Data Summary Report – 2018

The Groundwater (GW) and Surface Water (SW) Data Summary Report, completed by Roux, summarized the results of groundwater and surface water investigations that were completed from August 2016 through July 2017 (Roux, 2018a) to achieve the Phase I SC objectives listed in the RI/FS Work Plan (Roux, 2015a).

Phase II SC Data Summary Report – 2019

The Phase II SC program, completed by Roux, was designed to address any outstanding data gaps in order to conduct the risk assessment and complete the RI. CFAC and Roux completed a Phase II SC from June 2018 through October 2018, which included the collection and laboratory analysis of soil, sediment, groundwater, surface water, and porewater samples from within and around Site features. Within the same time period, a Background Investigation was conducted that included collection and laboratory analysis of soil, sediment, and surface water samples from reference areas outside of the Site boundaries. The Phase II SC activities were performed in accordance with the USEPA-approved Phase II SAP and the Background Investigation SAP (Roux, 2018b; 2018c). The results of the Phase II SC and Background Investigation field activities are provided in Sections 4 and 5 of the Phase II SC Data Summary Report (Roux, 2019), respectively.

The Phase II SC Data Summary Report also summarized the Supplemental South Pond Assessment sampling that was completed under the Expedited Risk Assessment SAP (Roux, 2017c).

Baseline Human Health Risk Assessment (BHHRA) – 2019

The objective of the BHHRA, completed by EHS Support, was to characterize the potential risks to human receptors posed by exposure to affected environmental media at the Site in the absence of any remedial action. The BHHRA was conducted in accordance with the methodology and assumptions presented in the BHHRA WP (EHS Support, 2018a). The BHHRA provides the basis for determining whether remedial action is necessary to address potential risk to human health in the various exposure areas identified at the Site, as well as the extent of remedial action required. The BHHRA supports the FS in the evaluation of remedial alternatives to address any unacceptable current or future risk to human receptors from exposure to contaminants of concern (COCs); the results of the BHHRA are further discussed in Section 2.2.2.

Baseline Ecological Risk Assessment (BERA) – 2019

The overall purpose of the BERA, completed by EHS Support, was to evaluate whether environmental conditions associated with historical operations at the Site pose an unacceptable risk to ecological receptors in the absence of any remedial action. The BERA was conducted in accordance with the methodology and assumptions presented in the BERA WP (EHS Support, 2018b). The BERA provides the basis for determining whether remedial action is necessary to address potential risk to ecological receptors in the various exposure areas identified at the Site, as well as the extent of remedial action required. The BERA supports the FS in the evaluation of remedial alternatives to address any unacceptable current or future risk to ecological receptors from exposure to COCs; the results of the BERA are further discussed in Section 2.2.4.

Remedial Investigation Report – 2020

The purpose of the RI Report was to present the results of the multiple phases of the RI (i.e., the Phase I SC, the Supplemental South Pond Assessment, and the Phase II SC completed at the Site from April 2016 through November 2018) and to summarize the scope and results of the BHHRA and BERA prepared for the Site. Collectively, the information presented in the RI Report provides the foundation to support the development and evaluation of remedial alternatives in the FS.

1.3 Purpose of Report

The purpose of this FS Report is to identify, develop, screen, and conduct a detailed and comparative evaluation of a range of remedial alternatives for the Site that are capable of addressing unacceptable risks to human health and the environment from media contaminated as a result of historical Site operations. The highest-ranked remedial action alternative for the Site as a whole is also provided based on Roux's comparative analysis.

The elements of the FS process addressed in this FS Report include:

- Finalization of the preliminary Applicable or Relevant and Appropriate Requirements (ARARs) and Remedial Action Objectives (RAOs);
- Identification of Areas of Concern (AOCs);
- Screening of Remedial Technologies;
- Development of Remedial Action Alternatives;
- Detailed Evaluation of Remedial Action Alternatives; and
- Comparative Analysis of Remedial Action Alternatives.

1.4 Report Organization

This FS Report was prepared to fulfill the FS Scope of Work set forth in Section 7.3 of the RI/FS Work Plan (Roux, 2015a) and Section 5 of the Feasibility Study Work Plan (FSWP; Roux, 2020b), and in general accordance with the format outlined in the "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (USEPA, 1988). The remaining sections of this report include the following information:

> **Section 2 – Site Characteristics** provides the reader with an understanding of the CFAC Site. It includes the Site description and history, a summary of results from the baseline risk assessments, description of each decision unit (DU) and COCs by DU, fate and transport of these COCs, and past removal response and cleanup activities performed at the Site.

Section 3 – Remedial Objectives and Evaluation Criteria presents the ARARs, RAOs, Preliminary Remediation Goals (PRGs), and evaluation criteria against which each alternative will be assessed. PRGs were developed and presented in the USEPA-approved FSWP.

Section 4 – Identification and Screening of Technologies presents the general response actions (GRAs) that may satisfy the RAOs based on allowable exposure, PRGs, and ARARs. Remedial action alternatives assembled using technologies and process options retained through the technology screening process to formulate a range of remedial action alternatives for each DU are also provided.

Section 5 – Development and Description of Remedial Action Alternatives provides a detailed description of each remedial action alternative, including conceptual design elements specific to the Site.

Section 6 – Detailed Evaluation of Remedial Action Alternatives provides a detailed evaluation of each remedial action alternative developed in Section 5 with respect to the first seven of the nine National Contingency Plan (NCP) criteria: 1) overall protection of human health and the environment; 2) compliance with ARARs; 3) long-term effectiveness and permanence; 4) reduction of toxicity, mobility, or volume; 5) short-term effectiveness; 6) implementability; and 7) cost.

Section 7 – Comparative Analysis of Remedial Action Alternatives identifies the relative advantages and disadvantages of each remedial action alternative relative to one another, focusing on the relative performance of each alternative against the first seven NCP criteria against which each alternative was evaluated in Section 6. The relative performance against these criteria, combined with risk management decisions, will serve as the rationale for identifying the highest-ranked remedial action alternative based on Roux's comparative analysis.

Section 8 – References provides a list of references used in preparing this FS Report.

2. Site Characteristics

2.1 Site Background

The Site background information provided in the following sections includes:

- a general Site description;
- operational history;
- description of the environmental setting; and
- descriptions of Site features.

2.1.1 Site Description

The Site is located at 2000 Aluminum Drive near Columbia Falls, Flathead County, Montana. The Site is approximately two miles north-east from the center of Columbia Falls and is accessed by Aluminum Drive via North Fork Road (County Road 486). The boundaries of the Site were defined in the RI/FS Work Plan (Roux, 2015a) and are depicted on Figure 1. The Site consists of approximately 1,340 acres bounded by Cedar Creek Reservoir to the north, Teakettle Mountain to the east, Flathead River to the south, and Cedar Creek to the west.

The Site was operated as a primary aluminum reduction facility (commonly referred to as an aluminum smelter) from 1955 until 2009. A description of the operational history is provided in Section 2.1.2. Buildings and industrial facilities associated with former operations remaining at the Site at the start of the RI/FS in 2016 included offices, warehouses, laboratories, mechanical shops, a paste plant, coal tar pitch tanks, pump houses, a casting garage, and the potline facility. Decommissioning of the industrial facilities was completed in the third quarter of 2019. Following decommissioning, the remaining structures include the administration building, the main warehouse, two ancillary warehouses, and the fabrication shop.

The Site also includes seven closed landfills, one open landfill that hasn't been used since 2009, two closed leachate ponds, and several percolation ponds. A rectifier yard and switchyard owned by Bonneville Power Administration and a right-of-way for the Burlington Northern Railroad are also within the Site boundaries. A map showing the locations of these and other Site features is provided for reference on Figure 2. A description of the various Site features is provided in Section 2.1.4.

There are no ongoing manufacturing or commercial activities at the Site. A definitive future land use plan has not been developed for the Site. CFAC maintains a limited onsite staff that is responsible for the maintenance of the remaining buildings and infrastructure at the Site, as well as maintenance associated with existing landfills.

The Flathead River, which forms the southern border of the Site, is used for recreational activities, including: boating, floating, kayaking, hunting, fishing, and bird-watching water activities. In addition, it has been documented that trespassers also may utilize other portions of the Site for recreational purposes, including all-terrain vehicle (ATV) riding, hunting, and fishing.

The nearest residences are located adjacent to the south-west Site boundary, approximately 0.80 miles west of the historical footprint of Site operations, in a neighborhood referred to as Aluminum City. The nearest groundwater wells used for drinking water are located within the Aluminum City neighborhood.

Several production wells historically pumped groundwater that was used both for industrial operations and for potable water. However, electric power to these wells was terminated as part of Site decommissioning activities. Therefore, existing onsite wells are non-operational, and they are not currently used for potable water.

2.1.2 Site Operational History

The Site was operated as a primary aluminum reduction facility from 1955 until 2009. Aluminum production at the Site was suspended in 2009 due to a downturn in aluminum market conditions, and CFAC announced the permanent closure of the facility in March 2015. A detailed description of the operational history at the Site was provided in Section 2.7.2 of the RI/FS Work Plan (Roux, 2015a).

During aluminum production, the Hall-Héroult process and the Vertical Stud Soderburg technology was used to reduce alumina into aluminum. In the Hall-Héroult process, aluminum oxide was dissolved into a sodium fluoride (cryolite) bath in a carbon-lined pot heated to 960 degrees Celsius. Electric current ran through a carbon anode made of petroleum coke and pitch, to a carbon cathode (a steel pot, firebrick liner, and a layer of carbon paste), reducing the aluminum ion to aluminum metal. The anode was consumed during the reaction and molten aluminum formed at the bottom of the pot. The molten aluminum was tapped from the pot and transported to the Cast House where it was cast into ingots for off-Site shipment. Over the years, as part of the casting process, various alloys and ingots have been produced at the facility.

The aluminum production process generated several waste products, most notably spent potliner (SPL). During the process, the sodium in the cryolite bath gradually penetrated the carbon paste lining of the pot, causing the carbon to swell and eventually fail. The typical lifespan of the carbon cathode was 5 to 7 years. To re-use the pot, the carbon lining of the pot (i.e., potliner) was removed and replaced with a new carbon lining. The SPL consisted of the thick layer of carbon bonded to an insulating brick layer containing fluoride, sodium, aluminum, and small amounts of cyanide. The fluoride and sodium in the SPL were from the sodium fluoride (cryolite) bath and the cyanide formed in the cathode as a side chemical reaction during aluminum production.

Cyanide and fluoride in SPL are leachable and have been shown at this Site and other sites to contaminate groundwater. Prior to it being listed as a hazardous waste, SPL generated at the Site was disposed of onsite at the West Landfill, Center Landfill, and East Landfill. Each of these landfills is described below in Section 2.1.4.1. After 1990, all SPL generated at the Site was taken offsite for disposal in accordance with applicable regulations.

The aluminum production process generated air emissions, including particulate fluoride, hydrogen fluoride, and polycyclic aromatic hydrocarbon (PAHs). The main sources of air emissions were typically the Paste Plant and the aluminum reduction facility (i.e., potline buildings; USEPA, 1998b). Air pollution from the smelting process was controlled using wet scrubbers until 1976, and air pollution from the Paste Plant also used a wet scrubber from 1955 to 1999. Wastewater from the paste plant wet scrubber was discharged to the North Percolation Ponds (CFAC, 2003). The aluminum reduction facility wet scrubbers were replaced with dry scrubbers in 1976, and an analysis of the sludge by the Columbia Falls Reduction Plant laboratory staff indicated that the sludge was approximately 80 percent (%) calcium fluoride on a dry weight basis, and also contained calcium oxide, magnesium oxide, sodium oxide, and iron oxide (Hydrometrics, 1993). The sludge generated from the aluminum reduction facility wet scrubbers was landfilled onsite at the Wet Scrubber Sludge Pond.

Liquid waste generated as a result of the aluminum reduction process and stormwater were discharged to several percolation ponds. The facility discharged to the percolation ponds in accordance with a Montana Pollutant Discharge Elimination System (MPDES) permit, first issued in 1994. A summary of the liquid waste disposal areas is provided in Section 2.7.2 of the RI/FS Work Plan (Roux, 2015a) and in Section 5.3 of the RI Report.

During historical facility operations, wastewater generated as a result of the aluminum reduction process was discharged indirectly to groundwater. Ground Water Pollution Control System Permit Number MGWPCS0005 was issued by the State of Montana on September 17, 1984. The plant was permitted to discharge indirectly to the groundwater. In 1993, Montana Alumina Investors Corporation (MAIC) applied for a MPDES permit for the groundwater, contaminated by historical SPL disposal practices, released via a seep to the Flathead River. Permit MT-0030066 was issued in 1994 authorizing MAIC to discharge process wastewater from its aluminum reduction plant to groundwater discharging to the Flathead River. The permit included special conditions requiring MAIC to cap the SPL landfill and investigate Site hydrology to track the cyanide concentration in groundwater from the landfill to the Flathead River. On February 1, 1999 and again on September 1, 2014, the State of Montana re-issued MPDES Permit No. MT-0030066. The Site MPDES Permit issued in September 2014 was subsequently terminated effective April 17, 2019 due to the permanent plant closure and demolition of the facility. However, it is recognized that the West Landfill and Wet Scrubber Sludge Pond area is the primary source of COCs to groundwater which continue to impact surface water and sediment porewater in the Seep Area.

2.1.3 Environmental Setting

Background information regarding the regional environmental setting is provided below.

2.1.3.1 Site Topography

The land surface elevation at the Site varies from approximately 3,020 to 3,535 feet above mean sea level (ft-amsl). On a Site-wide scale, the general slope is in the south to south-west direction towards the Flathead River. A topographic map of the Site provided as Plate 1 of the RI Report was prepared based upon a detailed photogrammetric survey completed on May 22, 2018.

Where it borders the Site, the Flathead River is present at an elevation of approximately 3,020 ft-amsl. Adjacent to the Flathead River is an area of land that contains the South Percolation Ponds, where the land surface in this area generally ranges between 3,020 and 3,040 ft-amsl. Immediately to the north of this area is a narrow steep slope that rises to an elevation of approximately 3,120 ft-amsl.

North of the steep slope is the Main Plant Area, where the topography is generally flat with an increase in elevation of approximately 5 feet from west to east across the plant. The area immediately east of the Main Plant increases at a slope and reaches elevations above 3,250 ft-amsl. East of this area, the elevation fluctuates by approximately 60 feet locally around Site landfill features and the Cedar Creek Reservoir Overflow Ditch. East of the Cedar Creek Reservoir Overflow Ditch, the elevation increases to about 3,535 ft-amsl at the Site boundary, adjacent to the base of Teakettle Mountain. The Site is bordered by Teakettle Mountain to the east, which reaches elevations greater than 5,000 ft-amsl.

In the area north and north-east of the Main Plant, the Site elevations vary locally around Site landfill features and the local slopes can vary significantly. In general, within the north-eastern area of the Site the elevations range from approximately 3,110 ft-amsl to 3,225 ft-amsl. The East Landfill, located on the north-eastern border of the Site, reaches elevations of 3,255 ft-amsl and is the highest elevated local feature on the Site. In the north-western area of the Site, the elevations range from approximately 3,095 ft-amsl to 3,175 ft-amsl.

2.1.3.2 Regional Climate Conditions

The Site is located at a latitude of 48º 23' N. Its mid-hemisphere latitude and intermontane setting results in wide seasonal climatic swings. Average annual precipitation in the region ranges from about 10-inches to 21-inches depending on the year. Greater precipitation at higher elevations is common; much of the precipitation is stored as snow. The regional climate is considered modified maritime (i.e., much of the precipitation regime is influenced by moist air masses from the Pacific Ocean traveling from west to east). Dry, cold air masses often move in the north to south direction from Canada. Mean annual temperature for nearby Kalispell, Montana is 43.95 ºF (6.64 ºC).

A meteorological data station is located at the Glacier Park International Airport. Climate data were downloaded from each station for the time period from 2005 through 2018 through the Phase II SC. The table below summarizes the average annual temperatures and precipitation observed at the station.

October 2005 – December 2018	Glacier International Airport
Average Daily Temperature (°F)	43.95
Average Daily Maximum Temperature (°F)	55.97
Average Daily Minimum Temperature (°F)	31.53
Average Annual Total Precipitation (inches)	16.19

Monthly data collected from the Glacier International Airport station indicates that most precipitation occurs in the early winter and late spring seasons. As discussed in Section 4.1.2.2.2 of the Phase II SC Data Summary Report (and Appendix L3 of the Phase II SC Data Summary Report), the maximum monthly precipitation over the past eleven years (from 2008 to 2018) most frequently occurred in June (six of eleven years) during high-water season and the minimum monthly precipitation most frequently occurred in August (four of eleven years) during low-water season. July through September were the driest months over the last eleven-year period and June was the wettest month over the last eleven-year period.

Based on data collected by the Western Regional Climate Center (WRCC, 2018), prevailing winds in the area, as measured at Glacier Park International Airport, are generally from the south and south-east. A wind rose diagram depicting the wind patterns was generated from Midwestern Regional Climate Center for Kalispell/Glacier Park Airport (Mean Wind Direction, 1948 – 2018) and is provided as Figure 4 of the Background Investigation SAP (Roux, 2018c).

2.1.3.3 Description of Aquatic, Terrestrial, and Transitional Habitat

Aquatic, terrestrial, and transitional habitats are present within the Site. This section describes the general physical, hydrological, or vegetative characteristics that describe habitats within the Stillwater Swan Wooded Valley ecoregion where the Site is located in Montana (Woods et al., 2002). The habitat types described for the Site were used as the basis for identifying ecological exposure areas for the BERA.

Aquatic habitats are characterized by perennial or near-perennial inundation with water and physical habitats that can support aquatic receptor species. In lotic aquatic habitats (flowing streams and rivers), flow conditions are suitable for the establishment of fish and invertebrate communities, as well as semi-aquatic birds or mammals that rely on aquatic flora or fauna as a food resource. Two lotic aquatic habitats exist within and around the Site, including the Flathead River and Cedar Creek. The Flathead River is considered a large river by the Montana Department of Environmental Quality (MDEQ). Large rivers are non-wadeable and almost always seventh-order or higher according to the Strahler stream order index (Strahler, 1964). Key physical habitat features of the Flathead River include cobble or gravel substrate; deep, fast-flowing water; and, depending on valley dimensions, multi-thread channels. In the river reach adjacent to the Site, the Flathead River provides marginal fish habitat for common species, with this section of the river being used as a migration corridor to access areas of more suitable habitat (Stagliano, 2015). Given the absence of extensive agriculture or other non-anthropogenic nutrient sources upgradient, the Flathead River is considered oligotrophic, which means it lacks macronutrients, such as phosphorus.

Cedar Creek is a small headwater stream that discharges to the Flathead River. Small headwater stream habitats in the region can be distinguished primarily by their hydrologic regime. Montane headwater streams that originate in the high-elevation peaks have characteristically high spring and early summer flows, a spring freshet, due to snow melt. Small headwater systems are also often oligotrophic.

Terrestrial habitats are dry, upland areas that may support aboveground and/or belowground terrestrial flora and fauna. Soils that are considered terrestrial habitat are limited to the vadose, or unsaturated zone, of the soil profile. Vegetation type is another key characteristic of physical terrestrial habitats. There are four primary terrestrial habitats on the Site, which are characterized predominately by the type of vegetation present. These habitats include mixed conifer forest, riparian forest, deciduous shrubland, and open grassland.

Transitional habitats are characterized by intermittent or seasonal surface water inundation. Transitional habitats can potentially support aquatic receptor species during certain life stages (e.g., benthic invertebrates, juvenile herpetofauna), as well as terrestrial species during dry periods (e.g., soil invertebrates, terrestrial plants).

Ecological exposure areas identified based on onsite habitat types are defined in Section 3.3.1 of the BERA. The evaluation of potential ecological receptors within exposure areas is distinguished based on the presence of aquatic, terrestrial, or transitional habitat characteristics.

2.1.4 Site Features

Several Site features were identified for investigation during the RI based upon review of prior investigations and evaluation of historical information as described in the RI/FS Work Plan (Roux, 2015a). The Site features investigated include landfills and leachate ponds, percolation ponds, buildings and operational areas, and surface water features. The Site features are described in the sections below. The locations of Site features are shown on Figure 2.

2.1.4.1 Landfills

Landfills operated at the Site and were utilized for disposal of a variety of wastes from 1955 to October 2009. Certain landfills were used for disposal of SPL from 1955 to 1990. The landfills are described in the following subsections and in detail in the RI/FS Work Plan (Roux, 2015a) and in Section 1.3.4.1 of the RI Report. The RI results indicate the West Landfill and Wet Scrubber Sludge Pond area is the primary source of cyanide and fluoride in groundwater at the Site and that the Center Landfill is likely a secondary source area. The results of the RI indicated the East Landfill, the Industrial Landfill, the Sanitary Landfill, and the Asbestos Landfills are not significant contributing sources to the cyanide and fluoride in groundwater.

West Landfill

The West Landfill comprises approximately 7.8 acres, with areal dimensions of approximately 615 feet by 600 feet and rises approximately 13 feet above grade on the eastern side of the landfill and over 20 feet above grade from the western side. The landfill reportedly is unlined.

As noted in the RI/FS Work Plan (Roux, 2015a), historical aerial photographs indicate the West Landfill appears undeveloped until between 1963 and 1974, later than the 1955 date described in several prior reports (CFAC, 2013; Weston, 2014; RMT, 1997). Minimal disturbance, and only along the southern boundary of the West Landfill, was observed in the 1956 and 1963 aerial photographs; while the majority of the West Landfill appeared to be in use by the time of the 1974 aerial photograph (Appendix F of the RI Report). Therefore, based on the historical aerial photographs, use of the West Landfill for SPL disposal commenced between 1963 and 1974. The West Landfill was used to dispose of SPL and other wastes through 1980, though SPL disposal into the West Landfill reportedly ended in 1970. The landfill was closed and covered with an earthen cap including a 6-inch clay layer in 1981 and capped with a synthetic (hypalon) cap in 1994 (CFAC, 2013).

The as-built drawings for the West Landfill cap completed in 1994 indicate the average depth of the waste within the landfill is 30 feet (Appendix G1 of the RI Report). Other sources indicate the depth of waste is approximately 48 feet in thickness (CFAC, 2013). Due to the range of waste thicknesses provided by various sources of information, there is uncertainty regarding the vertical extent of waste in the West Landfill; for the purpose of evaluating and comparing remedial alternatives in this FS Report, an average depth of waste of 35 feet has been assumed. Based on the topography of the landfill surface described above (i.e., 13 to 20 ft above surrounding grade) and an average waste depth of 35 feet, the base of the landfill is estimated to range between 15 and 22 ft below surrounding grade.

Groundwater levels in the area of the West Landfill range from approximately 36 feet below land surface (ft-bls) during high-water season to 87 ft-bls during low-water season. These water table depths are below the estimated base of the waste within the West Landfill, suggesting that groundwater does not saturate the waste, even under high-water conditions. However, this does not include any impacted underlying soils beneath the West Landfill.

As noted above, the West Landfill is unlined. Prior to construction of an effective low-permeability cap on the landfill in 1994, precipitation would have infiltrated through the landfill, generating SPL leachate that would have migrated vertically downward into groundwater. Some of the cyanide within this leachate would have been retained in the soil above the seasonal low-water table (which as described above can be more than 80 ft-bls) and available to serve as a residual source of cyanide to groundwater when the water table rises during the high-water season.

This conclusion is supported by an Electrical Resistivity/Induced Polarization (ER/IP) geophysical survey that was conducted as part of the Phase I SC to approximate the landfill bottom and landfill caps. As determined from the ER/IP geophysical survey, an area of low resistivity was identified to approximately 115 feet below the top of the West Landfill. The interpretation of these results suggested the depth of the waste material or impacted soil and groundwater underlying the West Landfill could be as thick as 115 feet; though it should be noted that these types of geophysical surveys are indirect measurements and subject to various interferences.

While no samples have been collected beneath the West Landfill, the long-term persistence of cyanide in groundwater directly downgradient of the landfill coupled with a low-permeability cap in place since 1994 indicates that impacted material likely extends into and beneath the seasonal high-water table and is serving as a continuing source of contamination. Impacted material above the water table could also come in contact with infiltrating surface water runoff via lateral migration of such water through the vadose zone.

Wet Scrubber Sludge Pond

The Wet Scrubber Sludge Pond is approximately 10.8 acres in size with areal dimensions of approximately 750 feet by 580 feet. The observed height of the berm surrounding the Wet Scrubber Sludge Pond is approximately 15 feet above surrounding grade. Based on the historical documents reviewed, the total depth of waste material including the above-grade portion is estimated to be approximately 30 feet. Groundwater levels measured in adjacent monitoring wells indicate that during high-water season, groundwater is observed to be approximately 60 ft-bls; though groundwater levels in CFMW-007 adjacent to the West Landfill were 35.5 ft-bls. During low-water season, groundwater is observed to be approximately 105 ft-bls.

The Wet Scrubber Sludge Pond reportedly received waste material from the wet scrubbers at the aluminum reduction plant from 1955 until 1980, at which time the wet scrubbers for the aluminum reduction plant were replaced with dry scrubbers that produce much less waste (RMT, 1997). The pond was subsequently capped with an earthen cap in 1981 and vegetated.

Center Landfill

The Center Landfill is approximately 1.8 acres in area, in a circular shape, with an aerial diameter of approximately 330 feet. The Center Landfill was also historically referred to as the carbon mound. The landfill was operated from 1970 to 1980 for disposal of SPL and was closed in 1980 (CFAC, 2013). Based on the historical documents reviewed, the landfill was constructed above grade and is approximately 15 feet above surrounding grade. Depth to groundwater in the area of the Center Landfill ranges from approximately 57 feet to 139 feet below surrounding grade.

The Center Landfill was reportedly unlined. The landfill was closed in 1980 and, based on historical drawings, capped with a 6-inch clay cap and 18-inches of till (Marquardt Billmayer, 1981). The Center Landfill appears to be a potentially contributing source to groundwater contamination, but to a lesser degree than the West Landfill and Wet Scrubber Sludge Pond area. The identification of the Center Landfill as a secondary source was based upon the detection of total cyanide at a concentration of 1,880 µg/L in monitoring well CFMW-017 in March 2017, exceeding the PRG of 200 µg/L. Monitoring well CFMW-017 was installed in 1980 through the Center Landfill. However, in all other sampling rounds the maximum concentration of cyanide in this well was 103 µg/L. In addition, the two wells installed adjacent to the Center Landfill on its downgradient side (CFMW-016 and CFMW-020) have exhibited a maximum total cyanide estimated concentration of 2.9 µg/L, and are typically non-detect with a detection limit of 2 µg/L). Given the low or non-detect concentrations of cyanide in groundwater from wells immediately adjacent to and downgradient of the Center Landfill, and because the Center Landfill was constructed above grade, underlying impacted material at the Center Landfill likely does not extend into the seasonal high-water table. Monitoring data presented in the RI Report indicate that the existing Center Landfill cap is effective in preventing impacts to groundwater downgradient of the Center Landfill. The need for cap improvements is further evaluated in Section 2.3.1.

East Landfill

The East Landfill encompasses an area of approximately 2.4 acres. The aerial dimensions are approximately 330 feet by 730 feet. Based on the historical documents reviewed, the East Landfill was constructed above ground level (CFAC, 2013), and is approximately 30 feet above the surrounding grade. Groundwater levels in the area of the East Landfill range from approximately 109 feet to 130 feet below surrounding grade.

The East Landfill was reportedly built with a clay liner and capped with a 6-inch thick clay layer, a synthetic membrane layer, and an 18-inch vegetated till cover (Appendix G2 of the RI Report). The landfill was also built with two lined leachate collection ponds. The landfill was operated from 1980 to 1990 for disposal of SPL and was closed in 1990.

The North Leachate Pond was located directly north of the East Landfill and was approximately 0.6 acres in size, with aerial dimensions of approximately 250 feet by 115 feet. The North Leachate Pond was lined with a Hypalon liner. The leachate pond received stormwater runoff and leachate from the East Landfill and was hydraulically connected to the Wet Scrubber Sludge Pond by a drainage pipe. The pond was also aerated to reduce concentrations of cyanide. The pond was closed in 1994.

The South Leachate Pond was located directly south of the East Landfill and was approximately 0.9 acres in size. The South Leachate Pond received stormwater runoff and leachate from the East Landfill. The South Leachate Pond was lined with Hypalon liner. Similar to the North Leachate Pond, the South Leachate Pond was aerated to reduce concentrations of cyanide (CFAC, 1994; CFAC, 2003). The pond was emptied in 1990 and was dried, capped, and closed in 1993.

Industrial Landfill

The Industrial Landfill is an inactive, uncovered landfill in the northern portion of the Site, encompassing approximately 12.4 acres. The aerial dimensions of the landfill are approximately 720 feet by 800 feet, though the shape is irregular. The height of the Industrial Landfill varies and ranges from approximately 10 to 20 feet above surrounding grade. Groundwater levels in the area of the Industrial Landfill range from approximately 19 feet to 31 feet below surrounding grade. As discussed in the RI Report, the data and analysis to date indicate that the Industrial Landfill is not a source of groundwater contamination at the Site.

The Industrial Landfill began operations in the 1980s based on aerial photography. The Industrial Landfill received non-hazardous waste and debris (CFAC, 2013) until landfilling operations ceased in October 2009. Details regarding the depth of landfilled material or presence of a liner are unknown.

Sanitary Landfill

The Sanitary Landfill is approximately 3.8 acres in size, approximately 330 feet wide by 540 feet long. Based on the historical documents reviewed, the depth of landfilled material is unknown. Groundwater levels in the area of the Sanitary Landfill range from approximately 23 feet to 94 feet below surrounding grade. As discussed in the RI Report, the data and analysis to date indicate that the Sanitary Landfill is not a source of groundwater contamination at the Site.

Based on aerial photography review, the Sanitary Landfill operated in the early 1980s. The landfill was reportedly clay-lined, and was used for plant garbage (RMT, 1997). According to the 2014 Site

Reassessment Report, the landfill was covered with clean fill and vegetated (Hydrometrics, 1992). The landfill cap is sloped away from Teakettle Mountain to promote runoff and is observed to be in good condition.

Asbestos Landfills

As described in the RI/FS Work Plan (Roux, 2015a), two areas were identified as being former asbestos disposal areas based on historical information. These areas are referred to as the North Asbestos Landfills and the South Asbestos Landfills. The North Asbestos Landfills are located north of the West Landfill and consist of two separate areas (i.e., North-West and North-East Asbestos Landfills); the South Asbestos Landfills are located south of the East Landfill, near the eastern boundary of the Site, and consist of two separate areas (i.e., South-West and South-East Asbestos Landfills). The four disposal areas are referred to collectively as the Asbestos Landfills.

The Asbestos Landfills were constructed as early as the late 1970s or early 1980s and were in use from 1993 to 2009. Details regarding disposal area construction are unknown; however, based on observations made during the Phase I SC field reconnaissance and test pitting activities, a natural soil cover overlies the asbestos materials within the disposal areas. The deepest asbestos bag observed was 4.5 ft-bls. There is no evidence of an engineered cap or liner. The RI Report did not identify the Asbestos Landfills as a potential source of groundwater contamination at the Site as asbestos is inert and insoluble.

2.1.4.2 Percolation Ponds

Water from Site operations and stormwater discharges to several percolation ponds. Details regarding the percolation ponds are provided in the sections below.

North-East Percolation Pond

The North-East Percolation Pond is approximately 2 acres in size, and the topography is depressed below the surrounding area with a maximum depth of approximately 14 ft-bls. The thickness of the waste material in the percolation pond ranges from approximately 0.5 to 2 feet based on visual observations made during drilling (i.e., vertical extent of highly viscous to solid black carbonaceous material). The North-East Percolation Pond was constructed in 1955, and based on the aerial photography review, the exact size and shape of the North-East Percolation Pond changed slightly over time. This percolation pond received discharges from various operations within the Main Plant Area until manufacturing ceased in 2009. Prior to 1978, these historical discharges included wastewater from the Carbon Cathode Soak Pits and likely contributed to groundwater contamination. The North-East Percolation Pond is currently operational as a discharge point for stormwater drainage and, based on data and analysis presented in the RI Report, is not a current source of groundwater contamination at the Site. Groundwater levels in the area of the North-East Percolation Pond range from approximately 30 feet to 73 feet below surrounding grade.

North-West Percolation Pond

The North-West Percolation Pond is approximately 8 acres in size, and the topography is depressed below the surrounding area with a maximum depth of approximately 22 ft-bls. The thickness of the waste material in the percolation pond ranges from approximately 0.5 to 2 feet based on visual observations made during drilling. The North-West Percolation Pond was constructed to receive overflow water from the North-East Percolation Pond and as such likely also contributed to groundwater contamination prior to 1978 when receiving wastewater from the Carbon Cathode Soak Pits. The two ponds were connected by an approximately 1,440-foot-long unlined ditch. Based on the review of aerial photography, the North-West

Percolation Pond appears to be in the process of being constructed in 1972. Based on data and analysis presented in the RI Report, the North-West Percolation Pond is not a current source of groundwater contamination at the Site. Groundwater levels in the area of the North-West Percolation Pond range from approximately 24 feet to 44 feet below surrounding grade.

South Percolation Ponds

The South Percolation Ponds are a series of three ponds located on the south end of the Site, adjacent to the Flathead River. Based on review of historical aerials, the South Percolation Ponds were constructed in the early 1960s in conjunction with the construction of the dam on the upriver (east side) of the South Percolation Ponds. The dam diverted water from a side channel of the Flathead River and allowed for construction of the ponds in the dewatered area. The ponds are 2.4, 1.2, and 6.6 acres in size (from west to east) forming a total of 10.2 acres and are connected in series. Wastewater and stormwater entered the South Percolation Pond system from a concrete pipe located on the west end of the pond system. From the pipe, water flows via an unlined ditch into the west pond. Groundwater levels in the area of the South Percolation Ponds range from approximately 8 feet to 14 feet below surrounding grade. The water level in the South Percolation Ponds has been observed to correlate closely with surface water elevations in the Flathead River, indicating a hydraulic connection between the two water bodies.

The South Percolation Ponds received water from the sewage treatment plant, the aluminum casting contact chilling water, non-contact cooling water from the rectifier and other equipment, process wastewater from the casting mold cleaning and steam cleaning, non-process wastewater from the fabrication shop steam cleaning, and stormwater. Following completion of the facility demolition, the only waters received by the South Percolation Ponds were stormwater discharge through the influent pipe at the west end of the ponds system and groundwater as discussed below. CFAC has since decommissioned the influent pipe to eliminate the direct discharge of stormwater into the Ponds as part of the Removal Action at the South Percolation Ponds, discussed in Section 2.3.5.

The South Percolation Pond Area is located within the extent of the “Seep Area” that was defined in the former MPDES Permit (#MT00300066) as the area which has potential to receive groundwater expressed from the upper hydrogeologic unit (see Section 2.1.5.2) to the Flathead River. The results of the RI indicate the soil/ sediment within the South Percolation Ponds are not a source of contamination at the Site, and that contaminants in the ponds are not impacting areas outside or downgradient of the ponds. This includes the elevated levels of cyanide and fluoride found in groundwater and in the Seep Area, which the results of the RI indicate are not measurably impacting surface water, sediment, or sediment porewater quality within the main channel of the Flathead River.

2.1.4.3 Buildings and Former Operational Areas

The Main Plant Area includes the buildings historically used for production of aluminum and various support buildings, warehouses, and storage areas. The Main Plant Area includes the following Site features:

- The Potline Buildings where the aluminum smelting occurred;
- The casting house, mechanical shops, Paste Plant, Rod Mill, and warehouses adjacent to the potlines; and
- The Rectifier Yards.

Details of these Site features are provided below. Decommissioning of the industrial facilities was completed in the third quarter of 2019.

Potline Buildings

The Main Plant Area is where the production of aluminum occurred. The facility was approximately 47 acres and spanned approximately 1,760 feet by 1,170 feet.

In 1955, the plant began operation with four pot rooms. The plant expanded to ten pot rooms in the 1960s. The potline buildings had courtyards and various support buildings in between the pot rooms. The courtyards contained air ventilation structures including the dry scrubbers. Support buildings include the casting house, offices, garages, and a briquette storage area (Anaconda Aluminum, 1981).

The dry scrubbers in the plant were installed to replace a wet scrubber sludge system, which operated until final installation of the dry scrubbers between 1976 and 1978.

Many raw materials were required for aluminum production and were stored on-Site. Raw materials were delivered to the Site at several transfer stations, located just north of the Main Plant, and adjacent to the railroad. Raw material transfer stations include the Petroleum Coke Building, the Alumina Unloading Stations, and the Lime Unloader station (Roux, 2015a).

Rod Mill

The Rod Mill is approximately 1.2 acres and is located on the south-western portion of the Main Plant Area. This area was used as a Rod Mill during the first decade of plant operation. Afterwards, the Rod Mill was used for storage. During the 1990s, the Rod Mill was used for storage of hazardous waste, including SPL and PCBs (RMT, 1997).

Paste Plant

The Paste Plant manufactured anode briquettes from petroleum coke and coal tar pitch. Once made, the briquettes were sent to the Main Plant Area for use in the pots. Several other buildings were part of the briquette making process, including the petroleum coke unloading building, a petroleum coke silo, a paste plant wet scrubber (replaced by a dry scrubber in 1999), coal tar pitch tanks, and a coal tar pitch unloading shed (RMT, 1997; E&E, 1988; CFAC, 2003).

Rectifier Yards

The Rectifier Yards are located in the south portion of the Main Plant Area and are approximately 18 acres in size. The Rectifier Yards were essential to powering the Site operations; the western Rectifier Yard has since been decommissioned. A portion of the eastern Rectifier Yards are still active and are owned by Bonneville Power Administration.

Transformers and capacitors in the Rectifier Yards historically used transformer oil containing PCBs. Transformer oil containing PCBs were removed in the 1990s (RMT, 1997).

Incremental Sampling Methodology (ISM) Grid Area

The ISM Grid Area comprises approximately 43 acres north of the Main Plant Area where aerial photographs indicate historical operations may have been conducted but no known source area exists. While the entire

Site was investigated via the collection of grab samples at soil boring locations, the ISM Grid Area was also investigated using ISM soil sampling methods to characterize average conditions across 43 individual grid cells, each approximately one acre in size. This area also encompasses the Former Drum Storage Area, a Site feature encompassing 1.1 acres adjacent to the West Landfill and the Wet Scrubber Sludge Pond.

2.1.4.4 Surface Water Features

There are four primary surface water bodies onsite: Flathead River, Cedar Creek, Cedar Creek Reservoir Overflow Ditch, and the Northern Surface Water Feature. These primary surface water bodies are described below. Surface water features specific to the Flathead River, including the "Seep Area",[1] Backwater Seep Sampling Area, and the Riparian Sampling Area are also described below.

Cedar Creek

Cedar Creek is fairly shallow and, based on elevation of the groundwater table, groundwater from the Site does not recharge into Cedar Creek. A tributary to Cedar Creek flows, or has flown, historically east of the Industrial Landfill and to the south-west, joining Cedar Creek approximately one-half mile to the south-west of the landfill.

Cedar Creek Reservoir Overflow Ditch

The Cedar Creek Reservoir Overflow Ditch runs from the Cedar Creek Reservoir to the Flathead River. The Cedar Creek Reservoir Overflow Ditch runs alongside the Sanitary Landfill, Center Landfill, the southern Asbestos Landfill, and the East Landfill and associated leachate ponds before discharging into the Flathead River.

Northern Surface Water Feature

The Northern Surface Water Feature is a seasonal ponding area located between Cedar Creek and the Cedar Creek Reservoir Overflow Ditch, just south of the Industrial Landfill. It is believed that during the spring, the snowmelt and increased seasonal precipitation creates a localized elevated or perched water table which feed the seeps. The substrate of the feature is predominantly grass covered with areas of channelization which help direct the groundwater from the seeps in the nearby cliff to the feature.

Flathead River

The Flathead River runs along the southern border of the Site. Groundwater from the Site discharges to the Flathead River along the "Seep Area" as described below.

Seep Area

The "Seep Area" is a documented groundwater discharge point to the Flathead River. Due to the steep banks along the Flathead River, some of the Site groundwater discharges from the cliffs and flows down to the Flathead River. Flowing seeps have been observed and documented along the Flathead River for over 1,000 feet.

Backwater Seep Sampling Area

The Backwater Seep Sampling Area represents the western portion of the "Seep Area". The Backwater Seep Sampling Area is a documented groundwater discharge point to the Flathead River that was historically

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[1] The "Seep Area" is where groundwater is expressed from the upper hydrogeologic unit (see Section 2.1.5.2) to the Flathead River.

sampled as part of the permit and was sampled throughout the RI. Some of the Site groundwater discharges at the base of the steep river bank into a backwater channel of the Flathead River.

Riparian Area

The Riparian Area is vegetated with a riparian forest and is located north of the Flathead River between the South Percolation Pond Area and the Backwater Seep Sampling Area. The Riparian Area is within the central portion of the "Seep Area". Groundwater seepage in this area drains via a small stream channel (less than a few feet wide) that discharges into the eastern end of the Backwater Seep Sampling Area.

2.1.5 Physical Characteristics of the Site

In order to generate a comprehensive dataset for the Site, multiple phases of investigation were completed as part of the RI including the Phase I SC, the Supplemental South Pond Assessment, and the Phase II SC. As detailed in the RI/FS Work Plan (Roux, 2015a), the RI was designed to supplement previous environmental investigations performed at the Site prior to the RI/FS; a detailed description and summary of results from these investigations as well as cleanup actions performed at the Site prior to the RI/FS was provided within the RI/FS Work Plan. A summary of the scope of work for each investigation phase of the RI is provided in Section 2 of the RI Report. Physical characteristics of the Site determined from the RI including Site stratigraphy, groundwater hydrology, and surface water hydrology are discussed in Section 3 of the RI Report and summarized in the sections below.

2.1.5.1 Site Stratigraphy

Lithologic data collected from soil borings completed as monitoring wells during the RI were utilized to generate hydrogeologic cross-sections depicting the stratigraphy beneath the Site (RI Report Plates 6 through 16). The geologic cross sections indicate three major stratigraphic units underlying the Site. The three stratigraphic units consist primarily, from land surface down, of:

- A layer of glaciofluvial and alluvial coarse-grained deposits, varying in vertical extent and grain size, depending on vicinity to Site features (i.e., Teakettle Mountain, Flathead River, etc.);
- A layer of dense, poorly sorted glacial till with interbedded deposits of glaciolacustrine clays and silts; and
- Bedrock.

A description of the three stratigraphic units observed on the cross-sections is provided below.

- The glacial outwash and alluvium layer typically contain coarse grained deposits (varying amounts of sand, gravel, and cobbles) with varying degrees of sorting and with lesser amounts of fines. The glacial outwash layer is encountered at the surface across most of the Site, with recent alluvial deposits present primarily near the southern border of the Site in the vicinity of the Flathead River. The cross sections indicate that the glacial outwash vertical thickness appears to be relatively consistent in areas north and west of the Main Plant Area, with average thicknesses ranging from 50 to 80 feet thick. The glacial outwash north of the Main Plant Area reaches maximum vertical thickness in the areas beneath the Former Drum Storage Area, West Landfill, Wet Scrubber Sludge Pond, and Center Landfill; where thickness was typically observed to range from 125 to 150 feet. The thickness tends to decrease close to Teakettle Mountain where bedrock elevations are shallower. Near the Flathead River, the vertical extent of the alluvial deposits is approximately 100 feet thick along the western/central southern boundary of the river.
- Glacial till was observed in the subsurface across most of the Site, typically beneath the coarse-grained outwash deposits. The glacial till layer is a dense, poorly-sorted deposit, consisting of varying amounts of sand, gravel, cobbles, silt, and clay. Based on field observations, the till was

typically noted to be drier and denser than the overlying coarse-grained deposits. The maximum vertical extent of the glacial till is unknown in the areas to the north, west, and south of the Site, as the next lithologic layer was not encountered during drilling. This indicates that the till is typically at least 200 feet thick or greater in these areas.

- Based on regional geologic literature, beneath the unconsolidated glacial deposits are pre-Cambrian aged bedrock. The literature indicates that the depth to bedrock increases in a south-western direction across the Site, as you increase in distance from Teakettle Mountain. This was confirmed during the Phase I SC. Bedrock was encountered in soil boring CFMW-023a, which is located to the east of the Site near Teakettle Mountain, at an approximate depth of 150 ft-bls. Weathered bedrock was also encountered in soil boring CFMW-008a (also located to the east of the Site near Teakettle Mountain) at approximately 130 ft-bls, and a more competent bedrock within the same boring at approximately 245 ft-bls. Bedrock was not encountered in any of the other deep soil borings completed at the Site, indicating that depth to bedrock is greater than 300 ft-bls across most of the Site.

As described in the fate and transport section below (Section 2.4), the RI results indicate the majority of contaminant mass resides and migrates within the upper half of the upper hydrogeologic unit (see Section 2.1.5.2).

2.1.5.2 Groundwater Hydrology

This section describes the hydrogeologic units, groundwater flow, hydraulic conductivity, and the groundwater/surface water relationship at the Site. Roux also evaluated temporal variability of the hydrologic data (i.e., elevation, discharge, precipitation) for groundwater and surface water features at the Site. Additional details regarding the groundwater hydrology and temporal variability (including additional tables and graphs) can be found in the Phase I SC Data Summary Report, GW/SW Data Summary Report, and Phase II SC Data Summary Report.

Hydrogeologic Units

The stratigraphic units underlying the Site form a complex hydrogeologic framework that influences groundwater elevations, groundwater flow, and COC migration beneath the Site. There are two hydrogeologic units discussed in the RI; these units are referred to as the upper hydrogeologic unit and the below upper hydrogeologic unit. The two hydrogeologic units and their characteristics are described below.

Upper Hydrogeologic Unit

The coarse-grained glacial outwash and alluvium deposits that are found above the glacial till are collectively referred to as the upper hydrogeologic unit at the Site. During drilling, the glacial deposits comprising the upper hydrogeologic unit were typically observed to be loose and wet when water was encountered at the water table. Based upon relatively consistent elevations at which groundwater was encountered within the upper hydrogeologic unit and the occurrence of groundwater at all drilling locations, it appears that the unit is horizontally continuous across the investigated area. The continuity of the upper hydrogeologic unit is also confirmed by hydraulic flow directions and gradients measured during monitoring well water level gauging.

While the upper hydrogeologic unit appears to be continuous across the Site, the groundwater within the upper hydrogeologic unit appears to exist under perched water table conditions. Perched zones have been documented to occur at various locations throughout the Kalispell Valley and have historically been referred to in regional literature as the Pleistocene perched aquifers (Konizeski et al., 1968). The perched conditions are supported by the lithology and the rapid and pronounced response to precipitation/seasonal changes that are observed around the Central Landfills Area and Main Plant Area. The saturated thickness of the upper hydrogeologic unit varies across the Site depending upon the depth to underlying glacial till and proximity to Teakettle Mountain. Saturated thickness was observed to be less near Teakettle Mountain when compared to areas beneath the landfills and west of the landfills.

Below Upper Hydrogeologic Unit

During drilling, the glacial till found below the upper hydrogeologic unit was typically characterized as containing a higher percentage of fines, and as denser and drier, than the overlying outwash and alluvium deposits. The till deposits were often characterized as stiff and moist or dry; in contrast to the overlying outwash and alluvium that was typically characterized as loose and wet. These observations indicate that the till deposits likely have a lower hydraulic conductivity than the overlying outwash and alluvium deposits. This is supported by observations during monitoring well development, where the deep wells screened within the tills typically yielded much less water than wells screened in the outwash deposits. This is also supported by slug testing data which was collected from monitoring wells screened in the glacial till.

Based upon the conceptual site model (CSM), bedrock is considered to define the bottom of the hydrogeologic system beneath the Site.

Groundwater Elevation and Flow

During the RI, the water level elevation data indicated that groundwater elevations fluctuate seasonally at varying magnitudes depending on the area of the Site. The data indicate that near Teakettle Mountain and the Central Landfills Area, average water levels fluctuated by approximately 25 feet during the RI; with the lowest levels occurring in October 2018 and the highest in June 2018. In the center of the Site, average water levels fluctuated by approximately 17 feet, with the lowest levels in March 2017 and the highest in June 2018. In the southern area of the Site, average water levels fluctuated by approximately 18 feet, with the lowest levels in March 2017 and the highest in June 2017.

The groundwater depth and groundwater elevations from monitoring wells screened in the upper hydrogeologic unit were utilized to create groundwater contour maps and to evaluate groundwater flow (RI Report Plate 17). Groundwater typically flows south-west away from Teakettle Mountain toward the Landfill Area. From the Landfill Area, groundwater continues to flow south-west until it reaches the center of the Site, where topography is relatively flat, and then flows south. Groundwater flows south from the center of the Site toward the Flathead River. In the Western Undeveloped Area, groundwater flows south-east, away from Aluminum City, and toward the Flathead River. Overall, the groundwater flow patterns described above remained consistent during all six rounds of water level gauging for the RI.

Hydraulic Gradients

The hydraulic gradients across the Site can generally be divided into three distinct areas. Near Teakettle Mountain and in the Central Landfills Area, the groundwater hydraulic gradient is steep (approximately 0.028 to 0.0719 ft/ft) and generally mirrors the steeper topography in that portion of the Site. Groundwater elevations in the center of the Site (near the North Percolation Ponds, former ISM Grid Area, and northern half of the Main Plant Area) typically vary by less than three feet across long distances (i.e., over 1,000 feet), indicating a relatively flat groundwater hydraulic gradient across the center of the Site (approximately 0.0013 to 0.005 ft/ft; i.e., generally an order of magnitude less than near the Central Landfills Area). The gradient then increases in the southern area of the Site between the Main Plant Area and the Flathead River (approximately 0.005 to 0.020 ft/ft), which is also consistent with the steep drop in topography between the railroad and the river.

Vertical Gradients

Groundwater elevations measured in monitoring well clusters (i.e., where there is a well screened within the upper hydrogeologic unit and an adjacent deep well screened below the upper hydrogeologic unit) were evaluated during the RI to determine vertical gradients beneath the Site. In all cases the elevations measured in deep wells screened below the upper hydrogeologic unit are lower than the elevations in adjacent wells screened within the upper hydrogeologic unit. The differences in elevations between the upper hydrogeologic unit wells and the wells screened below the upper hydrogeologic unit is typically greater than 25 feet, and in some cases, exceed 50 feet. This large difference is indicative of limited (if any) hydraulic connectivity between the two water bearing zones. The groundwater elevations measured in monitoring well clusters where both monitoring wells are screened in the upper hydrogeologic unit typically differ by less than 0.3 feet; and often by less than 0.1 feet, suggesting that at most locations there is limited vertical migration of water within the upper hydrogeologic unit.

Hydraulic Conductivity

Slug testing results from the RI were used to determine the hydraulic conductivity at the upper hydrogeologic unit and below the upper hydrogeologic unit monitoring well locations. The results indicate that the geometric mean hydraulic conductivity of the upper hydrogeologic unit (13.35 ft/day) is higher than the geometric mean hydraulic conductivity of the materials below the upper hydrogeologic unit (0.27 ft/day). These hydraulic conductivity values are consistent with geologic observations recorded in boring logs during drilling, which generally indicate wells below the upper hydrogeologic unit are screened in finer grained materials.

Additionally, hydraulic conductivity can vary by orders of magnitude over short distances within the upper hydrogeologic unit; the wide range of estimated hydraulic conductivity values (0.11 to 1,477 ft/day in the upper hydrogeologic unit; 0.004 to 113.6 ft/day below the upper hydrogeologic unit) is indicative of the heterogeneous geological conditions that are encountered beneath the Site. Slug test results for wells near the West Landfill and Wet Scrubber Sludge Pond have ranges from 20 ft/day to over 300 ft/day. In addition, a historical pump test at well CFMW-021 indicated a hydraulic conductivity of 326 ft/day (Hydrometrics, 1993). Based upon these ranges, an average hydraulic conductivity of 175 ft/day was assumed for purposes of the flow estimate calculations performed in Appendix A.

Groundwater/Surface Water Relationships

A groundwater seep was identified along the Flathead River in the Backwater Seep Sampling Area of the Site (Figure 2). The "Seep Area" encompasses a greater length of the Flathead River shoreline than just the Backwater Seep Sampling Area. Groundwater from the upper hydrogeologic unit is expressed to the sediment porewater and surface water located within the extent of the "Seep Area." Historically, groundwater has consistently been observed to discharge from the banks of the Backwater Seep Sampling Area. The hydrogeologic studies (i.e., groundwater elevation data and surface water elevation data) indicate that groundwater from the upper hydrogeologic unit discharges to Flathead River.

There is no evidence suggesting groundwater discharges to Cedar Creek, Cedar Creek Reservoir Overflow Ditch, or the Northern Surface Water Feature. The elevations of Cedar Creek, Cedar Creek Reservoir

Overflow Ditch, and the Northern Surface Water Feature are higher than the groundwater elevations beneath them, indicating that these Site features are losing water to the subsurface rather than gaining.

2.1.5.3 Surface Water Hydrology

The discharge and hydrology of Cedar Creek, Cedar Creek Reservoir Overflow Ditch, and the Flathead River were evaluated during the RI. Figure 2 depicts the locations of these surface water features. This section describes the surface water flow patterns and discharge and the effect of seasonal variability on flow patterns and discharge. Additional details regarding the surface water hydrology (including additional data tables and graphs) can be found in the Phase I SC Data Summary Report, GW/SW Data Summary Report, and Phase II SC Data Summary Report.

The Northern Surface Water Feature was determined not to be impacted by groundwater. It is an intermittent seasonal ponding area fed by snowmelt and increased seasonal precipitation during the spring and is dry with a grass covered area during the rest of the year.

Surface water discharge data for the Flathead River was reviewed during the RI from the nearest USGS monitoring station (Station No. 12363000) located approximately three miles downstream of the Site. The USGS monitoring station results showed that Phase I Round 4 (June 2017) and Phase II Round 1 (June 2018) captured high-water conditions of the Flathead River; and Phase I Round 1 (September 2016), Supplemental South Ponds Assessment activities (November 2017), and Phase II Round 2 (October 2018) captured low-water conditions of the Flathead River. These data also indicate that the dates for maximum Flathead River discharge over the last eleven years are typically within May and June, and dates of minimum discharge over the last eleven years range from October to March. These data indicate that the RI maximum and minimum discharge events occurred within a representative timeframe consistent with historical data and that the high-water and low-water sampling periods of the RI were well timed to coincide with the high-water and low-water conditions.

At the western Site boundary, Cedar Creek drains an additional 1.5 square miles, predominately from the western two thirds of the Site. The Cedar Creek Reservoir Overflow Ditch flows intermittently in the spring and regulates flow for Cedar Creek and the Cedar Creek Reservoir (Hydrometrics, 1985). Based upon proximity and land surface topography, some surface water runoff from the eastern side of the Site, originating from the East Landfill and the Sanitary Landfill, as well as runoff from the western flank of Teakettle Mountain, flows to Cedar Creek Reservoir Overflow Ditch. Excluding potential upgradient contributions from the Cedar Creek Reservoir, the Cedar Creek Reservoir Overflow Ditch has a catchment area of approximately 2 square miles. About 20% of this catchment area originates onsite and the remaining catchment extends to the peak of Teakettle Mountain to the east. Like Cedar Creek, the elevation of Cedar Creek Reservoir Overflow Ditch is higher than surrounding groundwater elevations within the Site, indicating that Cedar Creek Reservoir Overflow Ditch is a losing stream.

Discharge of Cedar Creek and Cedar Creek Reservoir Overflow Ditch were measured utilizing a mechanical current-meter method as described in Section 2.9.1 of the RI Report. Results of the discharge calculations are summarized in Appendix L4 of the Phase II SC Data Summary Report. Cedar Creek Reservoir Overflow Ditch was dry throughout most of the field program. The discharge was evaluated at multiple points along the surface water bodies in an effort to confirm the CSM; both Cedar Creek and Cedar Creek Reservoir Overflow Ditch are acting as losing streams as they flow through the Site. In Cedar Creek Reservoir Overflow Ditch, the discharge measured at locations on the northern end of the Site were typically higher than the locations at the southern end of the Site. These data indicate that the ditch was acting as a losing stream throughout the entire year (when wet) and thus losing water infiltration into the groundwater system. These data are also supported by visual field observations throughout the program where the northern end of Cedar Creek Reservoir Overflow Ditch was observed to be wet, while the southern end of the ditch was dry at the same time.

In Cedar Creek, the stream discharge did not decrease consistently from upstream to downstream measurement locations. The increases could be attributed to local surface water inputs from the west and/or could be within the margin of error of the field measurement method. As documented within the Phase I SC Data Summary Report, the creek bed of Cedar Creek is located above the water table in the upper hydrogeologic unit, indicating it is not a groundwater discharge location.

2.2 Baseline Risk Assessment Results Summary

The comprehensive dataset collected during the RI, which includes data for soil, groundwater, surface water, sediment, and sediment porewater, was used to assess human health and ecological risks for various exposure areas identified at the Site. Human health exposure areas are depicted on Figure 3. Ecological exposure areas are depicted on Figure 4. A summary of the exposure areas and anticipated future use for each area is described below.

The results of the risk assessments indicate only a subset of contaminants of potential concern (COPCs) contribute to risk estimates that exceed *de minimis* levels for potential human health risk (i.e., excess lifetime cancer risk (ELCR) of 1E-06 for carcinogens; or hazard quotient (HQ) of 1 for non-carcinogens) or pose moderate or higher risk from the ecological perspective (i.e., lowest observed adverse effect level HQ (HQ_{LOAEL}) values greater than 1 for at least one receptor). These COPCs contributing to risk exceeding *de minimis* levels were presented by exposure area in Tables 9 and 10 of the RI Report and further discussed in Section 2.4.1 of the FSWP. The Site-related COPCs requiring additional evaluation, henceforth referred to as contaminants of concern (COCs), were summarized in Tables 2-1 and 2-2 of the FSWP.

The findings from the RI indicate that PAHs,[2] cyanide, and fluoride are the COCs that are the primary risk drivers at the Site. These COCs are the most widespread across the Site, and generally overlap spatially with the other COCs (identified in Section 2.3 below), which contribute to risk in localized areas of the Site. In addition, other COCs (i.e., metals) were identified in soil, sediment, or surface water samples within a few specific exposure areas (e.g., South Percolation Ponds) and drive ecological risk in those areas.

Summaries of the results for the BHHRA (EHS Support, 2019d) and BERA (EHS Support, 2019e) are provided below.

2.2.1 Human Health Exposure Areas and Receptors

The objective of the BHHRA was to characterize the potential risks to human receptors posed by exposure to affected environmental media at the Site in the absence of any remedial action. The BHHRA provides the

[2] The PAHs driving risk at the Site are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.

basis for determining whether remedial action is necessary to address potential risk to human health in the various exposure areas identified at the Site, as well as the extent of remedial action required.

The format for the BHHRA follows the USEPA Risk Assessment Guidance for Superfund (RAGS) Part D (USEPA, 2001). The regulatory guidance for conducting the BHHRA includes RAGS Parts A through F (USEPA, 1989, 1991a, 1991b, 2001, 2004, and 2009), and other guidance documents and procedures that USEPA has issued in addition to the RAGS guidance. The additional guidance and procedures are referenced in the BHHRA WP (EHS Support, 2018a) as well as within the BHHRA (EHS Support, 2019d) where appropriate.

Included in the BHHRA is a review of the conceptual exposure models and discussion of exposure pathways for exposure areas. Exposure areas were defined considering both the current and reasonable anticipated future land use for the various areas of the Site. The boundaries of each exposure area were developed using professional judgement, and considered Site characteristics, current and potential future receptors, and the distribution of COPCs identified in the RI. Human health exposure areas are depicted on Figure 3. A summary of the exposure areas and anticipated future use for each area is described below.

- *Main Plant Area* – includes the area of historical manufacturing operations including the former Main Plant, associated buildings and infrastructure, and the former Rod Mill. The Main Plant Area is covered by impervious surfaces and there are no areas of significant vegetation other than weeds common to roadsides and disturbed areas. Based on the remote location from residential areas, flat land, and remaining post-decommissioning infrastructure, the foreseeable future use of this area is industrial or commercial.
- *North Percolation Pond Area* – is a water management area of historical wastewater discharge and consists of two ponds (North-East and North-West). Historical wastewater discharge flowed into the North-East pond from an influent ditch, and then to an approximately 1,440-foot-long unlined overflow ditch to the North-West Pond. Based on the depressed topography, the foreseeable future use of this area is industrial stormwater management.
- *Central Landfills Area* – consists of 12 distinct Site features (as shown on Figure 3) associated with waste management and disposal activities. Based on the existing Site features associated with waste management and disposal activities, the foreseeable future use of the Central Landfills Area is industrial (i.e., landfill management and maintenance activities).
- *Incremental Sampling Methodology (ISM) Grid Area* – comprises approximately 43 acres in the northern portion of the Main Plant Area and within the Central Landfills Area south of the landfills where aerial photographs indicate historical operations may have been conducted but no specific source area exists.
- *Industrial Landfill Area* – an inactive, uncapped landfill in the northern portion of the Site that received non-hazardous waste and debris. Based on the existing Site features associated with waste management and disposal activities, the foreseeable future use of this area is industrial (i.e., landfill management and maintenance).
- *Eastern Undeveloped Area* – undeveloped and vegetated with forest and shrubland, except for the area that includes the Borrow Pit Area. There were no operational activities conducted within this area. Based on limited accessibility (i.e., steep rugged terrain), proximity to landfills, Teakettle Mountain east of the area, the main rail line and Flathead River in the southern portion, and the Main Plant Area west of the area, the foreseeable future use of this area is industrial or undeveloped.
- *North-Central Undeveloped Area* – comprises undeveloped and vegetated shrubland in the northern portion of the Site, as well as roadways. There were no operational activities conducted within this area. Based on the proximity to landfills and the presence of the Northern Surface Water Feature, the foreseeable future use of this area is industrial or undeveloped.

- *Western Undeveloped Area* – includes roadways and mixed vegetation in the western third of the Site. Cedar Creek transects the area along the north-western border from north to south. The southwestern portion of this area is adjacent to the off-Site residential area referred to as Aluminum City. There were no operational activities conducted within this area. Based on the proximity to existing residential development, existing vegetative habitat, and main rail right-of-way immediately south of the area, the foreseeable future use of this area could be industrial, commercial, residential, or undeveloped for recreational use.
- *South Percolation Pond Area* – includes a series of three water management ponds and the surrounding vegetated area located on the south end of the Site adjacent to the Flathead River. Based on the existing operational ponds, riparian vegetation, and adjacent Flathead River, the foreseeable future use of this area is industrial water management or undeveloped.
- *Flathead River Area* – the portion of Flathead River which runs along the southern border of the Site. Based on the designated use of the Flathead River as well as local recreational uses, the current and future use of the Flathead River is recreational.
- *Backwater Seep Sampling Area* – a backwater area of the Flathead River west of the South Percolation Pond Area along the southern border of the Site that is documented as receiving groundwater discharge. Based on the presence of the steep relief and the backwater, it is foreseeable that the current and future use of this area will remain undeveloped; however, recreational users of the Flathead River may use the area for recreational purposes.
- *Groundwater* – groundwater was evaluated in the BHHRA utilizing three different exposure scenarios (Western Undeveloped Area Upper Hydrogeologic Unit, Plume Core Area[3] Upper Hydrogeologic Unit, and Site-wide Below Upper Hydrogeologic Unit).

Based on the current and reasonably foreseeable future use of the Site, and the potential for exposure to affected soil, groundwater, surface water, and sediment, the potential receptors within the overall Site boundary and associated Flathead River were identified for both current Site use and future use scenarios. Current potential receptors evaluated in the BHHRA are trespassers and recreationists. Potential future receptors evaluated include industrial or commercial workers, construction workers, residents, trespassers and recreationists (e.g., hunters and fishers). It is noted that the potential receptors vary by specific exposure area, as detailed within the BHHRA.

The BHHRA used default exposure assumptions as outlined in various USEPA guidance documents for the residential scenarios. Site-specific exposure assumptions were used for the following receptors:

- Trespassers;
- Industrial workers (stormwater, landfill, industrial);
- Construction workers; and
- Recreational (hunters, ATV riders, fisher, floaters).

Technical justification and references for the Site-specific assumptions were detailed within the BHHRA. The following presents a discussion on Site-specific exposure that were used in the BHHRA:

- A stormwater management worker is anticipated to conduct an inspection of the North Percolation Pond and Central Landfills areas once per week for approximately 1 hour per inspection. Consistent

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3 The “Plume Core Area” for cyanide is identified as the area where monitoring wells had detected concentrations of total cyanide of greater than 300 µg/l in any of the six sampling rounds. The “Plume Core Area” for fluoride is identified as the area where monitoring wells had detected concentrations of fluoride of greater than 2,000 µg/l in any of the six sampling rounds.

with the MDEQ exposure frequency surface soil recommendations, the stormwater management worker is assumed to be exposed to soils 8 months of the year or 38 weeks; therefore, the exposure frequency is 38 days per year for this receptor. The same exposure frequency is assumed for surface water and sediment.

- For the construction worker, MDEQ assumes that a building excavation may be open for as long as 4 months; therefore, the construction worker exposure frequency of 124 days per year was used (MDEQ, 2016; Development of Montana-Specific Default Soil Exposure Frequencies).
- A construction worker specific particulate emission factor (PEF) from surficial soil disturbance and dust releases for unpaved road traffic was calculated using the default assumptions from various USEPA guidance documents and a site-specific number of days with at least 0.01 inches of rainfall of 120.
- The reasonable maximum exposure for the recreationist (i.e., boater and floater) receptor is an exposure frequency of 10 days per year for 1 hour per lunch visit to the Backwater Seep Sampling Area (Richard Birdsell, personal communication). An adolescent recreationist is considered to be 6 to 16 years old; therefore, the exposure duration for the adolescent recreationist is 10 years. An exposure duration of 20 years is assumed for the adult recreationist. For the purposes of dermal exposure, the surface area is assumed to be whole body and is based on USEPA defaults for the adolescent and adult floaters and the exposure time is assumed to be 1 hour per visit.
- The fisher has an estimated exposure frequency of 10 days per year for 20 years and an exposure time of 1 hour per lunch visit to the Backwater Seep Sampling Area (Richard Birdsell, personal communication). Access to the Flathead River Area and Backwater Seep Sampling Area is via boat; however, exposure assumptions consistent with wading activities were used. Additionally, a fisher is conservatively assumed to keep two fish per day of fishing to consume, which corresponds to two fish meals. A typical meal is assumed to be 8 ounces per day, or 227 grams per day of fish. Therefore, the fish ingestion rate, normalized for one year, of 12,971 milligrams per day is assumed for this receptor.
- Because of the migratory nature of the fish caught by the fisher, and the lack of spawning areas along the reach of the Flathead River adjacent to the Site, the fish are not expected to be exposed to the surface waters within the Backwater Seep Sampling Area except for incidental incursions (Richard Birdsell, personal communication). Therefore, a migration ratio of 10 percent was applied to the relative percentage of time the fish would be exposed to COPCs within the Backwater Seep Sampling Area. This is a conservative migration ratio given the small surface water habitat within the Backwater Seep Sampling Area and the migratory nature of the fish species.
- The trespasser is an adolescent from 6 to 16 years of age and is assumed to access the Site seven days per year (Steve Wright, personal communication).
- The recreational trespasser (hunter) is assumed to access the Site 14 days per hunting season (Rich Birdsell, personal communication); for deer, the hunting season is September through November, and one deer is bagged for home consumption. The average weight of dressed deer is approximately 63 kg (average buck and doe, MDEQ website), and approximately 50 percent is edible venison. Therefore, the venison ingestion rate, normalized for one year, is 0.086 kilograms per day (kg/day).
- The recreationist trespasser (ATV rider) is assumed to access the Site one day per month (Steve Wright, personal communication).

2.2.2 BHHRA Conclusions

The BHHRA evaluated potential human health risks to receptors at the Site. Data collected during the RI investigation activities within each exposure area were used to characterize potential risks. The receptors evaluated in the current and future scenarios, as appropriate, included industrial workers (industrial worker, landfill management worker, and stormwater management worker), construction workers, recreational trespassers (ATV rider and hunter), adolescent trespassers, adolescent and adult recreationists (boater, floater, and fisher), and residents (adult and child). The BHHRA included the evaluation of potential exposures to COPCs in soil, surface water, sediment, and groundwater, as well as the potential exposure to COPCs in fish (i.e., uptake of COPCs in surface water) by recreationists (fisher) and exposure to COPCs in venison (i.e., uptake of COPCs in soil) by recreational trespassers (hunter). Default and Site-specific exposure assumptions were developed for these receptors.

Table 9-1 through Table 9-35 and Appendix I and Appendix J of the BHHRA presented the calculated cumulative risks for each receptor by COPC in each potentially complete exposure scenario identified in the CEM. Table 27 of the RI Report (Table 9-36 of the BHHRA) presents a summary of the ELCR and Hazard Index (HI) for each receptor.

Based on the evaluation of the BHHRA results, the following general conclusions can be drawn regarding human health risks at the Site.

Exposure Areas that Do Not Pose Risks Due to Site-Related Contamination

The conditions in the following exposure areas at the Site do not pose ELCR above *de minimis* levels or potential for non-cancer effects due to the presence of Site-related COPCs. These exposure areas include:

- Eastern Undeveloped Area;
- North-Central Undeveloped Area;
- Western Undeveloped Area;
- South Percolation Pond Area;
- Flathead River Area; and
- Backwater Seep Sampling Area.

As shown in Table 27 of the RI Report, it is noted that risk characterization results for the three undeveloped areas (i.e., Eastern, Western, and North-Central Undeveloped Areas) indicate a ELCR above 1E-06 or a non-cancer risk (HI >1) for exposure to surface soil. However, in each case, the risk was due to the presence of arsenic or manganese in soil, both of which were found in background soil samples at comparable concentrations. Therefore, these are not attributable to Site-related contamination, but rather to naturally occurring background conditions.

In addition, it is noted in the Western Undeveloped Area that one isolated detection of bis(2-ethylhexyl) phthalate in groundwater, at a concentration of 73 micrograms per liter (µg/L) at monitoring well CFMW-069 during the October 2018 sampling event, resulted in a calculated risk of 1E-05 for drinking water exposure under the hypothetical future residential scenario evaluated for this area. The prior sample collected at this location in June 2018 was non-detect, with a method detection limit (MDL) of 4.4 µg/L. Bis(2-ethylhexyl) phthalate is not a contaminant associated with historical operations at the Site, and it has not been identified at levels of concern anywhere on the Site. Given these factors and that bis(2-ethylhexyl) phthalate is recognized as a common field and lab contaminant (associated with plasticware), the calculated risk appears overestimated and unrelated to Site-related contamination. Therefore, bis(2-ethylhexyl) phthalate is not carried forward for evaluation of remedial alternatives.

Exposure Areas that Pose Risks Due to Site-Related Contamination

The conditions in the following exposure areas at the Site pose ELCR above *de minimis* levels or potential for non-cancer effects due to the presence of Site-related COCs:

- Main Plant Area (including the Main Plant ISM Grid Area);
- North Percolation Pond Area;
- Central Landfills Area (including the Central Landfills ISM Grid Area); and
- Industrial Landfill Area.

In addition, groundwater within the Plume Core Area poses risk based upon a hypothetical future residential drinking water scenario.

The key conclusions with respect to each of the above areas are presented below.

Main Plant Area: Risk in the Main Plant Area was calculated using both discrete and ISM soil sampling data. Discrete samples were collected across the entirety of the Main Plant Area (i.e., 290 acres). Using the discrete data, the calculated cumulative ELCRs range from 6E-07 for the trespasser scenario to 8E-06 for the industrial worker scenario. The ISM data was collected from a limited portion of the Site (i.e., a combined 43 acres between the Central Landfills Area and Main Plant Area). Using the ISM data for the Main Plant ISM Grid Area, the calculated cumulative ECLRs range from 2E-06 for the construction worker and trespasser scenarios to 2E-05 for the industrial worker scenario in that area. PAHs[4] in soil are the primary risk driver for the ELCR within the Main Plant Area. As stated in the BHHRA, concentrations of arsenic in soil in the Main Plant Area are comparable to concentrations of background soil samples. Therefore, the presence of arsenic in this exposure area is not attributed to Site-related contamination. This area also exhibits some potential non-cancer effects with the HI of 4 (developmental, nervous, and thyroid target organ systems) for both the industrial and construction worker.

North Percolation Pond Area: The BHHRA results indicate a calculated cumulative ELCR of 1E-04 for a stormwater management worker scenario and 5E-05 for a trespasser scenario. In each case, the risk driver is exposure to PAHs within the pond. The BHHRA results indicate no potential for non-cancer risk effects due to COCs in the North Percolation Pond Area.

Central Landfills Area: Risk in the Central Landfills Area was calculated using both discrete and ISM soil sampling data. Discrete samples were collected across the entirety of the Central Landfills Area (i.e., 128 acres). Using the discrete data, the calculated cumulative ELCRs range from 6E-07 for the trespasser scenario to 1E-05 for the landfill management worker scenario. The ISM data was collected from a limited portion of the Site (i.e., a combined 43 acres between the Central Landfills Area and Main Plant Area). Using the ISM data for the Central Landfills ISM Grid Area, the calculated cumulative ECLRs range from 2E-06 for the trespasser scenario to 3E-05 for the landfill management worker in that area. PAHs in soil are the primary risk driver for the Central Landfills Area. As presented in Table 9-37 of the BHHRA, the potential contribution

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[4] PAHs driving risk at the Site are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.

of risk from background for arsenic in the Central Landfills Area ranged from 57 to 63 percent. The BHHRA results indicate no potential for non-cancer risk effects due to COCs in the Central Landfills Area.

Industrial Landfill Area: The calculated cumulative ELCRs range from 2E-06 for the trespasser scenario to 1E-05 for the landfill management worker scenario. PAHs in soil are the primary risk driver for the Industrial Landfill Area. As presented in Table 9-37 of the BHHRA, the potential contribution of risk from background for arsenic in the Industrial Landfill Area is 50 percent. The BHHRA results indicate no potential for non-cancer risk effects due to COCs in the Industrial Landfill Area.

Groundwater Plume Core Area: As noted within the BHHRA, CFAC intends to prohibit the use of groundwater beneath the Site for potable use. However, as required by USEPA, the BHHRA evaluated risk associated with exposure to groundwater within the Plume Core Area under a residential exposure scenario[5] to provide a conservative evaluation of potential health risk in the absence of any controls.

The Plume Core Area was defined based upon evaluation of the cyanide and fluoride extents in groundwater within the upper hydrogeologic unit as described in Section 3.1 of the RI Report. Within this area, the calculated HIs for future adult exposure to total cyanide, free cyanide, and fluoride are 7E+01, 2E+00, and 5E+00, respectively; and cumulative HI is 8E+01. The calculated HIs for future child exposure to cyanide, free cyanide, and fluoride are 1E+02, 4E+00, and 9E+00, respectively, and cumulative HI is 1E+02. The results indicate potential for non-cancer effects if groundwater within the Plume Core Area is to be used as a source of drinking water.

In addition to the non-cancer effects, the results of the BHHRA indicate a calculated cumulative ELCR of 2E-04 for lifetime exposure (i.e., including exposure as a child, adolescent, and adult) to arsenic in groundwater under a future residential exposure scenario. Review of the data indicates the exposure point concentration (EPC) of 9.8 µg/L is primarily driven by elevated concentrations measured in two wells (CFMW-012 and CFMW-015, both adjacent to the West Landfill/Wet Scrubber Sludge Pond source area), where maximum concentrations were approximately 92 µg/L. The vast majority of wells within the Plume Core Area are non-detect for arsenic, with the typical MDL less than 1 µg/L.

2.2.3 Ecological Exposure Areas and Receptors

A BERA was conducted as part of the RI to evaluate whether environmental conditions associated with historical operations at the Site pose an unacceptable risk to ecological receptors based on the conceptual investigation framework presented in the BERA WP (EHS Support, 2018b) and two interim deliverables that are presented in Appendix A of the BERA. The BERA was conducted in accordance with USEPA guidance, primarily Ecological Risk Assessment Guidance for Superfund (ERAGS), and the BERA WP (EHS Support, 2018b) and interim work plan deliverables (EHS Support, 2019a, 2019b, 2019c). The complete BERA is provided in Appendix E of the RI Report.

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5 The BHHRA evaluated residential exposure in the Western Undeveloped Area including an assessment of the cumulative potential residential risks from exposure to soils and upper hydrogeologic groundwater (see BHHRA: Section 6.1.7 Western Undeveloped Area). In addition, the BHHRA assessed the cumulative potential residential risks from exposure to the plume core area groundwater as well as site-wide groundwater in the below upper hydrogeologic unit (see BHHRA: Section 6.1.13 Additional Groundwater Evaluation).

The Site was divided into exposure areas for conducting the BERA as part of the RI. The ecological exposure areas defined for the BERA are similar to the BHHRA exposure areas; but slightly modified and further subdivided as appropriate to represent primary habitat types and receptor groups that may be exposed to COPCs. Five surface water features – Cedar Creek, Cedar Creek Reservoir Overflow Ditch, Flathead River Riparian Area, South Percolation Ponds, and Northern Surface Water Feature – are treated as separate exposure areas within the BERA based upon the types of habitats present. In addition, the Flathead River exposure area was evaluated both with and without the Backwater Seep Sampling Area. Ecological exposure areas are depicted on Figure 4. A brief description of these features is provided below:

- *Cedar Creek* – Cedar Creek originates north of the Site in the Whitefish mountains and flows approximately three miles southwest towards the City of Columbia Falls. The portion of Cedar Creek present at the Site flows along the western Site boundary. Cedar Creek is fairly shallow and, based on elevation of the groundwater table, groundwater from the Site does not recharge into Cedar Creek.
- *Cedar Creek Reservoir Overflow Ditch* – The Cedar Creek Reservoir Overflow Ditch runs from the Cedar Creek Reservoir to the Flathead River. The Cedar Creek Reservoir Overflow Ditch runs alongside the Sanitary Landfill, the Center Landfill, the southern Asbestos Landfill, and the East Landfill and associated leachate ponds before discharging into the Flathead River.
- *Flathead River Riparian Area* – The Riparian Area is vegetated with a riparian forest and is located north of the Flathead River between the South Percolation Ponds and the Backwater Seep Sampling Area. Groundwater seepage in this area drains via a small stream channel (the "Flathead River Riparian Area Channel," less than a few feet wide) that discharges into the western end of the Backwater Seep Sampling Area.
- *South Percolation Ponds* – The South Percolation Ponds are a series of three ponds located on the south end of the Site, adjacent to the Flathead River. Groundwater levels in the area of the South Percolation Ponds range from approximately 8 feet to 14 feet below surrounding grade. The water level in the South Percolation Ponds has been observed to correlate closely with surface water elevations in the Flathead River; indicating a hydraulic connection between the two water bodies.
- *Northern Surface Water Feature* – The Northern Surface Water Feature is a seasonal ponding area located between Cedar Creek and the Cedar Creek Reservoir Overflow Ditch, just south of the Industrial Landfill. It is believed that during the spring, the snowmelt and increased seasonal precipitation creates a localized elevated or perched water table which feed the seeps. The substrate of the feature is predominantly grass covered with areas of channelization which help direct the groundwater from the seeps in the nearby cliff to the feature.
- *Backwater Seep Sampling Area* – a backwater area of the Flathead River west of the South Percolation Pond Area along the southern border of the Site that is documented as receiving groundwater discharge.

Ecological exposure areas were defined to represent the habitat types (aquatic, transitional, and terrestrial) and receptor groups that may be present and exposed to Site constituents. Ecological exposure areas were developed and grouped into three broad categories based on habitat types:

- Terrestrial Exposure Areas: Dry, upland areas that may support aboveground and/or belowground terrestrial flora and fauna.
    - Main Plant Area;
    - Central Landfills Area;
    - Industrial Landfill Area;

  - Eastern Undeveloped Area;
  - North-Central Undeveloped Area;
  - Western Undeveloped Area; and
  - Flathead River Riparian Area.[6]
- Transitional Exposure Areas: Characterized by intermittent or seasonal surface water inundation that may support aquatic or terrestrial receptors, depending on the time of year.
  - North Percolation Pond Area;
  - Cedar Creek Reservoir Overflow Ditch;
  - South Percolation Ponds; and
  - Northern Surface Water Feature.
- Aquatic Exposure Areas: Characterized by perennial or near-perennial inundation with water and physical habitats that can support aquatic receptor species.
  - Flathead River Riparian Area Channel;[7]
  - Flathead River Area;[8] and
  - Cedar Creek.

The type(s) of impacted environmental media varies among the different ecological exposure areas and associated habitats, and could include surface water, sediment (including porewater), and soil.

2.2.4 BERA Conclusions

The findings of the BERA are summarized below to describe the potential risks identified and the uncertainties associated with the conclusions. The BERA findings are evaluated for each ecological exposure area to support area-specific recommendations to guide risk management decision-making for the Site.

Terrestrial Exposure Areas

The overall results of the BERA for the terrestrial exposure areas are presented in Table 28 of the RI Report (Table 8-1 of the BERA) and are summarized below.

Exposure Areas that Do Not Pose Risks Due to Site-Related Contamination

Current conditions in the following terrestrial exposure areas at the Site are not likely to result in adverse ecological effects resulting from exposure to Site-related COCs:

- Eastern Undeveloped Area;
- North-Central Undeveloped Area;

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6 The Flathead River Riparian Area is a terrestrial exposure area that includes the terrestrial environment south of the railroad and up to the Flathead River. This area does not include aquatic exposure areas (i.e., Flathead Riparian Area Channel, Backwater Seep Sampling Area) or transitional exposure areas (i.e., South Percolation Ponds) in the surrounding area.

7 The Flathead River Riparian Area Channel is an aquatic exposure area that is surrounded by the Flathead River Riparian Area. This feature is presented in BERA Figure 2-2 and is presented as the Riparian Sampling Area on Figure 2 of the RI Report.

8 The Flathead River Area is an aquatic exposure area that includes the main channel of the Flathead River.

- Western Undeveloped Area; and
- Flathead River Riparian Area.

For the Eastern Undeveloped Area, North-Central Undeveloped Area, and Western Undeveloped Area, some sampling locations were identified with concentrations of barium or manganese that exceeded lowest observed effect concentration (LOEC) for terrestrial plants. However, these metals were present at concentrations consistent with background concentrations, and their presence was not attributed to Site-related pathways. Bis(2-ethylhexyl) phthalate in the Eastern Undeveloped Area exceeded a hazard quotient (HQ) based on no observed adverse effect level (NOAEL) (HQNOAEL) of 1 for the yellow-billed cuckoo, a special status species that is evaluated based only on NOAEL endpoints. However, as discussed in Section 7.1.7 of the BERA, bis(2-ethylhexyl) phthalate is not related to historical Site operations and is a common laboratory contaminant. Furthermore, it is not likely the yellow-billed cuckoo would be present at the Site due to its rarity in Montana and the absence of basic habitat requirements at the Site. Therefore, bis(2-ethylhexyl) phthalate is not carried forward for evaluation of remedial alternatives.

Exposure Areas that Pose Risks Due to Site-Related Contamination

Current conditions in the following terrestrial exposure areas at the Site have the potential to result in adverse effects to terrestrial receptors:

- Main Plant Area;
- Central Landfills Area;
- ISM Grid Area; and
- Industrial Landfill Area.

The key conclusions with respect to each of the above areas are presented below.

Main Plant Area: Risk estimates for the Main Plant Area, particularly in the north-central portion of this exposure area, indicate the potential for adverse effects associated with exposure to PAHs in soil within localized areas proximal to former operations. Direct contact exposure to PAHs in the Main Plant Area may result in adverse direct contact effects to terrestrial invertebrates in these localized areas. Exposure estimates for PAHs in soil resulted in wildlife ingestion lowest observed adverse effect level (LOAEL) HQ (HQ_{LOAEL}) values that exceeded 1 for two avian receptors (the American woodcock and the yellow-billed cuckoo), primarily due to the modeled ingestion of terrestrial invertebrates. In the northern portion of the Main Plant Area within the ISM Grid Area (i.e., Operational Area) footprint, there is potential for adverse effects for small mammals including the short-tailed shrew (exposure > HQ_{LOAEL} at 5 of 90 stations) and meadow vole (exposure > HQ_{LOAEL} at 9 of 90 stations).

Central Landfills Area: Risk estimates for the Central Landfills Area indicate the limited potential for adverse effects associated with exposure to PAHs and select metals, including copper, in soil within localized areas near the former Wet Scrubber Sludge Pond. The direct contact evaluation indicates that potential risk to soil invertebrates and terrestrial plants is low, although localized areas of PAHs and one elevated copper result at CFSB-002 (7,260 mg/kg) resulted in some no observed effect concentration (NOEC) and LOEC exceedances. Wildlife ingestion models indicate the potential for adverse effects to two avian receptors (the American woodcock and the yellow-billed cuckoo) and the short-tailed shrew associated with exposure to copper, PAHs, and Aroclor 1254 (a polychlorinated biphenyl, or PCB) assuming conservative exposure assumptions. However, wildlife exposure to copper was largely attributable to the anomalously high concentration at CFSB-002; EPCs for PAHs were also influenced by localized stations with elevated concentrations. Similar to the Main Plant Area, it is not likely the yellow-billed cuckoo would be exposed at estimated doses due to its rarity in Montana and the absence of basic habitat requirements in the Central Landfills Area. The modeled ingestion of terrestrial invertebrate prey items was the critical exposure pathway for wildlife receptors.

ISM Grid Area: Ecological risk estimates for the ISM Grid Area (i.e., Operational Area) were similar to risk estimates for overlapping areas within the Main Plant Area and Central Landfills Area. Direct contact exposure estimates indicate moderate risk to soil invertebrates and terrestrial plants based on soil exposure to PAHs and select metals, including copper, selenium (plants only), and zinc. Several of the decision units, particularly in the central third of the ISM Grid within the Central Landfills Area, contained concentrations of constituents that exceeded LOAEL-based benchmarks protective of small range receptors. Exceedances of LOAEL-based benchmarks in these DUs were primarily associated with LMW and HMW PAH exposure to the short-tailed shrew.

Industrial Landfill Area: Risk estimates for the Industrial Landfill Area indicate the limited potential for adverse effects associated with exposure to PAHs and select metals in soil. Risk estimates for the Industrial Landfill Area indicate limited potential for adverse effects associated with direct contact exposure to soil invertebrates and terrestrial plants. Wildlife ingestion models indicate estimated doses of nickel (the American woodcock and the short-tailed shrew) and HMW PAHs (the American woodcock and the yellow-billed cuckoo) resulting in HQ_{LOAEL} values from 1 to 5 in the Industrial Landfill Area, primarily due to the modeled ingestion of terrestrial invertebrate prey items. As a result, nickel and PAHs in soil at the Industrial Landfill Area represent a moderate risk to ecological receptors due to direct contact and indirect ingestion exposure pathways.

Based on these findings, the potential for adverse effects to ecological receptors exposed to soil in localized areas of the Main Plant Area, Central Landfills Area, ISM Grid Area, and Industrial Landfill Area cannot be entirely dismissed under current conditions. Concern regarding ecological exposure is limited to small bird and mammal populations that may use modified and disturbed habitats in developed areas of the Site. However, concerns regarding exposure to receptors representing other trophic groups is reduced due to the low-quality habitat available in these areas under current, developed conditions relative to the undeveloped portions of the Site.

Transitional Exposure Areas

Transitional exposure areas were evaluated assuming both dry (terrestrial) and inundated (semi-aquatic/aquatic) conditions. The overall results of the BERA for the transitional exposure areas are presented in Table 29 of the RI Report (Table 8-2 of the BERA; terrestrial scenario) and Table 30 of the RI Report (Table 8-3 of the BERA; aquatic scenario) and are summarized below.

Exposure Areas that Do Not Pose Risks Due to Site-Related Contamination

Current conditions in the following transitional exposure areas at the Site are not likely to result in adverse ecological effects resulting from the exposure to Site-related COCs:

- Cedar Creek Reservoir Overflow Ditch; and
- Northern Surface Water Feature.

Risk estimates for the Cedar Creek Reservoir Overflow Ditch indicate minimal risks to ecological receptors under dry and inundated scenarios. During periods of inundation, direct contact risk associated with surface water and sediment in the Cedar Creek Reservoir Overflow Ditch is expected to be minimal. Some exceedances of NOECs and LOECs in sediment and surface water were noted; however, consideration of Background Threshold Values (BTVs), concentration gradients, the low magnitude and frequency of exceedances, and other factors indicate that Site-related toxicity related to these constituents is unlikely. For times of the year when inundation does not occur, direct contact risk to terrestrial organisms is expected to be negligible relative to background risk. Wildlife risks associated with direct and indirect ingestion pathways to exposure media within the Cedar Creek Reservoir Overflow Ditch were negligible. The small-range receptor evaluation indicated that a single sample in this exposure area had concentrations that exceeded only the NOAEL benchmark; however, no LOAEL-based benchmarks were exceeded. Therefore, no constituents in media associated with the Cedar Creek Reservoir Overflow Ditch are considered to be of concern for direct or indirect ingestion by wildlife receptors.

The potential for adverse effects associated with constituents in media at the Northern Surface Water Feature Area is considered minimal under both dry and inundated scenarios. During periods of inundation, direct contact exposure to COCs in surface water and sediment is expected to be limited to background exposure. During dry periods, risks to soil invertebrates and terrestrial plants are negligible. Wildlife ingestion modeling results indicated HQ_{LOAEL} values slightly exceeding 1 for barium and selenium exposure to the American dipper. However, this risk estimate is likely overestimated because inundation is seasonal and varies interannually, and likely does not support a permanent benthic invertebrate community to provide a forage base for the American dipper.

Exposure Areas that Pose Risks Due to Site-Related Contamination

Current conditions in the following transitional exposure areas at the Site have the potential to result in adverse effects to ecological receptors:

- North Percolation Pond Area; and
- South Percolation Ponds.

The key conclusions with respect to each of the above areas are presented below.

North Percolation Pond Area: Risk estimates for the North Percolation Pond Area indicate the potential for adverse effects based on exposure through direct contact and wildlife ingestion pathways. The greatest potential for adverse direct contact effects is associated with exposure to cyanide, fluoride, metals,[9] and PAHs during inundated conditions in the North-East Percolation Pond. Under dry scenarios, exposure to PAHs in soil exceeded NOEC values protective of soil invertebrates. Elevated risks associated with direct and indirect ingestion by wildlife receptors were also observed in the North Percolation Pond based on the results of the food chain modeling.

The North Percolation Ponds represent low quality habitat for terrestrial or aquatic receptors, based on their use as a former wastewater management structure. Based on the degraded habitat function and value of the North Percolation Ponds, exposure pathways may be more limited than the exposure assumptions used in direct contact and ingestion pathway evaluations. However, based on the risk estimates presented in the BERA, exposure to

9 Metals driving risk in the North Percolation Pond Area are barium, cadmium, lead, nickel, selenium, thallium, vanadium, and zinc.

waste-related COCs in multiple media in the North Percolation Ponds has the potential to adversely affect ecological receptors. Further actions should be considered to reduce or further study the elevated ecological risk at this exposure area. Further risk assessment may not be beneficial, particularly in the North-East Percolation Pond until the future uses of the North Percolation Pond Area are determined.

South Percolation Ponds: The potential for adverse effects associated with constituents in media at the South Percolation Ponds is considered minimal under dry scenarios, but moderate under inundated scenarios due to potential adverse effects associated with direct contact with cyanide, metals, and PAHs in surface water. During periods of inundation, exposure to cyanide and select metals in surface water has the greatest potential for adverse effects to temporary aquatic communities via direct contact exposure pathways. Risk associated with direct and indirect ingestion by wildlife receptors in South Percolation Pond media is minimal based on the results of the food chain modeling.

Aquatic Exposure Areas

The overall results of the BERA for the aquatic exposure areas are presented in Table 31 of the RI Report (Table 8-4 of the BERA) and are summarized in this section.

Exposure Areas that Do Not Pose Risks Due to Site-Related Contamination

The conditions in one aquatic exposure area and a portion of another do not pose significant potential for adverse ecological effects resulting from the presence of Site-related COCs. These exposure areas include:

- Flathead River (excluding the Backwater Seep Sampling Area); and
- Cedar Creek.

For the portion of the Flathead River outside of the Backwater Seep Sampling Area, risk to ecological receptors is expected to be minimal. Outside of stations within the Backwater Seep Sampling Area, total and free cyanide concentrations were below NOEC benchmarks based on National Recommended Water Quality Criteria (NRWQC) criterion continuous concentration (CCC) and MDEQ chronic criteria, respectively. Filtered aluminum concentrations were below MDEQ chronic criteria. Barium concentrations in surface water outside of the Backwater Seep Sampling Area are consistent with regional conditions. Potential risks associated with direct and incidental wildlife ingestion pathways are considered to be minimal in the Flathead River main channel.

Potential risks associated with direct contact with surface water and sediment and wildlife ingestion pathways in Cedar Creek are considered to be negligible. Direct contact EPCs are generally below NOECs, with the exception of barium. However, barium concentrations in surface water and sediment porewater are consistent from upgradient to downgradient, indicating concentrations are representative of upgradient/ background conditions. Potential exposure to wildlife foraging in Cedar Creek is not considered to exceed background exposure.

Exposure Areas that Pose Risks Due to Site-Related Contamination

Exposure conditions in two aquatic exposure areas indicate the potential for adverse ecological effects due to direct contact pathways:

- Flathead River – Backwater Seep Sampling Area; and
- Flathead River Riparian Area Channel.

The key conclusions with respect to these areas are presented below.

Flathead River – Backwater Seep Sampling Area: The evaluation of Flathead River sediment, sediment porewater, and surface water data indicate that the greatest potential for ecological exposure to Site-related constituents is associated with direct contact exposure within the Backwater Seep Sampling Area, and areas where groundwater containing cyanide and fluoride discharges to surface water. Surface water exposure was greatest to cyanide (total and free), barium, and aluminum, with greater concentrations observed in the Backwater Seep Sampling Area. Attenuation of surface water concentrations to below both chronic and acute standards occurs rapidly with increasing distance from the Backwater Seep Sampling Area, particularly during periods of elevated discharge within the Flathead River. Outside of the stations within the Backwater Seep Sampling Area and stations along the shoreline immediately downstream of the Backwater Seep Sampling Area (CFSWP-026 through CFSWP-028), total and free cyanide concentrations were typically non-detect; and did not exceed chronic NRWQC- and MDEQ Circular DEQ-7 (DEQ-7) -based benchmarks, respectively, in multiple rounds of surface water sampling events. This finding indicates the potential area of exposure to aquatic receptors at concentrations exceeding NOECs and LOECs based on MDEQ (total cyanide) and NRWQC (free cyanide) benchmarks is spatially-limited to a groundwater-surface water mixing zone along the shoreline within and immediately adjacent to the Backwater Seep Sampling Area. Potential risks associated with direct and incidental wildlife ingestion pathways are considered to be minimal in the Backwater Seep Sampling Area.

Flathead River Riparian Area Channel: The evaluation of sediment and surface water data in the Flathead River Riparian Area Channel indicate the potential for adverse effects associated with direct contact exposure of aquatic receptors to cyanide (total and free), fluoride, and metals in surface water. Surface water data indicate potential exposure to COCs may be influenced by groundwater discharge similar to the Backwater Seep Sampling Area. A temporal analysis of COC concentrations in surface water indicate the greatest chronic exposure to cyanide in the Flathead River Riparian Area Channel likely occurs during periods of elevated discharge within the Flathead River.

2.2.5 Exposure Areas Requiring Additional Evaluation

As detailed above and in Sections 7 and 8.4 of the RI Report, and summarized in Section 8.5 of the RI Report, the following exposure areas are being carried forward for evaluation of remedial alternatives in the FS:

- Main Plant Area (including the Main Plant ISM Grid Area);
- North Percolation Pond Area;
- Central Landfills Area (including the Central Landfills ISM Grid Area);
- Industrial Landfill Area;
- South Percolation Ponds;
- Backwater Seep Sampling Area and Flathead River Riparian Area Channel; and
- Groundwater (Plume Core Area).

Based on the findings of the BHHRA and BERA and as discussed in the RI Report, exposure areas not listed above generally exhibit *de minimis* risk to human health and ecological receptors and, as such, are not proposed for further evaluation in the FS. These include:

- Eastern Undeveloped Area;
- North-Central Undeveloped Area;
- Western Undeveloped Area;
- Flathead River Area (excluding the Backwater Seep Sampling Area);
- Flathead River Riparian Area (excluding the Flathead River Riparian Area Channel);
- Cedar Creek;
- Cedar Creek Reservoir Overflow Ditch; and
- Northern Surface Water Feature.

The results of the risk assessments will only remain valid if future use of the Site matches the assumptions made in the risk assessments. Therefore, certain use restrictions consistent with the risk assessments must be applied (e.g., land use restrictions in the Eastern Undeveloped Area and North-Central Undeveloped Area to commercial or industrial use, only) and enforced at exposure areas not proposed for further evaluation in the FS. These restrictions, and the areas to which they apply, will be identified and addressed within the FS as common elements that are applicable to all remedial alternatives.

2.3 Contaminants of Concern by Decision Unit

Based on the size and complexity of the Site, decision units (DUs) with common elements or conditions were established in the FSWP to evaluate and address COCs specific to an environmental media and/or area of the Site. A total of six (6) DUs were defined to encompass the exposure areas identified in Section 2.2.5 as requiring additional evaluation:

- Landfills DU1;
- Landfills DU2;
- Soil DU;
- North Percolation Pond DU;
- River Area DU; and
- Groundwater DU.

The physical description of each DU, including location and media, are detailed in the subsections below. A map showing the areal extent of each DU is provided as Figure 5.

2.3.1 Landfills DU1

The Landfills DU1 is defined as the West Landfill, the Wet Scrubber Sludge Pond, the Center Landfill, and the surficial and shallow soil (0-0.5 and 0.5-2 ft-bls, respectively), if any, within their footprints. Each of these waste management units has been identified in the RI Report as a source of groundwater contamination at the Site to varying degrees. Specifically, the Center Landfill appears to be a potentially contributing source to groundwater contamination, but to a lesser degree than the West Landfill and Wet Scrubber Sludge Pond area.

Each of these waste management units are described in Section 2.1.4.1. The nature of the wastes and status of existing caps for each waste management unit is described below:

- The West Landfill was used to dispose of SPL and other wastes and was closed and covered with an earthen cap in 1981 including a 6-inch clay layer and capped with a synthetic (hypalon) cap in 1994. The landfill cap is sloped to promote runoff. The existing cap meets substantive MDEQ Class II landfill requirements and does not need to be improved. Leaching of contaminants from the West Landfill is attributed to the presence of impacted material that likely extends into and beneath the seasonal high-water table, and also potentially via lateral subsurface migration of water through the vadose zone into the landfill or underlying impacted materials. Therefore, additional low-permeability surface cap layers would not increase the effectiveness of the existing cap. Proper maintenance of the West Landfill cap will be included within all Landfills DU1 alternatives.
- The Wet Scrubber Sludge Pond received waste material from the wet scrubbers and was capped with an earthen cap in 1981 and vegetated. There is no documentation of clay or synthetic materials within the cap layers and the cap is not properly graded to promote runoff. Due to the nature of the wastes in this landfill and the fact that the existing cap is likely inadequate in preventing infiltration of precipitation and runoff through its wastes, it is anticipated that the Wet Scrubber Sludge Pond cap would need to be improved to comply with substantive MDEQ Class II landfill requirements.
- The Center Landfill was used for disposal of SPL until it was closed in 1980 and, based on historical drawings, capped with a 6-inch clay cap and 18-inches of till. Because the Center Landfill was constructed above grade, underlying impacted material likely does not extend into the seasonal high-water table and the landfill waste is not subject to lateral subsurface migration of water. Due to the limited thickness of the clay layer, it is anticipated that improvement of the Center Landfill cap by adding a low-permeability layer would further prevent infiltration of precipitation and runoff through its wastes, and would be expected to provide compliance with substantive MDEQ Class II landfill requirements as well as adequate and reliable containment of its wastes. Monitoring data presented in the RI Report indicate that the existing cap is effective in preventing impacts to groundwater downgradient of the Center Landfill, thus complying with groundwater ARARs; enhancement of the existing cap as proposed would only further improve these conditions.

The COCs in surficial and shallow soil in the Landfills DU1 are summarized in Table 2-1 below.

Table 2-1 Summary of COCs in Surficial and Shallow Soil in the Landfills DU1

COC	Human Health Soil	Ecological Soil
Metals		
Arsenic	X	
Copper		X
Nickel		X
PAHs		
Benzo(a)anthracene	X	
Benzo(a)pyrene	X	
Benzo(b)fluoranthene	X	
Dibenz(a,h)anthracene	X	
Indeno(1,2,3-c,d)pyrene	X	

COC	Human Health	Ecological
	Soil	Soil
LMW PAHs[10]		X
HMW PAHs[11]		X

In addition, although cyanide and fluoride are not risk drivers with respect to human health or ecological exposure pathways within the Landfills DU1, it is important to recognize that these three waste management units are the sources of cyanide and fluoride in groundwater downgradient of these features.

2.3.2 Landfills DU2

The Landfills DU2 is defined as the remaining waste management units in the Central Landfills Area and Industrial Landfill Area exposure areas and the surficial and shallow soil (0-0.5 and 0.5-2 ft-bls, respectively), if any, within their footprints. This includes the East Landfill, the Industrial Landfill, the Sanitary Landfill, and the Asbestos Landfills. The results of the RI Report indicate these landfills are not contributing sources of groundwater contamination at the Site.

Each of these waste management units are described in Section 2.1.4.1. The on-site landfills are exempt from the Montana Solid Waste Act under MCA 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility. The nature of the wastes and status of existing caps for each waste management unit, if present, is described below:

- The East Landfill was used to dispose of SPL and was capped with a 6-inch thick clay layer, a synthetic membrane layer, and an 18-inch vegetated till cover in accordance with the specifications of the approved closure plan. The closure of the East Landfill and regulatory acceptance of the closure is documented in the May 14, 1992 letter from the State of Montana Department of Health and Environmental Sciences to CFAC. The existing cap is graded to promote runoff and has demonstrated adequate and reliable containment for the past 30 years; as such, the existing cap does not need to be improved. Proper maintenance of the East Landfill cap will be included within all Landfills DU2 alternatives.
- The Industrial Landfill received non-hazardous waste and debris. It is an inactive, uncovered landfill that was only partially graded after operations ceased in 2009. This landfill has depressed areas and capacity for additional waste, and may therefore be used for onsite consolidation of excavated materials from other DUs if selected. Following consolidation and grading, the Industrial Landfill will need to be capped. Due to the nature of the wastes in this landfill, it is anticipated that the cap would need to comply with substantive MDEQ Class II landfill requirements.
- The Sanitary Landfill was reportedly clay lined prior to being used for plant garbage. The landfill was then covered with clean fill and vegetated. The landfill cap is sloped away from Teakettle Mountain to promote runoff and is observed to be in good condition. The existing cap has demonstrated adequate and reliable containment for more than 30 years; as such, the existing cap does not need to be improved. Proper maintenance of the Sanitary Landfill cap will be included within all Landfills DU2 alternatives.

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10 Low molecular weight (LMW) PAHs include acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and/or 2-methylnaphthalene.

11 High molecular weight (HMW) PAHs include benzo(a)anthracene), benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and/or pyrene.

- The Asbestos Landfills were used for asbestos disposal and are overlain by a natural soil cover based on observations made during the Phase I Site Characterization field reconnaissance and test pitting activities. While a soil cover is appropriate for these wastes, the grade of the existing cover is uneven with some small depressions; it is anticipated that supplemental cover material will be needed to eliminate surface depressions and a uniform vegetated cover will be established to prevent exposure and minimize erosion.

The COCs for the Landfills DU2 are summarized in Table 2-2 below.

Table 2-2 Summary of COCs in Surficial and Shallow Soil in the Landfills DU2

COC	Human Health	Ecological
	Soil	Soil
Metals		
Arsenic	X	
Copper		X
Nickel		X
Vanadium		X
PAHs		
Benzo(a)anthracene	X	
Benzo(a)pyrene	X	
Benzo(b)fluoranthene	X	
Dibenz(a,h)anthracene	X	
Indeno(1,2,3-c,d)pyrene	X	
LMW PAHs		X
HMW PAHs		X

2.3.3 Soil DU

The Soil DU is defined as the soil within the Main Plant Area, the ISM Grid Area, and the areas surrounding the waste management units in the Central Landfills Area exposure area (including the Former Drum Storage Area). Details regarding these areas are provided in Section 2.1.4.3. Individual waste management units within the Central Landfills Area exposure area are detailed in Sections 2.3.1 and 2.3.2, and are evaluated as part of Landfills DU1 and Landfills DU2 respectively.

The COCs for the Soil DU are summarized in Table 2-3 below.

Table 2-3 Summary of COCs in the Soil DU

COC	Human Health	Ecological
	Soil	Soil
Metals		
Arsenic	X	
Copper		X
Nickel		X

COC	Human Health	Ecological
	Soil	Soil
Selenium		X
Zinc		X
PAHs		
Benzo(a)anthracene	X	
Benzo(a)pyrene	X	
Benzo(b)fluoranthene	X	
Dibenz(a,h)anthracene	X	
Indeno(1,2,3-c,d)pyrene	X	
LMW PAHs		X
HMW PAHs		X

As documented in the BHHRA and BERA, the above COCs were determined based upon evaluation of potential exposure to soil at various depth intervals (ranging from 0 to 12 ft-bls) for human health exposure scenarios and from 0 to 2 ft-bls for ecological exposure scenarios.

It is noted that in some areas COCs are present in soil at greater depths than quantitatively evaluated in the risk assessments. However, there is no potential for receptors to be exposed to the COCs at these greater depths under current or reasonable future use scenarios; therefore, the remedial alternatives will focus on soil where there is potential for exposure. Access restrictions (i.e., institutional controls; ICs) to ensure the exposure assumptions with respect to deeper soils remain valid will also be included within the remedial alternatives as needed.

In addition, although cyanide and fluoride are not risk drivers with respect to human health or ecological exposure pathways for soil, the presence of these COCs in soil was evaluated during the RI relative to their potential contributions to groundwater impacts. With the possible exception of soils in the Former Drum Storage Area, the findings indicate that cyanide and fluoride in Site soils are not the source of the observed cyanide and fluoride groundwater plumes that have been delineated at the Site. Rather, the wastes and associated contaminated soil within and beneath the West Landfill, Wet Scrubber Sludge Pond, and Center Landfill area (i.e., Landfills DU1) are the primary sources of cyanide and fluoride in groundwater at the Site.

In the Former Drum Storage Area, cyanide and fluoride were detected at elevated concentrations in surficial and shallow soil samples (0-0.5 and 0.5-2 ft-bls, respectively) but decreased by an order of magnitude with increasing depth. Based on this finding, this feature may be a contributing source to the elevated cyanide and fluoride concentrations in groundwater that appear to originate beneath this area and the adjacent West Landfill and Wet Scrubber Sludge Pond area. However, the decrease in concentrations with depth and the absence of any observed waste materials suggest any contributions from the Former Drum Storage Area to groundwater contamination are much less than the contributions from the adjacent waste management units. The top 2 feet of the Former Drum Storage Area will be further evaluated with respect to cyanide and fluoride for remedial action.

2.3.4 North Percolation Pond DU

The North Percolation Pond DU consists of the North-East Percolation Pond and its influent ditch, the North-West Percolation Pond, and the approximately 1,440-foot-long overflow ditch. The North-West Percolation Pond is enclosed by existing fence. The North-East Percolation Pond is not currently enclosed by fence, but access is limited by fence generally encompassing the portion of the Site north of the Main Plant Area. Details regarding the North Percolation Ponds are provided in Section 2.1.4.2.

The COCs for the North Percolation Pond DU are summarized in Table 2-4 below.

Table 2-4 Summary of COCs in the North Percolation Pond DU

COC	Human Health		Ecological		
	Soil	Sediment	Soil	Sediment	Surface Water
Metals					
Arsenic	X	X			
Aluminum					X
Barium			X	X	X
Cadmium				X	X
Copper					X
Lead				X	
Nickel			X	X	
Selenium			X	X	
Thallium			X		
Vanadium			X	X	
Zinc				X	X
Other Inorganics					
Fluoride					X
PAHs					
Benzo(a)anthracene	X				
Benzo(a)pyrene	X	X			
Benzo(b)fluoranthene	X	X			
Dibenz(a,h)anthracene	X	X			
Indeno(1,2,3-c,d)pyrene	X	X			
LMW PAHs			X	X	
HMW PAHs			X	X	
Multiple PAH Compounds[1]					X

[1] Multiple PAH Compounds comprised of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, and indeno(1,2,3-c,d)pyrene, as defined in the BERA.

Surface water in the North Percolation Pond DU is seasonal in nature and is the result of stormwater accumulating in the topographic depressions created to form the North Percolation Ponds as part of the Site's historical operations and management of process water. The elevated concentrations of COCs in surface water in the North Percolation Ponds can be attributed to the direct contact of stormwater with impacted surface soil and sediment in the North Percolation Ponds and/or the influent stormwater drainage pipes. These elevated concentrations of COCs in surface water can be eliminated by decommissioning the influent pipes and preventing the direct contact of standing water with impacted surface soil/sediment. The direct contact of standing water with impacted surface soil/sediment can be prevented by altering the drainage and/or topography of the area, or by removing and/or covering the impacted surface soil/sediment in the North Percolation Ponds. Since the potential risk attributed to surface water in the North Percolation Pond DU will be mitigated by appropriately decommissioning the associated anthropogenic, engineered features and by addressing the potential risk attributed to soil and sediment in the DU, surface water for the North Percolation Pond DU is not carried forward through the technology screening.

2.3.5 River Area DU

The River Area DU is defined as the soil, sediment, sediment porewater, and surface water in the South Percolation Ponds, Backwater Seep Sampling Area, and Riparian Area Channel. Details regarding these features are provided below.

The hydrogeologic studies (i.e., groundwater elevation data and surface water elevation data) performed at the Site indicate that groundwater discharges to the Flathead River. As described in Section 2.1.5, the Backwater Seep Sampling Area, the Riparian Area Channel, and the South Percolation Ponds (i.e., the River Area DU) are all located within the extent of the “Seep Area”. The “Seep Area” was defined as the area which has potential to receive groundwater expressed from the upper hydrogeologic unit to the Flathead River (see Section 2.1.4.2). See Section 2.4 for additional discussion regarding contaminant fate and transport at the Site.

The COCs for the River Area DU are summarized in Table 2-5 below.

Table 2-5 Summary of COCs in the River Area DU

COC	Ecological			
	Soil	Surface Water	Sediment	Sediment Porewater
Metals				
Aluminum		X		
Barium	X	X	X	X
Copper		X		
Iron		X		
Other Inorganics				
Cyanide, total		X	X	X
Cyanide, free		X	X	X

In each of the Site features comprising the River Area DU, cyanide (total and/or free) is an identified COC in sediment, sediment porewater, and surface water. The results of the RI indicated that groundwater discharge to the Seep Area is the primary source of the cyanide in the River Area DU. In the River Area DU, the potential risk attributed to cyanide in sediment, sediment porewater, and surface water will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Alternatives addressing groundwater inputs will be assessed within the Groundwater DU.

The presence of metals in the River Area DU, on the other hand, is not attributed to the discharge of groundwater at the Seep Area. Historically, the South Percolation Ponds received water from the sewage treatment plant, the aluminum casting contact chilling water, non-contact cooling water from the rectifier and other equipment, process wastewater from the casting mold cleaning and steam cleaning, non-process wastewater from the fabrication shop steam cleaning, and stormwater. Following completion of the facility demolition, the only waters received by the South Percolation Ponds were stormwater discharge through the influent pipe at the west end of the ponds system in addition to groundwater.

The presence of metals, especially aluminum, at elevated concentrations in the discharge water collected at the South Percolation Ponds influent pipe for MPDES permit sampling suggests that the River Area DU metal COCs are conveyed to surface water in the River Area DU via this influent pipe. These metals are not present at elevated concentrations in groundwater immediately upgradient of the Seep, further supporting this conclusion. CFAC has since decommissioned the influent pipe to eliminate the direct discharge of stormwater into the Ponds as part of the Removal Action at the South Percolation Ponds, discussed in Section 2.3.5.

Removal Action at the South Percolation Ponds

As subsequently discussed in Section 3.4.5, the South Percolation Ponds were the only feature within the River Area DU that contained sediments with COCs at concentrations exceeding PRGs. To remediate contaminated sediments contained within the South Percolation Ponds, a Removal Action at the South Percolation Ponds was performed in accordance with the requirements of the Administrative Order on Consent effective July 21, 2020, between CFAC and USEPA (CERCLA Docket No. 08-2020-0002). Under the South Percolation Ponds Removal Action, CFAC decommissioned the South Percolation Ponds, removed the top foot of sediments to satisfy ecological PRGs, and removed the dam to allow the river to reclaim the channel that occupied this area prior to construction of the dam. This work was implemented in advance of FS completion to prevent erosion and transport of contaminated sediments by the Flathead River, and was performed in accordance with the USEPA-approved Removal Work Plan (Roux, 2020c).

2.3.6 Groundwater DU

The Groundwater DU is defined as the groundwater within the extent of the upper hydrogeologic unit underlying the Site described in Section 3.2.1 of the RI Report. As described in the RI Report and Section 2.4.3 of the FSWP, Site-related groundwater impacts appear limited to groundwater within the upper hydrogeologic unit. Groundwater is retained for further evaluation in the FS because of the potential human health risks associated with the hypothetical drinking water scenario, as well as discharge of groundwater to the River Area DU resulting in potential ecological risk and exceedances of surface water ARARs, as outlined in Section 2.3.2 of the FSWP.

The COCs for groundwater within the upper hydrogeologic unit are summarized in Table 2-6 below.

Table 2-6 Summary of COCs in the Groundwater DU

COC	Human Health
	Upper Hydrogeologic Unit
Metals	
Arsenic	X
Other Inorganics	
Cyanide, total	X
Cyanide, free	X
Fluoride	X

Groundwater at the Site generally flows in a southerly direction, from the Landfills DU1 source area toward the Flathead River. Groundwater levels measured immediately downgradient of the Landfills DU1 ranges from approximately 36 ft-bls during high-water season to approximately 105 ft-bls during low-water season. Immediately downgradient of the Landfills DU1, COC concentrations in groundwater typically range from approximately 2,060 ug/L to 11,500 ug/L for total cyanide, approximately 4,110 ug/L to 55,300 ug/L for fluoride, and a maximum of approximately 92 ug/L for arsenic. Iso-concentrations maps of total cyanide concentrations and fluoride concentrations in groundwater during all six rounds are shown on Plates 13 and 15 of the Phase II SC Data Summary Report (Roux, 2019), respectively.

As documented in the RI and published literature, the cyanide in groundwater at aluminum smelter sites is found primarily as an iron cyanide complex (e.g., ferrocyanide); sampling at the Site has confirmed that free cyanide typically comprises less than ten percent of the total cyanide concentration in groundwater. Iron cyanide complexes and free cyanide are mobile in groundwater under neutral to alkaline conditions and in soils with low clay content (such as the soils that comprise the upper hydrogeologic unit beneath the Site). Groundwater in the vicinity of Landfills DU1 has been observed to be highly alkaline with pH greater than 9.

2.4 Summary of Contaminant Fate and Transport

An evaluation of the fate and transport of COCs at the Site was conducted based upon knowledge of the Site physical characteristics, the concentrations and extent of COCs in various media, and source area characteristics. The evaluation considered the physicochemical characteristics of the COCs and various physical, chemical, and biological processes that influence contaminant fate and transport. The fate and transport analysis focused on contaminants that were identified as primary COCs through the risk assessment process, as described in Section 7 of the RI Report and Section 2.3 of this FS Report. A summary of the fate and transport evaluation is provided below.

2.4.1 Migration of COCs from Source Areas

The results of the RI indicate that groundwater is the primary migration pathway for the potential transport of COCs from the various source areas. In addition, results indicate that cyanide and fluoride are the primary COCs from a contaminant migration/fate and transport perspective. All other primary COCs identified in soil, sediment, or surface water samples within the source areas appear to be stable and not migrating at levels of concern based upon risk assessment results.

The six rounds of groundwater sampling conducted during the RI indicate that the West Landfill and Wet Scrubber Sludge Pond area appears to be the primary source of the cyanide and fluoride in groundwater. The Center Landfill and Former Drum Storage Area appear to be potentially contributing sources, but to a lesser degree than the West Landfill and Wet Scrubber Sludge Pond area. In the Former Drum Storage Area, the top 2 feet of the area have elevated concentrations of cyanide that are adjacent to the plume, and as such are further evaluated for remedial action in this FS. However, the decrease in concentrations with depth and the absence of any observed waste materials suggest any contributions from this area to groundwater contamination are much less than the contributions from the adjacent aforementioned areas.

A consistent pattern was observed during all six rounds of groundwater sampling; cyanide and fluoride migrates in a south/south-westerly direction from the aforementioned landfills toward the Flathead River. Total cyanide and fluoride concentrations in groundwater within the upper hydrogeologic unit decrease with increasing distance away from the landfills. Cyanide and fluoride concentrations measured in monitoring wells outside of the contours shown on Plate 18 and Plate 19 are less than one-half of the USEPA maximum contaminant levels (MCLs; USEPA, 2019b) in all six rounds of sampling. Cyanide concentrations are typically non-detect in the north, west, and south-west portions of the Site (e.g., near Aluminum City) during all rounds of sampling. These data, as well as the six rounds of groundwater flow data, indicate that migration of the cyanide and fluoride is not in the direction towards Aluminum City, but rather follows the southerly groundwater flow patterns towards the Flathead River. The findings also indicate that there is limited vertical migration and cyanide and fluoride are primarily migrating horizontally within the upper hydrogeologic unit.

The hydrogeologic studies (i.e., groundwater elevation data and surface water elevation data) indicate that groundwater discharges to the Flathead River. The Backwater Seep Sampling Area, the Riparian Sampling Area, and the South Percolation Pond Area are all located within the extent of the “Seep Area” where groundwater is expressed from the upper hydrogeologic unit to the Flathead River. Elevated concentrations of cyanide in sediment and sediment porewater are present in the Backwater Seep Sampling Area and Riparian Sampling Area. Elevated concentrations of fluoride in sediment porewater are present in the Backwater Seep Sampling Area, Riparian Sampling Area, and South Percolation Ponds; though fluoride was not detected at elevated concentrations in sediment in these features. These concentrations, along with the groundwater flow, indicate the groundwater is the primary source of the cyanide and fluoride concentrations in surface water, sediment, and sediment porewater measured in these areas. Concentrations of cyanide in surface water, sediment, and sediment porewater up-river in the Flathead River were typically non-detect, further supporting that groundwater discharge is the primary source of the cyanide in the sediment and surface water of the Backwater Seep Sampling Area and Riparian Sampling Area. In addition, direct discharges into the South Percolation Ponds could have contributed to surface water and sediment impacts in this area.

All surface water, sediment, and sediment porewater samples collected within the main stem of the Flathead River downgradient of the Backwater Seep Sampling Area, Riparian Sampling Area, and South Percolation Ponds during all six rounds of sampling were generally non-detect for total cyanide. Fluoride was generally detected in surface water and sediment samples collected within the main stem of the Flathead River downgradient of these areas, but at concentrations below screening levels; fluoride was typically not detected in sediment porewater samples. These findings confirmed that the elevated levels of cyanide and fluoride found in groundwater and in the Backwater Seep Sampling Area, Riparian Sampling Area, and the South

Percolation Pond, are not measurably impacting surface water, sediment, or sediment porewater quality within the main channel of the Flathead River.

2.4.2 Physicochemical Processes Affecting Migration of COCs in Site Media

The fate and transport of Site-related constituents released into the environment depends on the physicochemical properties and processes of the constituent and environmental media, and the physical characteristics of the migration pathway. Section 6.3 of the RI Report provides brief descriptions of the key properties and processes (i.e., leaching, advection and dispersion, diffusion, precipitation/dissolution, partitioning and adsorption, biological degradation and transformation, dilution, photolysis, and volatilization), and their effect on transport processes. The primary physicochemical process contributing to groundwater contamination (i.e., leaching) is described below.

Leaching

Leaching can occur when soils or waste contact either precipitation (i.e., rainwater) or groundwater, resulting in a liquid known as leachate. Leachate can move downward from a source into the water table and cause groundwater contamination. Leaching is the primary process responsible for the mobilization of cyanide and fluoride from wastes within West Landfill and Wet Scrubber Sludge Pond into the underlying groundwater. Rates of leaching of contaminants from soil or waste into groundwater depends on the solubility of the chemical, the tightness of binding of the chemical to soil, the amount of water the soil-bound chemical comes in contact with, and the chemical characteristics of the soil and recharging water.

Although the West Landfill was covered with a clay and synthetic membrane layer in 1994 to prevent infiltration of precipitation, the Wet Scrubber Sludge Pond was covered with only an earthen cap. However, the persistence of high concentrations of cyanide and fluoride in groundwater immediately downgradient of these landfills indicates that leaching of contaminants from wastes or highly impacted soils beneath these two landfills is ongoing.

In addition, groundwater in the vicinity of the landfills has been observed to be slightly to highly alkaline, with several wells exhibiting pH greater than 9. In general, Dzombak (2005) noted that the mobility of iron-cyanide complexes and free cyanide increases under alkaline conditions and soils with low clay content (such as the soils that comprise the upper hydrogeologic unit beneath the Site). Fluoride mobility in soil is also increased under alkaline conditions because the dissolution rate of fluoride minerals and salts is increased (Yadav, et al., 2018).

2.4.3 Cyanide and Fluoride Flux

Results of subsurface characterization and analytical laboratory testing were utilized to estimate the mass flux of cyanide and fluoride in the affected media (i.e., upper hydrogeologic unit groundwater) in Section 6.4.3 of the RI Report. Contaminant mass flux is the mass of contaminant per unit time (e.g., milligrams per day) that passes across a specific cross-sectional area within a groundwater contaminant plume. Mathematically, contaminant mass flux is the product of the contaminant concentration in groundwater and the groundwater discharge rate. Thus, contaminant mass flux (J) can be calculated as follows:

$$J = q_0 \cdot C$$

where

q_0 = groundwater discharge (ft^3/day), which is dependent on the width of the sub-transect and saturated thickness of the aquifer in the vicinity of the sub-transect, as well as the specific discharge (i.e., Darcy velocity)

C = contaminant concentration (mg/ft^3), which is a representative contaminant concentration selected for each sub-transect.

The purpose of the assessment was to evaluate general areas of the Site to determine how the mass flux of cyanide and fluoride varies across the Site. This information, in conjunction with other Site data, was used to identify which areas are contributing COCs and which areas should be of primary focus when evaluating potential remedial alternatives in the FS.

The results of the flux evaluation indicated that the mass flux of cyanide and fluoride are highest immediately downgradient of the landfills, which is consistent with the understanding that the landfills are the primary source of cyanide and fluoride in groundwater. Contaminant flux decreases with increasing distance from the landfills. Cyanide and fluoride flux continue to decrease with increasing distance from the source area toward Flathead River, indicating that there are no significant sources of cyanide or fluoride downgradient of the landfills.

3. Remedial Objectives and Evaluation Criteria

Based upon the review of available data, Site physical characteristics and hydrogeology, and results of the BHHRA and BERA, remedial objectives and evaluation criteria were developed for the Site. These include applicable or relevant and appropriate requirements (ARARs), Remedial Action Objectives (RAOs), and Preliminary Remediation Goals (PRGs) as presented in this section.

3.1 Applicable or Relevant and Appropriate Requirements

This section identifies ARARs and other guidance and criteria “to be considered” (TBC) for the Site. An ARAR is defined as a legally applicable or relevant and appropriate standard, requirement, criterion, or limitation under federal environmental law, or promulgated under state environmental or facility siting law that is more stringent than the federal law. “Applicable” requirements are established cleanup standards, control requirements, or other environmental protection requirements promulgated under federal or state law that specifically address a situation encountered at the Site. “Relevant and appropriate” requirements are those federal or state requirements that, while not legally “applicable” to the Site, address situations sufficiently similar to those encountered at the Site. CERCLA Section 121(d) requires that remedial actions either comply with, or have been granted a waiver from, an ARAR. TBCs are agency advisories, criteria, or guidance to be considered where ARARs do not exist. By definitions, TBCs are neither promulgated nor enforceable, and as such as not required as cleanup standards.

ARARs are divided into three categories: chemical-specific, action-specific, and location-specific standards as described below.

- **Chemical-Specific ARARs** are typically health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, are expressed as numerical values. The values represent cleanup standards (i.e., the acceptable concentration of a chemical at the site).
- **Action-Specific ARARs** are generally technology- or activity-based requirements or limitations on actions or conditions taken with respect to hazardous substances on the site. Action-specific ARARs do not typically determine the remedial alternative; however, the ARARs indicate how a selected alternative must be implemented or achieved.
- **Location-Specific ARARs** are restrictions on the concentrations of hazardous substances or the conduct of activities in special locations.

Preliminary ARARs have been identified by USEPA in consultation with MDEQ and are documented in Table 3-1 detailing:

- The chemical / location / action subject to requirement;
- The requirement(s);
- The prerequisite (i.e., why the requirement is important); and
- The citation(s).

This table presents a broad range of ARARs that may be applicable or relevant and appropriate for any of the remedial action alternatives assembled and evaluated within this FS. The ARARs will be further refined in the Record of Decision (ROD) upon final selection of the remedy.

In addition to the ARARs, the work performed within the RI/FS has been and will continue to be completed in general accordance with the National Contingency Plan (40 Code of Federal Regulations (CFR) Part 300).

3.1.1 ARAR Waivers

Section 121(d)(4) of CERCLA identifies six circumstances under which ARARs may be waived:

- **Interim Measure** – The remedial action selected is only a part of a total remedial action (interim remedy) and the final remedy will attain the ARAR upon its completion.
- **Greater Risk to Health and the Environment** – Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- **Technical Impracticability** – Compliance with the ARAR is technically impracticable from an engineering perspective.
- **Equivalent Standard of Performance** – An alternative remedial action will attain an equivalent standard of performance through the use of another method or approach.
- **Inconsistent Application of State Requirements** – The ARAR is a State requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.

The sixth circumstance applies only to §104 Superfund-financed remedial actions, and states that an ARAR may be waived if compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

3.2 Remedial Action Objectives

RAOs are qualitative statements that describe what a remedial action is intended to accomplish at a Site. RAOs can be specific to certain COCs, environmental media, and the exposure pathways and receptors to be protected. RAOs can take into consideration both current and future land use, as well as groundwater and surface water beneficial use designations.

Based upon the results of the BHHRA and BERA, preliminary RAOs (PRAOs) were identified in collaboration with USEPA and MDEQ and presented in the FSWP. Since then, legal review of the PRAOs by USEPA and MDEQ has determined the final RAOs as presented below. These RAOs are based upon reasonable anticipated future use of each exposure area as outlined in the BHHRA, and reiterated in Section 2.2.1 herein. The approach for developing and applying the PRGs referenced below is discussed in Section 3.3.

Solid Media

- Prevent ingestion, direct contact, and inhalation of contaminated soils and sediments that would result in unacceptable risk [cancer risk of 1E-05 or a target hazard quotient (HQ) of 1 or greater] from PAHs[1] assuming reasonably anticipated future land uses.

  [1] Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

- Reduce migration of arsenic, cyanide, and fluoride from contaminated soils and wastes that results in exceedances of Montana DEQ-7 standards in groundwater.
- Reduce migration of metals[2], cyanide, fluoride, and PAHs[3] from contaminated soils, sediments, and wastes that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater.

  [2] Aluminum, arsenic, barium, cadmium, copper, iron, lead, mercury, thallium, and zinc
  [3] Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, and indeno(1,2,3-C,D)pyrene

- Reduce ingestion of and direct contact with metals[4] and LMW/HMW PAHs from contaminated surficial and shallow soils that would result in LOEC- or LOAEL-based HQs greater than 1 for terrestrial and transitional ecological receptors.

  4 Barium, copper, nickel, selenium, thallium, vanadium, and zinc

- Reduce ingestion of and direct contact with metals[5], cyanide, and LMW/HMW PAHs from contaminated surficial and shallow soils and sediments that would result in LOEC- or LOAEL-based HQs greater than 1 for aquatic and semi-aquatic ecological receptors.

  5 Barium, cadmium, lead, nickel, selenium, vanadium, and zinc

Groundwater

- Reduce cyanide, fluoride, and arsenic concentrations in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards, prevent further degradation of groundwater that exceeds Montana DEQ-7 standards (i.e., ensure no actions are taken that could increase concentrations of COCs within the contaminant plume), and prevent expansion of the contaminant plume into groundwater that meets Montana DEQ-7 standards.

- Prevent ingestion of or direct contact with groundwater contaminated with arsenic, cyanide, and fluoride in excess of Montana DEQ-7 standards.

- Reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater.

Surface Water

- Restore metals[6], cyanide, fluoride, and PAH[7] concentrations in River Area DU surface water to the aquatic life criteria identified in Montana DEQ-7 as applied to State of Montana B-1 class waters.

  6 Aluminum, arsenic, barium, copper, iron, lead, mercury, and thallium

  7 Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene

3.3 Preliminary Remediation Goals

PRGs are target concentrations to be used in the development, evaluation, and selection of remedial alternatives. Ideally, a remedy that achieves PRGs will both comply with ARARs and reduce risk to levels that satisfy the NCP requirements for protection of public health and the environment (USEPA, 1991a). Using the exposure assumptions from the BHHRA and BERA, PRGs were developed in the FSWP to be protective of the most sensitive receptor in a given exposure area based on the current and likely future use of that exposure area. In general, human health PRGs are risk-based values such that, if not achieved, a cancer risk of 1E-05 or a target HQ of 1 or greater would result. Similarly, ecological PRGs are risk-based values such that, if not achieved, a lowest observed effect concentration (LOEC) or lowest observed adverse effect level (LOAEL) -based HQ greater than 1 would result for ecological receptors. In addition, chemical-specific ARARs were also identified as PRGs where appropriate (i.e., groundwater, surface water, and sediment porewater). The USEPA-approved PRGs as presented in the FSWP are provided by DU in Sections 3.3.1 through 3.3.6 below.

For the application of human health PRGs, consideration of potential receptors and exposure scenarios will be based on current and reasonably anticipated future use (e.g., industrial, commercial, residential) and activities (e.g., intermittent inspections versus full time commercial/industrial work) within human health exposure areas. For the application of ecological PRGs, consideration of potential receptor groups will be based on the availability of ecological habitats under current and reasonably anticipated future land use. The application of ecological PRGs within exposure areas will also consider the size of the home (foraging) range of the most sensitive wildlife receptor used as the basis for an ecological PRG, including small home range receptors. Ecological PRGs for small home range receptors will be applied on a point-by-point basis to understand the frequency and distribution of exceedances to evaluate the need for remedial action.

As discussed in the technical memorandums for PRG Development (Appendices A and B of the FSWP), the calculated, Site-specific, risk-based PRGs for COCs in soil/sediment should not be regarded as not-to-exceed values. Rather, based on the conservative assumptions and endpoints used in calculations, the calculated, Site-specific PRGs for COCs in soil/sediment represent a conservative estimate of the average concentration that receptors could be exposed to that would be expected to result in minimal risk. As such, they need not be applied on a point-by-point basis and will instead by applied by the exposure point concentration (EPC) method. Using the EPC method, attainment of human health and ecological PRGs will generally be based on achieving EPCs calculated as the 95 percent upper confidence limit of the mean concentration ($95UCL_{mean}$) that are equal to or less than human health or ecological PRGs within the respective exposure areas. This scenario may result (and often does) in constituents remaining in place within some limited areas at concentrations that exceed the calculated PRG. The exposure area as a whole, however, would achieve protection of human health (i.e., cancer risk less than 1E-05, target HQ less than 1) and the environment (i.e., LOEC- and LOAEL-based HQ less than or equal to 1).

The EPC method described above for soil/sediment is not applicable for ARARs-based standards which will be considered "not-to-exceed" PRG values, excluding statutorily allowable exceedances, and will be applied on a point-by-point basis. At this Site, groundwater and surface water PRGs are predominantly based on ARARs. In addition, PRGs based on BTVs and PRGs for small home range receptors will be applied on a point-by-point basis to understand the frequency and distribution of exceedances to evaluate the need for remedial action and will not be compared to $95UCL_{mean}$ EPCs. At this Site, the EPC method for calculated, Site-specific PRGs pertain to risk-based PRGs (i.e., excluding PRGs based on BTVs and PRGs for small home range receptors) for soil and sediment, for which ARARs do not exist.

Thematic maps displaying COC concentrations exceeding human health and ecological PRGs are provided in Appendices C through I of the FSWP and were considered in the development of the remedial approach; however, as discussed above, risk-based PRGs should not be regarded as not-to-exceed values and as such exceedances of the PRG alone do not determine whether an area requires remediation. As further discussed in Section 3.3.3, consideration of small range receptors was found to drive the remedial approach and thematic maps displaying COC concentrations exceeding small range receptor PRGs are provided in Appendix B.

3.3.1 Landfills DU1

The COCs in surficial and shallow soil in the Landfills DU1 and their corresponding PRGs are summarized in Table 3-2 below. Thematic maps (i.e., color-coded dot maps) that facilitate the identification of locations where the analyte was detected and where the analyte concentrations exceed the PRGs were presented in Appendices C and F of the FSWP.

Table 3-2 Applicable PRGs for COCs in Surficial and Shallow Soil in the Landfills DU1

COC	Applicable Soil PRG
Metals	
Nickel	140
PAHs	
HMW PAHs	69

All concentrations are in milligrams per kilogram (mg/kg)

Within the Landfills DU1, exceedances of PRGs for COCs in surficial and shallow soil exist within the footprint of the Wet Scrubber Sludge Pond. As further discussed in Section 5.1 below, except for the No Action Alternative, all alternatives for the Landfills DU1 involve either capping or removing the Wet Scrubber Sludge Pond, which would address the potential risk attributed to surficial and shallow soil in the Landfills DU1.

In addition, the COCs in the Landfills DU1 that are impacting groundwater at the Site are summarized in the Table 3-3 below.

Table 3-3 Summary of COCs Impacting Groundwater in the Landfills DU1

COC	Impact to Groundwater
Other Inorganics	
Cyanide, total	X
Cyanide, free	X
Fluoride	X

3.3.2 Landfills DU2

The COCs in surficial and shallow soil in the Landfills DU2 and their corresponding PRGs are summarized in Table 3-4 below. Thematic maps that facilitate the identification of locations where the analyte was detected and where the analyte concentrations exceed the PRGs were presented in Appendices C and F of the FSWP.

Table 3-4 Applicable PRGs for COCs in Surficial and Shallow Soil in the Landfills DU2

COC	Applicable Soil PRG	
	Central Landfills Area	Industrial Landfill Area
Metals		
Nickel	140	140
Vanadium		80
PAHs		
Benzo(a)pyrene	28	28
HMW PAHs	69	69

All concentrations are in milligrams per kilogram (mg/kg)

Exceedances of PRGs for COCs in surficial and shallow soil in the Landfills DU2 are limited to the footprint of the Industrial Landfill. As further discussed in Section 5.2 below, except for the No Action Alternative, all alternatives for the Landfills DU2 involve capping the Industrial Landfill which would address the potential risk attributed to surficial and shallow soil in the Landfills DU2.

3.3.3 Soil DU

The COCs for the Soil DU and their corresponding PRGs are summarized in Table 3-5 below. Thematic maps that facilitate the identification of locations where the analyte was detected and where the analyte concentrations exceed the PRGs were presented in Appendices C and F of the FSWP. Exceedances of PRGs in soil samples by exposure area were presented in Table 4-9 of the FSWP. As described in Section 2.3.3 above, the exposure areas comprising the Soil DU are the Main Plant Area, the Central Landfills Area (excluding the waste management units and the soil within their footprints), and the ISM Grid Area.

Table 3-5 Applicable PRGs for COCs in the Soil DU

COC	Human Health	Ecological	Applicable Soil PRG	
			Main Plant Area†	Central Landfills Area†
Metals				
Copper		X		490
Nickel		X		140
Selenium		X	3.4 (*ISM*)	

COC	Human Health	Ecological	Applicable Soil PRG	
			Main Plant Area†	Central Landfills Area†
Zinc		X	810 (*ISM*)	
PAHs				
Benzo(a)anthracene	X		280	280
Benzo(a)pyrene	X		20	28
Benzo(b)fluoranthene	X		280	280
Dibenz(a,h)anthracene	X		28	28
Indeno(1,2,3-c,d)pyrene	X		280	280
LMW PAHs		X	175	175
HMW PAHs		X	69	69

All concentrations are in milligrams per kilogram (mg/kg)
† Except nickel, COCs and PRGs applicable to the Main Plant Area or Central Landfills Area also apply to the ISM Grid Area.
ISM: COC and PRG applies to the ISM Grid Area, only.

Small range receptors were also considered in the BERA and included the meadow vole and the short-tailed shrew, which have home ranges of 0.13 acre and 1 acre, respectively. Both small range receptors are burrowing species and, as such, their exposure pathways were based on depth-weighted average concentrations of surficial and shallow soil samples (0-0.5 and 0.5-2 ft-bls, respectively) to provide a representative EPC for each soil sample location. Depth-weighted average concentrations for the 0 to 2 ft-bls sampling intervals were calculated by weighting the surficial sample by 0.25 and the shallow sample by 0.75 in proportion to the depths of each sample, as described in Section 5.3.3.3 of the BERA. Soil COCs for small range receptors apply to exposure areas as presented in Table 1 of Appendix B in the FSWP. These applicable COCs and their respective PRGs as presented in Tables A-5 and A-6 of Appendix B in the FSWP are summarized in Table 3-6 below.

Table 3-6 Applicable Small Range Receptor PRGs for COCs in the Soil DU

COC	Meadow Vole	Short-tailed Shrew	Applicable Ecological Exposure Area		
			Main Plant Area	ISM Grid Area	Central Landfills Area
Metals					
Copper	33,300	1,170			X

COC	Meadow Vole	Short-tailed Shrew	Applicable Ecological Exposure Area		
			Main Plant Area	ISM Grid Area	Central Landfills Area
Nickel	3,700	140			X
PAHs					
LMW PAHs	177,000	871			X
HMW PAHs	1,890	110	X	X	X

All concentrations are in milligrams per kilogram (mg/kg)

For each applicable COC, the protective PRG for the short-tailed shrew is a lower concentration than that for the meadow vole, and as such the small range receptor PRGs for each applicable exposure area utilize the protective PRGs for the short-tailed shrew. As discussed above, ecological PRGs for small range receptors will be applied on a point-by-point basis to understand the frequency and distribution of exceedances to evaluate the need for remedial action. Thematic maps displaying COC concentrations exceeding small range receptor PRGs are presented in Appendix B. Exceedances of small range receptor PRGs soil samples are presented by exposure area in Table 3-7 below.

Table 3-7 Exceedances of Small Range Receptor PRGs by Exposure Area

Ecological Exposure Area	Sample ID	Copper	Nickel	HMW PAHs
ISM Grid Area	CFISS-003	--	--	556.50
	CFISS-005	--	--	238.13
	CFISS-012	--	--	159.33
	CFISS-013	--	--	1,768.5
	CFISS-020	--	--	114.18
	CFISS-034	--	--	211.17
Main Plant Area	CFSB-040	--	--	406.50
	CFSB-042	--	--	112.48
	CFSB-044	--	--	324.33
Central Landfills Area	CFSB-002	1,840.50	--	--
	CFSB-004	--	--	159.06
	CFLP-009*	--	403.73	20.16
	CFLP-012*	--	212.60	--

All concentrations are in milligrams per kilogram (mg/kg). As discussed above, all concentrations are depth-weighted averages for the 0 to 2 ft-bls sampling interval for each soil sample location.

* Sample is outside the footprint of the Soil DU; CFLP-009 and CFLP-012 are within the footprint of the Wet Scrubber Sludge Pond and subsequently with the Landfills DU1.

-- Depth-weighted average for the 0 to 2 ft-bls sampling interval at this soil sample location does not exceedance this PRG.

Of the Soil DU COCs, PAHs constitute the majority of the PRG and small range receptor PRG exceedances as displayed on the thematic maps provided in Appendices C and F of the FSWP and Appendix B of this FS Report. In general, there are several localized areas where PAHs exceed their PRGs, most located within the area directly north of former Main Plant Building and south of the Wet Scrubber Sludge Pond. For each metal COC, there are only a few sample locations that exceed its PRG. Therefore, the remedial alternative for the Soil DU will primarily need to be effective in treatment of PAHs, as metals could, if necessary, be treated as isolated hotspots.

In addition, as discussed in Section 2.3.3 above, cyanide and fluoride were detected at elevated concentrations in surficial and shallow soil samples (0-0.5 and 0.5-2 ft-bls, respectively) in the Former Drum Storage Area and may be a contributing source to the elevated cyanide and fluoride concentrations in groundwater. Therefore, the top 2 feet of soil within the Former Drum Storage Area will be further evaluated with respect to cyanide and fluoride for remedial action.

For each Soil DU COC with one or more PRG exceedance in an applicable exposure area, the calculated $95UCL_{mean}$ value for the respective exposure area was compared to the PRG. $95UCL_{mean}$ values for human health and ecological COCs were calculated in the risk assessments and can be found in Appendix F of the BHHRA and Appendix I of the BERA, respectively. The calculated $95UCL_{mean}$ values for these COCs are shown in Tables 3-8 and 3-9 below.

$95UCL_{mean}$ values were not calculated for ecological ISM Grid Area COCs in the BERA; calculation of these values as presented in Table 3-9 below follows the methodology used in the BHHRA to calculate $95UCL_{mean}$ values for ISM Grid Area human health COCs. The calculations were performed using the most recent version of USEPA's ProUCL software, version 5.1.002 (5.1) and in accordance with the ProUCL guidance document (USEPA, 2015). Supporting documentation generated from ProUCL for these calculations are included in Appendix C.

Table 3-8 Calculated $95UCL_{mean}$ Values for Human Health COCs in the Soil DU

COC	Main Plant Area	ISM Grid Area				Central Landfills Area	
		Main Plant Area		Central Landfills Area			
	0 - 0.5	0 - 0.5	0 - 2	0 - 0.5	0 - 2	0 - 0.5	0 - 2
PAHs							
Benzo(a)anthracene	NE	NE	NE	NE	NE	NE	NE
Benzo(a)pyrene	13.98	**85.42**	**37.29**	24.71	**41.52**	10.57	8.55
Benzo(b)fluoranthene	NE	NE	NE	NE	NE	NE	NE
Dibenz(a,h)anthracene	NE	NE	NE	NE	11.85	NE	NE
Indeno(1,2,3-c,d)pyrene	NE	NE	NE	NE	NE	NE	NE

All concentrations are in milligrams per kilogram (mg/kg)
NA No applicable PRG for this exposure area
NE Maximum sample concentration in this exposure area does not exceed the applicable PRG; therefore the $95UCL_{mean}$ was not calculated.
Bold values exceed applicable PRG.

Table 3-9 Calculated 95UCL$_{mean}$ Values for Ecological COCs in the Soil DU

COC	Main Plant Area		ISM Grid Area		Central Landfills Area	
	0 - 0.5	0 - 2	0 - 0.5	0 - 2	0 - 0.5	0 - 2
Metals						
Copper	NA	NA	225.8	140.8	**720.9**	192.9
Nickel	NA	NA	NA	NA	23.52	60.08
Selenium	NA	NA	2.700	1.906	NA	NA
Zinc	NA	NA	426.3	174.9	NA	NA
PAHs						
LMW PAHs	39.85	18.25	167.6	**323.8**	54.00	57.47
HMW PAHs	**124.4**	51.46	**248.6**	**472.5**	**87.22**	**75.39**

All concentrations are in milligrams per kilogram (mg/kg)
NA PRG not applicable to this exposure area
Bold values exceed applicable PRG.

The calculated 95UCL$_{mean}$ values for the Soil DU COCs shown in Tables 3-8 and 3-9 above indicate that copper in the Central Landfills Area and HMW PAHs (which includes benzo(a)pyrene) in the Main Plant Area, Central Landfills Area, and ISM Grid Area will need to be addressed in remedial action alternatives evaluated in this FS Report.

Areas of Concern (AOCs)

Since the application of ecological PRGs for small range receptors is on a point-by-point basis, the AOCs within the Soil DU have been drawn to encompass each exceedance of small range receptor PRGs (see Appendix B). By addressing all exceedances of small range receptor PRGs, recalculated 95UCL$_{mean}$ values for applicable COCs and exposure areas would achieve PRGs for each COC in the Soil DU except for HMW PAHs in the ISM Grid Area (0-0.5) ecological exposure area and benzo(a)pyrene in the ISM Grid Area (Main Plant Area 0-0.5) human health exposure area. These recalculated 95UCL$_{mean}$ values are shown in Table 3-10 below. Supporting documentation generated from ProUCL are included in Appendix C.

Table 3-10 Recalculated 95UCL$_{mean}$ Values for COCs in the Soil DU

COC	Exposure Area	95UCL$_{mean}$
Human Health		
Benzo(a)pyrene	ISM Grid Area (Main Plant Area 0-0.5)	**43.5**
Benzo(a)pyrene	ISM Grid Area (Main Plant Area 0-2)	13.26
Benzo(a)pyrene	ISM Grid Area (Central Landfills Area 0-2)	13.02
Ecological		
Copper	Central Landfills Area (0-0.5)	16.65
LMW PAHs	ISM Grid Area (0-2)	13.49
HMW PAHs	Main Plant Area (0-0.5)	60.00
HMW PAHs	ISM Grid Area (0-0.5)	**105.4**

COC	Exposure Area	$95UCL_{mean}$
HMW PAHs	ISM Grid Area (0-2)	41.97
HMW PAHs	Central Landfills Area (0-0.5)	11.91
HMW PAHs	Central Landfills Area (0-2)	5.213

All concentrations are in milligrams per kilogram (mg/kg)
Bold values exceed applicable PRG.

In order to adequately address HMW PAHs in the ISM Grid Area (0-0.5) ecological exposure area and benzo(a)pyrene in the ISM Grid Area (Main Plant Area 0-0.5) human health exposure area, the AOCs have been drawn to encompass an additional soil sample location with an elevated concentration of benzo(a)pyrene in surficial soil (CFISS-033). By removing this sample, the recalculated $95UCL_{mean}$ for HMW PAHs in the ISM Grid Area (0-0.5) ecological exposure area is 66.38 mg/kg, which is less than the applicable PRG of 69 mg/kg. For the benzo(a)pyrene recalculation, however, removing sample location CFISS-033 reduces the number of samples for the ISM Grid Area (Main Plant Area 0-0.5) human health exposure area below ten – the minimum recommended sample size per the ProUCL guidance (USEPA, 2015). Therefore, the $95UCL_{mean}$ for benzo(a)pyrene was recalculated for all remaining samples in the entire ISM Grid Area (0-0.5).The recalculated $95UCL_{mean}$ for benzo(a)pyrene in the ISM Grid Area (0-0.5) is 11.9 mg/kg, which is less than the applicable PRG of 20 mg/kg. Supporting documentation generated from ProUCL is included in Appendix C.

The $95UCL_{mean}$ calculations presented above conclude that if the AOCs are remediated to address all exceedances of small range receptor PRGs as well as sample location CFISS-033, the Soil DU would achieve all applicable PRGs. In addition, the Former Drum Storage Area is an AOC with respective to cyanide and fluoride in the top 2 feet of soil. In summary, the following AOCs have been drawn to address COCs in surficial and shallow soil in the Soil DU:

- AOC A to address copper;
- AOC B (Former Drum Storage Area) to address cyanide and fluoride;
- AOC C through G to address HMW PAHs, including benzo(a)pyrene.

The AOCs as described herein are presented on Figure G1 of Appendix G.

The exact extents of the AOCs will be further delineated during the remedial design. Unless the delineation indicates that the small range receptor PRG exceedances are more widespread than currently understood, the remedial action alternatives evaluated in this FS Report would address all exceedances of small range receptor PRGs in addition to impacted soil resulting in exceedances of protective soil PRGs for both human health and ecological receptors.

3.3.4 North Percolation Pond DU

The COCs for the North Percolation Pond DU and their corresponding PRGs are summarized in Table 3-11 below. Thematic maps that facilitate the identification of locations where the analyte was detected and where the analyte concentrations exceed the PRGs were presented in Appendices C, D, F, G, and H of the FSWP. There are no releases from the North Percolation Pond DU to surface waters. In addition, based on data and analysis presented in the RI Report, the North Percolation Pond DU is not a current source of groundwater contamination at the Site.

Table 3-11 Applicable PRGs for COCs in the North Percolation Pond DU

COC	Applicable PRG			
	Soil	Sediment	Surface Water‡	
			Chronic	Acute
Metals†				
Arsenic	200	200		
Aluminum			87	750
Barium	1,000	300	220	2,000
Cadmium*		4.9	0.45	0.96
Copper*			5.16	7.29
Lead		120		
Nickel	140	48		
Selenium	3.4	1.38		
Thallium	0.5			
Vanadium	80	38		
Zinc*		450	66.6	66.6
Other Inorganics				
Cyanide, total		NA		
Fluoride			NA	NA
PAHs				
Benzo(a)anthracene	1,400		2.23	9.25
Benzo(a)pyrene	140	140	0.96	3.98
Benzo(b)fluoranthene	1,400	1,400	0.68	2.81
Benzo(g,h,i)perylene			0.44	1.82
Chrysene			2.04	8.49
Dibenz(a,h)anthracene	140	140		
Fluoranthene			7.11	29.5
Indeno(1,2,3-c,d)pyrene	1,400	1,400	0.28	1.14
LMW PAHs	175	196		
HMW PAHs	69	28.2		

All soil/sediment concentrations are in milligrams per kilogram (mg/kg).
All surface water concentrations are in micrograms per liter (µg/L).
NA:Parameter is a COC for the media as noted, but a PRG is not available or appropriate. A PRG was not developed for cyanide in sediment because cyanide does not persist in the sediment matrix
* The PRGs for cadmium, copper, and zinc are based on the hardness-specific DEQ-7 Aquatic Life Standards; values representative of Site-specific data as listed in the above table (i.e., minimum calculated standards based on two surface water samples collected from the North Percolation Ponds with hardness as calcium carbonate ranging from 50,000 to 224,000 µg/L) will be used as the PRGs.
† Except aluminum, standards for metals in surface water are based upon the analysis of samples following a "total recoverable" digestion procedure.
‡ As discussed in the BHHRA, the North Percolation Ponds are exempt from DEQ-7 Water Quality Standards as they are not state waters per MCA 75-5-103(34)(b)(i). Further, DEQ-7 Water Quality Standards for human health are not relevant or appropriate for the North Percolation Ponds as the exposure pathway for water consumption is incomplete.

In addition, small range receptor PRGs presented in Section 3.3.3 above are also applicable to the North Percolation Pond DU.

Exceedances of PRGs for COCs in surficial and shallow soil and sediment in the North Percolation Pond DU span the entire footprint of the DU including the North-East Percolation Pond and its influent ditch, the North-West Percolation Pond, and the overflow ditch. In addition, visible waste is present in the North-East Percolation Pond, the ditches, and portions of the North-West Percolation Pond.

3.3.5 River Area DU

The COCs for the River Area DU and their corresponding PRGs are summarized in Tables 3-12 through 3-14 below. Thematic maps that facilitate the identification of locations where the analyte was detected and where the analyte concentrations exceed the PRGs were presented in Appendices F through I of the FSWP.

Table 3-12 Applicable PRGs for COCs in the River Area DU – South Percolation Ponds

COC	Applicable PRG					
	Soil	Sediment	Sediment Porewater		Surface Water	
			Chronic	Acute	Chronic	Acute
Metals†						
Aluminum					87	750
Barium	1,000	300	220	2,000	220	1,000‡
Copper*					15.27	24.10
Iron					1,000	NA
Other Inorganics						
Cyanide, total		NA	NA	NA	4	22
Cyanide, free§			5.2	22	4	22

All soil/sediment concentrations are in milligrams per kilogram (mg/kg).
All porewater/surface water concentrations are in micrograms per liter (µg/L).
NA: Parameter is a COC for the media as noted, but a PRG is not available or appropriate. See discussion regarding cyanide in sediment and sediment porewater below.
* The PRGs for copper are based on the hardness-specific DEQ-7 Aquatic Life Standards; values representative of Site-specific data as listed in the above table (i.e., median calculated standards based on 26 surface water samples collected from the South Percolation Ponds with hardness as calcium carbonate ranging from 144,000 to 1,740,000 µg/L, with first, second, and third quartiles of 160,000, 178,000, and 214,000 µg/L, respectively) will be used as PRGs.
† Except aluminum, standards for metals in surface water are based upon the analysis of samples following a "total recoverable" digestion procedure. See discussion regarding metals in the River Area DU below.
‡ The PRG of 1,000 µg/L for barium in surface water is derived from the Montana DEQ-7 surface water standards for human health.
§ Free cyanide was not identified as a COC in the South Percolation Ponds sediment porewater within the BERA but is being carried forward as a COC through the FS.

Although not identified during the BHHRA and BERA as COCs in the River Area DU – South Percolation Ponds, the following parameters have exceeded the Montana DEQ-7 surface water standards for human health in at least one sample in the South Percolation Ponds and will therefore be included as analytes for future monitoring as part of remedial alternatives for the River Area DU:

- Metals: lead, mercury, and thallium;
- Other Inorganics: fluoride; and
- PAHs: benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-C,D)pyrene.

Table 3-13 Applicable PRGs for COCs in the River Area DU – Backwater Seep Sampling Area

COC	Applicable PRG				
	Sediment	Sediment Porewater		Surface Water	
		Chronic	Acute	Chronic	Acute
Metals†					
Aluminum				87	750
Other Inorganics					
Cyanide, total	NA*	NA*	NA*	4	22
Cyanide, free	NA*	5.2	22	4	22

All soil/sediment concentrations are in milligrams per kilogram (mg/kg).
All porewater/surface water concentrations are in micrograms per liter (µg/L).
NA: Parameter is a COC for the media as noted, but a PRG is not available or appropriate.
* See discussion regarding cyanide in sediment and sediment porewater below.
† See discussion regarding metals in the River Area DU below.

Although not COCs in the River Area DU – Backwater Seep Sampling Area, the following parameters have exceeded the Montana DEQ-7 surface water standards for human health in at least one sample in the Backwater Seep Sampling Area and will therefore be included as analytes for future monitoring as part of remedial alternatives for the River Area DU:

- PAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene.

Table 3-14 Applicable PRGs for COCs in the River Area DU – Riparian Area Channel

COC	Applicable PRG				
	Sediment	Sediment Porewater		Surface Water	
		Chronic	Acute	Chronic	Acute
Metals†					
Aluminum				87	750
Barium	300	220	2,000	220	1,000‡
Other Inorganics					
Cyanide, total	NA*	NA*	NA*	4	22
Cyanide, free	NA*	5.2	22	4	22

All soil/sediment concentrations are in milligrams per kilogram (mg/kg).
All porewater/surface water concentrations are in micrograms per liter (µg/L).
NA: Parameter is a COC for the media as noted, but a PRG is not available or appropriate.
* See discussion regarding cyanide in sediment and sediment porewater below.
† See discussion regarding metals in the River Area DU below.
‡ The PRG of 1,000 µg/L for barium in surface water is derived from the Montana DEQ-7 surface water standards for human health.

Although not COCs in the River Area DU – Riparian Area Channel, the following parameters have exceeded the Montana DEQ-7 surface water standards for human health in at least one sample in the Riparian Area Channel and will therefore be included as analytes for future monitoring as part of remedial alternatives for the River Area DU:

- Metals: arsenic, lead, mercury, and thallium.

In addition, although barium is an identified COC for sediment in the Riparian Area Channel, there are no exceedances of the sediment PRG for barium in this Site feature.

As discussed in the technical memorandum for PRG Development for Ecological Risk Drivers (Appendix B of the FSWP), a PRG was not developed for cyanide in sediment because cyanide does not persist in the sediment matrix. Instead, the cyanide PRG for the protection of benthic habitats is based on exposure to free cyanide in porewater. Discussed in the same technical memorandum is the appropriateness of using free cyanide measurements in porewater to evaluate exposure in benthic habitats rather than total cyanide measurements due to the consensus that free cyanide is the bioavailable and toxic form to benthic organisms and given that UV-mediated dissociation of cyanide complexes into free cyanide is limited in sediments by the lack of light penetration below the sediment-surface water interface. Therefore, remediation of cyanide in sediment will be considered successful by demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in sediment porewater in those areas.

3.3.6 Groundwater DU

The COCs for groundwater within the upper hydrogeologic unit and their corresponding PRGs are summarized in Table 3-15 below. Maps depicting the arsenic, cyanide (total), and fluoride plume areas exceeding PRGs within the upper hydrogeologic unit were provided in Appendix E of the FSWP and are included as Figures 6 through 8 in this FS Report. For each, the plume extent is identified as the area where monitoring wells had detected concentrations greater than the Montana DEQ-7 standards in any of the six sampling rounds throughout the RI. As presented in these figures, the extent of the arsenic and fluoride plumes are generally confined within the boundary of the cyanide plume extent. The area encompassing exceedances for any of the three COCs is encompassed by the extent of the Groundwater DU, as shown on Figure 5.

Table 3-15 Applicable PRGs for COCs in the Groundwater DU

COC	Applicable PRG
Metals	
Arsenic	10
Other Inorganics	
Cyanide, total	200
Cyanide, free	200
Fluoride	4,000

All concentrations are in micrograms per liter (µg/L)

Total cyanide and fluoride concentrations in groundwater within the upper hydrogeologic unit decrease with increasing distance away from the Landfills DU1, likely due to various natural attenuation processes such as biodegradation and adsorption. Fluoride and arsenic concentrations generally decrease to below PRGs within the portion of the Site north of the former Main Plant, while cyanide concentrations remain above PRGs across the Site including where groundwater discharges to surface water at the Seep Area.

3.4 Areas and Volumes of Impacted Media

The estimated areas and volumes of impacted media for each DU are tabulated below, focusing on locations contributing to risk and/or areas of known disposed wastes.

3.4.1 Landfills DU1

The approximate areas and estimated depths of waste for each of the waste management units within Landfills DU1 are shown in Table 3-16 below. The depths of waste for each waste management unit are estimated based on various sources of information cited in Section 2.1.4.1 above. The respective volumes of waste are calculated from the estimated depths and presented in cubic yards (CY).

Table 3-16 Estimated Areas and Volumes of Waste for Waste Management Units in Landfills DU1

Waste Management Unit	Area (acres)	Depth of Waste (*estimated*, ft)	Volume of Waste (estimated, CY)
Center Landfill	1.8	Approximately 15	Approximately 44,000
West Landfill	7.8	Approximately 30 to 48	Approximately 378,000 to 604,000
Wet Scrubber Sludge Pond	10.8	Approximately 30; Top of feature is 15 ft above grade	Approximately 522,000

Due to the range of waste thicknesses provided by various sources of information, there is uncertainty regarding the vertical extent of waste in the West Landfill; for the purpose of evaluating and comparing remedial alternatives in this FS Report, an average depth of waste of 35 feet has been assumed. The uncertainty of waste depth and volume in the West Landfill would have the most significant impact on an excavation remedy; alternatives which do not disturb the wastes stored in the existing waste management units would not be significantly impacted by the exact vertical extent of waste in the West Landfill.

These volume estimates do not include impacted underlying soils beneath the West Landfill that are likely contributing to groundwater contamination. As discussed in Section 2.1.4.1, it is likely that cyanide leached from the waste is retained within the soil underlying the waste above the seasonal low-water table (which can be more than 80 ft-bls) and available to serve as a residual source of cyanide to groundwater when the water table rises during the high-water season. For the purpose of evaluating and comparing remedial alternatives in this FS Report, an average depth of impacted underlying soils contributing to groundwater contamination of 50 ft below surrounding grade (i.e., approximately 30 ft in thickness) has been assumed.

In summary, the following depths and volumes have been assumed for the West Landfill:

- Average depth of waste – 35 ft, ranging between 15 and 22 ft below surrounding grade;
- Estimated volume of waste – 440,440 CY;
- Average depth of impacted underlying soils contributing to groundwater contamination – approximately 30 ft, extending to 50 ft below surrounding grade on average; and
- Estimated volume of impacted underlying soils – 377,520 CY.

Therefore, the average total depth of impacted material at the West Landfill is estimated to be 50 ft below surrounding grade. To adequately address the source of groundwater contamination at the Site, remedial alternatives for the Landfills DU1 would need to address impacted material at the West Landfill to this depth.

3.4.2 Landfills DU2

The approximate areas and estimated depths for each of the waste management units within the Landfills DU2 are shown in Table 3-17 below. As discussed in the RI Report, these landfills are not sources of groundwater contamination at the Site.

Table 3-17 Estimated Areas and Depths for Waste Management Units in Landfills DU2

Waste Management Unit	Area (acres)	Depth of Waste (*estimated*, ft)
Asbestos Landfills	3.4	Approximately 5
East Landfill	2.4	Approximately 30
Industrial Landfill	12.4	Approximately 10 to 20
Sanitary Landfill	3.8	Unknown

3.4.3 Soil DU

The approximate areas of impacted surficial and shallow soil within the Soil DU were determined in Section 3.3.3, and the corresponding AOCs are presented on Figure G1 of Appendix G. For each AOC, the approximate depth of impacted material is 2 ft; if a removal remedy is implemented at any AOC, collection and analysis of the 2 to 4 ft-bls sampling interval would be required to confirm underlying soils do not exceed small range receptor PRGs. The respective volumes of impacted soil are calculated from the estimated areas and depths and presented in CY in Table 3-18 below.

Table 3-18 Estimated Areas and Volumes of Impacted Soil for Areas of Concern in the Soil DU

Area of Concern	Estimated Area (acres)	Estimated Depth (ft-bls)	Estimated Volume (CY)
AOC A	0.12	2	390
AOC B	0.86	2	2,770
AOC C	1.60	2	5,160
AOC D	2.78	2	8,970
AOC E	1.86	2	6,000
AOC F	0.59	2	1,900
AOC G	0.15	2	480

The total estimated area and volume of impacted soil for AOCs in the Soil DU are 7.6 acres and 25,670 CY, respectively. The exact extents of the AOCs will be further delineated during the remedial design.

3.4.4 North Percolation Pond DU

The approximate areas and depths of impacted material for each of the pond structures within the North Percolation Pond DU are shown in Table 3-19 below. Reasonable lower and upper estimates of the average depth of the surficial layer of highly viscous to solid black carbonaceous material that exists across the majority of the North-East Percolation Pond, and intermittently across the ditches and North-West Percolation Pond. Based upon soil borings, the maximum thickness of this carbonaceous material ranges from 0.5 to 2 feet. It is estimated that on average 6 to 12 inches of soil beneath this carbonaceous material is impacted at levels that contribute to potential human health and ecological risk. The respective volumes for the estimated range of depths are calculated accordingly and presented in CY.

Table 3-19 Estimated Areas and Range of Volumes for North Percolation Pond Structures

Pond Structure	Area (acres)	Reasonable Lower Estimate		Reasonable Upper Estimate	
		Avg Depth (ft-bls)	Volume (CY)	Avg Depth (ft-bls)	Volume (CY)
North-East Percolation Pond	2.0	1.5	4,850	4	12,900
North-West Percolation Pond	8.0[1]	0.5	4,850	2	19,400
Influent Ditch	0.2	0.5	160	3	960
Overflow Ditch	0.4	0.5	320	3	1,920

[1] To calculate the estimated volume for the North-West Percolation Pond, an area of 6.0 acres was used to reflect the observed intermittent nature of the carbonaceous material.

For the purpose of evaluating and comparing remedial alternatives in this FS Report, the reasonable upper estimates calculated above have been assumed for a total volume of 35,180 CY.

3.4.5 River Area DU

The approximate areas and depths for each of the structures within the River Area DU are shown in Table 3-20 below. A reasonable lower estimate and a reasonable upper estimate of the average depth of each structure are provided based on the information available prior to implementation of the South Percolation Ponds Removal Action. The respective volumes for the estimated range of depths are calculated accordingly and presented in CY.

Table 3-20 Estimated Areas and Range of Volumes for River Area DU Structures

Structure	Area (acres)	Reasonable Lower Estimate		Reasonable Upper Estimate	
		Avg Depth (ft-bls)	Volume (CY)	Avg Depth (ft-bls)	Volume (CY)
South Percolation Ponds	10.2	0.5	8,200	2	33,000
Backwater Seep Sampling Area	No exceedances of sediment/soil PRGs in this area				
Riparian Area Channel	No exceedances of sediment/soil PRGs in this area				

As discussed in Section 2.3.5, the top foot of sediments in the South Percolation Ponds was removed under the Removal Action followed by post-excavation sampling to confirm attainment of ecological PRGs. Data from the post-excavation sampling resulted in the removal of an additional foot of sediment from one of the grids (Grid 8 of Pond 1). A total of 22,000 CY of sediment were removed from the South Percolation Ponds under the Removal Action, a volume within the range estimated during the planning of the Removal Action. Following completion of the Removal Action at the South Percolation Ponds, sediment/soil PRGs in the River Area DU have been achieved.

In the River Area DU, cyanide (total and/or free) is an identified COC in surface water and sediment porewater. The results of the RI indicated that groundwater discharge to the Seep Area is the primary source of the cyanide in the River Area DU. In the River Area DU, the potential risk attributed to cyanide in surface water and sediment porewater will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Alternatives addressing groundwater inputs will be assessed within the Groundwater DU.

3.4.6 Groundwater DU

The approximate area of the plume area (upper hydrogeologic unit) exceeding MCLs/DEQ-7 standards is 300 acres. The saturated thickness of the upper hydrogeologic unit varies across the Site depending upon the depth to underlying glacial till and the proximity to Teakettle Mountain. Saturated thickness was observed to be less near Teakettle Mountain when compared to areas beneath the Central Landfills Area and to the west of this area. Water level elevation data indicated that groundwater elevations fluctuate seasonally at varying magnitudes depending on the area of the Site; as such, the saturated thickness fluctuates seasonally. During high-water season, the saturated thickness of the upper hydrogeologic unit varies from approximately 19 feet to 92 feet. During low-water season, the saturated thickness of the upper hydrogeologic unit varies from approximately 1 foot to 77 feet.

As discussed in the RI Report, concentrations of cyanide and fluoride in upper hydrogeologic unit groundwater decrease with increasing depth. Therefore, the data indicate the upper portion of the upper hydrogeologic unit is conveying the majority of the contaminant mass.

4. Identification and Screening of Technologies

In accordance with the USEPA RI/FS Guidance (USEPA, 1988), technologies and process options were identified and screened for each general response action (GRA) described below. The draft technology screening and assembly of remedial action alternatives was submitted to USEPA/MDEQ prior to this FS Report to provide opportunity for the agencies' review and concurrence. Comments provided by USEPA/MDEQ are provided in Appendix D, and where applicable revisions to address these comments are incorporated herein.

The technology screening includes a broad range of technologies and process options with an emphasis on treatment technologies that are technically implementable, effective in mitigating potential risks posed by materials remaining at the Site, and capable of achieving the RAOs. Factors considered in the evaluation include the state of technology development, Site conditions, characteristics and distribution of impacted media, and specific COCs that could limit the effectiveness or implementability of a technology.

Sources of information considered for the technology screening included:

- Federal Remediation Technologies Roundtable;
- Various USEPA/MDEQ Guidance documents;
- Vendor information, case studies, and technical journal articles; and
- Roux professional judgement based on project experience on similar sites.

The various remedial technologies, described in the following sections, were screened based on their effectiveness, implementability, and cost. Technologies that are not viable based on these considerations were eliminated from further consideration. The results of this screening are detailed in Tables 4-1 through 4-6 and summarized in Section 4.3.

4.1 General Response Actions

GRAs are initial broad response actions considered during technology screening to address the RAOs for the contaminated media identified at the Site. GRAs may include either individual or combinations of the following:

- No Action;
- Access Restrictions, including institutional controls (ICs) and engineering controls (ECs);
- In Situ Treatment, including Monitored Natural Attenuation (MNA) processes;
- Ex Situ Treatment following excavation or groundwater extraction, with treatment performed at an onsite treatment unit;
- Containment; and
- Removal/ Collection and Disposal.

The following Sections 4.1.1 through 4.1.6 provide a general description of each GRA.

4.1.1 No Action

Under the no action response, no remedial actions would be performed to reduce the toxicity, mobility, or volume of COCs at the Site or to address Site remedial objectives. The no action response action considers ongoing natural attenuation, as well as continuation of existing controls (e.g., maintenance of existing Site fence). The no action response would not include any long-term monitoring or new controls beyond annual monitoring of the groundwater COCs in select monitoring wells.

This GRA is appropriate in areas of a site that already meet cleanup goals based on unrestricted use, and thus can be a component of the selected remedy. The no action response is required as a baseline for comparison against other technologies as specified under the NCP (40 CFR 300.430(e)(6)).

4.1.2 Access Restrictions

This GRA includes ICs and ECs. ICs are administrative controls or legal restrictions placed on land and groundwater use to protect the public against inadvertent exposure to hazardous constituents and/or to protect the integrity of a functioning or completed remedy. ICs may include land use restrictions, natural resource use restrictions, groundwater use restriction or management areas, property deed notices, declaration of environmental restrictions, access controls (digging/ drilling permits), surveillance, information posting or distribution, restrictive covenants, and federal/ state/ county/ local registries.

ECs generally include physical access restrictions such as fences or manned security to protect against trespasser exposure to contaminated soils, sediment, and surface water until RAOs can be achieved in the absence of such controls. For groundwater, ECs may include provision of an alternate water supply for current or future users when contaminated groundwater is identified as a current drinking water source.

4.1.3 *In Situ* Treatment

This GRA includes various technologies (biological, chemical, thermal, physical) to treat contaminated media below the ground surface or *in situ*. MNA of COCs in groundwater is also included within the scope of this GRA.

4.1.4 *Ex Situ* Treatment

This GRA includes technologies employed at an onsite treatment unit to treat contaminated media aboveground. Offsite treatment centers were not considered for the *Ex Situ* Treatment GRA due to the remote location of this Site; if impacted media is sent offsite, the media will be sent to a disposal facility.

4.1.5 Containment

This GRA isolates the contaminated media and restricts migration of contaminants. Containment response actions include physical barriers such as soil covers, landfill caps, and slurry walls, as well as hydraulic controls for groundwater such as extraction wells. Barriers may be permeable or low-permeability and are comprised of natural and/or synthetic materials. Containment reduces the mobility of the contaminated media and the potential for receptor exposure to contaminated media, but does not reduce volume or toxicity.

4.1.6 Removal and Disposal

This GRA includes excavation to remove contaminated media with long-term containment and management provided by disposing of the material at a secure onsite landfill or an offsite facility permitted under Subtitle D or Subtitle C of the Resource Conservation and Recovery Act (RCRA).

4.2 Technology Screening Criteria and Methodology

The technology screening qualitatively assesses each technology's ability to achieve the RAOs using the CERCLA criteria of effectiveness, implementability, and cost as defined in the NCP (40 CFR 300.430(e)(7)). Technologies that are not viable based on these considerations were eliminated from further consideration. A brief description of each evaluation criterion is provided below.

4.2.1 Effectiveness

Effectiveness refers to the ability of a technology and its associated process option(s) to perform as a stand-alone approach or component of a broader alternative to meet RAOs under the conditions and limitations present at a site. Additionally, the NCP (40 CFR 300) defines effectiveness as the *"degree to which an alternative reduces toxicity, mobility, or volume through treatment; minimizes residual risk; affords long-term protection; complies with ARARs; minimizes short-term effects; and how quickly it achieves protection."* Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that the evaluation of remedial technologies and process options with respect to effectiveness should focus on: *"(1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the RAOs; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site."*

4.2.2 Implementability

Implementability refers to the relative degree of difficulty anticipated in implementing a particular remedial technology and process option under technical, regulatory, and schedule constraints posed by a site. As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), process options and entire technology types can be eliminated from further consideration if a technology or process option cannot be effectively implemented at a site. As discussed in Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004), *"technical implementability is used as an initial screening of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site."* Administrative implementability, which includes *"the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology,"* is also considered in the initial screening.

4.2.3 Relative Cost

For the initial screening of technology types and process options, the cost criterion is relative; quantitative cost estimates are not prepared. Instead, remedial technology and process option costs are compared using narrative terms. Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that *"cost plays a limited role in the screening of process options. Relative capital and operations and maintenance (O&M) costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are low, medium, or high* *relative to other process options in the same technology type."* For this evaluation, relative cost is used to screen out process options that have a high capital cost if there are other choices that perform similar functions with similar effectiveness. Technology screening based on relative O&M costs was not specifically performed but was considered as part of the overall cost evaluation.

4.2.4 Assessment Methodology

The assessment of individual technologies and their associated process options was performed based on the criteria described above. To evaluate the effectiveness of each technology's process options, a detailed list of advantages and disadvantages was evaluated for each. Implementability was assessed by noting whether the technology is widely used, the ease of implementation, the need for pre-design activities and/or additional data, and the ability for the technology to address all COCs. Relative cost was assessed for each DU using a relative grading scale employing a "Low," "Moderate," or "High" rating. To create greater separation, a blended rating such as "Low to Moderate" or "Moderate to High" was included as shown in Table 4-7 below. Relative costs should not be compared between DUs.

Table 4-7 Relative Cost Grading Scale

Relative Cost	
0	None
$	Low
$$	Low to moderate
$$$	Moderate
$$$$	Moderate to high
$$$$$	High

Relative cost was used to screen out process options that have a high capital cost only if similar or greater effectiveness is available via other process option(s) at similar or lesser cost; relative cost alone was not used to justify not retaining a technology for further consideration.

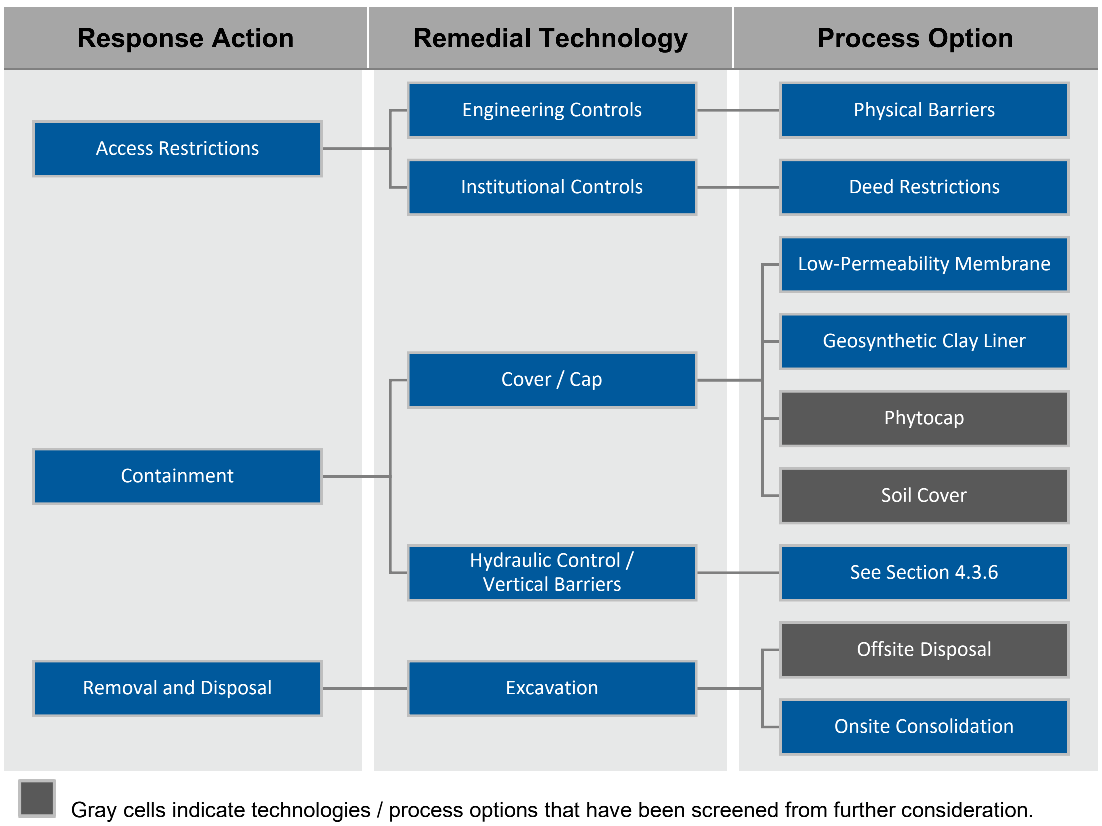
4.3 Technology Screening Results

As described in Section 4.2 above, individual remedial technologies and their associated process options were screened based on considerations of effectiveness, implementability, and relative cost. The screening step narrows the list of remedial technologies to identify the most viable candidates for use in assembling remedial action alternatives. The technology screening and screening results are detailed in Tables 4-1 through 4-6. The tables also note whether the technology is to be retained and, if not, the specific reason for elimination.

The remedial technologies and process options retained and eliminated from the screening are summarized by DU below. The No Action process option is retained for all DUs.

4.3.1 Landfills DU1

The waste management units comprising the Landfills DU1 are each described in Section 2.1.4.1. The nature of the wastes and status of existing caps for each waste management unit is summarized in Section 2.3.1. For each applicable GRA identified in Section 4.1, various remedial technologies with corresponding process options were identified for the Landfills DU1 and screened using the criteria and methodology discussed in Section 4.2. Detailed analyses of each technology and process option are discussed below and presented in Table 4-1. The figure below summarizes the technologies and process options screened, as well as whether it was eliminated or retained for further evaluation.



Access Restrictions

ICs and ECs are measures undertaken to limit or prohibit activities that may interfere with a cleanup action or result in exposure to contaminated media. They may be physical restrictions, such as fences or other barriers, or legal restrictions, such as use limitations recorded on the property deed. Deed restrictions would involve specific limitations on future land use incorporated into the property deed; deed restrictions are generally binding and must be transferred to all subsequent owners of the property.

Potentially applicable ICs and ECs for all the DUs at this Site include:

- Fences and warning signs to limit access to the Site or specific areas on the Site;
- Deed restrictions addressing land use and soil excavation, including construction activities that could damage or compromise caps or covers; and
- Use restrictions and monitoring requirements to prevent disturbance of caps, covers, or other ECs.

On-property development activities, such as agricultural or residential use, would be prohibited within the footprint of the Landfills DU1 waste management units. The property owner would retain all rights to preclude these activities from occurring onsite.

All of these ICs and ECs are potentially effective at preventing exposure to contaminated media, are easy to implement, and can be implemented at relatively low costs. In addition, access restrictions could be a component of a response action in combination with one or more other technologies. Therefore, they have been retained for further consideration.

<u>Containment – Engineered Covers / Caps</u>

Covering or capping the waste management units in the Landfills DU1 would provide barriers that prevent direct contact exposure to underlying impacted solid media as well as prevent erosion that might transport contamination away from the DU. Covers and caps are designed and graded to promote runoff of rainwater from the top of the cover. However, the various process options provide varying degrees of infiltration prevention. Material for a vegetated layer and/or an alternate soil cover (e.g., water balance cover) could be sourced locally within the state, and there is approximately 300,000 CY of coarse-grained material available from the onsite permitted borrow pit. The nearest high-quality clay sources are in northern Wyoming.

Low-Permeability Membranes

Low-permeability membranes contain a geomembrane of synthetic low-permeability material such as high-density polyethylene (HDPE). In addition to reducing the potential for direct contact with impacted solid media, low-permeability membranes would greatly reduce the volume of infiltration through the waste management units, thereby reducing the potential for migration of COCs in groundwater. Therefore, they have been retained for further consideration for the Landfills DU1.

Given that the Wet Scrubber Sludge Pond primarily accepted sludges, the material in this waste management unit may be of low load-bearing strength; pre-consolidation or solidification of the sludges via preloading to accelerate primary settlement or addition and mixing of amendments could be required to support installation of a low-permeability membrane at the Wet Scrubber Sludge Pond.

Geosynthetic Clay Liners (GCLs)

GCLs consist of a layer of low-permeability bentonite sandwiched between two mechanically bonded geotextiles. Like low-permeability membranes, GCLs would also greatly reduce the volume of infiltration through the waste management units, thereby reducing the potential for migration of COCs in groundwater. GCLs have a few advantages over natural clay materials as they are pre-manufactured to a design permeability standard and require less quality control during placement. Therefore, they have been retained for further consideration for the Landfills DU1.

Pre-consolidation or solidification of the sludges in the Wet Scrubber Sludge Pond may also be required to support installation of a GCL.

Phytocaps

Phytocapping is the process of establishing perennial vegetation on a layer of soil placed over the waste, such that the soil stores the water during rainfall events and the plants remove the water via transpiration. When the soil depth and plant density are optimized, it is possible to balance the rainfall input with the evapotranspiration rate to avoid excessive percolation of water into the buried waste. Phytocaps are also known as evapotranspiration or water balance covers.

While phytocaps provide a strong alternative to more traditional landfill caps for many applications, they are more sensitive to location, soil type, and climate than their counterparts. Phytocaps may be less effective during spring snowmelt and precipitation ahead of the growing season. At this Site, the growing season is short and significant volumes of snowmelt and precipitation are common each spring. Since the three waste management units in the Landfills DU1 have each been identified in the RI Report as a source of groundwater contamination at the Site to varying degrees, the year-round reduction of infiltration is a necessity for any potential remedial alternative to be evaluated for the Landfills DU1. As it is uncertain whether phytocaps would provide adequate reduction of infiltration at this Site, phytocaps for the Landfills DU1 have been screened from further consideration.

Soil Covers

Soil covers consist of a single soil layer that is often vegetated or rock-armored for erosion protection and for decreased percolation. The primary cover layer prevents direct contact exposure to underlying impacted solid media; however, soil covers do not prevent infiltration. As discussed with respect to phytocaps above, the reduction of infiltration is a necessity for any potential remedial alternative to be evaluated for the Landfills DU1. Therefore, soil covers for the Landfills DU1 have been screened from further consideration.

Containment – Hydraulic Control and Vertical Barriers

Containment via hydraulic control and/or vertical barriers is designed to prevent migration of contaminants to existing or potential downgradient receptors. Process options that may be viable for the Landfills DU1 also pertain to the Groundwater DU and as such are evaluated in Section 4.3.6 and Table 4-6. One or more process options for this GRA have been retained for further consideration for the Landfills DU1.

Removal and Disposal

USEPA established source containment as the presumptive remedy for municipal landfill sites regulated under CERCLA (see the directive Presumptive Remedy for CERCLA Municipal Landfill Sites) in 1993, and subsequently extended this presumptive remedy to military landfills in 1996 (USEPA, 1993; USEPA 1996). Although the Landfills DU1 waste management units are not municipal landfills, they share many of the landfill characteristics for applicability of the presumptive remedy: the waste types include nonhazardous sludge and industrial solid wastes, there are lesser quantities of hazardous wastes present compared to other wastes, and most notably the treatment of wastes is impractical due to the volume and heterogeneity of waste.

Although source containment would be an appropriate remedy for the Landfills DU1 waste management units thereby avoiding negative impacts of re-handling previously disposed material, an alternative that includes excavation of the waste materials in Landfills DU1 is evaluated herein. Excavated waste could then be disposed of at an offsite disposal facility or consolidated within a new, onsite repository meeting substantive RCRA Subtitle C requirements. The next subsection discusses the excavation component of such an alternative and is applicable to both excavation with offsite disposal and excavation with onsite consolidation; details specific to either offsite disposal or onsite consolidation are discussed in their respective subsections below.

Excavation

Excavation of the waste materials would involve physical removal of the material, which includes SPL mixed with other wastes, using earth-moving methods. This GRA (where practicable) has the advantage of providing the greatest removal of contaminants from a site. Given that the excavated material is disposed of offsite or properly managed within an onsite repository, it is expected that this removal would be permanent and effective in the long-term. The effectiveness of an excavation remedy would diminish if all impacted material were not removed (e.g., if impacted underlying soils continue to contribute to groundwater contamination); the effectiveness of a partial source removal is examined below.

The Landfills DU1 waste management units contain a combined estimated volume of waste upwards of 1 million bulk cubic yards (BCY), or more than 1.2 million loose cubic yards (LCY). This volume estimate does not include impacted underlying soils beneath the West Landfill that are likely contributing to groundwater contamination, which for the purpose of screening technologies and alternatives in this FS has been assumed to extend to 50 ft below surrounding grade (i.e., approximately 30 ft in thickness; or 380,000 CY) (see Section 2.1.4.1). To excavate material to approximately 50 feet below grade, sloping and benching would be required to maintain stability of the sidewalls. Collection and treatment of water that enters the open excavation would be necessary to maintain a safe and dry work area as well as to minimize impacts to groundwater from infiltration of precipitation and surface water runoff through waste and impacted soil.

The volume and depth of material to be excavated would be reduced under a partial source removal alternative. Such an alternative would limit the excavation to a depth less than the seasonal high-water table, a shallower depth than would be required to remove all waste and underlying impacted soils. By reducing the depth of the excavation, the requirements for sidewall stability and dewatering would be reduced, subsequently lessening a few of the technical challenges associated with a complete source removal alternative. However, by failing to remove impacted material from below the seasonal high-water table, a continuing source of contamination would not be addressed, diminishing the effectiveness of an excavation remedy such that achievement of RAOs (including ARARs) would be unlikely in the absence of additional remedial measures to contain the residual contamination. For this reason, a partial source removal alternative for Landfills DU1 was screened from further consideration.

Waste excavated from the Wet Scrubber Sludge Pond would contain primarily waste material from the wet scrubbers at the aluminum reduction plant (i.e., calcium fluoride sludge). Given that the Wet Scrubber Sludge Pond accepted sludges, the material in this waste management unit will be of low strength; physical solidification of the sludges via addition and mixing of amendments would likely be required prior to, or in conjunction with, the excavation of the Wet Scrubber Sludge Pond to facilitate material handling. The implementability and effectiveness of the physical solidification treatment process would be adversely impacted by the likely heterogeneous nature of the waste; as discussed in the RI Report, the Wet Scrubber Sludge Pond more closely resembled a landfilling operation from the 1950s into the 1960s prior to becoming the sludge pond.

The West Landfill and the Center Landfill were used to dispose of the SPL generated over the operational lifetimes of these landfills. The SPL was not considered a hazardous waste at the time of disposal. Thus, USEPA policy is clear that it is not a hazardous waste (55 FR 8758). Although SPL is now a listed hazardous waste requiring treatment prior to land disposal, USEPA stated in amendments to the NCP that such material is not subject to RCRA requirements, including land disposal restrictions, when it is relocated and contained within the same Area of Contamination as the originally disposed of material (55 FR 8758). The USEPA's rationale was that the material is not actually moved from what would be the equivalent of a RCRA unit and therefore it is not "placed in" a "land disposal unit" as defined by RCRA (55 FR 8758-8759). CFAC believes that the Landfills DU1 and the groundwater immediately to the south that is impacted by contaminant migration from the Landfills DU1 is an "Area of Contamination" as described in USEPA amendments to the NCP. Therefore, removal of SPL and soil or other material impacted by SPL from the Landfills DU1 and relocation of that material into a repository constructed in the Area of Contamination would not constitute placement of the material in a land disposal unit. Nonetheless, any new repository for SPL-impacted material in Landfills DU1 would comply with substantive requirements of RCRA Subtitle C for new landfills (e.g., liner, leachate collection, capping) as relevant and appropriate provisions governing design, construction, operation, closure, and post-closure care.

Based on the anticipated volume, depth, and characteristics of the impacted material which would need to be excavated, there are numerous risks and technical challenges which could complicate implementation of such a remedy and potentially compromise the effectiveness of the remedial action. These challenges would need to be further evaluated if this technology is retained. Evaluation of an excavation alternative for the Landfills DU1 would also need to assess the potential adverse environmental impacts resulting from an open excavation for an extended period as well as the potential adverse effects on human health from exposure to hazardous substances, fugitive dust, contaminant vapors/odors, exhaust emissions, and noise.

Although excavation is a proven method of removing contaminated surface and subsurface materials, it is not a proven method of removing previously-landfilled SPL material, or SPL intermingled with mixed industrial wastes, at the scale which would be required to address the Landfills DU1 waste management units. While there are numerous technical and administrative challenges associated with such an alternative, excavation is a commercially available technology and has the potential to be effective. Therefore, excavation has been retained for further consideration for the Landfills DU1 to evaluate the technical implementability of this alternative and its impacts to human health and the environment.

Onsite Consolidation

Under this option, excavated material would be landfilled in a newly constructed onsite repository meeting substantive RCRA Subtitle C requirements. The onsite repository would need to have a design capacity to store the volume of material excavated from the Landfills DU1, accounting for increase in volume of material from the Wet Scrubber Sludge Pond resulting from physical solidification. Assuming an average height of 20 feet, the onsite repository would have a footprint of over 40 acres. This would render a larger portion of the Site undevelopable compared to present and would not decrease the volume of impacted media at the Site. Due to the topography of the Site, the most suitable locations for a new repository would be closer than the existing location of the waste management units to the Flathead River, Cedar Creek, and/or residents in Aluminum City.

After the landfill is constructed, the onsite repository would require regular operations, maintenance, and monitoring (OM&M) activities for the long term.

Although there are significant concerns regarding the technical implementability of excavation of the Landfills DU1 waste management units and its impacts to human health and the environment, excavation with onsite consolidation has been retained for further consideration for the Landfills DU1.

Offsite Disposal

Under this option, excavated material would be transported to a permitted treatment, storage, and disposal facility (TSDF) where it would be landfilled following pre-treatment at the TSDF as appropriate. Because it would not be contained within the Area of Contamination, SPL-impacted material from the West Landfill and Center Landfill would need to be disposed of in a landfill permitted under RCRA Subtitle C, while waste from the Wet Scrubber Sludge Pond could be disposed of in either a RCRA Subtitle C or Subtitle D landfill. Disposal is subject to space availability and acceptance of the waste; only waste that meets the facility's permitting requirements can be accepted. The nearest RCRA Subtitle C landfill is located in Arlington, Oregon, nearly 500 miles from the Site. Using this facility, the need for pre-treatment of the excavated material would be determined by the Oregon DEQ. If pre-treatment is required, the rate of acceptance of the excavated material at the receiving TSDF would likely be significantly less than the generation rate at the Site, impeding progress of the excavation and ultimately increasing the duration of remedial activities. In addition, the USEPA acknowledged the difficulty in treating intermingled wastes by applying a treatment technology designed to address a listed RCRA hazardous waste, such as SPL, to waste material combined with SPL or soil impacted by SPL (see 55 FR 8760). CFAC believes that attempting to treat the SPL-impacted waste and soil from the West Landfill would also result in similar issues and further delay the rate of acceptance of excavated material at the receiving TSDF.

From the Site, the excavated material could be transported by truck or rail. Excavated material would be packaged in clean, leak-proof, vented containers and transported in accordance with United States Department of Transportation (USDOT) regulations as a RCRA hazardous waste by a licensed hazardous waste hauler with the appropriate manifests, permits, training, equipment, insurance, and financial responsibility. Assuming a capacity of 20 CY per truck/container, the estimated 1.2 million LCY of waste to be excavated from the Landfills DU1 waste management units would require 60,000 trucks/containers. In addition to the logistical coordination issues that are likely to arise given the volume of material to be handled and transported, the carbon footprint and air emissions associated with this process option would be extremely large and disproportionate to other technologies and process options evaluated in this FS. For example, based on the round-trip mileage from the Site to the nearest SPL disposal facility (Arlington, Oregon) of approximately 950 miles, approximately 60 million total truck miles would be driven if waste transport by truck was the selected approach. Further, residents in neighboring communities as well as communities along the designated route would be subject to trucks and/or trains regularly passing through their neighborhoods for several years. The impact to quality of life for the residents of these communities as well as to visitors of Glacier National Park due to this increased traffic would include noise, dust, and congestion (truck traffic or delays from railroad crossings) above and beyond the significant seasonal increases. During previous demolition activities at the Site, CFAC received complaints from the community. It should be emphasized that in comparison to those activities, excavation of the Landfills DU1 waste management units with offsite disposal would be significantly more disruptive for a longer period of multiple years; for reference, the SPL removal activities completed during demolition involved the transport of approximately 4 truckloads offsite per day (on average) over the course of one year, while removal of the Landfills DU1 wastes would require an estimated 70 truckloads offsite per day during an 8-month construction season over the course of approximately 4 to 5 years.

Health and safety are also substantial concerns with this process option as movement of material at this scale has statistically resulted in numerous incidents. Risk of traffic accidents during transportation increases the likelihood of injuries and inadvertent contaminant releases. The potential for releases during transport and the risk associated with such releases would be much greater than for other process options as they are directly proportional to the quantity of transported waste and the travel distance between the Site and the disposal facility. Further, the route from the Site to the nearest SPL disposal facility traverses approximately 130 miles of two-lane road before reaching the interstate; these roads are often well traveled during the tourist season (which overlaps the construction season), increasing the risk of traffic accidents. In addition, the route runs near the Flathead River and alongside the Flathead Lake for tens of miles, worsening the adverse effects a potential release would cause.

The health and safety risks for the workers involved with the loading, transporting, and unloading of the waste are also proportional to these metrics, and as such would also be expected to be significant. As an example, if the excavated waste material were to be transported to the nearest operational RCRA Subtitle C landfill exclusively by truck, the expected magnitude of persons injured as a result of transportation alone would be 35 persons, including at least one fatality.[12] This does not include loading or unloading the material, which may result in heavy equipment related injuries. Although the SPL-containing material would likely be transported primarily by rail, this statistic is presented to illustrate the potential risk associated with transporting such large volumes of material.

The costs associated with offsite disposal are generally high because of disposal fees and transportation costs to the facility. These costs increase nearly linearly as the volumes of waste increase. Due to the large volumes of waste that would be generated from excavating the Landfills DU1 waste management units, much of which would be listed hazardous waste, offsite disposal would be prohibitively expensive.

In summary, offsite disposal would negatively impact neighborhoods (both local and remote) and the environment over a significant period of time while also increasing the potential for traffic accidents, injuries, and inadvertent contaminant releases during transport. Other process options that have been retained for the Landfills DU1 are capable of achieving similar effectiveness as this process option without the adverse effects associated with offsite disposal discussed above. Therefore, excavation with offsite disposal for the Landfills DU1 has been screened from further consideration.

4.3.2 Landfills DU2

The waste management units comprising the Landfills DU2 are each described in Section 2.1.4.1. The nature of the wastes and status of existing caps for each waste management unit is summarized in Section 2.3.2. For each applicable GRA identified in Section 4.1, various remedial technologies with corresponding process options were identified for the Landfills DU2 and screened using the criteria and methodology discussed in Section 4.2. Detailed analyses of each technology and process option are discussed below and presented in Table 4-2. The figure below summarizes the technologies and process options screened, as well as whether it was eliminated or retained for further evaluation.

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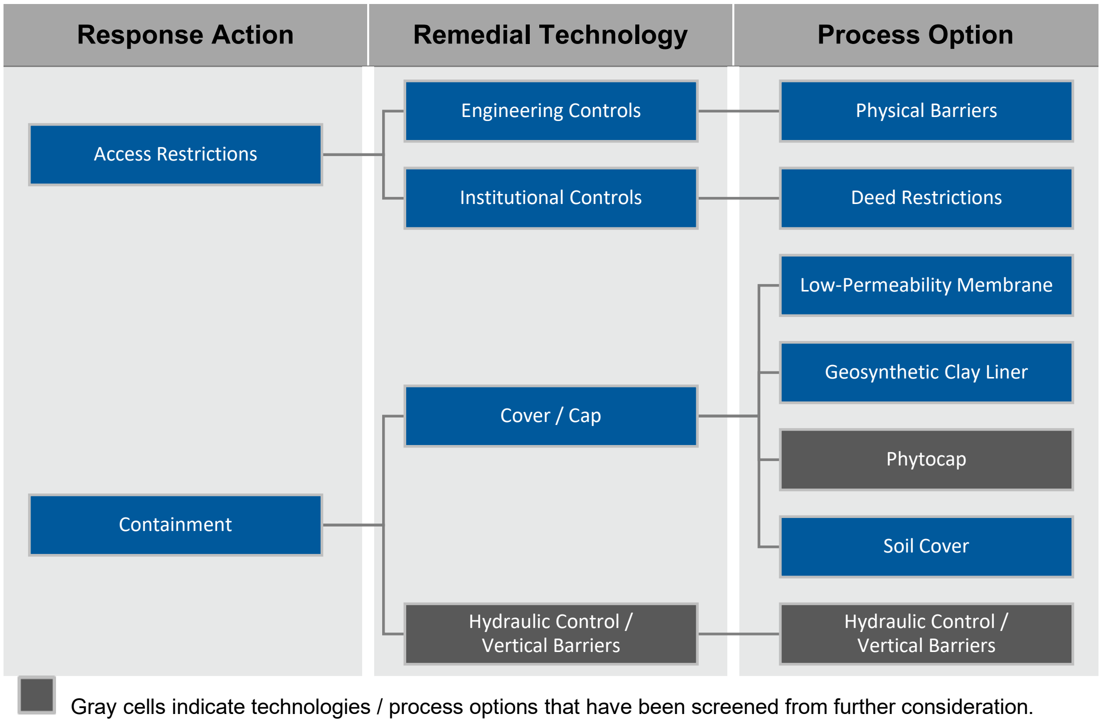
12 Based on 2017 trucking statistics provided by the Federal Motor Carrier Safety Administration (FMCSA). Large Truck and Bus Crash Facts 2017, Chapter 1, Trends Table 7. Large Truck Injury Crash Statistics, 1997-2017.



Access Restrictions

ICs and ECs discussed for the Landfills DU1 are also applicable to and retained for further consideration for the Landfills DU2.

Containment – Engineered Covers / Caps

Low-Permeability Membranes

Low-permeability membranes are described for the Landfills DU1 above. They have been retained for further consideration for the Industrial Landfill.

GCLs

GCLs are described for the Landfills DU1 above. They have been retained for further consideration for the Industrial Landfill.

Phytocaps

As discussed above, phytocaps are more sensitive to location, soil type, and climate than their more traditional landfill cap counterparts. Therefore, phytocaps have been screened from further consideration for the Landfills DU2.

Soil Covers

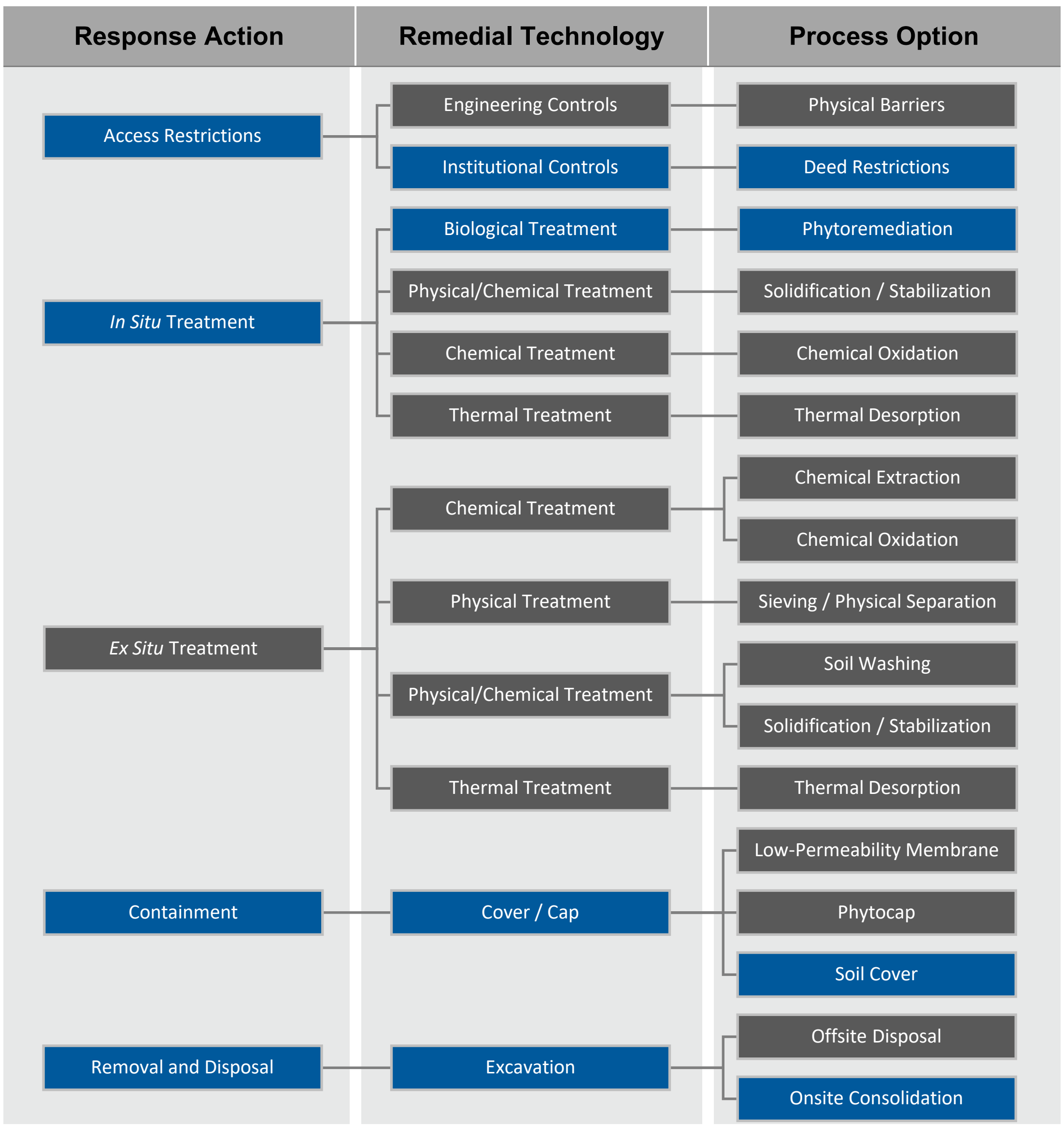
As discussed above, soil covers prevent direct contact exposure to underlying impacted solid media, protect against erosion, and decrease percolation. As the results of the RI Report indicate that the landfills in the Landfills DU2 are not contributing sources of groundwater contamination at the Site, a soil cover would provide adequate containment to prevent contact with impacted solid media in several of the landfills. Soil covers are retained for further consideration for the Asbestos Landfills.

Containment – Vertical Barriers

Since the results of the RI Report indicate that the landfills in the Landfills DU2 are not contributing sources of groundwater contamination at the Site, vertical barriers are not necessary or appropriate. Therefore, vertical barriers for the Landfills DU2 have been screened from further consideration.

4.3.3 Soil DU

For each GRA identified in Section 4.1, various remedial technologies with corresponding process options were identified for the Soil DU and screened using the criteria and methodology discussed in Section 4.2. Detailed analyses of each technology and process option are discussed below and presented in Table 4-3. The figure below summarizes the technologies and process options screened, as well as whether it was eliminated or retained for further evaluation.



Gray cells indicate technologies / process options that have been screened from further consideration.

Access Restrictions

ICs discussed for the Landfills DU1 are also applicable to and retained for further consideration for the Soil DU. While existing Site-wide fencing will help protect compliant human receptors from exposure to impacted soils, ECs restricting access specific to the Soil DU would not provide additional effectiveness and are therefore not retained for further consideration.

In Situ Treatment

Phytoremediation

Phytoremediation uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil. There are several types of phytoremediation, including rhizodegradation and phytostabilization. In the rhizodegradation process, the biodegradation of organic contaminants such as PAHs in the rhizosphere (area of soil surrounding the roots of the plants) is enhanced by the release of natural substances from the plant roots. Phytostabilization immobilizes contaminants such as metals at the interface of roots and soil using chemical compounds produced by plant.

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils; the typical range of effectiveness for phytoremediation groundcovers is 1 to 2 ft-bls. The groundcover also reduces erosion or migration of contaminants in shallow soils. As the Soil DU contains low to moderate concentrations of PAHs and metals in surficial and shallow soil (0-0.5 and 0.5-2 ft-bls, respectively), phytoremediation has been retained for further consideration for the Soil DU.

Solidification/ Stabilization

Solidification refers to techniques that encapsulate the waste, forming a solid material with high structural integrity such as a monolithic block, a clay-like material, or a granular particulate. The contaminants do not necessarily interact chemically with the solidification reagents but are mechanically locked within the solidified matrix. This treatment method does not destroy contaminants and often increases the volume of impacted material.

Stabilization refers to techniques that chemically reduce the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms. The physical nature and handling characteristics of the waste are not necessarily changed by stabilization. Methods involving combinations of solidification and stabilization are often used.

Both of these technologies are effective for treating metals in solids but are not effective for treating PAHs. These technologies are more often used for treatment of sludge-like material or material with high waste characteristics. These technologies do not provide a better effectiveness compared to more proven and easily implemented technologies (e.g., soil cover). Therefore, both solidification and stabilization for the Soil DU has been screened from further consideration.

Chemical Oxidation

The addition of chemical oxidants destroys contaminants by converting them into innocuous compounds. Typical chemical oxidants include permanganate, hydrogen peroxide/ Fenton's reagent (hydrogen peroxide catalyzed with iron), ozone, and persulfate. Oxidizing agents are non-specific and will react with any naturally occurring organic matter present; organics in soil can greatly increase the oxidant demand, require greater amounts of reagent. Although potentially effective for PAHs, oxidants are more commonly applied to address volatile organic compounds (VOCs) in soil and groundwater. Further, use of chemical oxidants could potentially mobilize metals (e.g., mobilization of arsenic, chromium, and copper from use of alkaline-activated persulfate; mobilization of chromium, copper, nickel, and/or zinc from use of iron-activated hydrogen peroxide or sodium persulfate). For these reasons, chemical oxidation for the Soil DU has been screened from further consideration.

Thermal Desorption

Low temperature thermal desorption (LTTD) systems heat impacted solid media to between 90 and 320 degrees Celsius (°C) to volatilize organic contaminants such as PAHs. Water is also volatilized, increasing the treatment residence time as moisture content increases and making the process ineffective in saturated soils. A carrier gas or vacuum system transports volatilized water and organics to a gas treatment system. The bed temperature and residence times of the system will volatilize selected contaminants but will not typically oxidize them. Decontaminated soil treated by LTTD retains its physical properties and ability to support biological activity.

Thermal desorption is an effective, proven technology for the treatment of PAHs in unsaturated soil. However, *in situ* thermal desorption is a very expensive technology to implement; other process options that would provide similar effectiveness at lesser cost have been retained. Therefore, *in situ* thermal desorption has been screened from further consideration for the Soil DU.

***Ex Situ* Treatment**

Ex situ treatment refers to the process of transforming, destroying, or detoxifying contaminants in excavated materials. Potential *ex situ* treatment options include chemical oxidation, solidification/ stabilization, and thermal desorption, which implement methods similar to those described above for their *in situ* counterparts. Additional potential *ex situ* treatment options include chemical extraction, soil washing, and sieving / physical separation. Chemical extraction and soil washing separate contaminants from soils using an extracting chemical solvent or wash solution. These methods are often performed after physical separation of the fine soil fraction from the bulk soil, concentrating the contaminated soils into a smaller volume through particle size separation (i.e., using different size sieves and screens).

Use of *ex situ* treatment technologies are generally high cost; there are several other GRAs that are highly effective for the COCs in the Soil DU and are implementable at lesser costs. Therefore, none of these options are retained for further consideration for the Soil DU.

Containment – Engineered Covers / Caps

Low-Permeability Membranes

Low-permeability membranes are described for the Landfills DU1 above. In the Soil DU, risk is driven by direct contact with impacted solid media, and there are other process options (e.g., soil covers) that are equally effective at reducing this risk, which can be implemented for a lesser cost. Therefore, low-permeability membranes for the Soil DU have been screened from further consideration.

Phytocaps

Phytocaps are described for the Landfills DU1 above. For reasons similar to those presented for low-permeability membranes above, phytocaps for the Soil DU have been screened from further consideration. Phytoremediation, an *in situ* treatment process option, was retained for the Soil DU above.

Soil Covers

Soil covers are described for the Landfills DU1 and Landfills DU2 above. In the Soil DU, a soil cover would provide adequate containment to prevent contact with impacted solid media. Therefore, soil covers are retained for further consideration for select areas of spatially concentrated COC distribution within the Soil DU.

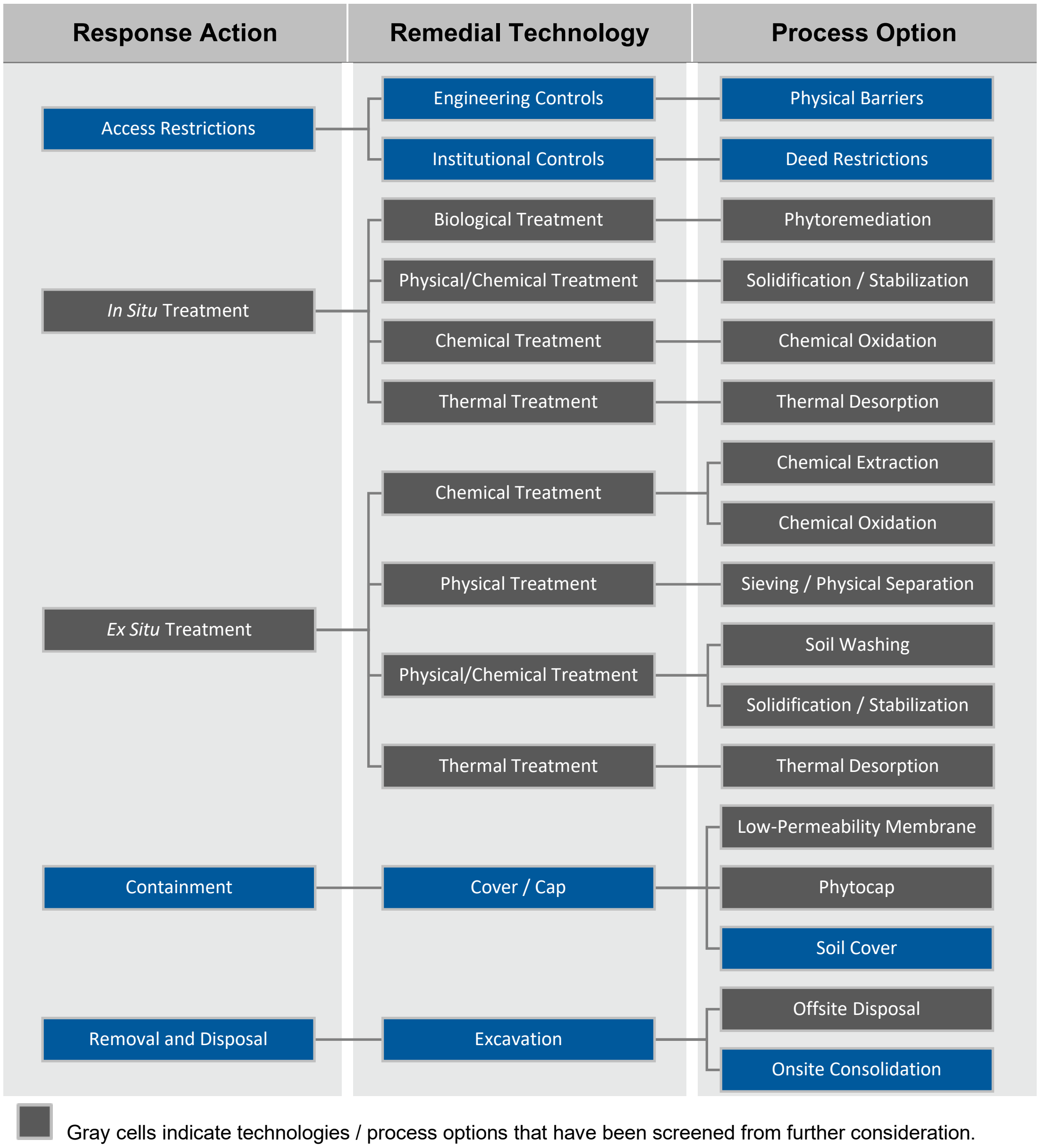
Removal and Disposal – Excavation

Impacted soils can be effectively removed by excavation using an excavator, backhoe, or other conventional earthmoving equipment. For surficial and shallow soil, this GRA has the advantage of providing the greatest removal of contaminants from a site. As a proven method of removing contaminated surface and subsurface materials, excavation is retained for further consideration for the Soil DU.

Due to the proximity of the Site to disposal outlets, transport of the excavated material would require long travel distances and the corresponding expenses. Since the Site has several viable locations for onsite consolidation, onsite consolidation is the process option retained for further consideration for the Soil DU.

4.3.4 North Percolation Pond DU

For each GRA identified in Section 4.1, various remedial technologies with corresponding process options were identified for the North Percolation Pond DU and screened using the criteria and methodology discussed in Section 4.2. Detailed analyses of each technology and process option are discussed below and presented in Table 4-4. The figure below summarizes the technologies and process options screened, as well as whether it was eliminated or retained for further evaluation.



Access Restrictions

ICs and ECs discussed for the Landfills DU1 are also applicable to and retained for further consideration for the North Percolation Pond DU.

In Situ Treatment

Phytoremediation

Phytoremediation is described for the Soil DU above. The high concentrations of PAHs and presence of viscous waste in the North Percolation Pond DU are not suitable for vegetation to establish root growth, therefore, phytoremediation for the North Percolation Pond DU has been screened from further consideration.

Solidification/ Stabilization

Solidification and stabilization is described for the Soil DU above. These process options would effectively treat metals in the North Percolation Pond soil/sediment, but a separate technology would be necessary to address PAHs.

These technologies do not provide a better effectiveness compared to more proven and easily implemented technologies (e.g., soil cover). Therefore, solidification and stabilization as the primary remedial mechanism for the North Percolation Pond DU has been screened from further consideration. Viscous, carbonaceous material may require physical solidification to support a cover/cap.

Chemical Oxidation

Chemical oxidation is described for the Soil DU above. Due to the elevated concentrations of PAHs and the presence of other organics in the impacted material, the oxidant demand would likely be very high. In addition, metals present in the impacted material that are already at elevated concentrations may be mobilized. Another process option would also be required as part of a treatment train since chemical oxidation would not address all the COCs present in the North Percolation Pond DU. Therefore, chemical oxidation for the North Percolation Pond DU has been screened from further consideration.

Thermal Desorption

Thermal desorption is described for the Soil DU above. Similar to chemical oxidation above, another process option would also be required as part of a treatment train since thermal desorption would not address all the COCs present in the North Percolation Pond DU. Therefore, thermal desorption for the North Percolation Pond DU has been screened from further consideration.

***Ex Situ* Treatment**

Ex situ treatment process options are described for the Soil DU above. For reasons similar to those presented for the Soil DU, none of these options are retained for further consideration for the North Percolation Pond DU.

Containment – Engineered Covers / Caps

Engineered covers / caps are described for the Landfills DU1 above. In the North Percolation Pond DU, a soil cover would provide adequate containment to prevent contact with impacted solid media. Therefore, soil covers are retained for further consideration for the North Percolation Pond DU.

For reasons similar to those presented for the Soil DU, low-permeability membranes and phytocaps for the North Percolation Pond DU have been screened from further consideration.

Removal and Disposal – Excavation

Excavation is described for the Soil DU above. For reasons similar to those presented for the Soil DU, excavation with onsite consolidation is retained for further consideration for the North Percolation Pond DU.

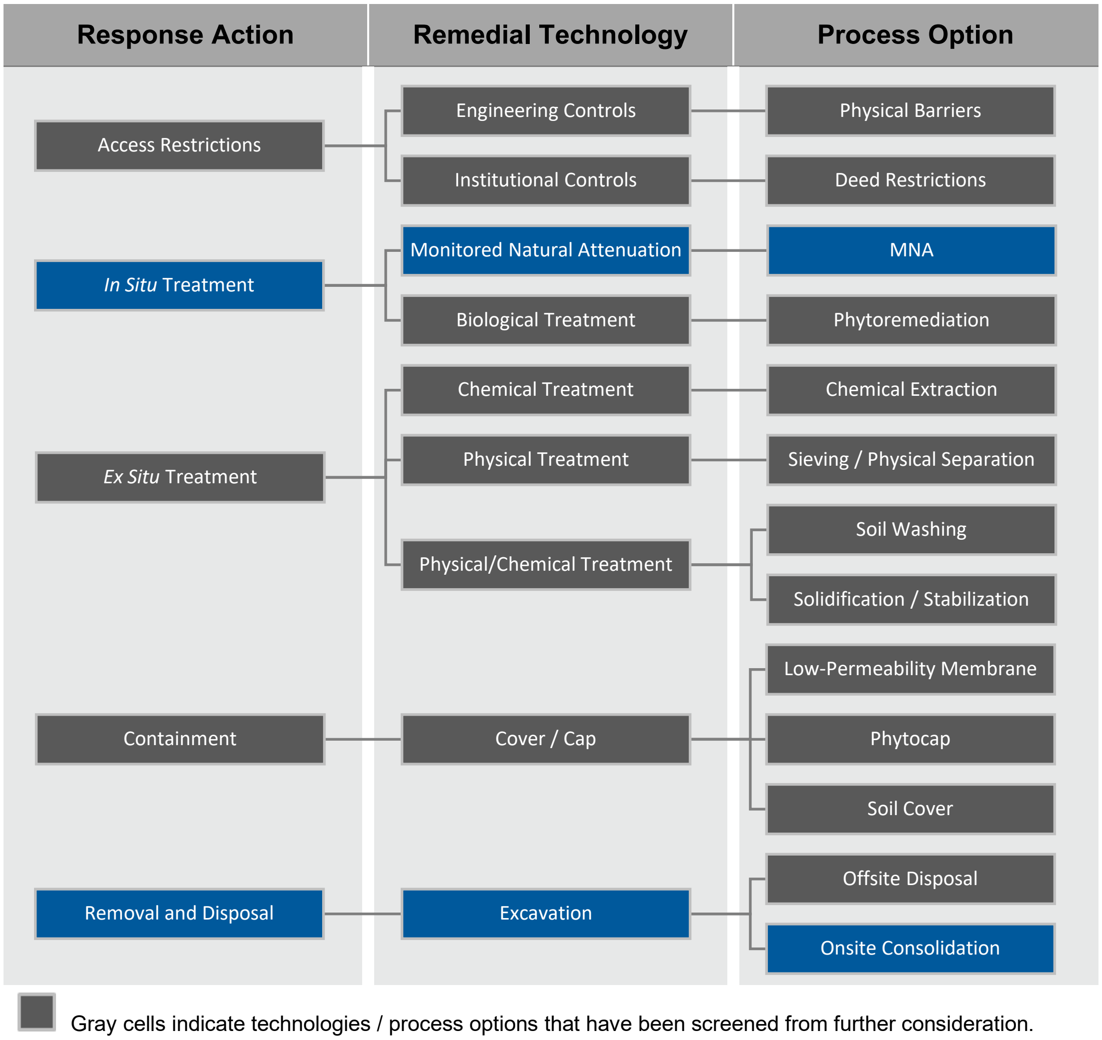
4.3.5 River Area DU

As discussed in Sections 2.3.5 and 3.3.5, the potential risk attributed to cyanide in sediment, sediment porewater, and surface water in the River Area DU will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Alternatives addressing groundwater inputs will be assessed within the Groundwater DU. Therefore, the technologies screened for remedial action in the River Area DU focus on mitigating ecological risk of COCs in soil/sediment.

To remediate contaminated sediments contained within the South Percolation Ponds, a Removal Action at the South Percolation Ponds was performed in accordance with the requirements of the Administrative Order on Consent effective July 21, 2020 (see Section 2.3.5). Following successful completion of the Removal Action, cyanide is the only COC remaining in the River Area DU.

For each GRA identified in Section 4.1, various remedial technologies with corresponding process options were identified for the River Area DU prior to execution of the Administrative Order on Consent encompassing the Removal Action at the South Percolation Ponds. These process options were screened using the criteria and methodology discussed in Section 4.2 in the draft Technology Screening Technical Memorandum dated May 13, 2020; detailed analyses of each technology and process option to address COCs in soil/sediment in the River Area DU were discussed in this draft memorandum, and Table 4-5 of this FS Report presents these prior analyses. Given that the Removal Action addressed contaminated sediments within the South Percolation Ponds (the only feature within the River Area DU that contained sediments with COCs at concentrations exceeding PRGs; see Section 3.4.5), many of these technologies and process options are no longer pertinent to the River Area DU and are not evaluated herein.

The figure below summarizes the technologies and process options screened prior to execution of the Removal Action Administrative Order on Consent, as well as whether it was eliminated or retained for further evaluation.



Access Restrictions

The River Area DU does not pose human health risks; the ICs and ECs discussed for the Landfills DU1 would not protect ecological receptors and are screened from further consideration for the River Area DU.

In Situ Treatment

Monitored Natural Attenuation (MNA)

MNA relies on natural mechanisms including a variety of physical (adsorption, dilution, dispersion, diffusion, volatilization), chemical (transformation or degradation), and/or biological (biodegradation) processes within subsurface materials that, under favorable conditions, reduce contaminant concentrations. There is no intervention to manipulate the physical, geochemical, or hydrological regime to improve attenuation. Comprehensive long-term monitoring would be conducted to evaluate and verify the progress of MNA. This process option is technically and administratively feasible; therefore, MNA is retained for further consideration for the River Area DU.

Phytoremediation

Phytoremediation is described for the Soil DU above. Various studies have been conducted for phytoremediation of cyanide in soils/sediment, including flooded soils. However, due to the location and terrain of the River Area DU alongside the Flathead River, the tendency for this area to flood during seasonal high waters, and the potential for the Flathead River to re-capture its historic side channel in the near future as a result of lateral migration of the main river stem, phytoremediation in the River Area DU may not be feasible. In addition, phytoremediation is not a favorable process option in the River Area DU due to the potential sensitivity to erosive forces and climate as well as the likely need for regular maintenance in an area where access is limited. Therefore, phytoremediation has been screened from further consideration for the River Area DU.

***Ex Situ* Treatment**

Ex situ treatment process options are described for the Soil DU above. Given that contaminated sediments were remediated under the Removal Action at the South Percolation Ponds, none of these options are retained for further consideration for the River Area DU.

Containment – Engineered Covers / Caps

Engineered covers / caps are described for the Landfills DU1 above. Given that contaminated sediments were remediated under the Removal Action at the South Percolation Ponds and that capping waste within the River Area DU would violate solid waste and floodplain ARARs, none of these options are retained for further consideration for the River Area DU.

Removal and Disposal – Excavation

Excavation is described for the Soil DU above. Excavation of sediments exceeding PRGs in the South Percolation Ponds under the Removal Action will prevent direct contact exposure of ecological receptors, prevent transport of the contaminated media away from the DU, and allow for re-establishment of a benthic community in the underlying, unimpacted sediments. Since excavation of contaminated sediments contained within the South Percolation Ponds was the objective of the Removal Action, this process option is retained for incorporation into the River Area DU remedial action alternatives.

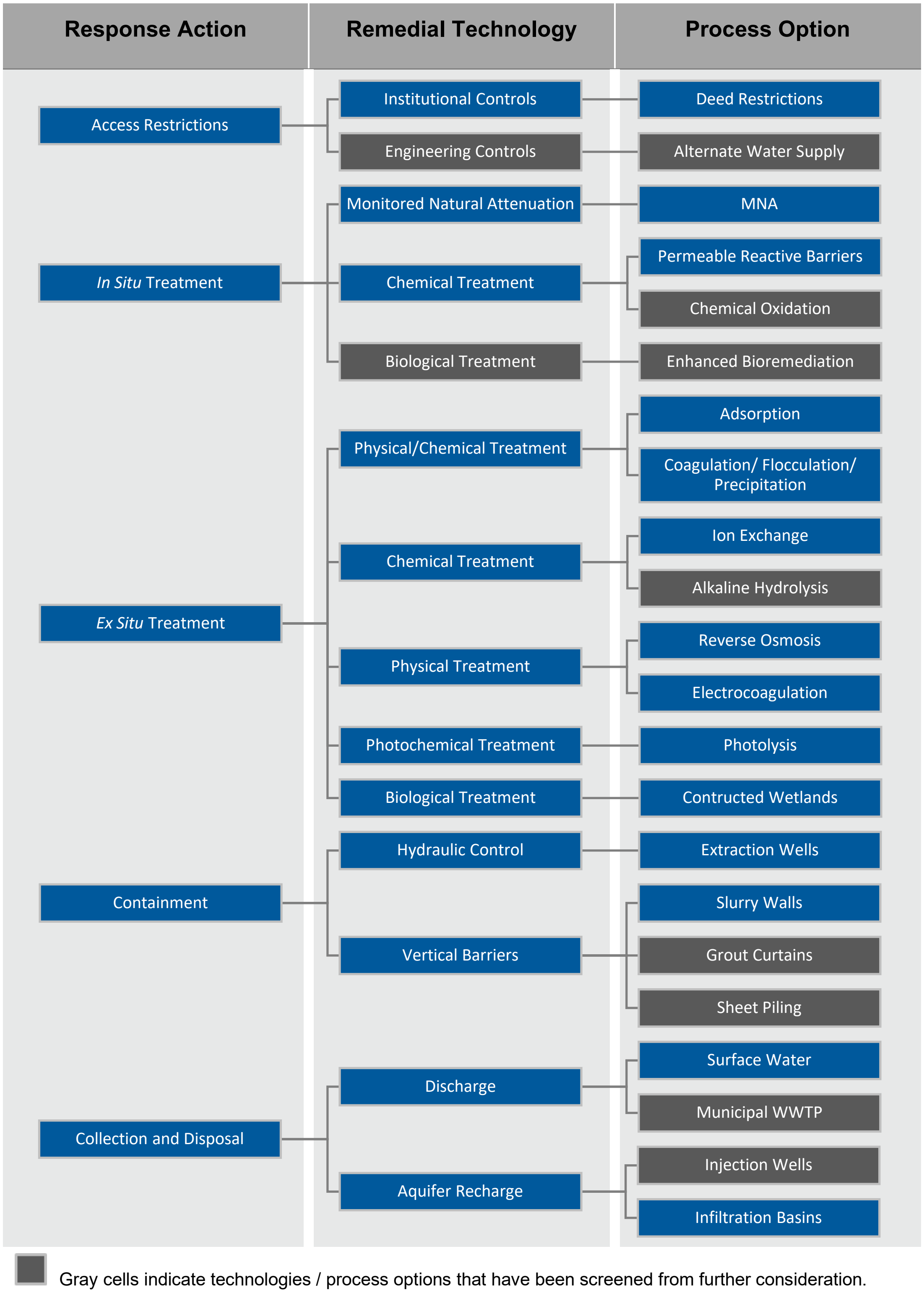
4.3.6 Groundwater DU

Groundwater is retained for further evaluation in the FS because of the potential human health risks associated with the hypothetical drinking water scenario assessed in the BHHRA and the exceedance of groundwater ARARs, as well as discharge of groundwater to the River Area DU resulting in potential ecological risk and exceedances of surface water ARARs. To address the groundwater contamination, various remedial technologies with corresponding process options were identified and screened. For most of these technologies, the scenario assessed includes implementation immediately downgradient of the Landfills DU1 where concentrations of cyanide, fluoride, and arsenic within the upper hydrogeologic unit are highest. By treating or containing the groundwater at the source, better effectiveness and efficiency could be achieved. The depths of the plume in this area extend from the water table, ranging from approximately 36 to 105 ft-bls (seasonal) with a typical range between 50 and 80 ft-bls, to the top of the glacial till (i.e., the top of the below upper hydrogeologic unit) encountered at approximately 120 to 150 ft-bls.

To address the potential ecological risk and exceedances of surface water ARARs in the River Area DU, some of these technologies were also assessed under an implementation scenario immediately upgradient of the River Area DU (just north of the Burlington Northern Railroad). As discussed in Section 2.3.5 above, the discharge of groundwater at the Seep Area is the primary source of cyanide in the River Area DU, where cyanide (total and/or free) is an identified COC in sediment, sediment porewater, and surface water. The depths of the cyanide plume in this area extend from the water table, approximately 50 to 80 ft-bls (seasonal), to the top of the glacial till encountered at approximately 125 to 200 ft-bls. Therefore, to address the potential risk attributed to cyanide in benthic habitats, various technologies were assessed to treat cyanide and/or contain groundwater immediately upgradient of the River Area DU. Fluoride and arsenic are not identified COCs for any media in the River Area DU and are not present above groundwater PRGs in this area of the Site, and therefore do not need to be treated under this implementation scenario.

Although arsenic is an identified COC for the Groundwater DU, it is noted that arsenic was detected above the PRG in only a total of four monitoring wells during all six rounds of sampling during the RI; only one of these four monitoring wells exceeded the PRG in each of the six sampling rounds (FSWP Table 4-11). Arsenic concentrations generally decrease to below PRGs within the portion of the Site north of the former Main Plant likely due to various natural attenuation processes, therefore the effectiveness of arsenic removal was not evaluated for the various *in situ* treatment technologies screened within this FS. The effectiveness of arsenic removal was, however, evaluated for *ex situ* treatment technologies implemented immediately downgradient of Landfills DU1 since the arsenic-containing groundwater would be extracted prior to reduction of concentrations below PRGs from natural attenuation processes and would require treatment for arsenic removal prior to discharge/disposal.

Each GRA, remedial technology, and process option identified for the Groundwater DU was screened using the criteria and methodology discussed in Section 4.2. Detailed analyses of each technology and process option are discussed below and presented in Table 4-6. The figure below summarizes the technologies and process options screened, as well as whether it was eliminated or retained for further evaluation.



Response Action
Remedial Technology
Process Option
Access Restrictions
Institutional Controls
Deed Restrictions
Engineering Controls
Alternate Water Supply
Monitored Natural Attenuation
MNA
In Situ Treatment
Chemical Treatment
Permeable Reactive Barriers
Chemical Oxidation
Biological Treatment
Enhanced Bioremediation
Physical/Chemical Treatment
Adsorption
Coagulation/ Flocculation/ Precipitation
Chemical Treatment
Ion Exchange
Alkaline Hydrolysis
Ex Situ Treatment
Physical Treatment
Reverse Osmosis
Electrocoagulation
Photochemical Treatment
Photolysis
Biological Treatment
Contructed Wetlands
Hydraulic Control
Extraction Wells
Containment
Vertical Barriers
Slurry Walls
Grout Curtains
Sheet Piling
Discharge
Surface Water
Municipal WWTP
Collection and Disposal
Aquifer Recharge
Injection Wells
Infiltration Basins
Gray cells indicate technologies / process options that have been screened from further consideration.

Access Restrictions

Institutional Controls

ICs are legal or administrative measures/restrictions placed to prevent or minimize human exposure to impacted groundwater at the Site. ICs to restrict land and groundwater use include deed restrictions to prohibit the use of groundwater for water supplies and/or consumption. Groundwater ICs could also include, subject to Montana Department of Natural Resources (MDNR) approval, designation of the groundwater within the plume extent as a Controlled Ground Water Area pursuant to Montana Code Annotated (MCA) 85-2-506 to prevent potable use of the contaminated groundwater.

More than one IC would likely be implemented together to enhance the remedy. Typically, ICs would be implemented in conjunction with other remedial components. ICs are effective at protecting compliant human receptors from exposure to contaminated groundwater, are easy to implement, and can be implemented at relatively low costs. Therefore, they have been retained for further consideration.

Alternate Water Supply

The objective of this process option would be to provide an alternate water supply to any receptors that use groundwater as their primary source of drinking water in the event their groundwater well was impacted by Site-related contamination. Groundwater is the primary source of drinking water for the residential community referred to as Aluminum City located immediately west of the Site.

The results of Aluminum City residential well monitoring conducted at least semiannually since 2013 have shown that impacted groundwater has not migrated beneath the residential areas. In addition, the Site groundwater monitoring data has demonstrated that contaminated groundwater is migrating toward the Flathead River, not towards the Aluminum City neighborhood.

Bottled water is currently used to provide potable water to the Site, and CFAC intends to continue providing such to meet its needs. In the event of future redevelopment of the Site, an alternate water supply for the Site may be needed. However, such alternative water supply would be best evaluated as part of the redevelopment process. Therefore, this response action has been eliminated from further consideration.

In Situ Treatment Technologies

In situ treatment technologies are used to reduce contaminant concentrations in place without removal or containment of groundwater. Many *in situ* options are typically applied at source areas or areas where contaminant concentrations are very high. However, some *in situ* treatment alternatives such as a permeable reactive barrier can also be applied at areas of lower contaminant concentrations.

Monitored Natural Attenuation

This process option relies on natural mechanisms including a variety of physical (adsorption, dilution, dispersion, diffusion, volatilization), chemical (transformation or degradation), and/or biological (biodegradation) processes within subsurface materials that, under favorable conditions, reduce contaminant concentrations in groundwater. There is no intervention to manipulate the physical, geochemical, or hydrological regime to improve attenuation. Comprehensive long-term groundwater quality monitoring would be conducted to evaluate and verify the progress of MNA. Groundwater samples would be collected from select wells and analyzed quarterly to confirm stable or improving conditions, or alert stakeholders if conditions were worsening. Natural attenuation of the groundwater COCs is likely occurring as evidenced by the decreasing concentrations of cyanide, fluoride, and arsenic with increasing distance away from the Landfills DU1. This response action has been retained for further consideration.

Permeable Reactive Barriers (PRBs)

PRBs are passive below-grade walls containing an engineered treatment zone with chemically active material that reacts with groundwater contaminants as they pass through the permeable barrier. The treatment zone would be placed in the aquifer perpendicular to the direction of groundwater flow, allowing the impacted groundwater in the upper hydrogeologic unit to flow through the strategically placed PRB. At this Site, a PRB would be installed immediately downgradient of the Landfills DU1 to capture the highest concentrations of the COCs from the source areas, or slightly upgradient of the River Area DU to intercept the cyanide plume prior to groundwater discharge at the Seep. The contaminants would be either retained or degraded within the reactive wall.

In either area, all or portions of the PRB would likely need to be installed as a “hanging” wall, which is less effective than a PRB that is keyed into an aquitard. While the top of the below upper hydrogeologic unit (i.e., the glacial till) is a lower permeability zone that serves as aquitard at the Site, the typical depth to this stratum is 120 to 150 ft-bls near the Landfills DU1 and 150 to over 200 ft-bls near the River Area DU, which is deeper than the practical depth for PRB installation.

One PRB option to address fluoride is a calcite barrier wall. Without additional amendments, a calcite barrier near the Landfills DU1 area, where groundwater has been observed to be highly alkaline with pH greater than 9, would have low to moderate effectiveness for fluoride removal. However, fluoride removal would increase with decreasing pH; pH regulation by addition/injection of carbon dioxide directly into the barrier would optimize barrier performance (Turner et al., 2007; Turner et al., 2014).

To address cyanide, a PRB option would contain a mixture of sand and elemental iron filings (e.g., zero-valent iron, or ZVI). Upon contact with water, corrosion of the elemental iron filings produces iron ions. In the presence of complexed or free cyanide, the iron ions are consumed by the cyanide to form precipitation products. By removing iron ions from solution via iron cyanide precipitation, the continued production of iron ions is promoted until consumption of the elemental iron filings is complete. If the elemental iron is completely consumed prior to the attainment of cyanide PRGs for groundwater, additional elemental iron would need to be introduced into the PRB for continued cyanide precipitation. Bench scale testing of these mechanisms indicates that *in situ* precipitation is a potential passive treatment approach for cyanide-contaminated groundwater by arresting the migration of cyanide plumes in the subsurface (Ghosh et al., 1999).

The presence of both cyanide and fluoride downgradient of the Landfills DU1 makes selection of a PRB in this area difficult as one type of treatment barrier would likely not be effective for both COCs. However, immediately upgradient of the River Area DU, cyanide is the only COC in groundwater. An iron PRB for cyanide removal could be installed as a hanging wall in the upper hydrogeologic unit upgradient of the River Area DU, which would effectively arrest the cyanide plume migrating toward the Seep. Therefore, the PRB process option specific to cyanide removal near the River Area DU has been retained for further evaluation.

Chemical Oxidation

In situ chemical oxidation (ISCO) involves delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants into innocuous end products. The appropriateness of ISCO technology at a site depends on matching the oxidant and delivery system to the site contaminants and site conditions. The oxidizing agents most commonly used for cyanide treatment are chlorine, hypochlorite, ozone, and hydrogen peroxide (Dzombak et al., 2005). None of these processes have been used for aluminum industry wastewater at a commercial scale for a variety of technical, economic, and environmental reasons.

ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration end points. The large area and depth of contamination would require a highly concentrated grid of multi-depth injection points within the plume footprint to achieve RAOs. In addition, ISCO is not effective for treatment of fluoride. Therefore, this technology will not be retained for further evaluation.

Enhanced Bioremediation

Enhanced bioremediation manipulates physical, chemical, and biological conditions of a contaminant plume to accelerate contaminant removal through the natural biodegradation and mineralization processes. Biodegradation is the process whereby microorganisms alter the structure of chemicals, while mineralization is the complete biodegradation of chemicals to carbon dioxide, water, and simple inorganic compounds. Biostimulation, bioaugmentation, and *in situ* adsorption are processes used to enhance the rate of biodegradation and mineralization.

Many groups of microorganisms can transform simple or complex cyanide compounds including bacteria, fungi, and algae. Cyanide is used as a nutrient by microbes for their growth, acting as a nitrogen source (Razanamahandry et al., 2017). Some microbes are able to use cyanide as both a carbon and nitrogen source. The ease of degradation of cyanides depends on their form and chemical stability. Free cyanide is the most readily degradable, followed by weak metal-cyanide complexes then strong metal-cyanide complexes. Common examples of weak metal-cyanide complexes include cyanide complexed with copper, zinc, nickel, cadmium, mercury, and silver. Common examples of strong metal-cyanide complexes include cyanide complexed with iron (ferrocyanide and ferricyanide), gold, cobalt, and platinum (Dzombak et al., 2005). *In situ* biological treatments are potentially effective for free cyanide but much less effective for complexed cyanide; they are not effective for fluoride contamination in the subsurface. In addition, degradation of the contaminants may be incomplete even with a high density of injection points. Therefore, this technology will not be retained for further evaluation.

***Ex Situ* Treatment Technologies**

Ex situ treatment GRAs are typically paired with groundwater extraction, collectively referred to as “pump and treat”. Groundwater extraction is further discussed under the Containment GRA Hydraulic Control process option below.

An *ex situ* treatment system may consist of a single treatment process or several treatment processes to remove different contaminants. Extracted groundwater could be pumped directly to the treatment system or into a holding tank to await treatment. Several potentially viable *ex situ* treatment technologies were identified for this Site including chemical, physical, biological, and photochemical processes.

Adsorption

In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase. Adsorption mechanisms are generally categorized as either physical adsorption, chemisorption, or electrostatic adsorption. Weak molecular forces provide the driving force for physical adsorption, while a chemical reaction forms a chemical bond between the compound and the surface of the solid in chemisorption. Electrostatic adsorption is evaluated in the Ion Exchange process option below.

The most common adsorbent is granular activated carbon (GAC), which is effective in removing cyanide but not fluoride or arsenic. One common adsorbent that would be highly effective for fluoride and arsenic removal is activated alumina. Activated alumina is a filter media made by treating aluminum ore so that it becomes porous and highly adsorptive. The medium requires periodic cleaning with an appropriate regenerant such as alum or acid in order to remain effective. The optimum pH for arsenic removal is between 5 and 6 so pre-treatment to decrease pH of the groundwater may be necessary.

Treatment of fluoride and arsenic via adsorption could be implemented within a traditional *ex situ* treatment system or within a constructed treatment wetland (see process option below). Adsorption is a viable, proven technology and is retained for further consideration.

Coagulation/ Flocculation/ Precipitation

This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation.

Precipitation of cyanide in the form of iron cyanide solids involves reaction of dissolved free or iron-complexed cyanide with excess dissolved iron (Ghosh et al., 1999). This could be achieved by adding ferrous and ferric salts to the treatment system such as ferrous sulfate and ferric chloride. The process would reduce the total cyanide content to approximately 1,000 to 3,000 ug/L which may be suitable as an initial step in a treatment train. Additional cyanide removal could be achieved by reducing the pH below 7; cyanide removal would continue to increase with decreasing pH until a pH of approximately 4 (Meeussen et al., 1992). Reducing the pH to increase cyanide removal may pose safety risks, which would be mitigated by adherence to the Site-specific Health and Safety Plan (HASP) and use of personal protective equipment (PPE).

There is also evidence that arsenic would be removed during coagulation with ferric chloride or adsorption onto preformed hydrous ferric oxide (Hering et al., 1996). The precipitates would be separated from the water by aeration and flocculation in a clarifier and subsequently dewatered to form a sludge that could be handled as a solid and disposed of in a landfill. Treated water leaving the filter would be discharged via one of the discharge/ disposal GRAs described below.

Conventional fluoride precipitation could be achieved through coagulation, flocculation, and settling steps. Extracted groundwater would be fed through rapid mix tanks, flocculation tanks, settling tanks, and sand filters. The cheapest and most common way to remove fluoride from groundwater is calcium precipitation by adding excess lime or calcium salts such as calcium chloride to form calcium fluoride. Arsenic would likely coprecipitate via adsorption to various precipitates formed during this treatment process (Renard et a., 2015), but the exact mechanisms would need to be assessed during pre-design activities. Overflow from the settling tanks would then be fed through sand filters to remove fine flocs and suspended solids to prevent well clogging during injection. As cyanide removal must be achieved as a separate treatment process before fluoride precipitation, the sludge produced in this process should not contain cyanides.

Cyanide removal using precipitation is a viable process option and fluoride removal using precipitation has been fully developed and used in a full-scale, continuous process to treat fluoride in aluminum plant wastewater. In addition, arsenic may coprecipitate with one or both of these processes. Therefore, this option is retained for further consideration.

Ion Exchange

Contaminated water passes through a properly conditioned column of ion exchange resin in which ions held electrostatically on the surface of a solid are exchanged for ions of a similar charge in solution. This technology has potential viability for treatment of ferrocyanide, fluoride, and arsenic; however, different ion exchange resins would be required for each COC.

For cyanide removal, the ion exchange process employs a weakly basic ion exchange resin that has high ferrocyanide selectivity. The resin adsorbs ferrocyanide and releases the anion that was formerly bound to the resin (Avery et al., 1975). The ion exchange process could also be employed for removal of fluoride by adsorption onto a strong base anion exchange resin. The most efficient fluoride removal would be achieved at neutral pH (Samadi et al., 2014). Selective removal of arsenic could be achieved using hybridized ion exchange fibers that contain dispersed hydrated ferric oxide nanoparticles (Greenleaf et al., 2006). Once the resin is exhausted, it is regenerated by replacing the adsorbed ions with hydroxide ions from sodium hydroxide. A subsequent replacement of the hydroxide ions with sulfate ions from sulfuric acid completes the regeneration cycle. The removed COCs, in their original but concentrated form, would require disposal. This process option would be extremely effective at removing Site COCs; therefore, this process option is retained for further consideration.

Alkaline Hydrolysis

Iron cyanide complexes may be hydrolyzed under alkaline conditions at elevated temperatures and pressures in the range of 165 to 180 °C and 100 to 150 pounds per square inch gauge (psig), respectively. Destruction of cyanide at high temperature and pressure forms residuals such as ammonia, formate, and ferric oxide. Extracted groundwater would be pumped through sand filters to remove suspended solids which could cause abrasion in the subsequent equipment. The filtered effluent would then be heated in a heat exchange unit and pumped at high pressure through an alkaline hydrolysis vessel.

Alkaline hydrolysis is effective for destruction of cyanide compounds in water with high concentrations of cyanide but is not a commonly used technology. This process is not effective for fluoride or arsenic removal. In addition, this process is associated with a certain degree of risk due to high temperature and high pressure. Therefore, alkaline hydrolysis is not retained for further consideration.

Reverse Osmosis

Reverse osmosis is a pressure-driven membrane separation process capable of removing dissolved COCs from water as a function of molecular size and electrical charge. This technology uses a semipermeable membrane that inhibits the passage of respective dissolved solids but allows water to pass. Feedwater is fed under pressure into the reverse osmosis unit where it is separated by the membrane into a waste brine stream and low-salinity product water. The waste brine stream must then be disposed of. Reverse osmosis only concentrates the contaminants into a smaller liquid stream; it does not destroy them. If this technology was implemented, the waste brine would contain concentrated cyanide, fluoride, and arsenic that would require further treatment or disposal.

This option would be effective in removing all the COCs from extracted groundwater and is therefore retained for further consideration.

Electrocoagulation

Electrocoagulation is a method of applying direct current to sacrificial electrodes that are submerged in an aqueous solution. Electrocoagulation is a relatively new technology that has recently played a more prominent role as an alternative process for defluroridation of drinking water and wastewater treatment. A separate process option(s) would be required for treatment of cyanide and arsenic.

In an electrocoagulation defluroridation system, contaminated groundwater flows through an electrolytic cell containing aluminum or iron/aluminum anodes. As electrical current is applied to the cell, the aluminum electrodes release aluminum ions that react with hydroxide and fluoride to form aluminum-fluoride-hydroxide flocs (aggregation of suspended particles) that are separated from water by coagulation and settling. In the electrocoagulation process, chemical substances are not used during operation, which results in less precipitant formation compared to chemical treatment.

Electrocoagulation is a relatively new technology, but it has been successfully pilot tested for implementation at an NPL site (Kaiser Mead, 2019). Therefore, this technology is retained for further consideration.

Photolysis

The primary removal mechanism of photolysis occurs via sunlight initializing the photodissociation of iron or complexed cyanide. Degradation of cyanides could also be achieved using photo-assisted methods under varied illumination conditions such as simulated solar light or UV light (Mediavilla et al., 2019). In the absence of light, iron cyanide complexes are stable and dissociate very little in groundwater. In the presence of light, the release of free cyanide as a result of photodissociation of cyanide complexes occurs very rapidly. Photolysis of cyanide could be utilized as a primary mechanism for treatment of complexed cyanide in surface flow wetland treatment (see Constructed Wetlands process option below) followed by biodegradation of free or weakly complexed cyanide.

This option is an appropriate technology for photodissociation of ferrocyanide. Photolysis does not affect free cyanide, fluoride, or arsenic, which, if necessary, would have to be removed in a separate treatment step. This option is retained for further consideration.

Constructed Wetlands

Constructed treatment wetlands are defined by USEPA as wastewater treatment systems that rely on physical, chemical, and biological processes typically found in natural wetlands to treat a relatively constant flow of wastewater. Constructed wetlands can either be free-water surface (FWS), also known as surface flow where there is an open water surface above the saturated media, or subsurface flow, where there is no open water surface and the water level is kept below the surface of the media. For FWS constructed wetlands, the depth of surface water does not exceed three feet.

The wetland treatment system would consist of one or more constructed wetland cells lined with low-permeability liners. The media is generally gravel of various sizes in which the pore space provides an environment for microbial and plant growth. Many groups of microorganisms can transform simple or complex cyanide compounds by using it as a nutrient for their growth, including aerobic and anaerobic bacteria, fungi, and algae (Razanamahandry et al., 2017). Aerobic and anaerobic microbe bioreactors and phytoremediation cells would biodegrade and uptake contaminants including free or weakly complexed cyanide in a low energy, continuous flow system (ITRC, 2003).

Constructed treatment wetlands with activated alumina in the cell media have successfully removed fluoride from water by readily forming aluminum fluoride (see Adsorption process option above). Arsenic would also be adsorbed in the presence of activated alumina. In general, constructed wetlands without sorbents in media have shown capability for removing arsenic (Lizama et al., 2011), but it is not a proven process option for this COC. Groundwater treatment utilizing the FWS constructed wetland technology would also benefit from photodissociation of iron cyanide complexes via photolysis (see Photolysis process option above).

The type, number, and sizes of the wetland cells within the constructed wetland would be based on groundwater extraction rates and optimal hydraulic retention time for the Site groundwater chemistry and environmental factors. During winter conditions, the constructed wetland cells would have to be maintained above freezing conditions to maintain the minimum flow rate and removal efficiency required from the system. For this reason, this technology may be better suited for alternatives that only need to run intermittently and/or do not need to be run when the Site is under low-flow conditions (i.e., fall and winter).

Aluminum Company of America (Alcoa) has successfully implemented pilot scale studies in the Northeastern US to evaluate the use of FWS constructed wetlands for the reduction of complexed and free cyanide and associated pollutants from groundwater and is currently utilizing constructed wetlands for cyanide removal. More recently, Kaiser Aluminum Mead Works NPL Site in Washington State has selected constructed wetlands for cyanide and fluoride removal from groundwater as part of the overall Site remedy and performed significant bench-scale testing which is documented in the Design Report (Kaiser Mead, 2019). While pH and the presence/competition of other compounds in the groundwater will need to be evaluated to determine the effectiveness of fluoride and arsenic removal, constructed wetlands are a viable technology for all the COCs in Site groundwater and therefore, this technology is retained for further consideration.

Containment

Containment GRAs are designed to prevent migration of contaminants to existing or potential downgradient receptors. Containment technologies include hydraulic control and several types of vertical barriers. These technologies provide containment by preventing the migration of groundwater from source areas containing elevated concentrations of COCs (i.e., implementation near Landfills DU1) or by preventing migration of groundwater to ecological receptors at the Seep (i.e., implementation upgradient of the River Area DU). Groundwater containment technologies may be designed to capture/ contain the groundwater plume in conjunction with groundwater treatment technologies and/or source area control such as capping of waste management units.

Hydraulic Control

Hydraulic control may be achieved by influencing the direction of groundwater flow with well capture zones created by a series of extraction wells. These extraction wells create points of low hydraulic head to which nearby groundwater flows. By optimizing the locations of the extraction wells and adjusting the groundwater pumping rates, a potentiometric surface can be manipulated to capture contaminated groundwater. The potentiometric surface can also be augmented by reinjection of treated groundwater at strategic locations. This capture zone prevents contaminated groundwater from migrating toward downgradient receptors.

This option would be capable of limiting plume migration from the source area or to a downgradient location within the current plume boundary. The concentration of contaminants in the plume downgradient of the extraction zone would diminish with time due to containment of the plume and the effect of natural attenuation processes.

Groundwater would be recovered by intercepting the plume via a series of extraction wells immediately downgradient of Landfills DU1 where the concentrations of cyanide and fluoride are the highest. An initial conceptual design to maintain hydraulic control in this area would involve installing 15 to 20 extraction wells at an approximate total flow rate of 300 to 400 gallons per minute (gpm). The well capture zones should overlap under various operational conditions, and the number, location, and spacing of the wells would be determined based on aquifer tests and modeling to optimize recovery of the plume. The extracted groundwater would require onsite, *ex situ* treatment followed by discharge/ disposal of treated groundwater.

In addition, groundwater could also be recovered by intercepting the cyanide plume immediately upgradient of the River Area DU. Such a design would intercept the cyanide plume prior to groundwater discharge at the Seep, mitigating potential ecological risk and exceedances of surface water ARARs in the River Area DU. However, at this location the plume is dispersed over a wider area and therefore will likely require more extraction wells with a greater total flow rate and greater associated costs in comparison to intercepting the plume via a series of extraction wells immediately downgradient of Landfills DU1 as described above. Calculations and documentation will be provided in the FS to support the conceptual design of both groundwater extraction scenarios.

This technology is technically feasible and widely used, therefore this process option will be retained for further evaluation both downgradient of the Landfills DU1 as well as upgradient of the River Area DU.

Vertical Barriers

Vertical subsurface barriers are made of a low-permeability material designed to contain or divert groundwater. Vertical engineered barriers (VEBs) can be used to slow and/or redirect groundwater flow thereby minimizing migration of contaminated groundwater, diverting contaminated groundwater from downgradient receptors, and/or enhancing the efficiency of a hydraulic barrier (i.e., groundwater pump and treat system). VEBs would also be effective at preventing infiltration of surface water runoff via lateral subsurface migration of such water through the vadose zone, thereby diverting unimpacted groundwater around the source area. At the Site, VEBs could be constructed immediately downgradient of Landfills DU1 to contain contaminated groundwater at the source area, or upgradient of the River Area DU to prevent contaminated groundwater from reaching the Seep. VEBs could also be constructed immediately upgradient of Landfills DU1 to divert uncontaminated groundwater around the source area. A fully-encompassing VEB would both divert uncontaminated groundwater around the source area and contain contaminated groundwater at the source area.

At the request of USEPA, Department of Energy (DOE), National Science Foundation (NSF), and Nuclear Regulatory Commission (USNRC), the Committee to Assess the Performance of Engineered Barriers was established to provide a technical assessment of the available information on VEB performance over time (National Research Council, 2007). Based on that assessment, the committee concluded that most engineered waste containment barrier systems that have been designed, constructed, operated, and maintained in accordance with current statutory regulations and requirements (as of 2007 when the study was published) have thus far provided environmental protection at or above specified levels. Long-term monitoring would need to be conducted to ensure performance over time. See the discussion of specific statistics regarding slurry wall effectiveness in Section 7.1.3.

Several common types of VEBs are discussed below, including slurry walls, grout curtains, and sheet pile walls.

Slurry Walls – A slurry wall consists of a vertically excavated trench that is filled with a low-permeability material to contain the contaminated groundwater. Most slurry walls are constructed of a soil, bentonite, and water mixture. The bentonite slurry is used primarily for wall stabilization during trench excavation. A soil-bentonite backfill material is then placed into the trench, displacing the slurry to create the cutoff or containment wall. Walls of this composition provide a barrier with low-permeability as well as chemical resistance. Slurry walls are typically placed at depths up to 80 feet and generally 2 to 4 feet in thickness; for depths greater than 80 feet and up to 150 feet, slurry walls are typically installed using clamshell bucket excavation and/or hydromill technologies.

The use of slurry walls as environmental cut-off barriers in the United States began in the late 1970s and early 1980s (USEPA, 1998a), and most systems have demonstrated the capability to function as intended over this 50-year period of record. Several factors that influence longevity, including physical changes, geochemical changes, and environmental compatibility, should be considered during the design phase to ensure that the slurry wall would perform as intended. Strict adherence to quality control of materials and placement during construction would also have an influence on wall longevity. Physical stress/strain forces can be prevented by avoiding placement of large loads (e.g., buildings) on or near the wall. Given the characteristics of the slurry wall backfill (i.e., blend of soil and bentonite clay, which are natural earthen materials resistant to degradation) and the environmental conditions of the subsurface (e.g., insulated from freeze-thaw cycles, locked-in-place by surrounding earthen materials), there is no reason to believe a properly designed slurry wall would not continue to perform over time.

At the Site, slurry walls could be constructed immediately downgradient (e.g., horseshoe shape) or fully encompassing the perimeter of one or more waste management units in the Landfills DU1 to contain contaminated groundwater at the source area. A slurry wall could also be constructed immediately upgradient of the Landfills DU1 to divert uncontaminated groundwater around the source area. At either location, slurry walls could be keyed into the lower permeability zone found at the top of the below upper hydrogeologic unit (i.e., the glacial till) that serves as an aquitard at the Site. This stratum is typically 120 to 150 ft-bls near the Landfills DU1. Alternatively, the slurry wall could be installed as a “hanging” wall that does not rely on being keyed into a low-permeability soil layer. Either design may require hydraulic control via extraction wells to ensure an inward gradient is maintained.

Immediately upgradient of the River Area DU, the top of the glacial till stratum is significantly deeper (typically greater than 150 ft-bls, and over 200 ft-bls in places). A slurry wall in this area would likely be less effective due to the increased depth to this stratum. Even as a hanging wall, groundwater would likely short-circuit the barrier through the gap between the bottom of the slurry wall and the top of the glacial till. Therefore, this process option is retained for further consideration either upgradient or downgradient of the Landfills DU1 waste management unit(s).

Grout Curtains – Grout curtains are thin, vertical, subsurface grout walls constructed by pressure-injecting grout into the soil matrix at closely spaced intervals such that each pillar of grout intersects the next, forming a continuous wall or curtain. Several lines of grout holes may be used to obtain a reasonably continuous and thick zone of grouted soil. When emplaced as designed, grout curtains reduce permeability and are therefore effective barriers to groundwater flow. Grouting also increases the mechanical strength of the grouted zone. Typical grouting materials include hydraulic cements, clays, bentonite, and silicates.

An important advantage of grout curtain emplacement is the ability to inject grout through relatively small diameter drill holes at unlimited depths. The main disadvantage of using grout curtains is the uncertainty that complete cutoff is attained; the continuity of grouting could be checked during emplacement by noting grout movement into ungrouted holes and by core drilling into the grouted zone; however, certainty will not be obtained until after completion during subsequent groundwater monitoring events. Additionally, grout curtains are more typically used for shorter length applications and the number of injection points required to achieve the necessary length required for groundwater containment at this Site will be very difficult to install effectively. Therefore, this option is not retained for further consideration.

Sheet Pile Walls – Sheet piles are long structural metal sections with vertical interlocks such that, when driven side by side, form a cutoff wall. Sheet piles are driven through unconsolidated materials with a vibratory hammer, pressing machine, or pile driver. Because the sheets are physically driven down from the surface, their use is limited to shallow depths.

Given the depth of groundwater contamination beneath the Site, sheet piling would not be an effective containment GRA at any location at this Site. Therefore, sheet piling will not be retained for further evaluation.

Groundwater Discharge/ Disposal

Groundwater discharge/ disposal GRAs are typically necessary when GRAs involving the collection or extraction of groundwater are implemented (e.g., pump and treat). After *ex situ* treatment of the groundwater, as needed, the primary options for groundwater disposal include discharge to surface water, aquifer recharge via injection wells or infiltration basins, and transport to an offsite location for disposal at a municipal wastewater treatment plant (WWTP).

Discharge to Surface Water

This process option involves discharge of treated groundwater to a surface water body. At this Site, treated groundwater could be discharged to the Flathead River immediately south of the Site. Waters within the Flathead River are classified by the MDEQ as B-1. At the point of discharge or at the downstream end of a mixing zone to the extent allowed by the state ARARs, water discharged to the Flathead River would need to meet criteria for surface water promulgated under the National Recommended Water Quality Criteria (NRWQC; USEPA, 2019a) and Montana DEQ-7 (MDEQ, 2019).

This process option is technically and administratively feasible; therefore, discharge to surface water near the Site has been retained for further evaluation.

Aquifer Recharge via Injection Wells

This process option involves the use of injection wells to inject treated groundwater into geologic formations. Many factors may adversely impact the implementability of this process option including the required discharge rate, the number of injection wells and associated area required to achieve the required discharge rate, and the depth to water. High O&M costs are also associated with injection wells. Given the availability of other, more favorable process options, discharge to the subsurface via injection wells will not be retained for further evaluation.

Aquifer Recharge via Infiltration Basins

An infiltration basin allows treated water to seep through the ground in a designated area. The treated water would discharge into an unlined infiltration basin excavated into the native soils, or potentially into an existing basin (such as the North-East Percolation Pond) provided that prior to use of the existing basin any contamination within it had been sufficiently remediated. The final number and sizes of basins required would depend on the rate of groundwater extraction and treatment and the infiltration rates of the native soils (which are high based upon historical use of percolation ponds at the Site). The infiltration basins could be constructed in a variety of areas, though placement near the groundwater treatment system would reduce piping costs and disturbance to the surrounding area.

This process option is technically and administratively feasible; therefore, discharge to the subsurface through infiltration basins has been retained for further evaluation.

Discharge to a Municipal Wastewater Treatment Plant

This process option involves the discharge of treated groundwater to the Columbia Falls WWTP for further treatment and disposal. A discharge approval would need to be obtained from the WWTP, and the *ex situ* treatment system effluent would need to meet existing discharge criteria.

This process option would require construction of a new pump station and force main to the Columbia Falls WWTP. Other discharge options described above are feasible and would be much less costly. Therefore, this process option will not be retained for further evaluation.

4.4 Assembled Remedial Action Alternatives

Technologies and process options retained above were assembled to formulate a range of remedial action alternatives for each DU. Since the Landfills DU1 waste management units are sources of groundwater contamination in the Groundwater DU, these two decision units and their remedies strongly impact each other. For example, an alternative that implements a containment response action for the West Landfill and the Wet Scrubber Sludge Pond area which is the primary source of cyanide and fluoride in groundwater addresses both the Landfills DU1 and the Groundwater DU. As such, the alternatives for these two decisions units have been assembled jointly to provide an appropriate range of remedial action alternatives for detailed evaluation.

The assembled remedial action alternatives are briefly described below; these alternatives form the basis for the FS and are further developed and described in Section 5, evaluated in Section 6, and compared in Section 7 of this FS Report.

4.4.1 Landfills DU1 and Groundwater DU Joint Alternatives

The following twelve alternatives for the combined Landfills DU1 and Groundwater DU (LDU1/GW-1 through LDU1/GW-6) are assembled for further development and evaluation in the FS.

For each alternative that includes treatment of extracted groundwater, one or more of the retained *ex situ* treatment technologies would be implemented; retained technologies include adsorption, coagulation/

flocculation/ precipitation, constructed wetlands, photolysis, electrocoagulation, ion exchange, and/or reverse osmosis. While a conceptual groundwater treatment process train is presented for the alternatives that include groundwater extraction, the selection and finalization of the *ex situ* treatment system process train would not occur until the pre-design or design phase. Treated groundwater would be disposed of via recharge to the aquifer via infiltration basins.

Alternative LDU1/GW-1: No Action

- Maintenance of the existing caps on the West Landfill, Wet Scrubber Sludge Pond, and Center Landfill as well as maintenance of the existing fence preventing access to these waste management units.
- No additional actions.

Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation

- ICs and ECs at each of the three waste management units in Landfills DU1, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- ICs for Site groundwater, including deed restrictions and well use restrictions to prevent or minimize human exposure to impacted groundwater at the Site.
- Monitored Natural Attenuation, including monitoring at/around each waste management unit in both the Landfills DU1 and Landfills DU2.
- Maintain existing cap at the West Landfill.
- Install a low-permeability membrane cap or GCL cap at the Wet Scrubber Sludge Pond and the Center Landfill.

Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Construct a slurry wall immediately upgradient of the West Landfill to divert unimpacted groundwater and surface water runoff around the source area. Design elements of the slurry wall (e.g., length, depth, location), including the need to include the Center Landfill within the diversion zone, will be further evaluated in Section 5.

Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB

- Measures identical to those listed for Alternative LDU1/GW-3A above.
- Install a PRB north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep.

Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction

- Measures identical to those listed for Alternative LDU1/GW-3A above.
- Install extraction wells north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Construct a slurry wall fully encompassing the perimeter of one or more waste management units in the Landfills DU1 to contain contaminated groundwater at the source area. Design elements of the slurry wall (e.g., length, depth, location), including the need to include the Center Landfill within the containment zone, will be further evaluated in Section 5.
- Maintain hydraulic control by extracting groundwater as necessary to maintain an inward gradient at the slurry wall. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-4B: Containment via Capping and Fully-Encompassing Slurry Wall, with Downgradient PRB

- Measures identical to those listed for Alternative LDU1/GW-4A above.
- Install a PRB north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep.

Alternative LDU1/GW-4C: Containment via Capping and Fully-Encompassing Slurry Wall with Downgradient Extraction

- Measures identical to those listed for Alternative LDU1/GW-4A above.
- Install extraction wells north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater at the source area using extraction wells immediately downgradient of Landfills DU1. Design elements of the extraction wells (e.g., number, locations, flow rate), including the need to include the Center Landfill within the containment zone, will be further evaluated in Section 5. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5B: Containment via Capping and Downgradient Hydraulic Control

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater downgradient using extraction wells north of the Burlington Northern Railroad. Design elements of the extraction wells (e.g., number, locations, flow rate) will be further evaluated in Section 5. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and Downgradient

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater at the source area using extraction wells immediately downgradient of Landfills DU1 and hydraulic control of groundwater downgradient using extraction wells north of the Burlington Northern Railroad. Design elements of the extraction wells (e.g., number, locations, flow rate), including the need to include the Center Landfill within the containment zone, will be further evaluated in Section 5. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-6: Excavation with Onsite Consolidation

- Excavate source material from Landfills DU1 including wastes and underlying soils contributing to groundwater contamination. Consolidate in a newly constructed onsite repository meeting substantive RCRA Subtitle C requirements. Design elements, including the need to excavate the Center Landfill and repository design, will be further evaluated in Section 5. If excavation does not include the Center Landfill, a low-permeability membrane cap or GCL cap will be installed at the Center Landfill.
- ICs for Site groundwater, including deed restrictions and well use restrictions to prevent or minimize human exposure to impacted groundwater at the Site until groundwater ARARs are achieved.
- Monitored Natural Attenuation, including monitoring at/around each waste management unit in both the Landfills DU1 and Landfills DU2.

4.4.2 Landfills DU2 Alternatives

The following two alternatives for the Landfills DU2 (LDU2-1 and LDU2-2) are assembled for further development and evaluation in the FS.

Alternative LDU2-1: No Action

- Maintenance of the existing caps on the East Landfill and Sanitary Landfill, maintenance of the existing soil covers on the Asbestos Landfills, and maintenance of the existing fences where present to limit access to these waste management units.
- No additional actions.

Alternative LDU2-2: Containment Capping

- ICs and ECs at each of the waste management units in Landfills DU2, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- Monitoring at/around each waste management unit in the Landfills DU2 as included under the Groundwater DU alternatives.
- Maintain existing caps at the East Landfill and Sanitary Landfill.
- Install a low-permeability membrane cap or GCL cap at the Industrial Landfill after grading, subsequent to onsite consolidation of excavated materials from other DUs if selected.
- Improve the existing soil cover at each of the Asbestos Landfills.

4.4.3 Soil DU Alternatives

The following four alternatives for the Soil DU (SO-1 through SO-4) are assembled for further development and evaluation in the FS. For all active alternatives, the Soil DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments. Another common element for all Soil DU Alternatives, excluding the No Action Alternative, is excavation of the top 2 feet of soil within the Former Drum Storage Area (included as a hotspot excavation within the active alternatives below).

Alternative SO-1: No Action

- No Action.

Alternative SO-2: Covers with Hotspot Excavation

- Install a soil cover for select areas of spatially concentrated COC distribution within the Soil DU to prevent contact with the impacted soil.
- Establish ICs in cover areas to ensure covers are maintained or acceptable alternative covers (i.e., buildings, pavement) are implemented as part of any future development.
- Excavation of discontinuous, isolated soil hotspots outside of cover footprints, as needed. Excavated materials could be consolidated underneath covers, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

Alternative SO-3: *In Situ* Phytoremediation with Hotspot Excavation

- *In situ* treatment of spatially concentrated PAH-impacted soils via phytoremediation.
- Establish ICs for areas of phytoremediation until treatment is completed.
- Excavation of discontinuous, isolated soil hotspots outside of treatment footprints, as needed. Excavated materials could be consolidated within treatment areas, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

Alternative SO-4: Excavation with Onsite Consolidation

- Excavate impacted soil in the Soil DU with disposal at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

4.4.4 North Percolation Pond DU Alternatives

The following four alternatives for the North Percolation Pond DU (NPP-1 through NPP-4) are assembled for further development and evaluation in the FS. For all active alternatives, the North Percolation Pond DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments.

Alternative NPP-1: No Action

- No Action.

Alternative NPP-2: Limited Excavation with Covers

- ICs and ECs at the North Percolation Pond DU, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- Decommission the influent pipes from which stormwater enters the North Percolation Pond system.
- Excavate impacted material in the influent and effluent ditches and consolidate in the North-East Percolation Pond.
- Install soil covers at the North-East and North-West Percolation Ponds to prevent contact with the impacted material. Perform physical solidification of the viscous, carbonaceous material if needed to support the cover.

Alternative NPP-3: Excavation with Cover

- Measures mirror those listed for Alternative NPP-2 above, with impacted material in the North-West Percolation Pond also excavated and consolidated in the North-East Percolation Pond. A soil cover would be installed at the North-East Percolation Pond, only.

Alternative NPP-4: Excavation with Onsite Consolidation

- Decommission the influent pipes from which stormwater enters the North Percolation Pond system.
- Excavate impacted material in the North Percolation Pond DU with disposal at an existing onsite repository (i.e., Wet Scrubber Sludge Pond).

4.4.5 River Area DU Alternatives

The following two alternatives for the River Area DU (RADU-1 and RADU-2) are assembled for further development and evaluation in the FS.

Alternative RADU-1: No Further Action

- Implementation of the Removal Action at the South Percolation Ponds as discussed in Section 2.3.5.
- No Further Action.

Alternative RADU-2: Excavation with Onsite Consolidation and Long-Term Monitoring

- Implementation of the Removal Action at the South Percolation Ponds as discussed in Section 2.3.5.
- Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater to evaluate and verify the progress of upgradient source control, groundwater remediation, and/or MNA implemented under the selected LDU1/GW Alternative.
- Monitoring of metals[1], fluoride, and PAHs[2] in the River Area DU surface water as identified in the Surface Water RAO and PRGs until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs).

  [1] Aluminum, arsenic, barium, copper, iron, lead, mercury, and thallium
  [2] Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene

As discussed in Section 2.3.5, the Removal Action at the South Percolation Ponds was implemented in accordance with the requirements of the Administrative Order on Consent effective July 21, 2020. The potential risk attributed to cyanide in sediment, sediment porewater, and surface water in the River Area DU will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Alternatives addressing groundwater inputs will be assessed within the Groundwater DU.

5. Development and Description of Remedial Action Alternatives

The remedial action alternatives assembled in Section 4.4 above are further developed and described below. The selected remedy for the Site will be a combination of any one alternative from each of the following sets of alternatives:

- Landfills DU1 and Groundwater DU Joint Alternatives;
- Landfills DU2 Alternatives;
- Soil DU Alternatives;
- North Percolation Pond DU Alternatives; and
- River Area DU Alternatives.

The need for pre-design activities will be identified for remedial alternatives as appropriate. Pre-design activities might include collection or compilation of additional information and data, including geotechnical investigations, supplemental delineation of COCs to refine extents and volumes of media for remediation, and treatability and/or pilot studies, to develop a detailed design for implementation of an alternative. Once an alternative has been selected as the Site remedy, such studies will be conducted during the pre-design and design phases for the remedy.

5.1 Landfills DU1 and Groundwater DU Joint Alternatives

Twelve alternatives for the combined Landfills DU1 and Groundwater DU (LDU1/GW-1 through LDU1/GW-6) are retained for further development and evaluation in the FS. These alternatives are described below and illustrated on figures provided in Appendix E. For all alternatives excluding the No Action Alternative (LDU1/GW-1) and the Excavation Alternative (LDU1/GW-6), the Landfills DU1 waste management units would be subject to ICs and ECs to prevent exposure to human and ecological receptors. For all alternatives excluding the No Action Alternative (LDU1/GW-1), Site groundwater would be subject to ICs to prevent or minimize human exposure to impacted groundwater at the Site until groundwater PRGs are achieved, including ARARs. Specific ICs and ECs for the Landfills DU1 and Groundwater DU are described within Section 5.1.2 below.

For each alternative that includes treatment of extracted groundwater, one or more of the retained *ex situ* treatment technologies would be implemented; technologies retained for further evaluation at the conclusion of the technology screening presented in Section 4 of this FS Report include adsorption, coagulation/ flocculation/ precipitation, constructed wetlands, photolysis, electrocoagulation, ion exchange, and/or reverse osmosis. Treated groundwater would be disposed of via recharge to the aquifer via infiltration basins. Selection of the *ex situ* treatment process will not be finalized until the pre-design or design phase.

5.1.1 Alternative LDU1/GW-1: No Action

Under the No Action alternative, no remedial actions would be performed to reduce the toxicity, mobility, or volume of COCs in the Landfills DU1 or Groundwater DU. The No Action alternative implies continuation of existing controls including proper maintenance of the existing caps on the West Landfill, Wet Scrubber Sludge

Pond, and Center Landfill as well as maintenance of the existing fence preventing access to these waste management units. The components of this alternative are shown on Figure E1 of Appendix E. No action would be taken to remediate groundwater.

The No Action alternative would not include any long-term monitoring or new controls and would not address the RAOs established for the Site. As discussed in Section 4.1, the No Action alternative is required as a baseline for comparison.

5.1.2 Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation

The primary elements associated with Alternative LDU1/GW-2 would include the following:

- Containment of source area waste management units via capping;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E2 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping element under this alternative includes maintenance of the existing low-permeability cap on the West Landfill and construction of new low-permeability caps on the Wet Scrubber Sludge Pond and Center Landfill. These actions would prevent or minimize further migration of contaminants from source materials within the waste management units to groundwater, and over time would result in a reduction of COC concentrations in groundwater beneath and downgradient of the Landfills DU1 waste management units.

As described in Section 2.3.1, the existing cap on the West Landfill consists of a multi-layer low-permeability cap that does not appear to require improvement based upon review of engineering as-built drawings and field observations.

The existing cap on the Wet Scrubber Sludge Pond, however, is not a low-permeability cap. In addition, the surface of the Wet Scrubber Sludge Pond is currently a topographic depression which promotes, rather than reduces, infiltration of precipitation through the underlying waste. Therefore, capping of the Wet Scrubber Sludge Pond would entail grading the Wet Scrubber Sludge Pond to allow construction of a low-permeability cap that would promote stormwater runoff rather than infiltration. It is estimated that the Wet Scrubber Sludge Pond would require approximately 43,000 CY of grading material to achieve a minimum slope requirement of 3% for a crowned cap design. The source of grading material could be remediation waste from the Soil DU or North Percolation Pond DU, onsite borrow material, imported soil, or a combination thereof. In addition, given that the Wet Scrubber Sludge Pond primarily accepted sludges, the material in this waste management unit may be of low load-bearing strength; pre-consolidation or solidification of the sludges via preloading to accelerate primary settlement or addition and mixing of amendments could be required to support installation of a low-permeability membrane at the Wet Scrubber Sludge Pond. It is anticipated the cap would comply with substantive requirements for an MDEQ Class II landfill cap and contain a low-permeability membrane, a drainage layer consisting of sand or a geocomposite layer, an 18-inch barrier soil layer, and a 6-inch topsoil layer with surface vegetation.

As described in Section 2.3.1, the Center Landfill reportedly is capped with a 6-inch layer of clay and 18 inches of till. A 6-inch clay layer is generally considered insufficient as a low-permeability layer for a long-term permanent landfill cap over hazardous material. Therefore, it is proposed to improve the Center Landfill cap by addition of a low-permeability membrane as well as a barrier soil layer and topsoil cover layer to obtain substantive requirements of RCRA Subtitle C cap.

Along with the capping activities described above, stormwater conveyance swales/ditches to convey stormwater off of and away from each of the Landfills DU1 waste management units would be constructed as necessary.

This alternative would also include regular inspections and long-term maintenance of the caps and water management controls to protect the integrity of the remedy.

Monitored Natural Attenuation

In addition to containment via capping, this alternative would rely upon MNA to reduce contaminant concentrations through physical, chemical, and biological processes until PRGs are attained. A description of MNA as a remedial technology is provided in Section 4.3.6.

Implementation of MNA at the Site would involve continued long-term monitoring of groundwater using a subset of the existing monitoring wells at the Site. Groundwater would be routinely sampled and analyzed for COCs (i.e., cyanide, fluoride, and arsenic) to continue to demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. In addition, the initial rounds of monitoring would include sampling and analysis for geochemical indicator parameters to identify and assess performance of the active MNA processes. Separately, under the selected RADU alternative, MNA within the River Area DU would be performed to document the reduction of cyanide concentrations in surface water and porewater.

For the first five years, monitoring would be conducted in June and October (i.e., twice a year) to document conditions during the high- and low-water season, respectively. Based upon groundwater sampling results from the first five years, the frequency of monitoring may be reduced to an annual basis. Groundwater monitoring under this alternative would continue until RAOs are achieved or, if not achieved, for a minimum of 30 years. The exact monitoring network and details regarding frequency of sampling and parameters analyzed would be identified in subsequent remedial design reports, as appropriate.

Long-term monitoring would also be performed at select monitoring wells at/around each waste management unit in both the Landfills DU1 and Landfills DU2.

Institutional and Engineering Controls

ICs applied under this alternative would include deed restrictions for the Landfills DU1 waste management units to prevent activities that could compromise function or integrity of the caps/containment systems or result in potential exposure to receptors. ECs applied under this alternative would include installation of fencing and signage around the perimeter of the Landfills DU1 waste management units to identify and physically restrict access to human receptors and some ecological receptors.

ICs applied to groundwater under this alternative would include deed restrictions to prohibit the use of groundwater for water supplies and/or consumption. Groundwater ICs could also include, subject to MDNR approval, designation of the groundwater within the plume extent as a Controlled Ground Water Area pursuant to MCA 85-2-506 to prevent potable use of the contaminated groundwater.

Under this alternative, reviews would be conducted once every five years to ensure continued performance of the remedy, consistent with CERCLA requirements.

5.1.3 Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall

The primary elements associated with Alternative LDU1/GW-3A would include the following:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the Landfills DU1;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E3 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Upgradient Slurry Wall

Under this alternative, a slurry wall would be constructed around the upgradient perimeter of the West Landfill and Wet Scrubber Sludge Pond as shown on Figure E3 of Appendix E. As discussed in Section 3 of Appendix A, the Center Landfill would not be included within the footprint of the slurry wall because wells immediately adjacent to and downgradient of the Center Landfill are compliant with PRGs. An upgradient slurry wall would divert unimpacted groundwater and surface water runoff around the West Landfill and Wet Scrubber Sludge Pond, including groundwater both above and below the fluctuating water table. This would reduce leaching of COCs to groundwater and the associated mass flux of contamination from beneath the waste management units.

The constructed slurry wall would be approximately 1,950 feet in length and 24 to 36 inches in width. The caps for the West Landfill and Wet Scrubber Sludge Pond would be engineered and/or modified as needed to ensure they extend over the top of the new slurry wall to prevent precipitation and runoff from infiltrating into the subsurface between the cap and vertical barrier. In addition, this alternative would require evaluation of stormwater management options that may be necessary to address high stormwater and meltwater runoff conditions in the spring, particularly in the area immediately to the north and east of the upgradient slurry wall.

The slurry wall would be placed vertically in the upper hydrogeologic unit to depths of 100 to 125 feet upgradient of the waste management units. Slurry walls are often keyed into a continuous, low-permeability confining layer, such as an aquitard, to prevent migration of groundwater and contaminants under the barrier. At this Site, the slurry wall would ideally be keyed into the top of the low-permeability glacial till unit that typically occurs between 100 and 125 ft-bls near the Landfills DU1 waste management units. As discussed in the technology screening presented in Section 4.3, installation of a slurry wall to the proposed depths would require the use of clamshells and/or hydromill technologies, which are standard equipment and proven methods for slurry wall construction.

To ensure the effectiveness of the slurry wall, the remedial design phase (including pre-design activities) should include detailed surveying, geotechnical and hydrogeologic investigations, and a bench-scale laboratory study. Geotechnical investigation during the remedial design phase would refine knowledge of subsurface conditions along the proposed alignment including depth of the key, site stratigraphy, soil or rock type/density, and grain size distribution. Additional physical testing of samples from soil borings may be required. If the key is deeper than is feasible or cost-effective in some areas, then the slurry wall would be constructed as a hanging wall in those sections. Hydrogeologic investigation would determine hydraulic conductivity, porosity, hydraulic head distribution, and other key design measures. The bench-scale study would be used to determine a suitable mixture of Site soils, borrow soils, and bentonite slurry to achieve the desired permeability and chemical compatibility with COCs.

Successful installation would be indicated by acceptable construction quality assurance (CQA) / construction quality control (CQC) during construction and post-construction performance monitoring. Key CQA/CQC measures during construction include trench key confirmation measurements, bentonite/soil ratio verification, real-time slurry density testing, and analysis of soil/bentonite mix backfill permeability. Examples of potentially acceptable CQA/CQC criteria are shown in Table 3-4 in the USEPA guidance document titled “Evaluation of Subsurface Engineered Barriers at Waste Sites” (USEPA, 1998a). Actual acceptance criteria would be specified within the remedial design work plan. Key post-construction performance monitoring would include measurements and analysis to assess for flow into and out of the containment system to ensure performance and remedial goals are met and groundwater sampling to confirm improvement in groundwater quality downgradient of the slurry wall.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.4 Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB

The primary elements associated with Alternative LDU1/GW-3B would include the following:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the Landfills DU1;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E4 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Upgradient Slurry Wall

The upgradient slurry wall as an additional source control measure under this alternative would be the same as that described in Section 5.1.3 for Alternative LDU1/GW-3A.

Downgradient Permeable Reactive Barrier

Under this alternative, a PRB would be constructed along the north side of the Burlington Northern Railroad as shown on Figure E4 of Appendix E. This alignment is perpendicular to the direction of groundwater flow in this area, and as such contaminants would be intercepted as groundwater passes through the PRB during natural migration within the aquifer. The PRB would contain a mixture of sand and elemental iron filings. The elemental iron filings in the form of zero valent iron (ZVI) would react with the contaminant to remove it from solution and/or catalyze the breakdown of cyanide that is currently migrating and discharging to surface water in the River Area DU approximately 300 to 400 ft downgradient of the PRB. Precipitation of iron cyanide within the PRB would be the expected primary removal mechanism.

The constructed PRB would be approximately 3,785 feet in length and 24 to 36 inches in width. The footprint of the wall spans the downgradient extent of the defined cyanide plume where concentrations exceed the PRG of 200 µg/L. The PRB substrate would vertically span from 60 ft-bls through 130 ft-bls. Data from the RI indicate that cyanide concentrations decrease significantly with increasing depth in the upper hydrogeologic unit; as such, intercepting the aquifer at this depth interval would be expected to treat groundwater with the highest concentrations of cyanide to achieve RAOs.

The PRB has a finite life span that is inversely proportional to the mass flux of contaminant entering the wall and directly proportional to the amount of reactive media within the wall. Under this alternative, the PRB would be constructed with a design life of 30 years. The source control measures and MNA component of this alternative are expected to reduce contaminant concentrations in groundwater upgradient of the PRB within the 30-year design life such that media replacement would, at most, only be necessary for a fraction of the wall footprint (e.g., 20% of the PRB). In order to provide appropriate residence time, the reactive media mixture would likely range from 20% ZVI and 80% sand mixture to 55% ZVI and 45% sand mixture by volume; a bench scale or pilot scale treatability study would be required during remedial design to determine the most appropriate ZVI to sand mixture ratio.

The PRB would require periodic monitoring as the groundwater passes through the barrier wall. Groundwater monitoring would be designed to assess the performance of cyanide removal through the PRB, as well as to confirm that water is not diverted around or beneath the PRB. Under this alternative, approximately five monitoring well pairs would be installed along the alignment as shown on Figure E4 of Appendix E to measure cyanide concentrations and hydraulic head on either side of the PRB. Where able, existing monitoring wells would be utilized for one or both wells in the pair. The newly constructed wells would be 4-inch diameter wells to a depth of approximately 130 ft-bls or less with a screened length of approximately 20 ft within the upper hydrogeologic unit. The final number of well pairs would be determined in the remedial design phase.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.5 Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction

The primary elements associated with Alternative LDU1/GW-3C would include the following:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the Landfills DU1;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E5 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Upgradient Slurry Wall

The upgradient slurry wall as an additional source control measure under this alternative would be the same as that described in Section 5.1.3 for Alternative LDU1/GW-3A.

Downgradient Groundwater Extraction, Treatment, and Discharge

Under this alternative, groundwater would be extracted along the north side of the Burlington Northern Railroad as shown on Figure E5 of Appendix E to hydraulically capture cyanide-containing groundwater prior to its migration and discharge to surface water in the River Area DU approximately 300 to 400 feet downgradient. The extracted groundwater would be pumped to an aboveground treatment system where it would be treated *ex situ* by a sequence of physical and chemical unit operations. The treated groundwater would be recharged back to the upper hydrogeologic unit using onsite infiltration basins in accordance with federal and state effluent standards.

Brief descriptions of the anticipated groundwater extraction, treatment, and discharge components of the system are provided below.

<u>Groundwater Extraction</u>: The conceptual design of the groundwater extraction system under this alternative consists of approximately ten vertical extraction wells to achieve an estimated total extraction rate of 500 gallon

per minute (gpm). Extraction wells would be 6-inch diameter wells to a depth of approximately 125 ft-bls with a screened length of approximately 50 ft within the upper hydrogeologic unit. Each well would be equipped with pitless adapters, pumps, risers, and associated conveyance piping capable of pumping 75 gpm.

A description of the assumptions and methodology used to estimate the number of extraction wells and pumping rates for this alternative is provided in Section 8 of Appendix A. If groundwater extraction and treatment is a component of the selected remedy, additional investigation of aquifer characteristics, vertical extent of cyanide, pump tests, and numerical modeling would be appropriate considerations in finalizing the number, locations, configurations, and pumping rates of the extraction wells during the remedial design phase.

<u>*Ex Situ* Treatment of Extracted Groundwater</u>: Extracted groundwater would be conveyed to an *ex situ* system for treatment prior to discharge back into the aquifer. Under this alternative, groundwater is extracted from along the north side of the Burlington Northern Railroad where cyanide is the only COC requiring treatment to meet groundwater PRGs.

A conceptual process flow diagram for groundwater treatment is provided in Figure E13 of Appendix E. The treatment process utilizes a subset of the technologies retained for further evaluation at the conclusion of the technology screening presented in Section 4 of this FS Report and is considered a relatively conservative approach to treatment of cyanide in water. This treatment process is provided for illustrative purposes and is not intended to represent a final or definitive treatment system. Other treatment processes or system configurations could be used, provided they are capable of cost-effectively achieving the required effluent concentrations. It is expected that bench scale treatability studies would be performed to finalize selection and sizing of treatment system components.

In this conceptual process flow, the extracted groundwater would first be sent to an equalization tank. The equalization tank would dampen variations in flow and groundwater quality among the extraction wells, thereby providing equalization of influent. Following equalization, total suspended solids (TSS) and metals that could cause fouling of subsequent COC treatment processes would be removed via chemical precipitation. Automated ferric chloride injection skids and a polymer addition system would provide chemical addition prior to the clarification units to facilitate ferric coprecipitation. The precipitate mixture would then be transferred to the clarification units where the solids would settle to the bottom. Sludge from the tank containing the flocs and precipitated solids collected from the bottom of the clarification units would be pumped via diaphragm pumps into a dewatering box system (e.g., filter press or geotube filter socks). Water leaving the dewatering box system would gravity drain to a sump and recycled back into the treatment train to the clarifier units. The dewatered sludge would be sent offsite for disposal. The clarifier units would be followed by sand filters and, if needed, bag filters to remove any fine particles that did not settle out. Effluent from the filters would pass through a series of zeolite media vessels (e.g., chabazite) and ion exchange vessels as the final polishing steps for cyanide removal.

Further evaluation of treatment options, bench and/or pilot scale treatability studies, final selection of treatment technology, and system sizing and design would take place during the remedial design phase.

A treatment system such as the one described above would need to be housed within a building of substantial size. If groundwater treatment is a component of the selected remedy, one of the exiting Site buildings could potentially be repurposed to house the treatment system; otherwise, construction of a new treatment system building would be required.

Discharge of Treated Groundwater: It is anticipated that treated groundwater would be discharged to infiltration basins for recharge back into the upper hydrogeologic unit. In either case, the extracted groundwater would be treated to achieve chemical- and action-specific ARARs for discharge to groundwater. It is noted that, depending upon which NPP Alternative is selected, the North Percolation Ponds could be viable discharge options.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.6 Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall

The primary elements associated with Alternative LDU1/GW-4A would include the following:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E6 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Fully-Encompassing Slurry Wall

Under this alternative, a slurry wall would be constructed around the entire perimeter of the West Landfill and Wet Scrubber Sludge Pond as shown on Figure E6 of Appendix E. As discussed in Section 3 of Appendix A, the Center Landfill would not be included within the footprint of the slurry wall because wells immediately adjacent to and downgradient of the Center Landfill are compliant with PRGs. See Section 5.1.3 for detailed description of design, construction, and performance monitoring considerations for a slurry wall.

Like the upgradient slurry wall described in Section 5.1.3 for Alternative LDU1/GW-3A, a fully-encompassing slurry wall would divert uncontaminated groundwater around the source area, including groundwater both above and below the fluctuating water table. Further, the fully-encompassing slurry wall would provide an additional measure of containment on the downgradient side of the source area which would, in conjunction with the caps, create a containment cell; waste materials, impacted underlying soil, and contaminated groundwater would be isolated within the cell, preventing migration of COCs. Mitigating the migration of COCs from the source area would significantly enhance the effectiveness of MNA in reducing downgradient groundwater concentrations and, in turn, surface water and porewater concentrations.

The constructed slurry wall would be approximately 3,700 feet in length. All other construction considerations for the fully-encompassing slurry wall, including depth, width, interconnectivity with the waste management unit caps, and evaluation of stormwater management needs, would be identical to those described for the upgradient slurry wall under Alternative LDU1/GW-3A in Section 5.1.3.

Also under this alternative, approximately eight piezometer pairs would be installed along the alignment to measure hydraulic head across the vertical barrier to assess containment performance as shown on Figure E6 of Appendix E. Where able, existing monitoring wells would be utilized for one or both wells in the pair. The newly constructed wells would be 4-inch diameter wells to a depth of approximately 100 ft-bls or less with a screened length of approximately 20 ft within the upper hydrogeologic unit. The final number of well pairs would be determined in the remedial design phase.

Following construction completion, hydraulic heads would be monitored regularly to assess the hydraulic gradient across the barrier. Ideally, an inward gradient would be observed to demonstrate that contaminated groundwater has no hydraulic potential to migrate out of the containment cell. In the absence of an inward gradient, the potential for groundwater movement and COC migration would have to be closely monitored and evaluated to ensure that contaminated groundwater is not migrating out of the containment cell. Given the low-permeability of the slurry wall, the flow of groundwater and in turn the flux of COCs through the vertical barrier is not expected to be at a rate that would compromise effectiveness of the remedy. However, if necessary, the wells inside the slurry wall containment cell could also serve as groundwater extraction wells if and when the inward gradient cannot be maintained in the absence of pumping and the absence of an inward gradient is preventing the achievement of RAOs and PRGs. The pumping rate required to maintain the inward gradient, if any, is expected to be periodic and minimal given that the containment cell would be designed and constructed in a manner to prevent entry of water into the cell.

If groundwater extraction is needed to maintain an inward gradient, the extracted groundwater would need to be treated prior to discharge. The *ex situ* treatment processes that would be implemented may be similar to those described under Alternative LDU1/GW-5A in Section 5.1.9, and for the purpose of the cost estimate in this FS Report the same treatment process has been assumed. However, groundwater extracted under this alternative would contain significantly higher concentrations of cyanide, fluoride, and arsenic as it would have been extracted directly from the source area. The low flow, high concentration groundwater extracted under this alternative may allow for a different treatment process than that described under Alternative LDU1/GW-5A and would use one or more of the *ex situ* treatment process options retained for further evaluation at the conclusion of the technology screening presented in Section 4 of this FS Report, including potential implementation of a constructed treatment wetland. While not considered under Alternative LDU1/GW-5A due to its high anticipated flow rates, a constructed treatment wetland would be a candidate technology under this alternative due to the low, batch flow anticipated from the periodic pumping, including curtailment of pumping during winter/freezing conditions. Regardless of the *ex situ* treatment process implemented, the treated groundwater would then be discharged through infiltration basins as discussed in Section 5.1.5.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.7 Alternative LDU1/GW-4B: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient PRB

The primary elements associated with Alternative LDU1/GW-4B would include the following:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E7 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Fully-Encompassing Slurry Wall

The fully-encompassing slurry wall as an additional source control measure under this alternative would be the same as that described in Section 5.1.6 for Alternative LDU1/GW-4A.

Downgradient Permeable Reactive Barrier

The downgradient PRB under this alternative would be the same as that described for Alternative LDU1/GW-3B in Section 5.1.4.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.8 Alternative LDU1/GW-4C: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient Extraction

- The primary elements associated with Alternative LDU1/GW-4C would include the following:
- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;

- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E8 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Containment via Fully-Encompassing Slurry Wall

The fully-encompassing slurry wall as an additional source control measure under this alternative would be the same as that described in Section 5.1.6 for Alternative LDU1/GW-4A.

Downgradient Groundwater Extraction, Treatment, and Discharge

The downgradient groundwater extraction, treatment, and discharge measures under this alternative would be the same as those described in Section 5.1.5 for Alternative LDU1/GW-3C.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.9 Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area

The primary elements associated with Alternative LDU1/GW-5A would include the following:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E9 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Source Area Groundwater Extraction, Treatment, and Discharge

Under this alternative, groundwater would be extracted immediately downgradient of the West Landfill and Wet Scrubber Sludge Pond as shown on Figure E9 of Appendix E to hydraulically capture contaminated groundwater prior to its migration away from the source area. As discussed in Section 3 of Appendix A, the Center Landfill would not be included within the footprint of the capture zone because wells immediately adjacent to and downgradient of the Center Landfill are compliant with PRGs. Mitigating the continued migration of COCs from the source area would significantly enhance the effectiveness of MNA in reducing downgradient groundwater concentrations and, in turn, surface water and porewater concentrations.

The extracted groundwater would be pumped to an aboveground treatment system where it would be treated *ex situ* by a sequence of physical and chemical unit operations. The treated groundwater would be recharged back to the upper hydrogeologic unit using onsite infiltration basins in accordance with federal and state effluent standards.

Brief descriptions of the anticipated groundwater containment, extraction, treatment, and discharge components of the system are provided below.

<u>Groundwater Extraction</u>: The conceptual design of the groundwater extraction system under this alternative consists of approximately ten vertical extraction wells from which groundwater would be recovered at rates sufficient to create interconnected capture zones to achieve hydraulic containment of contaminated groundwater emanating from beneath the West Landfill and Wet Scrubber Sludge Pond. As further described in Appendix A, the groundwater hydraulic gradients and saturated thickness of the aquifer at the source area vary greatly with the seasons. Based on measurements during high flow conditions (e.g., June 2018), it is estimated that a total extraction rate of 1500 gpm or greater may be required to achieve the desired hydraulic containment. However, based on measurements during low flow conditions (e.g., October 2018) the gradient and saturated thickness decrease substantially such that a total extraction rate of 100 gpm may be sufficient to achieve hydraulic containment. During high flow conditions, there is greater potential for the high groundwater levels to mobilize COCs in waste and/or underlying impacted soil that could become saturated within the high-water table; therefore, the conceptual design includes extraction of groundwater at the 1500 gpm rate (i.e., approximately 150 gpm per extraction well) to provide for capture of groundwater during high flow conditions. As flow conditions subside during the year, select wells could be turned off and/or throttled back using variable speed controllers to reduce the flow rates as appropriate.

Extraction wells would be 8-inch diameter wells to a depth of approximately 100 ft-bls with a screened length of approximately 50 ft within the upper hydrogeologic unit. Each well would be equipped with pitless adapters, pumps, risers, and associated conveyance piping capable of pumping 175 gpm.

A description of assumptions and methodology used to estimate the numbers of wells and pumping rates is provided in Appendix A. If groundwater extraction and treatment is a component of the selected remedy, additional investigation of aquifer characteristics, vertical extent of cyanide and fluoride, pump tests, and numerical modeling would be appropriate considerations in finalizing the number, locations, configurations, and pumping rates of the extraction wells during the remedial design phase.

<u>*Ex situ* Treatment of Extracted Groundwater</u>: Extracted groundwater would be conveyed to an *ex situ* system for treatment prior to discharge back into the aquifer. Under this alternative, groundwater is extracted from

the source area where cyanide, fluoride, and arsenic are the COCs requiring treatment to meet groundwater PRGs. In addition, the water could be highly alkaline and contain high total dissolved solids.

A conceptual process flow diagram for groundwater treatment is provided in Figure E14 of Appendix E. The process flow is similar to that described under Alternative LDU1/GW-3C in Section 5.1.5, with the addition of a precipitation step for arsenic and fluoride removal. This precipitation step would include activated alumina vessels added in series to the cyanide treatment zeolite media vessels.

The capacity and configuration of treatment components under this alternative are influenced by the wide range in flow conditions described above. Rather than a single treatment train designed to accommodate high flow conditions which are only present for a few months each year, it could be more cost-effective to have two or three parallel treatment trains such that one or two of the trains can be taken offline as flow conditions subside during the course of the year.

All other considerations for the source area extraction system, including further evaluation of treatment options, other remedial design phase activities, and the need for a treatment system building, would be identical to those described for the downgradient extraction system under Alternative LDU1/GW-3C in Section 5.1.5.

<u>Discharge of Treated Groundwater</u>: Treated groundwater would be discharged through infiltration basins as discussed in Section 5.1.5.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.10 Alternative LDU1/GW-5B: Containment via Capping and Downgradient Hydraulic Control

The primary elements associated with Alternative LDU1/GW-5B would include the following:

- Containment of source area waste management units via capping;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E10 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Downgradient Groundwater Extraction, Treatment, and Discharge

The downgradient groundwater extraction, treatment, and discharge measures under this alternative would be the same as those described in Section 5.1.5 for Alternative LDU1/GW-3C.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.11 Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and Downgradient

The primary elements associated with Alternative LDU1/GW-5C would include the following:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1) and downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E11 of Appendix E. Each of these elements is described below.

Containment via Capping

The capping source control measures under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

Source Area and Downgradient Groundwater Extraction, Treatment, and Discharge

The source area groundwater extraction, treatment, and discharge measures under this alternative would be the same as those described in Section 5.1.9 for Alternative LDU1/GW-5A.

The downgradient groundwater extraction, treatment, and discharge measures under this alternative would be the same as those described in Section 5.1.5 for Alternative LDU1/GW-3C.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2.

5.1.12 Alternative LDU1/GW-6: Excavation with Onsite Consolidation

The primary elements associated with Alternative LDU1/GW-6 would include the following:

- Excavation of wastes previously disposed within the source area waste management units;
- Characterization of soils beneath waste and removal as necessary to eliminate source material;
- Construction of an onsite repository meeting substantive RCRA Subtitle C requirements for disposal of excavated material;
- Containment of the Center Landfill via capping;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

The components of this alternative are shown on Figure E12 of Appendix E. Each of these elements is described below.

Excavation of Waste

Under this alternative, all waste currently stored within the West Landfill and the Wet Scrubber Sludge Pond would be excavated, removed from the source area, and disposed of at a newly constructed onsite repository meeting substantive RCRA Subtitle C requirements. This alternative specifically addresses the removal of source material from the Landfills DU1 waste management units including, as necessary, impacted underlying soils that are likely contributing to groundwater contamination. As discussed in Section 2.3.1, the depths of waste for each waste management unit are estimated based on various sources of information. During the implementation of this alternative, the underlying soils would be characterized following waste removal to determine the depth of excavation necessary to eliminate the source material. The source material beneath the waste would then be removed and disposed of in the same manner as the waste from the respective waste management unit.

At the West Landfill, waste material would be removed from the 7.8-acre footprint to an estimated average depth of approximately 35 ft. As described in Sections 2.1.4.1 and 3.4.1, although there is significant uncertainty regarding the depth of impacted underlying soil, it is expected to find that the source material extends into and beneath the seasonal high-water table. For the purposes of evaluation of this alternative and comparative analysis to other alternatives in this FS Report, it has been assumed that the excavation within the West Landfill would have to extend to an average depth of approximately 50 ft below surrounding grade to remove both the waste and underlying impacted soil. It is estimated that excavation of the West Landfill would generate over 820,000 CY of waste for disposal at the onsite repository.

Material excavated from the West Landfill would contain SPL. As discussed in Section 4.3.1 under the Excavation process option, under the NCP, excavated material would not require pre-treatment if relocated within or adjacent to Landfills DU1 but could require pretreatment if shipped offsite depending on the pre-treatment requirements in the state where the material would ultimately be disposed of.

At the Wet Scrubber Sludge Pond, waste material would be removed from the 10.8-acre footprint to an estimated depth of 15 ft-bls. This material would likely require physical solidification due to the high moisture content and low-strength characteristics of the sludge. Physical solidification of the waste would aid in material handling and transportation, in addition to improving the load bearing capacity of the material to support the low-permeability cap which would be constructed on the onsite repository at completion of the remedy. Physical solidification would be achieved by mixing the waste with reagents (e.g., cement kiln dusts, lime dust) prior to or during excavation of the waste. It is estimated that excavation of the Wet Scrubber Sludge Pond would generate approximately 575,000 CY of waste for disposal at the onsite repository, assuming a 10% increase in volume from solidification.

Implementation of this alternative would require extensive Site preparation activities prior to remedial construction, including mobilization of construction equipment to the Site, construction of temporary facilities (e.g., perimeter fencing, staging areas), construction of temporary access/haul roads, and implementation of erosion and sediment controls. In addition, fugitive dust and contaminant vapors/odors would need to be monitored and controlled during construction with engineering measures. It should be noted that SPL can be reactive with water in a way that produces toxic and explosive gases, which could further complicate this option. Disturbance of the SPL-impacted material would release cyanide gas, a poison if inhaled. Swallowing cyanide via fugitive dust would also be toxic. Measures such as continuous air monitoring would need to be implemented during construction and, depending on the results of such monitoring, the need for enclosed work areas and/or limitations on exposed waste areas may need to be considered. If required, either option would complicate and slow the implementation of the excavation and increase costs beyond those currently estimated. Further, while dividing the scope of the excavation into multiple work areas and enclosing each area during active excavation would mitigate the potential for exposure of the nearby community to emissions, inhalation/ingestion risk to workers during excavation activities would not be eliminated. Instead, a higher level of PPE (e.g., Level C) in addition to extensive monitoring requirements would be necessary to protect human health. Fugitive dust and contaminant vapors/odors would need to be monitored and controlled during construction with engineering measures. The higher level of PPE would also help mitigate direct contact exposure risk to construction works. Stormwater and construction water would also need to be managed as necessary.

Under this alternative, dewatering would likely be needed to collect and treat water that enters the open excavation. Adequate sloping and benching would also be required to maintain stability of the sidewalls; at the West Landfill, this would increase the footprint of the excavation by more than 30 percent. The need for and degree of these measures would depend on the depth of excavation and the depth to water table during construction activities. For the dewatering system, dewatering sumps would be installed as needed at low elevation areas within the excavation to allow for construction water removal. Adequately sized pumps and hoses would transfer collected water from the sump to a temporary construction water management system which would consist of similar removal processes to those described for Alternative LDU1/GW-5A in Section 5.1.9. Given the size and depth of the excavation, the pumping rates required to maintain a safe and dry work area are expected to be significant. Treated construction water would be recharged back to the upper hydrogeologic unit using onsite infiltration basins in accordance with federal and state effluent standards.

Following the excavation of waste from the Landfills DU1 waste management units, the former West Landfill and Wet Scrubber Sludge Pond locations would be backfilled and compacted to restore the area to the grade and topography currently surrounding the waste management units. The source of fill material could be onsite borrow material, imported soil, or a combination thereof. The areas would then be restored by vegetating the land surface.

Assuming remedial activities would be limited to an 8-month construction season, the estimated timeframe for completion of remedial construction under this alternative would take approximately 4 to 5 years. While best practices would be employed to limit the size of and/or cover the open excavation, it is anticipated that precipitation, surface runoff, or spring snowmelt would infiltrate the open excavation areas.

Construction of an Onsite Repository

Under this alternative, all waste material excavated and removed from the Landfills DU1 waste management units would be disposed of at a newly constructed onsite repository. The onsite repository would meet substantive RCRA Subtitle C requirements for a hazardous waste landfill and would have a design capacity to store over 1,400,000 CY of solid waste. The onsite repository would consist of a double composite liner with a leak detection and leachate collection system, stormwater run-on and runoff controls, and a final cover. Assuming an average height of 20 feet, the onsite repository would have a footprint of approximately 43-acres. Details regarding the general construction process of the onsite repository are provided below.

The construction process would begin with Site preparation activities similar to those described for excavation of the existing waste management units described above. The 43-acre footprint for the repository would be cleared, leveled, and undercut using excavators to the design depth, and an anchor trench with exterior berms would be constructed around the perimeter. The subbase consisting of native material would be graded and compacted to direct leachate towards low points at the perimeter of the repository. Next, the double composite liner would be installed, consisting of the following: (1) a low-permeability GCL, consisting of bentonite composites sandwiched between two layers of geotextile; (2) a leak detection geocomposite drainage layer comprised of non-woven polypropylene geotextile fabric bonded to a geonet made from HDPE; (3) a 40-mil HDPE geomembrane layer; (4) a 12-inch thick leachate collection system; and (5) a protective geotextile fabric to complete the uppermost layer of the double composite landfill liner. The leachate collection system would include perforated lateral piping spaced 50 feet apart across the entire repository footprint and would be backfilled with a 12-inch thick layer of high-permeability sand. Leachate would flow by gravity through the lateral piping and connect to header piping at the repository perimeter, which would outlet to collection sumps. From the sumps, leachate would be pumped to a force main and ultimately conveyed to leachate storage areas for offsite disposal.

Following construction of the double composite liner, filling of the onsite repository would be conducted concurrently with waste excavation from the West Landfill and Wet Scrubber Sludge Pond. This waste would be deposited and compacted in lifts to fill the onsite repository. After all material from the waste management units has been relocated to the onsite repository, construction of the final cap would occur. The final cap would consist of the following: (1) a low-permeability 40-mil HDPE geomembrane layer; (2) a low-permeability GCL; (3) a geocomposite drainage layer; (4) 18 inches of clean imported soil cover; and (5) 6 inches of topsoil cover to promote vegetation. The final cap would be compacted in lifts and graded to meet the design slope. Swales, chimney drains, and down drains would be constructed on the final cap to convey stormwater runoff towards a local recharge basin. The need for gas management (e.g., passive landfill vents) would be assessed during remedial design. The cap would be seeded to support the growth of vegetation. After construction of the onsite repository is complete, a groundwater monitoring well network would be installed at a downgradient location. Where able, existing monitoring wells would be utilized for the monitoring well network.

The onsite repository would require regular OM&M activities. OM&M would include activities such as (1) periodic maintenance of the cap and stormwater drainage systems; (2) operation of the leachate collection systems and maintenance of the sumps, pumps, and drainage piping; (3) transportation and disposal of leachate; (4) monitoring of the leak detection system; and (5) groundwater monitoring.

Containment of the Center Landfill via Capping

The capping source control measures under this alternative would be the same as those described for the Center Landfill in Section 5.1.2 for Alternative LDU1/GW-2. Capping source control measures would not be implemented for the West Landfill or Wet Scrubber Sludge Pond under this alternative.

Monitored Natural Attenuation

The MNA program under this alternative would be the same as that described in Section 5.1.2 for Alternative LDU1/GW-2.

Institutional and Engineering Controls

ICs and ECs established for the Center Landfill and for groundwater under this alternative would be the same as those described in Section 5.1.2 for Alternative LDU1/GW-2. ICs and ECs would not be established for the West Landfill or Wet Scrubber Sludge Pond under this alternative.

5.2 Landfills DU2 Alternatives

Two alternatives for the Landfills DU2 (LDU2-1 and LDU2-2) are retained for further development and evaluation in the FS. These alternatives are described below and illustrated on figures provided in Appendix F. The Containment via Capping Alternative (LDU2-2) would be subject to ICs and ECs to prevent exposure to human and ecological receptors. Specific ICs and ECs for the Landfills DU2 are described within Section 5.2.2 below. As discussed in the RI Report, these landfills are not sources of groundwater contamination at the Site; groundwater is addressed within the Landfills DU1 and Groundwater DU joint alternatives described in Section 5.1.

5.2.1 Alternative LDU2-1: No Action

Under the No Action alternative, no remedial actions would be performed to reduce the toxicity, mobility, or volume of COCs in the Landfills DU2. The No Action alternative implies continuation of existing controls including proper maintenance of the existing caps on the East Landfill and Sanitary Landfill, maintenance of the existing soil covers on the Asbestos Landfills, and maintenance of the existing fences where present to limit access to these waste management units.

The No Action alternative would not include any long-term monitoring or new controls and would not address the RAOs established for the Site. As discussed in Section 4.1, the No Action alternative is required as a baseline for comparison.

5.2.2 Alternative LDU2-2: Containment via Capping

The primary elements associated with Alternative LDU2-2 would include the following:

- Maintaining the existing caps on the East Landfill and Sanitary Landfill;
- Containment of the Industrial Landfill via capping;
- Improving the existing soil covers at the Asbestos Landfills;
- Establishment of ICs and ECs.

Each of these elements is described below.

Capping of Landfills

The capping element under this alternative includes maintenance of the existing low-permeability cap on the East Landfill, maintaining the existing cap on the Sanitary Landfill, construction of a new low-permeability cap on the Industrial Landfill, and improving the existing soil cover at each of the Asbestos Landfills. These actions would adequately mitigate exposure pathways to human health and ecological receptors by preventing direct contact.

As described in Section 2.3.2, the existing cap on the East Landfill consists of a multi-layer low-permeability cap, consisting of a 6-inch thick clay layer, a geomembrane layer, and an 18-inch vegetated till cover. The existing cap on the East Landfill does not appear to require improvement based upon review of engineering as-built drawings and field observations. As described in Section 2.3.2, the existing cap on the Sanitary Landfill consists of a cover layer comprised of clean fill. The cap appears to be in good condition and is vegetated. Although the thickness of the cap on the Sanitary Landfill is unknown, the Sanitary Landfill ceased operation in 1982, which exempts the landfill from RCRA Subtitle D, Part 258 requirements (40 CFR 258.1e). Both the East Landfill and the Sanitary Landfill have not been identified as sources to groundwater contamination. They have engineered covers that are sloped to promote drainage and vegetated to minimize the potential for erosion or abrasion of the existing covers. Also, both landfills have demonstrated the capability to function with minimum maintenance.

The Industrial Landfill is currently uncovered and has many surface depressions that may promote stormwater infiltration through the landfill's surface. During the South Percolation Ponds Removal Action, the existing surface depressions were filled, to an extent, with excavated material from the South Percolation Ponds and a temporary soil cover consisting of onsite borrow material. It is estimated that the Industrial Landfill would require approximately 56,000 CY of additional grading material to achieve a minimum slope requirement of 3% for a crowned cap design. Remediation waste from other DUs, onsite borrow material, imported soil, or a combination thereof will be used to continue filling surface depressions and for grading prior to constructing a low-permeability cap. The cap would comply with substantive MDEQ Class II landfill requirements and would consist of a grading layer, a low-permeability membrane, a drainage layer, an 18-inch layer of clean soil, and a 6-inch layer of topsoil with vegetation. Along with capping of the Industrial Landfill, stormwater conveyance swales/ditches and a perimeter berm would be constructed as necessary.

While the Asbestos Landfills are overlain by a natural soil cover, the grade of the existing cover is uneven with some small depressions. The thickness of the existing cover would be verified, and supplemental topsoil cover material would be placed as necessary to establish a minimum 12-inch soil layer, eliminate surface depressions, and establish a uniform vegetated cover to prevent exposure and minimize erosion. The surface would be graded following placement of cover material to prevent disturbing asbestos containing material. Additionally, limited stormwater conveyance swales/ditches would be constructed as necessary.

This alternative would also include regular inspections and long-term maintenance of the caps and water management controls to protect the integrity of the remedy.

Institutional and Engineering Controls

ICs applied under this alternative would include deed restrictions for the Landfills DU2 waste management units to prevent activities that could compromise function or integrity of the caps/containment systems or result in potential exposure to receptors. On-property development activities, such as agricultural or residential use, would be prohibited within the footprint of the Landfills DU2 waste management units. The property owner would retain all rights to preclude these activities from occurring onsite. ECs applied under this alternative would include installation of fencing and signage around the perimeter of the Landfills DU2 waste management units to identify and physically restrict access to human receptors and some ecological receptors.

Under this alternative, reviews would be conducted once every five years to ensure continued performance of the remedy, consistent with CERCLA requirements.

5.3 Soil DU Alternatives

Four alternatives for the Soil DU (SO-1 through SO-4) are retained for further development and evaluation in the FS. These alternatives are described below and illustrated on figures provided in Appendix G. As discussed in the RI Report, soils are not a significant source of the cyanide and fluoride concentrations observed in groundwater. For all alternatives excluding the No Action Alternative, the Soil DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments. For the alternative selected for implementation, the actual extents of containment, treatment, or excavation would be further delineated during remedial design via *in situ* pre-characterization sampling.

5.3.1 Alternative SO-1: No Action

Under the No Action alternative, no remedial actions would be performed to reduce the toxicity, mobility, or volume of COCs in the Soil DU. The No Action alternative implies continuation of existing controls including maintenance of the existing fence preventing access into the Site.

The No Action alternative would not include any long-term monitoring or new controls and would not address the RAOs established for the Site. As discussed in Section 4.1, the No Action alternative is required as a baseline for comparison.

5.3.2 Alternative SO-2: Covers with Hotspot Excavation

This alternative would provide containment of impacted material within AOCs C through E by installing soil covers. To adequately mitigate exposure pathways to human health and ecological receptors, a 2-foot thickness of clean material would comprise the soil covers. If needed, topsoil could be used for the top 6 inches of material to facilitate vegetation. The exact extents of the soil covers would be determined during remedial design via in situ pre-characterization sampling. The estimated collective cover area for the three AOCs is 6.24 acres. ICs encompassing the footprints of the soil covers would also be components of this alternative to prevent intrusive activities into the impacted material and damage to the covers. ICs may include deed restrictions to ensure future development is consistent with and does not compromise the effectiveness of the selected remedy. Construction of acceptable alternative covers (i.e., buildings, pavement) as part of future development would be consistent with this alternative.

Impacted material in AOC B (Former Drum Storage Area) under this alternative and under the other active alternatives for the Soil DU would be addressed by excavating surficial and shallow soils (0-0.5 ft-bls and 0.5-2 ft-bls, respectively). Since impacted material from AOC B (Former Drum Storage Area) may be a contributing source to the elevated cyanide and fluoride concentrations in groundwater, this material would be disposed of at an existing onsite repository (i.e., Wet Scrubber Sludge Pond) underneath its low-permeability cap. The volume of excavated material from AOC B is anticipated to be approximately 2,800 CY.

Impacted material in AOCs A, F, and G under this alternative would be addressed by excavating surficial and shallow soils. The exact extents, including depths, of excavation in each AOC would be determined during remedial design via *in situ* pre-characterization sampling. Impacted material from AOCs A, F, and G could be disposed of at an onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond) or consolidated within AOCs C through E underneath the soil cover. The volume of excavated material from AOCs A, F, and G is anticipated to be approximately 2,800 CY.

The components comprising this alternative would address the RAOs established for the Site as described in the detailed evaluation of this alternative in Section 6, Table 6-3.

5.3.3 Alternative SO-3: *In Situ* Phytoremediation with Hotspot Excavation

This alternative would provide *in situ* treatment of PAH-impacted material within AOCs C through E via phytoremediation. The COCs for these AOCs are HMW PAHs, specifically benzo(a)pyrene; as such, the selection of vegetation to be planted would predominantly consist of prairie grasses that stimulate rhizosphere biodegradation of these chemicals. A few example grasses that have demonstrated treatment of PAHs and would thrive at the Site, which is located within the United States Department of Agriculture (USDA) Hardiness Zone 4, include Canada Wild Rye (*Elymus canadensis*), Red Fescue (*Festuca ovina var. duriuscula*), Little Bluestem (*Schizachyrium scoparius*), and Switchgrass (*Panicum virgatum*).

Since the primary removal mechanism would occur in the rhizosphere, or root zone, minimal cover material would be added prior to seeding; topsoil would only be added as needed to facilitate vegetative growth. The exact extents of soil requiring treatment would be determined during remedial design via *in situ* pre-characterization sampling. Annual monitoring would include sampling soil from the rhizosphere for analysis of the COCs. If degradation performance is below the anticipated rate, tests to address plant health (e.g. nutrients, pH, microbial activity) would also be performed. ICs encompassing the footprints of the phytoremediation would be a component of this alternative until treatment is completed (i.e., small range receptor PRGs are attained) as determined by post-treatment confirmatory sampling.

As stated in Alternative SO-2 above, impacted surficial and shallow soils in AOC B (Former Drum Storage Area) would be excavated with disposal at the Wet Scrubber Sludge Pond.

Similar to Alternative SO-2 above, impacted material in AOCs A, F, and G under this alternative would be delineated during remedial design and excavated. The excavated material from AOC A would be disposed of at an onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond). PAH-impacted material from AOCs F and G would be consolidated within AOCs C through E and treated as part of the phytoremediation in these areas.

The components comprising this alternative would address the RAOs established for the Site as described in the detailed evaluation of this alternative in Section 6, Table 6-3.

5.3.4 Alternative SO-4: Excavation with Onsite Consolidation

This alternative would remove all impacted material exceeding small range receptor PRGs and/or resulting in exceedances of PRGs (as described in Section 3.3) by excavating the AOCs and consolidating the excavated material for disposal at an onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond). The exact extents, including depths, of excavation in each AOC would be determined during remedial design via *in situ* pre-characterization sampling. The volume of excavated material is anticipated to be approximately 25,000 CY. As stated in Alternative SO-2 above, excavated surficial and shallow soils from AOC B (Former Drum Storage Area) would be disposed of at the Wet Scrubber Sludge Pond.

The RAOs established for the Site would be addressed as described in the detailed evaluation of this alternative in Section 6, Table 6-3 without IC components.

5.4 North Percolation Pond DU Alternatives

Four alternatives for the North Percolation Pond DU (NPP-1 through NPP-4) are retained for further development and evaluation in the FS. As discussed in the RI Report, the North Percolation Ponds are not a significant source of the cyanide and fluoride concentrations observed in groundwater. These alternatives are described below and illustrated on figures provided in Appendix H. For each alternative comprising an excavation component, the actual depth of excavation will be determined during design or remediation using confirmatory sampling.

5.4.1 Alternative NPP-1: No Action

Under the No Action alternative, no remedial actions would be performed to reduce the toxicity, mobility, or volume of COCs in the North Percolation Pond DU. The No Action alternative implies continuation of existing controls including maintenance of the existing fence around the North-West Percolation Pond and that limits access to the North-East Percolation Pond.

The No Action alternative would not include any long-term monitoring or new controls and would not address the RAOs established for the Site. As discussed in Section 4.1, the No Action alternative is required as a baseline for comparison.

5.4.2 Alternative NPP-2: Limited Excavation with Covers

This alternative would provide containment of impacted areas within the North Percolation Pond DU by installing soil covers at the North-East and North-West Percolation Ponds. Physical solidification of the viscous, carbonaceous material present in the North Percolation Pond DU may be required to support the soil covers and would be implemented as needed. Impacted material in the influent and overflow ditches resulting in exceedances of PRGs (as described in Section 3.3) in the North Percolation Pond DU (reasonable upper estimate of approximately 2,880 CY; see Table 3-19) would be excavated and consolidated in the North-East Percolation Pond underneath the soil cover. To eliminate the influx of COCs, the influent pipes from which stormwater enters the North Percolation Pond system via the North-East Percolation Pond would be decommissioned.

ICs and ECs encompassing the footprint of the North-East and North-West Percolation Ponds would also be components of this alternative to prevent intrusive activities into the impacted material and damage to the covers. ICs and ECs may include deed restrictions, to ensure future development is consistent with and does not compromise the effectiveness of the selected remedy, and fencing, to physically prevent exposure to compliant human receptors and some ecological receptors, including maintenance of the existing fence and installation of additional fence as necessary (e.g., around the North-East Percolation Pond). In addition, the North Percolation Pond DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments. These components, coupled with consolidation and containment via soil covers, would address the RAOs established for the Site as described in the detailed evaluation of this alternative in Section 6, Table 6-4.

5.4.3 Alternative NPP-3: Excavation with Cover

This alternative would provide containment of impacted areas within the North Percolation Pond DU by installing a soil cover at the North-East Percolation Pond. Physical solidification of the viscous, carbonaceous material present in the North Percolation Pond DU may be required to support the soil cover and would be implemented as needed. Impacted material in the influent ditch, overflow ditch, and North-West Percolation Pond resulting in exceedances of PRGs (as described in Section 3.3) in the North Percolation Pond DU (reasonable upper estimate of approximately 22,280 CY; see Table 3-19) would be excavated and consolidated in the North-East Percolation Pond underneath the soil cover. To eliminate the influx of COCs, the influent pipes from which stormwater enters the North Percolation Pond system would be decommissioned.

ICs to prevent intrusive activities into the impacted material and damage to the soil cover would encompass the North-East Percolation Pond, only. In addition, the North Percolation Pond DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments. Other ICs and ECs under this alternative mirror the measures listed for Alternative NPP-2 above. These components, coupled with consolidation and containment via soil cover, would address the RAOs established for the Site as described in the detailed evaluation of this alternative in Section 6, Table 6-4.

5.4.4 Alternative NPP-4: Excavation with Onsite Consolidation

This alternative would remove all impacted material resulting in exceedances of PRGs (as described in Section 3.3) in the North Percolation Pond DU (reasonable upper estimate of approximately 35,180 CY; see Table 3-19) by excavating impacted material from the influent and overflow ditches, the North-West Percolation Pond, and the North-East Percolation Pond. To eliminate the influx of COCs, the influent pipes from which stormwater enters the North Percolation Pond system would be decommissioned.

The excavated material would be consolidated at an existing onsite repository (i.e., Wet Scrubber Sludge Pond) prior to capping of that waste management unit. Based upon the mix and concentrations of COCs in the soil/sediment that would be excavated from the North Percolation Pond DU as well as the presence of viscous waste, the Wet Scrubber Sludge Pond was determined to be the appropriate repository for this excavated material due to the comparability of the wastes. As discussed in Section 5.1.2, the capacity of the Wet Scrubber Sludge Pond is approximately 43,000 CY. The cap for the Wet Scrubber Sludge Pond would be implemented as part of the alternative for its respective DU (i.e., Landfills DU1); as such, this element of the remedy is not considered in the detailed evaluation of effectiveness, implementability, or cost for Alternative NPP-4. Physical solidification of the viscous, carbonaceous material from the North Percolation Pond DU may be required to support the Wet Scrubber Sludge Pond cap and would be implemented as needed.

Since all impacted material resulting in exceedances of PRGs would be removed from the North Percolation Pond DU under this alternative, ICs to prevent intrusive activities and damage to the soil cover would not be necessary. The North Percolation Pond DU would be subject to a Commercial Use designation for the entire footprint of the DU to reflect the assumptions made in the risk assessments. The RAOs established for the Site would be addressed as described in the detailed evaluation of this alternative in Section 6, Table 6-4 without other IC or EC components.

5.5 River Area DU Alternatives

Two alternatives for the River Area DU (RADU-1 and RADU-2) are retained for further development and evaluation in the FS. These alternatives are described below and illustrated on figures provided in Appendix I. As described in Section 2.3.5, excavation and onsite consolidation activities were completed as a part of the Removal Action at the South Percolation Ponds ("Removal Action") in accordance with the requirements of the Administrative Order on Consent effective July 21, 2020. As discussed in the RI Report, the River Area DU is not a source of groundwater contamination at the Site. The potential risk attributed to cyanide in sediment, sediment porewater, and surface water within the River Area DU will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Groundwater is addressed within the Landfills DU1 and Groundwater DU joint alternatives described in Section 5.1.

5.5.1 Alternative RADU-1: No Further Action

Under the No Further Action alternative, no additional remedial actions would be performed following the Removal Action to reduce the toxicity, mobility, or volume of COCs in the River Area DU. The Removal Action, described below, will address RAOs established for sediments at the Site and is expected to address the RAO established for metals in surface water at the Site. The No Further Action alternative would not include any long-term monitoring or new controls and would not address the RAO established for cyanide in surface water at the Site. As discussed in Section 4.1, a No Action alternative is required as a baseline for comparison.

Removal Action

The primary elements associated with the Removal Action at the South Percolation Ponds include:

- Decommissioning the influent pipe from which stormwater enters the South Percolation Pond system; and
- Excavating impacted sediment in the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill).

The Removal Action included decommissioning the influent pipe to the South Percolation Pond system to eliminate direct discharge of stormwater into the ponds, effectively eliminating the source of aluminum and other metals to surface water in the South Percolation Ponds. To decommission the influent pipe, the pipe and outlet structure in the South Percolation Pond Area was uncovered and removed and the excavation was backfilled with native material. The sections of discharge pipe that run below the existing railway right-of-way were excavated and exposed on the north and south sides of the railway and then abandoned with flowable fill so that the soil within the right-of-way remained undisturbed.

The Removal Action also included excavating the South Percolation Pond soils/sediments exceeding PRGs (approximately 0 to 1 ft) and relocation of soils/sediments to an existing onsite repository (i.e., the Industrial

Landfill). Prior to the excavation activities and periodically throughout the duration of the Removal Action, assessments of groundwater seeps were performed. Post-excavation sampling of soil/sediment was conducted to confirm attainment of PRGs. Sampling of surface water and sediment porewater was also conducted in accordance with the USEPA-approved Removal Work Plan (Roux, 2020c).

As discussed in the RI Report, soils/sediments in the South Percolation Ponds posed a moderate ecological risk but did not pose human health risk and were not a source to groundwater. Therefore, the material excavated from the South Percolation Ponds was suitable for placement in the Industrial Landfill, with the understanding that final closure of the Industrial Landfill will include a cap that complies with substantive MDEQ Class II landfill requirements (discussed in Section 5.2). The material was used to fill a portion of the existing depressions at the Industrial Landfill and were graded to promote stormwater runoff. Upon completion of transporting and compacting activities, a temporary one-foot cover consisting of onsite borrow fill was emplaced on top of the newly placed fill areas in the Industrial Landfill in a manner to prevent erosion and dust generation. Post-excavation samples were collected at the South Percolation Ponds to confirm no material remained in exceedance of PRGs. Data from the post-excavation sampling resulted in the removal of an additional foot of sediment from one of the grids (Grid 8 of Pond 1). A total of 22,000 CY of sediment were removed from the South Percolation Ponds under the Removal Action.

Following the removal of the South Percolation Pond soils/sediments, the existing dam was removed to allow the river to resume flowing in its original channel that occupied this area prior to construction of the dam. The remaining infrastructure located between the side channel and main stem of the Flathead River was also removed to allow natural lateral migration to occur unimpeded.

5.5.2 Alternative RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater

The primary elements associated with Alternative RADU-2 would include the following:

- Implementation of the Removal Action at the South Percolation Ponds, including:
  - Decommissioning the influent pipe from which stormwater enters the South Percolation Pond system; and
  - Excavating impacted sediment in the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill).
- Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater.
- Monitoring of metals[1], fluoride, and PAHs[2] in the River Area DU surface water as identified in the Surface Water RAO and PRGs until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs).

[1] Aluminum, arsenic, barium, copper, iron, lead, mercury, and thallium
[2] Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene

Removal Action

The Removal Action is described in Section 5.5.1.

Long-Term Monitoring of Surface Water and Sediment Porewater

Implementation of Alternative RADU-2 would involve continued long-term monitoring of the River Area DU to document the reduction of total cyanide concentrations in surface water and free cyanide concentrations in porewater. Under this alternative, surface water and sediment porewater would be routinely sampled and analyzed for cyanide (total and free, respectively) to demonstrate that concentrations of cyanide are decreasing over time.

Initial monitoring rounds would also include sampling of surface water metal COCs that exceed PRGs (i.e., aluminum, barium, copper, and iron) to demonstrate that removal of the influent pipe from which stormwater enters the South Percolation Pond system performed under the Removal Action eliminates the source of aluminum and other metals to surface water in the River Area DU. Other metals (i.e., arsenic, lead, mercury, and thallium), fluoride, and PAHs (i.e., benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-c,d)pyrene), which have exceeded the Montana DEQ-7 surface water standards for human health in at least one sample, would also initially be monitored in surface water in their respective features of the River Area DU (see Section 3.3.5) until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs).

Long-term monitoring would be performed at the same frequency as MNA, described in Section 5.1.2. For the first five years, monitoring would be conducted in June and October (i.e., twice a year) to document conditions during the high- and low-water season, respectively. Based upon sampling results from the first five years, the frequency of monitoring may be reduced to an annual basis. Surface water and sediment porewater monitoring under this alternative would continue until RAOs are achieved or, if not achieved, for a minimum of 30 years. The exact monitoring network and details regarding frequency of sampling and parameters analyzed would be identified in subsequent remedial design reports, as appropriate.

6. Detailed Evaluation of Remedial Action Alternatives

Remedial alternatives to be evaluated in this FS Report must address the threats to human health and the environment posed by the various contaminated media at the Site and meet the remedial objectives developed for the Site presented in Section 3 above. To facilitate the selection of remedial actions for implementation at the Site, each alternative is evaluated in detail against the nine CERCLA evaluation criteria.

Detailed evaluations of each retained alternative against the first seven evaluation criteria are provided in Tables 6-1 through 6-5. As further discussed below, the remaining two criteria will likely be assessed in the ROD prior to final selection of the remedy. The purpose of the individual detailed evaluations is to assess how and to what extent these evaluation criteria are met and to inform the comparative analysis presented in Section 7. The detailed evaluations are provided in tabular form so that minor differences across alternatives are easier to discern.

6.1 Evaluation Criteria

The first two criteria are "threshold" criteria that must be met for an alternative to be considered for implementation:

1. Overall protection of human health and the environment
2. Compliance with ARARs

Five "balancing" criteria are used to make comparison and to identify the major trade-offs between the remedial alternatives. Alternatives that satisfy the threshold criteria are evaluated further using the following five criteria:

1. Long-term effectiveness and permanence
2. Reduction of toxicity, mobility, or volume
3. Short-term effectiveness
4. Implementability
5. Cost

The remaining two criteria are "modifying" criteria and are usually assessed in the ROD prior to final selection of the remedy:

6. State acceptance
7. Community acceptance

The development of remedial alternatives is based on a broad consideration of three factors: Effectiveness (collectively Criteria 1 through 5), Implementability (Criterion 6), and Cost (Criterion 7). The fourth factor, Acceptance (Criteria 8 and 9), will be address by USEPA in the ROD once state and public comments are received on the FS Report and the proposed plan. A summary of each evaluation criteria is provided below.

Effectiveness

1. **Overall Protection of Human Health and the Environment –** This evaluation criterion evaluates whether each alternative can achieve and maintain adequate protection of human health and the environment in both the short- and long-term, and describes how risks associated with the potential Site-specific exposure pathways are eliminated, reduced, or controlled through treatment, engineering, and/or institutional controls to achieve RAOs. This evaluation criterion also allows for consideration of whether an alternative poses any unacceptable short-term (during remedial activities) or cross-media impacts; the criterion of overall protection of the environment explicitly includes balancing the ecological benefits of reducing COC exposures against the ecological impacts of the remedial option (USEPA, 1997). The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

2. **Compliance with ARARs –** This evaluation criterion is used to determine whether an alternative would satisfy all federal and state ARARs, including compliance with chemical-, action-, and location-specific ARARs. Chemical-specific ARARs are numerically represented by the PRGs. If the assessment indicates an ARAR will not be met, then the basis for justifying one of the six ARAR waivers allowed under CERCLA and provided in Section 3.1 would be discussed. A list of ARARs identified for the Site can be found in Table 3-1.

3. **Long-Term Effectiveness and Permanence –** This evaluation criterion evaluates the likelihood the remedy will be successful and the permanence it affords. The results of a remedial action are evaluated in terms of the potential exposure risk remaining at the Site after RAOs have been satisfied. Consideration should be given to the magnitude of residual risk posed by treatment residuals and/or untreated constituents remaining at the conclusion of remedial activities, and the requirement of a 5-year review. The characteristics of the residuals are considered to the degree they remain hazardous, considering their toxicity, mobility, volume, and propensity to bioaccumulate.

   In addition, the evaluation should include an assessment of the adequacy and reliability of controls, if any, that are used to manage treatment residuals or untreated constituents remaining at the Site. The evaluation may include an assessment of containment systems and institutional controls to determine whether they are sufficient to ensure any exposure to human and environmental receptors is within protective levels. Issues for evaluation are the type and degree of long-term management and operations, maintenance, and monitoring (OM&M) functions.

4. **Reduction of Toxicity, Mobility, and Volume through Treatment –** This evaluation criterion assesses the degree to which each alternative employs treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Factors to be considered, as appropriate, include the following:

   - The treatment process(es) the alternative employs and the materials it will treat;
   - The amount of hazardous substances, pollutants, or contaminants that will be destroyed or treated, including how the principal threat(s) will be addressed;
   - The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment (e.g., percent reduction);
   - The degree to which the treatment is irreversible;
   - The type and quantity of residuals that will remain following treatment, considering their persistence, toxicity, mobility, and propensity to bioaccumulate; and
   - Whether the alternative would satisfy the statutory preference for treatment as a principal element of the remedial action.

5. **Short-Term Effectiveness –** This evaluation criterion examines the effects of each alternative during the construction and implementation phase of the remedial action until RAOs are met. The short-term impacts of each alternative are assessed considering the following factors, as appropriate:

- Protection of the community during remedial actions;
- Protection of workers during remedial actions;
- Environmental impact during remedial actions; and
- Time until RAOs are achieved.

The environmental impact during remedial actions will consider the sustainability of the elements of the remediation including: energy requirements of the treatment system; air emissions; water requirements and impacts on water resources; land and ecosystem impacts; material consumption and waste generation; and long-term stewardship actions.

The time until RAOs are achieved will be measured from the date the ROD is issued, and will include the time for design, agency review and approval, and implementation of the selected remedy. The estimated durations for construction of remedy components are based on professional judgement, including experience at other sites under similar conditions, and input from specialty contractors where appropriate (e.g., PRBs, slurry walls). The estimated time until groundwater and surface water RAOs would be achieved are based on evaluations of groundwater flow and transport calculations discussed in Appendix A. For surficial and shallow soil and sediment posing risk of direct contact exposure, RAOs would typically be achieved immediately upon completion of remedy implementation.

Implementability

6. **Implementability –** This evaluation criterion considers the technical and administrative feasibility of executing an alternative, as well as the availability of services and materials required during its implementation. Implementability considerations often affect the timing of various remedial action alternatives (e.g., limitations on the season in which the remedial action can be implemented, the number and complexity of materials-handling steps that must be followed, and the need to secure technical services). The ease or difficulty of implementing each alternative will be assessed by considering the factors listed below.

   Technical feasibility:

   - Technical difficulties and unknowns associated with the construction and operation of a technology;
   - Reliability of the technology, focusing on technical problems that will lead to schedule delays;
   - Ease of undertaking additional remedial action, including what, if any, future remedial actions would be needed; and
   - Ability to monitor the effectiveness of the remedy.

   Administrative feasibility:

   - Activities needed to coordinate with other offices and agencies; and
   - The ability and time required to obtain any necessary approvals and permits from other agencies (for offsite actions).

   Availability of services and materials:

   - Availability of adequate offsite treatment, storage capacity, and disposal capacity and services;
   - Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources;
   - Availability of services and materials plus the potential of obtaining competitive bids; and

- Availability of prospective technologies.

Cost

7. **Cost –** This evaluation criterion estimates the expenditures required to complete each alternative's measures in terms of both capital and annual OM&M costs incurred over the life of the project. Given these values, a present-worth calculation for each alternative can be made for comparison. These costs are calculated in accordance with the USEPA Guide to Developing and Documenting Cost Estimates (USEPA, 2000b).

   Capital costs consist of direct and indirect costs. Direct costs include the cost of construction, equipment, land and site development, treatment, transportation, and disposal. Indirect costs include engineering expenses, license or permit costs, and contingency allowances. Annual OM&M costs are the post-construction costs required to ensure the continued effectiveness of the remedial action. Components of annual OM&M cost include the cost of operating labor, maintenance materials and labor, utilities, energy, residue disposal, purchased services, administration, insurance, taxes, licensing, maintenance reserve and contingency funds, rehabilitation, monitoring, reporting, and periodic site reviews. Expenditures that occur over different periods of time are analyzed using present worth, which discounts all future costs to a common base year. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. Assumptions associated with the present-worth calculations include a discount rate of 7 percent before taxes and after inflation, cost estimates in the planning years in constant dollars, and a period of performance that would vary depending on the activity but that would not exceed 30 years.

   The cost estimates for this FS Report are calculated with the intention of achieving the CERCLA FS cost-estimating goal for accuracy of -30 to +50 percent. The alternative cost estimates are in 2020 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project will depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. Most of these factors are not expected to affect the relative cost differences between alternatives.

   This criterion is further discussed in Appendix J. Detailed cost estimates for each retained alternative are also provided in Appendix J.

Acceptance

8. **State Acceptance –** This criterion relates to the State perception of the selected remedy and its acceptability as the method of remediation. State acceptance is usually assessed in the ROD following review of State comments on the Draft Final FS Report, and as such will not be evaluated in this FS Report. State acceptance indicates whether the state concurs with, opposes, or has no comment on the selected remedy.
9. **Community Acceptance –** The criterion relates to the public perception of the selected remedy and its acceptability as the method of remediation. Community acceptance is usually assessed in the ROD following a review of public comments received on the Draft Final FS Report, and as such will not be evaluated in this FS Report.

As discussed above, each alternative is evaluated against the threshold and balancing criteria; the two modifying criteria will be assessed by USEPA in the ROD.

6.2 Supplemental Screening of LDU1/GW Alternatives

Following the detailed evaluations of Landfills DU1 and Groundwater DU Joint Alternatives, the twelve alternatives were once again screened based on considerations of effectiveness, implementability, and relative cost to identify the most viable candidates for use in the comparative analysis. The results of the evaluation screened the following alternatives from further consideration:

- Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation;
- Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB;
- Alternative LDU1/GW-4B: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient PRB;
- Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area; and
- Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and Downgradient.

The primary reasons for screening each alternative from further consideration are discussed below.

Alternative LDU1/GW-2 comprises construction of low-permeability caps at the Wet Scrubber Sludge Pond and Center Landfill as well as maintenance of the low-permeability cap at the West Landfill. However, it does not include any additional source control measures to address underlying soils beneath the West Landfill that are likely contributing to groundwater contamination, nor does it include any downgradient groundwater treatment measures to mitigate impacts to ecological receptors in the River Area DU. Therefore, there are concerns Alternative LDU1/GW-2 would not satisfy threshold criteria (i.e., overall protection of human health and the environment; compliance with ARARs). For this reason, Alternative LDU1/GW-2 was screened from further consideration.

Alternatives LDU1/GW-3B and LDU1/GW-4B both include construction of a downgradient PRB. Based on additional research and communication with specialty contractors during the detailed evaluation of the alternatives, there are concerns with the effectiveness and implementability of a PRB for *in situ* cyanide treatment at the depth and scale that would be required at this Site. Effectiveness and implementability concerns also arose during detailed evaluation of Alternatives LDU1/GW-5A and Alternative LDU1/GW-5C, which both include hydraulic control at the source area. Due to the mix of COCs in groundwater at the source area (i.e., cyanide, fluoride, and arsenic) as well as the extremely high and seasonally variable flow rates that would need to be accommodated, the system necessary to treat groundwater under these alternatives would be very large and complex, and difficult to operate effectively from a technical feasibility perspective; thereby potentially compromising the effectiveness. For these reasons, Alternatives LDU1/GW-3B, 4B, 5A, and 5C were screened from further consideration.

7. Comparative Analysis of Remedial Action Alternatives

The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each remedial action alternative relative to one another, focusing on the relative performance of each alternative against the first seven evaluation criteria set forth by the NCP (40 CFR 300) as listed above in Section 6 and summarized in Table 7-1. For DUs with multiple retained alternatives, the relative performance of each alternative was evaluated with respect to each of the balancing criteria (i.e., CERCLA evaluation criteria 3 through 7) using the scoring system described below. The scores have no independent value; they are used as a tool to compare alternatives such that the alternative that scores highest maximizes performance relative to that criterion compared to the other alternatives in the same DU. The relative performance against these criteria, combined with risk management decisions, serve as the rationale for identifying the highest-ranked remedial action alternative for each DU and, ultimately, for the Site as a whole (Section 7.6).

Table 7-1 Summary of Evaluation Criteria

Evaluation Criteria		
Effectiveness	1	Overall protection of human health and the environment
	2	Compliance with ARARs
	3	Long-term effectiveness and permanence
	4	Reduction of toxicity, mobility, or volume
	5	Short-term effectiveness
Implementability	6	Implementability
Cost	7	Cost

For threshold criteria (Criteria 1 and 2), the rating can be one of two values; the criterion is either fully met or not met. Therefore, no numerical values are assigned to the threshold criteria. For balancing criteria (Criteria 3 through 7), the rating can range from zero to twenty; a twenty is scored for the alternative that best satisfies the criterion, and a zero is scored if the alternative clearly does not satisfy one or more of the criterion factors. For the cost criterion, the estimated present value costs are converted to a 0 to 20 scale, with the highest cost alternative receiving the lowest score and the no action alternative earning the highest score.

The numerical comparative analysis focuses on the balancing criteria. Determination of scoring values for each alternative is based on comparisons between the alternatives for each DU; the assigned scores are not meaningful if compared between DUs. In general, the higher the relative score, the better that alternative satisfies the respective criterion when compared to the other alternatives for that DU. For alternatives that meet both of the threshold criteria, the relative scores for each balancing criterion are then summed to yield an overall Balancing Criteria Score, which has a maximum possible score of 100. The Balancing Criteria

Score can then be compared between alternatives within a DU. Of the retained alternatives for each DU, the alternative with the highest Balancing Criteria Score meets the threshold criteria (i.e., it is protective of human health and the environment, and it is compliant with ARARs) and maximizes performance relative to the balancing criteria as a whole, making it the highest-ranked remedial action alternative for that DU.

Based on the comparative analyses for each DU, the highest-ranked remedial action alternatives as determined in Sections 7.1 through 7.5 were then assembled into a comprehensive, Site-wide remedial action alternative described in Section 7.6. Because each DU-specific remedial action alternative meets the threshold criteria and maximizes performance relative to the balancing criteria for its respective DU, the comprehensive Site-wide remedial action alternative provides the most effective approach to address the Site COCs and associated risks as identified in the BHHRA (EHS Support, 2019d) and BERA (EHS Support, 2019e). Based on the evaluations in this FS report, USEPA will issue a proposed remedial action plan for formal public comment. Based on the public comments, the ROD will evaluate the modifying CERCLA criteria: (8) state (or support agency) acceptance; and (9) community acceptance. Final selection of the remedy will be made by USEPA and the selected remedy will be identified in the ROD.

7.1 Landfills DU1 and Groundwater DU Joint Alternatives

The relative performance of the seven alternatives evaluated and retained for the combined Landfills DU1 and Groundwater DU against each of the seven evaluation criteria is discussed below. As discussed in Section 6.2, Alternatives LDU1/GW-2, 3B, 4B, 5A, and 5C have been screened from further consideration following detailed evaluation based upon concerns over satisfying threshold criteria (Alternative LDU1/GW-2) and effectiveness and implementability (Alternatives LDU1/GW-3B, 4B, 5A, and 5C). The following alternatives are retained for further evaluation and comparative analysis as described below:

- Alternative LDU1/GW-1: No Action;
- Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall;
- Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction;
- Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall;
- Alternative LDU1/GW-4C: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient Extraction;
- Alternative LDU1/GW-5B: Containment via Capping and Downgradient Hydraulic Control; and
- Alternative LDU1/GW-6: Excavation with Onsite Consolidation.

A summary of the comparative analysis of joint alternatives retained for Landfills DU1 and the Groundwater DU is provided in Table 7-2.

7.1.1 Overall Protection of Human Health and the Environment

All retained remedial alternatives, with the exception of Alternative LDU1/GW-1 (No Action), are protective of human health and the environment based on current land and groundwater use as well as reasonably expected future uses. Alternative LDU1/GW-1 would not be protective as the direct contact exposure routes, including exposure to impacted soil by small range receptors and to impacted surface water and porewater by ecological receptors in the River Area DU, would remain complete. Exposure pathways to impacted soil would be eliminated by removal under Alternative LDU1/GW-6 (Excavation with Onsite Consolidation) or through containment (i.e., capping) under all other active, retained alternatives. Exposure pathways to impacted surface water and porewater in the River Area DU would be mitigated by source control measures under all alternatives excluding LDU1/GW-1, and/or by downgradient groundwater treatment under Alternatives LDU1/GW-3C, 4C, and 5B. Therefore, this threshold criterion would be fully met by all active, retained alternatives.

7.1.2 Compliance with ARARs

All retained remedial alternatives, with the exception of Alternative LDU1/GW-1 (No Action), would comply with State and Federal chemical-specific ARARs identified in Table 3-1. Alternative LDU1/GW-1 would not meet chemical-specific ARARs as no action would be taken to address COCs currently present in the Landfills DU1 or Groundwater DU in exceedance of standards. Under Alternative LDU1/GW-5B, achievement of ARARs would be unlikely within the plume footprint downgradient of the waste management units and upgradient of the extraction wells; if selected, an ARAR waiver for groundwater would be a required component of this alternative. Alternative LDU1/GW-6 would likely result in an increase in concentrations of COCs downgradient of the Landfills DU1, both within and potentially beyond the current extent of the plume, in contravention of RAOs and non-degradation ARARs (see Table 6-1). However, short-term exemptions could be authorized by the agencies to comply with this chemical-specific ARAR. In addition, the active alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. Therefore, this threshold criterion would be fully met by all active, retained alternatives.

7.1.3 Long-term Effectiveness and Permanence

Alternative LDU1/GW-1 (No Action) is not considered to be effective in the long term because potential risks would not be managed; no reduction in the magnitude of residual risk would be achieved, and no additional controls would be implemented to control these risks. Alternative LDU1/GW-1 would therefore perform poorly against this criterion and as such was given the lowest score (0).

The other retained alternatives excluding Alternative LDU1/GW-6 (Excavation with Onsite Consolidation) would reduce the magnitude of residual risk in the Landfills DU1 by capping impacted soil resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. Maintenance as well as reliance on ICs would be required under these alternatives to prevent intrusive activities into impacted material and damage to the cap. Alternative LDU1/GW-6 would reduce the magnitude of residual risk in the Landfills DU1 by removing impacted soil resulting in exceedances of PRGs, and as such would not have engineering control measures in place in the former footprints of the Landfills DU1 waste management units. This alternative would require maintenance as well as reliance on ICs at the newly constructed onsite repository to ensure continued performance of the repository components including the low-permeability cap and the leachate collection system. Successful implementation of these alternatives would result in an ELCR below 1E-05 and HQ < 1 in the Landfills DU1 for both human health and ecological receptors.

All retained remedial alternatives, with the exception of Alternative LDU1/GW-1 (No Action), would reduce the magnitude of residual risk in groundwater over time and, subsequently, in surface water and porewater in the River Area DU through natural attenuation. The low-permeability caps maintained and constructed under the active, retained alternatives excluding Alternative LDU1/GW-6 (Excavation with Onsite Consolidation) would prevent infiltration of precipitation and runoff through the surface of the landfill and the underlying impacted materials, preventing/reducing leaching of COCs to groundwater. In addition, the active, retained alternatives excluding Alternative LDU1/GW-5B each have an additional source control measure beyond the capping of the waste management units to reduce the magnitude of residual risk and to increase the adequacy and reliability of the controls. Compared to Alternative LDU1/GW-1, the other retained alternatives would offer higher long-term effectiveness and permanence.

For Alternatives LDU1/GW-3A through LDU1/GW-4C, the slurry wall component of each alternative would be expected to provide long-term effectiveness as documented in numerous studies and evaluations including reports from dozens of USEPA Superfund sites and many large-scale civil infrastructure projects. In 1998, USEPA evaluated subsurface engineered barriers at 36 sites and found that 25 sites generally performed as designed and significantly improved the quality of groundwater and surface water in the vicinity of the site. Seven of the sites had insufficient data to determine long-term performance and four of the sites had leaks detected at the key which were repaired with relative ease (USEPA, 1998a). All the barriers that had documented leaks were repaired and the effectiveness of each barrier was restored. As discussed in the technology screening presented in Section 4.6, a comprehensive study concluded that most engineered waste containment barrier systems that have been designed, constructed, operated, and maintained in accordance with current statutory regulations and requirements (as of 2007 when the study was published) have thus far provided environmental protection at or above specified levels (National Research Council, 2007).

Given the characteristics of the slurry wall backfill (i.e., blend of soil and bentonite clay, which are natural earthen materials resistant to degradation) and the environmental conditions of the subsurface (e.g., insulated from freeze-thaw cycles, locked-in-place by surrounding earthen materials), there is no reason to believe a properly designed slurry wall would not continue to perform over time. Further, the soil-bentonite slurry wall would be compatible with the groundwater COCs and would not be subject to significant degradation. As such, it is expected that the slurry wall would maintain its low-permeability for the long term.

Under Alternative LDU1/GW-3A, an upgradient slurry wall would divert clean groundwater around the West Landfill and Wet Scrubber Sludge Pond. This would reduce the leaching of COCs to groundwater and the associated mass flux of contamination from beneath the waste management units, giving Alternative LDU1/GW-3A score of 15.

Under Alternative LDU1/GW-4A, a fully-encompassing slurry wall around the West Landfill and the Wet Scrubber Sludge Pond would contain contaminated groundwater within the footprint of the waste management units and prevent contaminant mass flux from beyond the containment cell. This would cut off the source of contamination to groundwater, giving this alternative greater long-term effectiveness and permanence than the upgradient slurry wall and a score of 18.

In addition to the slurry wall source control measure, downgradient groundwater extraction and treatment under Alternatives LDU1/GW-3C and 4C would provide cyanide treatment of groundwater at a location approximately 300 to 400 feet upgradient of the River Area DU. Downgradient groundwater extraction and treatment is considered an adequate and reliable control, however in the long term it is expected that the slurry wall component of these alternatives would control the source area such that downgradient groundwater treatment would not substantially increase the long-term effectiveness and permanence of those alternatives; therefore, the scores for Alternatives LDU1/GW-3C and 4C are the same as those for Alternatives LDU1/GW-3A and 4A, respectively.

Alternative LDU1/GW-5B would implement the downgradient groundwater extraction and treatment described above without an additional source control measure beyond the capping of the waste management units. Due to the absence of an additional source control measure, and because any prolonged system shutdowns would pose potential risk to ecological receptors in the River Area DU, this alternative was given a score of 10.

Alternative LDU1/GW-6 would achieve source control by removing waste material and underlying impacted soil from the West Landfill and Wet Scrubber Sludge Pond. This would prevent the leaching of COCs to groundwater and significantly reduce the potential for future migration of COCs, giving this alternative the greatest long-term effectiveness and permanence and a score of 20. Alternative LDU1/GW-6 would only achieve long-term effectiveness and permanence if all source material contributing to groundwater contamination, including impacted underlying soils, is removed.

Following successful implementation of any of the active, retained alternatives, the magnitude of residual risk would be less than target risk levels set by Montana DEQ-7 standards.

7.1.4 Reduction of Toxicity, Mobility or Volume

Under Alternative LDU1/GW-1 (No Action), there would be no reduction in toxicity, mobility, or volume of hazardous materials in the Landfills DU1 or Groundwater DU, and as such was given a score of 0.

The other retained alternatives would not reduce the volume of impacted waste and soils associated with the Landfills DU1 waste management units; however, they would reduce the toxicity and/or mobility of these impacted materials to varying degrees. In addition, several alternatives implement treatment of groundwater to reduce the toxicity of groundwater that is the source of contamination to surface water and porewater in the River Area DU. The relative reduction of toxicity and/or mobility of COCs in the Landfills DU1 and Groundwater DU anticipated under each alternative is discussed below.

Under the active, retained alternatives excluding Alternative LDU1/GW-6 (Excavation with Onsite Consolidation), the mobility of COCs from within the waste management units would be reduced due to the caps eliminating infiltration from precipitation and runoff. The addition of an upgradient slurry wall would reduce groundwater flow through the West Landfill and Wet Scrubber Sludge Pond, and as such Alternative LDU1/GW-3A was given the score of 9. The fully-encompassing slurry wall under Alternative LDU1/GW-4A would further reduce the mobility of COCs from within the waste management units as well as the groundwater flow and contaminant mass flux through the West Landfill and Wet Scrubber Sludge Pond. This reduction in mobility would be greater than that expected from an upgradient slurry wall, and as such Alternative LDU1/GW-4A was given the score of 14.

Under Alternatives LDU1/GW-3C and 4C, downgradient groundwater extraction and treatment would provide cyanide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. By treating downgradient groundwater for cyanide, this measure would reduce the toxicity in groundwater downgradient that is a source of contamination to surface water and porewater in the River Area DU, giving Alternatives LDU1/GW-3C and 4C slightly greater scores than those for Alternatives LDU1/GW-3A and 4A, respectively.

Downgradient groundwater extraction and treatment under Alternative LDU1/GW-5B would treat a continuous, high flow rate of contaminated groundwater for cyanide, reducing the toxicity in groundwater downgradient and, subsequently, surface water and porewater in the River Area DU. Extraction and treatment of groundwater downgradient, only, however would not reduce the mobility of COCs in groundwater beneath the Site. As such, Alternative LDU1/GW-5B was given a score of 10.

Under Alternative LDU1/GW-6, the mobility of COCs would be significantly reduced by removing impacted material from beneath the seasonal high-water table and effectively eliminating leaching and contaminant flux from the West Landfill and Wet Scrubber Sludge Pond. However, the physical solidification of sludge from the Wet Scrubber Sludge Pond, where needed, would increase the volume of hazardous material at the Site. Therefore, this alternative was given a score of 12.

For all active, retained alternatives, the reduction in mobility could be reversed if the caps or remedial measures are not maintained. The reduction in groundwater toxicity from groundwater extraction and treatment would be irreversible.

7.1.5 Short-term Effectiveness

Alternative LDU1/GW-1 (No Action) does not attain the criterion because it would not meet the RAOs and was therefore given a score of 0.

Under the active, retained alternatives excluding Alternative LDU1/GW-6 (Excavation with Onsite Consolidation), impacts to community are not anticipated or are expected to be limited to increased truck traffic through the community. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community. As necessary, ECs would be used to protect the community from dust, vapors, and noise. Best practices, including adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE, are highly effective at reducing risks to workers during implementation of the respective remedial actions.

Under Alternative LDU1/GW-6, construction of a new repository would be closer than the existing location of the Landfills DU1 waste management units to the Flathead River and/or residents in Aluminum City, increasing the potential for exposure to emissions and reducing the buffer zone between the contamination and potential receptors. Potential exposure risks to workers during remedial construction under this alternative are also greater than the other alternatives due to disturbance of hazardous source material in the West Landfill and Wet Scrubber Sludge Pond. In addition to potential exposure via direct contact, workers would potentially be exposed to cyanide gas, a toxin if inhaled or ingested. Workers would be required to wear Level C PPE and would need to adhere to the Site-specific HASP to avoid hazards associated with the remedial construction, including heavy equipment hazards and hazards associated with working around and within a deep excavation. The significantly longer period of construction associated with the Alternative LDU1/GW-6 significantly increases risk of serious safety incidents in comparison to the other alternatives.

Minimal potential risks to the environment are anticipated during construction of the waste management unit caps assuming implementation of adequate erosion controls. Slurry wall construction alternatives (i.e., Alternatives LDU1/GW-3A, 3C, 4A, and 4C) would result in moderate environmental impacts (i.e., air emissions and material consumption). Groundwater extraction and treatment alternatives (i.e., Alternatives LDU1/GW-3C, 4C, and 5B) would result in significant environmental impacts during operation of the groundwater treatment system affecting the sustainability consideration of these alternatives, including substantial energy consumption and considerable material consumption and waste generation over the lifetime of these alternatives. Excavation of impacted material from the waste management units (i.e., Alternative LDU1/GW-6) would result in significant environmental impacts (i.e., air emissions and energy consumption).

The RAOs that would need to be achieved by the selected alternative for the combined Landfills DU1 and Groundwater DU include: (1) minimize potential exposure to impacted material resulting in exceedances of PRGs; (2) prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards; (3) reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards; and (4) reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU. Under the active, retained alternatives excluding Alternative LDU1/GW-6, the first RAO would be met immediately following cap construction and establishment of ICs, which are estimated to be completed within 3 years. Under Alternative LDU1/GW-6, the first RAO would be met following completion of remedial construction and establishment of ICs, which are estimated to be completed within 4 to 5 years. For all active, retained alternatives, the second RAO would be met immediately following establishment of ICs, which is estimated to be completed within 1 year.

The third and fourth RAOs are would be met the quickest under an alternative with complete source control and downgradient groundwater treatment (i.e., Alternative LDU1/GW-4C). Therefore, the highest score (20) was given to Alternative LDU1/GW-4C. Alternatives with a fully-encompassing slurry wall, only (i.e., Alternative LDU1/GW-4A) or both an upgradient slurry wall and downgradient groundwater treatment (i.e., Alternative LDU1/GW-3C) would meet the third and fourth RAOs in the next quickest timeframe, and as such were given a score of 16. Alternative LDU1/GW-3A (upgradient slurry wall, only) would take a longer time to meet the third and fourth RAOs, and as such was given a score of 10. Alternative LDU1/GW-5B (downgradient hydraulic control) would achieve the fourth RAO in a relatively short timeframe, comparable to that of Alternatives LDU1/GW-3C and 4C, but does not have an additional source control measure beyond caps on the waste management units. Under Alternative LDU1/GW-5B, achievement of RAOs (including ARARs) would be unlikely within the plume footprint downgradient of the waste management units and upgradient of the extraction wells; if selected, an ARAR waiver for groundwater would be a required component of this alternative. A comprehensive long-term MNA program would be included under this alternative to monitor groundwater within the plume footprint. Because Alternative LDU1/GW-5B would take longer to meet the third RAO than the other active, retained alternatives, this alternative was given a score of 12.

Alternative LDU1/GW-6 is the only alternative to disturb the existing waste management units. During remedial action implementation (estimated to take 4 to 5 years), large-scale open excavation of the West Landfill and Wet Scrubber Sludge Pond would expose the waste and contaminated soil to precipitation and runoff over a multi-year period, resulting in leaching of contaminants and further degradation of groundwater. This would be in contravention of one of the RAOs for the Site which states: “prevent further degradation of groundwater that exceeds Montana DEQ-7 standards (i.e., ensure no actions are taken that could increase concentrations of COCs within the contaminant plume).” While best practices would be employed to limit the size of and/or cover the open excavation in between construction seasons, infiltration from precipitation, surface runoff, or spring snowmelt would not be eliminated, further contributing to groundwater degradation. Given the adverse impacts to the community, workers, and the environment in the short term as well as the breach of the RAO, Alternative LDU1/GW-6 was given a score of 5.

7.1.6 Implementability

Alternative LDU1/GW-1 (No Action) would be the easiest alternative to implement and was therefore given the highest score (20). Construction of the waste management unit caps, slurry walls, and downgradient groundwater extraction and treatment are expected to be technically and administratively implementable. These components of the alternatives would use established technologies that have been proven effective and reliable. All activities would be conducted onsite, so no offsite access or third-party approvals would be needed.

Construction of a slurry wall (upgradient or fully-encompassing) to the contemplated depths would require specialty contractor services that are available but would require advanced arrangements, likely with long lead times as well as extensive pre-design investigations along the proposed alignment. While the proposed depths would require the use of clamshell bucket excavation and/or hydromill technologies and the presence of cobbles and/or boulders would require rock breaking tools, these are standard equipment and proven methods for slurry wall construction. Based on discussions with three specialty contractors, it is expected that a slurry wall would be implementable, with the upgradient slurry wall being easier to implement than the fully-encompassing slurry wall due to the shorter length of the wall; these alternatives (i.e., Alternatives LDU1/GW-3A and 4A) were given the scores of 16 and 15, respectively.

Downgradient groundwater extraction and treatment would also be expected to be implementable; although the treatment system would be large to accommodate a flow rate of approximately 500 gpm throughout the entire year, the only COC requiring treatment in the extracted groundwater would be cyanide and treatment for cyanide removal is technically feasible. Other constituents in the extracted groundwater would need to be managed to prevent fouling of the cyanide polishing steps, but it is expected that these measures are also technically feasible. It is expected that the downgradient groundwater extraction and treatment system would be implementable and as such was given a score of 14 as a stand-alone technology (i.e., Alternative LDU1/GW-5B). In conjunction with a slurry wall (i.e., Alternatives LDU1/GW-3C and 4C), however, the added component increases the complexity of the remedial construction and therefore Alternatives LDU1/GW-3C and 4C were given scores lower than those for Alternatives LDU1/GW-3A and 4A, respectively.

The technical feasibility of excavation of impacted material from the waste management units (i.e., Alternative LDU1/GW-6) is questionable for several reasons discussed in the Technology Screening section of this FS Report as well as in the detailed evaluation of Alternative LDU1/GW-6 provided in Table 6-1. In summary, the volumes of waste and impacted underlying soils that would need to be removed under this alternative are extremely large (approximately 1.34 million CY). In addition, large quantities of water generated during construction would need to be collected for treatment of a mix of COCs (i.e., cyanide, fluoride, and arsenic). Uncertainties complicating implementation of the excavation alternative include, but are not limited to, the potential need for enclosed work areas and/or limitations on exposed waste areas. If required, either option would complicate and slow the implementation of the excavation alternative and increase costs beyond those currently estimated. Due to these technical challenges, Alternative LDU1/GW-6 was given a score of 5.

7.1.7 Cost

Detailed cost estimates for each alternative including capital cost and present value of OM&M are presented in Appendix J and summarized in Table 7-2. The highest score (20) was given to the lowest cost alternative (i.e., Alternative LDU1/GW-1, No Action; present value cost estimated to be less than $1 million) and the lowest score (0) was given to the highest cost alternative (i.e., Alternative LDU1/GW-6, Excavation with Onsite Consolidation; present value cost in excess of $165 million). The relative cost scores for the other retained alternatives were distributed on a linear scale between $1 and $165 million, resulting in a score of 16 for Alternative LDU1/GW-3A; a score of 14 for Alternatives LDU1/GW-4A and 5B; a score of 12 for Alternative LDU1/GW-3C; and a score of 10 for Alternative LDU1/GW-4C.

7.1.8 Summary of Comparative Analysis

A summary of the comparative analysis of joint alternatives retained for Landfills DU1 and the Groundwater DU is provided in Table 7-2. As discussed in Section 6.2, Alternatives LDU1/GW-2, 3B, 4B, 5A, and 5C have been screened from further consideration based upon concerns over satisfying threshold criteria (Alternative LDU1/GW-2) and effectiveness and implementability (Alternatives LDU1/GW-3B, 4B, 5A, and 5C); Alternatives LDU1/GW-1, 3A, 3C, 4A, 4C, 5B, and 6 are retained for further evaluation.

All six active, retained remedial alternatives would satisfy the two threshold criteria. With the exception of Alternative LDU1/GW-1 (No Action), the retained alternatives are protective of human health and the environment based on current land and groundwater use as well as reasonably expected future uses. Similarly, all the retained remedial alternatives, with the exception of Alternative LDU1/GW-1, would comply with State and Federal chemical-specific ARARs identified in Table 3-1. In addition, the alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. As a result, the No Action Alternative (Alternative LDU1/GW-1) is not a viable remedial action for the Landfills DU1 and Groundwater DU and is not retained for further evaluation.

The overall effectiveness of each remaining remedial alternative is determined by evaluating the first three balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; and short-term effectiveness. As described in Sections 7.1.3 through 7.1.5, Alternatives LDU1/GW-3C, 4A, and 4C have the greatest overall effectiveness. Comparatively, Alternatives LDU1/GW-3A, 5B, and 6 are not as effective overall in protecting human health and the environment due to limited source control measures (Alternatives LDU1/GW-3A and 5B) or potential for adverse impacts to human health and the environment during remedial action implementation that limit its short-term effectiveness (Alternative LDU1/GW-6).

The technical and administrative feasibility is greatest for Alternatives LDU1/GW-3A, 4A, and 5B; it is anticipated that these alternatives would be sufficiently implementable given adequate lead time. Alternatives LDU1/GW-3C and 4C are expected to be more difficult to implement than Alternatives LDU1/GW-3A and 4A due to the increased complexity of the remedial construction by adding another component in addition to a slurry wall (i.e., downgradient groundwater extraction and treatment system) associated with these alternatives. Due to reasons discussed in Section 7.1.6, Alternative LDU1/GW-6 would be the least technically feasibility and is therefore expected to be materially less implementable than the other remedial alternatives.

The estimated total costs of each alternative (i.e., capital cost and present value of OM&M) shows that Alternatives LDU1/GW-3A, 4A, and 5B are the least expensive alternatives (in ascending order). Comparatively, Alternatives LDU1/GW-3C, 4C, and 6 (in ascending order) are significantly more expensive. In accordance with the NCP, the selected remedial action must be cost-effective; its cost shall be proportional to its overall effectiveness. Alternative LDU1/GW-6 does not meet this criterion because its costs more than twice as much as the next most expensive alternative and exceeds the least expensive active and retained alternative by a factor of six. Furthermore, Alternative LDU1/GW-6 is less effective than Alternatives LDU1/GW-3C, 4A, and 4C. Therefore, Alternative LDU1/GW-6 is the least cost-effective alternative.

As reflected by the highest Balancing Criteria Score of 77 (Table 7-2), Alternative LDU1/GW-4A maximizes performance relative to the balancing criteria for the Landfills DU1 and Groundwater DU joint remedy because it is the most effective and technically feasible option for the cost. This alternative (Containment via Capping and Fully-Encompassing Slurry Wall) would achieve robust control of the source by containing contaminated groundwater and preventing contaminant mass flux from beyond the footprints of the Landfills DU1 waste management units. In combination with the waste management unit caps which would prevent the infiltration of precipitation and runoff through the impacted materials and prevent/reduce leaching of COCs to groundwater, the fully-encompassing slurry wall in Alternative LDU1/GW-4A would cut off the source of contamination to groundwater, providing the opportunity for flushing of porewater and MNA to reduce concentrations of COCs in groundwater downgradient of the waste management units and, subsequently, concentrations of COCs discharging to surface water in the River Area DU without recharge of contaminant mass. In comparison to the upgradient slurry wall (i.e., Alternative LDU1/GW-3A), the complete containment achieved by the fully-encompassing slurry wall would be expected to provide additional environmental benefit roughly proportional to the additional cost, hence the lower Balancing Criteria Score of 66. Conversely, Alternative LDU1/GW-4C would not be a cost-effective alternative because construction and operation of a downgradient groundwater extraction and treatment system in addition to the fully-encompassing slurry wall would not be expected to provide sufficient additional environmental benefit to warrant the additional cost. This is reflected in its Balancing Criteria Score of 74, which is lower than that of Alternative LDU1/GW-4A.

7.2 Landfills DU2 Alternatives

The relative performance of the two alternatives evaluated for the Landfills DU2 against each of the seven evaluation criteria is discussed below.

Alternative LDU2-2 would satisfy the two threshold criteria; it would be protective of human health and the environment based on current land use as well as reasonably expected future uses, and it would satisfy ARARs. There are no chemical-specific ARARs for soil, however Alternative LDU2-2 would meet RAOs established for the Site (e.g., PRGs). In addition, Alternative LDU2-2 would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. Because the No Action Alternative (Alternative LDU2-1) would not be protective of human health and the environment, it is not a viable remedial action for the Landfills DU2 and is not retained for further evaluation.

The overall effectiveness is determined by evaluating the first three balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; and short-term effectiveness. As described in Table 6-2, Alternative LDU2-2 would be effective overall in protecting human health and the environment by containing impacted material via capping which would be adequate and reliable in eliminating the direct contact exposure pathway and its associated risks.

Alternative LDU2-2 would be technically and administratively feasible. All activities would be conducted onsite, and treatability/pilot studies would not be required. Developments of offsite borrow sources for cover materials would be coordinated with the appropriate agencies.

The estimated total cost for Alternative LDU2-2 (i.e., capital cost and present value of OM&M) is approximately $7 million. The detailed cost estimate for this alternative including capital cost and present value of OM&M is presented in Appendix J.

Based on the above comparative analysis, Alternative LDU2-2 best satisfies the balancing criteria for the Landfills DU2. This alternative (Containment via Capping) would eliminate exposure pathways in the Landfills DU2 within a few years, immediately following construction of caps and establishment of ICs.

7.3 Soil DU Alternatives

The relative performance of the four alternatives evaluated for the Soil DU against each of the seven evaluation criteria is discussed below. A summary of the comparative analysis of the Soil DU alternatives is provided in Table 7-3.

7.3.1 Overall Protection of Human Health and the Environment

All the remedial alternatives, with the exception of Alternative SO-1 (No Action), are protective of human health and the environment based on current land use as well as reasonably expected future land uses. Alternative SO-1 would not be protective as the direct contact exposure route to impacted soil would remain complete. Alternatives SO-2 (Covers with Hotspot Excavation) would be protective by eliminating exposure pathways through containment while Alternatives SO-3 (*In Situ* Phytoremediation with Hotspot Excavation) and SO-4 (Excavation with Onsite Consolidation) would be protective by eliminating exposure pathways through treatment or removal, respectively. Therefore, this threshold criterion would be fully met by Alternatives SO-2, SO-3, and SO-4.

7.3.2 Compliance with ARARs

There are no chemical-specific ARARs for soil, therefore this threshold criterion would be fully met by all alternatives. However, Alternative SO-1 (No Action) would not meet RAOs established for the Site (e.g., PRGs) as no action would be taken to address COCs currently present in the Soil DU in exceedance of PRGs. All active alternatives would meet these RAOs. In addition, the active alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1.

7.3.3 Long-term Effectiveness and Permanence

Alternative SO-1 (No Action) is not considered to be effective in the long term because potential risks would not be managed; no reduction in the magnitude of residual risk would be achieved, and no additional controls would be implemented to control these risks. Alternative SO-1 would therefore perform poorly against this criterion and as such was given the lowest score (0). In contrast, all other retained alternatives (Alternatives SO-2 through SO-4) would offer high long-term effectiveness and permanence as described below.

Alternative SO-2 would reduce the magnitude of residual risk by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. The covers would require maintenance as well as reliance on ICs to prevent intrusive activities into impacted material and damage to the cover. Alternative SO-3 would reduce the magnitude of residual risk by treating PAH-impacted material resulting in exceedances of PRGs within the DU via phytoremediation. Successful completion of the phytoremediation treatment would eliminate the need for engineering control measures. Alternative SO-4 would reduce the magnitude of residual risk by removing impacted material resulting in exceedances of PRGs from the DU, and as such would not have engineering control measures in place.

Successful implementation of all active alternatives would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors.

Permanent treatment or removal of the impacted materials resulting in exceedances of PRGs from the Soil DU under Alternative SO-3 and SO-4, respectively, would provide the highest degree of long-term effectiveness and permanence. As such, these alternatives were given the highest scores (20). Alternative SO-2 would achieve a similar degree of long-term effectiveness, however the reduction in exposure potential would be reversed if ICs and cover are not maintained. Therefore, Alternative SO-2 was given a lower score of 10.

7.3.4 Reduction of Toxicity, Mobility or Volume

Under Alternative SO-1 (No Action) there would be no reduction in toxicity, mobility, or volume of hazardous materials in the Soil DU, and as such was given a score of 0.

Alternative SO-3 is the only alternative which would use treatment to reduce toxicity, mobility, or volume of hazardous materials. Under Alternative SO-3, all PAH-impacted material would be treated to concentrations below PRGs, and as such this alternative was given the highest score (20).

Under Alternative SO-2, there would be no reduction in toxicity or volume of hazardous materials in the Soil DU. However, under Alternative SO-4 the amount of hazardous materials in the Soil DU would be substantially reduced through removal, and this reduction would be irreversible. As such, Alternative SO-4 provides the next greatest reduction in toxicity, mobility, and volume of hazardous materials and was given a score of 15 while Alternative SO-2 was given a score of 12.

7.3.5 Short-term Effectiveness

Alternative SO-1 (No Action) does not attain the criterion because it would not meet the RAOs and was therefore given a score of 0. It is anticipated that RAOs would be achieved for Alternatives SO-2 and SO-4 immediately following construction activities and establishment of ICs, which are estimated to be completed within 2 years under these alternatives. Under Alternative SO-3, RAOs are expected to be met following successful completion of the phytoremediation treatment (about 10 years). Alternatives SO-2 and SO-4 were scored higher than Alternative SO-3 for this reason, with the exact scores modified by the impacts to community, workers, and environment as described below.

For all the alternatives, impacts to community are not anticipated. As necessary, ECs would be used to protect the community from dust, vapors, and noise. In addition, minimal potential risks to the environment are anticipated during implementation of each of the active alternatives assuming implementation of adequate erosion controls. Best practices, including adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE, are highly effective at reducing risks to workers during implementation of the respective remedial actions. Of the active alternatives, Alternative SO-4 would have more potential risks to workers because it would involve the most intrusive work and associated exposure risk. For this reason, in conjunction with the time to achieve RAOs discussed above, Alternatives SO-2, SO-3, and SO-4 were given scores of 20, 5, and 15, respectively.

7.3.6 Implementability

Alternative SO-1 (No Action) would be the easiest alternative to implement and was therefore given the highest score (20). The other alternatives are also expected to be technically and administratively implementable. The alternatives would use established technologies that have been proven effective and reliable. It is expected that treatability/pilot studies would not be required for Alternatives SO-2 and SO-4; a pilot study may be required for Alternative SO-3. All activities would be conducted onsite, so no offsite access or third-party approvals would be needed. The necessary engineering services would be readily available for all alternatives.

Alternatives SO-2 and SO-3 would both require soils for cover materials which may require import from offsite sources, whereas Alternative SO-4 does not; for this reason, Alternative SO-4 was given the second highest score (15). Since Alternative SO-3 may require a pilot study prior to implementation, Alternative SO-2 was given the higher score (12) over Alternative SO-3 (8).

7.3.7 Cost

Detailed cost estimates for each alternative are presented in Appendix J. There would be no costs associated with Alternative SO-1 (No Action), and as such this alternative was given the highest score (20). Alternative SO-2 is estimated to be the most expensive alternative for this DU (approximately $1.6 million) and was thus given the lowest score (10). Alternatives SO-3 and SO-4 would be comparable in cost, and their scores were distributed on a linear scale between $0 and $1.6 million, resulting in a score of 13 for Alternative SO-3 and a score of 12 for Alternative SO-4.

7.3.8 Summary of Comparative Analysis

A summary of the comparative analysis of alternatives retained for the Soil DU is provided in Table 7-3.

All active remedial alternatives would satisfy the two threshold criteria. With the exception of Alternative SO-1 (No Action), the retained alternatives are protective of human health and the environment based on current land use as well as reasonably expected future uses. There are no chemical-specific ARARs for soil, however all active alternatives would meet RAOs established for the Site (e.g., PRGs). In addition, the alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. Because the No Action Alternative (Alternative SO-1) would not be protective of human health and the environment, it is not a viable remedial action for the Soil DU and is not retained for further evaluation.

The overall effectiveness of each remaining remedial alternative is determined by evaluating the first three balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; and short-term effectiveness. As described in Sections 7.3.3 through 7.3.5, Alternatives SO-3 and SO-4 have the greatest overall effectiveness. Comparatively, Alternative SO-2 is not as effective overall in protecting human health and the environment.

The technical and administrative feasibility of each alternative shows that Alternative SO-4 would be the most implementable alternative. Alternatives SO-2 and SO-3 are expected to be more difficult to implement than Alternative SO-4 due to the import of materials associated with these alternatives. In addition, Alternative SO-3 may require a pilot study prior to implementation, making it more difficult to implement than Alternative SO-2.

The estimated total costs of each alternative (i.e., capital cost and present value of OM&M) shows that the costs of each active alternative are comparable, though Alternatives SO-3 and SO-4 are expected to cost less than Alternative SO-2.

As reflected by the highest Balancing Criteria Score of 77 (Table 7-3), Alternative SO-4 maximizes performance relative to the balancing criteria for the Soil DU. This alternative (Excavation with Onsite Consolidation) would permanently eliminate exposure pathways in the Soil DU within a few years, without the need for long-term ECs.

7.4 North Percolation Pond DU Alternatives

The relative performance of the four alternatives evaluated for the North Percolation Pond DU against each of the seven evaluation criteria is discussed below. A summary of the comparative analysis of the North Percolation Pond DU alternatives is provided in Table 7-4.

7.4.1 Overall protection of human health and the environment

All the remedial alternatives, with the exception of Alternative NPP-1 (No Action), are protective of human health and the environment based on current land use as well as reasonably expected future land uses. Alternative NPP-1 would not be protective as the direct contact exposure route to impacted soil/sediment would remain complete. Alternatives NPP-2 (Limited Excavation with Covers) and NPP-3 (Excavation with Cover) would be protective by eliminating exposure pathways through containment while Alternative NPP-4 (Excavation with Onsite Consolidation) would be protective by eliminating exposure pathways through removal. Therefore, this threshold criterion would be fully met by Alternatives NPP-2, NPP-3, and NPP-4.

7.4.2 Compliance with ARARs

All the remedial alternatives, with the exception of Alternative NPP-1 (No Action), would comply with State and Federal chemical-specific ARARs identified in Table 3-1. There are no chemical-specific ARARs for soil/sediment, however all active alternatives would meet RAOs established for the Site (e.g., PRGs). Alternative NPP-1 would not meet chemical-specific ARARs or soil/sediment RAOs as no action would be taken to address COCs currently present in the North Percolation Pond DU in exceedance of standards and/or PRGs. In addition, the active alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1. Therefore, this threshold criterion would be fully met by Alternatives NPP-2, NPP-3, and NPP-4.

7.4.3 Long-term effectiveness and permanence

Alternative NPP-1 (No Action) is not considered to be effective in the long term because potential risks would not be managed; no reduction in the magnitude of residual risk would be achieved, and no additional controls would be implemented to control these risks. Alternative NPP-1 would therefore perform poorly against this criterion and as such was given the lowest score (0). In contrast, all other retained alternatives (Alternatives NPP-2 through NPP-4) would offer high long-term effectiveness and permanence as described below.

Alternatives NPP-2 and NPP-3 would both reduce the magnitude of residual risk by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. The covers would be of the same type and thickness, and both would require maintenance as well as reliance on ICs to prevent intrusive activities into impacted material and damage to the cover. Alternative NPP-4 would reduce the magnitude of residual risk by removing impacted material resulting in exceedances of PRGs from the DU, and as such would not require an engineering control measure. Successful implementation of these alternatives would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors.

By permanently removing the impacted materials from the North Percolation Pond DU, Alternative NPP-4 would provide the highest degree of long-term effectiveness and permanence and as such was given the highest score (20). Alternatives NPP-2 and NPP-3 achieve a similar degree of long-term effectiveness and permanence, though the area requiring long-term management of residuals left in place would be greater in Alternative NPP-2 (10 acres) than Alternative NPP-3 (2 acres). As such, Alternative NPP-3 was given the higher score (15) over Alternative NPP-2 (10).

7.4.4 Reduction of Toxicity, Mobility or Volume

Under Alternative NPP-1 (No Action) there would be no reduction in toxicity, mobility, or volume of hazardous materials in the North Percolation Pond DU, and as such was given a score of 0.

None of the remedial alternatives use treatment to reduce toxicity, mobility, or volume of hazardous materials. Under Alternatives NPP-2 and NPP-3, there would be no reduction in toxicity or volume of hazardous materials in the North Percolation Pond DU. However, under Alternative NPP-4 the amount of hazardous materials in the North Percolation Pond DU would be substantially reduced through removal, and this reduction would be irreversible. As such, Alternative NPP-4 provides the greatest reduction in toxicity, mobility, and volume of hazardous materials and was given the highest score (20).

Though the mobility of contamination is limited under current conditions based on the results of the RI, the contaminant mobility may be reduced under Alternatives NPP-2 and NPP-3 by covering the impacted materials. The reduction in mobility from the cover could be reversed if the cover is not maintained. The potential for reversibility increases as the area of cover requiring maintenance increases. As such, Alternative NPP-3 was given the higher score (15) over Alternative NPP-2 (10) since the area of cover in Alternative NPP-3 (2 acres) would be less than the area of cover in Alternative NPP-2 (10 acres).

7.4.5 Short-term Effectiveness

Alternative NPP-1 (No Action) does not attain the criterion because it would not meet the RAOs and was therefore given a score of 0. In contrast, it is anticipated that RAOs would be achieved for all active alternatives (Alternatives NPP-2 through NPP-4) immediately following construction activities and establishment of ICs, which are estimated to be completed within 2 years for each of the active alternatives. The active alternatives would offer high short-term effectiveness as described below.

For all the alternatives, impacts to community are not anticipated. As necessary, ECs would be used to protect the community from dust, vapors, and noise. In addition, minimal potential risks to the environment are anticipated during implementation of each of the active alternatives assuming implementation of adequate erosion controls. Best practices, including adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE, are highly effective at reducing risks to workers during implementation of the respective remedial actions. Of the active alternatives, Alternative NPP-2 would have the lowest potential risks to workers because it would involve the least intrusive work and associated exposure risk; therefore, Alternative NPP-2 was given the highest score (20). The potential exposure risk to workers would be less under Alternative NPP-3 compared to Alternative NPP-4, and as such Alternative NPP-3 was given the higher score (18) over Alternative NPP-4 (15).

7.4.6 Implementability

Alternative NPP-1 (No Action) would be the easiest alternative to implement and was therefore given the highest score (20). The other alternatives are also expected to be technically and administratively implementable. The alternatives would use established technologies that have been proven effective and reliable. Physical solidification of the viscous, carbonaceous material present in the North Percolation Pond DU, if needed, may require bench or field pilot studies. All activities would be conducted onsite, so no offsite access or third-party approvals would be needed. The necessary engineering services would be readily available for all alternatives.

Alternatives NPP-2 and NPP-3 would both require soils for cover materials which may require import from offsite sources, whereas Alternative NPP-4 does not; for this reason, Alternative NPP-4 was given the second highest score (15). Since Alternative NPP-2 would require more material for cover than Alternative NPP-3, Alternative NPP-3 was given the higher score (12) over Alternative NPP-2 (10).

7.4.7 Cost

Detailed cost estimates for each alternative are presented in Appendix J. There would be no costs associated with Alternative NPP-1 (No Action), and as such this alternative was given the highest score (20). Alternative NPP-2 is estimated to be the most expensive alternative for this DU (approximately \$3.1 million) and was thus given the lowest score (10). Alternatives NPP-3 and NPP-4 would be comparable in cost, and their scores were distributed on a linear scale between \$0 and \$3.1 million, resulting in a score of 13 for both Alternative NPP-3 and Alternative NPP-4.

7.4.8 Summary of Comparative Analysis

A summary of the comparative analysis of alternatives retained for the North Percolation Pond DU is provided in Table 7-4.

All active remedial alternatives would satisfy the two threshold criteria. With the exception of Alternative NPP-1 (No Action), the retained alternatives are protective of human health and the environment based on current land use as well as reasonably expected future uses. Based on data and analysis presented in the RI Report, the North Percolation Pond DU is not a current source of groundwater contamination at the Site. Thus, all proposed remedial alternatives would ultimately result in groundwater beneath the North Percolation Pond DU achieving chemical-specific ARARs. Chemical-specific ARARs for surface water would be met under all active alternatives by 1) preventing the direct contact of standing water with impacted surface soil/sediment by covering or removing the impacted materials, and 2) eliminating the influx of COCs by decommissioning the influent pipes from which stormwater enters the North Percolation Pond system. There are no chemical-specific ARARs for soil or sediment, however all active alternatives would meet RAOs established for the Site (e.g., PRGs). In addition, the alternatives would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. Because the No Action Alternative (Alternative NPP-1) would not be protective of human health and the environment, it is not a viable remedial action for the North Percolation Pond DU and is not retained for further evaluation.

The overall effectiveness of each remaining remedial alternative is determined by evaluating the first three balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; and short-term effectiveness. As described in Sections 7.4.3 through 7.4.5, Alternatives NPP-3 and NPP-4 have the greatest overall effectiveness. Comparatively, Alternative NPP-2 is not as effective overall in protecting human health and the environment.

The technical and administrative feasibility of each alternative shows that Alternative NPP-4 would be the most implementable alternative. Alternatives NPP-2 and NPP-3 are expected to be more difficult to implement than Alternative NPP-4 due to the import of materials associated with these alternatives. Since Alternative NPP-2 would require significantly more material for cover than Alternative NPP-3, Alternative NPP-2 would be more difficult to implement than Alternative NPP-3.

The estimated total costs of each alternative (i.e., capital cost and present value of OM&M) shows that the costs of each active alternative are comparable, though Alternatives NPP-3 and NPP-4 are expected to cost less than Alternative NPP-2.

As reflected by the highest Balancing Criteria Score of 83 (Table 7-4), Alternative NPP-4 maximizes performance relative to the balancing criteria for the North Percolation Pond DU. This alternative (Excavation with Onsite Consolidation) would permanently eliminate exposure pathways in the North Percolation Pond DU within a few years, without the need for long-term ECs.

7.5 River Area DU Alternatives

The relative performance of the two alternatives evaluated for the River Area DU against each of the seven evaluation criteria is discussed below.

Alternative RADU-2 would satisfy the two threshold criteria; it would be protective of human health and the environment based on current land use as well as reasonably expected future uses, and it would satisfy ARARs. Under current and reasonably expected future uses, the River Area DU does not pose Site-related contamination risk to human health. There are no chemical-specific ARARs for soil or sediment, however Alternative RADU-2 would meet RAOs established for the Site (e.g., PRGs). In addition, Alternative RADU-2 would be designed to comply with action- and location-specific ARARs identified in Table 3-1, as applicable. Because the No Further Action Alternative (Alternative RADU-1) would not monitor cyanide in surface water and sediment porewater, it would not demonstrate that concentrations of cyanide are decreasing over time in response to implementation of the selected LDU1/GW Alternative upgradient. Lack of monitoring would not ensure long-term environmental protection, and as such RADU-1 is not a viable remedial action for the River Area DU and is not retained for further evaluation.

The overall effectiveness is determined by evaluating the first three balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; and short-term effectiveness. As described in Table 6-5, Alternative RADU-2 would be effective overall in protecting human health and the environment by removing contaminated sediment from the South Percolation Ponds, and routine sampling and analysis of surface water and sediment porewater would demonstrate progress towards achieving RAOs.

Alternative RADU-2 would be technically and administratively feasible. All activities would be conducted onsite, and treatability/pilot studies would not be required.

The estimated total cost for Alternative RADU-2 (i.e., capital cost and present value of OM&M) is approximately $1.4 million. The detailed cost estimate for this alternative including capital cost and present value of OM&M is presented in Appendix J. Note that this cost estimate does not include costs associated with the Removal Action, as this work is being performed under a separate Administrative Order on Consent as discussed in Section 2.3.5.

Based on the above comparative analysis, Alternative RADU-2 best satisfies the balancing criteria for the River Area DU. This alternative (Long-Term Monitoring of Surface Water and Sediment Porewater) would minimize potential exposure to impacted soil/sediment material resulting in exceedances of PRGs immediately following implementation of the Removal Action, and protect ecological receptors in the River Area DU by monitoring surface water and sediment porewater over time to ensure continued reductions of cyanide concentrations.

7.6 Site-wide Summary of Comparative Analyses

The preceding sections identify, develop, screen, and conduct a detailed and comparative evaluation of a range of remedial alternatives for each DU that are capable of addressing unacceptable risks to human health and the environment from media contaminated as a result of historical Site operations. This section assembles the highest-ranked remedial action alternatives for each DU into a comprehensive remedial action alternative for the Site as a whole. As discussed above, the detailed evaluation of each remedial action alternative and the comparative analyses of these alternatives were conducted against the CERCLA threshold and balancing criteria.

Because the highest-ranked remedial action alternatives maximize performance relative to the balancing criteria for their respective DUs, by extension the comprehensive Site-wide remedial action alternative maximizes performance relative to the balancing criteria for the Site as a whole. In addition, the comprehensive Site-wide alternative is comprised of an effective suite of response actions to address identified COC-impacted material resulting in exceedances of PRGs at the Site and associated risk; provide source control of waste and impacted material contributing to groundwater contamination; and, to the extent practicable, consolidate impacted soil/sediment remaining onsite. Implemented together, these response actions which comprise the highest-ranked remedial action alternatives for each DU would form an effective Site-wide remedy if chosen by USEPA in the ROD.

<u>Description of the Site-Wide Remedial Action Alternative</u>

Based on the findings of the BHHRA and BERA and as discussed in the RI Report, several exposure areas were determined to exhibit *de minimis* risk to human health and ecological receptors and, as such, were not further evaluated in the FS (i.e., are not encompassed within any of the Site DUs). However, to maintain the validity of the results of the risk assessments, future use of those exposure areas must match the assumptions made in the risk assessments. Therefore, certain use restrictions consistent with the risk assessments must be applied, including land use restrictions in the Eastern Undeveloped Area and North-Central Undeveloped Area to commercial or industrial use, only.

In addition, the Site-wide remedial action alternative incorporates components from the alternatives determined to best satisfy the balancing criteria for each DU (see Sections 7.1 through 7.5). Those alternatives and their primary elements are:

- Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall
    - Containment of source area waste management units via capping, including maintenance of the existing West Landfill cap and construction of low-permeability caps on the Wet Scrubber Sludge Pond and Center Landfill;

- Construction of a slurry wall fully encompassing the West Landfill and Wet Scrubber Sludge Pond keyed into the top of the low-permeability glacial till unit that typically occurs between 100 and 125 ft-bls near Landfills DU1;
  - Monitored natural attenuation including analysis of groundwater COCs (i.e., cyanide, fluoride, and arsenic) and geochemical indicator parameters to identify and assess performance of the active MNA processes; and
  - Establishment of ICs and ECs including deed restrictions for the Landfills DU1 waste management units to prevent activities that could compromise function or integrity of the caps/containment systems or result in potential exposure to receptors; deed restrictions to prohibit the use of groundwater for water supplies and/or consumption; and installation of fencing and signage around the perimeter of the Landfills DU1 waste management units to identify and physically restrict access to human receptors and some ecological receptors.
- Alternative LDU2-2: Containment via Capping
  - Maintaining the existing caps on the East Landfill and Sanitary Landfill;
  - Containment of the Industrial Landfill via capping by constructing a low-permeability cap;
  - Improving the existing soil covers at the Asbestos Landfills; and
  - Establishment of ICs and ECs including deed restrictions for the Landfills DU2 waste management units to prevent activities that could compromise function or integrity of the caps/containment systems or result in potential exposure to receptors; and installation of fencing and signage around the perimeter of the Landfills DU2 waste management units to identify and physically restrict access to human receptors and some ecological receptors.
- Alternative SO-4: Excavation with Onsite Consolidation
  - Excavate approximately 32,500 CY of impacted soil from the Soil DU with disposal at an onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond); and
  - Establish land use restrictions for the DU to allow for commercial or industrial use, only.
- Alternative NPP-4: Excavation with Onsite Consolidation
  - Excavate approximately 35,180 CY of impacted material from the North-East Percolation Pond, North-West Percolation Pond, influent ditch, and effluent ditch;
  - Consolidate excavated materials at the Wet Scrubber Sludge Pond with physical solidification as needed;
  - Establish land use restrictions for the DU to allow for commercial or industrial use, only; and
  - Decommission stormwater influent pipes.
- Alternative RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater
  - Implementation of the Removal Action at the South Percolation Ponds, including decommissioning the influent pipe from which stormwater enters the South Percolation Pond system and excavating approximately 22,000 CY of impacted sediment from the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill); and
  - Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater.

As discussed in Section 7.1.8, Alternative LDU1/GW-4A would achieve robust control of the source by containing contaminated groundwater and preventing contaminant mass flux from beyond the footprints of the Landfills DU1 waste management units. If necessary (see Section 5.1.6), groundwater could be extracted from inside the slurry wall containment cell to achieve an inward gradient to ensure that contaminated groundwater has no hydraulic potential to migrate out of the containment cell. In combination with the waste management unit caps which would prevent the infiltration of precipitation and runoff through the impacted materials and prevent/reduce leaching of COCs to groundwater, the fully-encompassing slurry wall in Alternative LDU1/GW-4A would cut off the source of contamination to groundwater, providing the opportunity for flushing of porewater and MNA to reduce concentrations of COCs in groundwater downgradient of the waste management units and, subsequently, concentrations of COCs discharging to surface water in the River Area DU without recharge of contaminant mass.

Implementation of excavation remedies at the Soil DU, North Percolation Pond DU, and River Area DU would consolidate impacted soil/sediment remaining onsite to the extent practicable while also providing needed fill material to grade and cap the Wet Scrubber Sludge Pond and Industrial Landfill at Landfills DU1 and Landfills DU2, respectively.

The total estimated cost to implement the Site-wide remedial action alternative (i.e., capital cost and present value of OM&M for 30 years) is approximately $58 million. Compared to this alternative, the costs associated with implementing other alternatives with a potential for additional environmental benefit are disproportionate and do not provide any significant incremental degree of increased environmental protectiveness. Therefore, as a cost-effective means of achieving protection of human health and the environment and compliance with ARARs, this Site-wide remedial action alternative is best suited for selection and implementation at the CFAC Site.

Respectfully submitted,

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TABLES

Italics Denote Table is Embedded within Report Text

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

State of Montana Preliminary Identification of State ARARs for CFAC NPL Site
06/09/2021 EPA/DEQ Joint Work Product REV. FINAL

Page Markers:

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
PAGE MARKER: CHEMICAL SPECIFIC REQUIREMENT Chemical-specific ARARs are usually health-or risk-based numerical values or methodologies used to determine acceptable concentrations of chemicals that may be found in or discharged to the environment			
Statute | Water Quality			
Presence of on-site chemical(s) that may be found in or discharged to the environment	Section 75-5-308, MCA *Available at*: https://leg.mt.gov/BILLS/mca/title_0750/chapter_0050/part_0030/section_0080/0750-0050-0030-0080.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 5. WATER QUALITY Part 3. Classification and Standards **Short-Term Water Authorizations -- Water Quality Standards**	☑Applicable* *Applicable to remedial actions that may have short-term impacts on water quality if DEQ determines the activities meet certain criteria.	Allows DEQ to grant short-term exemptions from the water quality standards for the purpose of allowing certain emergency environmental remediation activities
Statute | Public Water Supply			
Presence of on-site chemical(s) that may be found in or	40 C.F.R. § 141.62 *Available at*: https://www.epa.gov/sites/production/files/2015-09/documents/cfr-2014-title40-vol23-sec141-62_0.pdf **§ 141.62 Maximum contaminant levels for inorganic contaminants.**	☑Relevant and Appropriate	

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
discharged to public water supply			
Regulation | Surface Waters			
Presence of on-site chemical(s) that may be found in or discharged to specific water body at Site	ARM 17.30.608 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.30.608 Rule Title: WATER-USE CLASSIFICATIONS-- FLATHEAD RIVER DRAINAGE Department: Environmental Quality Chapter: Water Quality Subchapter: Surface Water Quality Standards and Procedures	☑Applicable	Comply with B-1 water-use classification for Flathead River drainage; ARM 17.30.623 codifies the B-1 water-use classification standards This section provides the beneficial uses for the B-1 classification, and provides that concentrations of toxic, carcinogenic, or harmful parameters of the waters may not exceed DEQ-7 standards. This section also provides the specific water quality standards for water classified as B-1.
	ARM 17.30.623 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E623 Rule Title: B-1 CLASSIFICATION STANDARDS Department: ENVIRONMENTAL QUALITY Chapter: WATER QUALITY Subchapter: Surface Water Quality Standards and Procedures	☑Applicable	Referenced in ARM 17.30.608
Presence of on-site chemical(s) that may be found in or discharged to surface water	ARM 17.30.637 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E637 Rule Title: GENERAL PROHIBITIONS Department: Environmental Quality Chapter: Water Quality Subchapter: Surface Water Quality Standards and Procedures	☑Applicable	Prohibits certain unpermitted discharges
Presence of on-site chemical(s) that may be found in or	ARM 17.30.641 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E641	☑Applicable	Provides standards for sampling and analysis of water to determine quality

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
discharged to state waters, triggering sampling and analysis requirements	Rule Title: SAMPLING METHODS Department: Environmental Quality Chapter: Water Quality Subchapter: Surface Water Quality Standards and Procedures		
Presence of on-site chemical(s) that may be found in or discharged to state waters, triggering sampling and analysis requirements	ARM 17.30.646 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E646 Rule Title: BIOASSAYS Department: Environmental Quality Chapter: Water Quality Subchapter: Surface Water Quality Standards and Procedures	☑Applicable	Provides standards for determining bioassay tolerance concentrations
Presence of on-site chemical(s) that may be found in or discharged to state waters	ARM 17.30.705 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E705 Rule Title: BIOASSAYS Department: Environmental Quality Chapter: Water Quality Subchapter: Nondegradation of Water Quality	☑Applicable	Provides that for any surface water, existing and anticipated uses and the water quality necessary to protect these uses must be maintained and protected unless degradation is allowed under the non-degradation rules at ARM 17.30.708
Regulation | Ground Waters			
Presence of on-site chemical(s) that may be found in or discharged to ground water	ARM 17.30.1006(1) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.30.1006 Rule Title: CLASSIFICATIONS, BENEFICIAL USES, AND SPECIFIC STANDARDS FOR GROUND WATERS Department: Environmental Quality Chapter: Water Quality Subchapter: Montana Ground Water Control System	☑Applicable	
Presence of chemical or metal in ground waters or surface waters	Montana Circular DEQ-7 *Available at*: https://deq.mt.gov/Portals/112/Land/StateSuperFund/Documents/DEQ-7_June2019_Final.pdf?ver=2019-07-16-085110-630 Montana Numeric Water Quality Standards	☑Applicable Note: DEQ-7 human health standards for the primary contaminants of	

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		concern in groundwater are listed below. Compliance with all DEQ-7 standards is required and remedial actions must meet the DEQ-7 standards for all contaminants at the facility, including any breakdown products generated during remedial actions.	
Presence of COC **arsenic** in on-site ground waters	DEQ-7, page 11 Arsenic Standards (µg/L): 10 Surface Water 10 Ground Water	☑Applicable	
Presence of COC **cyanide** in on-site ground waters	DEQ-7, page 23 Aquatic Life (µg/L): 22 – Acute 5.2 – Chronic Human Health Standards (µg/L): 140 – Surface Water 200 – Ground Water	☑Applicable	
Presence of COC **fluoride** in on-site ground waters	DEQ-7, page 41 Human Health Standards (µg/L): 4,000 Surface Water 4,000 Ground Water	☑Applicable	
Presence of COC **aluminum** in on-site surface waters	DEQ-7, page 10 Aquatic Life (µg/L): 750 – Acute 87 – Chronic Human Health Standards (µg/L): n/a – Surface Water	☑Applicable	

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	n/a – Ground Water		
Presence of COC **barium** in on-site surface waters	DEQ-7, page 12 Aquatic Life (µg/L): n/a – Acute n/a – Chronic Human Health Standards (µg/L): 1,000 – Surface Water 1,000 – Ground Water	☑Applicable	
Presence of COC **copper** in on-site surface waters	DEQ-7, page 23 Aquatic Life (µg/L): 3.79@ 25mg/L – Acute 2.85@ 25 mg/L – Chronic Human Health Standards (µg/L): 1,300 – Surface Water 1,300 – Ground Water	☑Applicable	
Presence of COC **iron** in on-site surface waters	DEQ-7, page 46 Aquatic Life (µg/L): n/a – Acute 1,000 – Chronic Human Health Standards (µg/L): n/a – Surface Water n/a – Ground Water	☑Applicable	
Presence of on-site chemical(s), specifically, methane, that may be found in or discharged to air	ARM 17.50.1106 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1106 Rule Title: EXPLOSIVE GASES CONTROL **17.50.1106** EXPLOSIVE GASES CONTROL	☑Applicable* *Sampling of landfill gases during the RI did not identify any explosive gases.	Specifies the concentration of methane gas generated by a solid waste facility cannot exceed 25 percent of the lower explosive limit (LEL) for methane in facility structures

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
PAGE MARKER: LOCATION SPECIFIC REQUIREMENT Location-specific requirements are restrictions place on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.			
Statute | Fish & Wildlife			
	Section 87-5-107(3), MCA *Available at*: https://leg.mt.gov/bills/mca/title_0870/chapter_0050/part_0010/section_0070/0870-0050-0010-0070.html TITLE 87. FISH AND WILDLIFE CHAPTER 5. WILDLIFE PROTECTION Part 1. Nongame and Endangered Species List Of Endangered Species	☑Applicable	Establishes "take provision"
Regulation | Montana Nongame And Endangered Species Act			
Presence of on-site endangered species	ARM 12.5.201 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=12%2E5%2E201 Rule Title: ENDANGERED SPECIES LIST Department: FISH, WILDLIFE, AND PARKS Chapter: RESOURCE PROTECTION Subchapter: Endangered Species	☑Applicable	Prohibits certain activities with respect to endangered species

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Statute | Floodplain and Floodway Management Act			
Location of designated floodway	Section 76-5-401, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0760/chapter_0050/part_0040/section_0010/0760-0050-0040-0010.html TITLE 76. LAND RESOURCES AND USE CHAPTER 5. FLOOD PLAIN AND FLOODWAY MANAGEMENT Part 4. Use of Flood Plains and Floodways	☑Applicable* *River DU only—Here and throughout, the location specific ARARs associated with floodplain/ floodways and streams are primarily concerned with the work that was done as part of the TCRA. These would also apply to any additional work that would be required in these locations, should the need to conduct such work arise. *Cross-reference*: ARM 36.15.601	Provides that residential, certain agricultural, industrial-commercial, recreational and other uses are permissible within the designated floodway, provided they do not require structures other than portable structures, fill, or permanent storage of materials or equipment.
Location of flood plain outside designated floodway	Section 76-5-402, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0760/chapter_0050/part_0040/section_0020/0760-0050-0040-0020.html TITLE 76. LAND RESOURCES AND USE CHAPTER 5. FLOOD PLAIN AND FLOODWAY MANAGEMENT Part 4. Use of Flood Plains and Floodways	☑Applicable* *River DU only *Cross-reference*: ARM 36.15.701	Provides that within the floodplain but outside the floodway, residential, commercial, industrial, and other structures may be permitted subject to certain conditions relating to placement of fill, roads, and floodproofing.
	Section 76-5-403(2), MCA *Available at*: https://leg.mt.gov/bills/mca/title_0760/chapter_0050/part_0040/section_0030/0760-0050-0040-0030.html TITLE 76. LAND RESOURCES AND USE CHAPTER 5. FLOOD PLAIN AND FLOODWAY MANAGEMENT Part 4. Use of Flood Plains and Floodways	☑Applicable* *River DU only *Cross-reference*: ARM 36.15.605(1)(b), 2(c) and (d)	Prohibits the following in a floodway: any structure or excavation that will cause water to be diverted from the established floodway, cause erosion, obstruct the natural flow of water, or reduce the carrying capacity of the floodway; or the disposal or

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			storage of solid or hazardous waste.
Regulation | Floodplain Management			
Location of use or obstruction of floodway or floodplain	ARM 36.15.216(2) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E15%2E216 Rule Title: PERMITS - CRITERIA - TIME LIMITS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Regulation and Enforcement	☑Applicable* *River DU only	Contain substantive factors that address obstruction or use within the floodway or floodplain
Location of certain ag, C&I, recreational and other permissible uses within designated floodway	ARM 36.15.601 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E15%2E601 Rule Title: USES ALLOWED WITHOUT PERMITS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Designated Floodway Minimum Standards	☑Applicable* *River DU only *Cross-reference*: Section 76-5-401, MCA	Provides that residential, certain agricultural, industrial-commercial, recreational and other uses are permissible within the designated floodway, provided they do not require structures other than portable structures, fill, or permanent storage of materials or equipment
Location of artificial obstructions within designated floodway	ARM 36.15.602(1), (5) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=36.15.602 Rule Title: USES REQUIRING PERMITS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Designated Floodway Minimum Standards	☑Applicable* *River DU only	Provides that certain artificial obstructions may be permitted within the designated floodways subject to issuance of a permit
Location of structure or excavation with potential to cause water diversion	ARM 36.15.605(1)(b), (2(c) and (d) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=36%2E15%2E605 Rule Title: PROHIBITED USES Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Designated Floodway Minimum Standards	☑Applicable* *River DU only *Cross-reference*: Section 76-5-403(2), MCA	Prohibits the following in a floodway: any structure or excavation that will cause water to be diverted from the established floodway, cause erosion, obstruct the natural flow of water, or reduce the carrying capacity of the floodway; or the disposal or storage of solid or hazardous waste

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Location of flood control works	ARM 36.15.606 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E15%2E606 Rule Title: PERMITS FOR FLOOD CONTROL WORKS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Designated Floodway Minimum Standards	☑Applicable* *River DU only	Provides that flood control works comply with safety standards for levees, floodwalls, and riprap
Location of certain structures within the floodplain but outside designated floodway	ARM 36.15.701 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=36%2E15%2E701 Rule Title: ALLOWED USES Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Flood Fringe Minimum Standards	☑Applicable* *River DU only *Cross-reference*: Section 76-5-402, MCA	Provides that within the floodplain but outside the floodway, residential, commercial, industrial, and other structures may be permitted subject to certain conditions relating to placement of fill, roads, and floodproofing
Location of solid and haz waste disposal within flood fringe	ARM 36.15.703 *Available At*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36.15.703 Rule Title: PROHIBITED USES Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: FLOODPLAIN MANAGEMENT Subchapter: Flood Fringe Minimum Standards	☑Applicable* *River DU only	Provides that solid and hazardous waste disposal and storage of flammable, toxic, hazardous, or explosive materials are prohibited anywhere in the floodways or floodplains
Statute | Stream Protection			
Altering of stream channel by state or local governmental entity	Section 87-5-502, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0870/chapter_0050/part_0050/section_0020/0870-0050-0050-0020.html TITLE 87. FISH AND WILDLIFE CHAPTER 5. WILDLIFE PROTECTION Part 5. Stream Protection	☑Relevant and Appropriate* *River DU only	Provides that a state agency or subdivision shall not construct, modify, operate, maintain or fail to maintain any construction project or hydraulic project which may or will obstruct, damage, diminish, destroy, change, modify, or vary the natural existing shape and form of any stream or its banks or tributaries in a manner that will adversely affect any fish or game habitat

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			The requirement that any such project must eliminate or diminish any adverse effect on fish or game habitat is applicable to the state in concurring upon any remedial actions to be conducted The Natural Streambed and Land Preservation Act of 1975, MCA 75-7-101 *et seq*. includes substantive requirement and is applicable to private parties as well as government agencies
Statute | Natural Streambed And Land Preserva-tion Act			
Altering of or modifying stream channel by a person	Section 75-7-111 *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0070/part_0010/section_0110/0750-0070-0010-0110.html Montana Code Annotated 2019 TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 7. AQUATIC ECOSYSTEM PROTECTIONS Part 1. Streambeds	☑Applicable* *River DU only	Provides that a person planning to engage in any activity that will physically alter or modify the bed or banks of a stream must give written notice to the Board of Supervisors of a Conservation District, the Directors of a Grass Conservation District, or the Board of County Commissioners if the proposed project in not within a district, and must submit a "310 Permit" application to one of those entities
Regulation | Natural Streambed And			

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Land Preservation Act			
	ARM 36.2.410 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E2%2E410 Rule Title: STANDARDS AND GUIDELINES Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: PROCEDURAL RULES Subchapter: Minimum Standards and Guidelines for Natural Streambed and Land Preservation Act of 1975	☑Applicable* *River DU only	Establishes minimum standards which would be applicable if a remedial action alters or affects a streambed, including any channel change. Projects must be designed and constructed using methods that minimize adverse impacts to the stream (both upstream and downstream) and future disturbances to the stream. All disturbed areas must be managed during construction and reclaimed after construction to minimize erosion. Temporary structures used during construction must be designed to handle high flows reasonably anticipated during the construction period. Temporary structures must be completely removed from the stream channel at the conclusion of construction and the area must be restored to a natural or stable condition. Channel alternation must be designed to retain original stream length or otherwise provide hydrologic stability. Streambank vegetation must be protected except where removal of such vegetation is necessary for the completion of the project. When removal of vegetation is necessary, it must be kept to a minimum. Riprap, rock, and other material used in a project must be of adequate size, shape and density and must

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			be properly placed to protect the streambank from erosion. The placement of road fill material in a stream, the placement of debris or other materials in a stream where it can erode or float into the stream, projects that permanently prevent fish migration, operation of construction equipment in a stream, and excavation of streambed gravels are prohibited unless specifically authorized by the district. Such projects must also protect the use of water for any useful or beneficial purpose. See 75-7-102, MCA
PAGE MARKER: ACTION SPECIFIC REQUIREMENTS Action-specific requirements are technology or activity based requirements or limitations or actions taken with respect to hazardous substances.			
Statute | Montana Water Quality Act			
Generally prohibiting degradation of high quality state waters	Section 75-5-303, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0050/part_0030/section_0030/0750-0050-0030-0030.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 5. WATER QUALITY Part 3. Classification and Standards **Nondegradation policy**	☑Applicable *Cross-reference*: ARM 17.30.1011	Provides that existing uses of state waters and the level of water quality necessary to protect those uses must be maintained and protected. Provides also that MDEQ may not authorize degradation unless certain criteria are met
Causing "pollution" of state waters	Section 75-5-605(a), (c), MCA *Available at*:https://leg.mt.gov/bills/mca/title_0750/chapter_0050/part_0060/section_0050/0750-0050-0060-0050.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 5. WATER QUALITY Part 6. Enforcement, Appeal, and Penalties	☑Applicable* *This provision would apply to remediation activities at the Site and could be met via BMPs, design, etc. Impacted groundwater discharging	Prohibits placement (or causing to be placed) any wastes where they will cause pollution of any state waters. Any placement of materials that is authorized by a permit issued by any state or federal agency is not a placement of wastes within the prohibition

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		to surface water at the Seep would ultimately need to achieve DEQ-7 Water Quality Standards under each retained remedial alternative. See Section 75-5-103(30, MCA): Definition of "Pollution" (DEQ-7 exceedances of water quality standards (risk-based element))	of this subsection (1)(a) if the agency's permitting authority includes provisions for review of the placement of materials to ensure that it will not cause pollution of state waters
Regulation | Water Quality			
Generally prohibiting degradation of high quality state waters	ARM 17.30.1011 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E1011 Rule Title: NONDEGRADATION Department: Environmental Quality Chapter: Water Quality Subchapter: Montana Ground Water Control System	☑Applicable	Establishes prohibition against degradation of high quality state waters
Discharging storm water associated with construction activity	ARM 17.30.1115(6)(c) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17%2E30%2E1115 Rule Title: NOTICE OF INTENT PROCEDURES: CONSTRUCTION ACTIVITY Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: WATER QUALITY Subchapter: Storm Water Discharges	☑Relevant and Appropriate* *This rule would apply to remedial action construction activities that may result in direct discharges of storm water to State Waters.	Provides for development and implementation of a SWPPP to properly manage storm water discharges associated with construction activities
Discharging water	17.30.1203(1), (3), (5), (8) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.30.1203	☑Applicable* *These provisions would apply to direct discharges to State Waters from a	Provides for technology-based treatment requirements under section 301(b) of the federal Clean Water Act

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Rule Title: CRITERIA AND STANDARDS FOR IMPOSING TECHNOLOGY-BASED TREATMENT REQUIREMENTS IN MPDES PERMITS - VARIANCE PROCEDURES Department: ENVIRONMENTAL QUALITY Chapter: WATER QUALITY Subchapter: Montana Pollutant Discharge Elimination System (MPDES) Standards .	point source from remedial activities at the Site.	
Discharging water from point source	ARM 17.30.1207(1) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.30.1207 Rule Title: EFFLUENT LIMITATIONS AND STANDARDS OF PERFORMANCE Department: ENVIRONMENTAL QUALITY Chapter: WATER QUALITY Subchapter: Montana Pollutant Discharge Elimination System (MPDES) Standards	☑Applicable* *These provisions would apply to discharges of wastewater or stormwater directly to surface water from implementation or operation and maintenance of a selected remedy. Impacted groundwater discharging to surface water at the Seep would ultimately need to achieve DEQ-7 Water Quality Standards under each retained remedial alternative.	Provides for effluent limitations and standards of discharges for point source dischargers other than POTWs
Constructing and excavating affecting water quality	ARM 17.30.1342(4), (5) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.30.1342 Rule Title: CONDITIONS APPLICABLE TO ALL PERMITS Department: ENVIRONMENTAL QUALITY Chapter: WATER QUALITY Subchapter: Montana Pollutant Discharge Elimination System (MPDES) Permits	☑Applicable* *The substantive provisions of ARM 17.30.1342(4), (5) would be applicable to Site activities that result in the direct discharge to State Waters.	The State of Montana has been delegated the authority to implement the Clean Water Act and these requirements are enforced in Montana through the MPDES. These regulations set forth the substantive requirements applicable to all MPDES and National Pollutant Discharge Elimination System permits. The substantive requirements, including the requirement to properly operate and maintain all facilities and systems of treatment and control, and applicable requirements

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Regulation | Stormwater Runoff Control Requirements			
Managing stormwater and dewatering	ARM 17.30.1344(1), (2)(b), (e), (f) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E30%2E1344 Rule Title: ESTABLISHING LIMITATIONS, STANDARDS, AND OTHER PERMIT CONDITIONS Department: ENVIRONMENTAL QUALITY Chapter: WATER QUALITY Subchapter: Montana Pollutant Discharge Elimination System (MPDES) Permits	☑Applicable* *These provisions would be applicable to Site activities that result in the direct discharge to State Waters. Impacted groundwater discharging to surface water at the Seep would ultimately need to achieve DEQ-7 Water Quality Standards under each retained remedial alternative. The substantive requirements of the general permits listed below would be applicable to activities at the Site that are governed by the general permits: --General Stormwater Permit for Construction Activities, Permit No MTR100000 (January 7, 2021) --General Stormwater Permit for Industrial Activity, Permit No.	Requires a storm water permit for storm water point sources. Generally, the permits require the permittee to implement best management practices (BMPs) and to take all reasonable steps to minimize or prevent any discharge which has a reasonable likelihood of adversely affecting human health or the environment. However, if there is evidence indicating potential or realized impacts on water quality due to any storm water discharge associated with the activity, an individual MPDES permit or alternative general permit may be required

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		MTR000000, January 31, 2018 --General Permit for Construction Dewatering, MTG070000 (March 1, 2020 If permanent lagoon used for remedy, other substantive requirements may be considered.	
Statute | Water			
Wasting & contaminating ground water	Section 85-2-505, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0850/chapter_0020/part_0050/section_0050/0850-0020-0050-0050.html TITLE 85. WATER USE CHAPTER 2. SURFACE WATER AND GROUND WATER Part 5. Ground Water	☑Applicable* *This provision would apply to remedial actions that involve maintenance or upgrades to existing wells or construction of new wells and withdrawal of groundwater.	Precludes the wasting of groundwater. Any well producing waters that contaminate other waters must be plugged or capped, and wells must be constructed and maintained so as to prevent waste, contamination, or pollution of groundwater
Constructing monitoring well	ARM 36.21.802 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E802 Rule Title: EXCLUSIONS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable* *This provision would apply to the construction of new monitoring wells but does not apply to and is not relevant or appropriate for existing monitoring wells at the Site.	Exclusions re specific requirements for constructing monitoring well
Constructing monitoring well	ARM 36.21.804 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E804 Rule Title: MONITOR WELL CONSTRUCTION MATERIALS	☑Applicable* *This provision would apply to the construction of new monitoring wells or maintenance or	Provides for specific requirements for constructing monitoring wells

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	upgrades to existing wells but does not otherwise apply to and is not relevant or appropriate for existing monitoring wells at the Site.	
Constructing monitoring well	ARM 36.21.805 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E805 Rule Title: SEAL/MATERIALS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable* *This provision would apply to the construction of new monitoring wells or maintenance or upgrades to existing wells but does not otherwise apply to and is not relevant and appropriate for existing monitoring wells at the Site.	Provides for specific requirements for constructing monitoring wells
Constructing monitoring well	ARM 36.21.806 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E806 Rule Title: INSTALLATION OF SEALS Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable* *This provision would apply to the construction of new monitoring wells or maintenance or upgrades to existing wells but does not otherwise apply to and is not relevant and appropriate for existing monitoring wells at the Site.	Provides for specific requirements for constructing monitoring wells
Constructing monitoring well	ARM 36.21.807 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=36%2E21%2E807 Rule Title: PREVENTION OF CONTAMINATION BY EQUIPMENT Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable* *This provision would apply to the construction of new monitoring wells or maintenance or upgrades to existing wells but does not otherwise apply to and is not	Provides for specific requirements for constructing monitoring wells

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		relevant and appropriate for existing monitoring wells at the Site.	
Constructing monitoring well	ARM 36.21.808 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E808 Rule Title: SITE PROTECTION AND SECURITY Department: NATURAL RESOURCES AND CONSERVATION, DEPARTMENT OF Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable* *This provision would apply to the construction of new monitoring wells or maintenance or upgrades to existing wells but does not otherwise apply to and is not relevant and appropriate for existing monitoring wells at the Site.	Provides for specific requirements for constructing monitoring wells
Abandoning monitoring well	ARM 36.21.810 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=36%2E21%2E810 Rule Title: ABANDONMENT Department: NATURAL RESOURCES AND CONSERVATION Chapter: BOARD OF WATER WELL CONTRACTORS Subchapter: Monitoring Well Construction Standards	☑Applicable	Provides for specifies requirements for abandoning monitoring wells
Regulation | Air			
On-site construction activity which causes settlement of particulate matter (dust)	ARM 17.8.204 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E204 Rule Title: AMBIENT AIR MONITORING Department: ENVIRONMENTAL QUALITY Chapter: AIR QUALITY Subchapter: Ambient Air Quality	☑Applicable* *This provision would apply to the generation of fugitive dust during the implementation of remedial activities.	Prohibits causing or contributing to concentrations of particulate matter in the ambient air such that the mass of settle particulate matter exceeds a 30 day average: 10 gm/m2, 30 day average, not to be exceeded. A measurement method is also provided

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
On-site construction activity which causes settlement of particulate matter	ARM 17.8.220 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E220 Rule Title: AMBIENT AIR QUALITY STANDARD FOR SETTLED PARTICULATE MATTER Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: AIR QUALITY Subchapter: Ambient Air Quality	☑Applicable* *This provision would apply to the generation of fugitive dust during the implementation of remedial activities.	Provides that no person shall cause or contribute to concentrations of particulate matter in the ambient air such that the mass of settled particulate matter exceeds a 30-day average of 10 grams per square meter (gm/m2). A measurement method is also provided
On-site construction activity which causes settlement of particulate matter affecting visibility	ARM 17.8.221 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E221 Rule Title: AMBIENT AIR QUALITY STANDARD FOR SETTLED PARTICULATE MATTER Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: AIR QUALITY Subchapter: Ambient Air Quality	☑Applicable* *This provision would apply to the generation of fugitive dust during the implementation of remedial activities.	Provides concentrations of particulate matter in ambient air shall not exceed annual average scattering coefficient of 3 x 10-5 per meter
On-site construction activity which causes settlement of PM-10 particulate matter affecting visibility	ARM 17.8.223 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E223 Rule Title: AMBIENT AIR QUALITY STANDARD FOR SETTLED PARTICULATE MATTER Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: AIR QUALITY Subchapter: Ambient Air Quality	☑Applicable* *This provision would apply to the generation of fugitive dust during the implementation of remedial activities.	Provides PM-10 concentrations in ambient air shall not exceed a 24-hour average of 150 ug/m3 of air and an annual average of 50 ug/m3 of air
Various activities resulting in emissions of airborne particulate	ARM 17.8.308 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E308 Rule Title: PARTICULATE MATTER, AIRBORNE Department: ENVIRONMENTAL QUALITY Chapter: AIR QUALITY Subchapter: Emission Standards	☑Applicable* *This provision would apply to the generation of fugitive dust during the implementation of remedial activities.	Provides that no person shall cause or authorize the production, handling, transportation or storage of any material, or cause or authorize the use of any street, road, or parking lot, or operate a construction facility or demolition project, unless reasonable precautions to control emissions of airborne particulate matter are taken. The regulation also states that emissions of airborne particulate matter must be controlled so that they do not "exhibit an opacity of 20

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			percent or greater average over six consecutive minutes."
Generation of dust emissions during response action activities	ARM 17.8.805 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E8%2E805 Rule Title: AMBIENT AIR CEILINGS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: AIR QUALITY Subchapter: Prevention of Significant Deterioration of Air Quality	☑Applicable	Provides ambient air ceilings, and states that no concentrations of a pollutant shall exceed concentrations permitted under the applicable secondary or the primary national ambient air quality standard, whichever concentration is lowest for the pollutant for a period of exposure
Regulation | Mining - Air			
Generating dust emissions during response action activities	ARM 17.24.761 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E761 Rule Title: AIR RESOURCES PROTECTION Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate to the generation of fugitive dust during the implementation of remedial activities.	Specifies a range of measures for controlling fugitive dust emissions during mining and reclamation activities. Some of the measures could be considered relevant and appropriate to control fugitive dust emissions in connection with excavation, earth moving and transportation conducted as part of the response action(s) at the facility. Such measures include, for example, paving, watering, chemically stabilizing, or frequently compacting and scraping roads ,promptly removing rock, soil or other dust-forming debris from roads, restricting vehicle speeds, revegetating, mulching, or otherwise stabilizing the surface of areas adjoining roads, restricting unauthorized vehicle travel, minimizing the area of disturbed land,

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			and promptly revegetating regraded lands
Regulation | Montana Solid Waste Management Act			
Building new Class II or IV landfill unit or laterally expanding existing Class II or IV landfill unit	ARM 17.50.1204(1)(b) *Available at*: https://www.google.com/search?q=ARM+17.50.1204(1)(b)&sourceid=ie7&rls=com.microsoft:en-US:IE-Address&ie=&oe=&gws_rd=ssl#spf=1614190843717 Rule Title: DESIGN CRITERIA - CLASS II AND CLASS IV LANDFILL UNITS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Design Criteria	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	Requires that a newly constructed or laterally expanded Class II landfill be designed and constructed utilizing a composite liner and leachate collection and removal system that is designed and constructed to maintain less than a 30-centimeter depth of leachate over the liner; or that the owner or operator has obtained MDEQ approval of an alternative design that ensures concentrations values will not be exceeded at the relevant point of compliance.
Building new Class II or IV landfill unit or laterally expanding existing	ARM 17.50.1205(3) *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1205 Rule Title: ADDITIONAL DESIGN CRITERIA - CLASS II AND CLASS IV LANDFILL UNITS	☑Applicable *The substantive requirements of this provision would apply to	Requires that the leachate system provide for accurate monitoring of the leachate and provide a minimum slope at the base of the overlying leachate collection

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Class II or IV landfill unit	Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Design Criteria	construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	layer equal to at least two percent
Monitoring ground water	ARM 17.50.1303 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1303 Rule Title: APPLICABILITY OF LANDFILL GROUND WATER MONITORING AND CORRECTIVE ACTION Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Ground Water Monitoring and Corrective Action	☑Applicable* *The substantive requirements of this provision would apply to ground water monitoring at a newly constructed Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during	Identifies requirements for groundwater monitoring

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to groundwater monitoring at the Industrial Landfill and the Wet Scrubber Sludge Pond. See also ARM 17.24.645 for ground water monitoring outside landfill units	
Abandoning monitoring well	ARM 17.50.1312 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1312 Rule Title: MONITORING WELL ABANDONMENT Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Ground Water Monitoring and Corrective Action	☑Applicable	Identifies requirements for monitoring well abandonment
Closing landfill unit	ARM 17.50.1403 *Available at*: http://mtrules.org/gateway/ruleno.asp?RN=17.50.1403 Rule Title: CLOSURE CRITERIA Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Closure and Post-Closure Care	☑Applicable *The substantive requirements of this provision would apply to closure of a newly constructed Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were	Provides closure requirements for Class II landfills. This includes the requirement that the cap be a minimum of 24 inches thick and other criteria, as follows: (1) install a cover that is designed to minimize infiltration and erosion, (2) design and construct the final cover system to minimize infiltration through the closed unit by the use of an infiltration layer that contains a minimum of 18 inches of earthen material and has a permeability less than or equal to the permeability of any bottom liner, barrier layer, or natural subsoils or a

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the closure of the Industrial Landfill and the Wet Scrubber Sludge Pond.	permeability no greater than 1 x 10-5 cm/sec, whichever is less, and (3)minimize erosion of the final cover by the use of an erosion layer that contains a minimum of six inches of earthen material that is capable of sustaining native plants
	ARM 17.50.1404 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1404 Rule Title: POST-CLOSURE CARE REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Closure and Post-Closure Care	☑Applicable* *The substantive requirements of this provision would apply to post-closure of a newly constructed Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the post-closure of the Industrial Landfill, the Wet Scrubber Sludge Pond, the West Landfill,	Provides for post closure care requirements for Class II landfills. Post closure care requires maintenance of the integrity and effectiveness of any final cover, including repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the cover and comply with the groundwater monitoring requirements found at ARM 17.50 subchapter 13

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		the Center Landfill, the East Landfill, the Sanitary Landfill, and the Asbestos Landfills.	
Regulation | Asbestos			
Controlling asbestos	ARM 17.74.351 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E74%2E351 Rule Title: INCORPORATION BY REFERENCE Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable* *This provision is applicable where remedial action activities involve the disturbance or new disposal of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/site features being addressed by remedial action under CERCLA) but is not applicable to or relevant or appropriate for the existing conditions of the Asbestos Landfills.	
Controlling asbestos	ARM 17.74.353 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E74%2E353 Rule Title: APPLICABILITY--ASBESTOS PROJECT REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable *This provision is applicable where remedial action activities involve the disturbance or new disposal of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/site features being addressed by remedial	Provides asbestos project requirements

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		action under CERCLA) but is not applicable to or relevant and appropriate for the existing conditions of the Asbestos Landfills.	
Controlling asbestos	ARM 17.74.354 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E74%2E354 Rule Title: INSPECTION REQUIREMENTS FOR DEMOLITION AND RENOVATION ACTIVITIES Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable* *This provision would apply to Site features that may require demolition or renovation as part of the selected remedial action under CERCLA.	Provides for inspection requirements for demolition and renovation activities
Controlling asbestos	ARM 17.74.356 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17%2E74%2E356 Rule Title: ASBESTOS PROJECT CONTROL MEASURES Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable* *This provision would apply to the disturbance of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/Site features being addressed by remedial action under CERCLA) but is not applicable to or relevant and appropriate for the existing conditions of the Asbestos Landfills.	Addresses requirements related to persons or entities engaged in asbestos related occupations, in charge of asbestos projects, or engaged in facility demolition or renovation activities. Training requirements for persons engaged in asbestos-type occupations are specified
Controlling asbestos	ARM 17.74.357 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17%2E74%2E357 Rule Title: STANDARDS AND METHODS FOR CLEARING ASBESTOS PROJECTS AND REQUIREMENTS FOR PERSONS CLEARING ASBESTOS PROJECTS Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control .	☑Applicable* *This provision would apply to the disturbance of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/Site features being	Provides for standards and methods for clearing asbestos projects

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		addressed by remedial action under CERCLA) but is not applicable to relevant and appropriate for the existing conditions of the Asbestos Landfills.	
Controlling asbestos	ARM 17.74.370 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E74%2E370 Rule Title: ENCLOSURE OF ASBESTOS-CONTAINING MATERIAL Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable* *This provision would apply to the disturbance of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/Site features being addressed by remedial action under CERCLA) but is not applicable to or relevant or appropriate for the existing conditions of the Asbestos Landfills.	Provides for enclosure of ACM
Controlling asbestos	ARM 17.74.371 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E74%2E371 Rule Title: ENCAPSULATION OF ASBESTOS-CONTAINING MATERIAL Department: ENVIRONMENTAL QUALITY Chapter: NOISE, ASBESTOS CONTROL, METHAMPHETAMINE CLEANUP Subchapter: Asbestos Control	☑Applicable *This provision would apply to the disturbance of asbestos containing material in the Asbestos Landfills (or if it is determined that asbestos is present in any other areas/Site features being addressed by remedial action under CERCLA) but is not applicable to or relevant and appropriate for the existing conditions of the Asbestos Landfills.	Provides for encapsulation of ACM

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Regulation | Montana Solid Waste Management Act			
Transporting solid waste to avoid discharge, dumping, spilling or leaking from transport vehicle	ARM 17.50.523 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E523 Rule Title: TRANSPORTATION Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Refuse Disposal	☑Applicable* *This provision would apply to the site transport of solid waste.	Provides that solid waste must be transported in such a manner as to prevent its discharge, dumping, spilling, or leaking from the transport vehicle
Placing landfill unit or laterally expanding Class II landfill unit in floodplains	ARM 17.50.1004 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1004 Rule Title: FLOODPLAINS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and	Provides certain requirements governing placement or lateral expansion of Class II landfill in floodplains

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		the Wet Scrubber Sludge Pond.	
Placing landfill unit or laterally expanding Class II landfill unit in wetlands	ARM 17.50.1005 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1005 Rule Title: WETLANDS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	Prohibits placement of a Class II or IV landfill in a wetland unless special conditions are met
Placing landfill unit or laterally expanding Class II landfill unit in fault area	ARM 17.50.1006 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1006 Rule Title: FAULT AREAS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate*	Prohibits placement of a Class II landfill within 200 feet of a fault that has had displacement in Holocene time unless special conditions are met

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		*Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	
Placing landfill unit or laterally expanding Class II landfill unit in seismic area	ARM 17.50.1007 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1007 Rule Title: SEISMIC AREAS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to	Prohibits placement of a Class II landfill in a seismic impact zone (as defined in ARM 17.50.1002(35)) unless special conditions are met

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	
Placing landfill unit or laterally expanding Class II landfill unit in seismic area	ARM 17.50.1008 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1008 Rule Title: UNSTABLE AREAS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	Prohibits placement of a Class II landfill in an unstable area, which are defined in ARM 17.50.1002(40) as including locations that are susceptible to events or forces that are capable of impairing the integrity of the landfill structural components responsible for preventing releases from the landfill
Placing solid waste management unit	ARM 17.50.1009 *Available at*: http://mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1009 Rule Title: LOCATION RESTRICTIONS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Location	☑Applicable* *The substantive requirements of this provision would apply to construction of a new Class II landfill.	Provides that a solid waste management facility must be located where a sufficient acreage of suitable land is available for solid waste management, including adequate separation of wastes from underlying groundwater and adjacent surface water. The facility

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements would be relevant and appropriate to the lateral expansion of the Industrial Landfill and the Wet Scrubber Sludge Pond.	may not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife or result in the destruction or adverse modification of critical habitat for those species. Also, the facility must manage solid waste, gas, and leachate
Managing hazardous waste	ARM 17.50.1103 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1103 Rule Title: PROCEDURES FOR EXCLUDING THE RECEIPT OF HAZARDOUS WASTE Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II landfills that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive	

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	
Managing landfill	ARM 17.50.1104 *Available at*: Rule Title: COVER MATERIAL REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	Provides for cover material requirements

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Managing landfill	ARM 17.50.1105 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1105 Rule Title: DISEASE VECTOR CONTROL Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	Provides for disease vector control
Managing landfill	ARM 17.57.1107 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1107 Rule Title: AIR CRITERIA Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities.	Provides for air criteria

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	
Managing landfill	ARM 17.50.1108 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1108 Rule Title: ACCESS REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during	Provides for access requirements

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	
Designing, constructing, and maintaining Class II landfill unit to control for 25-year storm discharge	ARM 17.50.1109 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.50.1109 Rule Title: RUN-ON AND RUN-OFF CONTROL SYSTEMS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other	Provides that Class II landfills be designed, constructed, and maintained with a run-on and run-off control system to address 25-year storm events

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		existing repository that receives solid waste during remedial activities.	
Operating Class II landfill unit so as to avoid discharge to state waters, including wetlands	ARM 17.50.1110 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1110 Rule Title: SURFACE WATER REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	Prohibits a Class II landfill from causing a discharge of a pollutant into state waters, including wetlands
Managing landfill	ARM 17.50.1111 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1111 Rule Title: LIQUIDS RESTRICTIONS Department: ENVIRONMENTAL QUALITY	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II	Provides for liquids restrictions

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	
Designing, constructing, and maintaining Class II landfill unit	ARM 17.50.1116(2)(a), (f) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E50%2E1116 Rule Title: OPERATING CRITERIA Department: ENVIRONMENTAL QUALITY Chapter: SOLID WASTE MANAGEMENT Subchapter: Landfill Operating Criteria	☑Applicable* *The substantive requirements of this provision would apply to new on-site Class II repositories that receive solid waste during response action activities. ☑Relevant and Appropriate* *Although the on-site landfills are exempt from	Requires that a Class II landfill be constructed utilizing a composite liner and leachate collection and removal system that is designed and constructed to maintain less than a 30-centimeter depth of leachate over the liner

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the substantive requirements of this provision would be relevant and appropriate for the Industrial Landfill and the Wet Scrubber Sludge Pond or any other existing repository that receives solid waste during remedial activities.	
Statute | Montana Solid Waste Management Act			
Designing, constructing, and maintaining Class II landfill unit	Section 75-10-206, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0100/part_0020/section_0060/0750-0100-0020-0060.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 10. WASTE AND LITTER CONTROL Part 2. Licensing of Refuse Disposal and Transportation Montana Solid Waste Management Act	☑Relevant and Appropriate* *Although the on-site landfills are exempt from classification under Mont. Code Ann. 75-10-214(b) because they were originally installed during the operation of an electrolytic reduction facility, the provision to grant a waiver to the rules promulgated under MCA 75-10-204 regarding solid waste management	Allows for variances in the design, construction, and operation criteria for non-hazardous waste landfills that are actively managed (i.e., a new disposal) within a site provided that certain criteria are met (e.g., failure to comply with the rules does not result in a danger to public health or safety).

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		systems would be relevant and appropriate for remedial actions that include new disposal of waste into the Industrial Landfill and the Wet Scrubber Sludge Pond.	
Transporting solid waste	Section 75-10-212, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0100/part_0020/section_0120/0750-0100-0020-0120.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 10. WASTE AND LITTER CONTROL Part 2. Licensing of Refuse Disposal and Transportation Montana Solid Waste Management Act	☑Applicable	Prohibits dumping or leaving any debris or refuse upon or within 200 yards of any highway, road, street, or alley of the State or other public property, or on privately owned property where hunting, fishing, or other recreation is permitted. However, the restrictions relating to privately owned property does not apply to the owner, his agents, or those disposing of debris or refuse with the owner's consent.
Statute | Montana Hazardous Waste Act			
Disposing used oil or hazardous waste unlawfully	Section 75-10-422, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0100/part_0040/section_0220/0750-0100-0040-0220.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 10. WASTE AND LITTER CONTROL Part 4. Hazardous Waste Management **75-10-422. Unlawful disposal.** It is unlawful to dispose of used oil or hazardous waste, as defined in this part or by rule, without a permit or, if a permit is not required under this part or rules adopted under this part, by any other means not authorized by law.	☑Applicable* *This provision would apply to used oil or hazardous waste generated during remedial action activities, if any.	Prohibits the unlawful disposal of hazardous waste
Regulation | Montana			

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Hazardous Waste Act			
Handling and disposing of hazardous waste	ARM 17.53.501 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.53.501 Rule Title: ADOPTION OF FEDERAL PROCEDURES FOR IDENTIFICATION AND LISTING OF HAZARDOUS WASTE (40 CFR 261) Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Identification and Listing of Hazardous Waste	☑Applicable* *The substantive requirements of this provision would apply to hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but does not apply to and is not relevant or appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	Adopts the equivalent of RCRA regulations at 40 C.F.R. Part 261, establishing standards for the identification and listing of hazardous wastes, including standards for recyclable materials and standards for empty containers, which certain State exceptions and additions.
Handling and disposing of hazardous waste	ARM 17.53.502 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.53.502 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL STANDARDS FOR IDENTIFICATION AND LISTING OF HAZARDOUS WASTE Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Identification and Listing of Hazardous Waste	☑Applicable* *This provision would apply to hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but does not apply to and is not relevant or appropriate for the material that is currently in the West Landfill and the Center	Adopts the equivalent to RCRA regulations at 40 C.F.R. Part 262, establishing standards that apply to generators of hazardous waste, including standards pertaining to the accumulation of hazardous wastes, with certain State exceptions and additions

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		Landfill as long as it remains in the landfills.	
	ARM 17.53.601 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E601 Rule Title: ADOPTION OF FEDERAL STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE (40 CFR 262) Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Generators of Hazardous Waste	☑Applicable* *The substantive requirements of this provision would apply to generators of hazardous waste during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but does not apply to and is not relevant or appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	See immediately above
	ARM 17.53.602 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E602 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Generators of Hazardous Waste	☑Applicable This provision would apply to generators hazardous waste during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but does not apply to and is not relevant or appropriate for the material that is currently in the West Landfill and the Center	See immediately above

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		Landfill as long as it remains in the landfills.	
Transporting hazardous waste	ARM 17.53.701 citing 40 C.F.R. part 263 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E701 Rule Title: ADOPTION OF FEDERAL STANDARDS APPLICABLE TO TRANSPORTERS OF HAZARDOUS WASTE (40 CFR 263) Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Transporters of Hazardous Waste	☑Applicable* *The substantive requirements of this provision would apply to transporters of hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill).	See immediately above
Transporting hazardous waste	ARM 17.53.702 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E702 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL STANDARDS APPLICABLE TO TRANSPORTERS OF HAZARDOUS WASTE Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Transporters of Hazardous Waste	☑Applicable* *The substantive requirements of this provision would apply to transporters of hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill).	See immediately above
Transporting and managing hazardous waste	ARM 17.53.704 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E704 Rule Title: TRAINING OF TRANSFER FACILITY PERSONNEL Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Transporters of Hazardous Waste	☑Applicable* *This provision would apply to transporters of hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the	See immediately above

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		West Landfill or the Center Landfill).	
Transporting and managing hazardous waste	ARM 17.53.706 (citing 40 C.F.R. part 265, subpart C with additions) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E706 Rule Title: EMERGENCY PREPAREDNESS, PREVENTION, AND RESPONSE AT TRANSFER FACILITIES Department: ENVIRONMENTAL QUALITY Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Transporters of Hazardous Waste	☑Applicable* *The substantive requirements of this provision would apply to transporters of hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill).	See immediately above
Managing and disposing of hazardous waste	ARM 17.53.707 (citing 40 C.F.R. §§ 262.30-.32 with additions) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E707 Rule Title: TRANSFER FACILITY CONTAINER HANDLING REQUIREMENTS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards Applicable to Transporters of Hazardous Waste	☑Applicable* *This provision would apply to transporters of hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill).	See immediately above
Managing and disposing hazardous waste	ARM 17.53.801 (incorporating by reference 40 C.F.R. part 264 with additions per ARM 17.53.802) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E801 Rule Title: ADOPTION OF FEDERAL STANDARDS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE, AND DISPOSAL FACILITIES (40 CFR 264) Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	☑Applicable* *The substantive provisions of ARM 17.53.801 would apply to owners and operators of hazardous waste treatment, storage, and disposal facilities utilized during remedial action activities, if any (e.g., re-disposal or active	See immediately above

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		management of material currently housed in the West Landfill or the Center Landfill), but do not apply to and are not relevant and appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	
Managing and disposing hazardous waste	ARM 17.53.802 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E802 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL STANDARDS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE AND DISPOSAL FACILITIES Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	☑Applicable* *The substantive provisions of ARM 17.53.802 would apply to owners and operators of hazardous waste treatment, storage, and disposal facilities utilized during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or Center Landfill), but do not apply to and are not relevant and appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	See immediately above
Managing and disposing of hazardous waste	ARM 17.53.1101 incorporating by reference 40 C.F.R. part 286 except as noted in ARM 17.53.1102 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E1101	☑Applicable* *The substantive requirements of this	See immediately above

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Rule Title: ADOPTION OF FEDERAL LAND DISPOSAL RESTRICTIONS (40 CFR 268) Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Land Disposal Restrictions	provision would apply to hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but do not apply to and are not relevant and appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	
Managing and disposing of hazardous waste	ARM 17.53.1102 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E1102 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL LAND DISPOSAL RESTRICTIONS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: HAZARDOUS WASTE Subchapter: Land Disposal Restrictions	☑Applicable* *These exceptions and additions could apply to hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but do not apply to and are not relevant and appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	Adopts the equivalent to RCRA regulations at 40 C.F.R. Part 270 and 124, which establish standards for permitted facilities, with certain state exceptions and additions

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Managing and disposing of hazardous waste	ARM 17.53.1202 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E53%2E1202 Rule Title: EXCEPTIONS AND ADDITIONS TO ADOPTION OF FEDERAL PROCEDURES FOR STATE ADMINISTERED PERMIT PROGRAM Department: ENVIRONMENTAL QUALITY Chapter: HAZARDOUS WASTE Subchapter: Hazardous Waste Permit Program	☑Applicable* *These provisions would apply to hazardous waste generated during remedial action activities, if any (e.g., re-disposal or active management of material currently housed in the West Landfill or the Center Landfill), but do not apply to and are not relevant and appropriate for the material that is currently in the West Landfill and the Center Landfill as long as it remains in the landfills.	Provisions of 40 C.F.R. Part 125 for criteria and standards for the impositions of technology-based requirements are adopted and incorporated into DEQ permits. For toxic and nonconventional pollutants treatment must apply the best available technology economically available (BAT); for conventional pollutants, application of the best conventional pollutant control technology (BCT) is required. Where effluent limitations are not specified for the particular industry or industrial category at issue, BCT/BAT technology-based treatment requirements are determined on a case by case basis using best professional judgment
Regulation | Federal Resource Conservation and Recovery Act Subtitle C Landfills			
Managing and disposing hazardous waste	40 C.F.R. Part 264 Subpart N *Available at:* Electronic Code of Federal Regulations (eCFR) TITLE 40: PROTECTION OF ENVIRONMENTAL PART 264-STANDARDS FOR OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE AND DISPOSAL FACILITIES	☑Relevant and Appropriate *The substantive requirements of 40 C.F.R. Part 264 Subpart N would be relevant and appropriate to new construction of an on-site repository for disposal of hazardous waste if	Provides requirements for design, construction operation, management, monitoring, closure and post-closure care for owners and operators of facilities that dispose of hazardous waste in

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		required as part of the remedial action at the Site but do not apply to and are not relevant and appropriate for existing landfills at the Site. **No pre-treatment is required**.	landfills, except as 40 C.F.R. § 264.1 provides otherwise.
STATUTE | Mine and Smelter Waste Remediation			
Reclaiming and revegetating	Section 75-10-1404, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0750/chapter_0100/part_0140/section_0040/0750-0100-0140-0040.html TITLE 75. ENVIRONMENTAL PROTECTION CHAPTER 10. WASTE AND LITTER CONTROL Part 14. Mine and Smelter Waste Remediation	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Requires the reclamation and revegetation of the land as rapidly, completely, and effectively as the most modern technology and the most advanced state of the art will allow. In developing a method of operation and plans for backfilling, water control, grading, topsoiling and reclamation, all measures shall be taken to eliminate damages to landowners and members of the public, their real and personal property, public roads, streams, and all other public property from soil erosion, subsidence, landslides, water pollution, and hazards dangerous to life and property
Statute | Montana Strip and Underground Mine Reclamation Act			

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Excavating cover material and/or waste material	Section 82-4-231(1), (2), (10), (11), MCA *Available at*: https://leg.mt.gov/bills/mca/title_0820/chapter_0040/part_0020/section_0310/0820-0040-0020-0310.html TITLE 82. MINERALS, OIL, AND GAS CHAPTER 4. RECLAMATION Part 2. Coal and Uranium Mine Reclamation	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste. *Cross-reference*: ARM 17.24.751	Provide that reclamation of mine waste materials shall, to the extent practicable using the best technology currently available, minimize disturbances and adverse impacts of the operation on fish, wildlife, and related environmental values and achieve enhancement of such resources where practicable, and shall avoid acid or other toxic mine drainage by such measures as preventing or removing water from contact with toxic producing deposits
Regulation | Strip And Under-Ground Mine Reclamation Act			
Excavating cover material and/or waste material	ARM 17.24.501 @@ *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E501 Rule Title: GENERAL BACKFILLING AND GRADING REQUIREMENTS Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Backfilling and Grading Requirements	☑Relevant and Appropriate* *This provision would be relevant and appropriate for remedial action activities which involve on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provides general backfilling and grading requirements for disturbed areas.
Excavating cover material and/or waste material	ARM 17.24.505(2), (3), (5) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E505 Rule Title: BURIAL AND TREATMENT OF EXPOSED MINERAL SEAMS AND WASTE MATERIALS	☑Relevant and Appropriate* *This provision would be relevant and appropriate for remedial action	Provides that acid, acid forming, toxic, toxic forming or other deleterious materials must not be buried or stored in proximity to a drainage course so as to cause or pose a threat of water pollution.

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Backfilling and Grading Requirements	activities which involve on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	This ARAR also prohibits the use of waste as construction material for embankments or impoundments
Excavating cover material and/or waste material	ARM 17.24.519 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E519 Rule Title: MONITORING FOR SETTLEMENT Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Backfilling and Grading Requirements	☑Relevant and Appropriate* *This provision would be relevant and appropriate for remedial action activities which involve on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provides that an operator may be required to monitor settling of regraded areas
Excavating cover material and/or waste material	ARM 17.24.631 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17%2E24%2E631 Rule Title: GENERAL HYDROLOGY REQUIREMENTS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate for remedial action activities which involve on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provides that disturbances to the prevailing hydrologic balance will be minimized. Changes in water quality and quantity, in the depth to groundwater and in the location of surface water drainage channels will be minimized, to the extent consistent with the selected response action. Other Pollution minimization devices must be used if appropriate, including stabilizing disturbed areas through land shaping, diverting runoff, planting quickly germinating and growing stands of temporary vegetation, regulating channel velocity of water, lining drainage channels with rock or vegetation, mulching, and control of acid-forming,

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
			and toxic-forming waste materials
Excavating cover material and/or waste material	ARM 17.24.633 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.24.633 Rule Title: WATER QUALITY PERFORMANCE STANDARDS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate for construction water/stormwater management in excavation areas.	Applicable: Provides all surface drainage from a disturbed area must be treated by the best technology currently available (BTCA)
Excavating cover material and/or waste material	ARM 17.24.634 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E634 Rule Title: RECLAMATION OF DRAINAGE BASINS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate for excavation of cover/waste material and construction of on-site repositories that receive waste during response action activities.	Provides that in reclamation of drainage, drainage design must emphasize channel and floodplain dimensions that approximate the pre-mining configuration and that will blend with the undisturbed drainage above and below the area to be reclaimed. The average stream gradient must be maintained with a concave longitudinal profile. This regulations provides specific requirements for designing the reclaimed drainage to: (1) approximate an appropriate geomorphic habit or characteristic pattern; (2) remain in dynamic equilibrium with the system without the use of artificial structural controls; (3) improve unstable pre-mining conditions; (4) provide for floods and for the long-term stability of the landscape; (5) establish a pre-mining diversity of aquatic habitats and riparian vegetation
Excavating cover material and/or waste material	ARM 17.24.635(1), (2), (3), (4) *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E635	☑Relevant and Appropriate* *This provision would be relevant and appropriate for diversions of surface	Set forth requirements for temporary and permanent diversions

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Rule Title: GENERAL REQUIREMENTS FOR TEMPORARY AND PERMANENT DIVERSION OF OVERLAND FLOW, THROUGH FLOW, SHALLOW GROUND WATER FLOW, EPHEMERAL DRAINAGEWAYS, AND INTERMITTENT AND PERENNIAL STREAMS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	water or groundwater flow required to construct, operate, and maintain a remedial action. Examples include modification of surface drainage and installation of slurry walls to divert flow around repositories.	
Excavating cover material and/or waste material	ARM 17.24.636 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E636 Rule Title: SPECIAL REQUIREMENTS FOR TEMPORARY DIVERSIONS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate for diversions of surface water or groundwater flow required to construct, operate, and maintain a remedial action. Examples include modification of surface drainage and installation of slurry walls to divert flow around repositories.	Set forth requirements for temporary and permanent diversions.
Excavating cover material and/or waste material	ARM 17.24.638 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E638 Rule Title: SEDIMENT CONTROL MEASURES Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate for excavation of cover/waste material and construction of on-site repositories that receive waste during response action activities.	Provides that discharge from diversions must be controlled to reduce erosion and minimize disturbance of the hydrologic balance

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Excavating cover material and/or waste material	ARM 17.24.640 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E640 Rule Title: DISCHARGE STRUCTURES Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology **17.24.640** DISCHARGE STRUCTURES	☑Relevant and Appropriate* *This provision would be relevant and appropriate to structures associated with on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste that discharge directly to surface water.	Provides that discharge from sedimentation ponds, impoundments, and diversions must be controlled by vegetation, energy dissipators, riprap channels, and other measures, where necessary, to reduce erosion, to prevent deepening or enlargement of stream channels, and to minimize disturbance of the hydrologic balance
Excavating cover material and/or waste material	ARM 17.24.644 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E644 Rule Title: PROTECTION OF GROUND WATER RECHARGE Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate *This provision would be relevant and appropriate to on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provide provisions for groundwater protection, groundwater recharge protection, and groundwater and surface water monitoring
Excavating cover material and/or waste material	ARM 17.24.645 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E645 Rule Title: GROUND WATER MONITORING Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	☑Relevant and Appropriate* *This provision would be relevant and appropriate to on-site repositories that receive waste during response action activities and to excavations.	Provides provisions for groundwater protection, groundwater recharge protection, and groundwater and surface water monitoring
Excavating cover material and/or waste material	ARM 17.24.646 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E646 Rule Title: SURFACE WATER MONITORING	☑Relevant and Appropriate *This provision would be relevant and appropriate to on-site repositories that	Provides provisions for surface water monitoring

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Transportation Facilities, Use of Explosives, and Hydrology	receive waste during response action activities and to excavations for removal of contaminated soil or waste that discharge to surface water.	
Excavating cover material and/or waste material	ARM 17.24.701 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E701 Rule Title: REMOVAL OF SOIL Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate to removal of uncontaminated soil that may be reused on-site but is not applicable to or relevant or appropriate for contaminated soil that is being removed for subsequent disposal.	Provides requirements for redistributing and stockpiling of soil for reclamation. Also outline practices to prevent compaction, slippage, erosion, and deterioration of biological properties of soil
Excavating cover material and/or waste material	ARM 17.24.702 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E702 Rule Title: REDISTRIBUTION AND STOCKPILING OF SOIL Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate to excavation of cover/waste material and construction of on-site repositories that receive waste during response action activities.	Provides requirements for redistributing and stockpiling of soil for reclamation. Also outline practices to prevent compaction, slippage, erosion, and deterioration of biological properties of soil
Excavating cover material and/or waste material	ARM 17.24.703 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E703 Rule Title: SUBSTITUTION OF OTHER MATERIALS FOR SOIL Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for	Provides that when using materials other than, or along with, soil for final surfacing in reclamation, the operator must demonstrate that the material (1) is at least as capable as the soil of supporting the approved vegetation and subsequent land use, and (2) the medium

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		removal of contaminated soil or waste.	must be the best available in the area to support vegetation. Such substitutes must be used in a manner consistent with the requirements for redistribution of soil in ARM 17.24.701 and 702
Excavating cover material and/or waste material	ARM 17.24.711 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E711 Rule Title: ESTABLISHMENT OF VEGETATION Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *The provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Requires that a diverse, effective, and permanent vegetative cover of the same seasonal variety and utility as the vegetation native to the area of land to be affected must be established. This provision would not be relevant and appropriate in certain instances, for example, where there is dedicated development
Excavating cover material and/or waste material	ARM 17.24.713 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E713 Rule Title: TIMING OF SEEDING AND PLANTING Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provides that seeding and planting of disturbed areas must be conducted during the first appropriate period for favorable planning after final seedbed preparation, but may not be more than ninety days after soil has been replaced
Excavating cover material and/or waste material	ARM 17.24.714 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E714 Rule Title: SOIL STABILIZING PRACTICES Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for	Requires use of a mulch or cover crop or both until an adequate permanent cover can be established. Use of mulching and temporary cover may be suspended under certain conditions

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
		removal of contaminated soil or waste.	
Excavating cover material and/or waste material	ARM 17.24.716 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E716 Rule Title: METHOD OF REVEGETATION Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Establishes the required method of vegetation
Excavating cover material and/or waste material	ARM 17.24.717 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E717 Rule Title: PLANTING OF TREES AND SHRUBS Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate* *This provision would be relevant and appropriate for new excavations for removal of contaminated soil or waste.	Relates to the planting of trees and other woody species if necessary, as provided in Section 82-4-233, MCA, to establish a diverse, effective, and permanent vegetative cover
Excavating cover material and/or waste material	ARM 17.24.718 *Available at*: http://mtrules.org/gateway/ruleno.asp?RN=17.24.718 Rule Title: SOIL AMENDMENTS, MANAGEMENT TECHNIQUES, AND LAND USE PRACTICES Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Requires soil amendments if necessary to establish a permanent vegetative cover
Excavating cover material and/or waste material	ARM 17.24.721 *Available at*: http://www.mtrules.org/gateway/ruleno.asp?RN=17.24.721 Rule Title: ERADICATION OF RILLS AND GULLIES Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF	☑Relevant and Appropriate *This provision would be relevant and appropriate for remedial activities and to excavations for removal	Specifies that rills and gullies must be stabilized and the area reseeded and replanted if the rills and gullies are disrupting the reestablishment of the vegetative cover

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
	Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	of contaminated soil or waste.	
Excavating cover material and/or waste material	ARM 17.24.723 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E723 Rule Title: MONITORING Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Requires periodic monitoring of vegetation, soils, water, and wildlife
Excavating cover material and/or waste material	ARM 17.24.724 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E724 Rule Title: REVEGETATION SUCCESS CRITERIA Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Specifies how revegetation success is measured
Excavating cover material and/or waste material	ARM 17.24.726 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E726 Rule Title: VEGETATION MEASUREMENTS Department: ENVIRONMENTAL QUALITY Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Sets the required methods for measuring vegetative success

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Excavating cover material and/or waste material	ARM 17.24.731 *Available at*: http://www.mtrules.org/gateway/RuleNo.asp?RN=17%2E24%2E731 Rule Title: ANALYSIS FOR TOXICITY Department: ENVIRONMENTAL QUALITY, DEPARTMENT OF Chapter: RECLAMATION Subchapter: Strip and Underground Mine Reclamation Act: Topsoiling, Revegetation, and Protection of Wildlife and Air Resources	☑Relevant and Appropriate *This provision would be relevant and appropriate for on-site repositories that receive waste during response action activities and to excavations for removal of contaminated soil or waste.	Provides if toxicity to plants or animals is suspected, comparative chemical analysis may be required
Statute | Weed Control			
Propagation of noxious weeds	Section 7-22-2116(1), MCA *Available at*: https://leg.mt.gov/bills/mca/title_0070/chapter_0220/part_0210/section_0160/0070-0220-0210-0160.html TITLE 7. LOCAL GOVERNMENT CHAPTER 22. WEED AND PEST CONTROL Part 21. County Weed Control	☑Applicable* *These requirements would apply to the reclamation of an area disturbed by grading, excavation, or similar actions, and require the revegetation of the area.	Prohibits allowing noxious weeds to propagate
Propagation of noxious weeds	Section 7-22-2152, MCA *Available at*: https://leg.mt.gov/bills/mca/title_0070/chapter_0220/part_0210/section_0520/0070-0220-0210-0520.html TITLE 7. LOCAL GOVERNMENT CHAPTER 22. WEED AND PEST CONTROL Part 21. County Weed Control	☑Applicable *These requirements would apply to the reclamation of an area disturbed by grading, excavation, or similar actions, and require the revegetation of the area.	Provides for preparation and implementation of weed control plan
Regulation | Weed Control			

Table 3-1 Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) Anaconda/CFAC Feasibility Study			
Site-Specific Characteristics	**Citation(s)**	**Prerequisite**	**Requirements**
Controlling specified noxious weeds	ARMS 4.5.206-.210 (Series citation) Available at: http://www.mtrules.org/gateway/ruleno.asp?RN=4.5.206 Department: AGRICULTURE Chapter: NOXIOUS WEED MANAGEMENT Subchapter: Designation of Noxious Weeds	☑Applicable* *Where listed noxious weeds may be present on-site	Provides for weed eradication where specified noxious weeds exist

Table 4-1. Evaluation of Remedial Technologies for Landfills DU1
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in Surficial and Shallow Soil in the Landfills DU1: Metals (arsenic, copper, nickel) and PAHs
Summary of COCs Impacting Groundwater in the Landfills DU1: cyanide and fluoride

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
No Action	None	A baseline for comparison among alternatives.	1. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Engineering Controls - Physical Barriers	Prevent human access to impacted media / waste by enclosing areas with fences and/or warning signs.	1. Protects compliant human receptors and some ecological receptors. 2. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Widely used technology. 2. Easily implemented.	$$	Low	x	Potentially viable process option in combination with one or more other technologies.
	Institutional Controls - Deed Restrictions	Prevent types of development that could lead to contact with impacted media.	1. Protects compliant human receptors. 2. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors.	1. Widely used technology. 2. Easily implemented.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
Containment	Cover / Cap - Impermeable Membrane	Provides low permeability geomembrane barrier (e.g., high density polyethylene (HDPE)) to prevent water infiltration through and contact with the impacted media / waste.	1. Provides high level of protection against groundwater infiltration and further leaching of contaminants from media / waste into groundwater. 2. Minimizes potential for direct exposure to contamination. 3. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Potential for punctures or tears during placement of cover soil. 5. Capping does not address the impact to groundwater from wastes or impacted materials that may sometimes be below the fluctuating water table.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction. 3. The WSSP may require solidification of material to support a cap; the WSSP primarily accepted sludges, which may have been of low strength.	$$$$	Moderate	x	Potentially viable process option in combination with institutional controls and/or monitoring.
	Cover / Cap - Geosynthetic Clay Liner (GCL)	Provides low permeability bentonite clay barrier in combination with geotextiles and/or geomembranes to prevent water infiltration through and contact with the impacted media / waste.	1. Provides high level of protection against groundwater infiltration and further leaching of contaminants from media / waste into groundwater. 2. Minimizes potential for direct exposure to contamination. 3. Capable of self-healing against small (≤1 inch diameter) punctures. 4. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Wetting and drying can cause GCL to swell or shrink; desiccation can lead to cracking and to an increase in hydraulic conductivity. 5. Capping does not address the impact to groundwater from wastes or impacted materials that may sometimes be below the fluctuating water table.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction. 3. The WSSP may require solidification of material to support a cap; the WSSP primarily accepted sludges, which may have been of low strength.	$$$$	Moderate	x	Potentially viable process option in combination with institutional controls and/or monitoring.
	Cover / Cap - Phytocap	Provides physical barrier to prevent contact with the impacted media / waste and reduces water infiltration though the waste. Has the added benefit of promoting continued degradation of residual PAHs in the soil.	1. Reduces the rate of water infiltration and further leaching of contaminants from media / waste into groundwater. 2. Evapotranspires large quantities of water, thus minimizing leachate generation. 3. Minimizes potential for direct exposure to contamination. 4. Creates ecological enhancements that would support and sustain indigenous and migratory wildlife species. 5. Vegetation stabilizes the cap and prevents erosion. 6. Facilitate *in situ* PAH biodegradation and metals sequestration in soils. 7. Negative effects of differential settling and cracking are not as great as they are for an impermeable membrane or GCL cap. 8. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil in the near-term. 2. Restrictions on future land use. 3. Not as effective as an impermeable membrane in decreasing infiltration, since permeability of the soil layer would not be low enough to significantly reduce this process. 4. Effectiveness can be limited during vegetative dormancy periods. 5. Capping does not address the impact to groundwater from wastes or impacted materials that may sometimes be below the fluctuating water table. 6. Potential translocation of COCs to above-ground plant biomass.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction. 3. Would need to demonstrate impermeability equivalency of the phytocap to a conventional cap since leachability is a concern for waste management units in Landfills DU1. 4. Need to quantify hydrologic control of wildlife plant species.	$$$	Low	Implementability	Eliminated from consideration.

ROUX

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Containment *cont'd*	Cover - Soil Cover	Provides permeable or low permeability soil cover to prevent contact with the impacted media / waste.	1. Minimizes potential for direct exposure to contamination. 2. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Does not prevent infiltration thru underlying waste to prevent groundwater contamination. 3. Restrictions on future land use. 4. Susceptible to settling and erosion. 5. Capping does not address the impact to groundwater from wastes or impacted materials that may sometimes be below the fluctuating water table.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction.	$$$	Low	Effectiveness	Eliminated from consideration.
	Hydraulic Control / Vertical Barriers	See Table 6. Evaluation of Remedial Technologies for the Groundwater DU.						x	One or more process options retained; refer to Section 5.6 and Table 6.
Removal and Disposal	Excavation - Offsite Disposal	Physical removal of contaminated media / waste with disposal at an offsite disposal facility.	1. Highly effective technology if all impacted media / waste is removed. 2. Short time frame for results following completion. 3. Will improve groundwater quality in the long-term by reducing source material.	1. Further degradation of groundwater expected; excavation of the Landfills DU1 waste management units would likely result in an increase in concentrations of COCs downgradient of the Landfills DU1, both within and potentially beyond the current extent of the plume. 2. Potential human health risk exposure during excavation activities. 3. Prolonged period of construction and transportation of wastes will be significantly disruptive to the community and to visitors of Glacier National Park. 4. Failure to remove all impacted material would significantly reduce effectiveness. 5. Disproportionate worker health and safety risks due to the nature and duration of excavation activities. 6. Disposal facilities are far from the Site, increasing emissions, risk of traffic accidents and potential contaminant releases, health and safety risks, and costs.	1. Not a widely used technology for previously-landfilled SPL material at the scale which would be required to address Landfills DU1 waste management units, though the technology is commercially available. The estimated volume of waste is upwards of 1 million LCY. 2. Significant pumping rates expected for collection of water entering the open excavation; a large and complex treatment system would be required. 3. Safety concerns with implementation; level C personal protective equipment (PPE) would be required. Construction of enclosed/ contained work areas would be necessary to effectively control emissions, but is impracticable. 4. Transport would require long travel distances due to proximity of the Site to disposal outlets. 5. To facilitate material handling, sludge from the WSSP would likely require physical solidification prior to, or in conjunction with, excavation. Heterogenous waste likely in the WSSP would adversely impact implementability and effectiveness of the solidification treatment process. 6. Not cost effective for deep excavations and large volumes of contamination. 7. A significant volume of generated waste would be hazardous; therefore, disposal costs would be even higher.	$$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost; Significant disruption to community and emissions from truck traffic	Eliminated from consideration.

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Removal and Disposal *cont'd*	Excavation - Onsite Consolidation	Physical removal of contaminated media / waste with consolidation and disposal at an onsite repository.	1. Highly effective technology if all impacted media / waste is removed. 2. Short time frame for results following completion. 3. Will improve groundwater quality in the long-term by reducing source material. 4. Minimizes transport and disposal costs.	1. Further degradation of groundwater expected; excavation of the Landfills DU1 waste management units would likely result in an increase in concentrations of COCs downgradient of the Landfills DU1, both within and potentially beyond the current extent of the plume. 2. Potential human health risk exposure during excavation activities. 3. Prolonged period of construction will be significantly disruptive to the community. 4. Failure to remove all impacted material would significantly reduce effectiveness. 5. Disproportionate worker health and safety risks due to the nature and duration of excavation activities. 6. Suitable locations for a new repository would be closer to potential receptors, increasing the potential for exposure to emissions associated with the repository and reducing the buffer zone between the contamination and potential receptors.	1. Not a widely used technology for previously-landfilled SPL material at the scale which would be required to address Landfills DU1 waste management units, though the technology is commercially available. The estimated volume of waste is upwards of 1 million LCY. 2. Significant pumping rates expected for collection of water entering the open excavation; a large and complex treatment system would be required. 3. Safety concerns with implementation; level C personal protective equipment (PPE) would be required. Construction of enclosed/ contained work areas would be necessary to effectively control emissions, but is impracticable. 4. Technical and administrative feasibility of constructing and implementing a temporary onsite hazardous waste treatment system is questionable. 5. To facilitate material handling, sludge from the WSSP would likely require physical solidification prior to, or in conjunction with, excavation. Heterogenous waste likely in the WSSP would adversely impact implementability and effectiveness of the solidification treatment process. 6. New onsite repository would need to meet substantive RCRA Subtitle C requirements. 7. Not cost effective for deep excavations and large volumes of contamination.	$$$$$	Moderate	x Retained, though there are significant concerns regarding the technical implementability of this technology; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Retained for further evaluation.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Table 4-2. Evaluation of Remedial Technologies for Landfills DU2
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in Surficial and Shallow Soil in the Landfills DU2: Metals (arsenic, copper, nickel, vanadium) and PAHs

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
No Action	None	A baseline for comparison among alternatives.	1. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Engineering Controls - Physical Barriers	Prevent human access to impacted media / waste by enclosing areas with fences and/or warning signs.	1. Protects compliant human receptors and some ecological receptors. 2. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Widely used technology. 2. Easily implemented.	$$	Low	x	Potentially viable process option in combination with one or more other technologies.
	Institutional Controls - Deed Restrictions	Prevent types of development that could lead to contact with impacted media.	1. Protects compliant human receptors. 2. Does not disturb previously-landfilled wastes.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors.	1. Widely used technology. 2. Easily implemented.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
Containment	Cover / Cap - Impermeable Membrane	Provides low permeability geomembrane barrier (e.g., high density polyethylene (HDPE)) to prevent water infiltration through and contact with the impacted media / waste.	1. Provides high level of protection against groundwater infiltration and further leaching of contaminants from media / waste into groundwater. 2. Minimizes potential for direct exposure to contamination. 3. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Potential for punctures or tears during placement of cover soil.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction.	$$$$	Moderate	x	Potentially viable process option for the Industrial Landfill in combination with institutional controls and/or monitoring.
	Cover / Cap - Geosynthetic Clay Liner (GCL)	Provides low permeability bentonite clay barrier in combination with geotextiles and/or geomembranes to prevent water infiltration through and contact with the impacted media / waste.	1. Provides high level of protection against groundwater infiltration and further leaching of contaminants from media / waste into groundwater. 2. Minimizes potential for direct exposure to contamination. 3. Capable of self-healing against small (≤1 inch diameter) punctures. 4. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Wetting and drying can cause GCL to swell or shrink; desiccation can lead to cracking and to an increase in hydraulic conductivity.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction.	$$$$	Moderate	x	Potentially viable process option for the Industrial Landfill in combination with institutional controls and/or monitoring.
	Cover / Cap - Phytocap	Provides physical barrier to prevent contact with the impacted media / waste and reduces water infiltration though the waste. Has the added benefit of promoting continued degradation of residual PAHs in the soil.	1. Reduces the rate of water infiltration and further leaching of contaminants from media / waste into groundwater. 2. Evapotranspires large quantities of water, thus minimizing leachate generation. 3. Minimizes potential for direct exposure to contamination. 4. Creates ecological enhancements that would support and sustain indigenous and migratory wildlife species. 5. Vegetation stabilizes the cap and prevents erosion. 6. Facilitate *in situ* PAH biodegradation and metals sequestration in soils. 7. Negative effects of differential settling and cracking are not as great as they are for an impermeable membrane or GCL cap. 8. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil in the near-term. 2. Restrictions on future land use. 3. Not as effective as an impermeable membrane in decreasing infiltration, since permeability of the soil layer would not be low enough to significantly reduce this process. 4. Effectiveness can be limited during vegetative dormancy periods. 5. Potential translocation of COCs to above-ground plant biomass.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction. 3. Need to quantify hydrologic control of wildlife plant species.	$$$	Low	Implementability	Eliminated from consideration.
	Cover - Soil Cover	Provides permeable or low permeability soil cover to prevent contact with the impacted media / waste.	1. Minimizes potential for direct exposure to contamination. 2. Does not disturb previously-landfilled wastes.	1. Does not remove or degrade contamination within the soil. 2. Does not prevent infiltration. 3. Restrictions on future land use. 4. Susceptible to settling and erosion.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction.	$$$	Low	x	Potentially viable process option for the Sanitary Landfill and Asbestos Landfills in combination with institutional controls and/or monitoring.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Table 4-3. Evaluation of Remedial Technologies for the Soil DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in the Soil DU: Metals (arsenic, copper, nickel, vanadium) and PAHs

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
No Action	None	A baseline for comparison among alternatives.	NA	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Engineering Controls - Physical Barriers	Prevent human access to impacted soil by enclosing areas with fences and/or warning signs.	1. Protects compliant human receptors and some ecological receptors.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Widely used technology. 2. Easily implemented.	$$	Low	Effectiveness	Beyond existing Site-wide fencing, ECs restricting access specific to the Soil DU are eliminated from consideration.
	Institutional Controls - Deed Restrictions	Prevent types of development that could lead to contact with impacted media or compromise covers.	1. Protects compliant human receptors.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors.	1. Widely used technology. 2. Easily implemented.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
In Situ Treatment	Biological Treatment - Phytoremediation	Rhizodegradation of shallow PAHs. Phytostabilization of some metals.	1. Effective for degrading PAHs and stabilizing some metals in shallow soil. 2. Vegetation plays a key role in controlling erosion. 3. Green technology.	1. Multi-year time frame before results are obtained (i.e., achievement of PRGs/RAOs). 2. Not effective for deeper impacts. 3. Does not destroy metals. 4. Separate technology may be necessary to address some metal(s).	1. Widely used and proven technology. 2. Implementable. 3. Agronomy data (evaluation of nutrients available to plants in soils) would need to be collected. Phytotoxicity would need to be evaluated.	$$$	Low	x	Potentially viable process option for areas with PAH impacts in shallow soils in combination with institutional controls and/or monitoring.
	Physical/ Chemical Treatment - Solidification/ Stabilization	Solidification encapsulates the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. Stabilization chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.	1. Effective for metals in unsaturated and saturated soils.	1. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*. 2. Separate technology would be necessary to address PAHs.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Surface cover, where none is currently present, would be required after treatment.	$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Chemical Treatment - Chemical Oxidation	*In situ* chemical oxidation (ISCO) injects oxidizing agents that react with contaminants to form innocuous end products.	1. Various chemical oxidants (e.g., permanganate, hydrogen peroxide / Fenton's reagent [hydrogen peroxide catalyzed with iron], ozone, persulfate) effective for PAHs. 2. May enhance long-term bioremediation.	1. Does not address metals and has potential for mobilization of metals (e.g., arsenic (if present as a sulfide), chromium, and copper from alkaline-activated persulfate; chromium, copper, nickel, and zinc from iron-activated hydrogen peroxide and sodium persulfate). Separate technology would be necessary to address metals. 2. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Effectiveness is dependent on contact time of chemical application. 4. Organics in soil can greatly increase the oxidant demand.	$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Thermal Treatment - Thermal Desorption	Heating elements transfer heat to the soil by thermal conduction. Contaminants are removed by processes including boiling, evaporation, oxidation, and steam distillation.	1. Effective for PAHs in unsaturated soils.	1. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*. 2. Separate technology would be necessary to address metals.	1. Widely used technology. 2. Implementable for concentrated areas; specialty vendor/ contractor required. 3. Surface cover, where none is currently present, would be required prior to treatment. 4. Off-gas and condensate treatment would be required. 5. May require additional soil property information (particle size, moisture contents).	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-3. Evaluation of Remedial Technologies for the Soil DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Ex Situ Treatment	Chemical Treatment - Chemical Extraction	Separation of contaminants from soil through extraction methods after soil is excavated. Reagent TBD; an acid may be required.	1. Acid extraction process is effective for metals. 2. Solvent extraction process is effective for PAHs.	1. Heterogeneous waste may produce uneven treatment.	1. Not widely used technology. 2. Not easily implemented; specialty vendor/ contractor and proprietary chemicals are typically required. Different extraction processes necessary to address metals and PAHs. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Chemical Treatment - Chemical Oxidation	Chemical oxidation uses oxidizing agents that react with contaminants to form innocuous end products.	1. Various chemical oxidants (e.g., permanganate, hydrogen peroxide / Fenton's reagent [hydrogen peroxide catalyzed with iron], ozone, persulfate) effective for PAHs.	1. Does not address metals and has potential for mobilization of metals (e.g., arsenic (if present as a sulfide), chromium, and copper from alkaline-activated persulfate; chromium, copper, nickel, and zinc from iron-activated hydrogen peroxide and sodium persulfate). Separate technology would be necessary to address metals. 2. Heterogeneous waste may produce uneven treatment.	1. Not widely used technology. 2. Implementable. 3. Organics in soil can greatly increase the oxidant demand.	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical Treatment - Sieving / Physical Separation	Contaminant removal from soils by concentrating them into a smaller volume of soil through particle size separation (i.e., using different size sieves and screens).	1. Effective for PAHs and metals which tend to bind, either chemically or physically, to the fine (i.e., clay and silt) fraction of soil.	1. Separate technology and/or disposal would be necessary to address fine soil fraction. 2. If coarser material contains contaminant mass, it would still need to be addressed.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Would still require treatment or disposal of the fine soil fraction. 4. May require additional soil property information (particle size distribution, organic content, moisture content, etc.)	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical/ Chemical Treatment - Soil Washing	Contaminant removal from soils by dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time).	1. Effective for PAHs and metals.	1. Heterogeneous waste may produce uneven treatment.	1. Not widely used in the US. 2. Not easily implemented; difficult to formulate a single suitable washing solution that will consistently and reliably remove all COCs; sequential washing using different wash formulations and/or soil-to-wash fluid ratios may be required. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size distribution, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical/ Chemical Treatment - Solidification/ Stabilization	Solidification encapsulates the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. Stabilization chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.	1. Effective for metals in unsaturated and saturated soils.	1. Heterogeneous waste may produce uneven treatment. 2. Separate technology would be necessary to address PAHs.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Bulking of waste would occur increasing volume of material to be further managed. 4. Surface cover, where none is currently present, would be required after treatment.	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Thermal Treatment - Thermal Desorption	Heating elements transfer heat to the soil by thermal conduction. Contaminants are removed by processes including boiling, evaporation, oxidation, and steam distillation.	1. Effective for PAHs in unsaturated soils.	1. Heterogeneous waste may produce uneven treatment. 2. Separate technology would be necessary to address metals.	1. Not widely used technology. Commercial availability is limited. 2. Implementable. 3. Off-gas and condensate treatment would be required. 4. May require additional soil property information (particle size, moisture contents).	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-3. Evaluation of Remedial Technologies for the Soil DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Containment	Cover / Cap - Impermeable Membrane	Provides low permeability barrier to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Potential for punctures or tears during placement of cover soil.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction.	$$$$	Moderate	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover / Cap - Phytocap	Provides low permeability barrier to prevent contact with the impacted media and has the added benefit of promoting continued degradation of residual PAHs in the soil.	1. Minimizes potential for direct exposure to contamination. 2. Creates ecological enhancements that would support and sustain indigenous and migratory wildlife species. 3. Vegetation stabilizes the cover and prevents erosion. 4. Facilitates *in situ* PAH biodegradation and metals sequestration in soils. 5. Negative effects of differential settling and cracking are not as great as they are for an impermeable membrane or GCL cap.	1. Does not remove or degrade contamination within the soil in the near-term. 2. Restrictions on future land use. 3. Effectiveness can be limited during vegetative dormancy periods. 4. Potential translocation of COCs to above-ground plant biomass.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction.	$$$	Low	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover - Soil Cover	Provides permeable or low permeability soil cover to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction.	$$$	Low	x	Potentially viable process option in combination with institutional controls and/or monitoring.
Removal and Disposal	Excavation - Offsite Disposal	Physical removal of contaminated media with disposal at an offsite disposal facility.	1. Highly accepted and effective technology. 2. Short time frame for results following completion.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction but transport would require long travel distances due to proximity of the Site to disposal outlets.	$$$$$+	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Excavation - Onsite Consolidation	Physical removal of contaminated media with consolidation and disposal at an onsite repository.	1. Highly accepted and effective technology. 2. Short time frame for results following completion. 3. Minimizes transport and disposal costs.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction. 3. Onsite repository(s) would need to meet substantive requirements.	$$$$	Low	x	Potentially viable process option as a stand-alone approach or in combination with institutional controls and/or monitoring.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Table 4-4. Evaluation of Remedial Technologies for the North Percolation Pond DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in the North Percolation Pond DU soil/sediment: Metals (arsenic, barium, cadmium, lead, nickel, selenium, thallium, vanadium, zinc), cyanide (total), and PAHs

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
No Action	None	A baseline for comparison among alternatives.	NA	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Engineering Controls - Physical Barriers	Prevent human access to impacted media by enclosing areas with fences and/or warning signs.	1. Protects compliant human receptors and some ecological receptors.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Widely used technology. 2. Easily implemented.	$$	Low	x	Potentially viable process option in combination with one or more other technologies.
	Institutional Controls - Deed Restrictions	Prevent types of development that could lead to contact with impacted media or compromise covers.	1. Protects compliant human receptors.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors.	1. Widely used technology. 2. Easily implemented.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
In Situ Treatment	Biological Treatment - Phytoremediation	Rhizodegradation of shallow PAHs, phytodegradation of cyanide, and phytostabilization of some metals.	1. Effective for degrading PAHs and cyanide and stabilizing some metals in shallow soil/sediment. 2. Vegetation plays a key role in controlling erosion. 3. Green technology.	1. Multi-year time frame before results are obtained (i.e., achievement of PRGs/RAOs). 2. Not effective for deeper impacts. 3. Does not destroy metals. 4. Separate technology may be necessary to address some metal(s).	1. Widely used and proven technology. 2. Difficult to establish a healthy phyto population in current conditions (i.e., in viscous carbonaceous material) without amendments. 3. Agronomy data (evaluation of nutrients available to plants in soils) would need to be collected. Phytotoxicity would need to be evaluated.	$$$	Low	Implementability	Eliminated from consideration.
	Physical/ Chemical Treatment - Solidification/ Stabilization	Solidification encapsulates the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. Stabilization chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.	1. Can eliminate physical hazards associated with viscous waste. 2. Effective for metals in unsaturated and saturated soils.	1. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*. 2. Separate technology would be necessary to address PAHs.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Surface cover, where none is currently present, would be required after treatment.	$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Chemical Treatment - Chemical Oxidation	*In situ* chemical oxidation (ISCO) injects oxidizing agents that react with contaminants to form innocuous end products.	1. Various chemical oxidants (e.g., permanganate, hydrogen peroxide / Fenton's reagent [hydrogen peroxide catalyzed with iron], ozone, persulfate) effective for PAHs. 2. May enhance long-term bioremediation.	1. Does not address metals and has potential for mobilization of metals (e.g., arsenic (if present as a sulfide), chromium, and copper from alkaline-activated persulfate; chromium, copper, nickel, and zinc from iron-activated hydrogen peroxide and sodium persulfate). Separate technology would be necessary to address metals. 2. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*.	1. Widely used, proven, and commercially available technology. 2. Implementable, though high expected chemical demand from elevated concentrations of COCs would require multiple rounds of treatment. 3. Effectiveness is dependent on contact time of chemical application. 4. Organics in soil/sediment can greatly increase the oxidant demand.	$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Thermal Treatment - Thermal Desorption	Heating elements transfer heat to the soil by thermal conduction. Contaminants are removed by processes including boiling, evaporation, oxidation, and steam distillation.	1. Effective for PAHs in unsaturated soils.	1. Heterogeneous waste may produce uneven treatment. The presence of obstructions, if present, will make it difficult to effectively address contamination *in situ*. 2. Separate technology would be necessary to address metals.	1. Widely used technology. 2. Implementable; specialty vendor/ contractor required. 3. Surface cover, where none is currently present, would be required prior to treatment. 4. Off-gas and condensate treatment would be required. 5. May require additional soil property information (particle size, moisture contents).	$$$	None	Effectiveness	Eliminated from consideration.

Table 4-4. Evaluation of Remedial Technologies for the North Percolation Pond DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Ex Situ Treatment	Chemical Treatment - Chemical Extraction	Separation of contaminants from soil through extraction methods after soil is excavated. Reagent TBD; an acid may be required.	1. Acid extraction process is effective for metals. 2. Solvent extraction process is effective for PAHs.	1. Heterogeneous waste may produce uneven treatment.	1. Not widely used technology. 2. Not easily implemented; specialty vendor/ contractor and proprietary chemicals are typically required. Different extraction processes necessary to address metals and PAHs. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Chemical Treatment - Chemical Oxidation	Chemical oxidation uses oxidizing agents that react with contaminants to form innocuous end products.	1. Various chemical oxidants (e.g., permanganate, hydrogen peroxide / Fenton's reagent [hydrogen peroxide catalyzed with iron], ozone, persulfate) effective for PAHs.	1. Does not address metals and has potential for mobilization of metals (e.g., arsenic (if present as a sulfide), chromium, and copper from alkaline-activated persulfate; chromium, copper, nickel, and zinc from iron-activated hydrogen peroxide and sodium persulfate). Separate technology would be necessary to address metals. 2. Heterogeneous waste may produce uneven treatment.	1. Not widely used technology. 2. Implementable. 3. Organics in soil/sediment can greatly increase the oxidant demand.	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical Treatment - Sieving / Physical Separation	Contaminant removal from soils by concentrating them into a smaller volume of soil through particle size separation (i.e., using different size sieves and screens).	1. Effective for PAHs and metals which tend to bind, either chemically or physically, to the fine (i.e., clay and silt) fraction of soil.	1. Separate technology and/or disposal would be necessary to address fine soil fraction. 2. If coarser material contains contaminant mass, it would still need to be addressed.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Would still require treatment or disposal of the fine soil fraction. 4. May require additional soil property information (particle size distribution, organic content, moisture content, etc.)	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical/ Chemical Treatment - Soil Washing	Contaminant removal from soils by dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time).	1. Effective for PAHs and metals.	1. Heterogeneous waste may produce uneven treatment.	1. Not widely used in the US. 2. Not easily implemented; difficult to formulate a single suitable washing solution that will consistently and reliably remove all COCs; sequential washing using different wash formulations and/or soil-to-wash fluid ratios may be required. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size distribution, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical/ Chemical Treatment - Solidification/ Stabilization	Solidification encapsulates the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. Stabilization chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.	1. Will increase the stability and overall performance of viscous waste. 2. Effective for metals in unsaturated and saturated soils.	1. Heterogeneous waste may produce uneven treatment. 2. Separate technology would be necessary to address PAHs.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Bulking of waste would occur increasing volume of material to be further managed. 4. Surface cover, where none is currently present, would be required after treatment.	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Thermal Treatment - Thermal Desorption	Heating elements transfer heat to the soil by thermal conduction. Contaminants are removed by processes including boiling, evaporation, oxidation, and steam distillation.	1. Effective for PAHs in unsaturated soils.	1. Not effective for saturated soils. 2. Heterogeneous waste may produce uneven treatment. 3. Separate technology would be necessary to address metals.	1. Not widely used technology. Commercial availability is limited. 2. Implementable. 3. Off-gas and condensate treatment would be required. 4. May require additional soil property information (particle size, moisture contents).	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-4. Evaluation of Remedial Technologies for the North Percolation Pond DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Containment	Cover / Cap - Impermeable Membrane	Provides low permeability barrier to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination.	1. Does not remove or degrade contamination within the soil. 2. Restrictions on future land use. 3. Susceptible to settling and erosion. 4. Potential for punctures or tears during placement of cover soil.	1. Widely used, proven, and commercially available technology. 2. More difficult to implement in comparison to the vegetative soil cap construction process option; some conventional and specialty construction.	$$$$	Moderate	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover / Cap - Phytocap	Provides low permeability barrier to prevent contact with the impacted media and has the added benefit of promoting continued degradation of residual PAHs in the soil/sediment.	1. Minimizes potential for direct exposure to contamination. 2. Creates ecological enhancements that would support and sustain indigenous and migratory wildlife species. 3. Vegetation stabilizes the cover and prevents erosion. 4. Facilitates *in situ* PAH biodegradation and metals sequestration in soils. 5. Negative effects of differential settling and cracking are not as great as they are for an impermeable membrane or GCL cap.	1. Does not remove or degrade contamination within the soil/sediment in the near-term. 2. Restrictions on future land use. 3. Effectiveness can be limited during vegetative dormancy periods. 4. Potential translocation of COCs to above-ground plant biomass.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction. 3. Viscous, carbonaceous material may require physical solidification to support a cover.	$$$	Low	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover - Soil Cover	Provides permeable or low permeability soil cover to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination.	1. Does not remove or degrade contamination within the soil/sediment. 2. Restrictions on future land use. 3. Susceptible to settling and erosion.	1. Widely used, proven, and commercially available technology. 2. Implementable; conventional construction. 3. Viscous, carbonaceous material may require physical solidification to support a cover.	$$$	Low	x	Potentially viable process option in combination with institutional controls and/or monitoring.
Removal and Disposal	Excavation - Offsite Disposal	Physical removal of contaminated media with disposal at an offsite disposal facility.	1. Highly accepted and effective technology. 2. Short time frame for results following completion.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction but transport would require long travel distances due to proximity of the Site to disposal outlets. 3. Viscous, carbonaceous material may require physical solidification prior to offsite disposal.	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Excavation - Onsite Consolidation	Physical removal of contaminated media with consolidation and disposal at an onsite repository.	1. Highly accepted and effective technology. 2. Short time frame for results following completion. 3. Minimizes transport and disposal costs.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction. 3. Viscous, carbonaceous material may require physical solidification prior to onsite disposal. 4. Onsite repository(s) would need to meet substantive requirements.	$$$	Low	x	Potentially viable process option as a stand-alone approach or in combination with institutional controls and/or monitoring.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Table 4-5. Evaluation of Remedial Technologies for the River Area DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in the River Area DU soil/sediment: barium and cyanide (total and free)
Note: This technology screening was prepared prior to execution of the Administrative Order on Consent encompassing the Removal Action at the South Percolation Ponds, and as such includes various technologies that would no longer be applicable following successful completion of the Removal Action.

Response Action	Remedial Technology and Process Option	Description	Effectiveness: Advantages	Effectiveness: Disadvantages	Implementability	Capital Cost	O&M Cost	Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
No Action	None	A baseline for comparison among alternatives.	1. Does not disturb benthic organisms or their habitat.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Engineering Controls - Physical Barriers	Prevent access to impacted areas by enclosing contaminated soil/sediment with fences or other physical barriers.	1. May protect some ecological receptors. 2. Does not disturb benthic organisms or their habitat.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Would not protect benthic organisms.	1. Widely used technology. 2. Easily implemented.	$$	Low	Effectiveness	Eliminated from consideration.
	Institutional Controls - Deed Restrictions	Prevent or restrict the future use of the area.	1. Would protects compliant human receptors if there was risk to human health. 2. Does not disturb benthic organisms or their habitat.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors.	1. Widely used technology. 2. Easily implemented.	$	Low	Effectiveness	Eliminated from consideration.
In Situ Treatment	Monitored Natural Attenuation (MNA)	MNA relies on natural mechanisms to reduce concentrations of COCs. Comprehensive long-term monitoring performed to evaluate and verify the progress of MNA.	1. Monitoring will confirm stable or improving conditions, or alert stakeholders if conditions are worsening. 2. Does not disturb benthic organisms or their habitat.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors exposed to impacted media in benthic habitats in the near-term. 3. If conditions change to unstable or increasing then additional response actions may be necessary.	1. Widely used technology. 2. Easily implemented.	$	Low	x	Potentially viable process option as a stand-alone approach or in combination with one or more other technologies.
	Biological Treatment - Phytoremediation	Phytodegradation of cyanide. Phytoextraction of barium.	1. Effective for removing cyanide from shallow soil/sediment as well as from sediment porewater and surface water. 2. Effective for extracting barium from shallow soil/sediment. 3. Vegetation plays a key role in controlling erosion. 4. Green technology.	1. Multi-year time frame before results are obtained (i.e., achievement of PRGs/RAOs). 2. Does not destroy metals. 3. Sensitive to erosive forces and climate.	1. Widely used and proven technology. 2. Difficult to implement in the River Area DU due to steep terrain, tendency to flood, and the potential for the Flathead River to re-capture its historic side channel. Regular maintenance likely required where access is limited. 3. Agronomy data (evaluation of nutrients available to plants in soils) would need to be collected. Phytotoxicity would need to be evaluated.	$$	Low	Implementability	Eliminated from consideration.
Ex Situ Treatment	Chemical Treatment - Chemical Extraction	Separation of contaminants from soil through extraction methods after soil is excavated. Reagent TBD; an acid may be required.	1. Acid extraction process is effective for metals and strong acid dissociable (SAD; total) cyanide.	1. Heterogeneous soil/sediment mixture may produce uneven treatment.	1. Not widely used technology. 2. Not easily implemented; specialty vendor/ contractor and proprietary chemicals are typically required. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical Treatment - Sieving / Physical Separation	Contaminant removal from soils by concentrating them into a smaller volume of soil through particle size separation (i.e., using different size sieves and screens).	1. Effective for metals which tend to bind, either chemically or physically, to the fine (i.e., clay and silt) fraction of soil.	1. Separate technology and/or disposal would be necessary to address fine soil fraction. 2. If coarser material contains contaminant mass, it would still need to be addressed.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Would still require treatment or disposal of the fine soil fraction. 4. May require additional soil property information (particle size distribution, organic content, moisture content, etc.)	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Physical/ Chemical Treatment - Soil Washing	Contaminant removal from soils by dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time).	1. Effective for metals.	1. Separate technology and/or disposal would be necessary to address fine soil fraction. 2. If coarser material contains contaminant mass, it would still need to be addressed.	1. Not widely used in the US. 2. Implementable. 3. Complex waste mixtures would need to be disposed of. 4. May require additional soil property information (particle size distribution, portion coefficients, CEC/AEC, organic content, moisture content, etc.)	$$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-5. Evaluation of Remedial Technologies for the River Area DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Response Action	Remedial Technology and Process Option	Description	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Ex Situ Treatment *cont'd*	Physical/ Chemical Treatment - Solidification/ Stabilization	Solidification encapsulates the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. Stabilization chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.	1. Effective for metals in unsaturated and saturated soils that are a source to groundwater contamination.	1. Heterogeneous soil/sediment mixture may produce uneven treatment.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. Bulking of waste would occur increasing volume of material to be further managed. 4. Surface cover, where none is currently present, would be required after treatment.	$$$$$	None	Not applicable; soil/sediment in the River Area DU is not a source to groundwater contamination.	Eliminated from consideration.
Containment	Cover / Cap - Impermeable Membrane	Provides low permeability barrier to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination.		1. Widely used, proven, and commercially available technology. 2. Difficult to implement in the River Area DU due to steep terrain, tendency to flood, and the potential for the Flathead River to re-capture its historic side channel.	$$$$	Moderate	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover / Cap - Phytocap	Provides low permeability barrier to prevent contact with the impacted media.	1. Minimizes potential for direct exposure to contamination. 2. Vegetation stabilizes the cover and prevents erosion. 3. Facilitates *in situ* metals sequestration in soils/sediments. 4. Negative effects of differential settling and cracking are not as great as they are for an impermeable membrane or GCL cap.	1. Uncertainty of long term stability due to river erosive forces. 2. Does not remove or degrade contamination within the soil/sediment in the near-term. 3. Sensitive to climate. 4. Effectiveness can be limited during vegetative dormancy periods. 5. Potential translocation of COCs to above-ground plant biomass.	1. Widely used, proven, and commercially available technology. 2. Difficult to implement in the River Area DU due to steep terrain, tendency to flood, and the potential for the Flathead River to re-capture its historic side channel.	$$$	Low	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Cover - Soil Cover	Provides permeable soil / sediment cover to prevent contact of benthic organisms with the impacted media.	1. Minimizes potential for direct exposure to contamination. 2. Allow for re-establishment of a benthic community in the clean cover sediments.	1. Uncertainty of long term stability due to river erosive forces. 2. Does not remove or degrade contamination within the soil/sediment.	1. Widely used, proven, and commercially available technology. 2. Difficult to implement in the River Area DU due to steep terrain, tendency to flood, and the potential for the Flathead River to re-capture its historic side channel.	$$$	Low	x	Potentially viable process option as a stand-alone approach or in combination with monitoring.
Removal and Disposal	Excavation - Offsite Disposal	Physical removal of contaminated media with disposal at an offsite disposal facility.	1. Highly accepted and effective technology. 2. Short time frame for results following completion. 3. Allow for re-establishment of a benthic community in the underlying, unimpacted sediments.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction but transport would require long travel distances due to proximity of the Site to disposal outlets. 3. Material removed may require dewatering or amendments prior to offsite disposal.	$$$$	None	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.
	Excavation - Onsite Consolidation	Physical removal of contaminated media with consolidation and disposal at an onsite repository.	1. Highly accepted and effective technology. 2. Short time frame for results following completion. 3. Allow for re-establishment of a benthic community in the underlying, unimpacted sediments. 4. Minimizes transport and disposal costs.	1. Potential exposure during excavation activities.	1. Widely used, proven, and commercially available option. 2. Implementable; conventional construction. 3. Onsite repository(s) would need to meet substantive requirements.	$$$	Low	x	Potentially viable process option as a stand-alone approach or in combination with monitoring.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Table 4-6. Evaluation of Remedial Technologies for the Groundwater DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Summary of COCs in the Groundwater DU: Primarily cyanide and fluoride; arsenic present in localized area near Landfills DU1.

General Response Action	Remedial Technology and Process Option	Description *Process options specific to each COC described in Section 5.6.*	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
No Action	None	A baseline for comparison among alternatives.	NA	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors exposed to surface water impacted by groundwater discharge.	1. Easily implemented technically but has low administrative feasibility.	0	None	x	Required by NCP to be retained as a stand-alone alternative to form a basis for comparison with other alternatives.
Access Restrictions	Institutional Controls - Deed Restrictions	Legal or administrative restrictions to minimize human exposure to impacted groundwater at the Site.	1. Protects compliant human receptors. *Assumes annual monitoring of the groundwater COCs in select wells.*	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors exposed to surface water impacted by groundwater discharge.	1. Administratively and technically feasible to implement. Institutional controls could be implemented in layers to enhance remedy. 2. Widely used technology. 3. Easily implemented.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
	Engineering Controls - Alternate Water Supply	Establish private distribution of bottled water supply for onsite potable water requirements.	1. Prevent human exposure to impacted groundwater by providing site personnel with bottled water for short-term potable water needs. *Assumes annual monitoring of the groundwater COCs in select wells.*	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors exposed to surface water impacted by groundwater discharge. 3. Does not prevent contaminant plume migration or reduce contamination.	1. Administratively and technically feasible to implement for short term water contingency. 2. Easily implemented. 3. Long term water contingency may be expensive.	$$	Moderate	Bottled water is currently used to provide potable water to the Site, and CFAC intends to continue providing such to meet its needs. In the event of future redevelopment of the Site, an alternate water supply for the Site may needed. However, such alternative water supply would be best evaluated as part of the redevelopment process.	Eliminated from consideration.
In Situ Treatment	Monitored Natural Attenuation (MNA)	MNA relies on natural mechanisms to reduce concentrations of COCs. Comprehensive long-term groundwater monitoring would be implemented to evaluate and verify the progress of MNA.	1. Monitoring will confirm stable or improving conditions, or alert stakeholders if conditions are worsening.	1. Does not reduce the mobility, toxicity, or volume of impacted media in the near-term. 2. Does not protect ecological receptors exposed to surface water impacted by groundwater discharge in the near-term. 3. If conditions change to unstable or increasing then additional response actions may be necessary. 4. Does not address the ongoing contamination of groundwater by the source area.	1. Widely used technology. 2. Easily implemented. 3. The use of MNA requires more thorough monitoring than other remedies; typically must be used in conjunction with source control, and a clear understanding of the fate and transport of the COCs at the site is required.	$	Low	x	Potentially viable process option in combination with one or more other technologies.
	Chemical Treatment - Permeable Reactive Barriers (PRBs)	PRBs are passive below-grade walls containing an engineered treatment zone with chemically active material that reacts with groundwater contaminants as they pass through the permeable barrier.	1. Calcite PRBs effective in capturing fluoride from SPL-impacted groundwater (Landfills DU1) 2. Iron and sand PRBs potentially effective in arresting migration of cyanide plumes in the subsurface (Landfills DU1, River Area DU) 3. Pilot scale and lab scale studies implemented at Hydro Aluminum smelter in Australia using different types of reactive barriers were successful for fluoride and cyanide removal from SPL-impacted groundwater.	1. Requires sequential or multiple PRB treatment trains with multiple types of reactive media to achieve cyanide and fluoride removal at the source area landfills. 2. All or portions of the PRB would likely need to be installed as a "hanging" wall, which is less effective than a PRB that is keyed into an aquitard. 3. Barrier may lose effectiveness over time. 4. May have technical uncertainties associated with the chemically active treatment zone. 5. Does not address the ongoing contamination of groundwater by the source area.	1. Widely used, proven, and commercially available technology. 2. Implementable in areas that are not capped or covered by a building. Treating an area upgradient of a target area can beneficially impact the target area (e.g., groundwater seeps). 3. Geochemical and groundwater modeling may be required for design of barrier wall type and thickness.	$$$	High	x	Potentially viable process option in combination with one or more other technologies.
	Chemical Treatment - Chemical Oxidation	*In situ* chemical oxidation (ISCO) injects oxidizing agents, such as ozone or hydrogen peroxide, that react with contaminants to form innocuous end products.	1. Effective for treating cyanide (high percent removal for all species). 2. Complete destruction of cyanide to nitrogen gas and bicarbonate. 3. May enhance long-term bioremediation.	1. Not effective for fluoride removal. 2. Potential for mobilization of metals (e.g., arsenic (if present as a sulfide), chromium, and copper from alkaline-activated persulfate; chromium, copper, nickel, and zinc from iron-activated hydrogen peroxide and sodium persulfate). 3. Does not address the ongoing contamination of groundwater by the source area.	1. Widely used, proven, and commercially available technology. 2. Implementable in areas that are not capped or covered by a building. Treating an area upgradient of a target area can beneficially impact the target area (e.g., groundwater seeps). 3. The large area and depth of contamination would require a highly concentrated grid of multi-depth injection points. 4. Would likely require multiple injection rounds. 5. Organics in soil can greatly increase the oxidant demand.	$$$	High	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-6. Evaluation of Remedial Technologies for the Groundwater DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

General Response Action	Remedial Technology and Process Option	Description *Process options specific to each COC described in Section 5.6.*	Effectiveness: Advantages	Effectiveness: Disadvantages	Implementability	Cost: Capital Cost	Cost: O&M Cost	Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
In Situ Treatment *cont'd*	Biological Treatment - Enhanced Bioremediation	Enhanced bioremediation manipulates *in situ* conditions to accelerate natural biological processes to degrade contaminants or produce byproducts which remove contaminants via redox reactions.	1. Effective for treating cyanide (moderate percent removal for all species). 2. Long-term treatment.	1. Not effective for fluoride removal. 2. Inhibitory compounds (e.g., high cyanide concentrations) or complex conditions (e.g., low pH) may be present or created, which would prevent biological activity and degradation. Reducing conditions may also potentially mobilize metals (e.g., arsenic). 3. Does not address the ongoing contamination of groundwater by the source area.	1. Widely used, proven, and commercially available technology. 2. Implementable in areas that are not capped or covered by a building. Treating an area upgradient of a target area can beneficially impact the target area (e.g., groundwater seeps).	$	Low	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration as a stand-alone approach.
Ex Situ Treatment (Pump and Treat)	Physical/Chemical Treatment - Adsorption	In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase.	1. Effective for treating cyanide using granular activated carbon (GAC). 2. Effective for treating fluoride and arsenic using activated alumina. 3. Concentrations are reduced dramatically and quickly.	1. Different media required for different COCs.	1. Widely used, proven, and commercially available technology. 2. Implementable. 3. May require pretreatment depending on groundwater quality and pH. 4. Spent media has to be replaced (and disposed of) or regenerated. 5. May require pH adjustment post-treatment. 6. Depending on capacity, a large footprint for the system housing and storage of spent and new media would be required.	$$$	High	x	Potentially viable process option in combination with extraction.
	Physical/ Chemical Treatment - Coagulation/ Flocculation/ Precipitation (Treatment of Cyanide)	The presence of excess dissolved iron and/or reduction in pH precipitates iron cyanide solids which can be disposed of as a solid.	1. Effective for cyanide removal. 2. Reliable processes. 3. Coprecipitation/adsorption of arsenic likely.	1. Not effective for fluoride removal.	1. Widely used, proven, and commercially available technology. 2. Implementable. Depending on capacity, a large footprint for the treatment plant will be required. 3. Byproduct of hydroxide precipitates will need to be managed. 4. Geochemical modeling may be required for design of treatment train.	$$$	V. High	x	Potentially viable process option in combination with fluoride treatment and extraction.
	Physical/ Chemical Treatment - Coagulation/ Flocculation/ Precipitation (Treatment of Fluoride)	Excess calcium salts are added to extracted groundwater to precipitate out fluoride, which could then be removed after coagulation and settling or through sand filtration.	1. Effective for treating fluoride. 2. Sludge produced does not contain cyanides. 3. Coprecipitation/adsorption of arsenic likely.	1. Cyanide removal must be achieved as a separate treatment before fluoride precipitation.	1. Widely used, proven, and commercially available technology. 2. Implementable. Depending on capacity, a large footprint for the treatment plant will be required. 3. System requires regular maintenance and a trained operator. 4. Requires dewatering and disposal of sludge and other byproducts of treatment. 5. Geochemical modeling may be required for design of treatment train.	$$$	High	x	Potentially viable process option in combination with cyanide treatment and extraction.
	Chemical Treatment - Ion Exchange	Ion exchange column uses an anion exchange resin in which ions held electrostatically on the surface are exchanged with ions of similar charge in solution.	1. Effective for treating ferrocyanide, fluoride, and arsenic. 2. Resistant to organic fouling.	1. Not effective for free cyanide or thiocyanate forms of cyanide. 2. Presence of competing anions may result in inefficient removal of contaminants.	1. Not widely used technology. 2. Implementable with a specialty vendor/ contractor; proprietary chemicals are typically required. 3. Spent resin filter media has to be replaced (and disposed of) or regenerated often; regeneration of the resin is quick and efficient. 4. Depending on capacity, a large footprint for the equipment would be required as treatment of cyanide and fluoride would require separate resin columns.	$$$$	V. High	x	Potentially viable process option in combination with extraction.
	Chemical Treatment - Alkaline Hydrolysis	Under alkaline conditions at elevated temperatures and pressures, iron cyanide complexes can be hydrolyzed to form ammonia, formate, and ferric oxide.	1. Effective for cyanide removal. 2. Reliable processes.	1. Not effective for fluoride removal. 2. Certain degree of health and safety risk due to high temperature and high pressure.	1. Well developed technology for cyanide removal from industrial wastes and SPL leachates. 2. Implementable with careful handling of chemicals.	$$$$	V. High	Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration as this process option is associated with high degree of risk.

Table 4-6. Evaluation of Remedial Technologies for the Groundwater DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

General Response Action	Remedial Technology and Process Option	Description *Process options specific to each COC described in Section 5.6.*	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Ex Situ Treatment (Pump and Treat) *cont'd*	Physical Treatment - Reverse Osmosis	Reverse osmosis applies a pressure gradient to a semipermeable membrane to inhibit the passage of charged particles while allowing water to pass. COCs would be separated into a waste brine stream.	1. Effective for treating cyanide, fluoride, and arsenic (high percent removal for all species).	1. Does not reduce the toxicity or mass of contamination.	1. Well established and commercially available technology. 2. Implementable. Could require a large footprint for the filter housing and storage of spent and new filters. 3. Concentrated COCs in waste brine would require further treatment or disposal. 4. Membranes require careful maintenance to control fouling. 5. High operating costs	$$$$	V. High	x	Potentially viable process option in combination with extraction.
	Physical Treatment - Electrocoagulation	Electrocoagulation is a method of applying direct current to sacrificial electrodes to form solid aluminum-fluoride-hydroxide flocs, which can then be separated via coagulation and settling.	1. Effective for treating fluoride. 2. Concentrations are reduced dramatically and quickly.	1. Not effective for cyanide removal.	1. Recently developed as an alternative process for defluoridation for drinking water industry. 2. The technology is implementable based on the success of laboratory and pilot scale tests for similar projects. 3. Generation of fluoride-bearing aluminum hydroxide waste sludge which would need to be disposed of. 4. Less precipitant formation compared to chemical treatment.	$$$	High	x	Potentially viable process option in combination with cyanide treatment and extraction.
	Photochemical Treatment - Photolysis	Photolysis is a process which uses sunlight or UV light to dissociate iron cyanide into free cyanide.	1. Effective for converting ferrocyanide complexes to free cyanide. 2. Reliable processes. 3. Successful pilot testing at Alcoa's Tennessee site and Kaiser Mead NPL site.	1. Not effective for fluoride removal. 2. Not a stand-alone remedy; cyanide complexes converted to free cyanide which requires removal in subsequent step such as aeration and/or biological treatment. 3. Effectiveness dependent on duration of exposure to sunlight or UV light.	1. Well developed, but not widely used, technology. 2. Implementable.	$$	Moderate	x	Potentially viable process option in combination with extraction and subsequent treatment for free cyanide.
	Biological Treatment - Constructed Wetlands	Constructed wetlands recreate natural wetland processes to treat a relatively constant flow of water. Wetlands combine photolysis and biodegradation for cyanide treatment and could adsorb fluoride and arsenic with activated alumina.	1. Effective for treating cyanide (moderate percent removal for all species). 2. Could be effective for treating fluoride and arsenic with addition of activated alumina. 3. The technology has been effective based on the success of laboratory pilot scale tests for similar sites, such as that conducted at Kaiser Mead.	1. Reduced effectiveness in the winter.	1. Well developed, but not widely used, technology. 2. Implementable, but operations are sensitive to changes in environmental conditions. 3. Economical alternative to conventional wastewater treatment systems. 3. Requires a large footprint to achieve necessary residence times (e.g., 3 to 7 days); sufficient land available onsite for low to moderate flow rates (e.g., 25 to 100 gpm over 2 to 6 acres). 4. Adsorption to wetlands media may result in soils that need to be treated/removed. 5. The technology is implementable based on the success of laboratory pilot scale tests for similar sites, such as that conducted at Kaiser Mead.	$$	Moderate	x	Potentially viable process option in combination with extraction.
Containment	Hydraulic control- Extraction Wells	Series of extraction wells which create a capture zone to provide hydraulic control of groundwater to contain the contaminant plume.	1. Capture zone minimizes migration of impacted groundwater, preventing discharge to the Seep Area and protecting ecological receptors in the River Area DU. 2. Capable of limiting plume mitigation within its current boundary. 3. Particularly useful where physical barriers are impractical.	1. Does not reduce the toxicity or mass of contamination in the near-term. 2. Not a stand-alone remedy. 3. Complex groundwater flow patterns andhigh hydaulic conductivities may make hydraulic control difficult, limiting its effectiveness.	1. Technically feasible and well established technology 2. Implementable; conventional construction. 3. Must be combined with an *ex situ* treatment method which allows for disposal onsite; otherwise offsite disposal will be required. 4. High hydraulic conductivities at the Site may mean high pumping rates and closely spaced wells to achieve hydraulic containment. 5. If implemented without physical barriers, higher pumping rates would be required to achieve hydraulic containment. 6. If extraction wells are located near the Flathead River, pumping rates would require careful control to minimize extraction of river water.	$$$	High	x	Potentially viable process option as a focused containment response action in combination with one or more *Ex Situ* Treatment technologies.

Table 4-6. Evaluation of Remedial Technologies for the Groundwater DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

General Response Action	Remedial Technology and Process Option	Description *Process options specific to each COC described in Section 5.6.*	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Containment *cont'd*	Vertical barriers- Slurry Walls	Slurry walls are vertically excavated trenches filled with low-permeability material (soil, bentonite, and water mixture) which work to contain contaminated groundwater.	1. Isolates the plume from contaminant source areas. 2. Prevents or minimizes the flux of contaminant mass off the source. 3. Containment zone minimizes migration of impacted groundwater, preventing discharge to the Seep Area and protecting ecological receptors in the River Area DU. 4. The soil-bentonite slurry wall would be compatible with the groundwater COCs and would not be subject to significant degradation.	1. Does not reduce the toxicity or mass of contamination in the near-term. 2. Near the River Area DU, groundwater would likely short-circuit the barrier due to the absence of an aquitard within practical depth of slurry wall installation.	1. Widely used, proven, and commercially available technology. 2. Implementable using clamshell bucket excavation and/or hydromill technologies at depths greater than 80 ft, but cost of wall increases by about a factor of three. The presence of cobbles and/or boulders would require rock breaking tools. Quality control required for implementation. 3. Near Landfills DU1, slurry walls could be keyed into the lower permeability zone found at the top of the below upper hydrogeologic unit (i.e., the glacial till) that serves as an aquitard at the Site or installed as a "hanging" wall that does not rely on being keyed into an impermeable soil layer. 4. Groundwater may need to be extracted from behind the slurry wall to achieve an inward gradient.	$$$$	V. High	x	Potentially viable process option as a stand-alone approach or in combination with one or more other technologies near the Landfills DU1. May require groundwater extraction wells to maintain an inward gradient.
	Vertical Barriers- Grout curtains	By drilling and grouting successive intervals of vertical holes, grout curtains can impede groundwater flow through a continuous thick zone of grouted soil.	1. Isolates the plume from contaminant source areas. 2. Prevents or minimizes the flux of contaminant mass off the source. 3. Containment zone minimizes migration of impacted groundwater, preventing discharge to the Seep Area and protecting ecological receptors in the River Area DU. 4. Able to inject grout through relatively small diameter drill holes at unlimited depths.	1. Does not reduce the toxicity or mass of contamination in the near-term. 2. Uncertainty that complete cutoff is attained.	1. Technically feasible and well established technology. 2. Typically used for shorter length applications; the number of injection points required to achieve the necessary length required for groundwater containment at this Site will be very difficult to install effectively. 3. Groundwater may need to be extracted from behind the grout curtain to achieve an inward gradient.	$$$$	V. High	Effectiveness; Implementability	Eliminated from consideration.
	Vertical Barriers - Sheet Piling	Sheet piles create a physical barrier to groundwater flow by driving interlocked sheets with a vibratory driver.	1. Reduces the flux of contaminant mass off the source.	1. Does not reduce the toxicity or mass of contamination in the near-term. 2. Limited effectiveness at the Site where groundwater contamination greatly exceeds the practical limits of driving sheet piles into the aquifer.	1. Widely used, proven, and commercially available technology. 2. Difficult to implement at the Site where COC concentrations are present at depths that greatly exceed the practical limits of driving sheet piles into the aquifer. 3. Groundwater may need to be extracted from behind the sheet piling to achieve an inward gradient.	$$$$	V. High	Effectiveness; Implementability	Eliminated from consideration.
Groundwater Discharge/ Disposal	Discharge to Surface Water	Treated groundwater would be discharged to the Flathead River immediately south of the Site.	1. Highly accepted and effective technology.	NA	1. Technically and administratively feasible. 2. Implementable; groundwater must be treated to achieve surface water standards before discharge or, if permitted, within mixing zone. 3. Reporting may be more rigorous than other discharge options. 4. Avoids costly disposal fees for recovered water. 5. Standard filtration technologies may not achieve objectives for removal of total suspended solids and turbidity.	$$	Moderate	Implementability	Eliminated from consideration.
	Discharge to Municipal Wastewater Treatment Plant	Extracted groundwater can be treated onsite or discharged untreated to the Columbia Falls WWTP.	1. Highly accepted and effective technology.	NA	1. Difficult to implement at the Site; travel distances to facilities are prohibitive. 2. Local WWTP may not have necessary capacity for influent/concentration loadings. 3. Likely required installation of new pump station along with force main to sanitary sewer. 4. Discharge approval permits have to be obtained. 5. Less stringent discharge standards than other discharge options; primary treatment such as settling may still be required to meet sewer permit requirements.	$$$$	V. High	Implementability	Eliminated from consideration.
	Aquifer Recharge via Injection wells	Treated groundwater can be reinjected into the aquifer via upgradient injection wells.	1. Highly accepted and effective technology.	1. Well clogging could reduce effectiveness over time.	1. Technically and administratively feasible. 2. Implementable; groundwater must be treated to achieve groundwater standards before discharging to subsurface. Maintenance required. 3. Avoids costly disposal fees for recovered water.	$$$	High	Implementability; Similar or greater effectiveness available via other process option(s) at similar or lesser cost	Eliminated from consideration.

Table 4-6. Evaluation of Remedial Technologies for the Groundwater DU
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

General Response Action	Remedial Technology and Process Option	Description *Process options specific to each COC described in Section 5.6.*	Effectiveness		Implementability	Cost		Retainment of Process Option (x) or Elimination with Rationale	Process Option Viability and Applicability for Remedial Alternatives
			Advantages	Disadvantages		Capital Cost	O&M Cost		
Groundwater Discharge/ Disposal *cont'd*	Aquifer Recharge via Infiltration Basins	Treated groundwater can be reinjected into the aquifer via upgradient infiltration basins backfilled with coarse stone aggregate.	1. Highly accepted and effective technology.	NA	1. Technically and administratively feasible. 2. Implementable; groundwater must be treated to achieve groundwater standards before discharging to subsurface. Conventional construction and minimal maintenance. 3. Avoids costly disposal fees for recovered water. 4. Would require significant land area unusable for development.	$$	Moderate	x	Potentially viable process option in combination with one or more *Ex Situ* Treatment technologies.

Note: DU - Decision Unit. Refer to Section 2.3 of the FS Report for detailed descriptions of each DU.

Alternative LDU1/GW-1: No Action

Description of Alternative:

- Maintenance of the existing caps on the West Landfill, Wet Scrubber Sludge Pond, and Center Landfill;
- Maintenance of the existing fence preventing access to these waste management units; and
- No additional actions.

This alternative is described in Section 5.1.1.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	Contaminants would remain in place. The direct contact exposure route, including exposure to small range receptors, would remain complete.	Contaminants in groundwater would continue to migrate downgradient and cyanide would continue to be expressed in the River Area DU. As such, the direct contact exposure route to ecological receptors would remain complete.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	There are no chemical-specific ARARs for soil.	Chemical-specific ARARs for COCs groundwater (i.e., arsenic, cyanide, fluoride) would not be met.
Compliance with Action-Specific ARARs		
	No action would be taken and therefore, there are no action-specific ARARs.	No action would be taken and therefore, there are no action-specific ARARs.
Compliance with Location-Specific ARARs		
	No location-specific ARARs have been identified for this alternative.	No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	Potential risks would not be managed.	Potential risks would not be managed.
Adequacy and Reliability of Controls		
	Existing caps on the waste management units would be maintained. Additional controls would not be in place.	Controls would not be in place.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	No treatment used.	No treatment used.
Amount of Hazardous Materials Destroyed or Treated		
	No reduction in amount of hazardous materials.	No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	No change to the toxicity, mobility and volume of contaminants.	Degree of reduction in toxicity, mobility, and volume of contaminants via natural attenuation is expected to be low.
Degree to Which Treatment is Irreversible		
	NA; no treatment used.	NA; no treatment used.
Type and Quantity of Residuals Remaining After Treatment		
	NA; no treatment used.	NA; no treatment used.
Statutory Preference for Treatment		
	Would not meet preference for treatment as a principal element of remediation.	Would not meet preference for treatment as a principal element of remediation.
Short-Term Effectiveness		
Protection of Community During Remedial Actions		
	No remedial action performed.	No remedial action performed.

Protection of Workers During Remedial Actions		
	No remedial action performed.	No remedial action performed.
Environmental Impacts During Remedial Actions		
	No remedial action performed.	No remedial action performed.
Time Until RAOs are Achieved		
	RAOs would not be achieved.	RAOs would not be achieved.
	Implementability	
Technical Feasibility		
	Feasible; no actions would be taken.	Feasible; no actions would be taken.
Administrative Feasibility		
	Feasible; no actions would be taken.	Feasible; no actions would be taken.
Availability of Services and Materials		
	No services or materials required.	No services or materials required.
	Cost	
*Total Present Worth Cost**		
$ 769,050	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation

Description of Alternative:

- Containment of source area waste management units via capping;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.2.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The existing cap on the West Landfill and new caps on the WSSP and Center Landfill would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to prevent/reduce leaching of COCs to groundwater. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The caps over all source area WMUs would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and prevent/reduce leaching of COCs to groundwater. • While in the absence of a continuing source of contamination MNA would reduce concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU, this alternative does not include any additional source control measures to address underlying soils beneath the West Landfill that are likely contributing to groundwater contamination, nor does it address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. In the absence of additional source control measures under this alternative, it is unlikely that MNA would reduce concentrations of COCs to ARAR levels in a reasonable time. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	With caps over all source area WMUs to prevent/reduce leaching of COCs to groundwater, and in the absence of a continuing source of contamination, MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU. However, as described under the short-term effectiveness criterion for this alternative, capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor would it address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, in the absence of additional source control measures under this alternative, it is unlikely that MNA would reduce concentrations of COCs to ARAR levels in a reasonable time.
Compliance with Action-Specific ARARs		
	The new caps over the WSSP and Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps.	The groundwater component of this alternative is not anticipated to trigger any action-specific ARARs.
Compliance with Location-Specific ARARs		

	No location-specific ARARs have been identified for this alternative.	No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	• The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to reduce the leaching of COCs from the WMUs. • Impacted materials would remain in place, untreated, beneath the caps. Alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1.	• The magnitude of residual risk following successful completion of the MNA program would be less than target risk levels set by Montana DEQ-7 standards. However, as described under the short-term effectiveness criterion for this alternative, capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor would it address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, in the absence of additional source control measures under this alternative, it is unlikely that MNA would reduce concentrations of COCs to ARAR levels in a reasonable time.
Adequacy and Reliability of Controls		
	• The caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The potential presence of impacted materials beneath the seasonal high-water table could significantly reduce the adequacy of the caps as source control measures, most specifically at the West Landfill. • Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long-term effectiveness and permanence.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate progress towards achieving RAOs. • ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	No treatment used.	No treatment used.
Amount of Hazardous Materials Destroyed or Treated		
	No reduction in amount of hazardous materials within the source area WMUs.	Capping of the source area WMUs would result in some reduction of contaminant concentrations and mass downgradient.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	The mobility of COCs from within the WMUs would be reduced due to elimination of infiltration from precipitation and runoff. The mobility of COCs from impacted underlying soils beneath the water table or from any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table would remain unchanged. The toxicity and volume of waste in the WMUs would remain unchanged.	Due to the limited source control measures to address a continuing source of contamination, there would be only be a limited reduction in concentrations of COCs in groundwater and surface water, and therefore only a limited reduction in the toxicity of contaminated groundwater and surface water over time.
Degree to Which Treatment is Irreversible		
	NA; no treatment used.	NA; no treatment used.
Type and Quantity of Residuals Remaining After Treatment		
	NA; no treatment used.	NA; no treatment used.
Statutory Preference for Treatment		
	Would not meet preference for treatment as a principal element of remediation.	Would not meet preference for treatment as a principal element of remediation.
Short-Term Effectiveness		
Protection of Community During Remedial Actions		
	• The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs; consequently, no impacts to community are anticipated during onsite cap construction and maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Capping would likely require the import of fill/grading materials which would increase truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate that the extent of groundwater contamination is not expanding or threatening community water supply wells. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater.

Protection of Workers During Remedial Actions		
	• Minimal potential exposure risk to workers during construction activities as wastes would not be excavated. • Construction risks during installation of the cap would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.	• Potential physical and exposure hazards to workers during installation of additional monitoring wells (if needed) and sampling is limited. Risks would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	• Minimal potential risks to the environment during cap construction assuming implementation of adequate erosion controls.	• No short-term impacts to the environment are anticipated during groundwater sampling activities under the MNA program.
Time Until RAOs are Achieved		
	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cap construction and establishment of ICs, which are estimated to be completed within 3 years.	• The RAO to prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards would be met immediately following establishment of ICs, which is estimated to be completed within 1 year. • The RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met 14 to 26 years following elimination or full containment of the source. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination or full containment of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties. • Capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, under this alternative, elimination or full containment of the source is not anticipated and attainment of RAOs under this alternative would be expected to take much longer than the timeframes outlined above.
	Implementability	
Technical Feasibility		
	Capping is an established technology that has been proven effective and reliable for containment; would not require treatability/ pilot studies. However, as a stand-alone containment technology (as proposed in this alternative), a detailed pre-design investigation would be required to demonstrate significant source material does not exist beneath the seasonal high-water table.	MNA is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated the MNA component of this alternative.
Administrative Feasibility		
	All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Development of offsite borrow source(s) for fill/grading materials would require coordination and approval from the affected agency.	Administratively feasible to implement ICs such as deed restrictions on future land use and a Controlled Ground Water Area designation for groundwater within the plume extent. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	Necessary engineering services and contractor services readily available for cap design, installation, and maintenance. Low permeability soils for cap materials may require import from distant / out-of-state locations.	Necessary engineering services and materials readily available for installation of additional monitoring wells (if needed) and maintenance of existing monitoring well network.
	Cost	
*Total Present Worth Cost**		
$ 14,182,613	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.3.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The existing cap on the West Landfill and new caps on the WSSP and Center Landfill would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and the upgradient slurry wall would divert clean groundwater around impacted underlying soils beneath the water table that are likely contributing to groundwater contamination and address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Together, this alternative would provide containment of impacted materials within the WMUs to reduce leaching of COCs to groundwater. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The caps over all source area WMUs would prevent the infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and prevent/reduce leaching of COCs to groundwater. • The upgradient slurry wall would divert clean groundwater around the West Landfill and WSSP, including groundwater both above and below the fluctuating water table. In conjunction with the caps over all source area WMUs, contact of water with impacted materials (including materials beneath the water table) would be reduced. This would reduce leaching of COCs to groundwater and the associated mass flux of contamination from beneath the WMUs, which in turn would improve the effectiveness of MNA in reducing concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	• There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	• With caps over all source area WMUs and an upgradient slurry wall to reduce leaching of COCs, MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU.
Compliance with Action-Specific ARARs		
	• The new caps over the WSSP and Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps. • Slurry wall construction activities would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling; and stormwater/erosion controls.	• Action-specific ARARs triggered by the slurry wall component of this alternative are addressed under the Landfills DU1 evaluation. • The other groundwater components of this alternative are not anticipated to trigger any action-specific ARARs.
Compliance with Location-Specific ARARs		
	• No location-specific ARARs have been identified for this alternative.	• No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		

Magnitude of Residual Risk		
	• The upgradient slurry wall in conjunction with the caps would reduce the leaching of COCs from the WMUs. • Impacted materials would remain in place, untreated, beneath the caps. Alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1.	• The magnitude of residual risk following successful completion of the MNA program would be less than target risk levels set by Montana DEQ-7 standards.
Adequacy and Reliability of Controls		
	• The caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The potential presence of impacted materials beneath the seasonal high-water table would be addressed by the upgradient slurry wall by diverting clean groundwater around the West Landfill and WSSP. The degree of containment would be impacted by the ability to key the slurry wall into the low permeability glacial till unit at the Site. Based on the COCs in groundwater at the Site and their concentrations, the slurry wall is expected to have long-term effectiveness and permanence; pre-design bench testing would be required to verify wall compatibility with COCs in groundwater. • Expected to provide long-term effectiveness as documented in numerous studies and evaluations including reports from dozens of USEPA Superfund sites and many large-scale civil infrastructure projects; see USEPA, 1998 and National Research Council, 2007. Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long-term effectiveness and permanence.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate progress towards achieving RAOs. • ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
	Reduction of Toxicity, Mobility, and Volume through Treatment	
Treatment Process Used and Materials Treated		
	No treatment used.	No treatment used.
Amount of Hazardous Materials Destroyed or Treated		
	No reduction in amount of hazardous materials within the source area WMUs.	Upgradient slurry wall and capping of the source area WMUs would result in some reduction of contaminant concentrations and mass downgradient.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	The mobility of COCs from within the WMUs would be reduced due to elimination of infiltration from precipitation and runoff as well as reduced groundwater flow through the WMU footprints. The toxicity and volume of waste in the WMUs would remain unchanged.	The reduction in concentrations of COCs in groundwater and, subsequently, surface water in the River Area DU resulting from improved containment via the upgradient slurry wall, capping, and MNA would reduce the toxicity of contaminated groundwater and surface water over time. While attainment of RAOs would take a prolonged period, it is expected that measurable reductions in contaminant mass flux and COC concentrations would be observed immediately following completion of the slurry wall construction.
Degree to Which Treatment is Irreversible		
	NA; no treatment used.	NA; no treatment used.
Type and Quantity of Residuals Remaining After Treatment		
	NA; no treatment used.	NA; no treatment used.
Statutory Preference for Treatment		
	Would not meet preference for treatment as a principal element of remediation.	Would not meet preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	• The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs; consequently, no impacts to community are anticipated during onsite cap and	• Routine sampling and analysis of groundwater under the MNA program would demonstrate that the extent of groundwater contamination is not expanding or threatening community water supply wells.

	slurry wall construction and maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Capping and slurry wall construction would require the import of fill/grading and slurry materials which would increase truck traffic through the community and pose associated hazards. Approximately 80 to 90% of excavated soils would be reused in the slurry wall, minimizing the need for disposal. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.	• ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater.
Protection of Workers During Remedial Actions		
	• Minimal potential exposure risk to workers during construction activities as wastes would not be excavated (i.e., slurry wall would be outside of waste limits); however, soil and groundwater beneath the water table would contain COCs. • Construction risks during cap and slurry wall construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.	• Potential physical and exposure hazards to workers during installation of additional monitoring wells (if needed) and sampling is limited. Risks would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	• Minimal potential risks to the environment during cap and slurry wall construction assuming implementation of adequate erosion controls. • Moderate environmental impacts (i.e., air emissions and material consumption) during slurry wall construction affecting the sustainability consideration of this alternative. No additional environmental impacts over the lifetime of this alternative.	• No short-term impacts to the environment are anticipated during groundwater sampling activities under the MNA program.
Time Until RAOs are Achieved		
	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following design and construction of the cap and slurry wall in addition to establishment of ICs, which are estimated to be completed within 4 years.	• The RAO to prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards would be met immediately following establishment of ICs, which is estimated to be completed within 1 year. • The RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met 14 to 26 years following elimination or full containment of the source. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination or full containment of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties. • The upgradient slurry wall would likely not achieve full containment of the source; therefore, attainment of groundwater and River Area DU RAOs under this alternative would be expected to take the upper end of the range or longer.
	Implementability	
Technical Feasibility		
	• Capping is an established technology that has been proven effective and reliable for containment; would not require treatability/ pilot studies. • Slurry walls are an established and proven technology, with effective installation to depths of 150 ft and greater reported by contractors. Achieving depths greater than 100 ft would require clamshell bucket excavation and/or hydromill technologies. The presence of cobbles / boulders would require rock breaking tools. • Would require pre-design investigation to ascertain detailed geotechnical data along the proposed alignment. If keying into the low permeability glacial till unit would not be feasible, groundwater modeling may be needed to evaluate effectiveness of various hanging wall depths.	• Technical feasibility of slurry wall construction for this alternative is addressed under the Landfills DU1 evaluation. • MNA is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated with the MNA component of this alternative.
Administrative Feasibility		
	• All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow	• Administratively feasible to implement ICs such as deed restrictions on future land use and a Controlled Ground Water Area designation for groundwater

	source(s) for fill/grading materials would require coordination and approval from the affected agency.	within the plume extent. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	• Necessary engineering services and contractor services readily available for cap design, installation, and maintenance. • Slurry wall construction to contemplated depths would require specialty contractor services that are available but would require advanced arrangements, likely with long lead times. • Low permeability soils for cap and slurry wall materials may require import from distant / out-of-state locations.	• Necessary engineering services and materials readily available for installation of additional monitoring wells (if needed) and maintenance of existing monitoring well network.
Cost		
*Total Present Worth Cost**		
$ 27,716,290	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.4.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The downgradient PRB would provide cyanide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations of cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The downgradient PRB would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A.
Compliance with Location-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The PRB would have a finite period of effectiveness; once the reactive media is consumed the PRB would no longer intercept cyanide if present in groundwater prior to surface water discharge in the River Area DU. The design basis for the PRB would be 30 years. However, the long-term effectiveness would be compromised if design life goal is not achieved, or if the source control and MNA components of this alternative take longer than 30 years. Under such circumstances, replacement of media within the PRB or construction of a new PRB, would be needed to maintain the effectiveness the remedy.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • ZVI and sand mixture in the PRB would reduce concentrations of cyanide in groundwater primarily through precipitation prior to surface water discharge in the River Area DU.
Amount of Hazardous Materials Destroyed or Treated		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition:

		• The PRB would be expected to treat approximately 71 kg of cyanide in the first year following installation. Removal rates would decrease in subsequent years as upgradient cyanide concentrations decrease and as the reactive media is expended.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The removal of cyanide from groundwater as it flows through the PRB would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Cyanide would be removed from groundwater primarily through precipitation; this removal would be permanent as, under natural conditions, the cyanide would not be expected to dissolve back into the groundwater. However, bench testing would be required to confirm the degree to which the treatment is irreversible.
Type and Quantity of Residuals Remaining After Treatment		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Approximately 35,000 CY of spent reactive media which would contain the precipitated and adsorbed cyanide would remain in place within the PRB at the conclusion of the remedy.
Statutory Preference for Treatment		
	See evaluation for Alternative LDU1/GW-3A.	Would satisfy preference for treatment as a principal element of remediation.
Short-Term Effectiveness		
Protection of Community During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The property line is located approximately 3,000 or more ft away from the location of the PRB; consequently, no impacts to community are anticipated during PRB construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • PRB construction would require the import of the ZVI and sand mixture components which would increase truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.
Protection of Workers During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Minimal potential exposure risk to workers as wastes would not be excavated (i.e., PRB outside of waste limits); however, soil and groundwater beneath the water table would contain COCs. Construction risks during PRB construction, including inhalation of ZVI granular materials, would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	Moderate environmental impacts (i.e., air emissions) to transport spoils from PRB construction trenching to onsite repository, adversely affecting the sustainability consideration of this alternative. No additional environmental impacts over the lifetime of this alternative.
Time Until RAOs are Achieved		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The PRB would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and installation of the PRB is estimated to require 4 years to complete; the PRB would be installed after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following completion of the PRB.
Implementability		
Technical Feasibility		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: Use of PRBs for groundwater remediation is an established technology. However, several site-specific factors affect the feasibility evaluation at the Site as summarized below: • Bench scale studies at other sites indicate PRB media can effectively remove cyanide. However, full-scale projects demonstrating the effectiveness of PRBs for cyanide were not encountered in review of the published

		literature. As a result, extensive bench-scale studies would be needed to confirm treatability, determine the optimal reactive media mix, and confirm adequate life expectancy of the PRB (i.e., permanence of the removal process). • The contemplated depth of the PRB (130 ft) would complicate the feasibility of trench excavation and media placement. While experienced slurry wall/PRB construction contractors indicate such depth is feasible, the target depth is greater than any applications reviewed in the published literature (which are typically less than 75 feet). The presence of coarse-grained material at depth (e.g., cobbles / boulders) would further complicate installation. • As a hanging wall PRB, permeability of the PRB would need to be confirmed to ensure it is comparable to that of the surrounding formation to prevent diversion of contaminated groundwater beneath or around the PRB. Pre-design investigations would be required to ascertain detailed geotechnical data along proposed alignment.
Administrative Feasibility		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • PRB construction activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Construction of PRB to contemplated depths is not considered standard industry practice and would require specialty contractor services that are available but would require advanced arrangements, likely with long lead times.
	Cost	
*Total Present Worth Cost**		
$ 77,921,920	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.5.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The downgradient groundwater extraction and treatment would provide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The downgradient groundwater extraction and treatment would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The treatment and discharge of extracted groundwater would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The groundwater extraction and treatment system would need to operate until the source control and MNA components of this alternative achieve RAOs. • Any prolonged system shutdowns would pose potential risk to ecological receptors in the River Area DU.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	See evaluation for Alternative LDU1/GW-3A.	• Extracted groundwater containing cyanide in exceedance of PRGs would be treated in an ex situ treatment system prior to the discharge of the treated water via onsite infiltration basins. Treatment processes would potentially include chemical precipitation, filtration, ion exchange, and/or reverse osmosis. Further evaluation of treatment options, bench and/or pilot scale treatability studies, and final selection of treatment technology would take place during the remedial design phase.
Amount of Hazardous Materials Destroyed or Treated		

	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The groundwater extraction and treatment would be expected to treat 500 gpm of contaminated groundwater during both high and low flow conditions.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The removal of cyanide from groundwater intercepted by the downgradient extraction wells would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	See evaluation for Alternative LDU1/GW-3A.	• The removal of contaminants from the treated groundwater would be irreversible. • If downgradient extraction and treatment is discontinued, then contaminants in groundwater would continue to be discharged to surface water in the River Area DU.
Type and Quantity of Residuals Remaining After Treatment		
	See evaluation for Alternative LDU1/GW-3A.	• The groundwater treatment process would generate spent media and residuals that would require regularly offsite disposal over the lifetime of this alternative.
Statutory Preference for Treatment		
	Discussed under Groundwater DU evaluation.	Would satisfy the statutory preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • The property line is located approximately 3,000 or more ft away from the location of the groundwater extraction and treatment system; consequently, no impacts to community are anticipated during system construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Mobilization of large construction equipment and materials for installation of the extraction wells and groundwater extraction and treatment system would create increased traffic, noise, and nuisance dust. Appropriate mitigative activities would be implemented to protect surrounding community.
Protection of Workers During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Potential for exposure to impacted soils during installation of extraction wells and subsurface conveyance piping. Potential exposure to contaminated water during system maintenance. • Construction risks during drilling of extraction wells and during cap and groundwater treatment system construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Short-term impacts during construction would be minimal. • A potential impact of long-term groundwater extraction at high rates is induced infiltration of water from the Flathead River (i.e., the pumping of river water). Preliminary analysis indicates the pumping rates contemplated would not induce infiltration from the Flathead River; however, further evaluation of this and monitoring would be conducted. Pumping rates would be adjusted as needed to avoid this impact.
Time Until RAOs are Achieved		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Installation of the groundwater extraction and treatment system would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and construction of the groundwater extraction and treatment system is estimated to require 4 years to complete; the treatment system would begin operation after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following system startup.
	Implementability	
Technical Feasibility		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition:

		• Groundwater extraction and treatment is an established and proven technology to capture and contain contaminated groundwater plumes. Treatment system units would need to be housed within a building for freeze protection. • Would require pre-design investigations, including additional vertical delineation of concentrations within the upper hydrogeologic unit and pump test to quantify hydraulic conductivity and transmissivity. • Treatability studies would be required to finalize process and design of the groundwater treatment system.
Administrative Feasibility		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	See evaluation for Alternative LDU1/GW-3A.	See evaluation for Alternative LDU1/GW-3A. In addition: • Necessary engineering services and contractor services readily available for groundwater extraction and treatment system design, construction, and maintenance.
Cost		
*Total Present Worth Cost**		
$ 62,258,574	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-4A: Containment via Capping and Fully Encompassing Slurry Wall

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.6.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The existing cap on the West Landfill and new caps on the WSSP and Center Landfill would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and the fully-encompassing slurry wall would divert clean groundwater around impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table, and contain contaminated groundwater. Together, this alternative would provide full containment of impacted materials within the WMUs to prevent leaching of COCs to groundwater. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The caps over all source area WMUs would prevent the infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and prevent/reduce leaching of COCs to groundwater. • The fully-encompassing slurry wall around the West Landfill and WSSP would divert clean groundwater around the West Landfill and WSSP, including groundwater both above and below the fluctuating water table, and contain contaminated groundwater, preventing contaminant mass flux from beyond the WMU footprints. • The combined effect of containment via capping and the fully-encompassing slurry wall would cut off the source of contamination to groundwater, providing the opportunity for flushing of porewater and MNA to reduce concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU without recharge of contaminant mass. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	• There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	• With caps over all Landfills DU1 WMUs and an upgradient slurry wall to prevent leaching of COCs, MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU. • The ability for MNA to achieve chemical-specific ARARs would be enhanced by the fully-encompassing slurry wall around the West Landfill and WSSP.
Compliance with Action-Specific ARARs		
	• The new caps over the WSSP and Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps. • Slurry wall construction activities would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling; and stormwater/erosion controls.	• Action-specific ARARs triggered by the slurry wall component of this alternative are addressed under the Landfills DU1 evaluation. • The other groundwater components of this alternative are not anticipated to trigger any action-specific ARARs.

Compliance with Location-Specific ARARs		
	• No location-specific ARARs have been identified for this alternative.	• No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	• The fully-encompassing slurry wall in conjunction with the caps would prevent the leaching of COCs from the WMUs. • Impacted materials would remain in place, untreated, beneath the caps. Alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1 • Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long term effectiveness and permanence.	• The magnitude of residual risk following successful completion of the MNA program would be less than target risk levels set by Montana DEQ-7 standards. • The ability for MNA to achieve chemical-specific ARARs would be enhanced by the fully-encompassing slurry wall around the West Landfill and WSSP.
Adequacy and Reliability of Controls		
	• The caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The potential presence of impacted materials beneath the seasonal high-water table would be addressed by the fully-encompassing slurry wall by diverting clean groundwater around the West Landfill and WSSP and greatly reducing mass flux of contamination from beneath these WMUs. The degree of containment would be impacted by the ability to key the slurry wall into the low permeability glacial till unit at the Site. Based on the COCs in groundwater at the Site and their concentrations, the slurry wall is expected to have long-term effectiveness and permanence; pre-design bench testing would be required to verify wall compatibility with COCs in groundwater. • Provisions for extraction and treatment of groundwater from within the containment cell would ensure contaminated groundwater has no hydraulic potential to migrate out of the containment cell, further enhancing the reliability of the controls. • Expected to provide long-term effectiveness as documented in numerous studies and evaluations including reports from dozens of USEPA Superfund sites and many large-scale civil infrastructure projects; see USEPA, 1998 and National Research Council, 2007. Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long-term effectiveness and permanence.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate progress towards achieving RAOs. • ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	No treatment used.	No treatment used.
Amount of Hazardous Materials Destroyed or Treated		
	No reduction in amount of hazardous materials within the source area WMUs.	Fully-encompassing slurry wall and capping of the source area WMUs would result in reduction of contaminant concentrations and mass downgradient.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	The mobility of COCs from within the WMUs would be greatly reduced due to elimination of infiltration from precipitation and runoff as well as reduced groundwater flow and contaminant mass flux through the WMU footprints. The toxicity and volume of waste in the WMUs would remain unchanged.	The reduction in concentrations of COCs in groundwater and, subsequently, surface water in the River Area DU resulting from improved source area containment via capping and the fully-encompassing slurry wall and downgradient MNA would significantly reduce the toxicity of contaminated groundwater and surface water over time. Prior to attainment of RAOs, it is expected that measurable reductions in contaminant mass flux and COC concentrations would be observed immediately following completion of the slurry wall construction.
Degree to Which Treatment is Irreversible		

	NA; No treatment used.	NA; No treatment used.
Type and Quantity of Residuals Remaining After Treatment		
	NA; No treatment used.	NA; No treatment used.
Statutory Preference for Treatment		
	Would not meet preference for treatment as a principal element of remediation.	Would not meet preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	• The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs; consequently, no impacts to community are anticipated during onsite cap and slurry wall construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Capping and slurry wall construction would require the import of fill/grading and slurry materials which would increase truck traffic through the community and pose associated hazards. Approximately 80 to 90% of excavated soils would be reused in the slurry wall, minimizing the need for disposal. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate that the extent of groundwater contamination is not expanding or threatening community water supply wells. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater.
Protection of Workers During Remedial Actions		
	• Minimal potential exposure risk to workers as wastes would not be excavated (i.e., slurry wall would be outside of waste limits); however, soil and groundwater beneath the water table would contain COCs. • Construction risks during cap and slurry wall construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.	• Potential physical and exposure hazards to workers during installation of additional monitoring wells (if needed) and sampling is limited. Risks would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	• Minimal potential for environmental impact during cap construction assuming implementation of adequate erosion controls. • Moderate environmental impacts (i.e., air emissions and material consumption) during slurry wall construction affecting the sustainability consideration of this alternative. No additional environmental impacts over the lifetime of this alternative.	• No short-term impacts to the environment are anticipated during groundwater sampling activities under the MNA program.
Time Until RAOs are Achieved		
	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following design and construction of the cap and slurry wall in addition to establishment of ICs, which are estimated to be completed within 4 years.	• The RAO to prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards would be met immediately following establishment of ICs, which is estimated to be completed within 1 year. • The RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met 14 to 26 years following elimination or full containment of the source. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination or full containment of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties. • The fully-encompassing slurry wall would achieve full containment of the source; therefore, attainment of River Area DU RAOs under this alternative would be expected to be within the estimated range.
	Implementability	
Technical Feasibility		
	• Capping is an established technology that has been proven effective and reliable for containment; would not require treatability/ pilot studies.	• Technical feasibility of slurry wall construction is addressed under the Landfills DU1 evaluation.

	• Slurry walls are an established and proven technology, with effective installation to depths of 150 ft and greater reported by contractors. Achieving depths greater than 100 ft would require clamshell bucket excavation and/or hydromill technologies. The presence of cobbles / boulders would require rock breaking tools. • Would require pre-design investigation to ascertain detailed geotechnical data along the proposed alignment. If keying into the low permeability glacial till unit would not be feasible, groundwater modeling may be needed to evaluate effectiveness of various hanging wall depths. • If and only if extraction of groundwater from within the containment cell is necessary to ensure contaminated groundwater has no hydraulic potential to migrate out of the containment cell, treatability studies would be required to finalize process and design of the groundwater treatment system.	• MNA is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated with the MNA component of this alternative.
Administrative Feasibility		
	• All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow source(s) for fill/grading materials would require coordination and approval from the affected agency.	• Administratively feasible to implement ICs such as deed restrictions on future land use and a Controlled Ground Water Area designation for groundwater within the plume extent. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	• Necessary engineering services and contractor services readily available for cap design, installation, and maintenance. • Slurry wall construction to contemplated depths would require specialty contractor services that are available but would require advanced arrangements, likely with long lead times. • Low permeability soils for cap and slurry wall materials may require import from distant / out of state locations.	• Necessary engineering services and materials readily available for installation of additional monitoring wells (if needed) and maintenance of existing monitoring well network.
	Cost	
*Total Present Worth Cost**		
$ 45,642,497	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-4B: Containment via Capping and Fully Encompassing Slurry Wall with Downgradient PRB

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.7.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The downgradient PRB would provide cyanide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations of cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The downgradient PRB would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A.
Compliance with Location-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The PRB would have a finite period of effectiveness; once the reactive media is consumed the PRB would no longer intercept cyanide if present in groundwater prior to surface water discharge in the River Area DU. The design basis for the PRB would be 30 years. However, the long-term effectiveness would be compromised if design life goal is not achieved, or if the source control and MNA components of this alternative take longer than 30 years. Under such circumstances, replacement of media within the PRB or construction of a new PRB, would be needed to maintain the effectiveness the remedy.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • ZVI and sand mixture in the PRB would reduce concentrations of cyanide in groundwater primarily through precipitation prior to surface water discharge in the River Area DU.
Amount of Hazardous Materials Destroyed or Treated		

	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The PRB would be expected to treat approximately 71 kg of cyanide in the first year following installation. Removal rates would decrease in subsequent years as upgradient cyanide concentrations decrease and as the reactive media is expended.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The removal of cyanide from groundwater as it flows through the PRB would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Cyanide would be removed from groundwater primarily through precipitation; this removal would be permanent as, under natural conditions, the cyanide would not be expected to dissolve back into the groundwater. However, bench testing would be required to confirm the degree to which the treatment is irreversible.
Type and Quantity of Residuals Remaining After Treatment		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Approximately 35,000 CY of spent reactive media which would contain the precipitated and adsorbed cyanide would remain in place within the PRB at the conclusion of the remedy.
Statutory Preference for Treatment		
	See evaluation for Alternative LDU1/GW-4A.	Would satisfy preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The property line is located approximately 3,000 or more ft away from the location of the PRB; consequently, no impacts to community are anticipated during PRB construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • PRB construction would require the import of the ZVI and sand mixture components which would increase truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.
Protection of Workers During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Minimal potential exposure risk to workers as wastes would not be excavated (i.e., PRB outside of waste limits); however, soil and groundwater beneath the water table would contain COCs. Construction risks during PRB construction, including inhalation of ZVI granular materials, would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	Moderate environmental impacts (i.e., air emissions) to transport spoils from PRB construction trenching to onsite repository, adversely affecting the sustainability consideration of this alternative. No additional environmental impacts over the lifetime of this alternative.
Time Until RAOs are Achieved		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The PRB would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and installation of the PRB is estimated to require 4 years to complete; the PRB would be installed after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following completion of the PRB.
	Implementability	
Technical Feasibility		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: Use of PRBs for groundwater remediation is an established technology. However, several site-specific factors affect the feasibility evaluation at the Site as summarized below:

		• Bench scale studies at other sites indicate PRB media can effectively remove cyanide. However, full-scale projects demonstrating the effectiveness of PRBs for cyanide were not encountered in review of the published literature. As a result, extensive bench-scale studies would be needed to confirm treatability, determine the optimal reactive media mix, and confirm adequate life expectancy of the PRB (i.e., permanence of the removal process). • The contemplated depth of the PRB (130 ft) would complicate the feasibility of trench excavation and media placement. While experienced slurry wall/PRB construction contractors indicate such depth is feasible, the target depth is greater than any applications reviewed in the published literature (which are typically less than 75 feet). The presence of coarse-grained material at depth (e.g., cobbles / boulders) would further complicate installation. • As a hanging wall PRB, permeability of the PRB would need to be confirmed to ensure it is comparable to that of the surrounding formation to prevent diversion of contaminated groundwater beneath or around the PRB. Pre-design investigations would be required to ascertain detailed geotechnical data along proposed alignment.
Administrative Feasibility		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • PRB construction activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Construction of PRB to contemplated depths is not considered standard industry practice and would require specialty contractor services that are available but would require advanced arrangements, likely with long lead times.
Cost		
*Total Present Worth Cost**		
$ 95,724,036	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-4C: Containment via Capping and Fully Encompassing Slurry Wall with Downgradient Extraction

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.8.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The downgradient groundwater extraction and treatment would provide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The downgradient groundwater extraction and treatment would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The treatment and discharge of extracted groundwater would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The groundwater extraction and treatment system would need to operate until the source control and MNA components of this alternative achieve RAOs. • Any prolonged system shutdowns would pose potential risk to ecological receptors in the River Area DU.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	See evaluation for Alternative LDU1/GW-4A.	• Extracted groundwater containing cyanide in exceedance of PRGs would be treated in an ex situ treatment system prior to the discharge of the treated water via onsite infiltration basins. Treatment processes would potentially include chemical precipitation, filtration, ion exchange, and/or reverse osmosis. Further evaluation of treatment options, bench and/or pilot scale treatability studies, and final selection of treatment technology would take place during the remedial design phase.
Amount of Hazardous Materials Destroyed or Treated		

	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The groundwater extraction and treatment would be expected to treat 500 gpm of contaminated groundwater during both high and low flow conditions.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The removal of cyanide from groundwater intercepted by the downgradient extraction wells would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	See evaluation for Alternative LDU1/GW-4A.	• The removal of contaminants from the treated groundwater would be irreversible. • If downgradient extraction and treatment is discontinued, then contaminants in groundwater would continue to be discharged to surface water in the River Area DU.
Type and Quantity of Residuals Remaining After Treatment		
	See evaluation for Alternative LDU1/GW-4A.	• The groundwater treatment process would generate spent media and residuals that would require regularly offsite disposal over the lifetime of this alternative.
Statutory Preference for Treatment		
	Discussed under Groundwater DU evaluation.	Would satisfy the statutory preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • The property line is located approximately 3,000 or more ft away from the location of the groundwater extraction and treatment system; consequently, no impacts to community are anticipated during system construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Mobilization of large construction equipment and materials for installation of the extraction wells and groundwater extraction and treatment system would create increased traffic, noise, and nuisance dust. Appropriate mitigative activities would be implemented to protect surrounding community.
Protection of Workers During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Potential for exposure to impacted soils during installation of extraction wells and subsurface conveyance piping. Potential exposure to contaminated water during system maintenance. • Construction risks during drilling of extraction wells and during cap and groundwater treatment system construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Short-term impacts during construction would be minimal. • A potential impact of long-term groundwater extraction at high rates is induced infiltration of water from the Flathead River (i.e., the pumping of river water). Preliminary analysis indicates the pumping rates contemplated would not induce infiltration from the Flathead River; however, further evaluation of this and monitoring would be conducted. Pumping rates would be adjusted as needed to avoid this impact.
Time Until RAOs are Achieved		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Installation of the groundwater extraction and treatment system would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and construction of the groundwater extraction and treatment system is estimated to require 4 years to complete; the treatment system would begin operation after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following system startup.
	Implementability	
Technical Feasibility		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition:

		• Groundwater extraction and treatment is an established and proven technology to capture and contain contaminated groundwater plumes. Treatment system units would need to be housed within a building for freeze protection. • Would require pre-design investigations, including additional vertical delineation of concentrations within the upper hydrogeologic unit and pump test to quantify hydraulic conductivity and transmissivity. • Treatability studies would be required to finalize process and design of the groundwater treatment system.
Administrative Feasibility		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	See evaluation for Alternative LDU1/GW-4A.	See evaluation for Alternative LDU1/GW-4A. In addition: • Necessary engineering services and contractor services readily available for groundwater extraction and treatment system design, construction, and maintenance.
	Cost	
*Total Present Worth Cost**		
$ 74,303,074	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.9.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The existing cap on the West Landfill and new caps on the WSSP and Center Landfill would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to prevent/reduce leaching of COCs to groundwater. • Groundwater extraction on the downgradient side of the West Landfill and WSSP will provide hydraulic containment of contaminated groundwater that would continue to emanate from beneath these WMUs. The extracted groundwater would be treated prior to discharge. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The caps over all source area WMUs would prevent the infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and prevent/reduce leaching of COCs to groundwater. • Groundwater extraction on the downgradient side of the West Landfill and WSSP will provide hydraulic containment of contaminated groundwater that would continue to emanate from beneath the WMUs. The extracted groundwater would be treated to effluent standards prior to discharge. • The combined effect of containment via capping and hydraulic control would cut off the source of contamination to groundwater, providing the opportunity for flushing of porewater and MNA to reduce concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU without recharge of contaminant mass. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	With caps over all source area WMUs to prevent/reduce leaching of COCs and hydraulic containment to intercept the flow of contaminated groundwater, MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU.
Compliance with Action-Specific ARARs		
	The new caps over the WSSP and Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps.	The treatment and discharge of extracted groundwater would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	No location-specific ARARs have been identified for this alternative.	No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		

	• The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to reduce the leaching of COCs from the WMUs. • Impacted materials would remain in place, untreated, beneath the caps. Alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1. • Extraction and treatment of groundwater would gradually reduce the magnitude of contaminant mass in the West Landfill, the Wet Scrubber Sludge Pond, and their underlying soils.	• The magnitude of residual risk following successful completion of the MNA program would be less than target risk levels set by Montana DEQ-7 standards. • Any prolonged system shutdowns could compromise the hydraulic containment process, resulting in migration of impacted groundwater to downgradient areas and increasing the residual risk in groundwater until the MNA program is once again able to achieve Montana DEQ-7 standards.
Adequacy and Reliability of Controls		
	• The caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The groundwater extraction and treatment system would need to operate in perpetuity to maintain hydraulic containment of contaminated groundwater emanating from beneath the WMUs. • Any prolonged system shutdowns could compromise the hydraulic containment process, resulting in migration of impacted groundwater to downgradient areas. • Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long term effectiveness and permanence.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate progress towards achieving RAOs. • ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
	Reduction of Toxicity, Mobility, and Volume through Treatment	
Treatment Process Used and Materials Treated		
	Extracted groundwater containing cyanide, fluoride, and arsenic in exceedance of PRGs would be treated in an *ex situ* treatment system prior to the discharge of the treated water via onsite infiltration basins.	Discussed under the Landfills DU1 evaluation.
Amount of Hazardous Materials Destroyed or Treated		
	The groundwater extraction and treatment would be expected to treat approximately 1,500 gpm of contaminated groundwater during high flow conditions and approximately 110 gpm of during low flow conditions.	Discussed under the Landfills DU1 evaluation.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	The groundwater extraction and treatment system would provide hydraulic containment and treatment of COCs present in groundwater emanating from beneath the LDU1 WMUs; thereby providing a high degree of reduction in toxicity, mobility, and volume of groundwater contamination.	The reduction in concentrations of COCs in groundwater resulting from improved source area containment via capping and groundwater extraction and downgradient MNA would significantly reduce the toxicity of contaminated groundwater over time. Prior to attainment of RAOs, it is expected that measurable reductions in contaminant mass flux and COC concentrations would be observed immediately following startup of groundwater extraction.
Degree to Which Treatment is Irreversible		
	• The removal of contaminants from the treated groundwater would be irreversible. • If extraction and treatment is discontinued, then contaminants in groundwater would resume migration from the source area WMU to downgradient areas.	Discussed under the Landfills DU1 evaluation.
Type and Quantity of Residuals Remaining After Treatment		
	There would be no residuals remaining onsite after the groundwater treatment process. Any spent media or residuals from *ex situ* treatment processes would be disposed of offsite in accordance with ARARs.	Discussed under the Landfills DU1 evaluation.
Statutory Preference for Treatment		
	Would satisfy preference for treatment as a principal element of remediation.	Discussed under the Landfills DU1 evaluation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		

	• The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs; consequently, no impacts to community are anticipated during onsite construction or maintenance of the cap or groundwater extraction and treatment system. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Mobilization of large construction equipment and materials for installation of the extraction wells and groundwater extraction and treatment system would create increased traffic, noise, and nuisance dust. Appropriate mitigative activities would be implemented to protect surrounding community. • Capping would likely require the import of fill/grading materials which would increase truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.	• Routine sampling and analysis of groundwater under the MNA program would demonstrate that the extent of groundwater contamination is not expanding or threatening community water supply wells. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater.
Protection of Workers During Remedial Actions		
	• Potential for exposure to impacted soils during installation of extraction wells and subsurface conveyance piping. Potential exposure to contaminated water during system maintenance. • Construction risks during drilling of extraction wells and during cap and groundwater treatment system construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.	• Potential physical and exposure hazards to workers during installation of additional monitoring wells (if needed) and sampling is limited. Risks would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	• Minimal potential for environmental impact during cap and groundwater treatment system construction assuming implementation of adequate erosion controls. • Significant environmental impacts during operation of the groundwater treatment system affecting the sustainability consideration of this alternative; significant energy consumption and considerable material consumption and waste generation over the lifetime of this alternative.	• No short-term impacts to the environment are anticipated during groundwater sampling activities under the MNA program.
Time Until RAOs are Achieved		
	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cap construction and establishment of ICs, which are estimated to be completed within 4 years.	• The RAO to prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards would be met immediately following establishment of ICs, which is estimated to be completed within 1 year. • The RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met 14 to 26 years following elimination or full containment of the source. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination or full containment of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties. • The groundwater extraction hydraulic control would achieve full containment of the source; therefore, attainment of River Area DU RAOs under this alternative would be expected to be within the estimated range.
	Implementability	
Technical Feasibility		
	• Capping is an established technology that has been proven effective and reliable for containment; would not require treatability/ pilot studies. • Groundwater extraction and treatment is an established and proven technology to capture and contain contaminated groundwater plumes. However, due to the mix of COCs in groundwater at the source area (i.e., cyanide, fluoride, and arsenic) as well as the extreme variability in flow rates that would need to be accommodated, the system necessary to treat groundwater under this alternative would be very large and complex.	• Technical feasibility of source area groundwater extraction and treatment is addressed under the Landfills DU1 evaluation. • MNA is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated with the MNA component of this alternative.

	• Would require pre-design investigations, including additional vertical delineation of concentrations within the upper hydrogeologic unit and pump test to quantify hydraulic conductivity and transmissivity. • Treatability studies would be required to finalize process and design of the groundwater treatment system.	
Administrative Feasibility		
	• All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Development of offsite borrow source(s) for fill/grading materials would require coordination and approval from the affected agency.	• Administratively feasible to implement ICs such as deed restrictions on future land use and Controlled Ground Water Area designation for groundwater within the plume extent. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	• Necessary engineering services and contractor services readily available for cap design, installation, and maintenance • Necessary engineering services and contractor services readily available for groundwater extraction and treatment system design, construction, and maintenance. • Low permeability soils for cap and slurry wall materials may require import from distant / out of state locations.	• Necessary engineering services and materials readily available for installation of additional monitoring wells (if needed) and maintenance of existing monitoring well network.
	Cost	
*Total Present Worth Cost**		
$ 67,268,047	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-5B: Containment via Capping and Downgradient Hydraulic Control

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.10.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The existing cap on the West Landfill and new caps on the WSSP and Center Landfill would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to prevent/reduce leaching of COCs to groundwater. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The caps over all source area WMUs would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table and prevent/reduce leaching of COCs to groundwater. • While in the absence of a continuing source of contamination MNA would reduce concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU, this alternative does not include any additional source control measures to address underlying soils beneath the West Landfill that are likely contributing to groundwater contamination. • The downgradient groundwater extraction and treatment would provide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	• With caps over all source area WMUs to prevent/reduce leaching of COCs to groundwater, and in the absence of a continuing source of contamination, MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU. However, as described under the short-term effectiveness criterion for this alternative, capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor would it address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, in the absence of additional source control measures under this alternative, it is unlikely that MNA would reduce concentrations of COCs in groundwater within the plume footprint upgradient of the extraction wells to ARAR levels in a reasonable time.

		• The downgradient groundwater extraction and treatment would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	The new caps over the WSSP and Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps.	The treatment and discharge of extracted groundwater would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	No location-specific ARARs have been identified for this alternative.	No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	• The caps would prevent infiltration of precipitation and runoff through the surface of the WMUs and the underlying impacted materials above the seasonal high-water table to reduce the leaching of COCs from the WMUs. • Impacted materials would remain in place, untreated, beneath the caps. Alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1.	• The magnitude of residual risk following successful completion of the MNA program would be less than target risk levels set by Montana DEQ-7 standards. However, as described under the short-term effectiveness criterion for this alternative, capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor would it address any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, in the absence of additional source control measures under this alternative, it is unlikely that MNA would reduce concentrations of COCs in groundwater within the plume footprint upgradient of the extraction wells to ARAR levels in a reasonable time. • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	• The caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The potential presence of impacted materials beneath the seasonal high-water table could significantly reduce the adequacy of the caps as source control measures, most specifically at the West Landfill. • Periodic inspections (minimum annual basis) and maintenance/repairs would be performed as needed to ensure long-term effectiveness and permanence.	• The downgradient groundwater extraction and treatment should provide a reliable hydraulic control to prevent continued discharge of contaminated groundwater to surface water in the River Area DU. The groundwater extraction and treatment system would need to operate until the source control and MNA components of this alternative achieve RAOs. • Any prolonged system shutdowns would pose potential risk to ecological receptors in the River Area DU. • Routine sampling and analysis of groundwater under the MNA program would demonstrate progress towards achieving RAOs. • ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	No treatment used.	Extracted groundwater containing cyanide in exceedance of PRGs would be treated in an *ex situ* treatment system prior to the discharge of the treated water via onsite infiltration basins. Treatment processes would potentially include chemical precipitation, filtration, ion exchange, and/or reverse osmosis. Further evaluation of treatment options, bench and/or pilot scale treatability studies, and final selection of treatment technology would take place during the remedial design phase.
Amount of Hazardous Materials Destroyed or Treated		
	No reduction in amount of hazardous materials within the source area WMUs.	• Capping of the source area WMUs would result in some reduction of contaminant concentrations and mass downgradient. • The groundwater extraction and treatment would be expected to treat 500 gpm of contaminated groundwater during both high and low flow conditions.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		

	The mobility of COCs from within the WMUs would be reduced due to elimination of infiltration from precipitation and runoff. The mobility of COCs from impacted underlying soils beneath the water table or from any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table would remain unchanged. The toxicity and volume of waste in the WMUs would remain unchanged.	• Due to the limited source control measures to address a continuing source of contamination, there would only be a limited reduction in concentrations of COCs in groundwater and surface water, and therefore only a limited reduction in the toxicity of contaminated groundwater and surface water over time. • The removal of cyanide from groundwater intercepted by the downgradient extraction wells would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	NA; no treatment used.	• The removal of contaminants from the treated groundwater would be irreversible. • If downgradient extraction and treatment is discontinued, then contaminants in groundwater would continue to be discharged to surface water in the River Area DU.
Type and Quantity of Residuals Remaining After Treatment		
	NA; no treatment used.	The groundwater treatment process would generate spent media and residuals that would require regularly offsite disposal over the lifetime of this alternative.
Statutory Preference for Treatment		
	Discussed under Groundwater DU evaluation.	Would satisfy the statutory preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	• The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs; consequently, no impacts to community are anticipated during onsite cap construction and maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Capping would likely require the import of fill/grading materials which would increase truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community.	• The property line is located approximately 3,000 or more ft away from the location of the groundwater extraction and treatment system; consequently, no impacts to community are anticipated during system construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Mobilization of large construction equipment and materials for installation of the extraction wells and groundwater extraction and treatment system would create increased traffic, noise, and nuisance dust. Appropriate mitigative activities would be implemented to protect surrounding community. • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the extent of groundwater contamination is not expanding or threatening community water supply wells. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater.
Protection of Workers During Remedial Actions		
	• Minimal potential exposure risk to workers during construction activities as wastes would not be excavated. • Construction risks during installation of the cap would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.	• Potential for exposure to impacted soils during installation of extraction wells and subsurface conveyance piping. Potential exposure to contaminated water during system maintenance. • Construction risks during drilling of extraction wells and during cap and groundwater treatment system construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	• Minimal potential risks to the environment during cap construction assuming implementation of adequate erosion controls.	• Short-term impacts during construction would be minimal. • A potential impact of long-term groundwater extraction at high rates is induced infiltration of water from the Flathead River (i.e., the pumping of river water). Preliminary analysis indicates the pumping rates contemplated would not induce infiltration from the Flathead River; however, further evaluation of this and monitoring would be conducted. Pumping rates would be adjusted as needed to avoid this impact.
Time Until RAOs are Achieved		

	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cap construction and establishment of ICs, which are estimated to be completed within 4 years.	• The RAO to prevent ingestion of or direct contact with groundwater containing COCs in excess of Montana DEQ-7 standards would be met immediately following establishment of ICs, which is estimated to be completed within 1 year. • The RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met 14 to 26 years following elimination or full containment of the source. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination or full containment of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties. • Capping would not address impacted underlying soils beneath the water table that are likely contributing to groundwater contamination, nor any lateral migration of groundwater through the vadose zone into wastes or impacted soil above the water table. Therefore, under this alternative, elimination or full containment of the source is not anticipated and attainment of Groundwater DU RAOs would be expected to take longer than the timeframe outlined above. • Installation of the groundwater extraction and treatment system would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and construction of the groundwater extraction and treatment system is estimated to require 4 years to complete; the treatment system would begin operation after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following system startup.
Implementability		
Technical Feasibility		
	Capping is an established technology that has been proven effective and reliable for containment; would not require treatability/ pilot studies. However, as a stand-alone containment technology (as proposed in this alternative), a detailed pre-design investigation would be required to demonstrate significant source material does not exist beneath the seasonal high-water table.	• Groundwater extraction and treatment is an established and proven technology to capture and contain contaminated groundwater plumes. Treatment system units would need to be housed within a building for freeze protection. • Would require pre-design investigations, including additional vertical delineation of concentrations within the upper hydrogeologic unit and pump test to quantify hydraulic conductivity and transmissivity. • Treatability studies would be required to finalize process and design of the groundwater treatment system. • MNA is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated the MNA component of this alternative.
Administrative Feasibility		
	All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Development of offsite borrow source(s) for fill/grading materials would require coordination and approval from the affected agency.	• Administratively feasible to implement ICs such as deed restrictions on future land use and a Controlled Ground Water Area designation for groundwater within the plume extent. It is expected that regulatory approval should be obtainable for the components comprising this alternative. • All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	Necessary engineering services and contractor services readily available for cap design, installation, and maintenance. Low permeability soils for cap materials may require import from distant / out-of-state locations.	Necessary engineering services and contractor services readily available for groundwater extraction and treatment system design, construction, and maintenance.
Cost		
*Total Present Worth Cost**		
$ 48,724,897	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at Source Area and Downgradient

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1) and downgradient groundwater (i.e., north of the Burlington Northern Railroad), *ex situ* treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.11.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The downgradient groundwater extraction and treatment would provide treatment of groundwater at a location approximately 300 feet upgradient of the River Area DU. This would further reduce concentrations cyanide in groundwater beyond source control measures and MNA, subsequently reducing concentrations of cyanide discharging to surface water in the River Area DU.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The downgradient groundwater extraction and treatment would further reduce cyanide concentrations beyond source control measures and MNA to expedite compliance with chemical-specific ARARs for surface water and porewater (i.e., cyanide PRGs) in the River Area DU.
Compliance with Action-Specific ARARs		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The treatment and discharge of extracted groundwater would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A.
BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Alternative would mitigate direct contact exposure for ecological receptors in the River Area DU.
Adequacy and Reliability of Controls		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The groundwater extraction and treatment system would need to operate until the source control and MNA components of this alternative achieve RAOs. • Any prolonged system shutdowns would pose potential risk to ecological receptors in the River Area DU.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	See evaluation for Alternative LDU1/GW-5A.	• Extracted groundwater containing cyanide in exceedance of PRGs would be treated in an ex situ treatment system prior to the discharge of the treated water via onsite infiltration basins. Treatment processes would potentially include chemical precipitation, filtration, ion exchange, and/or reverse osmosis. Further evaluation of treatment options, bench and/or pilot scale treatability studies, and final selection of treatment technology would take place during the remedial design phase.
Amount of Hazardous Materials Destroyed or Treated		

	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The groundwater extraction and treatment would be expected to treat 500 gpm of contaminated groundwater during both high and low flow conditions.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The removal of cyanide from groundwater intercepted by the downgradient extraction wells would significantly reduce the toxicity of contaminated groundwater over time and, subsequently, the toxicity of surface water and porewater in the River Area DU.
Degree to Which Treatment is Irreversible		
	See evaluation for Alternative LDU1/GW-5A.	• The removal of contaminants from the treated groundwater would be irreversible. • If downgradient extraction and treatment is discontinued, then contaminants in groundwater would continue to be discharged to surface water in the River Area DU.
Type and Quantity of Residuals Remaining After Treatment		
	See evaluation for Alternative LDU1/GW-5A.	• The groundwater treatment process would generate spent media and residuals that would require regularly offsite disposal over the lifetime of this alternative.
Statutory Preference for Treatment		
	Discussed under Groundwater DU evaluation.	Would satisfy the statutory preference for treatment as a principal element of remediation.
	Short-Term Effectiveness	
Protection of Community During Remedial Actions		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • The property line is located approximately 3,000 or more ft away from the location of the groundwater extraction and treatment system; consequently, no impacts to community are anticipated during system construction, or during maintenance activities. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise. • Mobilization of large construction equipment and materials for installation of the extraction wells and groundwater extraction and treatment system would create increased traffic, noise, and nuisance dust. Appropriate mitigative activities would be implemented to protect surrounding community.
Protection of Workers During Remedial Actions		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Potential for exposure to impacted soils during installation of extraction wells and subsurface conveyance piping. Potential exposure to contaminated water during system maintenance. • Construction risks during drilling of extraction wells and during cap and groundwater treatment system construction would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Short-term impacts during construction would be minimal. • A potential impact of long-term groundwater extraction at high rates is induced infiltration of water from the Flathead River (i.e., the pumping of river water). Preliminary analysis indicates the pumping rates contemplated would not induce infiltration from the Flathead River; however, further evaluation of this and monitoring would be conducted. Pumping rates would be adjusted as needed to avoid this impact.
Time Until RAOs are Achieved		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Installation of the groundwater extraction and treatment system would accelerate attainment of ARARs/PRGs for surface water and porewater in the River Area DU. Design and construction of the groundwater extraction and treatment system is estimated to require 4 years to complete; the treatment system would begin operation after construction of the caps on the source area WMUs and the slurry wall. The RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU would likely require 6 to 9 years to achieve following system startup.
	Implementability	
Technical Feasibility		

	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Groundwater extraction and treatment is an established and proven technology to capture and contain contaminated groundwater plumes. Treatment system units would need to be housed within a building for freeze protection. • Would require pre-design investigations, including additional vertical delineation of concentrations within the upper hydrogeologic unit and pump test to quantify hydraulic conductivity and transmissivity. • Treatability studies would be required to finalize process and design of the groundwater treatment system.
Administrative Feasibility		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials		
	See evaluation for Alternative LDU1/GW-5A.	See evaluation for Alternative LDU1/GW-5A. In addition: • Necessary engineering services and contractor services readily available for groundwater extraction and treatment system design, construction, and maintenance.
	Cost	
*Total Present Worth Cost**		
$ 98,483,516	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU1/GW-6: Excavation with Onsite Consolidation

Description of Alternative:

- Excavation of wastes previously disposed within the West Landfill and Wet Scrubber Sludge Pond;
- Characterization of soils beneath waste and removal as necessary to eliminate source material;
- Construction of an onsite repository meeting RCRA Subtitle C requirements for disposal of excavated material;
- Containment of the Center Landfill via capping;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.12.

Evaluation Criteria	Landfills DU1	Groundwater DU
THRESHOLD CRITERIA		
Overall Protection of Human Health and the Environment		
How Alternative Provides Human Health and Environmental Protection		
	• The removal of waste material and underlying impacted soil from the West Landfill and WSSP, and the enhanced cap on the Center Landfill, would eliminate these WMUs as sources of groundwater contamination. • The new onsite repository would be constructed in a manner to prevent the infiltration of precipitation and runoff through the impacted materials and prevent/reduce leaching of COCs to groundwater, and ultimately the migration of COCs to surface water within the River Area DU. • The new repository and the new cap on the Center Landfill, would mitigate the potential long-term risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. • The cap on the onsite repository and new cap on the Center Landfill would provide containment of impacted material and prevent migration of COCs via stormwater runoff and prevent leaching of COCs to groundwater. Any leachate generated form the new repository would be collected and treated. • ICs and ECs would ensure the long-term effectiveness of the remedy. ICs would minimize the potential for damage to the cap. Cap integrity would be maintained through regular inspections and repairs; leachate would be monitored on a regular basis; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.	• The elimination of the LDU1 sources of contamination to groundwater would allow for MNA to reduce concentrations of COCs in groundwater downgradient of the WMUs and, subsequently, concentrations of COCs discharging to surface water in the River Area DU. • However, during remedial action, large-scale open excavation of the WMUs would expose the waste and contaminated soil to precipitation and runoff over a multi-year period, resulting in leaching of contaminants and further degradation of groundwater. This would be in contravention of RAOs for the Site which state: "during remedial action prevent further degradation of groundwater that exceeds Montana DEQ-7 standards (i.e., ensure no actions are taken that could increase concentrations of COCs within the contaminant plume)". • Routine sampling and analysis of groundwater under the MNA program would demonstrate that the plume is not expanding and that concentrations of COCs are decreasing over time. • ICs would prevent use of contaminated groundwater and prevent potential exposure to COCs in groundwater until ARARs are achieved. • Ongoing protectiveness would be regularly assessed as part of the CERCLA five-year review process.
Compliance with ARARs		
Compliance with Chemical-Specific ARARs		
	• There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).	• By removing the waste and source material from the WMUs and containing within the onsite repository, this would eliminate leaching of COCs to groundwater and MNA would reduce concentrations of COCs in groundwater, ultimately achieving compliance with chemical-specific ARARs for groundwater downgradient of the WMUs and for surface water and porewater in the River Area DU.
Compliance with Action-Specific ARARs		
	• The design and construction of the new onsite repository and new cap over the Center Landfill would comply with substantive action-specific ARARs regarding design and construction of landfill caps.	The treatment and discharge of leachate generated within the new repository would comply with ARARs associated with the MPDES program.
Compliance with Location-Specific ARARs		
	No location-specific ARARs have been identified for this alternative.	No location-specific ARARs have been identified for this alternative.

BALANCING CRITERIA		
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk		
	• This alternative would prevent the leaching of COCs from the WMUs to groundwater and significantly reduce the potential for future migration of COCs. Impacted materials would be removed from the source area and contained within a lined and capped landfill. • This alternative would effectively eliminate the direct contact exposure pathway to the impacted materials and its associated risks. Implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU1.	See evaluation for Alternative LDU1/GW-2. In addition: • The ability for MNA to achieve chemical-specific ARARs would be compromised unless all underlying soils contributing to groundwater contamination are removed.
Adequacy and Reliability of Controls		
	• Landfill caps are considered adequate and reliable in preventing direct contact of COCs remaining in place and in preventing the infiltration of precipitation and runoff through the impacted materials. • The double composite landfill liner with leachate collection system is adequate and reliable for detecting a breach in the primary liner.	• ICs are considered adequate and reliable controls to prevent ingestion/ exposure to contaminated groundwater until RAOs are achieved.
Reduction of Toxicity, Mobility, and Volume through Treatment		
Treatment Process Used and Materials Treated		
	No treatment used.	No treatment used.
Amount of Hazardous Materials Destroyed or Treated		
	The amount of hazardous materials within the source area WMUs would be substantially reduced; however, the hazardous materials would be consolidated at another part of the Site and the overall amount of hazardous materials at the Site would remain unchanged.	Discussed under the Landfills DU1 evaluation.
Degree of Expected Reductions in Toxicity, Mobility, and Volume		
	The mobility of COCs from within the WMUs would be reduced due to removal of the source. The toxicity of waste at the Site would remain unchanged. The volume of waste at the Site would increase due to solidification of material from the WSSP.	The reduction in concentrations of COCs in groundwater resulting from source removal and downgradient MNA would significantly reduce the toxicity of contaminated groundwater over time. Prior to attainment of RAOs, it is expected that measurable reductions in contaminant mass flux and COC concentrations would be observed immediately following removal of all source material from the West Landfill and WSSP.
Degree to Which Treatment is Irreversible		
	NA; no treatment used.	NA; no treatment used.
Type and Quantity of Residuals Remaining After Treatment		
	NA; no treatment used.	NA; no treatment used.
Statutory Preference for Treatment		
	Would not meet preference for treatment as a principal element of remediation.	Would not meet preference for treatment as a principal element of remediation.
Short-Term Effectiveness		
Protection of Community During Remedial Actions		
	• The import of materials and contractor resources for construction of the new repository would result in a large increase in truck traffic through the community and pose associated hazards. Such hazards could be mitigated through implementation of traffic control plans and appropriate notifications/communications to the community. • Tracking of hazardous material from trucks or from Site runoff could impact roadways. This can be mitigated through ECs such as stormwater management and erosion controls, decontamination area, truck wash, etc. • Air emissions during construction and waste handling would pose potential risk to the community. To mitigate this potential risk, measures such as	See evaluation for Alternative LDU1/GW-2.

	continuous air monitoring would need to be implemented during construction and, depending on the results of such monitoring, the need for enclosed work areas and/or limitations on exposed waste areas may need to be considered. • The western property line (i.e., the property line nearest the community) is located approximately 6,000 or more ft away from the Landfills DU1 WMUs. Due to the topography of the Site, the most suitable location for a new repository was determined to be the area between the LDU1 landfills and the former Main Plant Area. This location is closer than the existing location of the WMUs to the Flathead River and/or residents in Aluminum City, increasing the potential for exposure to emissions and reducing the buffer zone between the contamination and potential receptors.	
Protection of Workers During Remedial Actions		
	• High potential exposure risk to workers during remedial construction via direct contact as hazardous wastes would be handled multiple times throughout excavation, transportation, disposal, and compaction. Workers would be required to wear Level C PPE. • High potential exposure risk to workers during remedial construction via ingestion. Disturbance of the SPL-impacted material may release cyanide gas, a poison if inhaled. Additionally, swallowing cyanide via fugitive dust would be toxic. Vapor suppression controls would be used during excavation of the West Landfill. • Hazards to workers of health and safety risks associated with working around heavy machinery for the duration of the remedy implementation (approximately 4 to 5 years). • Excavation of the West Landfill would likely extend to 50 ft bls or deeper, requiring sloping or benching for sidewall stability. Deep excavations pose a risk to worker safety. • The timeframe required to implement this alternative (approximately 4 to 5 years) increases the duration of exposure to each item described above.	Deep excavations may require dewatering and treatment of groundwater, increasing the potential exposure risk to workers of groundwater impacted by COCs.
Environmental Impacts During Remedial Actions		
	• This alternative would require handling a large volume of hazardous waste, increasing the risk of a spill or unintentional deposition of hazardous material to the environment. • Implementation of this alternative would result in a volume of energy consumption and greenhouse gas emissions that are inordinately large due to the number of trucks and heavy equipment, and materials required for construction. • Potential deposition of air emissions in nearby soils and surface water would increase the potential risk to the environment.	• During remedial action, large-scale open excavation of the WMUs would expose the waste and contaminated soil to precipitation and runoff over a multi-year period, resulting in leaching of contaminants and further degradation of groundwater. This would be in contravention of RAOs for the site which state: "during remedial action prevent further degradation of groundwater that exceeds Montana DEQ-7 standards (i.e., ensure no actions are taken that could increase concentrations of COCs within the contaminant plume)". • The potential treatment of dewatered groundwater from the West Landfill excavation would generate spent media and residuals that would require regular offsite disposal over the lifetime of this alternative.
Time Until RAOs are Achieved		
	• The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met following completion of remedial construction and establishment of ICs, which are estimated to be completed within 6 to 7 years (i.e., two years for remedial design / planning, and a minimum of 4 to 5 years for implementation). • As discussed under Excavation in Section 4.3.1, pre-treatment of SPL-impacted material has not been included under this alternative. If a pre-treatment step should be required for all or some of the excavated material, the time to achieve RAOs would increase.	See evaluation for Alternative LDU1/GW-2. In addition: • Full source control would likely take more than 6 years to achieve (i.e., two years for remedial design / planning, and a minimum of 4 to 5 years for implementation). Following source elimination, the RAO to reduce concentrations of COCs in groundwater within the upper hydrogeologic unit to levels below Montana DEQ-7 standards is estimated to be met in 14 to 26 years. Similarly, the RAO to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU is estimated to be met 35 to 60 years following elimination of the source. See Appendix A for derivation of these time estimates and associated limitations/uncertainties.

Implementability		
Technical Feasibility		
	• Not a widely used or proven technology for previously landfilled SPL-material at the scale which would be required. Several complicating factors complicate the technical feasibility of this alternative. • While measures would be taken to minimize impacts to groundwater; it is technically infeasible to prevent infiltration of water through impacted material which would increase groundwater contamination during remedial action. • Large quantities of water generated during construction would need to be collected for treatment of cyanide, fluoride, and arsenic prior to discharge, further complicating the implementation of this alternative. • The potential need for enclosed work areas and/or limitations on exposed waste areas would complicate and slow the implementation of the excavation alternative and increase costs beyond those currently estimated. • As discussed under Excavation in Section 4.3.1, pre-treatment of SPL-impacted material has not been included under this alternative. If a pre-treatment step should be required for all or some of the excavated material, the technical feasibility of this alternative would become even more questionable.	See evaluation for Alternative LDU1/GW-2.
Administrative Feasibility		
	All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Development of offsite borrow source(s) for fill/grading materials would require coordination and approval from the affected agency. Onsite repository would need to substantively meet RCRA Subtitle C requirements.	See evaluation for Alternative LDU1/GW-2.
Availability of Services and Materials		
	Necessary engineering services and contractor services readily available for onsite repository design, construction, and maintenance. Low permeability soils for cap materials may require import from distant / out-of-state locations.	See evaluation for Alternative LDU1/GW-2.
Cost		
*Total Present Worth Cost**	*Note: The cost estimate for this alternative does not include a pre-treatment step within the excavation process option. If a pre-treatment step should be required for all or some of the excavated material (see Section 4.3.1), additional costs not included within this estimate would be incurred.*	
$ 165,590,849	--	--

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU2-1: No Action

Description of Alternative:

- Maintenance of the existing caps on the East Landfill and Sanitary Landfill;
- Maintenance of the existing soil covers on the Asbestos Landfills;
- Maintenance of the existing fences where present to limit access to these waste management units; and
- No additional actions.

This alternative is described in Section 5.2.1.

Evaluation Criteria
Threshold Criteria
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Contaminants would remain in place. The direct contact exposure route would remain complete.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil.
Compliance with Action-Specific ARARs
No action would be taken and therefore, there are no action-specific ARARs.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
Balancing Criteria
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Potential risks would not be managed.
Adequacy and Reliability of Controls
Controls would not be in place.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
No change to the toxicity, mobility and volume of contaminants.
Degree to Which Treatment is Irreversible
No treatment used.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment.
Short-Term Effectiveness
Protection of Community During Remedial Actions
No remedial action performed.
Protection of Workers During Remedial Actions
No remedial action performed.
Environmental Impacts During Remedial Actions
No remedial action performed.
Time Until RAOs are Achieved
RAOs would not be achieved.
Implementability
Technical Feasibility
Feasible; no actions would be taken.
Administrative Feasibility
Feasible; no actions would be taken.
Availability of Services and Materials
No services or materials required.
Cost
*Total Present Worth Cost**
$ 797,715

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative LDU2-2: Containment via Capping

Description of Alternative:

- Maintaining the existing caps on the East Landfill and Sanitary Landfill;
- Containment of the Industrial Landfill via capping;
- Improving the existing soil cover at the Asbestos Landfills;
- Establishment of ICs and ECs.

This alternative is described in Section 5.2.2.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Maintaining, improving, and/or constructing new landfill caps at the LDU2 WMUs would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3) and with impacted waste materials within the WMUs. ICs and ECs would ensure the long-term effectiveness of the remedy by minimizing the potential for damage to the caps. Cap integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; cap design and construction with ICs; and post closure O&M.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would substantially reduce the potential risks from contaminants left in place by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Landfills DU2.
Adequacy and Reliability of Controls
Capping would be adequate and reliable in preventing direct contact of COCs remaining in place, given that integrity of the caps is properly maintained through regular inspections and repairs. Requires reliance on ICs to prevent intrusive activities into impacted material and damage to the caps.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity and volume of contaminants in the Landfills DU2 would remain. The containment of the material via capping would reduce the potential mobility of COCs in the Landfills DU2, which is limited under current conditions based on the results of the RI.
Degree to Which Treatment is Irreversible
No treatment used; reduction in mobility is reversible if ICs and caps are not maintained.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, capping of landfills is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The western property line (i.e., the property line nearest the community) is located approximately 5,000 ft away from the Industrial Landfill and even farther from the other Landfills DU2 WMUs; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during cap construction. This alternative includes improving the existing caps on the Asbestos Landfills; therefore disturbance of existing asbestos is not anticipated; however, the remedial design would include provisions for asbestos control in accordance with the substantive requirements of the applicable ARARs. Construction risks would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during construction of caps assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following construction of caps and establishment of ICs, which are expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; would not require treatability/ pilot studies.
Administrative Feasibility
All activities would be conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow sources for cover materials would require coordination and approval from the affected agency.
Availability of Services and Materials
Necessary engineering services readily available for cap installation and maintenance. Soils for cover materials may require import from offsite sources.
Cost
*Total Present Worth Cost**
$ 6,967,323

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative SO-1: No Action

Description of Alternative:

- No Action.

This alternative is described in Section 5.3.1.

Evaluation Criteria
Threshold Criteria
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Contaminants would remain in place. The direct contact exposure route, including exposure to small range receptors, would remain complete.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil.
Compliance with Action-Specific ARARs
No action would be taken and therefore, there are no action-specific ARARs.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
Balancing Criteria
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Potential risks would not be managed.
Adequacy and Reliability of Controls
Controls would not be in place.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
No change to the toxicity, mobility and volume of contaminants.
Degree to Which Treatment is Irreversible
No treatment used.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment.
Short-Term Effectiveness
Protection of Community During Remedial Actions
No remedial action performed.
Protection of Workers During Remedial Actions
No remedial action performed.
Environmental Impacts During Remedial Actions
No remedial action performed.
Time Until RAOs are Achieved
RAOs would not be achieved.
Implementability
Technical Feasibility
Feasible; no actions would be taken.
Administrative Feasibility
Feasible; no actions would be taken.
Availability of Services and Materials
No services or materials required.
Cost
*Total Present Worth Cost**
$0

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative SO-2: Covers with Hotspot Excavation

Description of Alternative:

- Install a soil cover for select areas of spatially concentrated COC distribution within the Soil DU.
- Establish ICs in cover areas and land use restrictions for the DU to allow for commercial or industrial use, only.
- Excavation of discontinuous, isolated soil hotspots outside of cover footprints, as needed. Excavated materials could be consolidated underneath covers, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

This alternative is described in Section 5.3.2.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Cover would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3). ICs would minimize the potential for damage to the cover and/or direct contact with impacted soil under current and future Site uses. Cover integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling, consolidation, and disposal; soil cover construction with ICs; and post closure O&M.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would substantially reduce the potential risks from contaminants left in place by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Soil DU.
Adequacy and Reliability of Controls
A cover would be adequate and reliable in preventing direct contact of COCs remaining in place, given that cover integrity is properly maintained through regular inspections and repairs. Requires reliance on ICs to prevent intrusive activities into impacted material and damage to the cover.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity and volume of contaminants in the Soil DU would remain. However, the area of impacted material (and subsequently the exposure potential to contaminants) in the Soil DU would be reduced by approximately 1.72 acres. The consolidation of material and containment via soil cover would reduce the potential mobility of COCs in the Soil DU, which is limited under current conditions based on the results of the RI.
Degree to Which Treatment is Irreversible
No treatment used; reduction in mobility is reversible if ICs and cover are not maintained.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, a cover is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,000 or more ft away from the Soil DU AOCs; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation and installation of the cover would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during cover construction assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cover construction and establishment of ICs, which are expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; would not require treatability/ pilot studies.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow sources for cover materials would require coordination and approval from the affected agency.
Availability of Services and Materials
Necessary engineering services readily available for cover installation and maintenance. Soils for cover materials may require import from offsite sources.
Cost
*Total Present Worth Cost**
$ 1,606,306

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative SO-3: *In Situ* Phytoremediation with Hotspot Excavation

Description of Alternative:

- *In situ* treatment of spatially concentrated PAH-impacted soils via phytoremediation.
- Establish ICs for areas of phytoremediation until treatment is completed, and land use restrictions for the DU to allow for commercial or industrial use, only.
- Excavation of discontinuous, isolated soil hotspots outside of treatment footprints, as needed. Excavated materials could be consolidated within treatment areas, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

This alternative is described in Section 5.3.3.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Alternative would mitigate the potential risk to humans and ecological receptors by eliminating potential for direct contact with impacted soil resulting in exceedances of PRGs (as described in Section 3.3); excavation of select AOCs would remove the exposure pathway in those areas, and phytoremediation of PAH-impacted material in other AOCs would reduce the concentrations of PAHs to acceptable levels.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil; this alternative would address potential risk in the Soil DU by breaking the risk pathway for direct contact exposures (AOCs employing excavation) or by reducing PAH concentrations to acceptable levels via treatment (AOCs employing phytoremediation) until RAOs established in the FSWP (e.g., PRGs) are met.
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling, consolidation, and disposal; establishment of phytoremediation treatment areas; and post closure O&M.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would remove or treat contaminants exceeding small range receptor PRGs and/or resulting in exceedances of PRGs, eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Soil DU
Adequacy and Reliability of Controls
No control measures would be necessary after successful completion of the phytoremediation treatment since all contaminated materials exceeding small range receptor PRGs and/or resulting in exceedances of PRGs would have been removed or treated.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
Phytoremediation would reduce concentrations of PAHs in soils in AOCs where employed.
Amount of Hazardous Materials Destroyed or Treated
All hazardous PAH-impacted surficial and shallow soils in the Soil DU (to be delineated during remedial design) would be treated via phytoremediation.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Phytoremediation would reduce concentrations of PAHs to acceptable levels in AOCs where employed, reducing toxicity, mobility, and volume of hazardous materials. Excavation of AOC B (Former Drum Storage Area) may reduce potential leachability (mobility) of cyanide and fluoride if this material is in fact a contributing source to the elevated cyanide and fluoride concentrations in groundwater.
Degree to Which Treatment is Irreversible
Both excavation and treatment, once successfully completed, would be irreversible.
Type and Quantity of Residuals Remaining After Treatment
None; soils after phytoremediation treatment would be comparable to other onsite surficial and shallow soil.
Statutory Preference for Treatment
Would meet statutory preference for treatment.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,000 or more ft away from the Soil DU AOCs; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation and establishment of phytoremediation treatment areas would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during excavation and establishment of phytoremediation treatment areas assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met following successful completion of the phytoremediation treatment, which is expected to be completed within 10 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; may require a pilot study prior to implementation.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials
Necessary engineering services readily available for establishment of phytoremediation treatment areas and maintenance. Topsoil, if needed, may require import from offsite sources.
Cost
*Total Present Worth Cost**
$ **1,171,948**

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative SO-4: Excavation with Onsite Consolidation

Description of Alternative:

- Excavate impacted soil in the Soil DU with disposal at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).
- Establish land use restrictions for the DU to allow for commercial or industrial use, only.

This alternative is described in Section 5.3.4.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
The potential risk to humans and ecological receptors from direct contact with impacted soil would be eliminated by excavating all impacted material resulting in exceedances of PRGs (as described in Section 3.3) in the DU. This material would be consolidated at another part of the Site and properly contained via cover/cap.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil; this alternative would address potential risk by removing the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs).
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; and onsite waste handling, consolidation, and disposal.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would remove contaminants exceeding small range receptor PRGs and/or resulting in exceedances of PRGs, eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would mitigate potential risk to small range receptors and result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the Soil DU.
Adequacy and Reliability of Controls
No control measures would be necessary since all contaminated materials exceeding small range receptor PRGs and/or resulting in exceedances of PRGs would be removed from the Soil DU.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
The amount of hazardous materials in the Soil DU would be substantially reduced; however, impacted soil would be consolidated at another part of the Site and the overall amount of hazardous materials at the Site would remain unchanged.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity, mobility, and volume of contaminants in the Soil DU would be substantially reduced; however, impacted soil would be consolidated at another part of the Site and the overall toxicity and volume of hazardous materials at the Site would remain unchanged.
Degree to Which Treatment is Irreversible
No treatment used; excavation of soil would result in irreversible reduction of toxicity, mobility, and volume of hazardous materials in the Soil DU.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, excavation is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,000 or more ft away from the Soil DU AOCs; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation activities would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during excavation activities assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following excavation, which is expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; would not require treatability/ pilot studies.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials
Necessary engineering services and materials readily available for excavation activities.
Cost
*Total Present Worth Cost**
$ **1,237,989**

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative NPP-1: No Action

Description of Alternative:

- No Action.

This alternative is described in Section 5.4.1.

Evaluation Criteria
Threshold Criteria
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Contaminants would remain in place. The direct contact exposure route would remain complete.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
Would not meet chemical-specific ARARs for surface water; there are no chemical-specific ARARs for soil or sediment.
Compliance with Action-Specific ARARs
No action would be taken and therefore, there are no action-specific ARARs.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
Balancing Criteria
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Potential risks would not be managed.
Adequacy and Reliability of Controls
Controls would not be in place.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
No change to the toxicity, mobility and volume of contaminants.
Degree to Which Treatment is Irreversible
No treatment used.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment.
Short-Term Effectiveness
Protection of Community During Remedial Actions
No remedial action performed.
Protection of Workers During Remedial Actions
No remedial action performed.
Environmental Impacts During Remedial Actions
No remedial action performed.
Time Until RAOs are Achieved
RAOs would not be achieved.
Implementability
Technical Feasibility
Feasible; no actions would be taken.
Administrative Feasibility
Feasible; no actions would be taken.
Availability of Services and Materials
No services or materials required.
Cost
*Total Present Worth Cost**
$0

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative NPP-2: Limited Excavation with Covers

Description of Alternative:

- Excavate impacted material in the influent and effluent ditches and consolidate in the North-East Percolation Pond;
- Install soil covers at the North-East and North-West Percolation Ponds with physical solidification as needed;
- Establish ICs and ECs, including land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.2.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Cover would mitigate the potential risk of human and ecological exposure through direct contact of impacted soil/sediment resulting in exceedances of PRGs (as described in Section 3.3). ICs would minimize the potential for damage to the cover and/or direct contact with impacted soil/sediment under current and future Site uses. Cover integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil or sediment; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs). Chemical-specific ARARs for surface water would be met by 1) preventing the direct contact of standing water with impacted surface soil/sediment by covering the impacted materials, and 2) eliminating the influx of COCs by decommissioning the influent pipes from which stormwater enters the North Percolation Pond system.
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling, consolidation, and disposal; soil cover construction with ICs; and post closure O&M.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would substantially reduce the potential risks from contaminants left in place over 10 acres in the North Percolation Pond DU by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the NPP DU.
Adequacy and Reliability of Controls
A cover would be adequate and reliable in preventing direct contact of COCs remaining in place, given that cover integrity is properly maintained through regular inspections and repairs. Requires reliance on ICs to prevent intrusive activities into impacted material and damage to the cover. This alternative would require maintenance of 10 acres of soil cover.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity and volume of contaminants in the NPP DU would remain. However, the area of impacted material (and subsequently the exposure potential to contaminants) in the NPP DU would be reduced by 1 acre. The consolidation of material and containment via soil cover would reduce the potential mobility of COCs in the NPP DU, which is limited under current conditions based on the results of the RI.
Degree to Which Treatment is Irreversible
No treatment used; reduction in mobility is reversible if ICs and cover are not maintained.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, a cover is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,500 or more ft away from the NPP DU; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation and installation of the cover would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during cover construction assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cover construction and establishment of ICs, which are expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; physical solidification, if needed, may require bench or field pilot studies.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow sources for cover materials would require coordination and approval from the affected agency.
Availability of Services and Materials
Necessary engineering services readily available for cover installation and maintenance. Soils for cover materials may require import from offsite sources.
Cost
*Total Present Worth Cost**
$ 3,129,010

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative NPP-3: Excavation with Cover

Description of Alternative:

- Excavate impacted material in the North-West Percolation Pond, influent ditch, and effluent ditch;
- Consolidate excavated materials and install soil cover at the North-East Percolation Pond with physical solidification as needed;
- Establish ICs and ECs, including land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.3.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Cover would mitigate the potential risk of human and ecological exposure through direct contact of impacted soil/sediment resulting in exceedances of PRGs (as described in Section 3.3). ICs would minimize the potential for damage to the cover and/or direct contact with impacted soil/sediment under current and future Site uses. Cover integrity would be maintained through regular inspections and repairs; reporting of the verification of the effectiveness of ICs would be conducted, as necessary.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil or sediment; this alternative would address potential risk by breaking the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs). Chemical-specific ARARs for surface water would be met by decommissioning the influent pipes from which stormwater enters the North Percolation Pond system via the North-East Percolation Pond and by addressing the potential risk attributed to soil/sediment in the DU.
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; onsite waste handling, consolidation, and disposal; soil cover construction with ICs; and post closure O&M.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would substantially reduce the potential risks from contaminants left in place over 2 acres in the North Percolation Pond DU by covering impacted material resulting in exceedances of PRGs with clean material, effectively eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the NPP DU.
Adequacy and Reliability of Controls
A cover would be adequate and reliable in preventing direct contact of COCs remaining in place, given that cover integrity is properly maintained through regular inspections and repairs. Requires reliance on ICs to prevent intrusive activities into impacted material and damage to the cover. This alternative would require maintenance of 2 acres of soil cover.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
No reduction in amount of hazardous materials.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity and volume of contaminants in the NPP DU would remain. However, the area of impacted material (and subsequently the exposure potential to contaminants) in the NPP DU would be reduced by 9 acres. The consolidation of material and containment via soil cover would reduce the potential mobility of COCs in the NPP DU, which is limited under current conditions based on the results of the RI.
Degree to Which Treatment is Irreversible
No treatment used; reduction in mobility is reversible if ICs and cover are not maintained.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, a cover is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,500 or more ft away from the NPP DU; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation and installation of the cover would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during cover construction assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following cover construction and establishment of ICs, which are expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; physical solidification, if needed, may require bench or field pilot studies.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative. Developments of offsite borrow sources for cover materials would require coordination and approval from the affected agency.
Availability of Services and Materials
Necessary engineering services readily available for cover installation and maintenance. Soils for cover materials may require import from offsite sources.
Cost
*Total Present Worth Cost**
$ 2,346,093

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative NPP-4: Excavation with Onsite Consolidation

Description of Alternative:

- Excavate impacted material in the North-East Percolation Pond, North-West Percolation Pond, influent ditch, and effluent ditch;
- Consolidate excavated materials at the Wet Scrubber Sludge Pond with physical solidification as needed;
- Establish land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.4.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
The potential risk of human and ecological exposure through direct contact of impacted soil/sediment would be mitigated by excavating all impacted material resulting in exceedances of PRGs (as described in Section 3.3) in the DU. This material would be consolidated at another part of the Site and properly contained via cover/cap.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil or sediment; this alternative would address potential risk by removing the risk pathway for direct contact exposures and meeting RAOs established in the FSWP (e.g., PRGs). Chemical-specific ARARs for surface water would be met by decommissioning the influent pipes from which stormwater enters the North Percolation Pond system via the North-East Percolation Pond and by addressing the potential risk attributed to soil/sediment in the DU.
Compliance with Action-Specific ARARs
Alternative would be designed to meet action-specific ARARs related to worker protection, health, and safety; and onsite waste handling, consolidation, and disposal.
Compliance with Location-Specific ARARs
No location-specific ARARs have been identified for this alternative.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Alternative would remove contaminants resulting in exceedances of PRGs, eliminating the direct contact exposure pathway and the associated risks. Successful implementation of this alternative would result in an ELCR below 1E-05 and HQ < 1 for both human health and ecological receptors in the NPP DU.
Adequacy and Reliability of Controls
No control measures would be necessary since all contaminated materials resulting in exceedances of PRGs would be removed from the NPP DU.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
The amount of hazardous materials in the NPP DU would be substantially reduced; however, impacted soil/sediment would be consolidated at another part of the Site and the overall amount of hazardous materials at the Site would remain unchanged.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
Toxicity, mobility, and volume of contaminants in the NPP DU would be substantially reduced; however, impacted soil/sediment would be consolidated at another part of the Site and the overall toxicity and volume of hazardous materials at the Site would remain unchanged.
Degree to Which Treatment is Irreversible
No treatment used; excavation of soil/sediment would result in irreversible reduction of toxicity, mobility, and volume of hazardous materials in the NPP DU.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment; however, excavation is a common remedy.
Short-Term Effectiveness
Protection of Community During Remedial Actions
The property line is located approximately 3,500 or more ft away from the NPP DU; consequently, no impacts to community are anticipated. However, as necessary, ECs would be used to protect the community from dust, vapors, and noise.
Protection of Workers During Remedial Actions
Minimal potential exposure risk to workers during excavation activities; construction risk during excavation activities would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE.
Environmental Impacts During Remedial Actions
Minimal potential risks to the environment during excavation activities assuming implementation of adequate erosion controls.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted material resulting in exceedances of PRGs would be met immediately following excavation and establishment of ICs, which are expected to be completed within 2 years.
Implementability
Technical Feasibility
Would use established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites; physical solidification, if needed, may require bench or field pilot studies.
Administrative Feasibility
All activities are conducted onsite; no offsite access or third-party approvals needed. It is expected that regulatory approval should be obtainable for the components comprising this alternative.
Availability of Services and Materials
Necessary engineering services and materials readily available for excavation activities.
Cost
*Total Present Worth Cost**
$ 2,286,195

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative RADU-1: No Further Action

Description of Alternative:

- Implementation of Removal Action at the South Percolation Ponds including:
    - Decommissioning the influent pipe from which stormwater enters the South Percolation Pond system; and
    - Excavating impacted sediment in the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill).
- No Further Action.

This alternative is described in Section 5.5.1.

Evaluation Criteria
Threshold Criteria
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
Implementation of the Removal Action would mitigate the potential risk to ecological receptors by eliminating potential for ingestion and/or direct contact with impacted soil/sediment resulting in exceedances of PRGs (as described in Section 3.3). No further action would be taken to provide environmental protection. Under current and reasonably expected future uses, the River Area DU does not pose Site-related contamination risk to human health.
Compliance with ARARs
Compliance with Chemical-Specific ARARs
There are no chemical-specific ARARs for soil/sediment; the Removal Action would address potential risk by breaking the risk pathway for ingestion/direct contact exposures and meeting RAOs established for soil/sediment in the FSWP (e.g., PRGs). While the RAOs for surface water and sediment porewater would be addressed as a part of the Groundwater DU, no further action would be taken to demonstrate substantive requirements of chemical-specific ARARs have been met.
Compliance with Action-Specific ARARs
The Removal Action was designed to meet the substantive requirements of action-specific ARARs related to worker protection, health, and safety; waste transportation; stormwater management and erosion control. Under this alternative, no further action would be taken and therefore, there are no additional action-specific ARARs.
Compliance with Location-Specific ARARs
The Removal Action was designed to meet the substantive requirements of location-specific ARARs related to wetlands, floodplains, and wildlife. Under this alternative, no further action would be taken and therefore, there are no additional location-specific ARARs.
Balancing Criteria
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
Implementation of the Removal Action would reduce ingestion of and direct contact with metals from contaminated soil/sediment that would result in LOEC- or LOAEL-based HQs greater than 1 for ecological receptors. Potential risks from surface water and sediment porewater would not be managed or monitored under this Alternative.
Adequacy and Reliability of Controls
Controls would not be in place.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
No treatment used.
Amount of Hazardous Materials Destroyed or Treated
During the Removal Action, the amount of impacted soil/sediment in the River Area DU would be substantially reduced. Remedial activities associated with the Groundwater DU would result in reduction of contaminant concentrations in surface water and sediment porewater in the River Area DU.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
As a part of the Removal Action, the toxicity, mobility, and volume of contaminants in soil/sediment in the River Area DU would be substantially reduced. Remedial activities associated with the Groundwater DU would result in varying degrees of reduction in toxicity, mobility, and volume of contaminant concentrations in surface water and sediment porewater in the River Area DU.
Degree to Which Treatment is Irreversible
No treatment used; excavation of soil/sediment during the Removal Action would result in irreversible reduction of toxicity, mobility, and volume of impacted materials in the River Area DU.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment as a principal element of remediation.
Short-Term Effectiveness
Protection of Community During Remedial Actions
Implementation of the Removal Action is anticipated to have minimal impact to the community. Although the South Percolation Ponds are located adjacent to the Flathead River, which is commonly used by the public for recreational activities, construction is scheduled for late fall/winter of 2020 when no recreational floaters are anticipated. Also, the Flathead River is wide in this area providing ample room for public recreation. If recurring unauthorized entry occurs, additional signage on the riverbank would be installed for community protection. In addition, no impacts to the community are anticipated from disposal at the Industrial Landfill; the western property line (i.e., the property line nearest the community) is located approximately 5,000 ft away from the Industrial Landfill and the existing fencing around the landfill prevents unauthorized access. During implementation of the Removal Action, ECs would be used to protect the community from dust, vapors, and noise. Under this alternative, no further remedial action would be taken following the Removal Action.
Protection of Workers During Remedial Actions
During implementation of the Removal Action, there is minimal potential exposure risk to workers anticipated during excavation activities; construction risk during excavation activities would be mitigated by adherence to the Site-specific HASP, ECs (e.g., dust suppression), and use of PPE. Under this alternative, no further remedial action would be taken following the Removal Action.
Environmental Impacts During Remedial Actions
During implementation of the Removal Action, there are minimal potential risks to the environment during excavation activities; excavation activities will be performed outside the existing limits of flow for the Flathead River, and precautions will be implemented to protect and preserve the natural habitat such as the implementation of adequate erosion controls. Following excavation activities, removal of the dam under the Removal Action will have a positive impact on the environment by promoting reclamation of the natural habitat that previously existed at the South Percolation Ponds. Under this alternative, no further remedial action would be taken following the Removal Action.
Time Until RAOs are Achieved
The RAOs to minimize potential exposure to impacted soil/sediment material resulting in exceedances of PRGs would be met immediately following implementation of the Removal Action. The RAO to restore concentrations of metals in surface water is also expected to be met in the River Area DU immediately following implementation of the Removal Action. While the RAOs to restore concentrations of cyanide in surface water and sediment porewater would be addressed as a part of the Groundwater DU, no

	further action in the River Area DU would be taken to demonstrate RAOs have been achieved for surface water and sediment porewater.
Implementability	
Technical Feasibility	
	The Removal Action includes the use of established technologies that have been proven effective and reliable for remediation of these COCs and media at other sites. This alternative is feasible; no further actions would be taken.
Administrative Feasibility	
	During implementation of the Removal Action, all activities are conducted onsite; no offsite access or third-party approvals needed. This alternative is feasible; no further actions would be taken.
Availability of Services and Materials	
	Necessary engineering services and materials readily available for implementation of the Removal Action. No services or materials required for taking no further actions.
Cost	
*Total Present Worth Cost**	
	$0; does not include costs associated with the Removal Action.

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Alternative RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater

Description of Alternative:

- Implementation of Removal Action at the South Percolation Ponds including:
  - Decommissioning the influent pipe from which stormwater enters the South Percolation Pond system; and
  - Excavating impacted sediment in the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill).
- Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater.
- Monitoring of metals[1], fluoride, and PAHs[2] in the River Area DU surface water as identified in the Surface Water RAO and PRGs until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs).

[1] Aluminum, arsenic, barium, copper, iron, lead, mercury, and thallium
[2] Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene

This alternative is described in Section 5.5.2.

Evaluation Criteria
THRESHOLD CRITERIA
Overall Protection of Human Health and the Environment
How Alternative Provides Human Health and Environmental Protection
See Alternative RADU-1 for Removal Action evaluation. Routine sampling and analysis of total cyanide in surface water and free cyanide in sediment porewater would demonstrate that concentrations of these COCs are decreasing over time. Initial monitoring rounds would also include sampling of surface water metal COCs that exceed PRGs (i.e., aluminum, barium, copper, and iron) to demonstrate that removal of the influent pipe from which stormwater enters the South Percolation Pond system performed under the Removal Action eliminates the source of aluminum and other metals to surface water in the River Area DU. Other metals (i.e., arsenic, lead, mercury, and thallium), fluoride, and PAHs (i.e., benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene), which have exceeded the Montana DEQ-7 surface water standards for human health in at least one sample, would also initially be monitored in surface water in the River Area DU until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs).
Compliance with ARARs
Compliance with Chemical-Specific ARARs
See Alternative RADU-1 for Removal Action evaluation. Long-term monitoring of surface water and sediment porewater would demonstrate substantive requirements of chemical-specific ARARs have been met.
Compliance with Action-Specific ARARs
See Alternative RADU-1 for Removal Action evaluation. Long-term monitoring of surface water and sediment porewater is not anticipated to trigger any action-specific ARARs.
Compliance with Location-Specific ARARs
See Alternative RADU-1 for Removal Action evaluation. Long-term monitoring of surface water and sediment porewater is not anticipated to trigger any location-specific ARARs.
BALANCING CRITERIA
Long-Term Effectiveness and Permanence
Magnitude of Residual Risk
See Alternative RADU-1 for Removal Action evaluation. The magnitude of residual risk following successful completion of long-term monitoring of surface water and sediment porewater would be less than target risk levels set by Montana DEQ-7 standards.
Adequacy and Reliability of Controls
See Alternative RADU-1 for Removal Action evaluation. Routine sampling and analysis of surface water and sediment porewater would demonstrate progress towards achieving RAOs.
Reduction of Toxicity, Mobility, and Volume through Treatment
Treatment Process Used and Materials Treated
See evaluation for Alternative RADU-1.
Amount of Hazardous Materials Destroyed or Treated
See evaluation for Alternative RADU-1.
Degree of Expected Reductions in Toxicity, Mobility, and Volume
See evaluation for Alternative RADU-1.
Degree to Which Treatment is Irreversible
See evaluation for Alternative RADU-1.
Type and Quantity of Residuals Remaining After Treatment
NA; no treatment used.
Statutory Preference for Treatment
Would not meet preference for treatment as a principal element of remediation.
Short-Term Effectiveness
Protection of Community During Remedial Actions
See Alternative RADU-1 for Removal Action evaluation. It is expected that long-term monitoring of surface water and sediment porewater would not have any adverse impacts on the community.
Protection of Workers During Remedial Actions
See Alternative RADU-1 for Removal Action evaluation. Potential physical and exposure hazards to workers sampling is limited. Risks would be mitigated by adherence to the Site-specific HASP and use of PPE.
Environmental Impacts During Remedial Actions
See Alternative RADU-1 for Removal Action evaluation. No short-term impacts to the environment are anticipated during routine sampling activities under the long-term monitoring program.
Time Until RAOs are Achieved
See Alternative RADU-1 for Removal Action evaluation. See LDU1/GW alternatives for estimates of the time to reduce migration of cyanide in groundwater that results in exceedances of Montana DEQ-7 aquatic life criteria in surface water and porewater at the River Area DU.
Implementability
Technical Feasibility
See Alternative RADU-1 for Removal Action evaluation. Long-term monitoring is an established technology that would not require treatability/ pilot studies; no technical feasibility issues associated with the monitoring component of this alternative.
Administrative Feasibility
See Alternative RADU-1 for Removal Action evaluation. There are no administrative feasibility issues associated with the long-term monitoring component of this alternative.
Availability of Services and Materials
See Alternative RADU-1 for Removal Action evaluation. Necessary services and materials are readily available for implementation of the long-term monitoring component of this alternative.

Cost
*Total Present Worth Cost**
$ 1,401,725; does not include costs associated with the Removal Action.

* This preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of the potential remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

Removal Action Alternative and Balancing Criteria Score[3]		Threshold Criteria[1]		Balancing Criteria and Relative Score[1]					
		Effectiveness		*Effectiveness*			*Implementability*	*Cost*	
		Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Present Value Cost[2]	
<u>Alternative LDU1/GW-1:</u> **No Action**	**Total: NA[3]**	Criterion Met: **No**	Criterion Met: **No**	**0**	**0**	**0**	**20**	**20**	**$ 769,050**
<u>Alternative LDU1/GW-3A:</u> **Containment via Capping and Upgradient Slurry Wall**	**Total: 66**	Criterion Met: **Yes**	Criterion Met: **Yes**	**15**	**9**	**10**	**16**	**16**	**$ 27,716,290**
<u>Alternative LDU1/GW-3C:</u> **Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction**	**Total: 65**	Criterion Met: **Yes**	Criterion Met: **Yes**	**15**	**12**	**16**	**10**	**12**	**$ 62,258,574**
<u>Alternative LDU1/GW-4A:</u> **Containment via Capping and Fully-Encompassing Slurry Wall**	**Total: 77**	Criterion Met: **Yes**	Criterion Met: **Yes**	**18**	**14**	**16**	**15**	**14**	**$ 45,642,497**
<u>Alternative LDU1/GW-4C:</u> **Containment via Capping and Fully-Encompassing Slurry Wall with Downgradient Extraction**	**Total: 74**	Criterion Met: **Yes**	Criterion Met: **Yes**	**18**	**16**	**20**	**10**	**10**	**$ 74,303,074**
<u>Alternative LDU1/GW-5B:</u> **Containment via Capping and Downgradient Hydraulic Control**	**Total: 60**	Criterion Met: **Yes**	Criterion Met: **Yes**	**10**	**10**	**12**	**14**	**14**	**$ 48,724,897**
<u>Alternative LDU1/GW-6:</u> **Excavation with Onsite Consolidation**	**Total: 42**	Criterion Met: **Yes**	Criterion Met: **Yes**	**20**	**12**	**5**	**5**	**0**	**$ 165,590,849**

[1] The relative performance of each alternative was evaluated with respect to each of the CERCLA evaluation criteria using the scoring system presented in Section 7. Threshold criteria are either fully met or not met, and balancing criteria are rated from 0 to 20 relative to the other alternatives for this DU. The scores have no independent value; they are only meaningful when compared among the different alternatives for the respective DU.
[2] The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of potential remedial alternatives. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
[3] The Balancing Criteria Score for an alternative is the sum of the relative scores for each of its five balancing criteria if and only if the two threshold criteria are met; for the No Action Alternative, the threshold criteria are not met and therefore the Balancing Criteria Score is not a numerical value.

Removal Action Alternative and Balancing Criteria Score[3]	Threshold Criteria[1]		Balancing Criteria and Relative Score[1]				
	Effectiveness		*Effectiveness*			*Implementability*	*Cost*
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Present Value Cost[2]
Alternative SO-1: **No Action**	Alternative SO-1 is the only alternative that would not be protective of human health and the environment.	There are no chemical-specific ARARs for soil, however Alternative SO-1 is the only alternative that would not meet RAOs established in the FSWP (e.g., PRGs). Under Alternative SO-1, no action would be taken and therefore there are no action- or location-specific ARARs.	The potential risks associated with the Soil DU would not be addressed or managed under Alternative SO-1. Receptors may be exposed to impacted materials in the absence of remedial measures. Alternative SO-1 would not have any controls in place.	No treatment used for Alternative SO-1. No reduction in toxicity, mobility, or volume under Alternative SO-1, though the mobility of contamination is limited under current conditions based on the results of the RI.	No remedial action performed under Alternative SO-1, so there would be no worker risks or additional risks to the community or the environment. However, the potential risks associated with the Soil DU would not be addressed. RAOs will not be achieved under Alternative SO-1.	Technically and administratively feasible as no action would be taken. No materials or services required under Alternative SO-1.	$ -
Total: NA[3]	Criterion Met: **No**	Criterion Met: **Yes**	**0**	**0**	**0**	**20**	**20**
Alternative SO-2: **Covers with Hotspot Excavation**	All active alternatives including Alternative SO-2 would be protective; Alternative SO-2 would prevent human health and ecological risk by eliminating exposure pathways through containment and hotspot removal.	There are no chemical-specific ARARs for soil, however all active alternatives including Alternative SO-2 would meet RAOs established in the FSWP (e.g., PRGs). All active alternatives can be designed to comply with action- and location-specific ARARs.	Alternative SO-2 would have greater residual risk and less permanence than Alternatives SO-3 and SO-4. The controls for Alternative SO-2 would be adequate and reliable if properly maintained.	No treatment used for Alternative SO-2. Under Alternative SO-2, the toxicity and volume of contaminated materials in AOCs employing covers would remain unchanged and are thus greater than under Alternatives SO-3 and SO-4. The mobility of contamination is limited under current conditions based on the results of the RI. Although not through treatment, contaminant mobility may be reduced under Alternative SO-2 by covering the impacted materials. The reduction in mobility could be reversed if the cover is not maintained. AOCs employing excavation offer reduction in toxicity, mobility, and volume of impacted material in the Soil DU comparable to that of Alternatives SO-3 and SO-4.	Of the active alternatives, Alternatives SO-2 and SO-3 have the lowest potential risks to workers; they have the least intrusive work and associated exposure risk compared to Alternative SO-4. The Soil DU Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met immediately following cover construction and establishment of ICs (within 2 years), comparable to Alternative SO-4 and sooner than Alternative SO-3.	Alternative SO-2 is technically feasible, comparable to the other active alternatives. Alternative SO-2 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative SO-2 and the other active alternatives. Soils for cover materials may require import from offsite sources; Alternative SO-2 would require the most cover material of all the alternatives.	$ 1,606,306
Total: 64	Criterion Met: **Yes**	Criterion Met: **Yes**	**10**	**12**	**20**	**12**	**10**

Table 7-3. Comparative Analysis of the Soil DU Alternatives
Columbia Falls Aluminum Company, LLC, Feasibility Study, 2000 Aluminum Drive, Columbia Falls, MT

Removal Action Alternative and Balancing Criteria Score[3]	Threshold Criteria[1]		Balancing Criteria and Relative Score[1]				
	Effectiveness		*Effectiveness*			*Implementability*	*Cost*
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Present Value Cost[2]
<u>Alternative SO-3:</u> ***In Situ*** **Phytoremediation with Hotspot Excavation**	All active alternatives including Alternative SO-3 would be protective; Alternative SO-3 would prevent human health and ecological risk by eliminating exposure pathways through treatment and hotspot removal.	There are no chemical-specific ARARs for soil, however all active alternatives including Alternative SO-3 would meet RAOs established in the FSWP (e.g., PRGs). All active alternatives can be designed to comply with action- and location-specific ARARs.	Alternatives SO-3 and SO-4 would have the least residual risk and greatest permanence of all the alternatives. Alternative SO-3 would achieve this by treating or removing the contaminants from the DU. Alternative SO-3 would not have any engineering controls in place after successful completion of the phytoremediation treatment.	Alternative SO-3 offers reduction in toxicity, mobility, and volume of impacted material through treatment in AOCs where phytoremediation is employed. The reduction of PAH concentrations would be irreversible, and contaminants would not be transferred to another part of the Site. AOCs employing excavation offer reduction in toxicity, mobility, and volume of impacted material in the Soil DU comparable to that of Alternatives SO-2 and SO-4.	Of the active alternatives, Alternatives SO-2 and SO-3 have the lowest potential risks to workers; they have the least intrusive work and associated exposure risk compared to Alternative SO-4. The Soil DU Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met following successful completion of the phytoremediation treatment (about 10 years), requiring more time than the other active alternatives.	Alternative SO-3 is technically feasible, comparable to the other active alternatives. Alternative SO-3 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative SO-3 and the other active alternatives. May require a pilot study prior to implementation. Topsoil, if needed, may require import from offsite sources; under Alternative SO-3, less cover material would be required than under Alternative SO-2.	$ 1,171,948
Total: 66	Criterion Met: **Yes**	Criterion Met: **Yes**	**20**	**20**	**5**	**8**	**13**
<u>Alternative SO-4:</u> Excavation with Onsite Consolidation	All active alternatives including Alternative SO-4 would be protective; Alternative SO-4 would prevent human health and ecological risk by eliminating exposure pathways through removal.	There are no chemical-specific ARARs for soil, however all active alternatives including Alternative SO-4 would meet RAOs established in the FSWP (e.g., PRGs). All active alternatives can be designed to comply with action- and location-specific ARARs.	Alternatives SO-3 and SO-4 would have the least residual risk and greatest permanence of all the alternatives. Alternative SO-4 would achieve this by removing the contaminants from the DU. Alternative SO-4 would not have any engineering controls in place.	No treatment used for Alternative SO-4. Alternative SO-4 offers reduction in toxicity, mobility, and volume of impacted material in the Soil DU by physically removing the contaminated material from the DU. This reduction in the Soil DU would be irreversible and is comparable to that of Alternative SO-3, however, under Alternative SO-4 the material is transferred to another part of the Site and the overall toxicity and volume of hazardous materials at the Site would remain unchanged.	Of the active alternatives, Alternative SO-4 has the greatest potential risks to workers; it has the most intrusive work and associated exposure compared to Alternatives SO-2 and SO-3. The Soil DU Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met immediately following excavation (within 2 years), comparable to Alternative SO-2 and sooner than Alternative SO-3.	Alternative SO-4 is technically feasible, comparable to the other active alternatives. Alternative SO-4 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative SO-4 and the other active alternatives.	$ 1,237,989
Total: 77	Criterion Met: **Yes**	Criterion Met: **Yes**	**20**	**15**	**15**	**15**	**12**

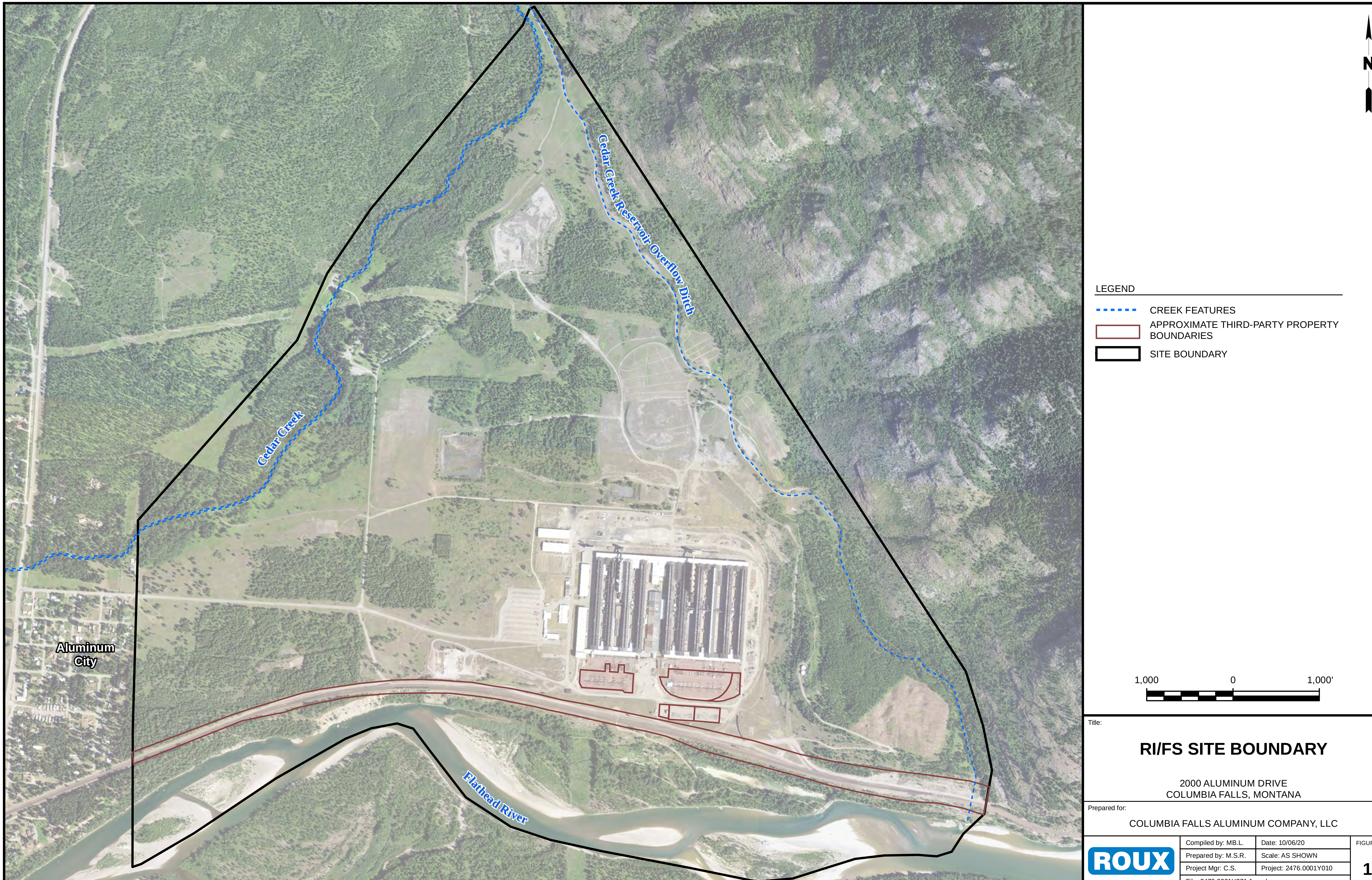
1 The relative performance of each alternative was evaluated with respect to each of the CERCLA evaluation criteria using the scoring system presented in Section 7. Threshold criteria are either fully met or not met, and balancing criteria are rated from 0 to 20 relative to the other alternatives for this DU. The scores have no independent value; they are only meaningful when compared among the different alternatives for the respective DU.
2 The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of potential remedial alternatives. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
3 The Balancing Criteria Score for an alternative is the sum of the relative scores for each of its five balancing criteria if and only if the two threshold criteria are met; for the No Action Alternative, at least one threshold criterion is not met and therefore the Balancing Criteria Score is not a numerical value.

Removal Action Alternative and Balancing Criteria Score[3]	Threshold Criteria[1]		Balancing Criteria and Relative Score[1]				
	Effectiveness		*Effectiveness*			*Implementability*	*Cost*
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Present Value Cost[2]
Alternative NPP-1: **No Action**	Alternative NPP-1 is the only alternative that would not be protective of human health and the environment.	Alternative NPP-1 is the only alternative that would not comply with chemical-specific ARARs. Under Alternative NPP-1, no action would be taken and therefore there are no action- or location-specific ARARs.	The potential risks associated with the NPPs would not be addressed or managed under Alternative NPP-1. Receptors may be exposed to impacted materials in the absence of remedial measures. Alternative NPP-1 would not have any controls in place.	No treatment used for all alternatives including Alternative NPP-1. No reduction in toxicity, mobility, or volume under Alternative NPP-1, though the mobility of contamination is limited under current conditions based on the results of the RI.	No remedial action performed under Alternative NPP-1, so there would be no worker risks or additional risks to the community or the environment. However, the potential risks associated with the NPPs would not be addressed. RAOs will not be achieved under Alternative NPP-1.	Technically and administratively feasible as no action would be taken. No materials or services required under Alternative NPP-1.	$ -
Total: NA[3]	Criterion Met: **No**	Criterion Met: **No**	**0**	**0**	**0**	**20**	**20**
Alternative NPP-2: **Limited Excavation with Covers**	All active alternatives including Alternative NPP-2 would be protective; Alternative NPP-2 would prevent human health and ecological risk by eliminating exposure pathways through containment, as does Alternative NPP-3.	All active alternatives including Alternative NPP-2 would comply with chemical-specific ARARs and can be designed to comply with action- and location-specific ARARs.	Residual risks are similar for Alternatives NPP-2 and NPP-3 since the volumes of remaining contaminated media are the same for both, and greater than for Alternative NPP-4. Alternative NPP-2 has a greater footprint for potential exposure (10 acres) compared to Alternative NPP-3 (2 acres). The controls for Alternative NPP-2 would be adequate and reliable if properly maintained. Alternatives NPP-2 and NPP-3 would have equal adequacy and reliability of controls since the cover type and thickness would be the same under both alternatives.	No treatment used for all alternatives including Alternative NPP-2. Under Alternatives NPP-2 and NPP-3, the toxicity and volume of contaminated materials would remain unchanged and are thus greater than under Alternative NPP-4. The mobility of contamination is limited under current conditions based on the results of the RI. Although not through treatment, contaminant mobility may be reduced similarly from Alternatives NPP-2 and NPP-3 by covering the impacted materials. The reduction in mobility could be reversed if the cover is not maintained.	Of the active alternatives, Alternative NPP-2 has the lowest potential risks to workers; it has the least intrusive work and associated exposure risk compared to Alternatives NPP-3 and NPP-4. The NPP Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met immediately following cover construction and establishment of ICs (within 2 years), comparable to the other active alternatives.	Alternative NPP-2 is technically feasible, comparable to the other active alternatives. Alternative NPP-2 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative NPP-2 and the other active alternatives. Soils for cover materials may require import from offsite sources; a greater amount of cover materials would be required for Alternative NPP-2 than for the other active alternatives.	$ 3,129,010
Total: 60	Criterion Met: **Yes**	Criterion Met: **Yes**	**10**	**10**	**20**	**10**	**10**

Removal Action Alternative and Balancing Criteria Score[3]	Threshold Criteria[1]		Balancing Criteria and Relative Score[1]				
	Effectiveness		*Effectiveness*			*Implementability*	*Cost*
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Present Value Cost[2]
Alternative NPP-3: Excavation with Cover	All active alternatives including Alternative NPP-3 would be protective; Alternative NPP-3 would prevent human health and ecological risk by eliminating exposure pathways through containment, as does Alternative NPP-2.	All active alternatives including Alternative NPP-3 would comply with chemical-specific ARARs and can be designed to comply with action- and location-specific ARARs.	Residual risks are similar for Alternatives NPP-2 and NPP-3 since the volumes of remaining contaminated media are the same for both, and greater than for Alternative NPP-4. Alternative NPP-3 has a smaller footprint for potential exposure (2 acres) compared to Alternative NPP-2 (10 acres). The controls for Alternative NPP-3 would be adequate and reliable if properly maintained. Alternatives NPP-2 and NPP-3 would have equal adequacy and reliability of controls since the cover type and thickness would be the same under both alternatives.	No treatment used for all alternatives including Alternative NPP-3. Under Alternatives NPP-2 and NPP-3, the toxicity and volume of contaminated materials would remain unchanged and are thus greater than under Alternative NPP-4. The mobility of contamination is limited under current conditions based on the results of the RI. Although not through treatment, contaminant mobility may be reduced similarly from Alternatives NPP-2 and NPP-3 by covering the impacted materials. The reduction in mobility could be reversed if the cover is not maintained.	Of the active alternatives, Alternative NPP-3 has the second lowest potential risks to workers; it has the second least intrusive work and associated exposure risk after Alternative NPP-2. The NPP Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met immediately following cover construction and establishment of ICs (within 2 years), comparable to the other active alternatives.	Alternative NPP-3 is technically feasible, comparable to the other active alternatives. Alternative NPP-3 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative NPP-3 and the other active alternatives. Soils for cover materials may require import from offsite sources; amount of cover materials required for Alternative NPP-3 would be less than that for Alternative NPP-2 and more than that for Alternative NPP-4.	$ 2,346,093
Total: 73	Criterion Met: **Yes**	Criterion Met: **Yes**	**15**	**15**	**18**	**12**	**13**
Alternative NPP-4: Excavation with Onsite Consolidation	All active alternatives including Alternative NPP-4 would be protective; Alternative NPP-4 would prevent human health and ecological risk by eliminating exposure pathways through removal.	All active alternatives including Alternative NPP-4 would comply with chemical-specific ARARs and can be designed to comply with action- and location-specific ARARs.	Alternative NPP-4 would have the least residual risk and greatest permanence of all the alternatives by removing the contaminants from the DU. Alternative NPP-4 would not have any ECs in place.	No treatment used for all alternatives including Alternative NPP-4. Of all the alternatives, Alternative NPP-4 offers the greatest reduction in toxicity, mobility, and volume of impacted material in the NPP DU by physically removing the contaminated material from the DU; however, the material is transferred to another part of the Site and the overall toxicity and volume of hazardous materials at the Site would remain unchanged. This reduction in the NPP DU would be irreversible.	Of the active alternatives, Alternative NPP-4 has the greatest potential risks to workers; it has the most intrusive work and associated exposure compared to Alternatives NPP-2 and NPP-3. The NPP Alternatives are not expected to pose additional risks to the community or the environment during implementation. RAOs are expected to be met immediately following excavation and establishment of ICs (within 2 years), comparable to the other active alternatives.	Alternative NPP-4 is technically feasible, comparable to the other active alternatives. Alternative NPP-4 is administratively feasible, comparable to the other active alternatives. Necessary engineering services are readily available for Alternative NPP-4 and the other active alternatives. Unlike Alternatives NPP-2 and NPP-3, no soils for cover materials would be required for this alternative.	$ 2,286,195
Total: 83	Criterion Met: **Yes**	Criterion Met: **Yes**	**20**	**20**	**15**	**15**	**13**

[1] The relative performance of each alternative was evaluated with respect to each of the CERCLA evaluation criteria using the scoring system presented in Section 7. Threshold criteria are either fully met or not met, and balancing criteria are rated from 0 to 20 relative to the other alternatives for this DU. The scores have no independent value; they are only meaningful when compared among the different alternatives for the respective DU.
[2] The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of potential remedial alternatives. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternatives. Detailed cost estimates for each alternative are presented in Appendix J and represent an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
[3] The Balancing Criteria Score for an alternative is the sum of the relative scores for each of its five balancing criteria if and only if the two threshold criteria are met; for the No Action Alternative, the threshold criteria are not met and therefore the Balancing Criteria Score is not a numerical value.

FIGURES



Title:

RI/FS SITE BOUNDARY

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX	Compiled by: MB.L.	Date: 10/06/20	FIGURE
	Prepared by: M.S.R.	Scale: AS SHOWN	1
	Project Mgr: C.S.	Project: 2476.0001Y010	
	File: 2476.0001Y271.1.mxd		

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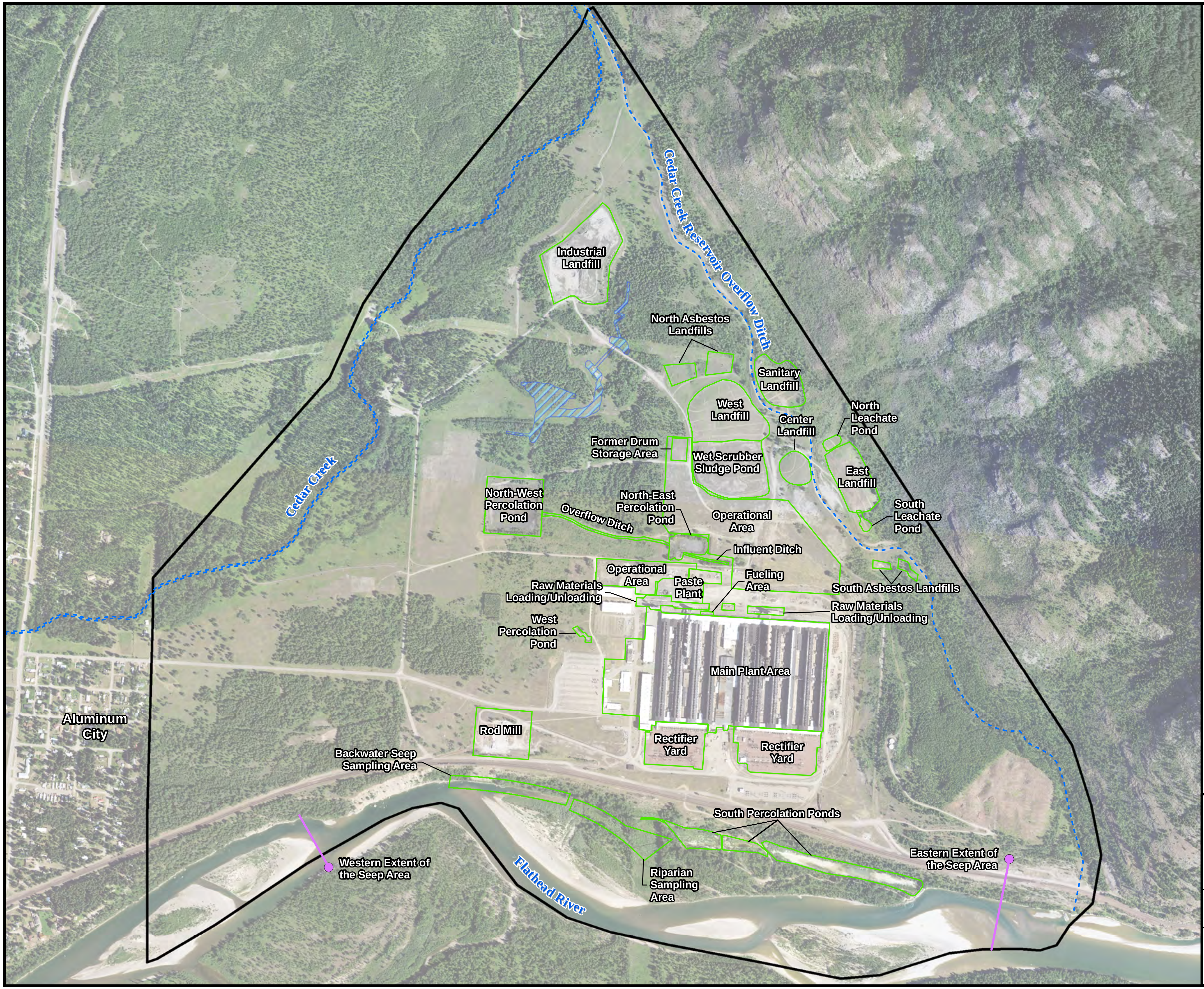

N

LEGEND

MARKER IDENTIFYING THE EXTENT OF THE SEEP AREA AS DEFINED IN THE FORMER MPDES PERMIT (#MT00300066)

SITE FEATURES

CREEK FEATURES

NORTHERN SURFACE WATER FEATURE EXTENT

SITE BOUNDARY

1,000 0 1,000'

Title:

SITE FEATURES

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 10/06/20	FIGURE
Prepared by: M.S.R.	Scale: AS SHOWN	2
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.2.mxd		

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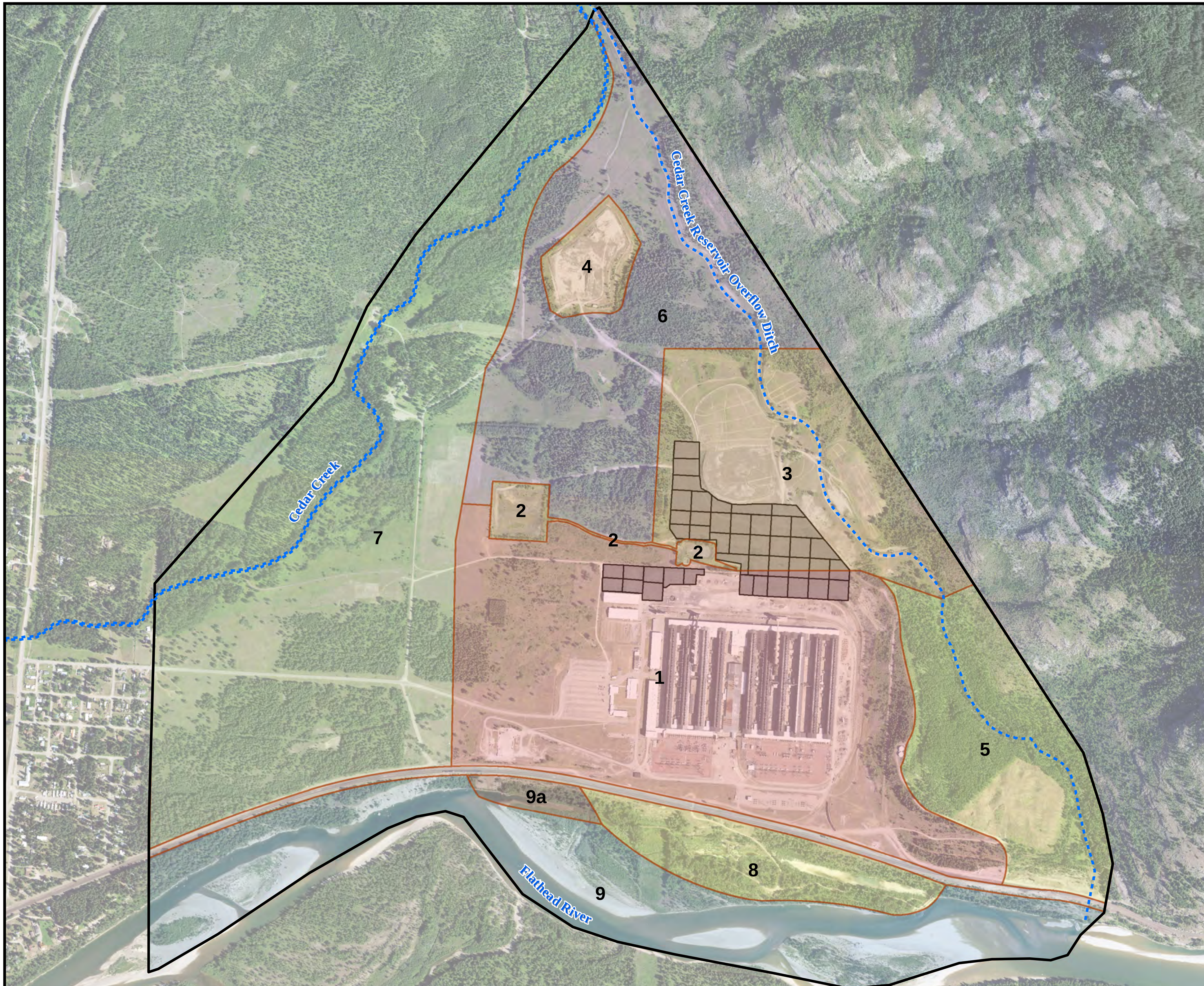

LEGEND

- CREEK FEATURES
- SITE BOUNDARY
- 1 MAIN PLANT AREA
- 2 NORTH PERCOLATION POND AREA
- 3 CENTRAL LANDFILLS AREA
- 4 INDUSTRIAL LANDFILL AREA
- 5 EASTERN UNDEVELOPED AREA
- 6 NORTH-CENTRAL UNDEVELOPED AREA
- 7 WESTERN UNDEVELOPED AREA
- 8 SOUTH PERCOLATION POND AREA
- 9 FLATHEAD RIVER AREA
- 9A BACKWATER SEEP SAMPLING AREA
- ISM GRID AREA

Title:

HUMAN HEALTH EXPOSURE AREAS

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 10/06/20	FIGURE
Prepared by: M.S.R.	Scale: AS SHOWN	3
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.3.mxd		

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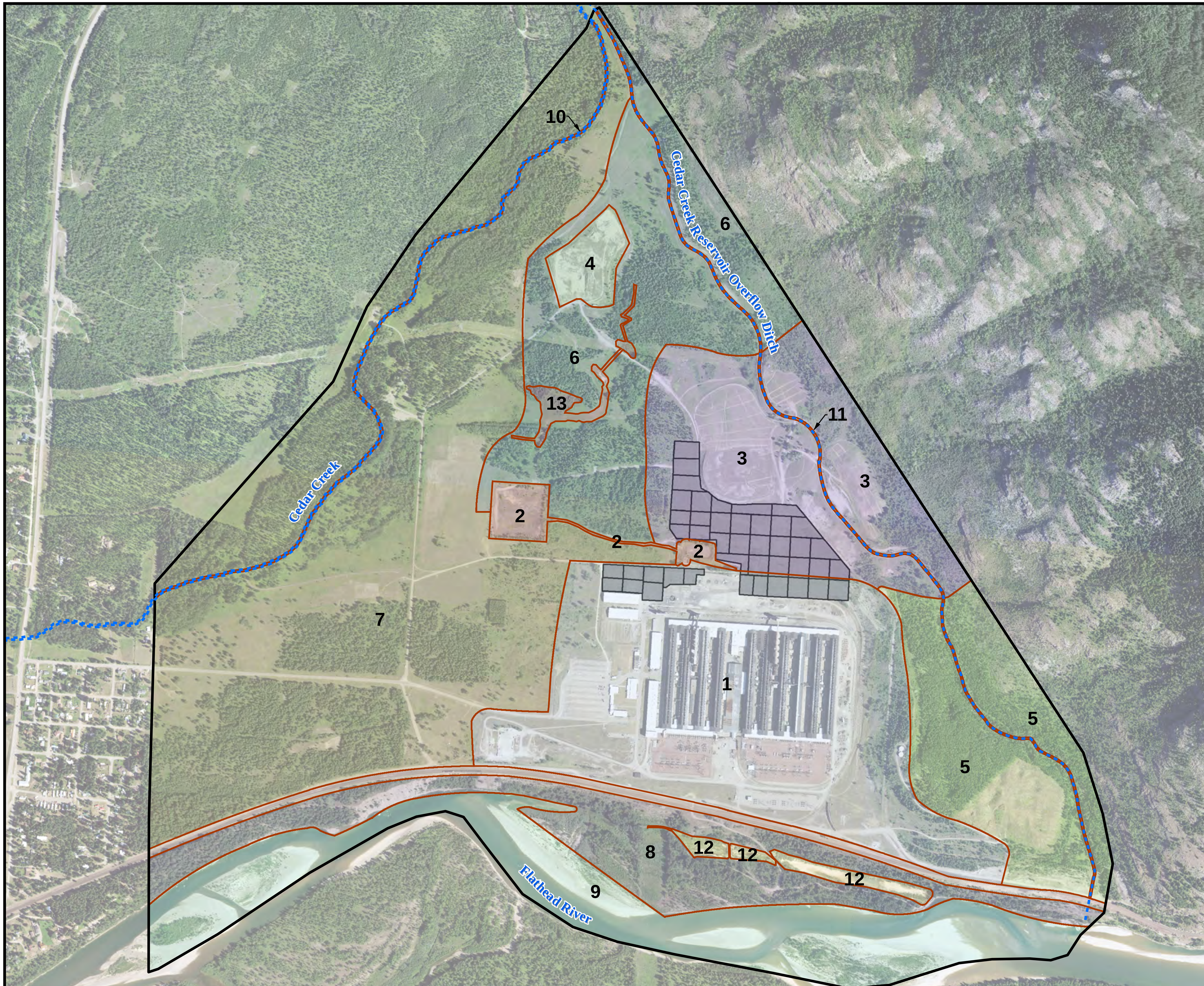

LEGEND

- CREEK FEATURES
- SITE BOUNDARY
- 1 MAIN PLANT AREA
- 2 NORTH PERCOLATION POND AREA
- 3 CENTRAL LANDFILLS AREA
- 4 INDUSTRIAL LANDFILL AREA
- 5 EASTERN UNDEVELOPED AREA
- 6 NORTH-CENTRAL UNDEVELOPED AREA
- 7 WESTERN UNDEVELOPED AREA
- 8 FLATHEAD RIPARIAN AREA
- 9 FLATHEAD RIVER AREA
- 10 CEDAR CREEK
- 11 CEDAR CREEK RESERVOIR OVERFLOW DITCH
- 12 SOUTH PERCOLATION PONDS
- 13 NORTHERN SURFACE WATER FEATURE
- ISM GRID AREA

Title:

ECOLOGICAL EXPOSURE AREAS

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

		FIGURE
Compiled by: C.S.	Date: 10/06/20	4
Prepared by: M.S.R.	Scale: AS SHOWN	
Project Mgr: C.S.	Project: 2476.0001Y010	
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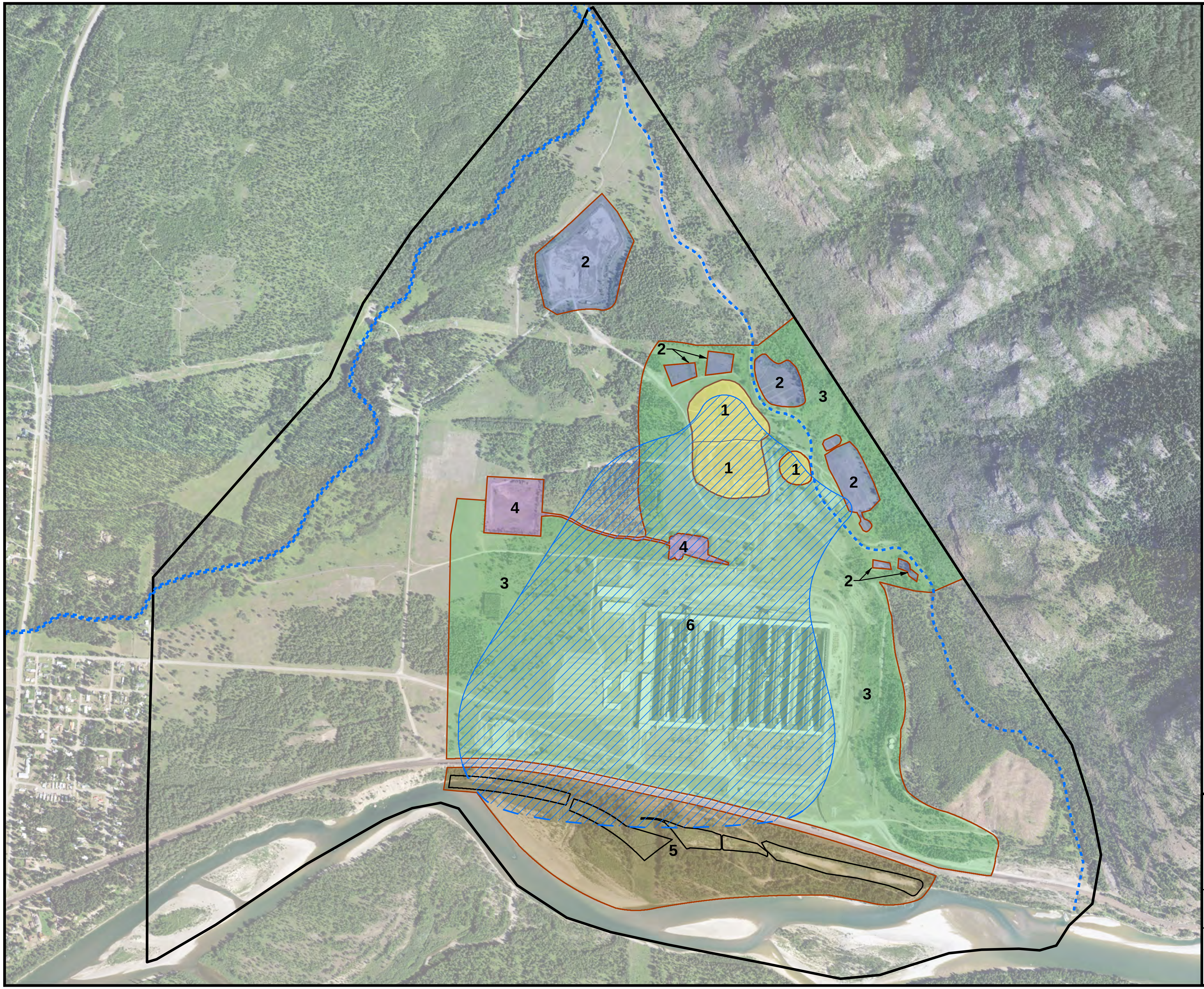

LEGEND

- CREEK FEATURES
- 1 LANDFILLS DECISION UNIT1
- 2 LANDFILLS DECISION UNIT2
- 3 SOIL DECISION UNIT
- 4 NORTH PERCOLATION POND DECISION UNIT
- 5 RIVER AREA DECISION UNIT
- 6 GROUNDWATER DECISION UNIT
- SITE FEATURES WITHIN RIVER AREA DU
- SITE BOUNDARY

NOTES

1. THE EXTENT OF THE GROUNDWATER DU FOR THE EVALUATION OF REMEDIAL ALTERNATIVES IS THE SITE-WIDE GROUNDWATER WITHIN THE UPPER HYDROGEOLOGIC UNIT UNDERLYING THE SITE. THE CONTOUR SHOWN REPRESENTS THE COMBINED AREAL FOOTPRINT OF ARSENIC, CYANIDE, AND FLUORIDE EXCEEDANCES OF PRGS.
2. LANDFILLS DU1 INCLUDES THE WEST LANDFILL, THE WET SCRUBBER SLUDGE POND, AND THE CENTER LANDFILL.
3. LANDFILLS DU2 INCLUDES THE EAST LANDFILL, THE INDUSTRIAL LANDFILL, THE SANITARY LANDFILL, AND THE NORTH AND SOUTH ASBESTOS LANDFILLS.

Title:

DECISION UNITS

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 10/06/20	FIGURE
Prepared by: M.S.R.	Scale: AS SHOWN	5
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.5.mxd		

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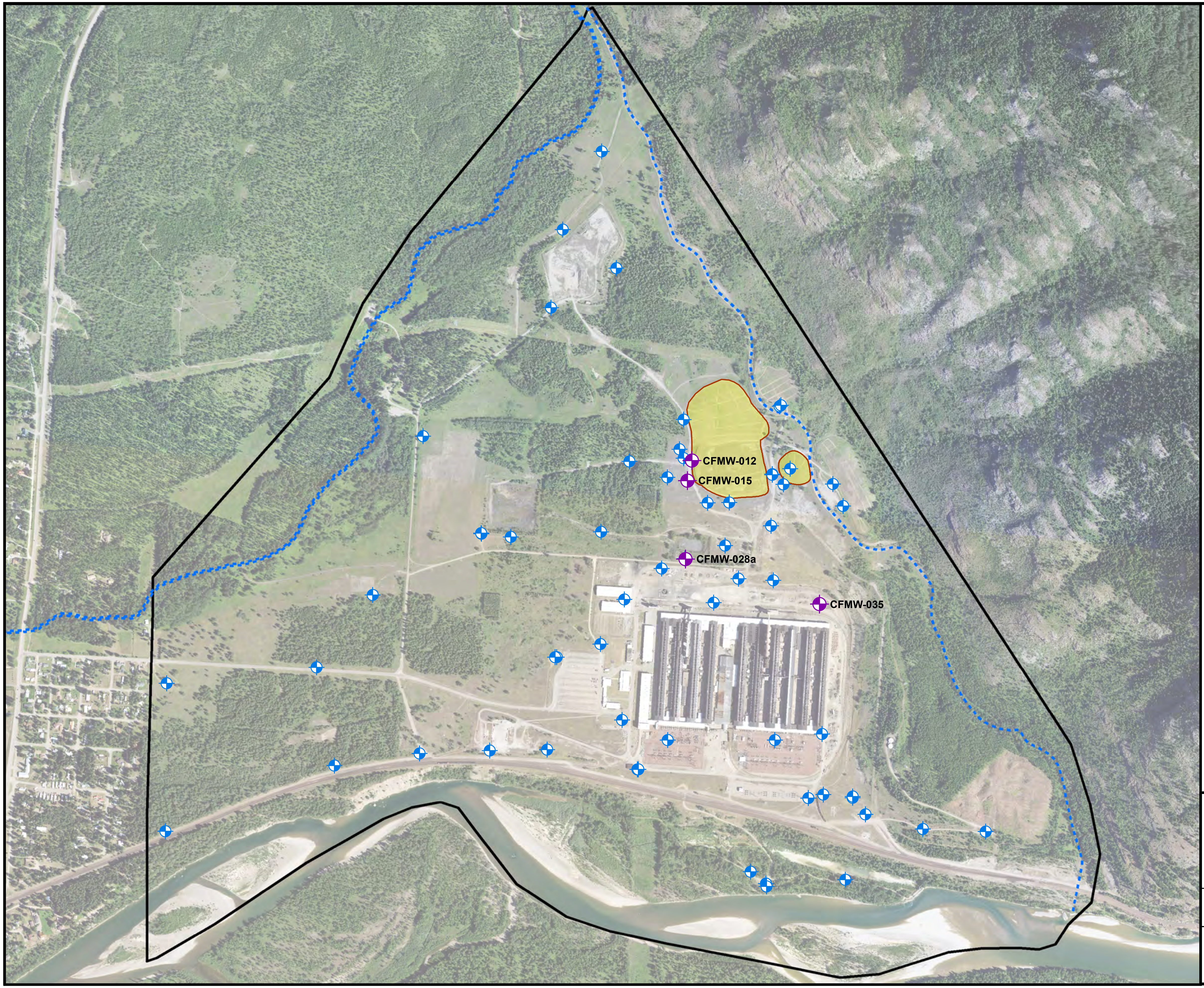

Title:

CONCENTRATIONS OF ARSENIC IN UPPER HYDROGEOLOGIC UNIT GROUNDWATER – HUMAN HEALTH PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX	Compiled by: C.S.	Date: 10/06/20	FIGURE
	Prepared by: M.S.R.	Scale: AS SHOWN	6
	Project Mgr: C.S.	Project: 2476.0001Y010	
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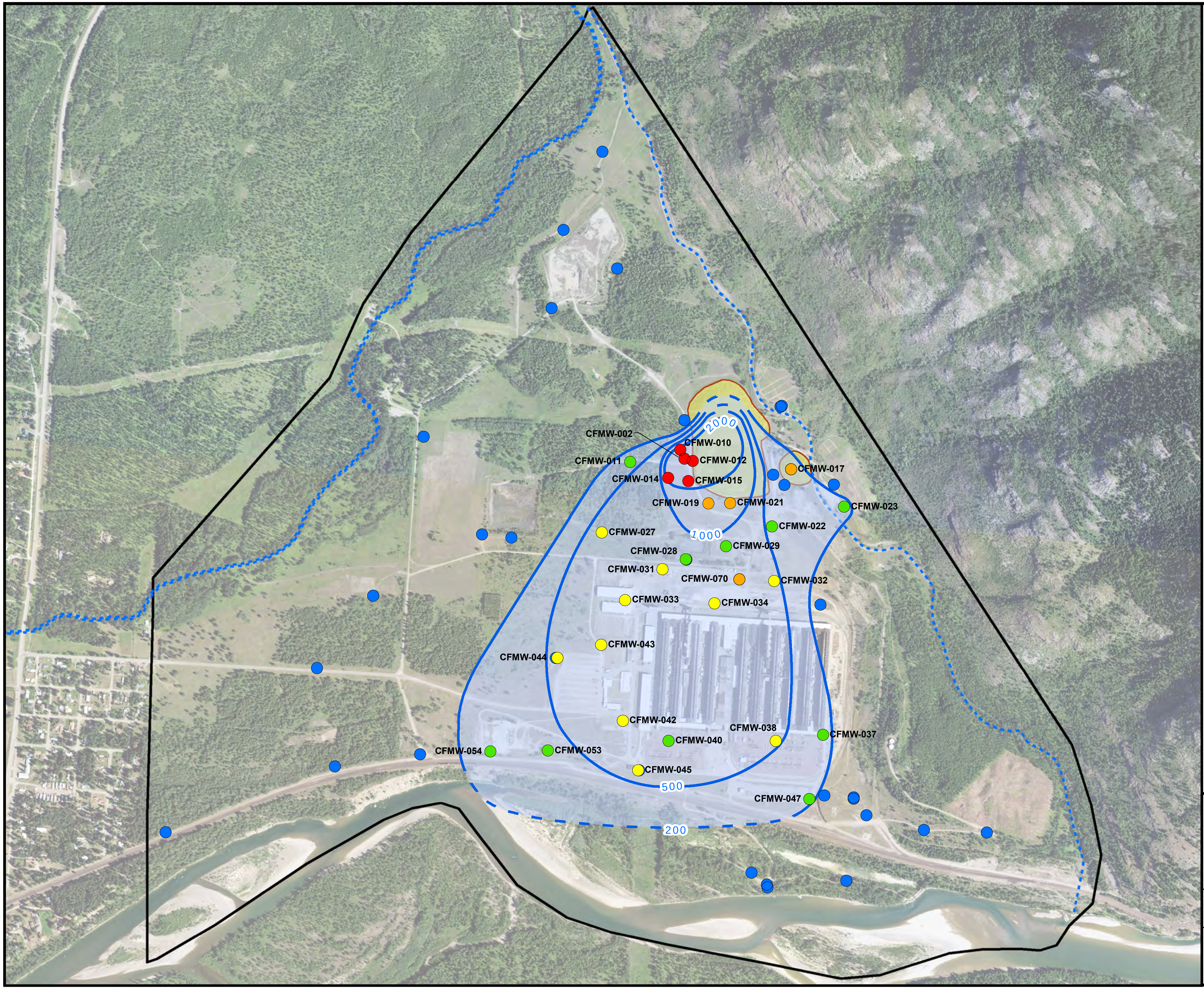

N

LEGEND

LANDFILLS DECISION UNIT1

APPROXIMATE EXTENT OF DETECTED CONCENTRATIONS GREATER THAN DEQ-7 GROUNDWATER HUMAN HEALTH STANDARDS

200 APPROXIMATE EXTENT OF DENOTED CONCENTRATION (DASHED WHERE INFERRED)

CREEK FEATURES

SITE BOUNDARY

CONCENTRATION LEGEND

- <200
- 200 - 500
- 500 - 1,000
- 1,000 - 2,000
- >2,000

NOTE

EPA RISK BASED SCREENING LEVEL DRINKING WATER MCL AND DEQ-7 GROUNDWATER HUMAN HEALTH STANDARD FOR TOTAL CYANIDE IS 200 µG/L

1,000 0 1,000'

Title:

CONCENTRATIONS OF TOTAL CYANIDE IN UPPER HYDROGEOLOGIC UNIT GROUNDWATER – HUMAN HEALTH PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 10/06/20	FIGURE
Prepared by: M.S.R.	Scale: AS SHOWN	
Project Mgr: C.S.	Project: 2476.0001Y010	7
File: 2476.0001Y271.7.mxd		

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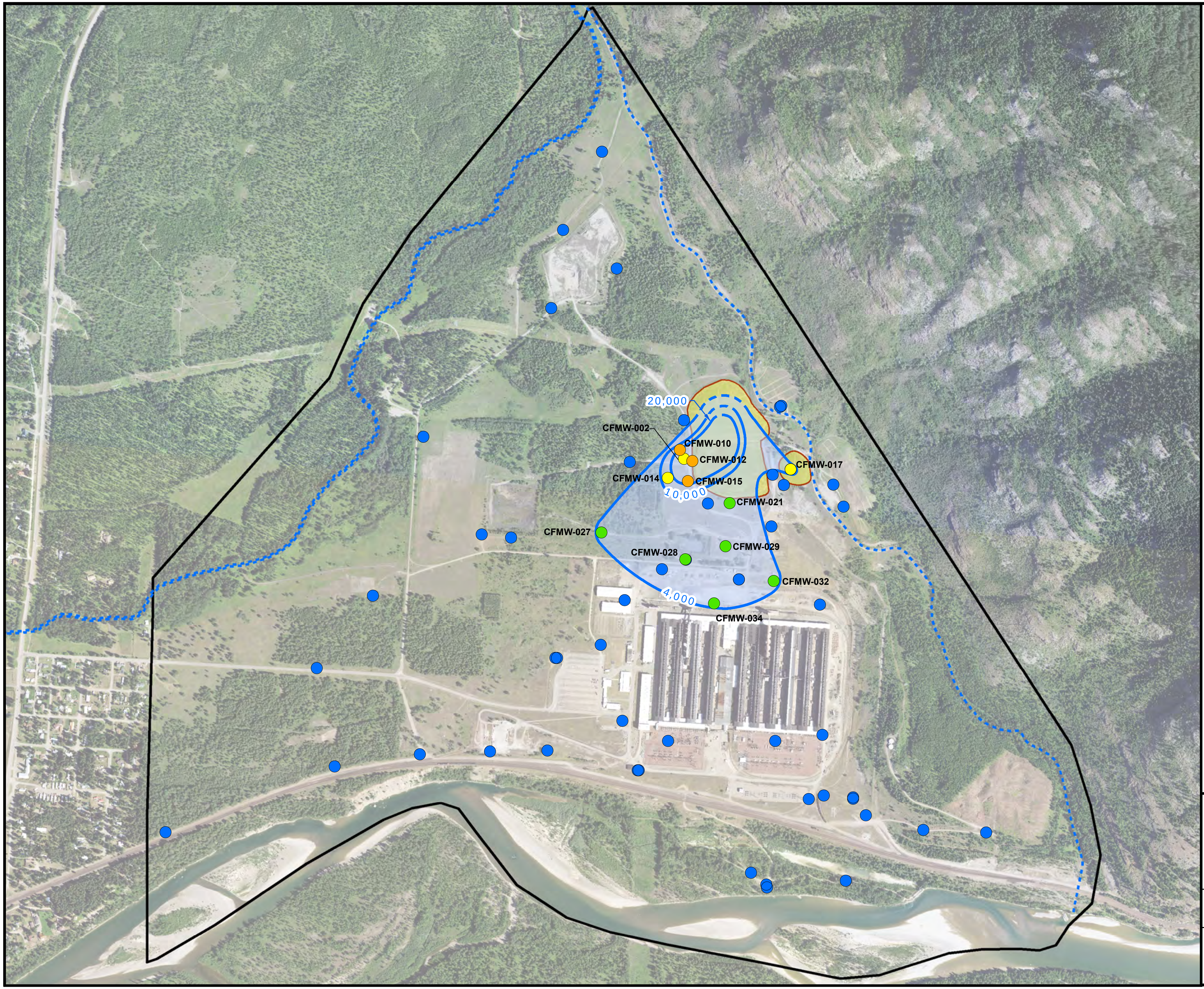

LEGEND

- LANDFILLS DECISION UNIT1
- APPROXIMATE EXTENT OF DETECTED CONCENTRATIONS GREATER THAN DEQ-7 GROUNDWATER HUMAN HEALTH STANDARDS
- 4,000 APPROXIMATE EXTENT OF DENOTED CONCENTRATION (DASHED WHERE INFERRED)
- CREEK FEATURES
- SITE BOUNDARY

CONCENTRATION LEGEND

- <4,000
- 4,000 - 10,000
- 10,000 - 20,000
- >20,000

NOTE

EPA RISK BASED SCREENING LEVEL DRINKING WATER MCL AND DEQ-7 GROUNDWATER HUMAN HEALTH STANDARD FOR FLUORIDE IS 4,000 µG/L

Title:

CONCENTRATIONS OF FLUORIDE IN UPPER HYDROGEOLOGIC UNIT GROUNDWATER – HUMAN HEALTH PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 10/06/20	FIGURE
Prepared by: M.S.R.	Scale: AS SHOWN	8
Project Mgr: C.S.	Project: 2476.0001Y010	
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APPENDICES

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APPENDIX A

Hydrogeologic Evaluation for Groundwater Remediation Alternatives

Appendix A
Hydrogeologic Evaluation for Groundwater Remediation Alternatives

Columbia Falls Aluminum Company
Columbia Falls, Flathead County Montana

Prepared for:

Columbia Falls Aluminum Company, LLC
2000 Aluminum Drive
Columbia Falls, Flathead County, Montana 59912

Prepared by:

Roux Environmental Engineering and Geology, D.P.C.
209 Shafter Street
Islandia, New York 11749

2476.0001Y271/CV-APA

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Plates

Acronym List

Acronym:	Definition:
ARARs	Applicable or Relevant and Appropriate Requirements
b	Saturated Thickness
CFAC	Columbia Falls Aluminum Company, LLC
Ci	Initial Contaminant Concentration
COC	Contaminant of Concern
Cs	Remedial Action Objective Concentration
DEQ-7	Montana Department of Environmental Quality Circular-7 Numeric Water Quality Standards
DU	Decision Unit
FS	Feasibility Study
FSWP	Feasibility Study Work Plan
ft	Feet
ft-bls	Feet Below Land Surface
ft-btoc	Feet Below Top of Casing
ft/day	Feet per Day
GIS	Geographic Information Systems
gpm	Gallons Per Minute
GW	Groundwater
i	Hydraulic Gradient
K	Hydraulic Conductivity
L	Downgradient Length of Contamination
LDU1	Landfills Decision Unit 1
MCL	Maximum Contaminant Limit
MDEQ	Montana Department of Environmental Quality
MNA	Monitored Natural Attenuation
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goals
PV	Pore Volume
Q	Extraction Rate
R	Retardation Factor
RAO	Remedial Action Objective
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
t	Time
µg/L	Micrograms per Liter
USEPA	United States Environmental Protection Agency
v	Groundwater Effective Velocity
w	Plume Width

1. Introduction

Roux Environmental Engineering and Geology, D.P.C. (Roux) has prepared this Hydrogeologic Evaluation for Groundwater Remediation Alternatives as an appendix to the Feasibility Study (FS) Report for the Superfund Site referred to as Anaconda Aluminum Co. Columbia Falls Reduction Plant, located two miles northeast of Columbia Falls in Flathead County, Montana (hereinafter, "the Site"). The purpose of the appendix is to describe the methodology used to develop conceptual locations; lengths and depths of slurry walls and/or permeable reactive barriers (PRBs); and conceptual design of groundwater extraction scenarios for the groundwater remediation alternatives being evaluated within the FS.

As described in Section 5.1 of the FS Report, there are 12 different remedial alternatives that address the Landfills Decision Unit 1 (LDU1) and Groundwater (GW) Decision Unit. These alternatives include various combinations of technologies that were retained for further evaluation based upon the results of the technology screening (Section 4 of the FS Report). The specific elements that are the subject of this hydrogeologic evaluation and the remedial alternatives to which they apply are outlined below:

- Upgradient Slurry Wall (LDU1/GW-3A; LDU1/GW-3B; and LDU1/GW-3C)
- Fully-Encompassing Slurry Wall (LDU1/GW-4A; LDU1/GW-4B; and LDU1/GW-4C)
- Downgradient Permeable Reactive Barrier (LDU1/GW-3B and LDU1/GW-4B)
- Hydraulic Control at the Source Area (LDU1/GW-5A and LDU1/GW-5C)
- Downgradient Hydraulic Control (LDU1/GW-5B and LDU1/GW-5C)
- Time Estimates for Achievement of Remedial Action Objectives (RAOs; all alternatives)

A brief summary of background information pertinent to the hydrogeologic evaluation is provided below, followed by discussion of each of the above items. Detailed information regarding the Site is presented within the body of the FS Report as well as within the Remedial Investigation Report (RI Report; Roux, 2020a). All of the Site-specific data referenced and utilized within the evaluations conducted herein are taken from the RI Report.

2. Background Information

The following section describes background information for the Site as it pertains to the hydrogeologic evaluation of groundwater remediation alternatives, including Site stratigraphy, groundwater hydrogeology and flow, and the Landfills DU1 as a source area. All data interpretation statements contained in this section have been taken from prior United States Environmental Protection Agency (USEPA) approved reports; specifically, the RI Report (Roux, 2020a) and Feasibility Study Work Plan (FSWP; Roux, 2020b).

<u>Site Stratigraphy</u>

A summary of regional and Site geology was provided in Section 2.4 of the Remedial Investigation/ Feasibility Study Work Plan (RI/FS Work Plan; Roux, 2015) based on previous investigations at the Site and published literature for the Kalispell Valley region. Lithologic data collected from soil borings completed as monitoring wells during the RI were utilized to generate generalized hydrogeologic cross-sections depicting the stratigraphy beneath the Site. Plate 1 presents the locations for four generalized hydrogeologic cross-sections, including:

- Section A-A' (Plate 2) oriented south-west to north-east and perpendicular to Teakettle Mountain, extending from the western boundary of the Site across the West Landfill;
- Section B-B' (Plate 3) oriented west to east across the southern portion of the Site, extending from the western boundary of the Site to the eastern boundary of the Site;
- Section C-C' (Plate 4) oriented north-west to south-east and parallel to Teakettle Mountain, extending from the western side of the Industrial Landfill to the Flathead River; and
- Section D-D' (Plate 5) oriented west to east, extending across the Former Drum Storage Area, Wet Scrubber Sludge Pond, and the East Landfill.

A description of the three stratigraphic units observed on the generalized cross-sections is provided below:

- The glacial outwash and alluvium layer typically contain coarse grained deposits (varying amounts of sand, gravel, and cobbles) with varying degrees of sorting and with lesser amounts of fines. The glacial outwash layer is encountered at the surface across most of the Site, with recent alluvial deposits present primarily near the southern border of the Site in the vicinity of the Flathead River. The cross sections indicate that the glacial outwash vertical thickness appears to be relatively consistent in areas north and west of the Main Plant Area, with average thicknesses ranging from 50 to 80 feet thick. The glacial outwash north of the Main Plant Area reaches maximum vertical thickness in the areas beneath the Former Drum Storage Area, West Landfill, Wet Scrubber Sludge Pond, and Center Landfill; where thickness was typically observed to range from 125 to 150 feet. The thickness tends to decrease close to Teakettle Mountain where bedrock elevations are shallower. Near the Flathead River, the vertical extent of the alluvial deposits is approximately 100 feet thick along the western/central southern boundary of the river.
- Glacial till was observed in the subsurface across most of the Site, typically beneath the coarse-grained outwash deposits. The glacial till layer is a dense, poorly-sorted deposit, consisting of varying amounts of sand, gravel, cobbles, silt, and clay. Based on field observations, the till was typically noted to be drier and denser than the overlying coarse-grained deposits. The maximum vertical extent of the glacial till is unknown in the areas to the north, west, and south of the Site, as the next lithologic layer was not encountered during drilling. This indicates that the till is typically at least 200 feet thick or greater in these areas.
- Based on regional geologic literature, beneath the unconsolidated glacial deposits are pre-Cambrian aged bedrock. The literature indicates that the depth to bedrock increases in a south-western direction across the Site, as you increase in distance from Teakettle Mountain. This

was confirmed during the Phase I Site Characterization. Bedrock was encountered in soil boring CFMW-023a, which is located to the east of the Site near Teakettle Mountain, at an approximate depth of 150 feet below land surface (ft-bls). Weathered bedrock was also encountered in soil boring CFMW-008a (also located to the east of the Site near Teakettle Mountain) at approximately 130 ft-bls, and a more competent bedrock within the same boring at approximately 245 ft-bls. Bedrock was not encountered in any of the other deep soil borings completed at the Site, indicating that depth to bedrock is greater than 300 ft-bls across most of the Site.

Groundwater Hydrogeology

The above described stratigraphic units underlying the Site form a complex hydrogeologic framework that influences groundwater elevations, groundwater flow, and contaminant migration beneath the Site. The Site stratigraphy results in two hydrogeologic units at the Site; these units are referred to as the upper hydrogeologic unit and the below upper hydrogeologic unit. The two hydrogeologic units and their characteristics are described in detail below.

The coarse-grained glacial outwash and alluvium deposits found above the glacial till are collectively referred to as the “upper hydrogeologic unit” at the Site. While the upper hydrogeologic unit appears to be continuous across the Site, the groundwater within the upper hydrogeologic unit appears to exist under perched water-table conditions. Glacial tills found in the “below upper hydrogeologic unit” were typically characterized as containing a higher percentage of fines, and as denser and drier than the overlying outwash and alluvium deposits. These observations indicate the till deposits likely have a lower hydraulic conductivity than the overlying outwash and alluvium deposits, which is supported by observations during monitoring well development where the new, deep wells screened within the tills typically yielded less water than wells screened in the outwash deposits, as well as based on slug testing results. Based upon the Conceptual Site Model bedrock is considered to define the bottom of the hydrogeologic system beneath the Site. A detailed description of the hydrogeologic units at the Site is provided in Section 3.2 of the RI Report (Roux, 2020a).

Groundwater Flow

The groundwater depth and groundwater elevations from monitoring wells screened in the upper hydrogeologic unit were utilized to create groundwater contour maps and to evaluate groundwater flow. The groundwater contour maps from the RI are provided on Plate 6. Groundwater typically flows south-west away from Teakettle Mountain toward the Landfill Area. From the Landfill Area, groundwater continues to flow south-west until it reaches the center of the Site, and then flows south. Groundwater flows south from the center of the Site toward the Flathead River. In the Western Undeveloped Area, groundwater flows south-east, away from Aluminum City, and toward the Flathead River. Overall, the groundwater flow patterns described above remained consistent during all six rounds of water level gauging for the RI.

The groundwater flow maps (Plate 6) indicate that the hydraulic gradients near Teakettle Mountain and in the Central Landfill Area are steep and generally mirrors the steeper topography in that portion of the Site. Groundwater elevations in the center of the Site typically vary by less than three feet across long distances (i.e., over 1,000 feet), indicating a relatively flat groundwater hydraulic gradient across the center of the Site (i.e., generally an order of magnitude less than near the Central Landfill Area). The gradient then increases in the southern area of the Site between the Main Plant Area and the Flathead River (which is also consistent with the steep drop in topography between the railroad and the river). Based on the groundwater elevation data obtained from the monitoring well clusters, there is limited downward vertical migration of groundwater flow within the upper hydrogeologic unit.

During the RI, the water level elevation data collected from the upper hydrogeologic unit indicated that groundwater elevations fluctuate seasonally at varying magnitudes depending on the area of the Site. The fluctuations in these upper hydrogeologic unit monitoring wells corresponded with spring thaw and snow melt and seasonal precipitation. Data collected from manual water-level gauging events indicate that near Teakettle Mountain and the Central Landfill Area, average water levels fluctuated by approximately 25 feet between gauging events during the RI; with the lowest levels occurring in October 2018 and the highest in June 2018. Measured depth to water ranged from 106.90 feet below top of casing (ft-btoc) to 57.20 ft-btoc. Adjacent to the West Landfill and Wet Scrubber Sludge Pond, groundwater elevations in the upper hydrogeologic unit can fluctuate by as much as 70 feet seasonally, as observed from pressure transducer data installed at CFMW-007; located on the western boundary of the West Landfill. In the center of the Site, average water levels fluctuated by approximately 17 feet; with the lowest levels in March 2017 and the highest in June 2018. Measured depth to water ranged from 73.07 ft-btoc to 20.98 ft-btoc. In the southern area of the Site, average water levels fluctuated by approximately 18 feet; with the lowest levels in March 2017 and the highest in June 2017. Measured depth to water ranged from 106.17 ft-btoc to 44.44 ft-btoc.

Waste Management Units as Source Area

The West Landfill and Wet Scrubber Sludge Pond area is the primary source of cyanide and fluoride in groundwater at the Site. Iso-concentration maps generated as part of the RI indicate that the highest cyanide and fluoride concentrations in groundwater appear to originate at the West Landfill and Wet Scrubber Sludge Pond area consistently during all six rounds of sampling. Appendices E1 through E12 of the FS Report present the 200 micrograms per liter (µg/L) contour for cyanide. Cyanide and fluoride emanate from this source area and migrate in south/south-westerly direction from the aforementioned Landfills Area toward the Flathead River. Total cyanide and fluoride concentrations in groundwater within the upper hydrogeologic unit decrease with increasing distance away from the waste management units. Cyanide and fluoride concentrations measured in monitoring wells outside of the Plume Core Area were less than one-half of the USEPA maximum contaminant limit (MCL) in all six rounds of sampling and are typically non-detect or at background concentrations adjacent to Aluminum City.

The Center Landfill is a potential secondary source area for the observed elevated cyanide and fluoride concentrations in groundwater, based on the elevated concentrations in groundwater detected directly beneath the landfill during two of the six groundwater monitoring events during the RI; see Section 3 below for additional discussion.

The results of the RI indicated that the Industrial Landfill, East Landfill, and Sanitary Landfill are not significant contributing sources to the cyanide and fluoride in groundwater.

3. Center Landfill

As mentioned above and documented within the RI Report and the FS Report, the West Landfill and Wet Scrubber Sludge Pond area has been identified as the primary source of groundwater contamination at the Site. The Center Landfill has been identified as a potential secondary source of groundwater contamination at the Site. The identification of the Center Landfill as a secondary source was based upon the detection of total cyanide at a concentration of 1,880 µg/L in monitoring well CFMW-017 in March 2017, exceeding the PRG of 200 µg/L. Monitoring well CFMW-017 was installed in 1980 through the Center Landfill. However, in all other sampling rounds the maximum concentration of cyanide in this well was 103 µg/L. In addition, the two wells installed adjacent to the Center Landfill on its downgradient side (CFMW-016 and CFMW-020) have exhibited a maximum total cyanide estimated concentration of 2.9 µg/L; and are typically non-detect with a detection limit of 2 µg/L).

Given that the wells immediately adjacent to and downgradient of the Center Landfill are compliant with preliminary remediation goals (PRGs), the Center Landfill has been excluded from the area to be addressed by both the Upgradient Slurry Wall and Fully-Encompassing Slurry Wall, as well as excluded from the area to be addressed by Hydraulic Control. It is noted that the Center Landfill has still been retained for cap enhancement to ensure it does not become a significant source in the future, since the low permeability cap on the Center Landfill is only comprised of 6-inches of clay, covered by soil.

4. Upgradient Slurry Wall

An upgradient slurry wall is a key element of Alternatives LDU1/GW-3A through 3C. The purpose of the upgradient wall is to divert unimpacted groundwater and surface water runoff around the primary source area (i.e., the West Landfill and Wet Scrubber Sludge Pond). The upgradient wall would work in conjunction with the existing low permeability cap on the West Landfill and proposed cap on the Wet Scrubber Sludge Pond to reduce contact of water with waste materials and impacted soil (including material both above and beneath the fluctuating water table) to prevent or reduce continued impacts to groundwater.

The location and length of the wall were estimated based upon evaluation of groundwater flow directions beneath and in the immediate vicinity of the source area; as determined during the RI (Plate 6). The flow direction during each of the six rounds of monitoring is in a southwest direction beneath the West Landfill and Wet Scrubber Sludge Pond. Based upon this direction and professional judgement, a conceptual orientation of an upgradient slurry wall is shown in Appendices E3 through E5 of the FS Report (for Alternatives LDU1/GW-3A through 3C, respectively). The wall would begin on the northwest side of the West Landfill and extend in a clockwise direction around the West Landfill and down to the southeast corner of the Wet Scrubber Sludge Pond, for a total wall length of approximately 1,950 ft.

In order for the upgradient wall to be effective in diverting groundwater around the waste material and any underlying impacted soil, the wall would extend beneath the depth of impacted material. In addition, to prevent runoff from the caps from flowing between caps and the upgradient wall, the caps on the West Landfill and Wet Scrubber Sludge Pond would need to be slightly modified to extend over the top of the slurry wall.

In order to minimize potential for underflow beneath the wall and then upward flow into the impacted materials on the downgradient side of the wall, keying the wall into the top of the lower permeability glacial till unit that underlies the area is recommended as part of this alternative. The existing data indicate the depth to top of the till is generally 100 to 125 ft below land surface along the path of the wall. However, deeper depths are possible in areas. Therefore, the final depth of the wall would be based upon further pre-design investigations and evaluations to evaluate the effect of differing wall depths, including completion of the slurry wall as a hanging wall (i.e., bottom of wall not keyed into the top of the till).

5. Fully-Encompassing Slurry Wall

A fully-encompassing slurry wall is a key element of Alternatives LDU-1/GW-4A through 4C. Similar to the upgradient slurry wall, a fully-encompassing slurry wall would divert unimpacted groundwater and surface water runoff around the West Landfill and Wet Scrubber Sludge Pond; and work in conjunction with the low permeability caps to reduce contact of water with waste materials and impacted soil (including material both above and beneath the fluctuating water table) to prevent continued impacts to groundwater. However, the fully-encompassing slurry wall would provide an additional measure of containment on the downgradient side of the primary source area which, in conjunction with the caps, create a containment cell effectively isolating and preventing migration of contaminants of concern (COCs) associated with waste materials, impacted soil, and groundwater within the cell. Cutting off the continued migration of contaminants from the source area would significantly enhance the effectiveness of monitored natural attenuation (MNA) in reducing downgradient groundwater concentrations and in turn surface water concentrations to PRGs and Applicable or Relevant and Appropriate Requirements (ARARs).

The conceptual orientation of the fully-encompassing slurry wall around the perimeter of the primary source area is shown in Appendices E6 through E8 of the FS Report (for Alternatives LDU1/GW-4A through 4C, respectively), which provides a wall length of approximately 3,700 ft.

Technical considerations regarding the depth of the wall (e.g., extending beneath impacted materials, and, if possible, keying into the top of the lower permeability glacial till), are the same as for the upgradient slurry wall. Therefore, a wall depth of 100 to 125 ft-bls is anticipated. Also, similar to the upgradient wall, the caps on the West Landfill and Wet Scrubber Sludge Pond would need to be slightly modified to extend over the top of the slurry wall to prevent runoff from the caps from flowing between caps and the wall.

A final technical consideration for this option is including provisions for intermittent pumping of water from within the containment cell to ensure that groundwater levels within the cell remain lower than groundwater levels immediately outside of the cell; thereby creating an inward gradient. Such pumping may not be necessary for the wall to be effective in achieving RAOs; however, installation of a limited number of wells (e.g., eight) within the containment cell to allow for monitoring and, if necessary, extraction of groundwater to maintain an inward gradient is recommended as part of this alternative.

6. Downgradient PRB

A downgradient PRB is a key component of Alternatives LDU1/GW-3B and LDU1/GW-4B. The purpose of the PRB under each of these alternatives is to provide for the in-situ treatment of cyanide in groundwater at a location close to the point of groundwater discharge to surface water in the River Area DU. As such, the PRB would be installed on the north side of and parallel to the Burlington Northern railroad right-of-way in the southern portion of the Site as shown in Appendices E4 and E7 of the FS Report (for Alternatives LDU1/GW-3B and 4B, respectively). This location is approximately 250 to 350 ft upgradient of the various surface water discharge locations within the River Area DU (e.g., the Backwater Seep Sampling Area, the Riparian Area Channel, and the South Percolation Ponds). The western and eastern extents of the conceptual PRB wall were selected to correspond to the maximum extent of where cyanide concentrations in groundwater were found to exceed 200 µg/L (the PRG/ARAR for groundwater), which also appears to generally correspond to the extent of where surface water concentrations exceed ARARs within the River Area DU (as shown in the figures as the extent of total cyanide exceeding 200 µg/L). This results in a PRB with an approximate length of 3,320 ft.

The depth of a PRB is typically designed to encompass, at a minimum, the vertical extent of the contaminant plume that is being targeted for treatment. Along the proposed path of the conceptual PRB at the Site, the depth to groundwater (and coincidentally the top of the contaminant plume) typically varies between 50 and 80 ft-bls. Along this path, well clusters screened at both shallow and deeper depths within the upper hydrogeologic unit (e.g., CFMW-45/45a and CFMW-49/49a) indicate the bulk of the contaminant mass and all detections exceeding 200 µg/L appears to occur within the upper 50 feet of the saturated zone. Targeting the upper 50 ft of the saturated zone would suggest a PRB depth varying between 100 and 130 ft-bls along the length of the PRB.

It often is desirable to extend the PRB depth further in order to key the PRB into a lower permeability layer beneath the target treatment zone to prevent bypass (i.e., underflow) of the PRB. However, the low permeability zone is typically located at depths of 150 ft-bls or greater along the path of the conceptual PRB; and 130 ft-bls (i.e., bottom of the target zone) is at the practical technological limits for PRB installation. Therefore, keying into the glacial till would not be a design objective in this application. Since the PRB will not be keyed into a low permeability layer, the vast majority of the PRB would be comprised of permeable reactive media to allow the pass through flow of groundwater (as opposed to a funnel and gate PRB, which has an increased potential for groundwater bypass of the PRB if not keyed into a low permeability zone). An important consideration in design of the PRB should be to ensure the permeability of the PRB is greater than that of the surrounding geologic formation (also accounting for some reduction in PRB permeability with time) to minimize the potential flow of contaminated groundwater around or beneath the PRB.

7. Hydraulic Control at the Source Area

As described above in Section 2, the West Landfill and Wet Scrubber Sludge Pond area has been identified as the primary source of the groundwater contamination at the Site. Groundwater extraction immediately downgradient of these LDU1 waste management units is a key component of Alternatives LDU1/GW-5A and LDU1/GW-5C. The objective of the groundwater extraction in each of these alternatives is to hydraulically contain and capture groundwater containing high concentrations of COCs prior to its migration away from the source area towards the River Area DU where the contaminated groundwater currently discharges to surface water. Cutting off the continued migration of contaminants from the source area would significantly enhance the effectiveness of MNA in reducing downgradient groundwater concentrations and in turn surface water concentrations to PRGs and ARARs.

The methodology and assumptions utilized to provide order of magnitude estimates of pumping rates required to achieve the above objective as well as the conceptual number and locations of wells that would be utilized in the process is described below. The methodology utilizes analytical methods that are presented in hydrogeology literature as well as in USEPA's guidance document titled "A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems" (USEPA, 2008) and Figure 1.

It should be noted that this is a conceptual design for the purpose of evaluating this option within the FS Report. Given the heterogenous nature of the hydrogeology as documented during the RI, the results presented herein should be considered order of magnitude estimates. In the event hydraulic control at the source area is a component of the selected remedy for the Site, additional investigation of aquifer characteristics, vertical extent of cyanide and fluoride, pump tests, and numerical modeling would be appropriate considerations in finalizing the number, locations, configurations, and pumping rates of the various extraction wells during the remedial design phase.

<u>Target Capture Zone</u>

The area targeted for hydraulic containment and capture at the source is where cyanide and fluoride in groundwater are emanating from beneath the West Landfill and Wet Scrubber Sludge Pond at concentrations exceeding their respective groundwater PRGs (200 μg/L for total cyanide and 4,000 μg/L for fluoride). The extent of this area was relatively consistent across the six rounds of groundwater sampling conducted during the RI. In plain view, this area extends in a counterclockwise direction from the southwest portion of the West Landfill (beginning just south of CFMW-007) to the southeast portion of the Wet Scrubber Sludge Pond (ending to the east of CFMW-021), as depicted in Appendices E9 and E11 of the FS Report (for Alternatives LDU1/GW-5A and 5C, respectively).

The groundwater flow direction beneath the source area is to the southwest. Based upon this flow direction, Appendices E9 and E11 of the FS Report (for Alternatives LDU1/GW-5A and 5C, respectively) also depicts a groundwater flux transect approximately 1,000 ft long across the width of plume.

The vertical extent of the contaminant plume is limited to within the upper hydrogeologic unit. Based upon RI water level data, the average saturated thickness of the upper hydrogeologic unit at the source area was estimated to be 66 feet during June 2018 (a high water condition) and 52 feet during October 2018 (a low water condition). However, based upon data from downgradient monitoring well clusters it has been shown that concentrations decrease with depth in the aquifer. Based upon these observations and for purposes of flow rate calculations, the conceptual target capture zone for this alternative is the upper half of the aquifer (33 ft and 26 ft for high and low water conditions, respectively)

Estimated Flow Rate Calculation

The estimated groundwater extraction rate required to capture the groundwater flux across the target capture zone described above can be calculated as shown in Equation 1 below and is presented as Figure 1 (USEPA, 2008):

Equation 1: $Q = K \cdot (b \cdot w) \cdot i$

Where:

Q = extraction rate
K = hydraulic conductivity
b = saturated thickness
w = plume width
i = hydraulic gradient

As described above, the target capture zone plume width is estimated to be 1,000 ft; and the plume thickness is estimated to be 33 ft during high water conditions and 26 ft during low water conditions.

The RI Report documents that hydraulic conductivity can vary by orders of magnitude over short distances within the upper hydrogeologic unit. Slug test results for wells near the source area have ranges from 20 feet per day (ft/day) to over 300 ft/day. In addition, a historical pump test at well CFMW-021 indicated a hydraulic conductivity of 326 ft/day (Hydrometrics, 1993). Based upon these ranges, an average hydraulic conductivity of 175 ft/day was assumed for purposes of the flow estimate calculation.

The hydraulic gradient has also been shown to exhibit order of magnitude seasonal variations in the vicinity of the West Landfill and Wet Scrubber Sludge Pond; with an estimated gradient of 0.052 ft/ft based on the June 2018 high water condition and 0.004 ft/ft based on the October 2018 low water condition.

Based upon the above estimates regarding Site conditions, a groundwater extraction rate of approximately 1,560 gallons per minute (gpm) would be required to hydraulically contain the plume at the source under high water conditions. Under low water conditions the extraction is reduced to approximately 100 gpm. Calculations are summarized in Table A-1 and Table A-2.

The wide fluctuation in rates is directly related to changes in gradient and saturated thickness that occur at and in the vicinity of the source area in response to seasonal variations. During the spring season, increased precipitation, snowmelt, and runoff from Teakettle Mountain all contribute to a high seasonal recharge rate, and in turn the higher water levels and gradients described above.

While the high groundwater condition at the Site only lasts for a few months during each year, it is during that period when the water is more likely to contact any contaminated waste or soil that may be beneath the source area. It is also the time of year when the greatest mass flux of contamination migrates from the source area. Thus, for hydraulic control to be effective it is recommended that the extraction and treatment system be designed to address the high flow condition; while still maintaining operational flexibility to function effectively at the reduced flow rates.

Analytical Capture Zone Calculations for Extraction Wells

In addition to estimating the total flow rate required to capture the flux of contaminated groundwater, analytical capture zone calculations were performed to assess spacing and locations of potential extraction wells. Given the heterogeneous geology and the high flow conditions that need to be addressed, it is assumed that ten extraction wells would be installed around the downgradient side of the source area. Ten wells would provide operational flexibility to vary pumping rates in individual wells as may be needed to address the heterogeneous conditions and still ensure capture.

Utilizing the analytical capture zone equations presented in Table A-1, Table A-2, and Figure 1, the calculation results indicate that for the high flow condition, a pumping rate of up to 170 gpm at each well (for a total flow rate of 1,500 gpm) would create slightly overlapping capture zones, which are required to achieve the hydraulic containment objective. For the low flow condition, the calculations indicate a pumping rate of 11 gpm at each well (for a total flow rate of 110 gpm) would be sufficient. The analytical calculations also indicate the extraction wells should be located approximately 150 to 200 ft downgradient of the source area to ensure adequate propagation and overlap of the capture zones occurs at the downgradient edge of the source.

A conceptual arrangement of wells evenly spaced across the width of the plume is shown in Appendices E9 and E11 of the FS Report (for Alternatives LDU1/GW-5A and 5C, respectively). For purposes of cost estimate development (as discussed in Section 6 of the FS Report), it is assumed the wells would each be 8-inch inside diameter and installed to a completion depth of 100 ft-bls.

Groundwater COC Concentrations Requiring Treatment

An estimate of the cyanide, fluoride, and arsenic concentrations that would be present in the groundwater extracted by each well shown in Appendices E9 and E11 of the FS Report (for Alternatives LDU1/GW-5A and 5C, respectively) was based upon the concentrations measured in the nearest monitoring wells, and then averaging the concentrations. This exercise was performed for both high and low flow conditions utilizing the data from the RI. Under high flow conditions, an average cyanide concentration of approximately 1,500 µg/L was estimated; while under low flow conditions, an average concentration of 3,500 µg/L was estimated. Under high flow conditions, an average fluoride concentration of approximately 13,000 µg/L was estimated; while under low flow conditions, an average concentration of 10,400 µg/L was estimated. Under high flow conditions, an average arsenic concentration of approximately 24 µg/L was estimated; while under low flow conditions, an average concentration of 14 µg/L was estimated.

As noted above, the estimated extraction rates described above are order of magnitude estimates using an analytical calculation method that incorporates many simplifying assumptions. While this estimate is suitable for the purposes of the FS, it is possible that required flow rates could be higher or lower than those noted above.

8. Downgradient Hydraulic Control

As described above in Section 2, the cyanide plume emanating from the Landfills DU1 waste management units migrates in a southward direction ultimately discharging to surface water in the River Area DU approximately 3,500 ft downgradient from the source area. Groundwater extraction near the downgradient southern extent of the plume, prior to its discharge to surface water, is a key component of Alternatives LDU1/GW-5B and LDU1/GW-5C. The objective of the downgradient groundwater extraction in each of these alternatives is to hydraulically capture groundwater containing high concentrations of cyanide prior to its discharge to surface water in the River Area DU.

The methodology and assumptions utilized to provide estimates of groundwater extraction rates required to achieve the above objective as well as the conceptual number and locations of wells that would be utilized in the process is described below. The methodology utilizes analytical methods that are presented in hydrogeology literature as well as in the USEPA guidance document titled "A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems" (USEPA, 2008).

It should be noted that this is a conceptual design for the purpose of evaluating this option within the FS Report. Given the heterogenous nature of the hydrogeology as documented during the RI, the results presented herein should be considered order of magnitude estimates. In the event downgradient hydraulic control is a component of the selected remedy for the Site, additional investigation of aquifer characteristics, pump tests, and numerical modeling would be appropriate considerations in finalizing the number, locations, configurations, and pumping rates of the various extraction wells during the remedial design phase.

Target Capture Zone

The plume area targeted for hydraulic capture is where cyanide in groundwater exceeds its groundwater PRGs (200 µg/L for total cyanide) prior to the plume migrating beneath the Burlington Northern railroad right-of-way in the southern portion of the Site. The width of the plume containing cyanide at concentrations exceeding the PRG in this area is approximately 3,320 ft based upon the six rounds of groundwater sampling conducted during the RI (as shown as the 200 µg/L contour for cyanide in Appendices E1 through E12 of the FS Report).

The vertical extent of the contaminant plume is limited to within the upper hydrogeologic unit. Based upon data from downgradient monitoring well clusters, it has been shown that concentrations decrease with depth in aquifer such that the vertical extent of the target capture zone is the upper 35 feet of the saturated zone (i.e., from the water table to 35 ft beneath the water table).

Estimated Flow Rate Calculation

The estimated groundwater extraction rate required to capture the groundwater flux across the target capture zone described above can be calculated according to Equation 1 shown above in Section 7.

The RI Report documents that the hydraulic conductivity values determined from slug tests on several monitoring wells in the target capture zone area typically are less than 10 ft/day. However, the testing is limited and some wells slightly upgradient indicate hydraulic conductivities of 50 and 115 ft/day. Based upon these values, an average hydraulic conductivity of 30 ft/day was assumed for purposes of an order of magnitude estimate flow calculation.

The hydraulic gradient in the southern area of the Site, in the vicinity of the target capture zone, is relatively consistent throughout the year. An average gradient of 0.02 ft/ft was assumed for the order of magnitude estimate flow rate calculation.

Based upon the above estimates regarding Site conditions, a groundwater extraction rate of approximately 390 gpm would be required to hydraulically capture the plume immediately upgradient of the railroad right-of-way. The available data indicate that this extraction rate should be relatively uniform throughout the year in contrast to the large fluctuation in rates anticipated for the hydraulic control at the source option previously described. Calculations are summarized in Table A-3.

Analytical Capture Zone Calculations for Extraction Wells

In addition to estimating the total flow rate required to capture the flux of contaminated groundwater, analytical capture zone calculations were performed to assess spacing and locations of potential extraction wells. Given the heterogeneous geology and the high flow conditions that need to be addressed, it is assumed that ten extraction wells would be installed immediately upgradient of the Burlington Northern railroad right-of-way. Ten wells would provide operational flexibility to vary pumping rates in individual wells as may be needed to address the heterogeneous conditions and still ensure capture.

Utilizing the analytical capture zone equations presented in Table A-3, the calculation results indicate that a pumping rate of 50 gpm at each well (for a total flow rate of 500 gpm) would create overlapping capture zones, which is required to capture the plume.

One additional consideration for this pumping scenario is to avoid inducing infiltration of surface water from the Flathead River. The analytical capture zone calculations indicate the downgradient extent of the capture zone at each well is approximately 70 ft. The distance to surface water from the pumping wells is greater than 250 ft. Based on the current analysis, it is unlikely that groundwater extraction as described would induce infiltration of surface water. However, in the event downgradient hydraulic control is a part of the selected remedy, this would warrant further evaluation during the remedial design phase.

As noted above, the estimated extraction rates described above are order of magnitude estimates using an analytical calculation method that incorporates many simplifying assumptions. While this order of magnitude estimate is suitable for the purposes of the FS, it is possible that required flow rates could be higher or lower than those noted above.

Cyanide Concentration Requiring Treatment

An estimate of the cyanide concentration that would be present in the groundwater extracted by each well shown in Appendices E10 and E11 of the FS Report (for Alternatives LDU1/GW-5B and 5C, respectively) was estimated based upon the average of total cyanide concentration measured in monitoring wells in the proposed area of groundwater extraction. The average cyanide concentration across the target capture zone was estimated to be 330 µg/L.

9. Time Estimates for Achievement of RAOs

Mass flux evaluations were conducted for cyanide and fluoride in upper hydrogeologic unit groundwater at the Site during the RI (Section 6 of the RI Report; Roux, 2020a). The evaluation indicated that mass flux of cyanide and fluoride are highest immediately downgradient of the West Landfill and Wet Scrubber Sludge Pond, which is consistent with the understanding that the area of these waste management units is the primary source of cyanide and fluoride in groundwater. Contaminant flux decreases with increasing distance from LDU1. With respect to cyanide, the decrease in flux with increasing distance from LDU1 is likely due to various attenuation process such as biodegradation, sorption, dispersion, and dilution.

The transport rate of contaminants in groundwater is affected by the effective groundwater flow velocity in the aquifer, the chemical composition of the aquifer, and the chemical nature of the contaminants. As described in Section 6.4.3 of the RI Report, the contaminant velocity estimate for cyanide ranges from 2.8 to 4.4 ft/day. Utilizing the contaminant velocity estimate and a distance of 3,500 feet from the base of the Wet Scrubber Sludge Pond ("Landfill Area") to the Seep Area, it is estimated that cyanide may take approximately 3 to 4.5 years to migrate from the Landfill Area to the Seep Area. Similarly, using the distance of 300 feet from the downgradient extraction/PRB area to the Seep Area, it is estimated that cyanide may take approximately 0.2 to 1.5 years to migrate from the downgradient extraction/PRB area (i.e., from just north of the railroad right-of way) to the Seep Area. This evaluation is summarized in the below table.

Table A-4. Estimate of Cyanide Migration in Groundwater

Cyanide Evaluation	Distance (ft)	High Contaminant Velocity Estimate (ft/day)	High Velocity Travel Time to Flathead River (days)	High Velocity Travel Time to Flathead River (years)	Low Contaminant Velocity Estimate (ft/day)	Low Velocity Travel Time to Flathead River (days)	Low Velocity Travel Time to Flathead River (years)
Landfill Area to Seep Area	3,500	4.38	1,072	2.94	2.84	1,654	4.53
Downgradient Extraction/PRB Area to Seep Area	300	4.38	68	0.19	2.84	1.6	0.29

High and Low average estimates of cyanide contaminant velocity based on Table 26 from RI Report.
Distance estimate calculated utilizing Geographic Information Systems (GIS).
ft – feet
ft/day - feet per day

The results of the cyanide migration estimates described above indicate that following implementation of effective source control at the LDU1 waste management units (without downgradient measures; e.g., Alternatives LDU1/GW-3A, LDU1/GW-4A, LDU1/GW-5A, or LDU1/GW-6), reductions in cyanide concentrations at or near the Seep Area should begin to be observed within 4.5 years. Similarly, following implementation of an effective groundwater treatment remedy closer to the Seep Area, at the downgradient extraction / PRB area (e.g., Alternatives LDU1/GW-3B or 3C; LDU1/GW-4B or 4C; or LDU1/GW-5B or 5C), reductions in downgradient cyanide concentrations at or near the Seep Area should begin to be observed within one year. However, these improvements would not be expected to result in attainment of RAOs for cyanide within the timeframes described above because groundwater does not flow in a plug-flow fashion due to dispersion/mixing and attenuation within the aquifer. Therefore, a batch flushing model method was utilized to evaluate the duration for groundwater to achieve cyanide RAOs following the implementation of a remedial alternative that would isolate the contaminant source. A batch flushing model is a simple yet effective method to assess remedy performance during the FS stage. This model estimates the number of pore volumes of water that must pass through the aquifer and the time required for concentrations in a plume to decline from measured cyanide concentrations to remedial objectives. The batch flushing model utilized herein has been described in peer-reviewed technical literature (Zheng et al., 1991; US NRC, 1994; Brusseau, 1996) as well as incorporated in regulatory guidance (Wisconsin Department of Natural Resources, 2014).

It should be noted that this analysis applies only to the reduction of contaminant mass/concentrations in groundwater; not to the reduction of contaminant mass in the source area. The batch flushing model hypothetically assumes that the contaminant source has been completely isolated and all contaminants are in the dissolved phase. The batch flushing calculation conducted for cyanide as part of the FS is described below and presented in Table A-5.

9.1 Batch Flushing Model Description

The batch flushing model can be described as three calculation steps: 1) estimate the number of pore volumes (PV) of groundwater that must flow through the aquifer in order to reduce the initial contaminant concentration to the RAO concentration; 2) estimate the time required for groundwater to traverse the length of contamination considering the length of the plume and average effective groundwater flow velocity; and 3) estimate the time duration for the required number of pore volumes to flow through the aquifer. These three calculation steps are performed using Equations 2 through 4 as outlined below.

Equation 2: $PV = - R \ln(C_s / C_i)$, or $2.303\ R \log(C_i / C_s)$

Where:

PV = number of pore volumes to flush the contaminant;
R = retardation factor (unitless);
C_s = RAO concentration;
C_i = initial contaminant concentration; and
2.303 is a conversion factor from natural log to log10.

Equation 3: $t = L/v$

Where:

t = time it would take for groundwater to traverse the downgradient length of contamination
L = downgradient length of contamination
v = groundwater effective velocity

Equation 4: $T = (PV)\ t$

Where:

T = time to reduce the contaminant level from Ci to Cs due to flushing alone
PV = number of pore volumes estimated from Equation 2;
t = time estimated from Equation 3.

9.2 Model Scenarios and Input Values

The batch flushing model described above was implemented for three scenarios that correspond to various LDU1/GW remedial alternatives being evaluated for the Site as summarized below:

- Scenario 1 - Source Control to Achieve Groundwater RAOs: This scenario was performed to estimate the time required to achieve the cyanide groundwater RAO of 200 µg/L (i.e., the USEPA MCL) throughout the plume following the implementation of an effective source control remedy at the LDU1 source area. The results from this scenario are used to evaluate the source control alternatives at the LDU1 waste management units (without downgradient measures; e.g., Alternatives LDU1/GW-2, LDU1/GW-3A, LDU1/GW-4A, LDU1/GW-5A, and LDU1/GW-6). Scenario 1 was evaluated utilizing varying inputs for the downgradient length of contamination to estimate the number of pore volumes and duration to achieve RAOs at varying locations throughout the plume, including: the full length of the plume from the Landfill Area to the Seep Area (3,500 ft); one-half the distance to the Seep Area (1750 ft); and one-quarter of the distance to the Seep Area (875 ft).
- Scenario 2 - Source Control to Achieve Surface Water RAOs: This scenario was performed to estimate the time required to achieve the cyanide surface water RAO of 5.2 µg/L (i.e., the MDEQ Circular-7 Numeric Water Quality Standards [DEQ-7] chronic criteria) at the Seep Area following the implementation of an effective source control remedy at the LDU1 source area. The results from this scenario are used to evaluate the same source control alternatives as Scenario 1; but specific to timeframes to achieve RAOs at the Seep Area.
- Scenario 3 - Downgradient Hydraulic Containment or In-Situ Treatment to Achieve Surface Water RAOs: This scenario was performed to estimate the time required to achieve the cyanide surface water RAO of 5.2 µg/L at the Seep Area following the implementation of an effective hydraulic control remedy or in-situ treatment remedy close to the Seep Area. The results from this scenario are used to evaluate the downgradient groundwater treatment alternatives (e.g., Alternatives LDU1/GW-3B or 3C; LDU1/GW-4B or 4C; and LDU1/GW-5B or 5C).

For each scenario certain model input parameters were adjusted, using a range of values based upon results of the RI, to calculate an average time estimate to achieve RAOs, as well as a high-range time estimate. The model input parameters for each scenario are presented on Table A-5.

9.3 Batch Flushing Model Results

The results of the batch flushing model calculations for each scenario are summarized and discussed below, as well as presented in Table A-5.

Table A-6. Results of Scenario #1: Source Control to Achieve Groundwater RAOs

LDU1/GW Alternative Scenario	PV (number of pore volumes needed to reach RAO)	t (time for groundwater to traverse the downgradient length of contamination; years)	T (years to reduce the contaminant level from C_i to C_s due to flushing alone)
Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	3.1	4.7	14.6
Migration of Cyanide from Landfill Area to Seep Area (High Range)	4.8	5.5	26

A time period of approximately 15 years is the average time estimate to achieve the cyanide groundwater RAO (i.e., the USEPA MCL of 200 µg/L) throughout the plume following implementation of a remedy that isolates the source. The high-range time estimate for this scenario is approximately 26 years.

As indicated in Table A-5, the results of the batch flushing also indicate that monitoring wells at varying locations throughout the length of the plume would achieve RAOs in advance of monitoring wells further downgradient. For example, at one-half of the distance to the Seep Area, on average, it could take approximately 7 years to observe cyanide concentrations reduced to the USEPA MCL. At one-quarter of the distance to the Seep Area, on average, it could take approximately 4 years.

Table A-7. Results of Scenario #2: Source Control to Achieve Surface Water RAOs

LDU1/GW Alternative Scenario	PV (number of pore volumes needed to reach RAO)	t (time for groundwater to traverse the downgradient length of contamination; years)	T (years to reduce the contaminant level from C_i to C_s due to flushing alone)
Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	7.7	4.7	35.7
Migration of Cyanide from Landfill Area to Seep Area (High Range)	10.9	5.5	60

A time period of approximately 35 years is the average time estimate to achieve the cyanide surface water RAO (i.e., the DEQ-7 chronic criteria of 5.2 μg/L) at the Seep Area following implementation of a remedy that isolates the source. The high-range time estimate for this scenario is approximately 60 years.

Table A-8. Results of Scenario #3: Downgradient Hydraulic Containment or In-Situ Treatment to Achieve Surface Water RAOs

LDU1/GW Alternative Scenario	PV (number of pore volumes needed to reach RAO)	t (time for groundwater to traverse the downgradient length of contamination; years)	T (years to reduce the contaminant level from C_i to C_s due to flushing alone)
Migration of Cyanide from Downgradient Area to Seep Area utilizing Average Estimates	5.1	1.1	5.6
Migration of Cyanide from Downgradient Area to Seep Area (High Range)	6.0	1.5	9

A time period of approximately 6 years is the average time estimate to achieve the cyanide surface water RAO (i.e., the DEQ-7 chronic criteria of 5.2 μg/L) at the Seep Area following implementation of a downgradient remedy that intercepts and cuts off the plume just north of the railroad right-of-way. The high-range time estimate for this scenario is approximately 9 years.

It should be noted that the surface water present in the Seep Area (i.e., Backwater Seep Sampling Area, Riparian Area, and South Percolation Ponds) during low-flow season is predominantly groundwater expressing from the Site. To the extent that the Flathead River discharge is also input into the system, compliance with DEQ-7 criteria could be achieved with groundwater discharging at slightly higher concentrations.

9.4 Model Limitations

As described above, the batch flushing model was utilized to provide a range of time estimates for various remedial alternatives to achieve the RAOs for groundwater and surface water at the Site. These estimates are utilized within the FS when evaluating the short-term effectiveness (i.e., time to achieve RAOs) for each alternative, as well as in the comparative analysis of remedial alternatives. However, it is important to note that the remediation time estimates from the modeling are subject to high degree of uncertainty due to the variability, both spatially and temporally, of the hydrogeologic conditions across the Site; the complex physicochemical processes that can affect the rate of contaminant migration at the Site; and the fact that modeling must utilize numerous simplifying assumptions to address a very complex problem. The degree of uncertainly is reflected in a wide range between the average and high-range time estimates for each remedial scenario evaluated.

A primary limitation of batch flushing model is the assumption of homogeneous subsurface conditions and a constant effective groundwater velocity throughout the Site and over time. Actual conditions of the subsurface vary greatly both spatially and temporally and will impact the timeframes estimated herein. For example, highly permeable zones with local preferential flow paths would allow groundwater contaminants to flush quicker, while lower permeability zones contribute to slower flushing. If high permeability zones exist between layers of lower conductive material, average hydraulic conductivity values may not reflect groundwater flow velocity within the most transmissive portions of the aquifer (i.e., contaminant movement through, and flushing from, the highly permeable zone may be underestimated).

While high permeability zones act as preferential flow paths and flush quicker, groundwater can continue to be impacted from contaminants that have migrated into and reside within low permeability zones. Such low permeability zones may act as a residual source and can cause long-lasting persistence of contaminant concentrations in groundwater. Once contaminants have been flushed from highly transmissive zones, contaminants that have migrated into less permeable strata will slowly diffuse back into the more permeable zones over time. For example, where clay zones have become contaminated, these low permeability zones can remain as residual sources of contamination within an aquifer after surrounding higher permeability zones have been remediated (Zheng et al., 1991). This can become a rate limiting process that increases the time necessary to achieve RAOs.

10. References

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TABLES

Table A-1. Estimated Upgradient Flow Rate and Capture Zone Calculations (High Range)
Columbia Falls Aluminum Company, LLC, FS Report, 2000 Aluminum Drive, Columbia Falls, MT

Scenario: Containment via Capping, and Hydraulic Control at the Source Area - High Water June 2018. Install Extraction wells to maintain hydraulic control Landfills DU1 at the Landfills DU1 source area to contain contaminated groundwater at the source area.			**Assumptions and Notes:**
Extraction at landfill to maintain hydraulic control	10	wells	
Flow rate of each well	170	gpm	
Estimated flow rate calculation $Q = K.(b.W).i.factor$			
Q = extraction rate	**600600**	**ft3/day**	Assuming full saturated thickness
	3123	**gpm**	
Q = extraction rate	**300300**	**ft3/day**	Assuming half saturated thickness
	1562	**gpm**	
K = hydraulic conductivity	175	ft/day	Assume uniform hydraulic conductivity (175 ft/day); K ranges from less than 30 to over 300 ft/day
I = hydraulic gradient	0.052	ft/ft	Approximate hydraulic gradient; June 2018.
w = plume width	1000	ft	Distance from southeast corner of Wet Scrubber Sludge Pond (200 ppb CN contour) to just south of CFMW-07
b = aquifer saturated thickness	66	ft	
1/2 saturated thickness	33	ft	Assume upper 1/2 of saturated thickness is what requires capture
Factor = 1			Assumed Factor = 1 which could underestimate flow rate if there are other sources of water (e.g., deeper groundwater)
Capture zone width calculation, one equivalent extraction well			
$Y_{max} = \frac{Q}{2\,K\,b\,i}$ $Y_{well} = \frac{Q}{4\,K\,b\,i}$			Steady state flow, fully penetrating wells
Y max = capture width far upgradient of well	**500**	**ft**	Y max should be greater than 1/2 plume width for successful capture
Y well = capture width at the location of well	**250**	**ft**	Y max = capture zone width far upgradient of equivalent well from centerline of plume (one half of capture zone width at an infinite upgradient distance)
Q = Extraction rate	300300	ft3/day	
T = transmissivity, K* b	5775	ft2/day	Y well = capture zone width at the location of the well from centerline of plume
K = hydraulic conductivity	175	ft/day	
I = hydraulic gradient	0.052	ft/ft	
b = saturated thickness	33	ft	Using 1/2 of saturated thickness in calculation
Number of pumping wells to capture plume			
Total wells to be installed (professional judgement)	**10**	**wells**	
Flow rate at each well	**170**	**gpm**	
	32692	ft3/day	
Y max (@ each well)	54	ft	Assume uniform parameters at individual wells
Xo downgradient end of capture zone	17	ft	
Capture zone equation $\frac{y}{x} = \tan(\frac{2\pi Kbi}{Q}.y)$			
Solve for x, given different values for y (that are less than Ymax)	y (ft)	x (ft)	Coordinates for plotting of capture zone.
	0.1	-17	
	25	-3	
	30	5	
	35	17	
	40	36	
	45	74	
	50	190	
	54	2033	

Table A-2. Estimated Upgradient Flow Rate and Capture Zone Calculations (Low Range)
Columbia Falls Aluminum Company, LLC, FS Report, 2000 Aluminum Drive, Columbia Falls, MT

Scenario: Containment via Capping, and Hydraulic Control at the Source Area - Low Water October 2018. Install Extraction wells to maintain hydraulic control Landfills DU1 at the Landfills DU1 source area to contain contaminated groundwater at the source area.			**Assumptions and Notes:**
Extraction at landfill to maintain hydraulic control	10	wells	
Flow rate of each well	11	gpm	
Estimated flow rate calculation $Q = K.(b.W).i.factor$			
Q = extraction rate	**36400**	**ft3/day**	Assuming full saturated thickness
	189	**gpm**	
Q = extraction rate	**18200**	**ft3/day**	Assuming half saturated thickness
	95	**gpm**	
K = hydraulic conductivity	175	ft/day	Assume uniform hydraulic conductivity (175 ft/day); K ranges from less than 30 to over 300 ft/day
I = hydraulic gradient	0.004	ft/ft	Approximate hydraulic gradient; June 2018.
w = plume width	1000	ft	Distance from southeast corner of Wet Scrubber Sludge Pond (200 ppb CN contour) to just south of CFMW-07
b = aquifer saturated thickness	52	ft	
1/2 saturated thickness	26	ft	Assume upper 1/2 of saturated thickness is what requires capture
Factor = 1			Assumed Factor = 1 which could underestimate flow rate if there are other sources of water (e.g., deeper groundwater)
Capture zone width calculation, one equivalent extraction well			
$Y_{max} = \frac{Q}{2\,K\,b\,i}$ $Y_{well} = \frac{Q}{4\,K\,b\,i}$			Steady state flow, fully penetrating wells
Y max = capture width far upgradient of well	**500**	**ft**	Y max should be greater than 1/2 plume width for successful capture
Y well = capture width at the location of well	**250**	**ft**	Y max = capture zone width far upgradient of equivalent well from centerline of plume (one half of capture zone width at an infinite upgradient distance)
Q = Extraction rate	18200	ft3/day	
T = transmissivity, K* b	4550	ft2/day	Y well = capture zone width at the location of the well from centerline of plume
K = hydraulic conductivity	175	ft/day	
I = hydraulic gradient	0.004	ft/ft	
b = saturated thickness	26	ft	Using 1/2 of saturated thickness in calculation
Number of pumping wells to capture plume			
Total wells to be installed (professional judgement)	**10**	**wells**	
Flow rate at each well	**11**	**gpm**	
	2115	ft3/day	
Y max (@ each well)	58	ft	Assume uniform parameters at individual wells
Xo downgradient end of capture zone	19	ft	
Capture zone equation $\frac{y}{x} = \tan(\frac{2\pi Kbi}{Q}.y)$			
Solve for x, given different values for y (that are less than Ymax)	y (ft)	x (ft)	Coordinates for plotting of capture zone.
	0.1	-19	
	25	-6	
	30	2	
	35	12	
	40	27	
	45	52	
	50	106	
	55	321	
	56	481	

Table A-3. Estimated Downgradient Flow Rate and Capture Zone Calculations
Columbia Falls Aluminum Company, LLC, FS Report, 2000 Aluminum Drive, Columbia Falls, MT

Scenario: Containment via Capping, Downgradient Extraction			Assumptions and Notes:
Extraction Downgradient	10	wells	
Flow rate of each well	50	gpm	
Estimated flow rate calculation $Q = K.(b.W).i.factor$			
Q = extraction rate	**149580**	**ft3/day**	Assuming full saturated thickness
	778	**gpm**	
Q = extraction rate	**74790**	**ft3/day**	Assuming half saturated thickness
	389	**gpm**	
K = hydraulic conductivity	30	ft/day	Assume uniform hydraulic conductivity (175 ft/day); K ranges from less than 30 to over 300 ft/day
I = hydraulic gradient	0.020	ft/ft	Approximate hydraulic gradient; June 2018.
w = plume width	3324	ft	Distance from southeast corner of Wet Scrubber Sludge Pond (200 ppb CN contour) to just south of CFMW-07
b = aquifer saturated thickness	75	ft	
1/2 saturated thickness	37.5	ft	Assume upper 1/2 of saturated thickness is what requires capture
Factor = 1			Assumed Factor = 1 which could underestimate flow rate if there are other sources of water (e.g., deeper groundwater)
Capture zone width calculation, one equivalent extraction well			
$Y_{max} = \frac{Q}{2\,K\,b\,i}$ $Y_{well} = \frac{Q}{4\,K\,b\,i}$			Steady state flow, fully penetrating wells
Y max = capture width far upgradient of well	**1662**	**ft**	Y max should be greater than 1/2 plume width for successful capture
Y well = capture width at the location of well	**831**	**ft**	Y max = capture zone width far upgradient of equivalent well from centerline of plume (one half of capture zone width at an infinite upgradient distance)
Q = Extraction rate	74790	ft3/day	
T = transmissivity, K* b	1125	ft2/day	Y well = capture zone width at the location of the well from centerline of plume
K = hydraulic conductivity	30	ft/day	
I = hydraulic gradient	0.020	ft/ft	
b = saturated thickness	38	ft	Using 1/2 of saturated thickness in calculation
Number of pumping wells to capture plume			
Total wells to be installed (professional judgement)	**10**	**wells**	
Flow rate at each well	**50**	**gpm**	
	9615	ft3/day	
Y max (@ each well)	214	ft	Assume uniform parameters at individual wells
Xo downgradient end of capture zone	68	ft	
Capture zone equation $\frac{y}{x} = \tan(\frac{2\pi Kbi}{Q}.y)$			
Solve for x, given different values for y (that are less than Ymax)	y (ft)	x (ft)	Coordinates for plotting of capture zone.
	0.1	-68	
	25	-65	
	75	-38	
	103.5	-5	
	130	46	
	160	158	
	180	332	
	200	974	

Table A-5. Batch Flushing Calculation Estimates
Columbia Falls Aluminum Company, LLC, FS Report, 2000 Aluminum Drive, Columbia Falls, MT

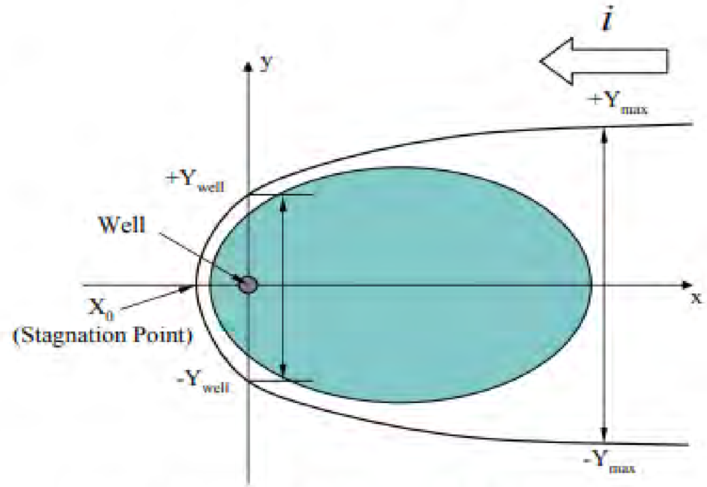
Groundwater Alternative Scenario			Migration Scenario	K (conductivity, cm/s)	I (gradient, dh/dl)	ne (soil effective porosity)	foc (fraction of soil organic C)	r (bulk density, g/cm3)	Koc (for cyanide	L (downgradient length of contamination, m)	Ci (initial cyanide concentration, ug/L)	Cs (RAO concentration, ug/L)	Effective Groundwater Velocity (m/yr)	R	PV (number of pore volumes needed to reach RAO)	t (time for groundwater to traverse the downgradient length of contamination; years)	T (years to reduce the contaminant level from Ci to Cs due to flushing alone)
													K i / ne	$R=1+(\frac{\rho_b}{n_e})(K_{oc})(f_{oc})$	PV=2.303 R log (ci/Cs) 2.303 is a conversion factor from natural log to log10	L/v	T=(PV*t)
SCENARIO 1	Source Control to Achieve Groundwater RAOs	1	Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	--	--	--	--	--	--	1,067	2,500	200	229.2	1.24	3.1	4.7	14.6
SCENARIO 1	Source Control to Achieve Groundwater RAOs	2	Migration of Cyanide from Landfill Area to Seep Area (High Range)	0.062	0.004	0.40	0.019	1.60	8.93	1,067	3,500	200	194.7	1.679	4.8	5.5	26
			All scenarios - Length assumes 3500 ft from base of Wet Scrubber Sludge Pond to Seep Area (1066.8 m); soil effective porosity average (0.4), fraction of organic carbon average (0.019), bulk density average (1.6 g/cm3) from RI Report mass flux calculations. Cs is the cyanide in groundwater RAO (i.e., USEPA MCL/Montana DEQ-7 Human Health Standard) of 200 ug/L.														
			1 - Calculated utilizing cyanide concentration average (2,500 ug/L), effective groundwater velocity average (2.06 ft/day), and retardation factor average (1.24) from RI Report mass flux calculations for all transects.														
			2 - Calculated utilizing hydraulic conductivity average for Landfill Area (175 ft/day), low-flow gradient (0.004 ft/ft), high-range soil adsorption coefficient for soil organic carbon (8.93), and cyanide concentration low-flow conditions average (3,500 ug/L) from RI Report mass flux calculations.														
SCENARIO 1	Source Control to Achieve Groundwater RAOs	3	Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	--	--	--	--	--	--	533	2,500	200	229.2	1.24	3.1	2.3	7.3
SCENARIO 1	Source Control to Achieve Groundwater RAOs	4	Migration of Cyanide from Landfill Area to Seep Area (High Range)	0.062	0.004	0.40	0.019	1.60	8.93	533	3,500	200	194.7	1.679	4.8	2.7	13
			All scenarios - Length assumes 1750 ft (i.e., 1/2 distance from Source Area to Seep Area) (533.4 m); soil effective porosity average (0.4), fraction of organic carbon average (0.019), bulk density average (1.6 g/cm3) from RI Report mass flux calculations. Cs is the cyanide in groundwater RAO (i.e., USEPA MCL/Montana DEQ-7 Human Health Standard) of 200 ug/L.														
			Scenarios 3 and 4 utilize the same input parameters as Scenarios 1 and 2, respectively, with the exception of length.														
SCENARIO 1	Source Control to Achieve Groundwater RAOs	5	Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	--	--	--	--	--	--	267	2,500	200	229.2	1.24	3.1	1.2	3.6
SCENARIO 1	Source Control to Achieve Groundwater RAOs	6	Migration of Cyanide from Landfill Area to Seep Area (High Range)	0.062	0.004	0.40	0.019	1.60	8.93	267	3,500	200	194.7	1.679	4.8	1.4	7
			All scenarios - Length assumes 875 ft (i.e., 1/4 distance from Source Area to Seep Area) (266.7 m); soil effective porosity average (0.4), fraction of organic carbon average (0.019), bulk density average (1.6 g/cm3) from RI Report mass flux calculations. Cs is the cyanide in groundwater RAO (i.e., USEPA MCL/Montana DEQ-7 Human Health Standard) of 200 ug/L.														
			Scenarios 5 and 6 utilize the same input parameters as Scenarios 1 and 2, respectively, with the exception of length.														
SCENARIO 2	Source Control to Achieve Surface Water RAOs	7	Migration of Cyanide from Landfill Area to Seep Area utilizing Average Estimates	--	--	--	--	--	--	1,067	2,500	5.2	229.2	1.24	7.7	4.7	35.7
SCENARIO 2	Source Control to Achieve Surface Water RAOs	8	Migration of Cyanide from Landfill Area to Seep Area (High Range)	0.062	0.004	0.40	0.019	1.60	8.93	1,067	3,500	5.2	194.7	1.679	10.9	5.5	60
			All scenarios - Length assumes 3500 ft from base of Wet Scrubber Sludge Pond to Seep Area (1066.8 m); soil effective porosity average (0.4), fraction of organic carbon average (0.019), bulk density average (1.6 g/cm3) from RI Report mass flux calculations. Cs is the cyanide in surface water RAO (i.e., DEQ-7 chronic criteria) of 5.2 ug/L.														
			7 - Calculated utilizing cyanide concentration average (2,500 ug/L), effective groundwater velocity average (2.06 ft/day), and retardation factor average (1.24) from RI Report mass flux calculations for all transects.														
			8 - Calculated utilizing hydraulic conductivity average for Landfill Area (175 ft/day), low-flow gradient (0.004 ft/ft), high-range soil adsorption coefficient for soil organic carbon (8.93), and cyanide concentration low-flow conditions average (3,500 ug/L) from RI Report mass flux calculations.														
SCENARIO 3	Downgradient Hydraulic Containment or In-Situ Treatment to Achieve Surface Water RAOs	9	Migration of Cyanide from Downgradient Area to Seep Area utilizing Average Estimates	--	--	--	--	--	--	91	330	5.2	83.4	1.24	5.1	1.1	5.6
SCENARIO 3	Downgradient Hydraulic Containment or In-Situ Treatment to Achieve Surface Water RAOs	10	Migration of Cyanide from Downgradient Area to Seep Area (High Range)	0.004	0.020	0.44	0.014	1.48	8.93	91	350	5.2	61.9	1.421	6.0	1.5	9
			All scenarios - Length assumes 300 ft from downgradient extraction area to Seep Area (91.4 m); soil effective porosity average (0.44), fraction of organic carbon average (0.014), bulk density average (1.48 g/cm3) from RI Report mass flux calculations. Cs is the cyanide in surface water RAO (i.e., DEQ-7 chronic criteria) of 5.2 ug/L.														
			9 - Calculated utilizing cyanide concentration average (330 ug/L), effective groundwater velocity average (0.75 ft/day), and retardation factor average (1.24) from RI Report mass flux calculations for all transects.														
			10 - Calculated utilizing hydraulic conductivity average for downgradient area during low-flow (12.25 ft/day), low-flow gradient (0.020 ft/ft), high-range soil adsorption coefficient for soil organic carbon (8.93), and cyanide concentration low-flow conditions average (350 ug/L) from RI Report mass flux calculations.														

FIGURES

Capture Zone Width Calculation, One Extraction Well

Assumptions:

- homogeneous, isotropic, confined aquifer of infinite extent
- uniform aquifer thickness
- fully penetrating extraction well(s)
- uniform regional horizontal hydraulic gradient
- steady-state flow
- negligible vertical gradient
- no net recharge, or net recharge is accounted for in regional hydraulic gradient
- no other sources of water introduced to aquifer due to extraction (e.g., from rivers or leakage from above or below)



$$x = \frac{-y}{\tan\left(\frac{2\pi Ti}{Q}y\right)} \quad -or- \quad y = \pm\left(\frac{Q}{2Ti}\right) - \left(\frac{Q}{2\pi Ti}\right)\tan^{-1}\left(\frac{y}{x}\right)$$

$$X_0 = -Q/2\pi Ti \quad ; \quad Y_{\max} = \pm Q/2Ti \quad ; \quad Y_{well} = \pm Q/4Ti$$

(must use consistent units, such as "ft" for distance and "day" for time)

Where:

Q	=	extraction rate
T	=	transmissivity, $K \cdot b$
K	=	hydraulic conductivity
b	=	saturated thickness
i	=	regional (i.e., pre-remedy-pumping) hydraulic gradient
X_0	=	distance from the well to the downgradient end of the capture zone along the central line of the flow direction
Y_{max}	=	maximum capture zone width from the central line of the plume
Y_{well}	=	capture zone width at the location of well from the central line of the plume

The above equation is used to calculate the outline of the capture zone. Solving the equation for $x = 0$ allows one to calculate the distance between the dividing streamlines at the line of wells ($2 \cdot Y_{well}$) and solving the equation for $x = \infty$ allows one to calculate the distance between the dividing streamlines far upstream from the wells ($2 \cdot Y_{max}$). One can also calculate the distance from the well to the stagnation point (X_0) that marks the downgradient end of the capture zone by solving for x at $y = 0$. For any value of y between 0 and Y_{max}, one can calculate the corresponding x value, allowing the outline of the capture zone to be calculated.

USEPA, 2008. A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems.

PLATES

1. Generalized Hydrogeologic Cross Section Transects
2. Generalized Hydrogeologic Cross Section A-A'
3. Generalized Hydrogeologic Cross Section B-B'
4. Generalized Hydrogeologic Cross Section C-C'
5. Generalized Hydrogeologic Cross Section D-D'
6. Potentiometric Surface Contour Map Upper Hydrogeologic Unit

LEGEND

- RI/FS SITE BOUNDARY
- SURFACE WATER FEATURE
- SITE FEATURE
- CFMW-035 LOCATION AND DESIGNATION OF MONITORING WELL SCREENED IN UPPER HYDROGEOLOGIC UNIT
- CFMW-052 LOCATION AND DESIGNATION OF FORMER PRODUCTION WELL
- CFMW-032a LOCATION AND DESIGNATION OF MONITORING WELL SCREENED BELOW UPPER HYDROGEOLOGIC UNIT
- A TRANSECT LINE

N

425' 0 425'

Title:

GENERALIZED HYDROGEOLOGIC CROSS SECTION TRANSECTS

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY

ROUX

Compiled by: L.J.	Date: 08OCT20	PLATE
Prepared by: G.M.	Scale: AS SHOWN	A1
Project Mgr: M.R.	Project: 2476.0001Y008	
File: 2476.0001Y271.04.DWG		

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GEOLOGIC CROSS SECTION A–A'

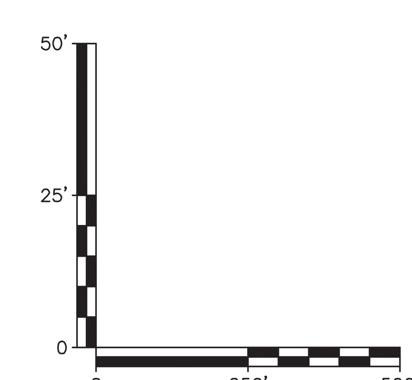
HORIZONTAL SCALE: 1" = 250'
VERTICAL SCALE: 1" = 25'
VERTICAL EXAGGERATION = 10X

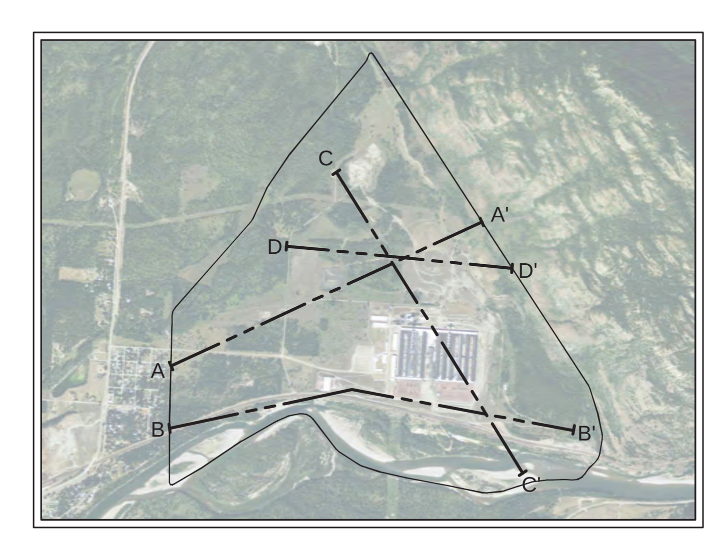
LEGEND

- FINE TO COARSE SAND WITH VARYING AMOUNTS OF GRAVEL AND SILT (OUTWASH/ALLUVIUM)
- PRIMARILY SILT (TILL)
- PRIMARILY CLAY WITH SOME SILT AND VARYING AMOUNTS OF SANDS AND GRAVELS (TILL)
- FINE TO COARSE SAND AND SILT WITH VARYING AMOUNTS OF GRAVEL AND CLAY (TILL)
- BEDROCK
- POTENTIOMETRIC HEAD GROUNDWATER ELEVATION
- MONITORING WELL GROUNDWATER SCREENED IN THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- MONITORING WELL GROUNDWATER SCREENED BELOW THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- INFERRED BASE OF UPPER HYDROGEOLOGIC UNIT

NOTES

1. POTENTIOMETRIC HEAD GROUNDWATER ELEVATIONS ARE BASED ON JUNE 4/5, 2018 GAUGING DATA.
2. HISTORIC WELL LOGS FOR MONITORING WELLS CFMW–008 (TW–9), CFMW–057 (TW–12) AND CFMW–056 (TW–11) DID NOT PROVIDE WELL SCREEN INFORMATION.





Title:

GENERALIZED HYDROGEOLOGIC CROSS SECTION A-A'

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: L.J.	Date: 08OCT20	PLATE
Prepared by: G.M.	Scale: AS SHOWN	A2
Project Mgr: M.R.	Project: 2476.0001Y008	
File: 2476.0001Y271.05.DWG		

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GEOLOGIC CROSS SECTION B–B'

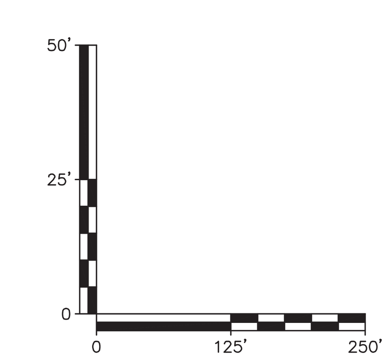
HORIZONTAL SCALE: 1" = 125'
VERTICAL SCALE: 1" = 25'
VERTICAL EXAGGERATION = 5X

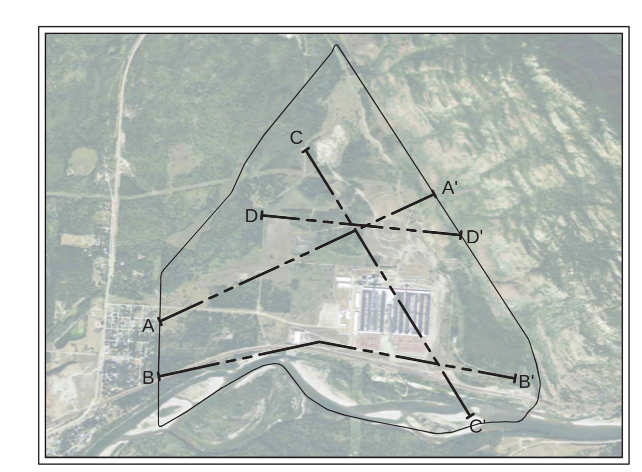
LEGEND

FINE TO COARSE SAND WITH VARYING AMOUNTS OF GRAVEL AND SILT (OUTWASH/ALLUVIUM)	POTENTIOMETRIC HEAD GROUNDWATER ELEVATION
PRIMARILY CLAY WITH SOME SILT AND VARYING AMOUNTS OF SANDS AND GRAVELS (TILL)	MONITORING WELL GROUNDWATER SCREENED IN THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
PRIMARILY SILT (TILL)	MONITORING WELL GROUNDWATER SCREENED BELOW THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
FINE TO COARSE SAND AND SILT WITH VARYING AMOUNTS OF GRAVEL AND CLAY (TILL)	INFERRED BASE OF UPPER HYDROGEOLOGIC UNIT

NOTE

1. POTENTIOMETRIC HEAD GROUNDWATER ELEVATIONS ARE BASED ON JUNE 4/5, 2018 GAUGING DATA.
2. HISTORIC WELL LOGS FOR MONITORING WELLS CFMW–051 (PW–5) AND CFMW–052 (PW–4) PROVIDED INCORRECT WELL SCREEN INFORMATION.





Title:

GENERALIZED HYDROGEOLOGIC CROSS SECTION B-B'

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COPANY, LLC

ROUX

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Prepared by: G.M.	Scale: AS SHOWN	A3
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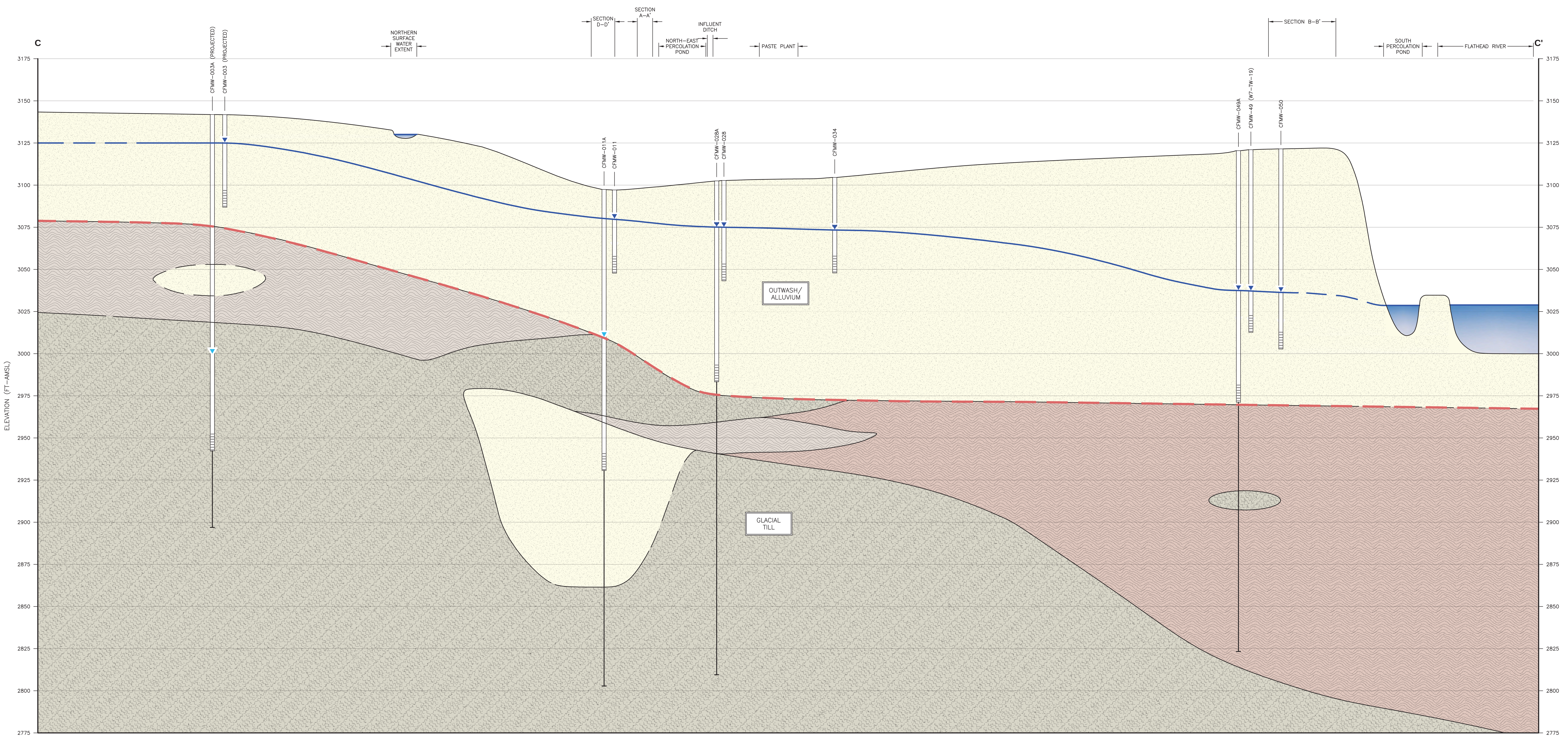


GEOLOGIC CROSS SECTION C–C'

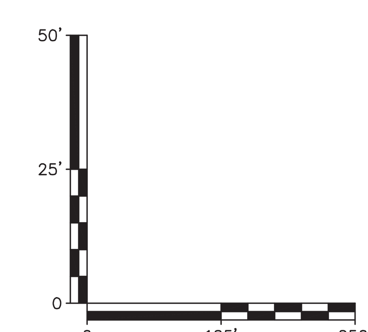
HORIZONTAL SCALE: 1" = 125'
VERTICAL SCALE: 1" = 25'
VERTICAL EXAGGERATION = 5X

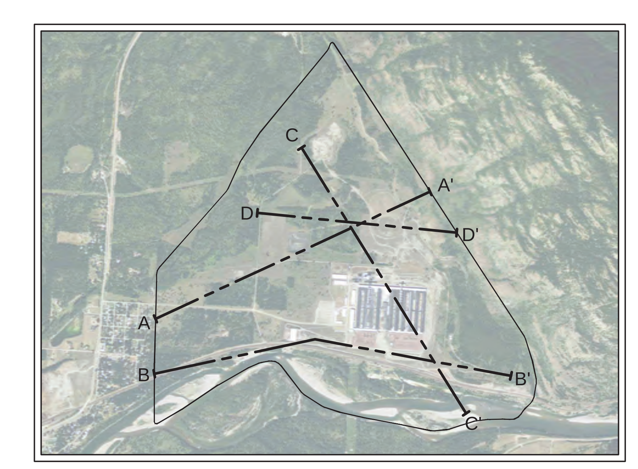
LEGEND

- FINE TO COARSE SAND WITH VARYING AMOUNTS OF GRAVEL AND SILT (OUTWASH/ALLUVIUM)
- PRIMARILY SILT (TILL)
- FINE TO COARSE SAND AND SILT WITH VARYING AMOUNTS OF GRAVEL AND CLAY (TILL)
- PRIMARILY CLAY WITH SOME SILT AND VARYING AMOUNTS OF SANDS AND GRAVELS (TILL)
- POTENTIOMETRIC HEAD GROUNDWATER ELEVATION
- MONITORING WELL GROUNDWATER SCREENED IN THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- MONITORING WELL GROUNDWATER SCREENED BELOW THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- INFERRED BASE OF UPPER HYDROGEOLOGIC UNIT

NOTE

POTENTIOMETRIC HEAD GROUNDWATER ELEVATIONS ARE BASED ON JUNE 4/5, 2018 GAUGING DATA.





Title:

GENERALIZED HYDROGEOLOGIC CROSS SECTION C-C'

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COPANY, LLC

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Prepared by: G.M.	Scale: AS SHOWN	A4
Project Mgr: M.R.	Project: 2476.0001Y008	
File: 2476.0001Y271.06.DWG		

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GEOLOGIC CROSS SECTION D–D'

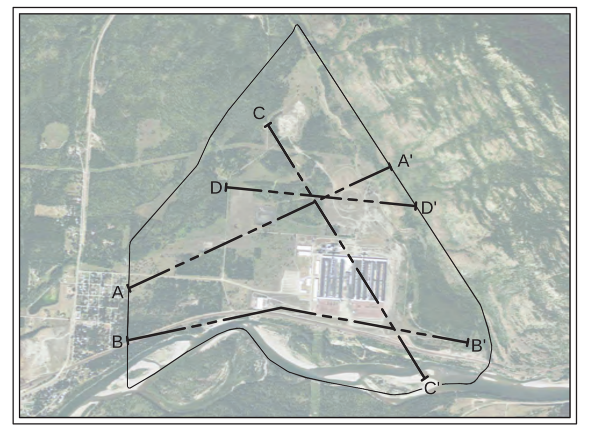
HORIZONTAL SCALE: 1" = 125'
VERTICAL SCALE: 1" = 25'
VERTICAL EXAGGERATION = 5X

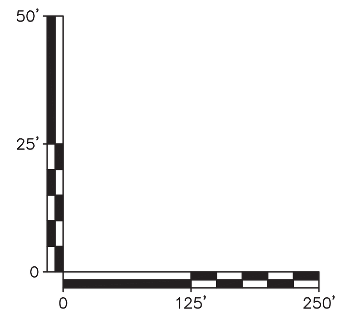
LEGEND

- FINE TO COARSE SAND WITH VARYING AMOUNTS OF GRAVEL AND SILT (OUTWASH/ALLUVIUM)
- PRIMARILY CLAY WITH SOME SILT AND VARYING AMOUNTS OF SANDS AND GRAVELS (TILL)
- FINE TO COARSE SAND AND SILT WITH VARYING AMOUNTS OF GRAVEL AND CLAY (TILL)
- BEDROCK
- POTENTIOMETRIC HEAD GROUNDWATER ELEVATION
- MONITORING WELL GROUNDWATER SCREENED IN THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- MONITORING WELL GROUNDWATER SCREENED BELOW THE UPPER HYDROGEOLOGIC UNIT POTENTIOMETRIC SURFACE
- INFERRED BASE OF UPPER HYDROGEOLOGIC UNIT

NOTE

POTENTIOMETRIC HEAD GROUNDWATER ELEVATIONS ARE BASED ON JUNE 4/5, 2018 GAUGING DATA.





Title:

GENERALIZED HYDROGEOLOGIC CROSS SECTION D-D'

Prepared for:

COLUMBIA FALLS ALUMINUM COPANY, LLC

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	Prepared by: G.M.	Scale: AS SHOWN	A5
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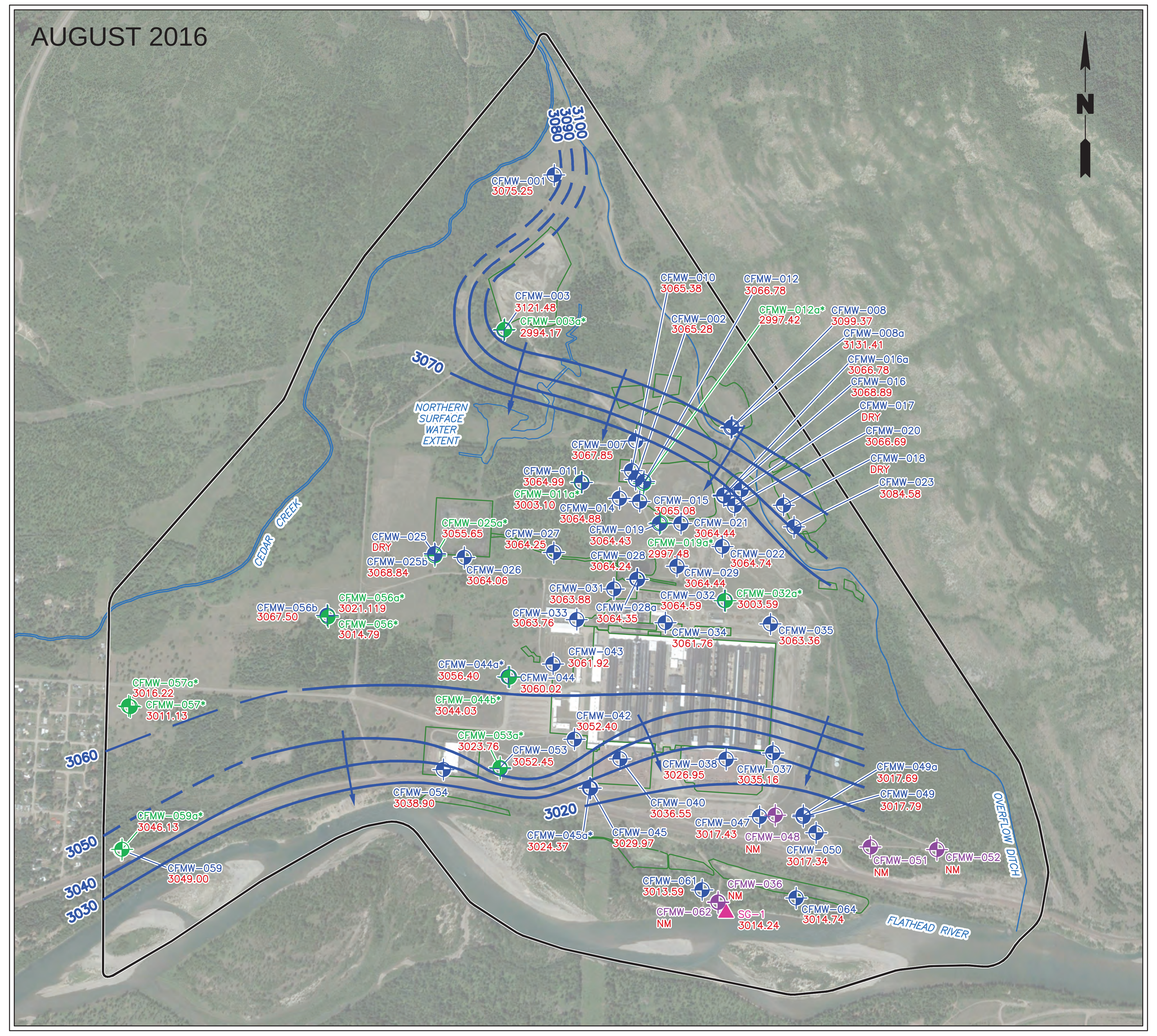
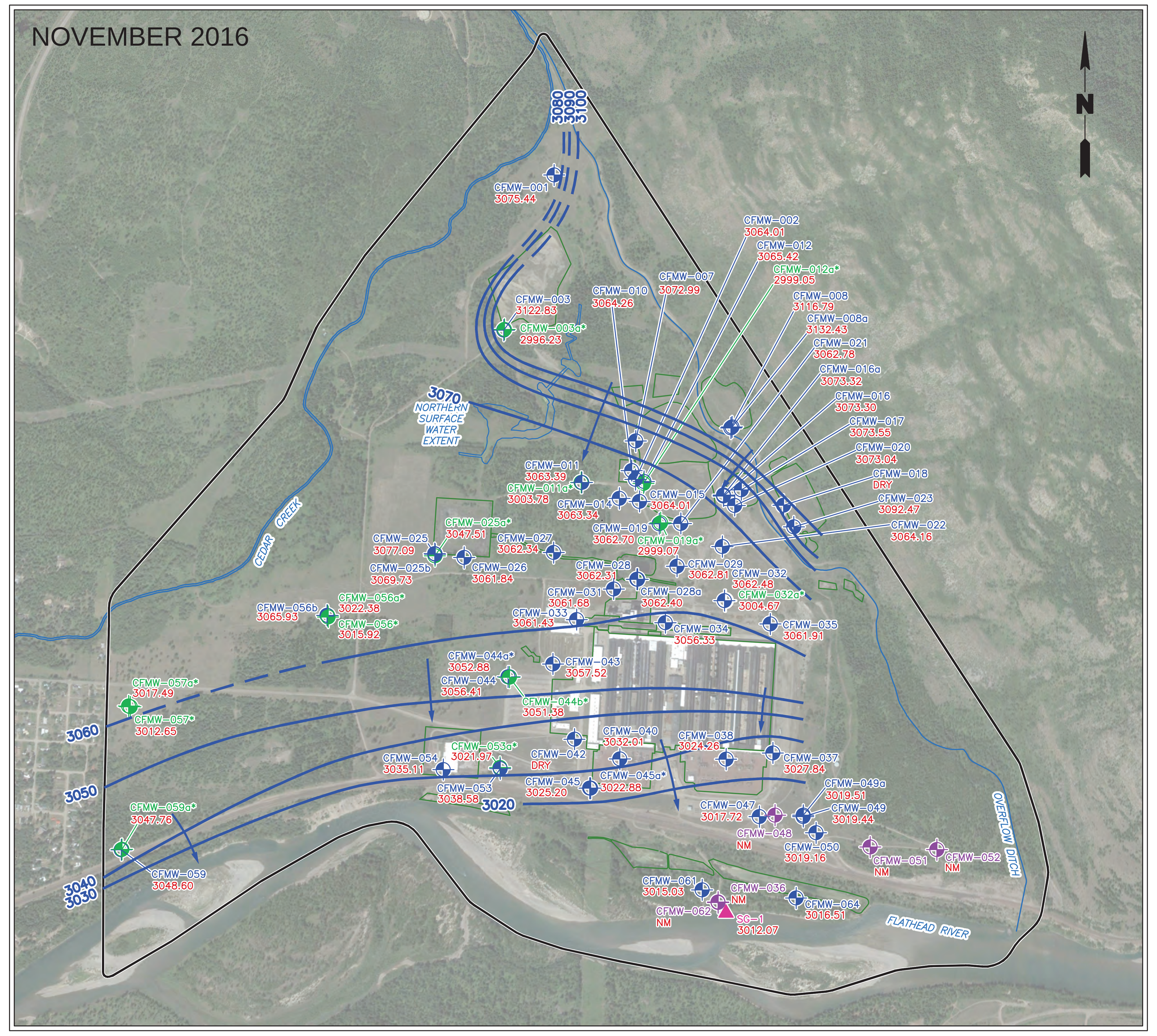
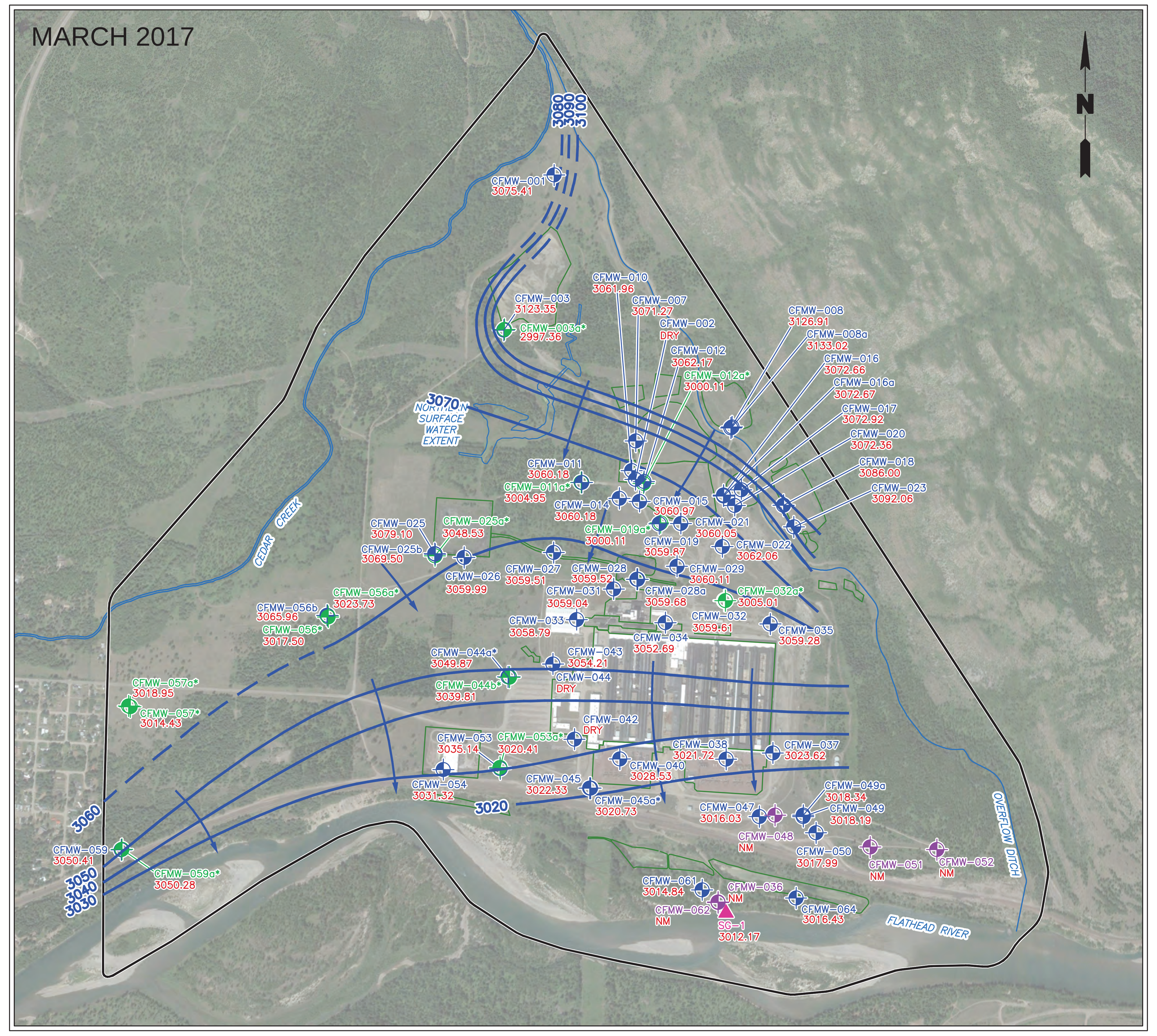
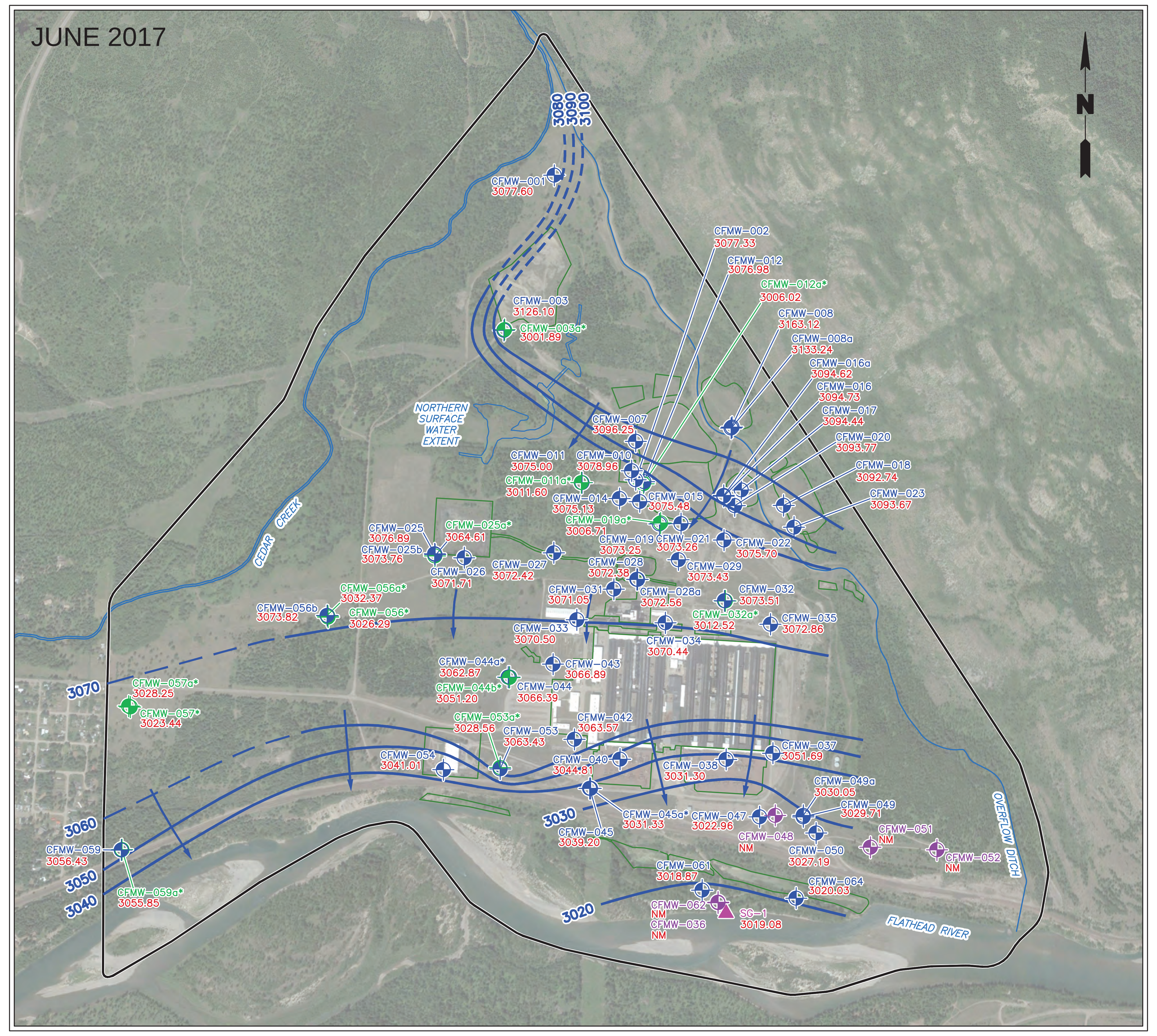
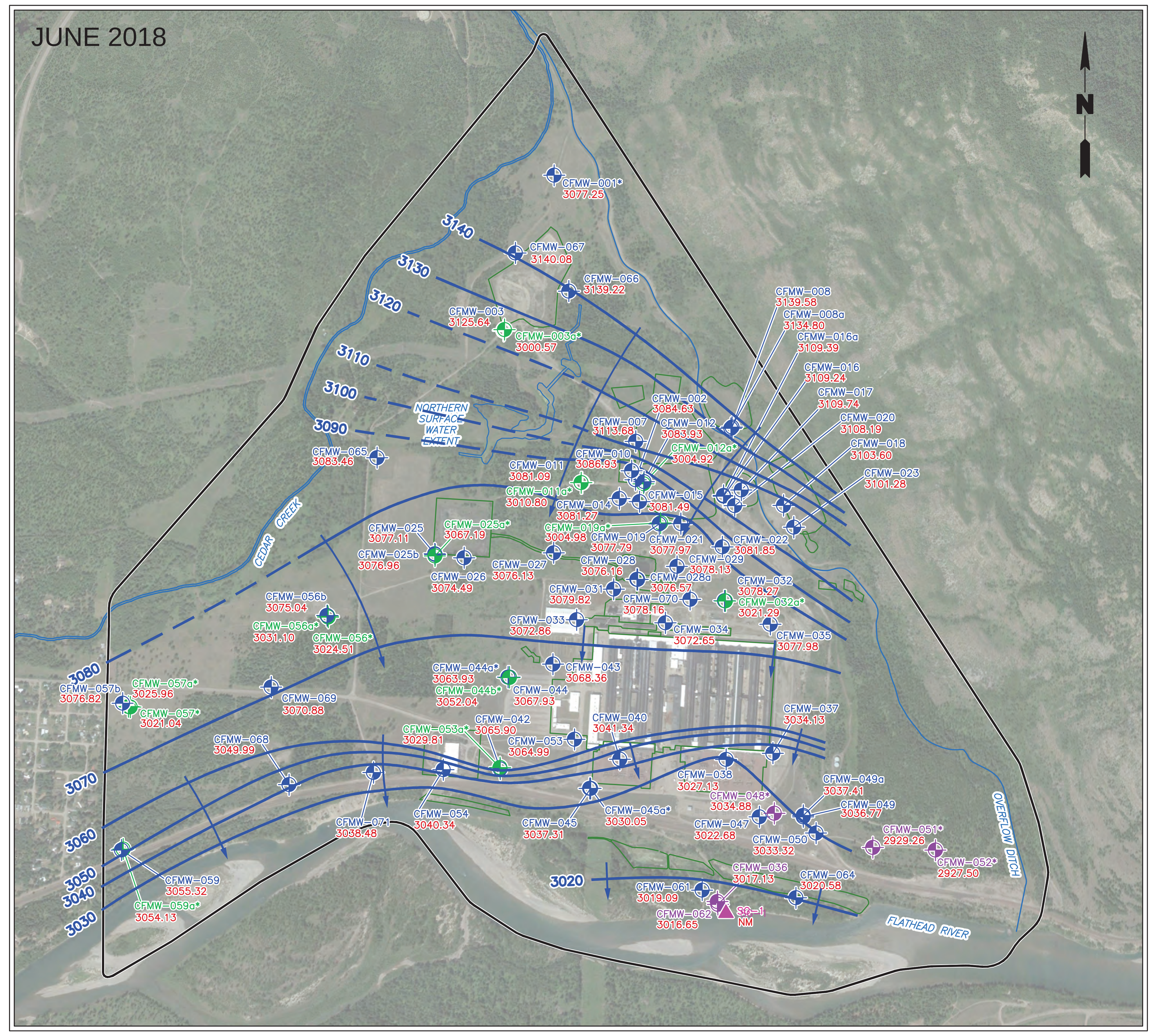
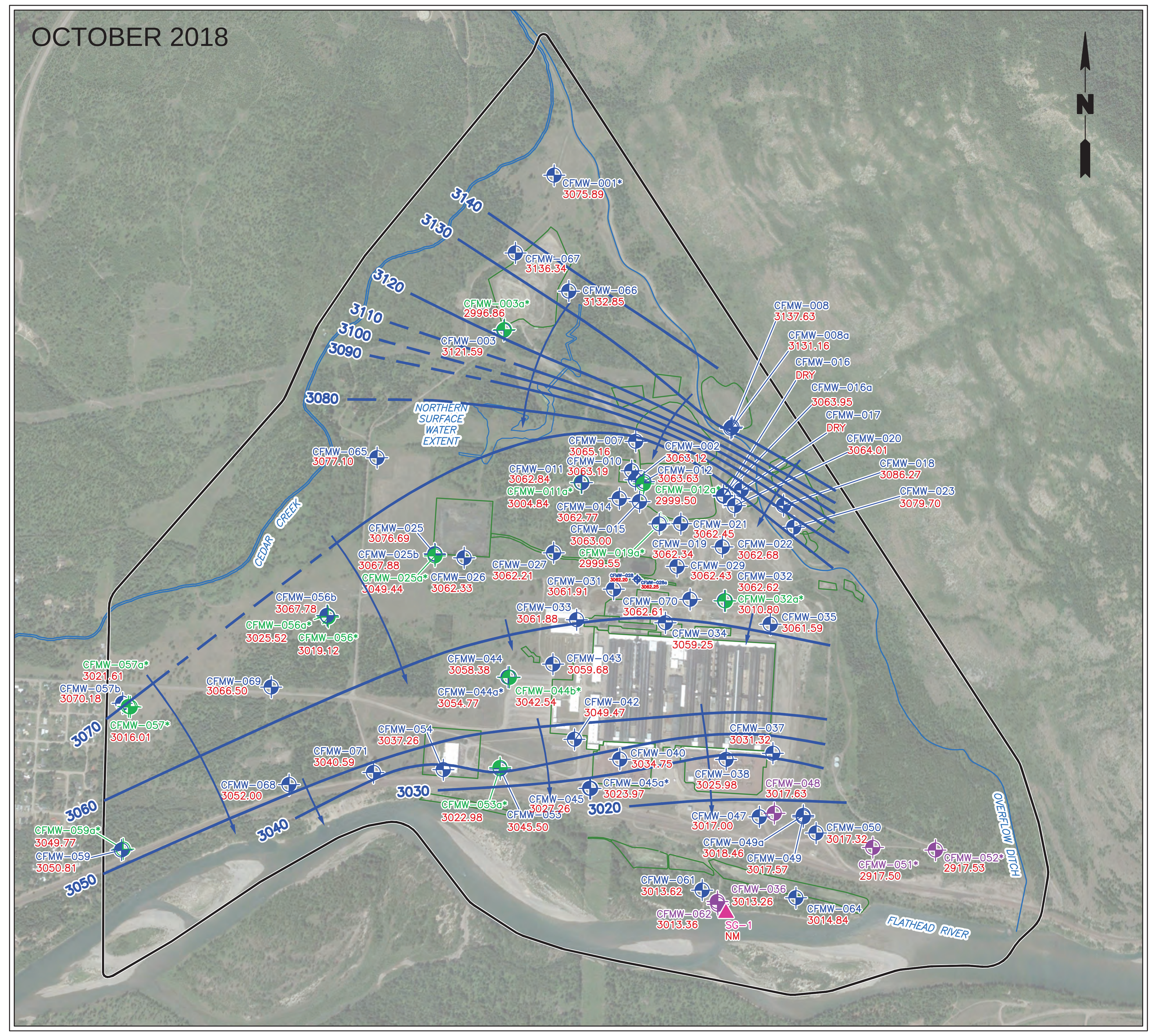












LEGEND

	RI/FS SITE BOUNDARY
	SURFACE WATER FEATURE
	SITE FEATURE
CFMW-035	LOCATION AND DESIGNATION OF MONITORING WELL SCREENED IN UPPER HYDROGEOLOGIC UNIT
CFMW-052	LOCATION AND DESIGNATION OF FORMER PRODUCTION WELL
CFMW-032a*	LOCATION AND DESIGNATION OF MONITORING WELL SCREENED BELOW UPPER HYDROGEOLOGIC UNIT
SG-1	LOCATION AND DESIGNATION OF SURFACE WATER STAFF GAUGE
3188.99	LOCATION WHERE SITE FEATURE WAS SURVEYED
3061.59	POTENTIOMETRIC SURFACE IN FEET ABOVE MEAN SEA LEVEL
NM	NOT MEASURED
DRY	INSUFFICIENT WATER TO COLLECT SAMPLE
*	NOT USED IN CONTOURING
3080	CONTOUR LINE OF EQUAL POTENTIOMETRIC SURFACE (DASHED WHERE INFERRED)
	INFERRED FLOW DIRECTION

NOTE

MONITORING WELLS SCREENED BELOW UPPER HYDROGEOLOGIC UNIT ARE NOT USED IN CONTOURING.

N

1,000 0 1,000

Title:

POTENTIOMETRIC SURFACE CONTOUR MAP UPPER HYDROGEOLOGIC UNIT

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

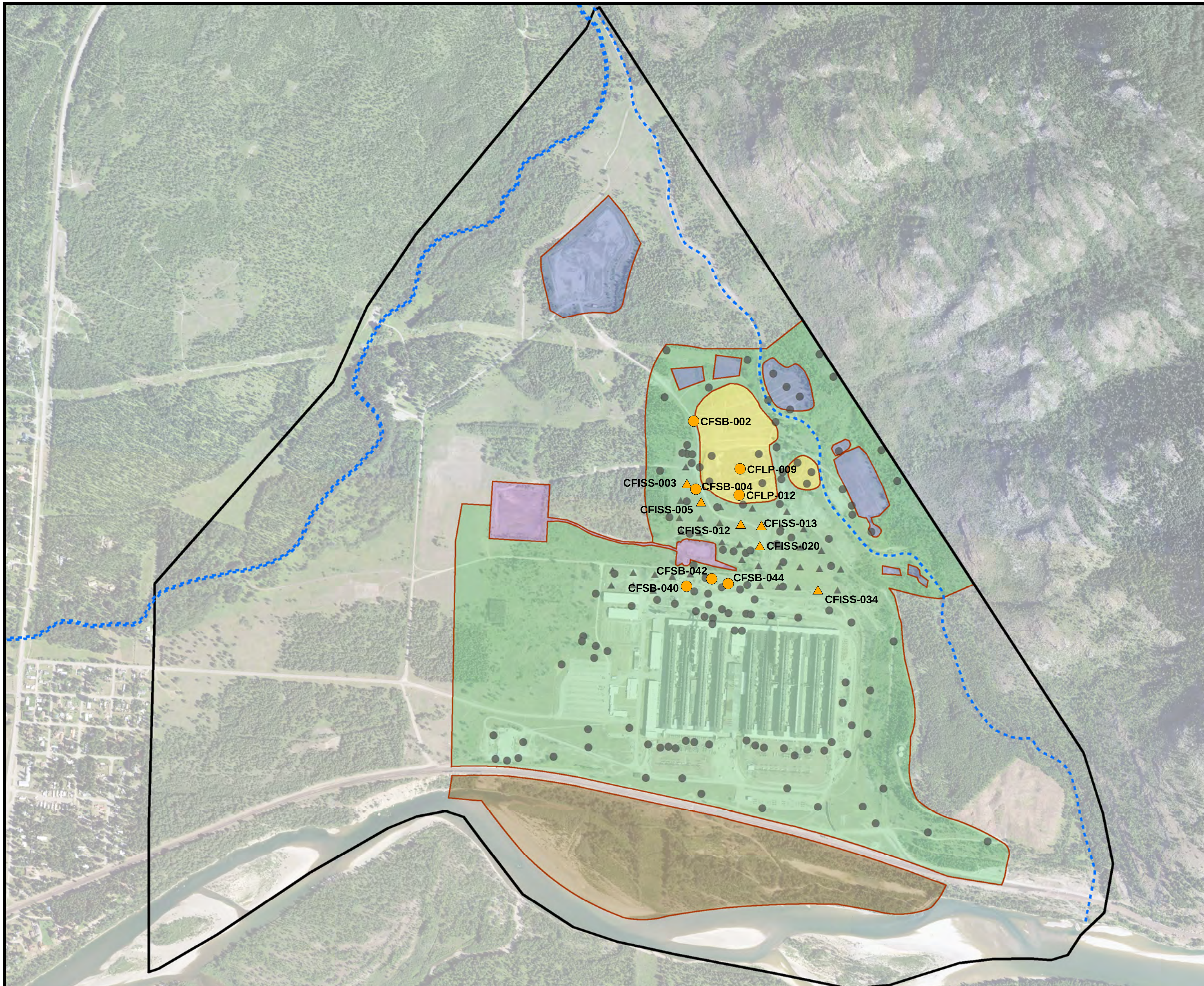
COLUMBIA FALLS ALUMINUM COMPANY

ROUX			PLATE
	Compiled by: L.J.	Date: 08OCT20	
	Prepared by: G.M.	Scale: AS SHOWN	A6
	Project Mgr: M.R.	Project: 2476.0001Y010	
	File: 2476.0001Y271.08.DWG		

APPENDIX B

Small Range Receptor PRG Comparison – Soil Thematic Maps

1. Exceedances of Small Range Receptor PRGs in Soil Samples
2. Concentrations of Copper in Soil Samples – Small Range Receptor PRG Comparison
3. Concentrations of Nickel in Soil Samples – Small Range Receptor PRG Comparison
4. Concentrations of LMW PAHs in Soil Samples – Small Range Receptor PRG Comparison
5. Concentrations of HMW PAHs in Soil Samples – Small Range Receptor PRG Comparison



N

LEGEND - EA 1, 3, & ISM GRID AREA

SO	ISM	
●	▲	LOCATION WITH NO EXCEEDANCES
●	▲	LOCATION WITH ONE OR MORE PROTECTIVE SOIL SMALL RANGE RECEPTOR PRG EXCEEDANCE

1,000 0 1,000'

Title:

EXCEEDANCES OF SMALL RANGE RECEPTOR PRGS IN SOIL SAMPLES

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	
Project Mgr: C.S.	Project: 2476.0001Y010	B1
File: 2476.0001Y271.B1.mxd		

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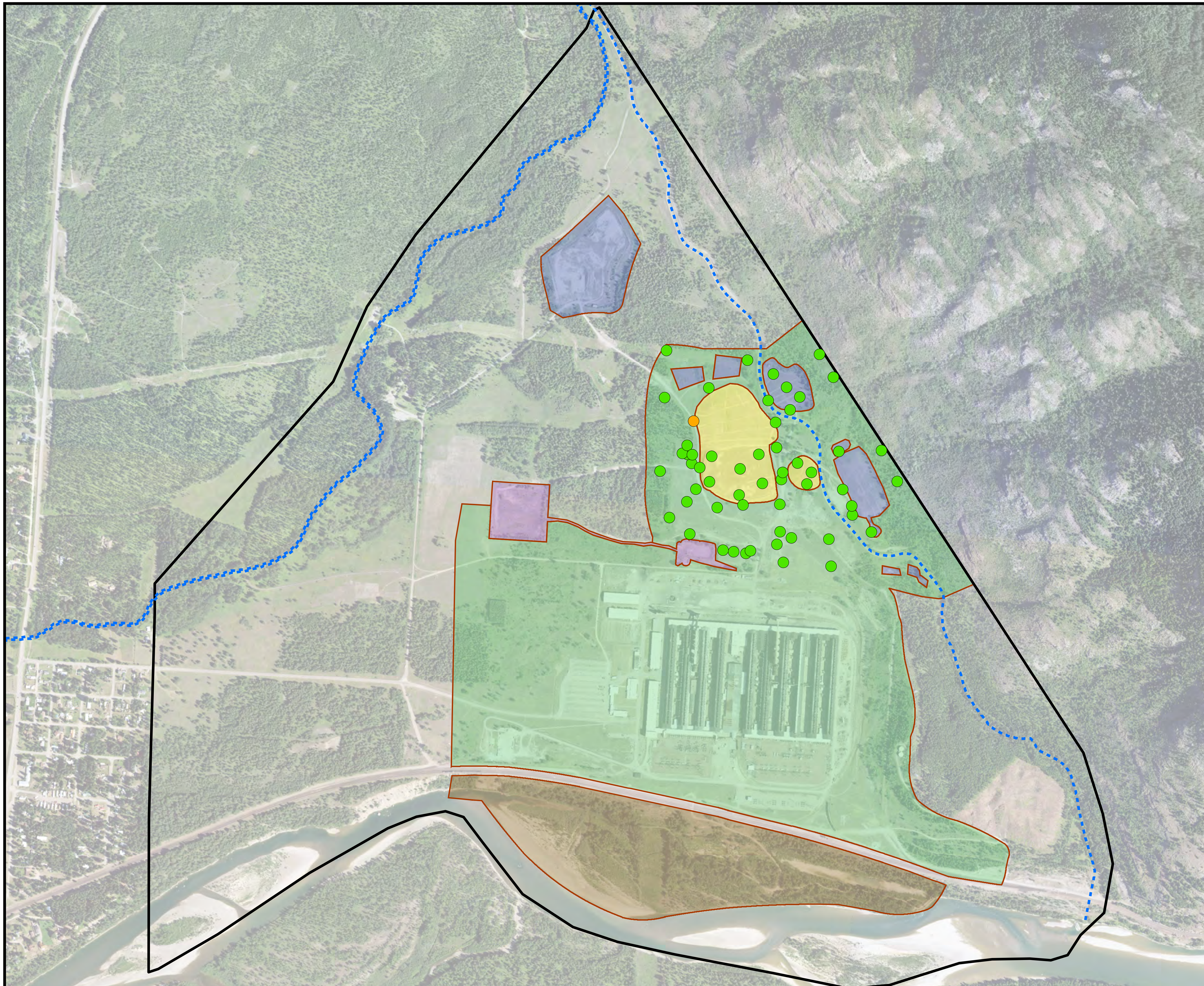

Title:

CONCENTRATIONS OF COPPER IN SOIL SAMPLES – SMALL RANGE RECEPTOR PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	B2
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.B2.mxd		

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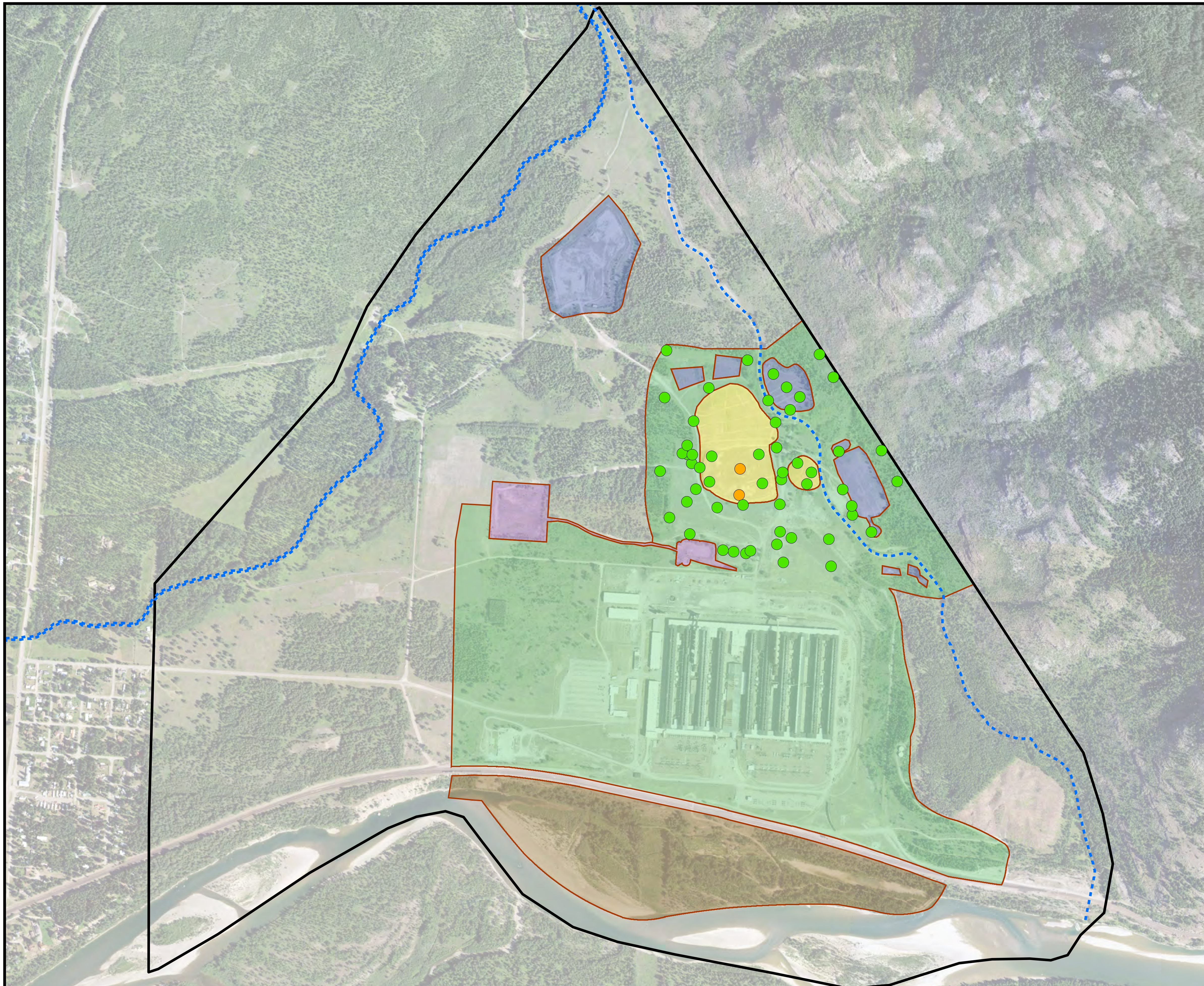

CONCENTRATION LEGEND - EA 3

- ANALYTE NOT DETECTED
- ND - 140 (LESS THAN PROTECTIVE SOIL SMALL RANGE RECEPTOR PRG)
- >140 (GREATER THAN PROTECTIVE SOIL SMALL RANGE RECEPTOR PRG)

ALL CONCENTRATIONS ARE IN MILLIGRAMS PER KILOGRAM (MG/KG)

N

1,000 0 1,000'

Title:

CONCENTRATIONS OF NICKEL IN SOIL SAMPLES – SMALL RANGE RECEPTOR PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	B3
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.B3.mxd		

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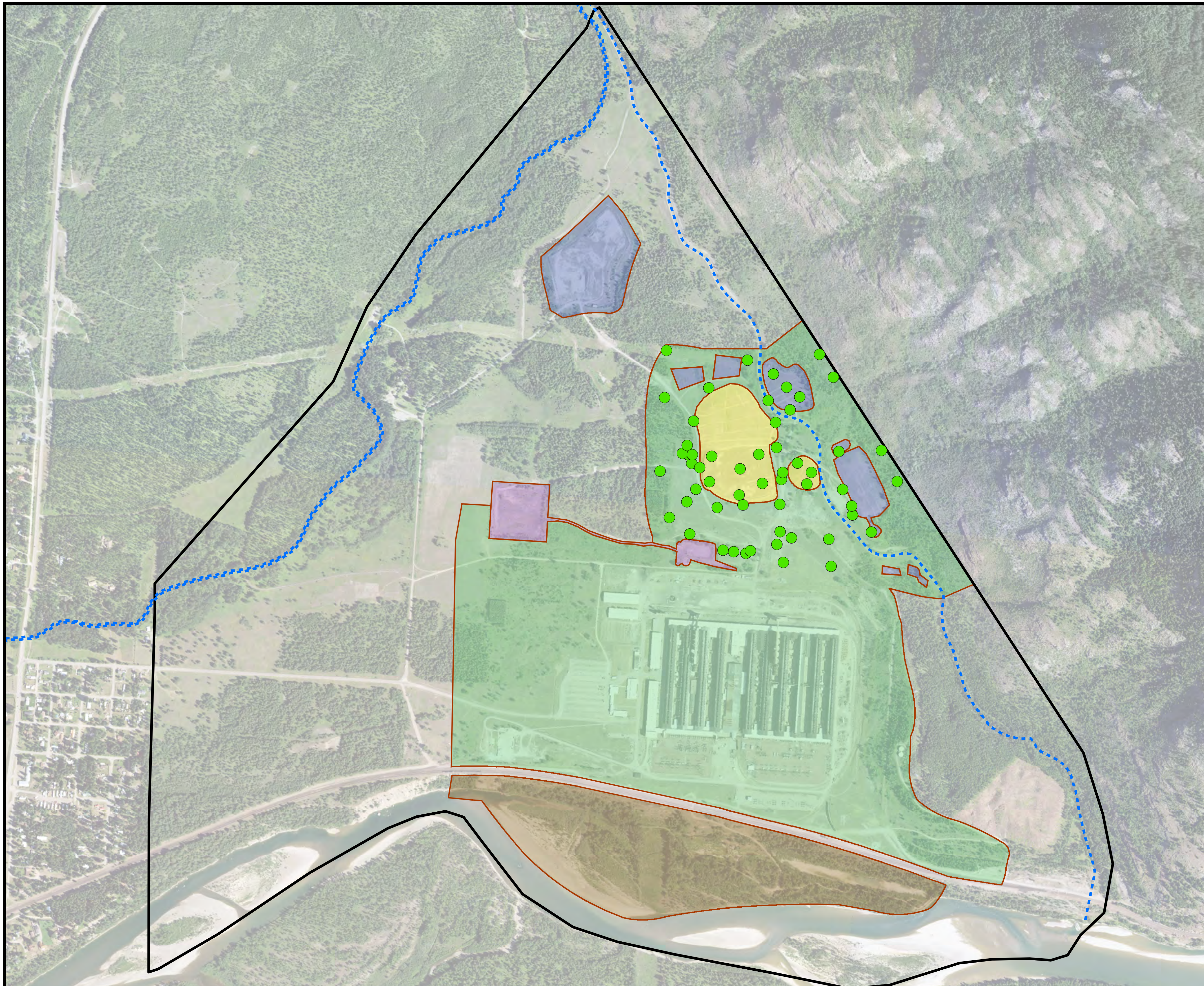

Title:

CONCENTRATIONS OF LMW PAHS IN SOIL SAMPLES – SMALL RANGE RECEPTOR PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	B4
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.B4.mxd		

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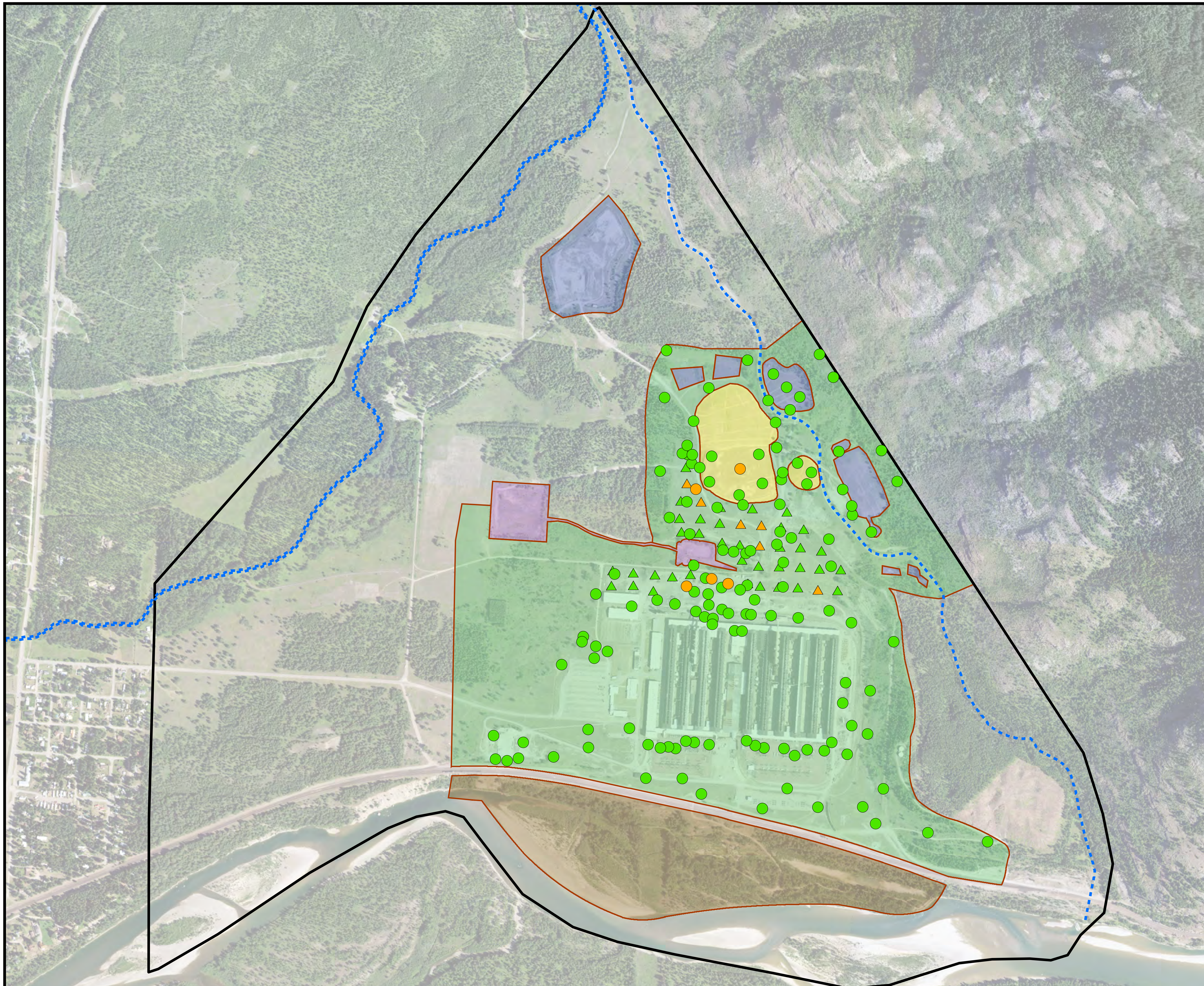

N

CONCENTRATION LEGEND - EA 1, 3 & ISM GRID AREA

SO	ISM	
● (blue)	▲ (blue)	ANALYTE NOT DETECTED
● (green)	▲ (green)	ND - 110 (LESS THAN PROTECTIVE SOIL SMALL RANGE RECEPTOR PRG)
● (orange)	▲ (orange)	>110 (GREATER THAN PROTECTIVE SOIL SMALL RANGE RECEPTOR PRG)

ALL CONCENTRATIONS ARE IN MILLIGRAMS PER KILOGRAM (MG/KG)

1,000 0 1,000'

Title:

CONCENTRATIONS OF HMW PAHS IN SOIL SAMPLES – SMALL RANGE RECEPTOR PRG COMPARISON

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX	Compiled by: C.S.	Date: 09/29/20	APPENDIX
	Prepared by: M.S.R.	Scale: AS SHOWN	B5
	Project Mgr: C.S.	Project: 2476.0001Y010	
	File: 2476.0001Y271.B5.mxd		

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APPENDIX C

Protective Soil PRG Comparison – 95UCLmean ProUCL Outputs

ProUCL Output

ISM Grid Area (0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/6/2020 11:49:35 PM		
From File	ISM_0-0.5_RSD_HIGH_ProUCL_Inputs_-_ISM_Grid_Area.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Copper			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	17.6	Mean	95.12
Maximum	996	Median	29.8
SD	187.3	Std. Error of Mean	29.99
Coefficient of Variation	1.969	Skewness	3.672
Normal GOF Test			
Shapiro Wilk Test Statistic	0.453	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.384	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	145.7	95% Adjusted-CLT UCL (Chen-1995)	163.3
		95% Modified-t UCL (Johnson-1978)	148.6
Gamma GOF Test			
A-D Test Statistic	5.128	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.787	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.298	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.147	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.785	k star (bias corrected MLE)	0.742
Theta hat (MLE)	121.1	Theta star (bias corrected MLE)	128.2
nu hat (MLE)	61.25	nu star (bias corrected)	57.87
MLE Mean (bias corrected)	95.12	MLE Sd (bias corrected)	110.4

		Approximate Chi Square Value (0.05)	41.38
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	40.83
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	133	95% Adjusted Gamma UCL (use when n<50)	134.8
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.793	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.198	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.868	Mean of logged Data	3.797
Maximum of Logged Data	6.904	SD of logged Data	1
Assuming Lognormal Distribution			
95% H-UCL	108.6	90% Chebyshev (MVUE) UCL	112.5
95% Chebyshev (MVUE) UCL	130.8	97.5% Chebyshev (MVUE) UCL	156.2
99% Chebyshev (MVUE) UCL	206		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	144.5	95% Jackknife UCL	145.7
95% Standard Bootstrap UCL	145.3	95% Bootstrap-t UCL	192.8
95% Hall's Bootstrap UCL	165.7	95% Percentile Bootstrap UCL	146
95% BCA Bootstrap UCL	171.9		
90% Chebyshev(Mean, Sd) UCL	185.1	95% Chebyshev(Mean, Sd) UCL	225.8
97.5% Chebyshev(Mean, Sd) UCL	282.4	99% Chebyshev(Mean, Sd) UCL	393.5
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	225.8		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Selenium			

ProUCL Output

ISM Grid Area (0-0.5)

General Statistics			
Total Number of Observations	39	Number of Distinct Observations	28
		Number of Missing Observations	0
Minimum	0.36	Mean	2.148
Maximum	16	Median	1.68
SD	2.594	Std. Error of Mean	0.415
Coefficient of Variation	1.208	Skewness	4.351
Normal GOF Test			
Shapiro Wilk Test Statistic	0.541	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.848	95% Adjusted-CLT UCL (Chen-1995)	3.14
		95% Modified-t UCL (Johnson-1978)	2.896
Gamma GOF Test			
A-D Test Statistic	1.21	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.764	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.162	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.144	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.628	k star (bias corrected MLE)	1.52
Theta hat (MLE)	1.319	Theta star (bias corrected MLE)	1.413
nu hat (MLE)	127	nu star (bias corrected)	118.5
MLE Mean (bias corrected)	2.148	MLE Sd (bias corrected)	1.742
		Approximate Chi Square Value (0.05)	94.4
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	93.55
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	2.697	95% Adjusted Gamma UCL (use when n<50)	2.722
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.115	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			

Lognormal Statistics			
Minimum of Logged Data	-1.022	Mean of logged Data	0.427
Maximum of Logged Data	2.773	SD of logged Data	0.771
Assuming Lognormal Distribution			
95% H-UCL	2.7	90% Chebyshev (MVUE) UCL	2.878
95% Chebyshev (MVUE) UCL	3.257	97.5% Chebyshev (MVUE) UCL	3.783
99% Chebyshev (MVUE) UCL	4.815		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	2.831	95% Jackknife UCL	2.848
95% Standard Bootstrap UCL	2.823	95% Bootstrap-t UCL	3.738
95% Hall's Bootstrap UCL	5.827	95% Percentile Bootstrap UCL	2.918
95% BCA Bootstrap UCL	3.277		
90% Chebyshev(Mean, Sd) UCL	3.394	95% Chebyshev(Mean, Sd) UCL	3.958
97.5% Chebyshev(Mean, Sd) UCL	4.742	99% Chebyshev(Mean, Sd) UCL	6.28
Suggested UCL to Use			
95% H-UCL	2.7		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.			
Zinc			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	54.3	Mean	184.9
Maximum	1939	Median	86.6
SD	345.9	Std. Error of Mean	55.39
Coefficient of Variation	1.871	Skewness	4.152

ProUCL Output

ISM Grid Area (0-0.5)

Normal GOF Test			
Shapiro Wilk Test Statistic	0.388	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.407	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	278.2	95% Adjusted-CLT UCL (Chen-1995)	315.3
		95% Modified-t UCL (Johnson-1978)	284.4
Gamma GOF Test			
A-D Test Statistic	7.112	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.777	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.364	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.145	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.065	k star (bias corrected MLE)	1
Theta hat (MLE)	173.6	Theta star (bias corrected MLE)	184.8
nu hat (MLE)	83.08	nu star (bias corrected)	78.02
MLE Mean (bias corrected)	184.9	MLE Sd (bias corrected)	184.8
		Approximate Chi Square Value (0.05)	58.67
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	58.01
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	245.8	95% Adjusted Gamma UCL (use when n<50)	248.6
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.677	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.284	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	3.995	Mean of logged Data	4.682
Maximum of Logged Data	7.57	SD of logged Data	0.783
Assuming Lognormal Distribution			
95% H-UCL	193.2	90% Chebyshev (MVUE) UCL	205.7

95% Chebyshev (MVUE) UCL	233.1	97.5% Chebyshev (MVUE) UCL	271.2
99% Chebyshev (MVUE) UCL	345.9		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	276	95% Jackknife UCL	278.2
95% Standard Bootstrap UCL	274.5	95% Bootstrap-t UCL	419.3
95% Hall's Bootstrap UCL	316.1	95% Percentile Bootstrap UCL	288.9
95% BCA Bootstrap UCL	328.6		
90% Chebyshev(Mean, Sd) UCL	351	95% Chebyshev(Mean, Sd) UCL	426.3
97.5% Chebyshev(Mean, Sd) UCL	530.8	99% Chebyshev(Mean, Sd) UCL	736
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	426.3		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Total LMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	0.87	Mean	53.41
Maximum	1004	Median	10.7
SD	163.6	Std. Error of Mean	26.2
Coefficient of Variation	3.064	Skewness	5.484
Normal GOF Test			
Shapiro Wilk Test Statistic	0.329	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.374	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	97.58	95% Adjusted-CLT UCL (Chen-1995)	121.1
		95% Modified-t UCL (Johnson-1978)	101.4

ProUCL Output

ISM Grid Area (0-0.5)

Gamma GOF Test			
A-D Test Statistic	2.85	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.826	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.26	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.151	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.442	k star (bias corrected MLE)	0.425
Theta hat (MLE)	120.9	Theta star (bias corrected MLE)	125.7
nu hat (MLE)	34.46	nu star (bias corrected)	33.15
MLE Mean (bias corrected)	53.41	MLE Sd (bias corrected)	81.93
		Approximate Chi Square Value (0.05)	20.98
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	20.6
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	84.36	95% Adjusted Gamma UCL (use when n<50)	85.93
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.131	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.139	Mean of logged Data	2.512
Maximum of Logged Data	6.912	SD of logged Data	1.549
Assuming Lognormal Distribution			
95% H-UCL	89.45	90% Chebyshev (MVUE) UCL	76
95% Chebyshev (MVUE) UCL	93	97.5% Chebyshev (MVUE) UCL	116.6
99% Chebyshev (MVUE) UCL	162.9		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	96.5	95% Jackknife UCL	97.58
95% Standard Bootstrap UCL	95.3	95% Bootstrap-t UCL	251.8
95% Hall's Bootstrap UCL	249.6	95% Percentile Bootstrap UCL	103.3
95% BCA Bootstrap UCL	132.9		
90% Chebyshev(Mean, Sd) UCL	132	95% Chebyshev(Mean, Sd) UCL	167.6

97.5% Chebyshev(Mean, Sd) UCL	217	99% Chebyshev(Mean, Sd) UCL	314.1
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	167.6		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	39
		Number of Missing Observations	0
Minimum	3.65	Mean	128
Maximum	1434	Median	37.9
SD	279.6	Std. Error of Mean	44.77
Coefficient of Variation	2.184	Skewness	3.797
Normal GOF Test			
Shapiro Wilk Test Statistic	0.466	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.328	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	203.5	95% Adjusted-CLT UCL (Chen-1995)	230.7
		95% Modified-t UCL (Johnson-1978)	208
Gamma GOF Test			
A-D Test Statistic	1.953	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.81	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.221	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.149	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.527	k star (bias corrected MLE)	0.504
Theta hat (MLE)	242.7	Theta star (bias corrected MLE)	254
nu hat (MLE)	41.14	nu star (bias corrected)	39.3

MLE Mean (bias corrected)	128	MLE Sd (bias corrected)	180.3
		Approximate Chi Square Value (0.05)	25.94
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	25.51
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	193.9	95% Adjusted Gamma UCL (use when n<50)	197.2
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.96	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.102	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.295	Mean of logged Data	3.658
Maximum of Logged Data	7.268	SD of logged Data	1.497
Assuming Lognormal Distribution			
95% H-UCL	248.6	90% Chebyshev (MVUE) UCL	217.2
95% Chebyshev (MVUE) UCL	264.7	97.5% Chebyshev (MVUE) UCL	330.7
99% Chebyshev (MVUE) UCL	460.1		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	201.6	95% Jackknife UCL	203.5
95% Standard Bootstrap UCL	201.7	95% Bootstrap-t UCL	344.4
95% Hall's Bootstrap UCL	523.5	95% Percentile Bootstrap UCL	203.2
95% BCA Bootstrap UCL	236.8		
90% Chebyshev(Mean, Sd) UCL	262.3	95% Chebyshev(Mean, Sd) UCL	323.1
97.5% Chebyshev(Mean, Sd) UCL	407.6	99% Chebyshev(Mean, Sd) UCL	573.4
Suggested UCL to Use			
95% H-UCL	248.6		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			

It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

ProUCL Output

ISM Grid Area (0-2)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/6/2020 11:51:32 PM		
From File	ISM_0-2_RSD_HIGH_ProUCL_Inputs_-_ISM_Grid_Area.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Copper			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	39
		Number of Missing Observations	0
Minimum	15.7	Mean	64.26
Maximum	576.4	Median	23.8
SD	109.7	Std. Error of Mean	17.56
Coefficient of Variation	1.707	Skewness	3.454
Normal GOF Test			
Shapiro Wilk Test Statistic	0.489	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.384	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	93.86	95% Adjusted-CLT UCL (Chen-1995)	103.5
		95% Modified-t UCL (Johnson-1978)	95.48
Gamma GOF Test			
A-D Test Statistic	5.511	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.781	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.326	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.146	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.944	k star (bias corrected MLE)	0.889
Theta hat (MLE)	68.05	Theta star (bias corrected MLE)	72.3
nu hat (MLE)	73.65	nu star (bias corrected)	69.32
MLE Mean (bias corrected)	64.26	MLE Sd (bias corrected)	68.16

		Approximate Chi Square Value (0.05)	51.15
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	50.54
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	87.07	95% Adjusted Gamma UCL (use when n<50)	88.13
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.751	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.239	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.754	Mean of logged Data	3.547
Maximum of Logged Data	6.357	SD of logged Data	0.916
Assuming Lognormal Distribution			
95% H-UCL	74.36	90% Chebyshev (MVUE) UCL	78.15
95% Chebyshev (MVUE) UCL	89.98	97.5% Chebyshev (MVUE) UCL	106.4
99% Chebyshev (MVUE) UCL	138.7		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	93.14	95% Jackknife UCL	93.86
95% Standard Bootstrap UCL	93.22	95% Bootstrap-t UCL	123.5
95% Hall's Bootstrap UCL	110.4	95% Percentile Bootstrap UCL	93.63
95% BCA Bootstrap UCL	104.5		
90% Chebyshev(Mean, Sd) UCL	116.9	95% Chebyshev(Mean, Sd) UCL	140.8
97.5% Chebyshev(Mean, Sd) UCL	173.9	99% Chebyshev(Mean, Sd) UCL	239
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	140.8		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Selenium			

ProUCL Output

ISM Grid Area (0-2)

General Statistics			
Total Number of Observations	39	Number of Distinct Observations	35
		Number of Missing Observations	0
Minimum	0.248	Mean	1.637
Maximum	5.695	Median	1.673
SD	0.996	Std. Error of Mean	0.159
Coefficient of Variation	0.608	Skewness	1.759
Normal GOF Test			
Shapiro Wilk Test Statistic	0.876	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.124	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	1.906	95% Adjusted-CLT UCL (Chen-1995)	1.947
		95% Modified-t UCL (Johnson-1978)	1.913
Gamma GOF Test			
A-D Test Statistic	0.457	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.755	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.114	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.142	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2.876	k star (bias corrected MLE)	2.672
Theta hat (MLE)	0.569	Theta star (bias corrected MLE)	0.613
nu hat (MLE)	224.3	nu star (bias corrected)	208.4
MLE Mean (bias corrected)	1.637	MLE Sd (bias corrected)	1.002
		Approximate Chi Square Value (0.05)	176
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	174.8
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	1.939	95% Adjusted Gamma UCL (use when n<50)	1.952
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.954	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.14	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			

Lognormal Statistics			
Minimum of Logged Data	-1.396	Mean of logged Data	0.309
Maximum of Logged Data	1.74	SD of logged Data	0.654
Assuming Lognormal Distribution			
95% H-UCL	2.095	90% Chebyshev (MVUE) UCL	2.243
95% Chebyshev (MVUE) UCL	2.5	97.5% Chebyshev (MVUE) UCL	2.856
99% Chebyshev (MVUE) UCL	3.557		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	1.899	95% Jackknife UCL	1.906
95% Standard Bootstrap UCL	1.9	95% Bootstrap-t UCL	1.96
95% Hall's Bootstrap UCL	2.065	95% Percentile Bootstrap UCL	1.897
95% BCA Bootstrap UCL	1.938		
90% Chebyshev(Mean, Sd) UCL	2.115	95% Chebyshev(Mean, Sd) UCL	2.332
97.5% Chebyshev(Mean, Sd) UCL	2.633	99% Chebyshev(Mean, Sd) UCL	3.223
Suggested UCL to Use			
95% Student's-t UCL	1.906		
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Zinc			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	39
		Number of Missing Observations	0
Minimum	48.7	Mean	102.9
Maximum	582.3	Median	69.83
SD	103.1	Std. Error of Mean	16.51
Coefficient of Variation	1.002	Skewness	3.612
Normal GOF Test			

Shapiro Wilk Test Statistic	0.495	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.337	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	130.7	95% Adjusted-CLT UCL (Chen-1995)	140.2
		95% Modified-t UCL (Johnson-1978)	132.3
Gamma GOF Test			
A-D Test Statistic	4.912	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.757	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.278	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.143	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2.492	k star (bias corrected MLE)	2.318
Theta hat (MLE)	41.28	Theta star (bias corrected MLE)	44.39
nu hat (MLE)	194.4	nu star (bias corrected)	180.8
MLE Mean (bias corrected)	102.9	MLE Sd (bias corrected)	67.58
		Approximate Chi Square Value (0.05)	150.7
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	149.6
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	123.4	95% Adjusted Gamma UCL (use when n<50)	124.3
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.739	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.225	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	3.886	Mean of logged Data	4.42
Maximum of Logged Data	6.367	SD of logged Data	0.546
Assuming Lognormal Distribution			
95% H-UCL	114.7	90% Chebyshev (MVUE) UCL	122.7
95% Chebyshev (MVUE) UCL	134.7	97.5% Chebyshev (MVUE) UCL	151.5
99% Chebyshev (MVUE) UCL	184.3		

Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	130	95% Jackknife UCL	130.7
95% Standard Bootstrap UCL	129.8	95% Bootstrap-t UCL	167.8
95% Hall's Bootstrap UCL	220.8	95% Percentile Bootstrap UCL	132.6
95% BCA Bootstrap UCL	142.7		
90% Chebyshev(Mean, Sd) UCL	152.4	95% Chebyshev(Mean, Sd) UCL	174.9
97.5% Chebyshev(Mean, Sd) UCL	206	99% Chebyshev(Mean, Sd) UCL	267.2
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	174.9		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Total LMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	39
		Number of Missing Observations	0
Minimum	0.615	Mean	91.19
Maximum	2005	Median	6.548
SD	333.2	Std. Error of Mean	53.36
Coefficient of Variation	3.654	Skewness	5.365
Normal GOF Test			
Shapiro Wilk Test Statistic	0.299	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.4	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	181.2	95% Adjusted-CLT UCL (Chen-1995)	227.9
		95% Modified-t UCL (Johnson-1978)	188.8
Gamma GOF Test			

A-D Test Statistic	4.47	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.855	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.289	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.153	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.311	k star (bias corrected MLE)	0.304
Theta hat (MLE)	292.9	Theta star (bias corrected MLE)	299.5
nu hat (MLE)	24.29	nu star (bias corrected)	23.75
MLE Mean (bias corrected)	91.19	MLE Sd (bias corrected)	165.3
		Approximate Chi Square Value (0.05)	13.66
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	13.36
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	158.6	95% Adjusted Gamma UCL (use when n<50)	162.2
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.938	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.146	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.486	Mean of logged Data	2.312
Maximum of Logged Data	7.604	SD of logged Data	1.811
Assuming Lognormal Distribution			
95% H-UCL	144.7	90% Chebyshev (MVUE) UCL	103.2
95% Chebyshev (MVUE) UCL	128.6	97.5% Chebyshev (MVUE) UCL	163.9
99% Chebyshev (MVUE) UCL	233.3		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	179	95% Jackknife UCL	181.2
95% Standard Bootstrap UCL	176	95% Bootstrap-t UCL	599.3
95% Hall's Bootstrap UCL	536.9	95% Percentile Bootstrap UCL	185.9
95% BCA Bootstrap UCL	246.3		
90% Chebyshev(Mean, Sd) UCL	251.3	95% Chebyshev(Mean, Sd) UCL	323.8
97.5% Chebyshev(Mean, Sd) UCL	424.4	99% Chebyshev(Mean, Sd) UCL	622.1

Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	323.8		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	39
		Number of Missing Observations	0
Minimum	1.408	Mean	148
Maximum	2806	Median	23.75
SD	465	Std. Error of Mean	74.46
Coefficient of Variation	3.143	Skewness	5.287
Normal GOF Test			
Shapiro Wilk Test Statistic	0.333	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.376	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	273.5	95% Adjusted-CLT UCL (Chen-1995)	337.8
		95% Modified-t UCL (Johnson-1978)	284
Gamma GOF Test			
A-D Test Statistic	2.903	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.836	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.236	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.152	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.394	k star (bias corrected MLE)	0.381
Theta hat (MLE)	375.2	Theta star (bias corrected MLE)	388.2
nu hat (MLE)	30.76	nu star (bias corrected)	29.73
MLE Mean (bias corrected)	148	MLE Sd (bias corrected)	239.7
		Approximate Chi Square Value (0.05)	18.28

Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	17.92
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	240.6	95% Adjusted Gamma UCL (use when n<50)	245.4
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.969	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0903	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.342	Mean of logged Data	3.325
Maximum of Logged Data	7.939	SD of logged Data	1.68
Assuming Lognormal Distribution			
95% H-UCL	279.5	90% Chebyshev (MVUE) UCL	219.2
95% Chebyshev (MVUE) UCL	270.8	97.5% Chebyshev (MVUE) UCL	342.4
99% Chebyshev (MVUE) UCL	483.1		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	270.4	95% Jackknife UCL	273.5
95% Standard Bootstrap UCL	269.1	95% Bootstrap-t UCL	740.4
95% Hall's Bootstrap UCL	708.5	95% Percentile Bootstrap UCL	288
95% BCA Bootstrap UCL	368.9		
90% Chebyshev(Mean, Sd) UCL	371.3	95% Chebyshev(Mean, Sd) UCL	472.5
97.5% Chebyshev(Mean, Sd) UCL	613	99% Chebyshev(Mean, Sd) UCL	888.8
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	472.5		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

ProUCL Output

ISM Grid Area (Main Plant Area 0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/5/2020 8:28:35 PM		
From File	ISM 40 MPA SO 0-0_5 ProUCL - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
BenzoAPyrene_RSD_HIGH_HALF_ND			
General Statistics			
Total Number of Observations	10	Number of Distinct Observations	10
		Number of Missing Observations	0
Minimum	0.463	Mean	14.3
Maximum	59.9	Median	5.174
SD	19.61	Std. Error of Mean	6.202
Coefficient of Variation	1.371	Skewness	1.695
Normal GOF Test			
Shapiro Wilk Test Statistic	0.739	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.842	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.336	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.262	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	25.67	95% Adjusted-CLT UCL (Chen-1995)	28.05
		95% Modified-t UCL (Johnson-1978)	26.22
Gamma GOF Test			
A-D Test Statistic	0.395	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.768	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.205	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.279	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.613	k star (bias corrected MLE)	0.496
Theta hat (MLE)	23.34	Theta star (bias corrected MLE)	28.85
nu hat (MLE)	12.25	nu star (bias corrected)	9.911
MLE Mean (bias corrected)	14.3	MLE Sd (bias corrected)	20.31

		Approximate Chi Square Value (0.05)	3.886
Adjusted Level of Significance	0.0267	Adjusted Chi Square Value	3.258
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	36.47	95% Adjusted Gamma UCL (use when n<50)	43.5
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.842	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.153	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.262	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.77	Mean of logged Data	1.655
Maximum of Logged Data	4.093	SD of logged Data	1.62
Assuming Lognormal Distribution			
95% H-UCL	219.3	90% Chebyshev (MVUE) UCL	40.25
95% Chebyshev (MVUE) UCL	51.52	97.5% Chebyshev (MVUE) UCL	67.16
99% Chebyshev (MVUE) UCL	97.88		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	24.5	95% Jackknife UCL	25.67
95% Standard Bootstrap UCL	23.76	95% Bootstrap-t UCL	33.96
95% Hall's Bootstrap UCL	24.97	95% Percentile Bootstrap UCL	25.16
95% BCA Bootstrap UCL	28.77		
90% Chebyshev(Mean, Sd) UCL	32.9	95% Chebyshev(Mean, Sd) UCL	41.33
97.5% Chebyshev(Mean, Sd) UCL	53.03	99% Chebyshev(Mean, Sd) UCL	76.01
Suggested UCL to Use			
95% Adjusted Gamma UCL	43.5		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

ProUCL Output

ISM Grid Area (Main Plant Area 0-2)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/5/2020 8:29:41 PM		
From File	ISM 43 MPA SO 0-2 ProUCL - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
BenzoAPyrene_RSD_HIGH_HALF_ND			
General Statistics			
Total Number of Observations	26	Number of Distinct Observations	26
		Number of Missing Observations	0
Minimum	0.201	Mean	7.979
Maximum	59.9	Median	3.049
SD	13.2	Std. Error of Mean	2.59
Coefficient of Variation	1.655	Skewness	2.962
Normal GOF Test			
Shapiro Wilk Test Statistic	0.595	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.92	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.323	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.17	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	12.4	95% Adjusted-CLT UCL (Chen-1995)	13.85
		95% Modified-t UCL (Johnson-1978)	12.65
Gamma GOF Test			
A-D Test Statistic	0.721	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.795	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.163	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.179	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.642	k star (bias corrected MLE)	0.594
Theta hat (MLE)	12.42	Theta star (bias corrected MLE)	13.44
nu hat (MLE)	33.39	nu star (bias corrected)	30.87
MLE Mean (bias corrected)	7.979	MLE Sd (bias corrected)	10.35

		Approximate Chi Square Value (0.05)	19.18
Adjusted Level of Significance	0.0398	Adjusted Chi Square Value	18.57
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	12.84	95% Adjusted Gamma UCL (use when n<50)	13.26
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.984	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.92	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0804	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.17	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-1.606	Mean of logged Data	1.124
Maximum of Logged Data	4.093	SD of logged Data	1.446
Assuming Lognormal Distribution			
95% H-UCL	21.66	90% Chebyshev (MVUE) UCL	16.63
95% Chebyshev (MVUE) UCL	20.48	97.5% Chebyshev (MVUE) UCL	25.82
99% Chebyshev (MVUE) UCL	36.32		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	12.24	95% Jackknife UCL	12.4
95% Standard Bootstrap UCL	12.17	95% Bootstrap-t UCL	16.75
95% Hall's Bootstrap UCL	15.87	95% Percentile Bootstrap UCL	12.34
95% BCA Bootstrap UCL	14.03		
90% Chebyshev(Mean, Sd) UCL	15.75	95% Chebyshev(Mean, Sd) UCL	19.27
97.5% Chebyshev(Mean, Sd) UCL	24.15	99% Chebyshev(Mean, Sd) UCL	33.75
Suggested UCL to Use			
95% Adjusted Gamma UCL	13.26		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

ProUCL Output

ISM Grid Area (Central Landfills Area 0-2)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/5/2020 8:30:28 PM		
From File	ISM 42 CentLF SO 0-2 ProUCLs - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
BenzoAPyrene_RSD_HIGH_HALF_ND			
General Statistics			
Total Number of Observations	58	Number of Distinct Observations	51
Number of Detects	57	Number of Non-Detects	1
Number of Distinct Detects	50	Number of Distinct Non-Detects	1
Minimum Detect	0.0301	Minimum Non-Detect	0.00836
Maximum Detect	102.1	Maximum Non-Detect	0.00836
Variance Detects	199.1	Percent Non-Detects	1.724%
Mean Detects	5.304	SD Detects	14.11
Median Detects	1.906	CV Detects	2.661
Skewness Detects	6.096	Kurtosis Detects	41.12
Mean of Logged Detects	0.423	SD of Logged Detects	1.598
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.362	**Normal GOF Test on Detected Observations Only**	
5% Shapiro Wilk P Value	0	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.354	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.117	Detected Data Not Normal at 5% Significance Level	
Detected Data Not Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	5.212	KM Standard Error of Mean	1.839
KM SD	13.88	95% KM (BCA) UCL	9.011
95% KM (t) UCL	8.287	95% KM (Percentile Bootstrap) UCL	8.529
95% KM (z) UCL	8.237	95% KM Bootstrap t UCL	13.75
90% KM Chebyshev UCL	10.73	95% KM Chebyshev UCL	13.23
97.5% KM Chebyshev UCL	16.7	99% KM Chebyshev UCL	23.51
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	1.849	**Anderson-Darling GOF Test**	
5% A-D Critical Value	0.815	Detected Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.169	**Kolmogorov-Smirnov GOF**	
5% K-S Critical Value	0.125	Detected Data Not Gamma Distributed at 5% Significance Level	
Detected Data Not Gamma Distributed at 5% Significance Level			

Gamma Statistics on Detected Data Only			
k hat (MLE)	0.509	k star (bias corrected MLE)	0.494
Theta hat (MLE)	10.43	Theta star (bias corrected MLE)	10.75
nu hat (MLE)	57.98	nu star (bias corrected)	56.26
Mean (detects)	5.304		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	5.212
Maximum	102.1	Median	1.873
SD	14	CV	2.687
k hat (MLE)	0.485	k star (bias corrected MLE)	0.472
Theta hat (MLE)	10.74	Theta star (bias corrected MLE)	11.05
nu hat (MLE)	56.3	nu star (bias corrected)	54.72
Adjusted Level of Significance (β)	0.0459		
Approximate Chi Square Value (54.72, α)	38.72	Adjusted Chi Square Value (54.72, β)	38.38
95% Gamma Approximate UCL (use when n>=50)	7.366	95% Gamma Adjusted UCL (use when n<50)	7.432
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	5.212	SD (KM)	13.88
Variance (KM)	192.7	SE of Mean (KM)	1.839
k hat (KM)	0.141	k star (KM)	0.145
nu hat (KM)	16.35	nu star (KM)	16.84
theta hat (KM)	36.98	theta star (KM)	35.91
80% gamma percentile (KM)	5.52	90% gamma percentile (KM)	15.38
95% gamma percentile (KM)	28.87	99% gamma percentile (KM)	68.27
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (16.84, α)	8.558	Adjusted Chi Square Value (16.84, β)	8.407
95% Gamma Approximate KM-UCL (use when n>=50)	10.26	95% Gamma Adjusted KM-UCL (use when n<50)	10.44
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Approximate Test Statistic	0.984	Shapiro Wilk GOF Test	
5% Shapiro Wilk P Value	0.841	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0883	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.117	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			

ProUCL Output

ISM Grid Area (Central Landfills Area 0-2)

Mean in Original Scale	5.213	Mean in Log Scale	0.351
SD in Original Scale	14	SD in Log Scale	1.676
95% t UCL (assumes normality of ROS data)	8.287	95% Percentile Bootstrap UCL	8.562
95% BCA Bootstrap UCL	11.02	95% Bootstrap t UCL	13.79
95% H-UCL (Log ROS)	12.21		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	0.333	KM Geo Mean	1.395
KM SD (logged)	1.71	95% Critical H Value (KM-Log)	3.405
KM Standard Error of Mean (logged)	0.227	95% H-UCL (KM -Log)	13.02
KM SD (logged)	1.71	95% Critical H Value (KM-Log)	3.405
KM Standard Error of Mean (logged)	0.227		
DL/2 Statistics			
DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	5.212	Mean in Log Scale	0.321
SD in Original Scale	14	SD in Log Scale	1.763
95% t UCL (Assumes normality)	8.287	95% H-Stat UCL	14.69
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Lognormal Distributed at 5% Significance Level			
Suggested UCL to Use			
KM H-UCL	13.02		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.17/20/2020 12:56:11 PM		
From File	0-0.5_Soil_Sediment_ProUCL_Inputs_-_Main_Plant_Area - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	68	Number of Distinct Observations	68
		Number of Missing Observations	0
Minimum	0.195	Mean	30.27
Maximum	287.6	Median	5.785
SD	56.95	Std. Error of Mean	6.906
Coefficient of Variation	1.882	Skewness	2.882
Normal GOF Test			
Shapiro Wilk Test Statistic	0.571	Shapiro Wilk GOF Test	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.304	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	41.78	95% Adjusted-CLT UCL (Chen-1995)	44.2
		95% Modified-t UCL (Johnson-1978)	42.19
Gamma GOF Test			
A-D Test Statistic	2.92	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.824	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.207	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.115	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.47	k star (bias corrected MLE)	0.459
Theta hat (MLE)	64.34	Theta star (bias corrected MLE)	65.87
nu hat (MLE)	63.98	nu star (bias corrected)	62.49
MLE Mean (bias corrected)	30.27	MLE Sd (bias corrected)	44.65

		Approximate Chi Square Value (0.05)	45.3
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	44.99
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	41.75	95% Adjusted Gamma UCL (use when n<50)	42.04
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.165	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.115	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-1.637	Mean of logged Data	2.047
Maximum of Logged Data	5.662	SD of logged Data	1.729
Assuming Lognormal Distribution			
95% H-UCL	60	90% Chebyshev (MVUE) UCL	62.3
95% Chebyshev (MVUE) UCL	75.69	97.5% Chebyshev (MVUE) UCL	94.26
99% Chebyshev (MVUE) UCL	130.7		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	41.62	95% Jackknife UCL	41.78
95% Standard Bootstrap UCL	41.71	95% Bootstrap-t UCL	45.82
95% Hall's Bootstrap UCL	44.12	95% Percentile Bootstrap UCL	42.83
95% BCA Bootstrap UCL	44.18		
90% Chebyshev(Mean, Sd) UCL	50.98	95% Chebyshev(Mean, Sd) UCL	60.37
97.5% Chebyshev(Mean, Sd) UCL	73.39	99% Chebyshev(Mean, Sd) UCL	98.98
Suggested UCL to Use			
95% H-UCL	60		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

ProUCL Output

Central Landfills Area (0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.17/20/2020 12:55:25 PM		
From File	0-0.5_Soil_Sediment_ProUCL_Inputs_-_Central_Landfills_Area - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		

Copper

General Statistics			
Total Number of Observations	54	Number of Distinct Observations	41
		Number of Missing Observations	0
Minimum	6.7	Mean	14.92
Maximum	60	Median	13.5
SD	7.587	Std. Error of Mean	1.033
Coefficient of Variation	0.509	Skewness	4.16

Normal GOF Test			
Shapiro Wilk Test Statistic	0.654	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.332E-15	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.198	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.12	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			

Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16.65	95% Adjusted-CLT UCL (Chen-1995)	17.24
		95% Modified-t UCL (Johnson-1978)	16.75

Gamma GOF Test			
A-D Test Statistic	1.375	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.752	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.139	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.121	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			

Gamma Statistics			
k hat (MLE)	6.79	k star (bias corrected MLE)	6.425
Theta hat (MLE)	2.198	Theta star (bias corrected MLE)	2.322
nu hat (MLE)	733.3	nu star (bias corrected)	693.9
MLE Mean (bias corrected)	14.92	MLE Sd (bias corrected)	5.886

ProUCL Output

Central Landfills Area (0-0.5)

		Approximate Chi Square Value (0.05)	633.7
Adjusted Level of Significance	0.0456	Adjusted Chi Square Value	632.2
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	16.34	95% Adjusted Gamma UCL (use when n<50)	16.38
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.939	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.0125	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.105	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.12	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.902	Mean of logged Data	2.627
Maximum of Logged Data	4.094	SD of logged Data	0.36
Assuming Lognormal Distribution			
95% H-UCL	16.1	90% Chebyshev (MVUE) UCL	16.97
95% Chebyshev (MVUE) UCL	17.98	97.5% Chebyshev (MVUE) UCL	19.38
99% Chebyshev (MVUE) UCL	22.12		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	16.62	95% Jackknife UCL	16.65
95% Standard Bootstrap UCL	16.59	95% Bootstrap-t UCL	17.8
95% Hall's Bootstrap UCL	24.56	95% Percentile Bootstrap UCL	16.73
95% BCA Bootstrap UCL	17.4		
90% Chebyshev(Mean, Sd) UCL	18.02	95% Chebyshev(Mean, Sd) UCL	19.42
97.5% Chebyshev(Mean, Sd) UCL	21.37	99% Chebyshev(Mean, Sd) UCL	25.19
Suggested UCL to Use			
95% Student's-t UCL	16.65	or 95% Modified-t UCL	16.75
or 95% H-UCL	16.1		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			

It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.			
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	54	Number of Distinct Observations	54
		Number of Missing Observations	0
Minimum	0.0945	Mean	9.065
Maximum	197.2	Median	2.064
SD	28.33	Std. Error of Mean	3.855
Coefficient of Variation	3.125	Skewness	5.94
Normal GOF Test			
Shapiro Wilk Test Statistic	0.321	Shapiro Wilk GOF Test	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.376	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.12	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	15.52	95% Adjusted-CLT UCL (Chen-1995)	18.73
		95% Modified-t UCL (Johnson-1978)	16.04
Gamma GOF Test			
A-D Test Statistic	4.502	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.82	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.236	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.128	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.478	k star (bias corrected MLE)	0.464
Theta hat (MLE)	18.95	Theta star (bias corrected MLE)	19.54
nu hat (MLE)	51.65	nu star (bias corrected)	50.11
MLE Mean (bias corrected)	9.065	MLE Sd (bias corrected)	13.31
		Approximate Chi Square Value (0.05)	34.86
Adjusted Level of Significance	0.0456	Adjusted Chi Square Value	34.51
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	13.03	95% Adjusted Gamma UCL (use when n<50)	13.16

ProUCL Output

Central Landfills Area (0-0.5)

Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.204	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.102	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.12	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-2.359	Mean of logged Data	0.867
Maximum of Logged Data	5.284	SD of logged Data	1.439
Assuming Lognormal Distribution			
95% H-UCL	11.91	90% Chebyshev (MVUE) UCL	11.44
95% Chebyshev (MVUE) UCL	13.7	97.5% Chebyshev (MVUE) UCL	16.84
99% Chebyshev (MVUE) UCL	23		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	15.41	95% Jackknife UCL	15.52
95% Standard Bootstrap UCL	15.62	95% Bootstrap-t UCL	31.44
95% Hall's Bootstrap UCL	37.74	95% Percentile Bootstrap UCL	16.08
95% BCA Bootstrap UCL	19.7		
90% Chebyshev(Mean, Sd) UCL	20.63	95% Chebyshev(Mean, Sd) UCL	25.87
97.5% Chebyshev(Mean, Sd) UCL	33.14	99% Chebyshev(Mean, Sd) UCL	47.42
Suggested UCL to Use			
95% H-UCL	11.91		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.			

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.17/20/2020 12:56:43 PM		
From File	0-2_Depth_Weighted_Soil_ProUCL_Inputs_-_Central_Landfills_Area - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		

Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	53	Number of Distinct Observations	53
		Number of Missing Observations	0
Minimum	0.173	Mean	3.775
Maximum	50.12	Median	1.208
SD	8.287	Std. Error of Mean	1.138
Coefficient of Variation	2.195	Skewness	4.407
Normal GOF Test			
Shapiro Wilk Test Statistic	0.449	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.332	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.121	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	5.682	95% Adjusted-CLT UCL (Chen-1995)	6.384
		95% Modified-t UCL (Johnson-1978)	5.796
Gamma GOF Test			
A-D Test Statistic	3.122	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.806	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.197	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.128	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.604	k star (bias corrected MLE)	0.582
Theta hat (MLE)	6.252	Theta star (bias corrected MLE)	6.484
nu hat (MLE)	64.01	nu star (bias corrected)	61.72
MLE Mean (bias corrected)	3.775	MLE Sd (bias corrected)	4.948

		Approximate Chi Square Value (0.05)	44.65
Adjusted Level of Significance	0.0455	Adjusted Chi Square Value	44.24
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	5.219	95% Adjusted Gamma UCL (use when n<50)	5.267
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.0469	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0997	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.121	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-1.754	Mean of logged Data	0.306
Maximum of Logged Data	3.914	SD of logged Data	1.307
Assuming Lognormal Distribution			
95% H-UCL	5.213	90% Chebyshev (MVUE) UCL	5.224
95% Chebyshev (MVUE) UCL	6.187	97.5% Chebyshev (MVUE) UCL	7.523
99% Chebyshev (MVUE) UCL	10.15		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	5.648	95% Jackknife UCL	5.682
95% Standard Bootstrap UCL	5.684	95% Bootstrap-t UCL	8.359
95% Hall's Bootstrap UCL	14.07	95% Percentile Bootstrap UCL	5.734
95% BCA Bootstrap UCL	6.65		
90% Chebyshev(Mean, Sd) UCL	7.19	95% Chebyshev(Mean, Sd) UCL	8.737
97.5% Chebyshev(Mean, Sd) UCL	10.88	99% Chebyshev(Mean, Sd) UCL	15.1
Suggested UCL to Use			
95% H-UCL	5.213		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

ProUCL Output

ISM Grid Area (0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/7/2020 12:02:53 AM		
From File	ISM_0-0.5_RSD_HIGH_ProUCL_Inputs_-_ISM_Grid_Area - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	33	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	3.65	Mean	57.22
Maximum	412	Median	34.8
SD	87.05	Std. Error of Mean	15.15
Coefficient of Variation	1.521	Skewness	2.849
Normal GOF Test			
Shapiro Wilk Test Statistic	0.606	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.335	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.152	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	82.89	95% Adjusted-CLT UCL (Chen-1995)	90.18
		95% Modified-t UCL (Johnson-1978)	84.14
Gamma GOF Test			
A-D Test Statistic	1.171	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.786	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.184	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.159	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.783	k star (bias corrected MLE)	0.732
Theta hat (MLE)	73.08	Theta star (bias corrected MLE)	78.17
nu hat (MLE)	51.68	nu star (bias corrected)	48.31
MLE Mean (bias corrected)	57.22	MLE Sd (bias corrected)	66.88

		Approximate Chi Square Value (0.05)	33.36
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	32.72
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	82.87	95% Adjusted Gamma UCL (use when n<50)	84.5
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.954	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.105	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.152	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.295	Mean of logged Data	3.287
Maximum of Logged Data	6.021	SD of logged Data	1.24
Assuming Lognormal Distribution			
95% H-UCL	105.4	90% Chebyshev (MVUE) UCL	99.19
95% Chebyshev (MVUE) UCL	119	97.5% Chebyshev (MVUE) UCL	146.4
99% Chebyshev (MVUE) UCL	200.3		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	82.15	95% Jackknife UCL	82.89
95% Standard Bootstrap UCL	82.49	95% Bootstrap-t UCL	104.1
95% Hall's Bootstrap UCL	96.87	95% Percentile Bootstrap UCL	82.64
95% BCA Bootstrap UCL	96.5		
90% Chebyshev(Mean, Sd) UCL	102.7	95% Chebyshev(Mean, Sd) UCL	123.3
97.5% Chebyshev(Mean, Sd) UCL	151.9	99% Chebyshev(Mean, Sd) UCL	208
Suggested UCL to Use			
95% H-UCL	105.4		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

ProUCL Output

ISM Grid Area (0-2)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/7/2020 12:03:56 AM		
From File	ISM_0-2_RSD_HIGH_ProUCL_Inputs_-_ISM_Grid_Area - SHR Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Total LMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	33	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	0.615	Mean	9.658
Maximum	47.7	Median	6.255
SD	10.53	Std. Error of Mean	1.832
Coefficient of Variation	1.09	Skewness	1.999
Normal GOF Test			
Shapiro Wilk Test Statistic	0.777	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.222	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.152	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	12.76	95% Adjusted-CLT UCL (Chen-1995)	13.35
		95% Modified-t UCL (Johnson-1978)	12.87
Gamma GOF Test			
A-D Test Statistic	0.377	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.775	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.12	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.158	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.043	k star (bias corrected MLE)	0.968
Theta hat (MLE)	9.264	Theta star (bias corrected MLE)	9.978
nu hat (MLE)	68.81	nu star (bias corrected)	63.88
MLE Mean (bias corrected)	9.658	MLE Sd (bias corrected)	9.817

		Approximate Chi Square Value (0.05)	46.5
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	45.73
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	13.27	95% Adjusted Gamma UCL (use when n<50)	13.49
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.972	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0821	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.152	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.486	Mean of logged Data	1.717
Maximum of Logged Data	3.865	SD of logged Data	1.128
Assuming Lognormal Distribution			
95% H-UCL	17.64	90% Chebyshev (MVUE) UCL	17.33
95% Chebyshev (MVUE) UCL	20.56	97.5% Chebyshev (MVUE) UCL	25.04
99% Chebyshev (MVUE) UCL	33.84		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	12.67	95% Jackknife UCL	12.76
95% Standard Bootstrap UCL	12.68	95% Bootstrap-t UCL	13.89
95% Hall's Bootstrap UCL	14.18	95% Percentile Bootstrap UCL	12.92
95% BCA Bootstrap UCL	13.5		
90% Chebyshev(Mean, Sd) UCL	15.16	95% Chebyshev(Mean, Sd) UCL	17.65
97.5% Chebyshev(Mean, Sd) UCL	21.1	99% Chebyshev(Mean, Sd) UCL	27.89
Suggested UCL to Use			
95% Adjusted Gamma UCL	13.49		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Total HMW PAHs - 1/2MDL			

ProUCL Output

ISM Grid Area (0-2)

General Statistics			
Total Number of Observations	33	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	1.408	Mean	29.76
Maximum	132.1	Median	19.28
SD	31.97	Std. Error of Mean	5.566
Coefficient of Variation	1.074	Skewness	1.749
Normal GOF Test			
Shapiro Wilk Test Statistic	0.795	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.188	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.152	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	39.19	95% Adjusted-CLT UCL (Chen-1995)	40.72
		95% Modified-t UCL (Johnson-1978)	39.47
Gamma GOF Test			
A-D Test Statistic	0.371	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.776	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.121	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.158	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.989	k star (bias corrected MLE)	0.92
Theta hat (MLE)	30.08	Theta star (bias corrected MLE)	32.36
nu hat (MLE)	65.3	nu star (bias corrected)	60.7
MLE Mean (bias corrected)	29.76	MLE Sd (bias corrected)	31.03
		Approximate Chi Square Value (0.05)	43.78
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	43.04
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	41.26	95% Adjusted Gamma UCL (use when n<50)	41.97
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.965	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.931	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.112	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.152	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			

ProUCL Output

ISM Grid Area (0-2)

Lognormal Statistics			
Minimum of Logged Data	0.342	Mean of logged Data	2.809
Maximum of Logged Data	4.884	SD of logged Data	1.184
Assuming Lognormal Distribution			
95% H-UCL	58.46	90% Chebyshev (MVUE) UCL	56.3
95% Chebyshev (MVUE) UCL	67.16	97.5% Chebyshev (MVUE) UCL	82.24
99% Chebyshev (MVUE) UCL	111.9		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	38.91	95% Jackknife UCL	39.19
95% Standard Bootstrap UCL	38.85	95% Bootstrap-t UCL	43.66
95% Hall's Bootstrap UCL	43.38	95% Percentile Bootstrap UCL	39.54
95% BCA Bootstrap UCL	41.05		
90% Chebyshev(Mean, Sd) UCL	46.46	95% Chebyshev(Mean, Sd) UCL	54.02
97.5% Chebyshev(Mean, Sd) UCL	64.52	99% Chebyshev(Mean, Sd) UCL	85.14
Suggested UCL to Use			
95% Adjusted Gamma UCL	41.97		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

ProUCL Output

ISM Grid Area (0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/5/2020 8:38:42 PM		
From File	ISM 40 MPA SO 0-0_5 ProUCL - SHR and ISS-033 Removed - combined with CentLF.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
BenzoAPyrene_RSD_HIGH_HALF_ND			
General Statistics			
Total Number of Observations	39	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	0.463	Mean	7.883
Maximum	102.1	Median	2.723
SD	17.38	Std. Error of Mean	2.782
Coefficient of Variation	2.204	Skewness	4.575
Normal GOF Test			
Shapiro Wilk Test Statistic	0.436	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.355	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	12.57	95% Adjusted-CLT UCL (Chen-1995)	14.64
		95% Modified-t UCL (Johnson-1978)	12.91
Gamma GOF Test			
A-D Test Statistic	2.398	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.801	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.241	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.148	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.625	k star (bias corrected MLE)	0.594
Theta hat (MLE)	12.62	Theta star (bias corrected MLE)	13.28
nu hat (MLE)	48.71	nu star (bias corrected)	46.3
MLE Mean (bias corrected)	7.883	MLE Sd (bias corrected)	10.23

		Approximate Chi Square Value (0.05)	31.69
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	31.21
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	11.52	95% Adjusted Gamma UCL (use when n<50)	11.69
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.123	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.77	Mean of logged Data	1.081
Maximum of Logged Data	4.626	SD of logged Data	1.283
Assuming Lognormal Distribution			
95% H-UCL	11.9	90% Chebyshev (MVUE) UCL	11.43
95% Chebyshev (MVUE) UCL	13.68	97.5% Chebyshev (MVUE) UCL	16.79
99% Chebyshev (MVUE) UCL	22.91		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	12.46	95% Jackknife UCL	12.57
95% Standard Bootstrap UCL	12.43	95% Bootstrap-t UCL	19.38
95% Hall's Bootstrap UCL	27.03	95% Percentile Bootstrap UCL	12.97
95% BCA Bootstrap UCL	15.85		
90% Chebyshev(Mean, Sd) UCL	16.23	95% Chebyshev(Mean, Sd) UCL	20.01
97.5% Chebyshev(Mean, Sd) UCL	25.26	99% Chebyshev(Mean, Sd) UCL	35.57
Suggested UCL to Use			
95% H-UCL	11.9		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

ProUCL Output

ISM Grid Area (0-0.5)

UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.18/7/2020 12:06:02 AM		
From File	ISM_0-0.5_RSD_HIGH_ProUCL_Inputs_-_ISM_Grid_Area - SHR and ISS-033 Removed.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Total HMW PAHs - 1/2MDL			
General Statistics			
Total Number of Observations	32	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	3.65	Mean	46.14
Maximum	256	Median	30.6
SD	60.29	Std. Error of Mean	10.66
Coefficient of Variation	1.307	Skewness	2.455
Normal GOF Test			
Shapiro Wilk Test Statistic	0.653	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.93	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.283	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.154	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	64.21	95% Adjusted-CLT UCL (Chen-1995)	68.61
		95% Modified-t UCL (Johnson-1978)	64.98
Gamma GOF Test			
A-D Test Statistic	0.856	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.779	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.145	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.161	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data follow Appr. Gamma Distribution at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.925	k star (bias corrected MLE)	0.859
Theta hat (MLE)	49.9	Theta star (bias corrected MLE)	53.73
nu hat (MLE)	59.17	nu star (bias corrected)	54.96
MLE Mean (bias corrected)	46.14	MLE Sd (bias corrected)	49.79

		Approximate Chi Square Value (0.05)	38.92
Adjusted Level of Significance	0.0416	Adjusted Chi Square Value	38.2
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	65.14	95% Adjusted Gamma UCL (use when n<50)	66.38
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.951	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.93	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.118	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.154	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.295	Mean of logged Data	3.201
Maximum of Logged Data	5.545	SD of logged Data	1.157
Assuming Lognormal Distribution			
95% H-UCL	82.76	90% Chebyshev (MVUE) UCL	80.34
95% Chebyshev (MVUE) UCL	95.7	97.5% Chebyshev (MVUE) UCL	117
99% Chebyshev (MVUE) UCL	158.9		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	63.67	95% Jackknife UCL	64.21
95% Standard Bootstrap UCL	63.46	95% Bootstrap-t UCL	75.98
95% Hall's Bootstrap UCL	67.25	95% Percentile Bootstrap UCL	63.87
95% BCA Bootstrap UCL	69.16		
90% Chebyshev(Mean, Sd) UCL	78.11	95% Chebyshev(Mean, Sd) UCL	92.59
97.5% Chebyshev(Mean, Sd) UCL	112.7	99% Chebyshev(Mean, Sd) UCL	152.2
Suggested UCL to Use			
95% Adjusted Gamma UCL	66.38		
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			

APPENDIX D

EPA and DEQ Comments on the Draft Technology Screening Technical Memorandum

EPA and DEQ comments on the
Technology Screening Technical Memorandum, Columbia Falls Aluminum Company
Columbia Falls, Montana
Prepared for Columbia Falls Aluminum Company, LLC by Roux Environmental Engineering and Geology, D.P.C.
Dated May 13, 2020

Agency Comments Provided June 3, 2020
CFAC/Roux Responses Provided June 24, 2020

Following receipt of EPA and DEQ comments on the Technology Screening Technical Memorandum dated May 13, 2020 ("Tech Memo"), a conference call was held with USEPA, CDM Smith, CFAC, and Roux on June 15, 2020 to discuss the Agencies' comments on the Tech Memo, the technology screening including technologies retained and eliminated, and the assembled alternatives. USEPA indicated that a revised Tech Memo was not expected, and that instead the evaluation provided in the Tech Memo should be incorporated into the FS Report to comprise the Technology Screening and Alternative Development Sections. As such, it was noted that many of the Agencies' comments were provided to aid in the preparation of the FS Report.

Based upon this discussion, CFAC/Roux have prepared responses to the Agencies' comments organized into two sections: General Responses to Comments and Specific Responses to Comments. The General Responses to Comments section provides responses to recurring comments / themes within the comments to streamline the responses. A list of comments to which each General Response to Comments applies is also provided. The Specific Responses to Comments section presents each of the agencies comments; documents the General Response(s) to Comments that applies to each of the Agencies' comments, if applicable; and provides specific or more-detailed responses where appropriate.

General Responses to Comments

1. Technologies and process options retained throughout the technology screening were assembled in Section 6 of the Tech Memo to formulate a range of remedial action alternatives for each DU. The Assembly of Remedial Alternatives, revised to incorporate EPA and DEQ comments on the Tech Memo herein, are provided at the end of this Response to Comments document.

2. The comments identified in the list below are acknowledged and, as necessary and appropriate, will be addressed in the FS Report.

   Applies to General Comments #1b, 1c, 2, 3, 5, and 6; DEQ Notes Parts 1 and 2; Specific Comments #1, 5, 6, 8, 10–13, 15–17, 19, 20, 22, 23, 25, 27, 28, 29, 30, 33–36, 38–49; and Table Comments # 1, 3, 4, 6-8, 11, 13–16, 18, 19, 21–24.

3. The FSWP and prior Site documents provide general background information for the Site and supporting information for pertinent Site features. The FS Report will either include the

background information requested or, in some cases, clearly refer to specific prior documents and the locations within the documents where such information can be found.

Applies to General Comment #1a and Specific Comments #2–4, 7, 21, 37.

4. Several comments received from DEQ relate to PRAOs, PRGs, and/or comments previously addressed by CFAC/Roux. Please refer to previous documents and conversations with the Agencies, including but not limited to *Roux Responses to Additional RI Comments (January 13, 2020)* Comments #17, DEQ RA#2, DEQ RA#3, and DEQ RA#4, *Roux Responses to FSWP Comments (February 28, 2020)* Comments #8 and #27, the *Development of Preliminary Remediation Goals (PRGs) for Ecological Risk Drivers Memorandum* (Appendix B of the FSWP), Section 4.3.2 of the FSWP, and *CFAC/Roux Responses to EE/CA Comments (May 19, 2020)* Comments #3 and #6.

   Applies to DEQ Notes Part 3 and Specific Comment #9.

Specific Responses to Comments

General Comments

1. Landfills DU1 (generally Section 1.3.1/Section 5.1).

   1a. Additional basic summary information on the nature of the wastes in the different DU1 landfills should be included as it will help clarify and support the technology screening. What are the areal extents, depths and volumes of the different wastes? What was in the West Landfill versus the Center Landfill? What is the nature of the Wet Scrubber Sludge and what is it contaminated with? What is spent potliner, what is it contaminated with, why is it hazardous? This may be obvious to the primary project team, but not to an outsider. This will help to clarify why certain technologies might be needed for certain types of waste in the different landfills.

   See General Response to Comments #3.

   1b. More information is needed to explain why the caps on the West Landfill and Center Landfill (clay, synthetic materials) that were probably intended as low permeability caps are deficient and inadequate for protection of groundwater. What is different about the low permeability caps being evaluated and retained in the screening now? In other words, if the "old" caps were not effective, why would the "new" caps be expected to be effective?

   See General Response to Comments #2.

   Additional discussion will be provided to elaborate why the cap on the Center Landfill is considered to be inadequate, and how the proposed impermeable caps being evaluated for the Center Landfill are different from the existing cap. Based upon known conditions as documented in engineering as-built drawings referenced in the FSWP, the cap on the West Landfill is not deficient or inadequate, therefore CFAC/Roux has not proposed amending this cap in the RA alternatives.

1c. Whether or not the bottom of the waste in the Landfills DU1 may be saturated with groundwater needs to be presented (again, this may be obvious to the main project team, but not to an outsider). Is the waste periodically saturated? If so, it will remain a source in perpetuity unless additional measures are taken to also contain or control the groundwater. It is also unclear how much of the soil beneath the landfills may be contaminated and may be a secondary source to groundwater. These aspects must be clearly discussed, because if the waste is saturated, it reduces the effectiveness of all impermeable capping alternatives. Remedial alternatives for detailed analysis will need to include components in addition to impermeable covers to address this issue.

See General Response to Comments #2.

2. Under the evaluation of removal and disposal in Section 5.1, a discussion of the effectiveness (advantages) of source removal for remediation of groundwater needs to be added. The discussion focuses entirely on the disadvantages and implementability issues.

   See General Response to Comments #2.

3. The Agencies have concluded that the justification provided to eliminate the source removal alternative entirely in the technical memorandum is insufficient. Offsite removal could be screened out as too costly and disruptive to the community, but the removal of wastes leaching to groundwater to a properly engineered onsite location should remain as the high-end alternative to compare against what is potentially treatment of groundwater in perpetuity.

   See General Response to Comments #2.

4. The Agencies appreciate the preliminary list of alternatives for detailed analysis in Section 6; however, reserve the right to provide further comment and consideration to ensure all parties are in agreement before moving forward with the detailed analysis. Eleven alternatives for detailed analysis for the combined Landfills DU1 and Groundwater DU is a lot of permutations to consider.

   Based on the June 15, 2020 conference call with USEPA and CDM Smith, CFAC/Roux understand that EPA agrees with the technology screening and assembled alternatives provided in the Tech Memo (excluding changes explicitly requested in these comments), and that EPA agrees Roux should proceed with the detailed analysis of these alternatives and preparation of the FS Report. CFAC/Roux also understand that the Agencies reserve the right to provided further comment and consideration should elements of various alternatives be combined to form new alternatives, or if they determine that another alternative requires evaluation.

5. Tables, General Comment. In several instances throughout the tables, implementability issues are presented as disadvantages under effectiveness, and vice versa, effectiveness issues are presented under implementability. For example, if dewatering or pretreatment of contaminated soils is needed, it is an implementability issue, not an effectiveness disadvantage. The potential for human health exposure to contaminants is an effectiveness disadvantage, while the need for additional measures such as Level C personal protective equipment is an implementability issue. When a separate technology is needed for PAHs or

metals, it is an effectiveness issue, not an implementability issue. Steepness and potential flooding in the River DU is an implementability issue, while the potential of the Flathead river to recapture the side channel and obliterate a cover is an effectiveness issue. Rigorous reporting requirements are an implementation issue, not an effectiveness disadvantage. Please review all the effectiveness and implementability issues and recategorize if needed.

See General Response to Comments #2.

6. Tables, General Comment. The incorporation of literature studies specific to aluminum facilities is appreciated. However, proper citation of the literature studies within the technology tables is needed. In some cases, the tables read as if bench-scale and pilot-scale treatability studies have been performed at the site, when in fact, the statements appear to be referring to literature studies. Examples are provided in the specific comments. Also, please indicate which technologies would require site-specific bench-scale or pilot-scale studies.

   See General Response to Comments #2.

   The tables will be revised to clarify that the referenced bench-scale and pilot-scale treatability studies are not Site-specific. The literature is extensively cited in the text of the report, and as such CFAC/Roux propose leaving the citations off the tables to keep the tables as clear and concise as possible.

DEQ notes the following summary of the final remedial investigation report (RIR):

DEQ Notes Part 1. The major areas of the site which require remedial response action to reduce the human health/ecological risk are –

- Human health – top 2 feet of soil/sediment in the NE percolation pond, the NW percolation pond, and the connecting ditch (figures H1and H4, RIR).
- Ecological – Surface water where ground water is expressed as seeps. Tables 24, 25, 26 (RIR) confirm steady flow of impacted ground water to the south from upgradient of the DU1 area to the River DU area.

Plate 18 (February 20, 2020 RIR) clearly shows that the ground water upgradient of the DU1 area has not been impacted by the site COCs (Cyanide levels <2 ppb); groundwater immediately downgradient of the DU1 area has been severely impacted by DU1 (cyanide levels >2000 ppb); ground water South of the main plant site and North of the railroad tracks contain elevated levels of cyanide (150-450 ppb).

See General Response to Comments #2.

DEQ Notes Part 2. Plate 20 (February 20, 2020 RIR) confirms the strong ground water flow gradient from North to South under the site (3140 feet amsl to 3020 feet amsl).

- Tables 24, 25, and 26 and the geological cross-sections in plates 5-11 are used to calculate the mass flux of cyanide and fluoride in groundwater and the cyanide velocity estimates. The calculations are likely mathematically correct, but the cross-sections and assumptions distort the rate of cyanide and fluoride in ground water. The net result is that the level of cyanide migrating in ground water to the south seep area creates a significant ecological risk.

See General Response to Comments #2.

While acknowledged, the RIR, including flux calculations, has been approved. As presented, in the RIR, the mass flux and volume calculations are rough estimates based upon the best data available.

DEQ Notes Part 3. Figures E2, E3, H1, H9, and H10 (RIR) summarize the human health and ecological risk issues.

- Reduce shallow ground water flow in the vicinity of the wet scrubber sludge pond, the west landfill, the former drum storage area, the northeast percolation pond to less than 5 feet per day in the southwest, south, and southeast directions.

- Reduce total cyanide concentrations in Monitoring wells 14, 15, 19, 20, 21, and 22 to less than 200ug/L.

- Excavate surface soil and sediment to a depth of 2 feet deep in the backwater seep area, the riparian area, and the South percolation pond area. Dispose in the approved on-site repository. Reduce benzo-a-pyrene concentrations in the soil/sediment at 2 feet deep to less than 0.11 mg/kg.

See General Response to Comments #4.

Specific Comments

1. Page 4. DEQ notes that cyanide (total and free) and fluoride are the two key COCs in groundwater.
   See General Response to Comments #2.

2. Section 1.3.2/Section 5.2, Landfills DU2. While COCs are presented, the nature of the wastes in the different DU2 landfills should be included to clarify why certain technologies are appropriate for different landfills. For example, why is one technology retained for the Industrial Landfill but not others? For landfills already capped, are the existing covers appropriate for the wastes? Are the covers themselves contaminated? What is the areal extent and volumes of contaminated media to be addressed?

   See General Response to Comments #3.

   In addition, discussion regarding the appropriateness of each of the existing caps will be included.

3. Section 1.3.3/Section 5.3, Soils DU. Add information on the areas and volumes of contaminated soils to be addressed. We agree that the human health exposure is generally limited to 0-2 feet deep for soils.

See General Response to Comments #3.

4. Section 1.3.4/Section 5.4, North Percolation Pond DU. What are the areas and volumes of contaminated soils to be addressed? Are metals or PAHs the primary drivers in this DU?

   See General Response to Comments #3.

5. Section 1.3.4 and 1.3.5, COC summary tables. Please footnote that cadmium, copper, and zinc are hardness based, and note the hardness of the presented standard in the footnotes (for example, for the North Percolation Pond, the hardness was 50 mg/L). Additionally, aluminum is based on the dissolved fraction.

   See General Response to Comments #2.

6. Section 1.3.5/Section 5.5. River DU. While addressing the groundwater should eventually reduce risks in the in the backwater area seeps and porewater, there is uncertainty in the effectiveness and in the timeframe when improvements could be realized. Please provide an estimated timeframe when cyanide PRGs would be expected to be met in the River DU.

   See General Response to Comments #2.

7. Section 1.3.5/Section 5.5, River DU. What are the areas and volumes of contaminated soils/sediments to be addressed?

   See General Response to Comments #3.

8. Section 1.3.5. Analysis of RA alternatives will also need to consider the floodplain/floodway and solid waste ARARs as they relate to any waste located in the floodplain and floodway.

   See General Response to Comments #2.

9. Section 1.3.5. DEQ notes on page 9 and 10 that PRGs are available and appropriate for sediment and sediment porewater for total and free cyanide as COCs in the South Percolation Ponds, the Backwater Seep Sampling Area, and the Riparian Sampling Area.

   See General Response to Comments #4.

10. Section 1.3.5, page 10, first paragraph, second sentence. Please revise to read: "The Backwater Seep… (i.e., the River Area DU) are all located within the extent of the "Seep Area" described under the former MPDES Permit."

    See General Response to Comments #2.

11. Section 1.3.5, page 10, paragraph 2. Add "surface water" to the first sentence. DEQ notes that they agree with the first two sentences, but the focus of the rest of the paragraph seems to indicate that benthic organisms are not exposed to surface water. Please revise.

    See General Response to Comments #2.

12. Section 1.3.5, page 11, first paragraph. Add "and seep water from the groundwater" to the first paragraph.

See General Response to Comments #2.

13. Section 1.3.6. Groundwater DU. Please include a discussion of whether or not the fluctuation of the groundwater results in saturation of waste from the landfills.

    See General Response to Comments #2.

14. Section 1.3.6. DEQ notes on page 11 that the location for the 200 ppb cyanide PRG in groundwater needs to be specified and that the sentinel wells should be seven wells, equally spaced between MW-54 and MW-47 along the North side off the mainline railroad tracks.

    For the first part of this comment, see General Response to Comments #2.

    Specifying sentinel well locations is beyond the scope of the FS, and as such will not be addressed in the FS Report. Remedial alternatives will include provisions for groundwater monitoring using existing and, if necessary, additional monitoring wells along the north side of the Burlington Northern Railroad tracks. The numbers and locations of monitoring wells will be determined during the Remedial Design and Implementation phases of this project.

15. Section 4.1. Specific, measurable criteria to evaluate the effectiveness of all remedial action options will need to be developed.

    See General Response to Comments #2.

16. Section 5.1, page 20. Include additional discussion that "Access restrictions" can be a component of all viable response actions rather than a standalone option.

    See General Response to Comments #2.

17. Section 5.1, page 20. Engineered covers/caps do not address DU1 as the source of COCs in the groundwater and subsequently in surface water. They could be a component of a viable option which reduces/controls the COC source.

    See General Response to Comments #2.

18. Section 5.1, top of page 21. Solidification of sludges in the Wet Scrubber Sludge Pond is mentioned, but Solidification/Stabilization is not included as a technology for Landfills DU1. If it is likely needed for these wastes, it should be evaluated and retained.

    Repeat response from Roux Responses to Technology Screening Comments 021420 (May 13, 2020), Specific Comment #3 which questioned the applicability of S/S as a method of fluoride treatment (emphasis added):

    Solidification/stabilization for the Wet Scrubber Sludge Pond was originally included to address the potential need for solidification of low strength material to support a cap; it was not intended to be the primary remedial action to treat the calcium fluoride waste material. **This will be clarified by removing the S/S process option from the Landfills DU1 screening table** and adding a note under Implementability within the Impermeable Membrane and GCL cover/cap process options stating: "The WSSP may require solidification of material to support a cap; the WSSP primarily accepted sludges, which may have been of low strength." In addition, the following statement will be added under Implementability within the Excavation process options: "To facilitate material handling, sludge from the WSSP may require solidification prior to, or in conjunction with, excavation."

19. Section 5.1, Phytocaps. Please clarify that "Phytocaps" is synonymous with evapotranspiration or water balance covers. Also please explain specifically why the climate and growing season at the site makes their effectiveness uncertain (i.e., potential for much of the snowmelt and spring precipitation to infiltrate ahead of the short growing season).

    See General Response to Comments #2.

20. Section 5.1, Removal and Disposal, last paragraph. Delete the phrase, "At the request of USEPA and MDEQ".

    See General Response to Comments #2.

21. Section 5.1, Excavation, first paragraph. Include assumptions on how this estimate was derived. Previous studies had no estimate of the depths of wastes for the Wet Scrubber Sludge Pond and Central Landfill.

    Estimates of the depths of wastes for the Wet Scrubber Sludge Pond and Central Landfill were provided in Table 4-14 of the FSWP.

    See General Response to Comments #3.

22. Section 5.1, Excavation, first paragraph. Guidance for municipal landfill excavations are not relevant to landfills that have hazardous wastes and are leaking hazardous constituents. Many CERCLA remedies in Montana have resulted in excavation volumes far in excess of 100,000 cubic yards (some have resulted in millions of cubic yards of removal). Delete the practical excavation volume limit of 100,000 cubic yards.

    See General Response to Comments #2.

23. Section 5.1, Excavation, second paragraph. There are no data to confirm this depth of impacted soil. The RIR soil data does not indicate that the underlying soils are a significant source of COCs to groundwater.

    See General Response to Comments #2.

24. Section 5.1, Excavation, second paragraph. Is this excavation depth for the three areas the basis for the 1.2 million CY estimate? If limited to wastes alone, the volume estimate may be far less. Natural attenuation processes and/or flushing could be considered in addressing the footprint after the wastes have been removed. Soil data (figures H1-H4, RIR) indicate that excavation to about 10 feet bls would remove most of the COC source material. The estimate of needing to excavate over 1,000,000 yards is way over estimated based on the RIR soil data.

    As discussed in Section 4.4 of the FSWP, the estimated depths and volumes of wastes for each waste management unit in Landfills DU1 are based on the best available information, including historical documents, aerial photographs, and/or as-built drawings. These estimates indicate that waste within the West Landfill is likely 30 to 35 feet below surrounding grade. As presented in Table 4-14 of the FSWP, these estimates also indicate the total volume of wastes in Landfills DU1 is approximately 944,000 to 1,170,000 bulk cubic yard (BCY), or upwards of 1.2 to 1.5 million loose cubic yard (LCY). This estimate is for wastes, only, and does not include any potentially impacted soil beneath the wastes. The estimate of needing to excavate over 1,000,000 CY is, therefore, not over estimated.

As presented in Table 3 of the RIR, soil samples collected during the remedial investigation do not include samples from underlying soils beneath the Landfills DU1 waste management units. As such, Figures H1-H4 in the RIR do not show soil data (clean, impacted, or otherwise) for soil beneath 2 ft-bls within the footprints of the Landfills DU1 waste management units, since samples were not collected there. Therefore, the information shown in RIR Figures H1-H4 is not relevant to the depth of COC source material; instead, detailed information pertaining to the wastes, as described above, forms the basis for determining the depth of COC source material, which clearly indicates that excavation to about 10 feet bls would not remove most of the COC source material.

25. Section 5.1, Excavation, third paragraph. Collection and treatment of groundwater may not be an issue if the alternative is limited to waste only, not underlying soils.

    See General Response to Comments #2.

26. Section 5.1, Excavation, fourth paragraph (pages 22-23). This RCRA requirement is for the generation of new wastes and likely would not be applicable to historic wastes generated prior to 1988. If waste pre-treatment is not required, the concern goes away.

    CFAC/Roux are prepared to accept this comment to the extent that EPA is willing to provide CFAC written verification of this interpretation as it applies to this Site.

27. Section 5.1, Excavation, fifth paragraph, (page 23). The concerns raised in this paragraph are valid and should be brought forward in the detailed analysis.

    See General Response to Comments #2.

28. Section 5.1. Excavation. Because cyanide is the COC that reaches the River DU at concentrations that exceed acute and chronic aquatic life criteria, and fluoride does not, a partial removal alternative targeting cyanide sources only might be considered.

    See General Response to Comments #2.

29. Section 5.1, Onsite Consolidation, page 25. Cite and discuss "land ban" requirements. Legal review will be needed to determine if excavated material requires treatment before land-filling on-site.

    See General Response to Comments #2.

    See also response to Specific Comment #26. CFAC/Roux request that the Agencies expedite legal review of this matter as it greatly impacts the evaluation in the FS.

30. Section 5.2, page 27. DEQ notes they agree with the screening for DU2.

See General Response to Comments #2.

31. Section 5.3. page 29 screening summary figure. Thermal treatment is shown as screened out in the figure, but it is retained in Table 3 and in the text on page 31. Thermal desorption could be eliminated from the figure.

    Thermal treatment / thermal desorption has been retained as an *in situ* treatment for the Soil DU but screened from further consideration as an *ex situ* treatment. The screening summary figure on page 29 agrees with Table 3 and the text on page 31 to support this conclusion.

32. Section 5.3, Solidification/Stabilization. What is meant by "high waste characteristics"?

    This sentence will be removed.

33. Section 5.3, Ex Situ Treatment, page 31. The text states, "Use of ex situ treatment technologies are generally cost prohibitive at this Site." This wording is premature, and implies experience in implementing the technology at this specific site. At this point in the screening, the technology should just be noted as high cost, and screened out based on other effective technologies with lower costs.

    See General Response to Comments #2.

34. Section 5.4. Phytocaps. Why is the phytocap retained for the North Percolation Pond DU but screened out everywhere else? Is a low permeability cap needed for the North Percolation pond? Or is a vegetated soil cover adequate?

    See General Response to Comments #2.

35. Section 5.5, Page 34. Offsite disposal is shown as retained in the figure on page 34, which was likely not intended.

    See General Response to Comments #2.

36. Section 5.5, page 34. In the next to the last sentence, add surface water concentrations and pore water concentrations to the media to be monitored over time for reductions in COCs.

    See General Response to Comments #2.

37. Section 5.5, page 35, Access restrictions. Please add the exposure scenarios evaluated in the risk assessment for which the River area DU does not pose a human health risk, i.e., a floater who uses the river once a month for one hour, etc.

    See General Response to Comments #3.

38. Section 5.6, Page 36. Groundwater in certain areas may need to be remediated to levels more stringent than groundwater classification standards in order to achieve the standards for affected surface water.

    See General Response to Comments #2.

39. Section 5.6, Page 36, 37. Suggest evaluation of an additional response option entailing interception and diversion of "clean" groundwater upgradient of DU1, as this option would not require treatment.

    See General Response to Comments #2.

    A response option entailing diversion of upgradient groundwater around Landfills DU1 is included in Alternatives LDU1/GW IIIa-c.

40. Section 5.6, Access Restrictions, Institutional Controls. Include the establishment of a Controlled Ground Water Area designation for the site as defined in Figure 1 to limit potable water use.

    See General Response to Comments #2.

41. Section 5.6, PRBs. Ferrous sulfate is not iron filings. Please clarify the composition of the PRB. Also, who performed the bench testing?

    See General Response to Comments #2.

42. Section 5.6, PRBs (and generally). How does the depth of the groundwater plume compare to the backwater seeps/river elevation? What is the flow path of the contaminated groundwater to the River DU that needs to be interrupted to address the backwater seep and porewater? Is there any way to more specifically target a "zone" of the groundwater affected these areas? Would a "hanging wall" PRB treat the correct zone of the plume discharging to the river?

    See General Response to Comments #2.

43. Section 5.6, Coagulation/Flocculation/Precipitation. Reducing the pH to increase cyanide removal may pose safety risks.

    See General Response to Comments #2.

44. Section 5.6, Constructed Wetlands. Winter operation and performance effectiveness of a constructed wetland will need to be evaluated carefully, as snow cover will limit photolysis of cyanide, and cold temperatures may slow biological activity to minimal levels such that contaminated water passes through untreated. Consider evaluating operation for only 6 months of the year, possibly with storage and higher flow rates, while assuming the system will lie essentially dormant the rest of the year.

    See General Response to Comments #2.

45. Section 5.6, Page 44. Hydraulic control can be effective in controlling plume migration but would require water treatment long term.

    See General Response to Comments #2.

Extraction scenarios merely move the COC plume around.

CFAC/Roux do not agree that extraction scenarios merely move the COC plume around; extraction scenarios contain the plume and prevent further degradation of groundwater downgradient of the extraction wells.

46. Section 5.6, Page 45. Diverting clean groundwater around the DU1 landfills would reduce the flux of COCs migrating with the groundwater toward the South.

    See General Response to Comments #2.

    A response option entailing diversion of upgradient groundwater around Landfills DU1 is included in Alternatives LDU1/GW IIIa-c.

47. Section 6. Suggest renumbering the alternatives without roman numerals as they are cumbersome for such a large list (e.g., GW 4c instead of GW IVc).

    See General Response to Comments #2.

48. Section 6, Pages 48, 49, 50. DEQ supports evaluation of alternative LDU1/GW IIIa in detail.

    See General Response to Comments #2.

49. Section 6. For the Landfill DU2/Soil DU/North Percolation Pond DU/River DU removal alternatives, is an entirely new repository envisioned, or is consolidation into an existing landfill envisioned? It appears both are being considered more or less equally. This may need more clarification and evaluation.

    See General Response to Comments #2.

Tables:

1. All tables, No Action, Effectiveness, Advantages. Ongoing natural attenuation is listed as an advantage under no action. Suggest deleting this statement and leaving this cell blank, because mentioning natural attenuation here could raise many issues related to the much more stringent and robust level of characterization necessary to include natural attenuation as a remedy component.

   See General Response to Comments #2.

2. All tables, No action, Implementability. The statement is made that no action is “easily implemented technically but has low administrative feasibility”. What is meant by “low administrative feasibility?”

   No action alternatives are not expected to be approved by the agencies (i.e., low administrative feasibility) because it would not meet established PRAOs for the Site.

3. Tables 2 through 5. For the containment technologies for Landfill DU2, Soil DU, North Percolation Pond DU, and River DU, low permeability caps are presented and eliminated due

to “implementability”. However, it seems the reason they are eliminated is the “similar or greater effectiveness via other process options at a similar or lesser cost”. The purpose of these types of caps is to minimize leaching to groundwater, and for these other DUs, direct contact is the primary issue, not leaching to groundwater, so an impermeable cap in many cases would be unnecessary.

See General Response to Comments #2.

For Landfills DU2 (Table 2), low permeability cap containment technologies are retained for potential implementation at the Industrial Landfill; while the results of the RIR indicate the Industrial Landfill is not a contributing source of groundwater contamination at the Site, industrial non-hazardous waste and debris have been disposed of in this landfill and Site remediation wastes may be disposed of in this landfill in the future; as such, a low permeability cap may be the preferred technology for the Industrial Landfill.

4. Table 1, page 1. No action, access restrictions, and capping do not address DU1 as the main source of COCs to groundwater. These could be components of viable remedial options.

   See General Response to Comments #2.

5. Table 1 – Was solidification/stabilization considered for DU1? Please add to Table 1 if any portion of DU1 is within saturated zone at any time of the year.

   See response to Specific Comment #18.

6. Table 1, Excavation and Onsite Consolidation or Offsite Disposal, Implementability. Many CERCLA remedies in Montana have resulted in excavation volumes far in excess of 100,000 cubic yards (some have resulted in millions of cubic yards of removal). Delete the practical excavation volume of 100,000 cubic yards.

   See General Response to Comments #2.

7. Table 1. Evaluation of Remedial Technologies for Landfills DU1, Removal and Disposal, Excavation -Onsite Consolidation, Retainment of Process Option (x) or Elimination with Rationale – DU1 is the main source area and removal and proper disposal to ensure protection of groundwater in perpetuity is the most effective source control. Retain excavation/on-site consolidation for further consideration. Objectively evaluate the depth and area of excavation required to reduce the COC loading to groundwater to protective levels. The technology should be retained during the FS process as a point of comparison to other technologies, just as “no action” is retained for comparative purposes. Revisions to this table should be consistent with the comments provided for Section 5.1.

   See General Response to Comments #2.

8. Table 1 and Table 2, under cover/cap – impermeable membrane, advantages. The first statement says, “provides highest level of protection against groundwater infiltration and further leaching…” Change “highest” to “high”. Source removal would provide the highest level of protection.

   See General Response to Comments #2.

9. Table 2, Phytocap, Disadvantages. Control of gases is mentioned. Please elaborate why control of gases is a concern.

   Gases are not a concern for Landfills DU2. This disadvantage will be removed from Table 2.

10. Table 3. Evaluation of Remedial Technologies for the Soil DU, Ex-Situ Treatment, Physical/ Chemical Treatment -Soil Washing – Soil washing is a physical process that separates the more contaminated fine soil (more surface area) from the coarse material. Sometimes surfactants are added to aid in the suspension of the fines, but in general it is not a chemical process. The extraction by chemical means can be used in conjunction with soil washing but is a different technology. What is described appears to be chemical extraction (mostly). Please separate into two technologies.

    A similar comment was addressed in the *Roux Responses to Technology Screening Comments 021420 (May 13, 2020)*, Specific Comment #13.

11. Table 3, Excavation and Onsite Consolidation, O&M Cost and Process Option Viability. It is unclear why this says "none" with a note that it would be accounted for in another alternative for the landfill cover. This is premature as detailed alternatives are not yet crafted. It should just state "low". Delete the reference to the O&M being accounted for elsewhere as it just raises questions.

    See General Response to Comments #2

12. Table 4. DEQ notes that Figures H1 and H4 (RIR) clearly show that excavation of 2 feet of soil and capping in likely the most efficient and cost-effective option to reduce the human health risk to acceptable levels.

    The evaluation performed during the FS will determine the most efficient and cost-effective option to reduce the human health risk to acceptable levels.

13. Table 5, Cover/Cap – Impermeable Membrane, Effectiveness, Disadvantages. Add that impermeable barriers are not appropriate for the riparian zone and that they would not allow for re-establishment of the benthic community.

    See General Response to Comments #2.

14. Table 5. DEQ notes that effective remediation of DU1 and DU6 will address the Ecological risk in DU5.

    See General Response to Comments #2.

15. Table 6, Evaluation of Remedial Technologies for the Groundwater DU - Monitored Natural Attenuation (MNA), Effectiveness, Disadvantages – Please state that "the use of MNA requires more thorough monitoring than other remedies, typically must be used in conjunction with source control, and a clear understanding of the fate and transport of the COCs at the site is required".

    See General Response to Comments #2.

16. Table 6, page1. In situ treatment options and pump and treat options do not address the on-going contamination of groundwater by the source areas.

    See General Response to Comments #2.

17. Table 6, Evaluation of Remedial Technologies for the Groundwater DU - Chemical Treatment - Permeable Reactive Barriers (PRBs), Effectiveness, Advantages - The statement, “3. Pilot scale and lab scale studies using different types of reactive barriers were successful for fluoride and cyanide removal from SPL-impacted groundwater” implies that site-specific studies have been performed. Please add the appropriate citation(s) as appropriate.

    See response to General Comment #6.

18. Table 6, Evaluation of Remedial Technologies for the Groundwater DU – In-situ Treatment, Chemical Treatment - Chemical Oxidation, Effectiveness, disadvantages, no. 2 – Addition of an oxidant would not typically mobilize arsenic unless present as a sulfide. Please add in parentheses after arsenic “(if present as a sulfide)”.

    See General Response to Comments #2.

19. Table 6, Evaluation of Remedial Technologies for the Groundwater DU – Ex-situ Treatment Physical/ Chemical Treatment - Coagulation/Flocculation/ Precipitation (Treatment of Fluoride), Effectiveness, Advantages, No. 3 – Please add a reference that arsenic would adsorb to a fluorite or calcite precipitate or remove no. 3. Also indicate if geochemical modeling would be required to determine doses and confirm reactions.

    See General Response to Comments #2.

20. Table 6, Evaluation of Remedial Technologies for the Groundwater DU – Ex-situ Treatment Pump and Treat, Biological Treatment - Constructed Wetlands, Effectiveness, Advantages, No. 3 – The statement “3. The technology has been effective based on the success of laboratory pilot scale tests.” Needs a literature citation to make it clear that the tests were not site-specific.

    See response to General Comment #6.

21. Table 6 Evaluation of Remedial Technologies for the Groundwater DU – Ex-situ Treatment Pump and Treat, Biological Treatment - Constructed Wetlands, Implementability – Please indicate the approximate flow rate, residence times and area that this statement is based on. We recognize that the numbers would be crude estimates without the benefit of site-specific bench-scale or pilot-scale studies.

    See General Response to Comments #2.

22. Table 6, page 3. Need to evaluate options which intercept/divert clean groundwater upgradient of the DU1 source areas.

    See General Response to Comments #2.

A response option entailing diversion of upgradient groundwater around Landfills DU1 is included in Alternatives LDU1/GW IIIa-c.

23. Table 6, Evaluation of Remedial Technologies for the Groundwater DU, Containment, Hydraulic Control – Extraction Wells, Effectiveness, Disadvantages – Please add "Pumping rates would require careful control to minimize extracting river water".

    See General Response to Comments #2.

24. Table 6, Evaluation of Remedial Technologies for the Groundwater DU, Containment, Vertical Barriers-Grout curtains, Effectiveness, Disadvantages, no. 3 – Please modify to state that the technology would not only be more effective with pumping to reverse the gradient, but may require pumping due to flux of groundwater and increase in head behind the wall. Also, please add a bullet that the slurry wall may be incompatible with some constituents within the groundwater (unless already evaluated and ruled out, in which case the statement that the water is compatible should be added to the advantages).

    See General Response to Comments #2.

Assembly of Remedial Alternatives for Evaluation in the FS

(Adapted from Section 6 of the draft Technology Screening Technical Memorandum dated May 13, 2020 and revised to incorporate EPA and DEQ comments provided June 3, 2020.)

Landfills DU1 and Groundwater DU Joint Alternatives

The following twelve alternatives for the combined Landfills DU1 and Groundwater DU (LDU1/GW-1 through LDU1/GW-6) are assembled for further development and evaluation in the FS.

For each alternative that includes treatment of extracted groundwater, one or more of the retained *ex situ* treatment technologies would be implemented; retained technologies include adsorption, coagulation/ flocculation/ precipitation, constructed wetlands, photolysis, electrocoagulation, and/or reverse osmosis. Treated groundwater would be disposed of via discharge to surface water or recharge to the aquifer via infiltration galleries. The viability of these *ex situ* treatment and disposal technologies will be further evaluated in the FS, although selection of the *ex situ* treatment process would likely not be finalized until the pre-design or design phase.

Alternative LDU1/GW-1: No Action

- No Action. This alternative assumes annual monitoring of the COCs in the groundwater plume. Existing natural attenuation processes would continue.

Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation

- ICs and ECs at each of the three waste management units in Landfills DU1, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- ICs for Site groundwater, including deed restrictions and well use restrictions to prevent or minimize human exposure to impacted groundwater at the Site.
- Monitored Natural Attenuation.
- Maintain existing cap at the West Landfill.
- Install an impermeable membrane cap or GCL cap at the Wet Scrubber Sludge Pond and the Center Landfill.

Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Construct a slurry wall immediately upgradient of the Landfills DU1 to divert unimpacted groundwater and surface water runoff around the source area. Design elements of the slurry wall (e.g., length, depth, location), including the need to include the Center Landfill within the diversion zone, will be further evaluated in the FS.

Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB

- Measures identical to those listed for Alternative LDU1/GW-3A above.
- Install a PRB north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep.

Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction

- Measures identical to those listed for Alternative LDU1/GW-3A above.
- Install extraction wells north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall with Hydraulic Control

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Construct a slurry wall fully encompassing the perimeter of one or more waste management units in the Landfills DU1 to contain contaminated groundwater at the source area. Design elements of the slurry wall (e.g., length, depth, location), including the need to include the Center Landfill within the containment zone, will be further evaluated in the FS.
- Maintain hydraulic control by extracting groundwater as necessary to maintain an inward gradient at the slurry wall. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-4B: Containment via Capping, Fully-Encompassing Slurry Wall with Hydraulic Control, and Downgradient PRB

- Measures identical to those listed for Alternative LDU1/GW-4A above.
- Install a PRB north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep.

Alternative LDU1/GW-4C: Containment via Capping, Fully-Encompassing Slurry Wall with Hydraulic Control, and Downgradient Extraction

- Measures identical to those listed for Alternative LDU1/GW-4A above.
- Install extraction wells north of the Burlington Northern Railroad to treat cyanide in groundwater prior to discharge at the Seep. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater at the source area using extraction wells immediately downgradient of Landfills DU1. Design elements of the extraction wells (e.g., number, locations, flow rate), including the need to include the Center Landfill within the containment zone, will be further evaluated in the FS. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5B: Containment via Capping and Hydraulic Control at the Seep

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater at the Seep using extraction wells north of the Burlington Northern Railroad. Design elements of the extraction wells (e.g., number, locations, flow rate) will be further evaluated in the FS. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and the Seep

- Measures identical to those listed for Alternative LDU1/GW-2 above.
- Maintain hydraulic control of groundwater at the source area using extraction wells immediately downgradient of Landfills DU1 and at the Seep using extraction wells north of the Burlington

Northern Railroad. Design elements of the extraction wells (e.g., number, locations, flow rate), including the need to include the Center Landfill within the containment zone, will be further evaluated in the FS. *Ex situ* treatment and discharge of the extracted groundwater.

Alternative LDU1/GW-6: Excavation with Onsite Consolidation

- Excavate source material from Landfills DU1 including wastes and underlying soils contributing to groundwater contamination. Consolidate in a newly constructed onsite repository. Design elements, including the need to excavate the Center Landfill and repository design, will be further evaluated in the FS. If excavation does not include the Center Landfill, an impermeable membrane cap or GCL cap will be installed at the Center Landfill.
- ICs for Site groundwater, including deed restrictions and well use restrictions to prevent or minimize human exposure to impacted groundwater at the Site until groundwater ARARs are achieved.

Landfills DU2 Alternatives

The following three alternatives for the Landfills DU2 (LDU2-1 through LDU2-3) are assembled for further development and evaluation in the FS.

Alternative LDU2-1: No Action

- No Action.

Alternative LDU2-2: Containment Capping A

- ICs and ECs at each of the waste management units in Landfills DU2, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- Maintain existing cap at the East Landfill and Sanitary Landfill.
- Install an impermeable membrane cap or GCL cap at the Industrial Landfill after grading, subsequent to onsite consolidation of excavated materials from other DUs if selected.
- Improve the existing soil cover at each of the Asbestos Landfills.

Alternative LDU2-3: Containment Capping B

- Measures identical to those listed for Alternative LDU2-2 above.
- Enhance the existing cap at the Sanitary Landfill by constructing a vegetated soil cap.

Soil DU Alternatives

The following four alternatives for the Soil DU (SO-1 through SO-4) are assembled for further development and evaluation in the FS. A common element for all SO Alternatives includes a deed restriction for deeper soils to ensure the exposure assumptions with respect to deeper soils remain valid.

Alternative SO-1: No Action

- No Action.

Alternative SO-2: Covers with Hotspot Excavation

- Install a soil cover for select areas of spatially concentrated COC distribution within the Soil DU to prevent contact with the impacted soil.

- ICs in capped areas to ensure caps are maintained or alternative caps (i.e., buildings, pavement) are implemented as part of any future development.
- Excavation of discontinuous, isolated soil hotspots outside of cap footprints with disposal at an onsite repository, as needed.

Alternative SO-3: *In Situ* Treatment with Hotspot Excavation

- *In situ* treatment of spatially concentrated PAH-impacted soils via phytoremediation or thermal desorption.
- Excavation of discontinuous, isolated soil hotspots outside of treatment footprints with disposal at an onsite repository, as needed.

Alternative SO-4: Excavation with Onsite Consolidation

- Excavate impacted soil in the Soil DU with disposal at an onsite repository.

North Percolation Pond DU Alternatives

The following four alternatives for the North Percolation Pond DU (NPP-1 through NPP-4) are assembled for further development and evaluation in the FS.

Alternative NPP-1: No Action

- No Action.

Alternative NPP-2: Limited Excavation with Covers

- ICs and ECs at the North Percolation Pond DU, including deed restrictions to prevent development and fencing to physically prevent exposure to compliant human receptors and some ecological receptors.
- Decommission the influent pipes from which stormwater enters the North Percolation Pond system.
- Excavate impacted media in the influent and effluent ditches and consolidate in the Northeast Percolation Pond.
- Install a soil cover at the Northeast and Northwest Percolation Ponds to prevent contact with the impacted media. Physical stabilization of the viscous, carbonaceous material as needed to support the cover. The North Percolation Ponds may be a suitable onsite repository for excavated material from another DU prior to installation of a soil cover.

Alternative NPP-3: Excavation with Cover

- Measures mirror those listed for Alternative NPP-2 above, with impacted media in the Northwest Percolation Pond also excavated and consolidated in the Northeast Percolation Pond. A soil cover would be installed at the Northeast Percolation Pond, only.

Alternative NPP-4: Excavation with Onsite Consolidation

- Decommission the influent pipes from which stormwater enters the North Percolation Pond system.
- Excavate impacted media in the North Percolation Pond DU with disposal at an onsite repository.

River Area DU Alternatives

The following two alternatives for the River Area DU (RADU-1 and RADU-2) are assembled for further development and evaluation in the FS.

Alternative RADU-1: No Action

- No Action.

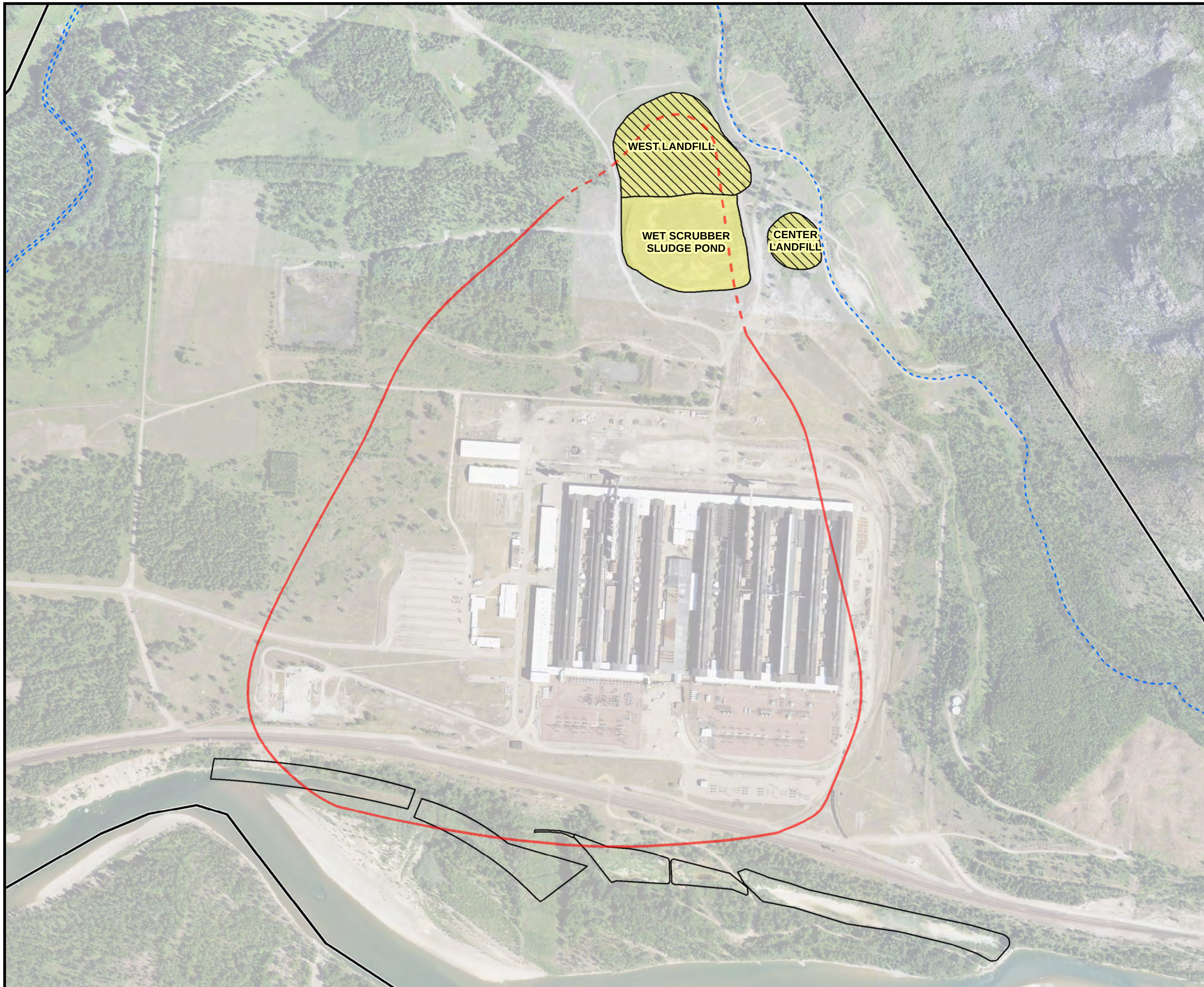
Alternative RADU-2: Excavation with Onsite Consolidation and Long-Term Monitoring

- Decommission the influent pipe from which stormwater enters the South Percolation Pond system.
- Excavate impacted sediment in the South Percolation Ponds with disposal at an onsite repository.
- Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater to evaluate and verify the progress of upgradient source control, groundwater remediation, and/or MNA implemented under the selected LDU1/GW Alternative.

The first two components of Alternative RADU-2 will be implemented as part of the removal action in accordance with the requirements of the Administrative Order on Consent dated XXX. The potential risk attributed to cyanide in sediment, sediment porewater, and surface water in the River Area DU will be mitigated by addressing groundwater inputs to benthic habitats and demonstrating reductions over time to total cyanide concentrations in surface water and free cyanide concentrations in porewater in those areas. Alternatives addressing groundwater inputs will be assessed within the Groundwater DU.

APPENDIX E

Figures Depicting Landfills DU1 and Groundwater DU Joint Alternatives



LEGEND

EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)

MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL AND EXISTING CAP ON CENTER LANDFILL

LANDFILLS DECISION UNIT1

SITE FEATURES WITHIN RIVER AREA DU

CREEK FEATURES

SITE BOUNDARY

NOTE

1. AREAS OF LANDFILLS DU1 SITE FEATURES:
   WEST LANDFILL - 7.8 ACRES
   WET SCRUBBER SLUDGE POND - 10.8 ACRES
   CENTER LANDFILL - 1.8 ACRES

Title:

ALTERNATIVE LDU1/GW-1: NO ACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E1
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File: 2476.0001Y271.E1.mxd		

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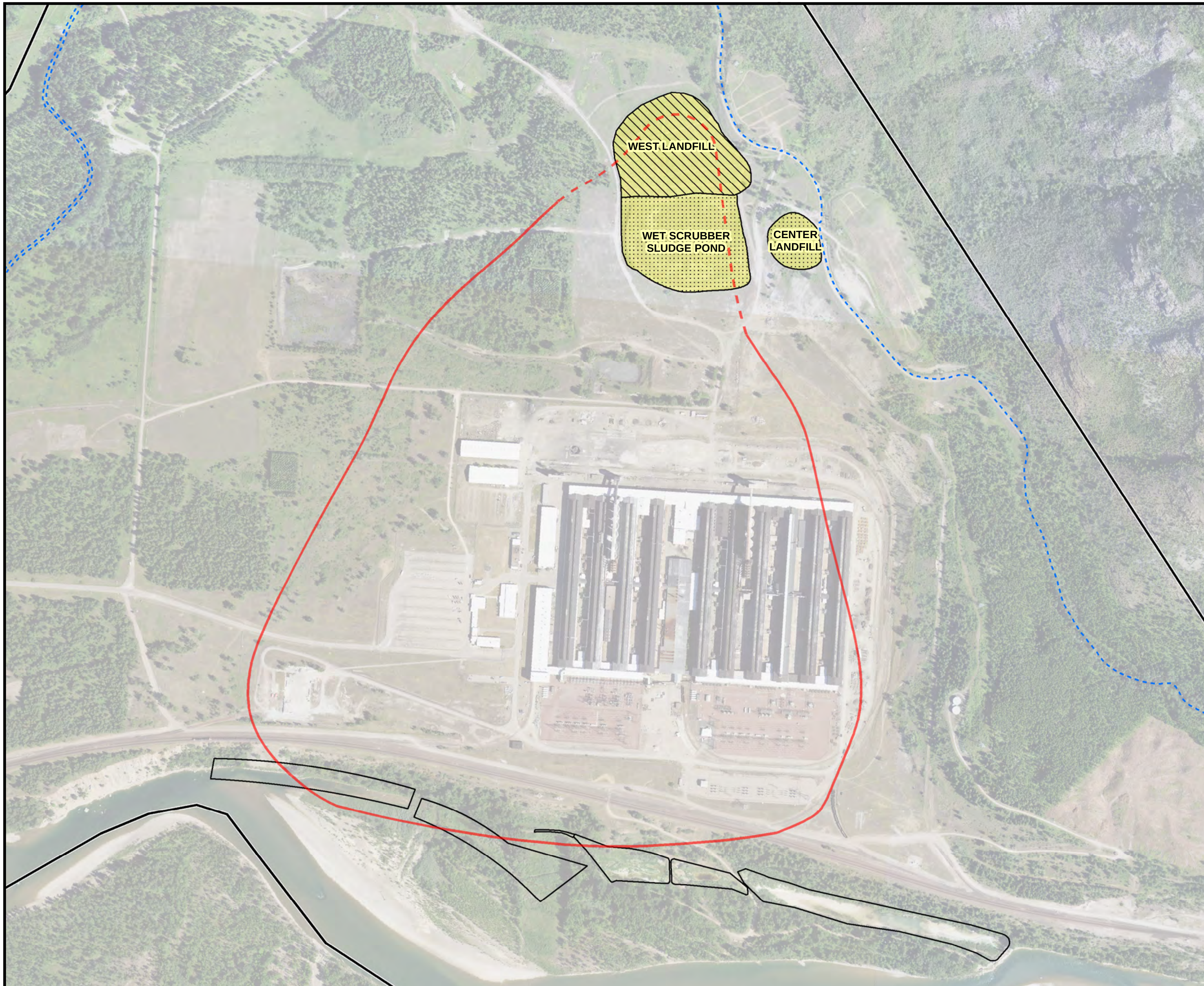

LEGEND

- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

NOTE

1. AREAS OF LANDFILLS DU1 SITE FEATURES:
   WEST LANDFILL - 7.8 ACRES
   WET SCRUBBER SLUDGE POND - 10.8 ACRES
   CENTER LANDFILL - 1.8 ACRES

Title:

ALTERNATIVE LDU1/GW-2: CONTAINMENT VIA CAPPING

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E2
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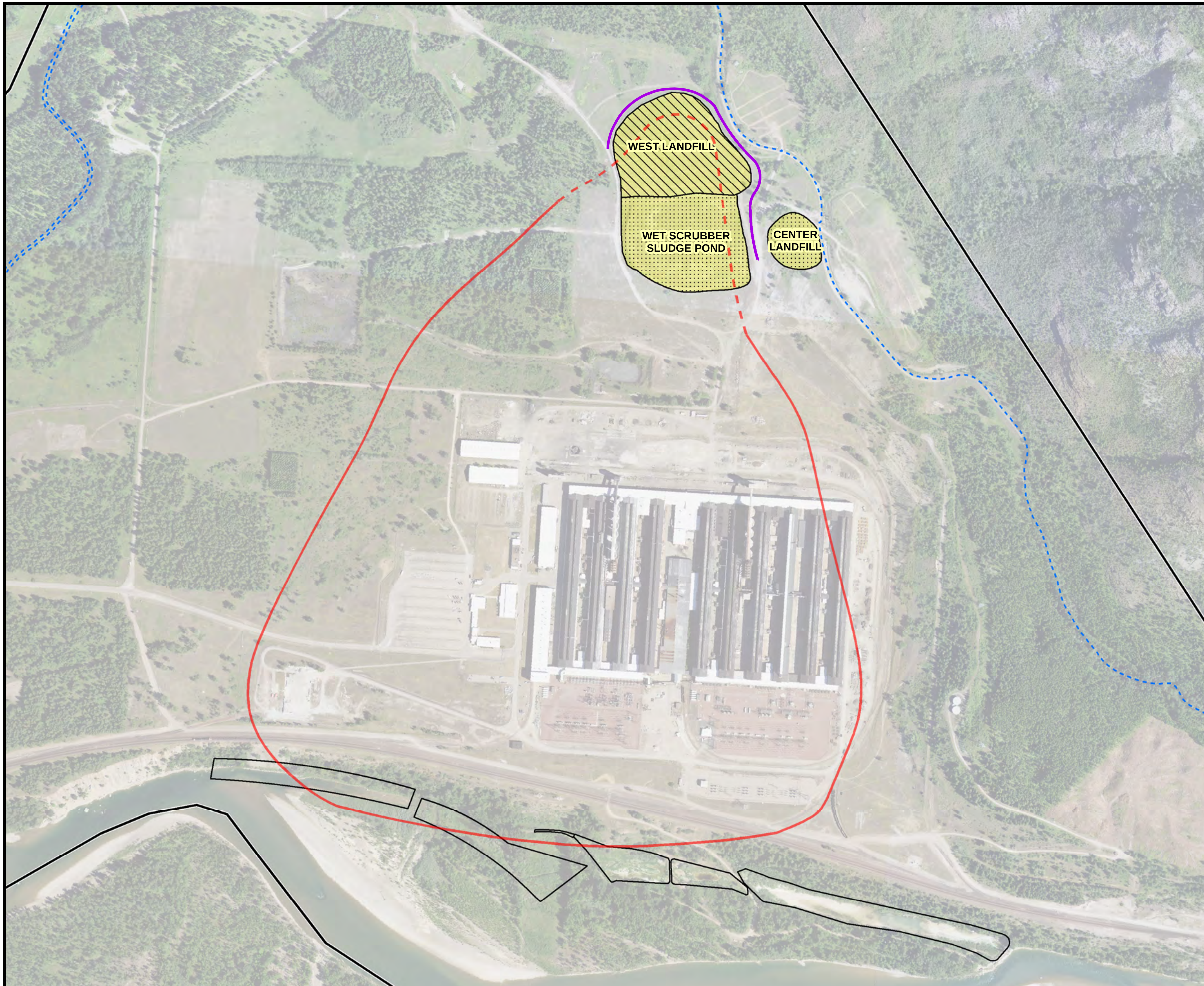

N

LEGEND

PROPOSED SLURRY WALL

EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)

MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL

CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL

LANDFILLS DECISION UNIT1

SITE FEATURES WITHIN RIVER AREA DU

CREEK FEATURES

SITE BOUNDARY

600 0 600'

Title:

ALTERNATIVE LDU1/GW-3A: CONTAINMENT VIA CAPPING AND UPGRADIENT SLURRY WALL

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E3
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File: 2476.0001Y271.E3.mxd		

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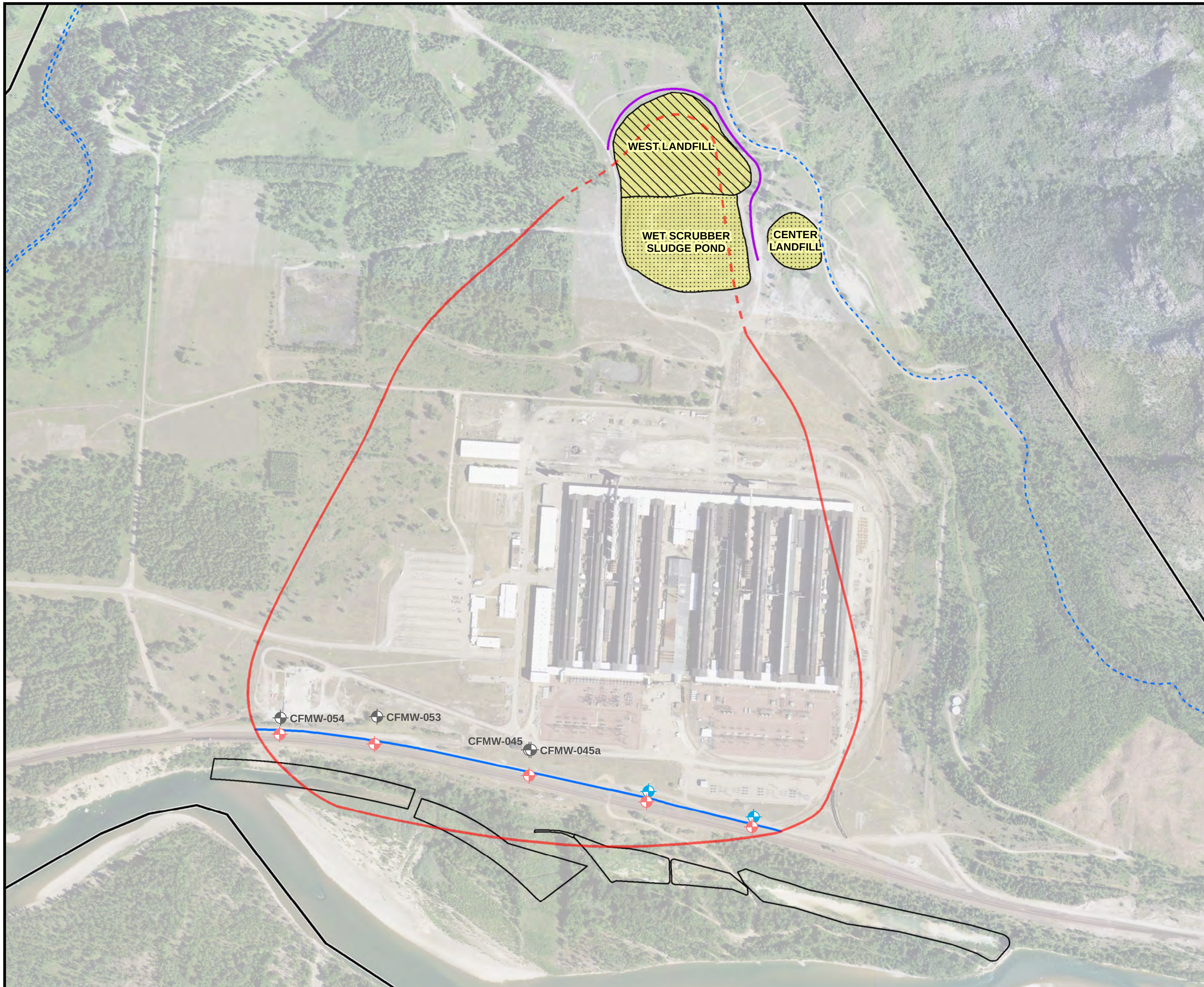

LEGEND

- LOCATION OF PROPOSED MONITORING WELL PAIRS – DOWNGRADIENT MONITORING WELL
- LOCATION OF PROPOSED MONITORING WELL PAIRS – UPGRADIENT MONITORING WELL
- LOCATION OF EXISTING MONITORING WELL
- PROPOSED SLURRY WALL
- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED PRB
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

Title:

ALTERNATIVE LDU1/GW-3B: CONTAINMENT VIA CAPPING AND UPGRADIENT SLURRY WALL WITH DOWNGRADIENT PRB

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E4
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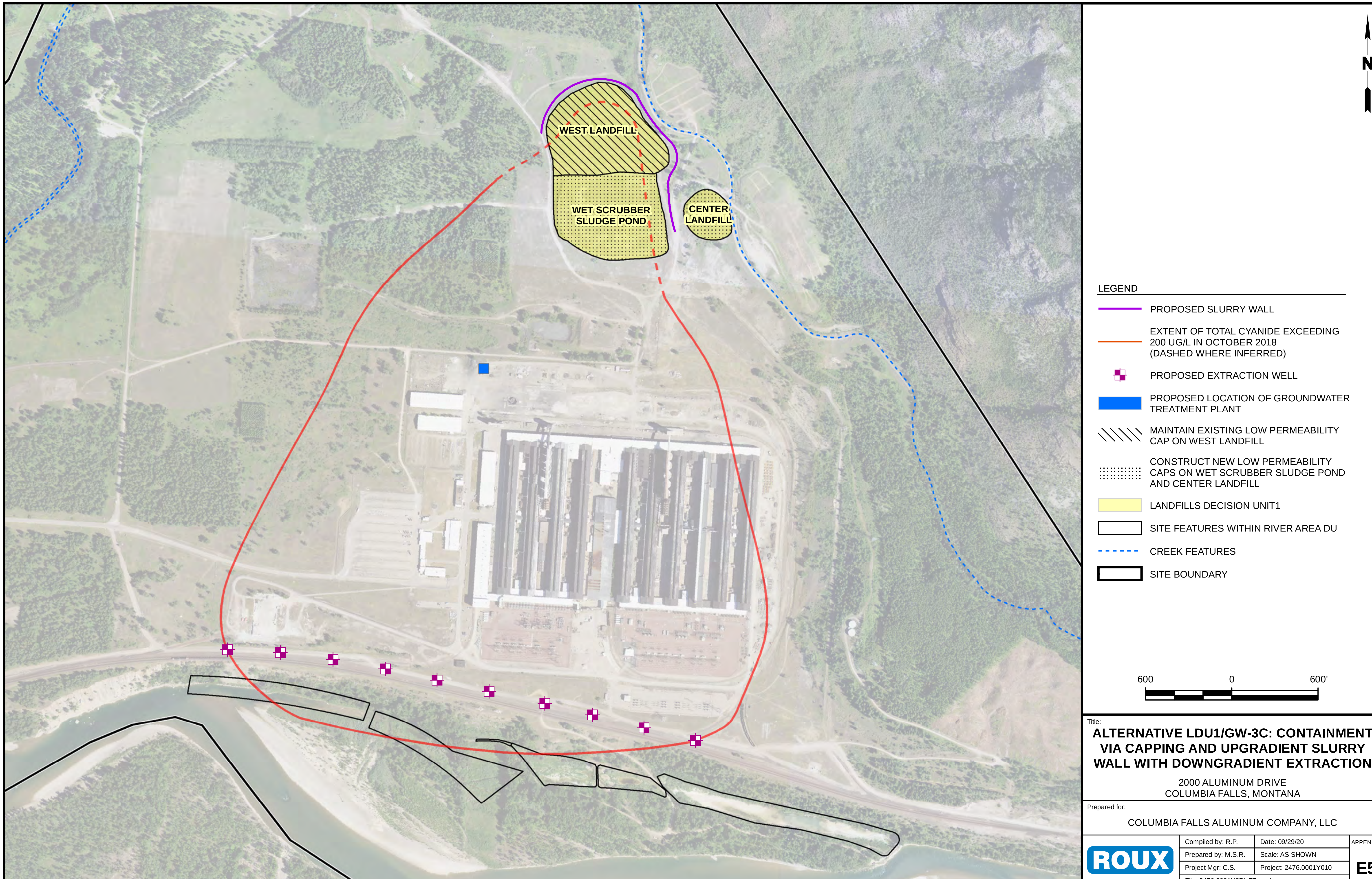

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Title:

ALTERNATIVE LDU1/GW-3C: CONTAINMENT VIA CAPPING AND UPGRADIENT SLURRY WALL WITH DOWNGRADIENT EXTRACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
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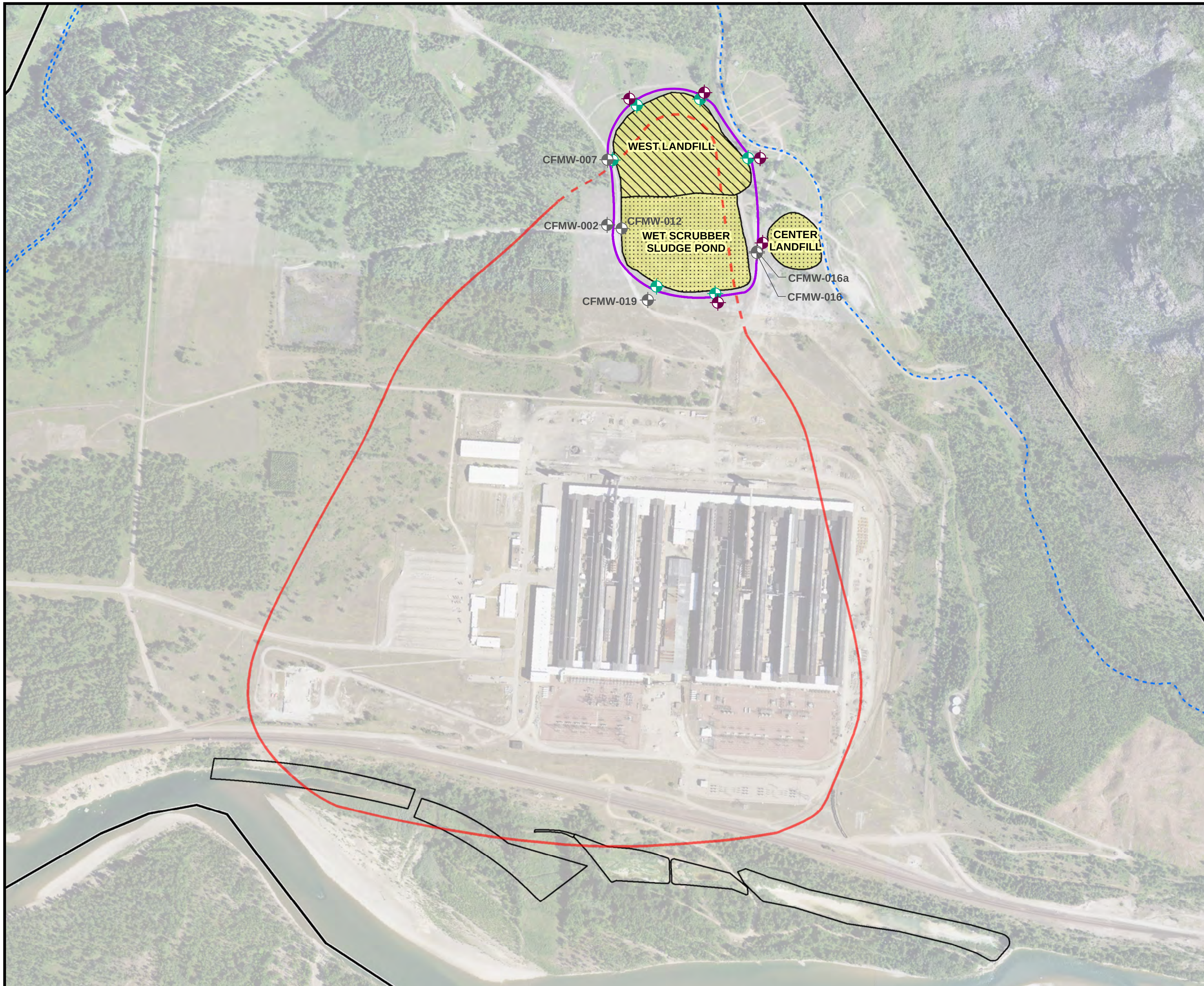

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LEGEND

- LOCATION OF PROPOSED PIEZOMETER PAIRS - INSIDE MONITORING WELL
- LOCATION OF PROPOSED PIEZOMETER PAIRS - OUTSIDE MONITORING WELL
- LOCATION OF EXISTING MONITORING WELL
- PROPOSED SLURRY WALL
- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. PIEZOMETER PAIRS CONSIST OF TWO MONITORING WELLS - ONE ON EITHER SIDE OF THE VERTICAL BARRIER. MONITORING WELLS INSIDE THE SLURRY WALL CAN BE USED FOR EXTRACTION OF GROUNDWATER IF NEEDED TO MAINTAIN AN INWARD GRADIENT.
2. NUMBER AND LOCATION OF MONITORING WELLS WILL BE DETERMINED DURING REMEDIAL DESIGN.

600 0 600'

Title:

ALTERNATIVE LDU1/GW-4A: CONTAINMENT VIA CAPPING AND FULLY-ENCOMPASSING SLURRY WALL

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E6
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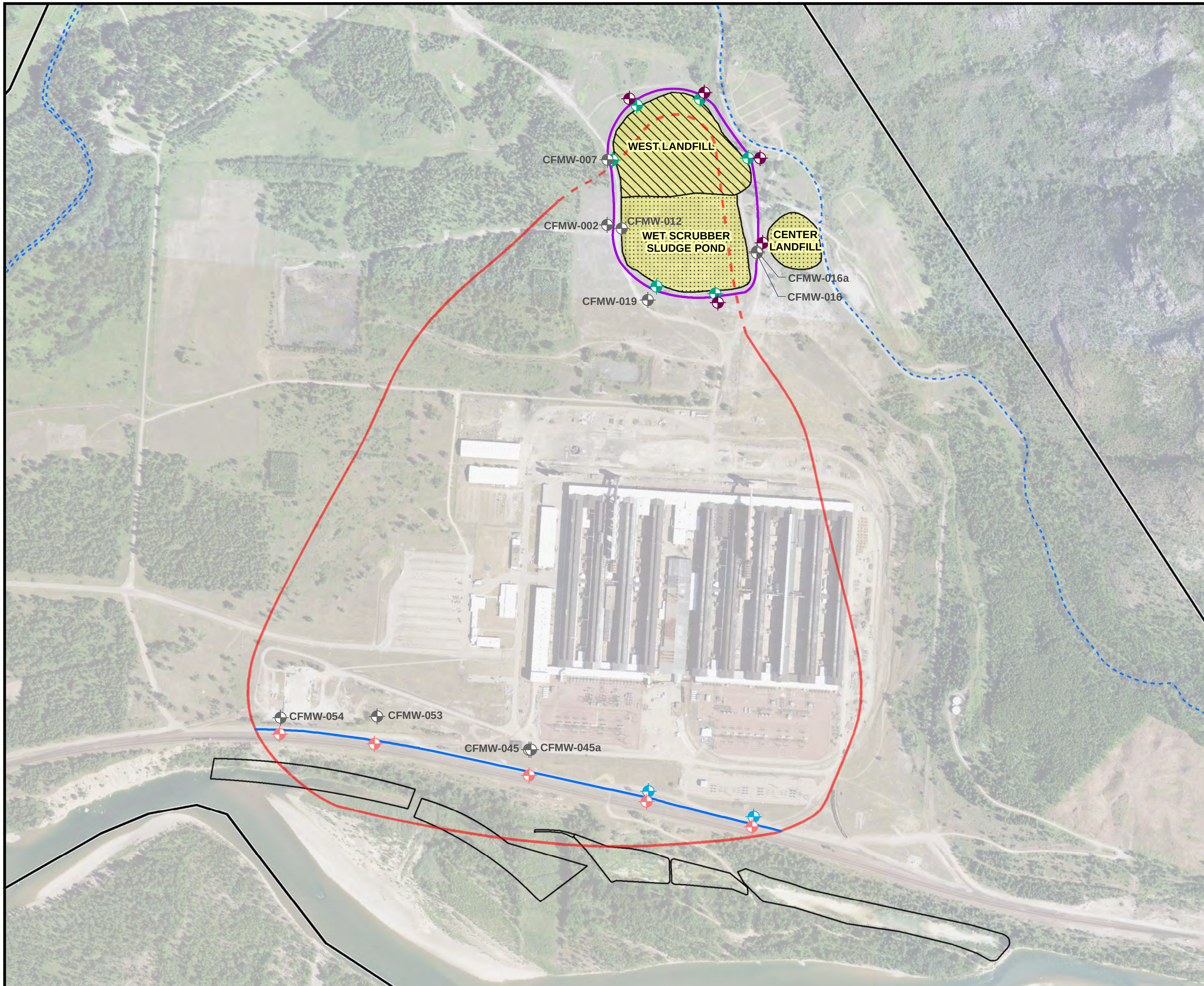

LEGEND

- LOCATION OF PROPOSED PIEZOMETER PAIRS - INSIDE MONITORING WELL
- LOCATION OF PROPOSED PIEZOMETER PAIRS - OUTSIDE MONITORING WELL
- LOCATION OF PROPOSED MONITORING WELL PAIRS – DOWNGRADIENT MONITORING WELL
- LOCATION OF PROPOSED MONITORING WELL PAIRS – UPGRADIENT MONITORING WELL
- LOCATION OF EXISTING MONITORING WELL
- PROPOSED SLURRY WALL
- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED PRB
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. PIEZOMETER PAIRS CONSIST OF TWO MONITORING WELLS - ONE ON EITHER SIDE OF THE VERTICAL BARRIER. MONITORING WELLS INSIDE THE SLURRY WALL CAN BE USED FOR EXTRACTION OF GROUNDWATER IF NEEDED TO MAINTAIN AN INWARD GRADIENT.
2. NUMBER AND LOCATION OF MONITORING WELLS WILL BE DETERMINED DURING REMEDIAL DESIGN.

Title:

ALTERNATIVE LDU1/GW-4B: CONTAINMENT VIA CAPPING AND FULLY-ENCOMPASSING SLURRY WALL WITH DOWNGRADIENT PRB

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E7
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.E7.mxd		

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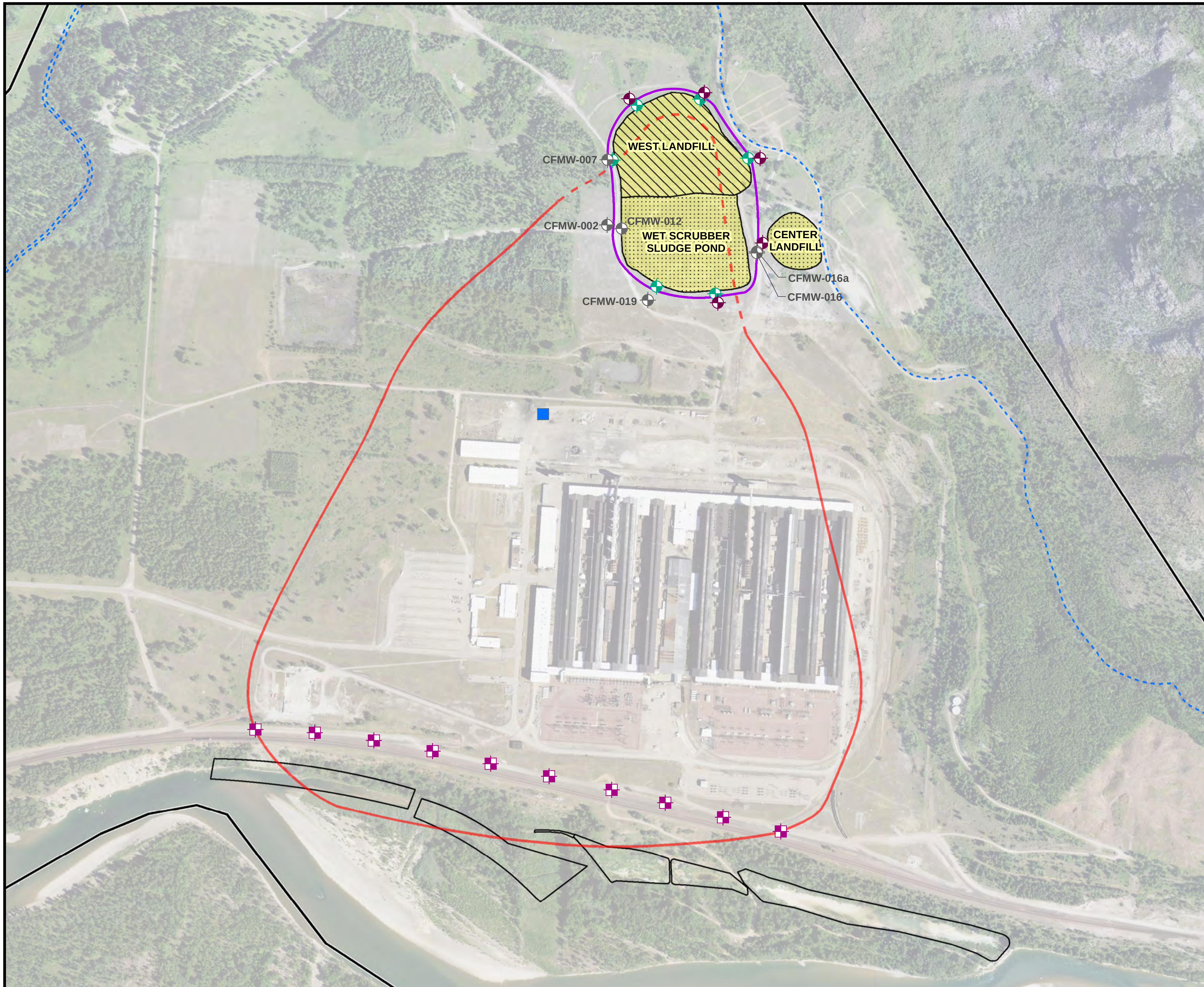

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LEGEND

- LOCATION OF PROPOSED PIEZOMETER PAIRS - INSIDE MONITORING WELL
- LOCATION OF PROPOSED PIEZOMETER PAIRS - OUTSIDE MONITORING WELL
- LOCATION OF EXISTING MONITORING WELL
- PROPOSED LOCATION OF GROUNDWATER TREATMENT PLANT
- PROPOSED SLURRY WALL
- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED EXTRACTION WELL
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. PIEZOMETER PAIRS CONSIST OF TWO MONITORING WELLS - ONE ON EITHER SIDE OF THE VERTICAL BARRIER. MONITORING WELLS INSIDE THE SLURRY WALL CAN BE USED FOR EXTRACTION OF GROUNDWATER IF NEEDED TO MAINTAIN AN INWARD GRADIENT.
2. NUMBER AND LOCATION OF MONITORING WELLS WILL BE DETERMINED DURING REMEDIAL DESIGN.

600 0 600'

Title:

ALTERNATIVE LDU1/GW-4C: CONTAINMENT VIA CAPPING AND FULLY-ENCOMPASSING SLURRY WALL WITH DOWNGRADIENT EXTRACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E8
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.E8.mxd		

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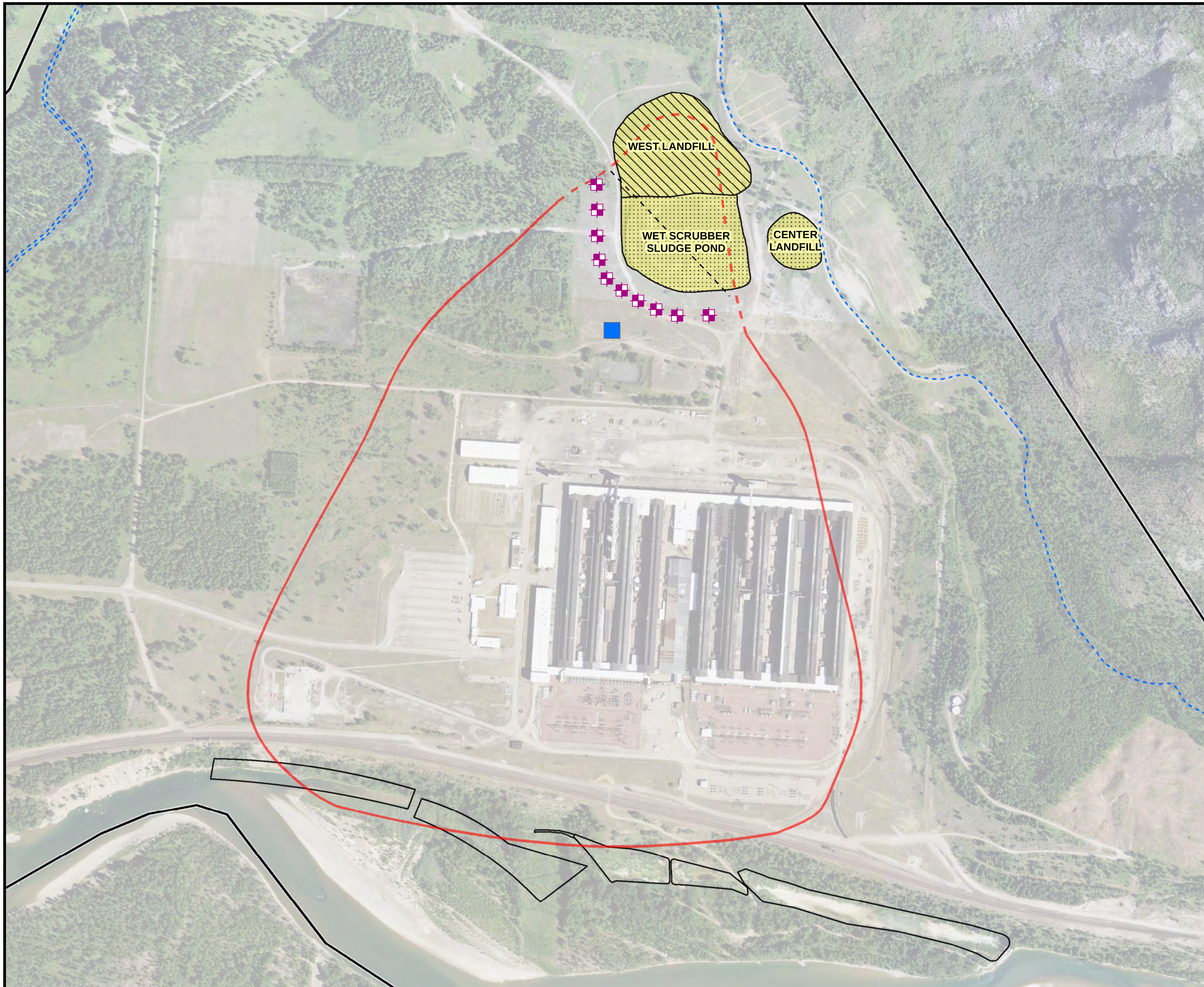

LEGEND

- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED EXTRACTION WELL
- PROPOSED LOCATION OF GROUNDWATER TREATMENT PLANT
- PROPOSED FLUX TRANSECTS FOR CAPTURE ZONE CALCULATION
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

600 0 600'

Title:

ALTERNATIVE LDU1/GW-5A: CONTAINMENT VIA CAPPING AND HYDRAULIC CONTROL AT THE SOURCE AREA

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	
Project Mgr: C.S.	Project: 2476.0001Y010	E9
File: 2476.0001Y271.E9.mxd		

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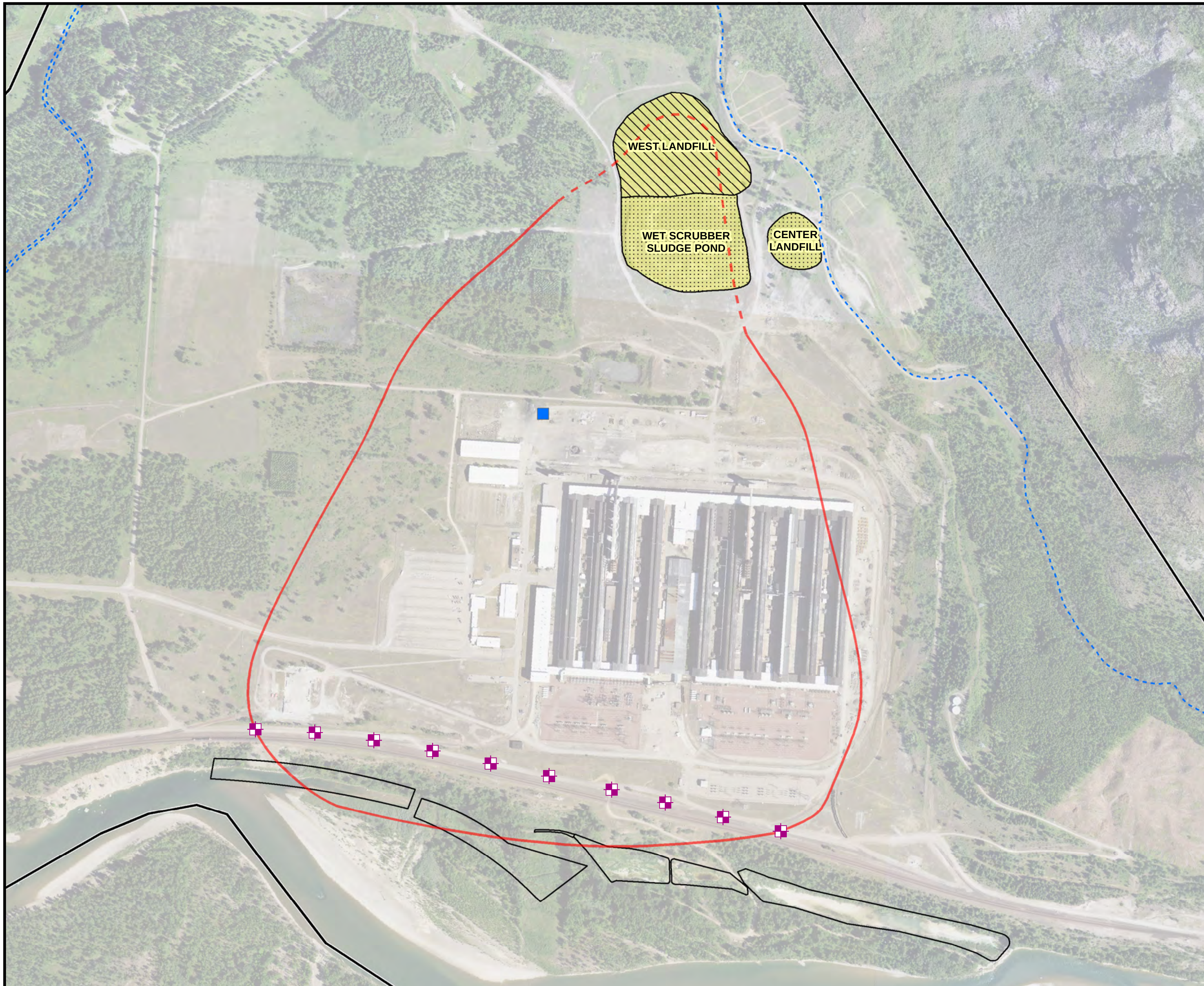

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LEGEND

- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED EXTRACTION WELL
- PROPOSED LOCATION OF GROUNDWATER TREATMENT PLANT
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

600 0 600'

Title:

ALTERNATIVE LDU1/GW-5B: CONTAINMENT VIA CAPPING WITH DOWNGRADIENT EXTRACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E10
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.E10.mxd		

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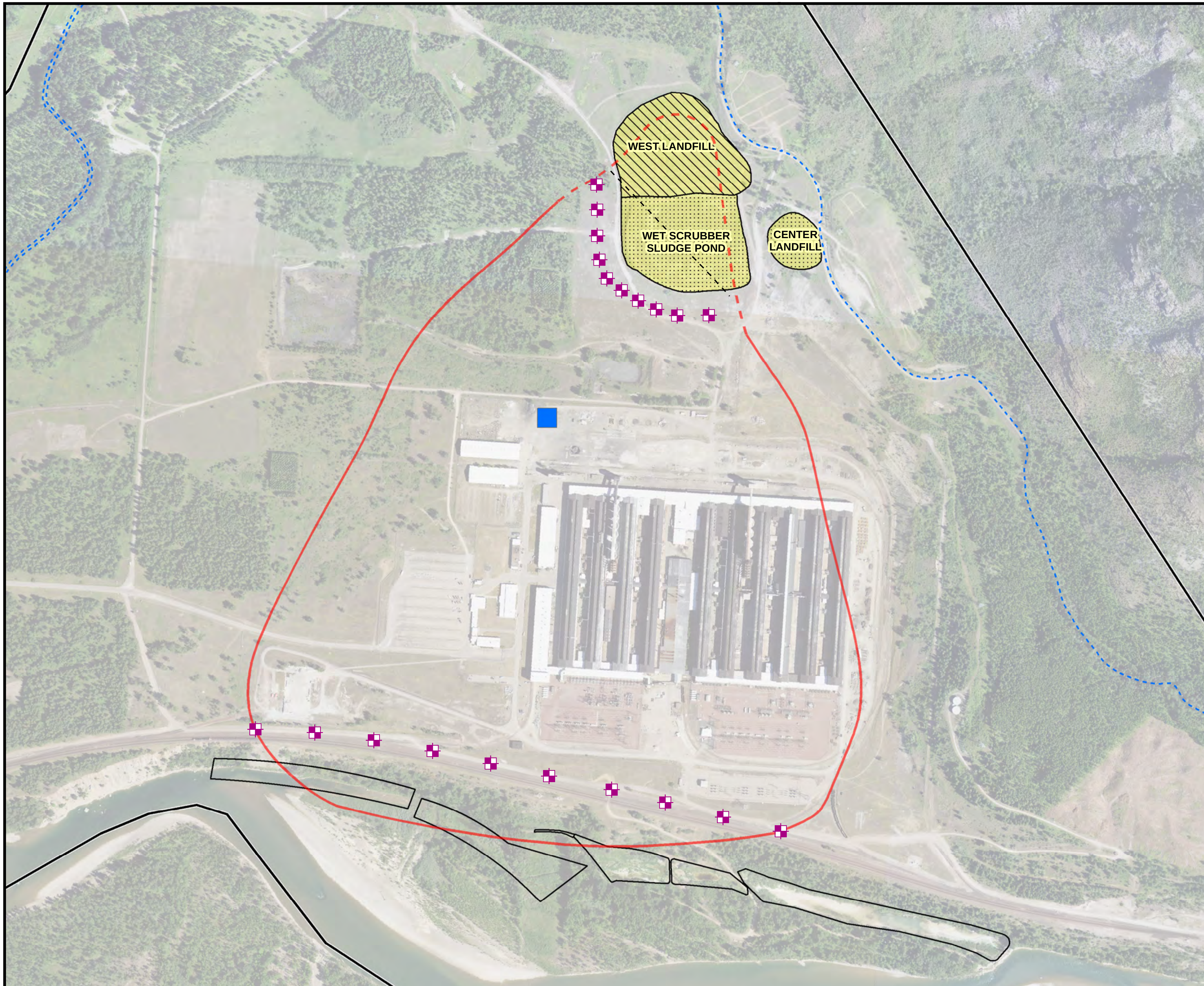

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LEGEND

- EXTENT OF TOTAL CYANIDE EXCEEDING 200 UG/L IN OCTOBER 2018 (DASHED WHERE INFERRED)
- PROPOSED EXTRACTION WELL
- PROPOSED LOCATION OF GROUNDWATER TREATMENT PLANT
- PROPOSED FLUX TRANSECTS FOR CAPTURE ZONE CALCULATION
- MAINTAIN EXISTING LOW PERMEABILITY CAP ON WEST LANDFILL
- CONSTRUCT NEW LOW PERMEABILITY CAPS ON WET SCRUBBER SLUDGE POND AND CENTER LANDFILL
- LANDFILLS DECISION UNIT1
- SITE FEATURES WITHIN RIVER AREA DU
- CREEK FEATURES
- SITE BOUNDARY

600 0 600'

Title:

ALTERNATIVE LDU1/GW-5C: CONTAINMENT VIA CAPPING AND HYDRAULIC CONTROL AT THE SOURCE AREA, WITH DOWNGRADIENT EXTRACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: R.P.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E11
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.E11.mxd		

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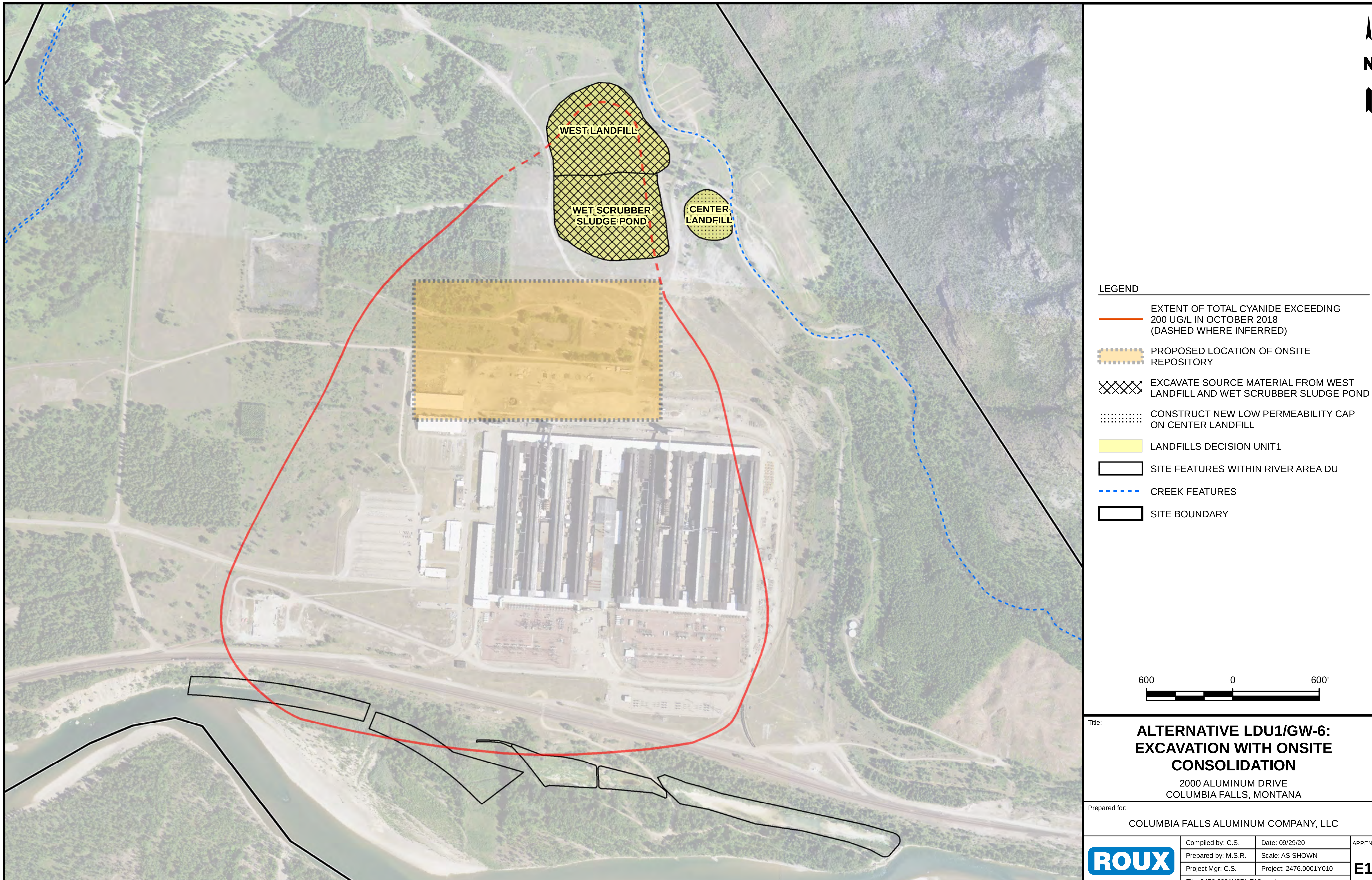

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Title:

ALTERNATIVE LDU1/GW-6: EXCAVATION WITH ONSITE CONSOLIDATION

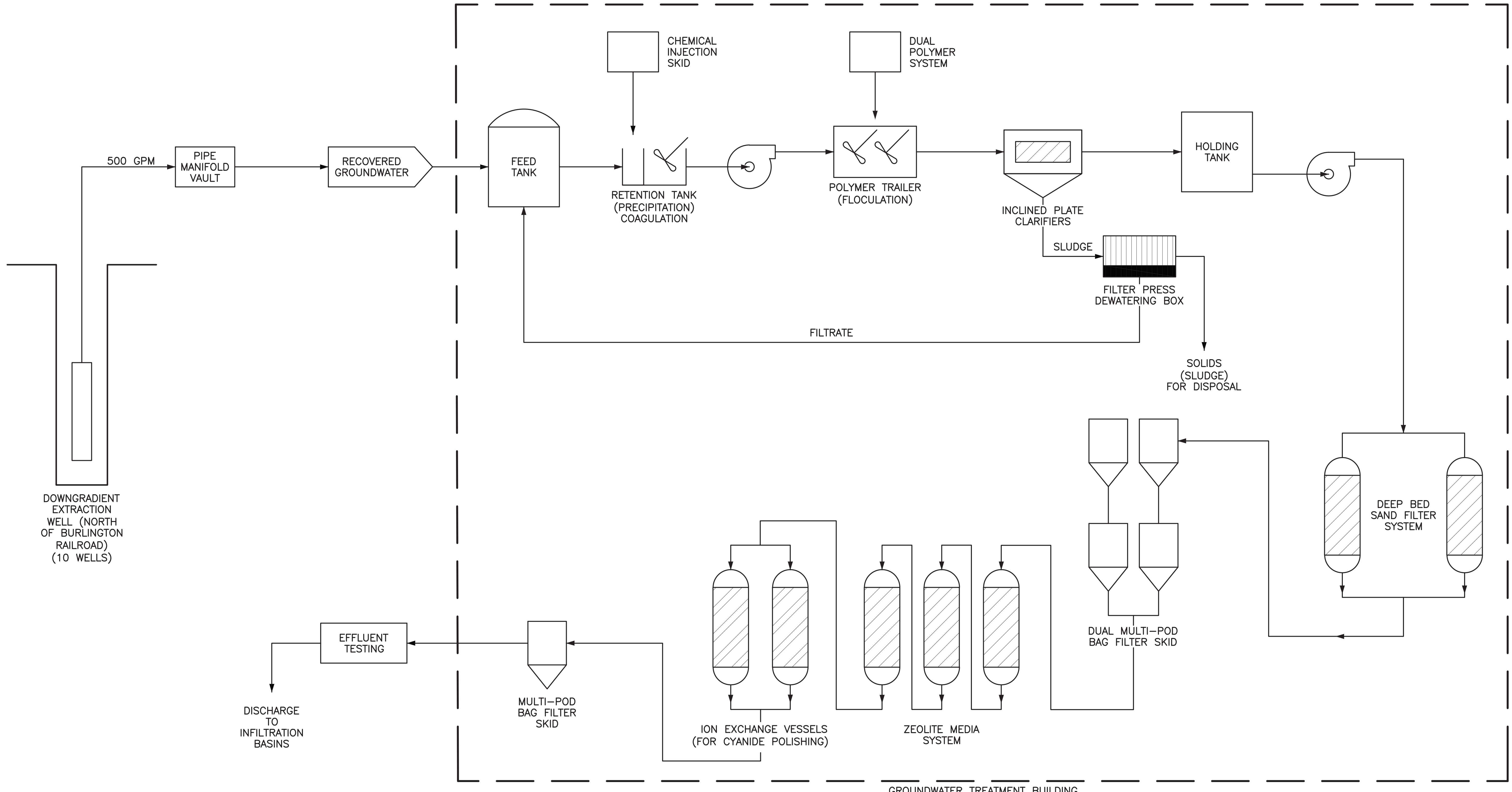
2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	E12
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.E12.mxd		



Title:

CONCEPTUAL PROCESS FLOW DIAGRAM FOR GROUNDWATER TREATMENT - CYANIDE REMOVAL

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY

Compiled by: R.P.	Date: 28AUG20	FIGURE
Prepared by: G.M.	Scale: NONE	E13
Project Mgr: A.B.	Project: 2476.000Y010	
File: 2476.0001Y271.01.DWG		

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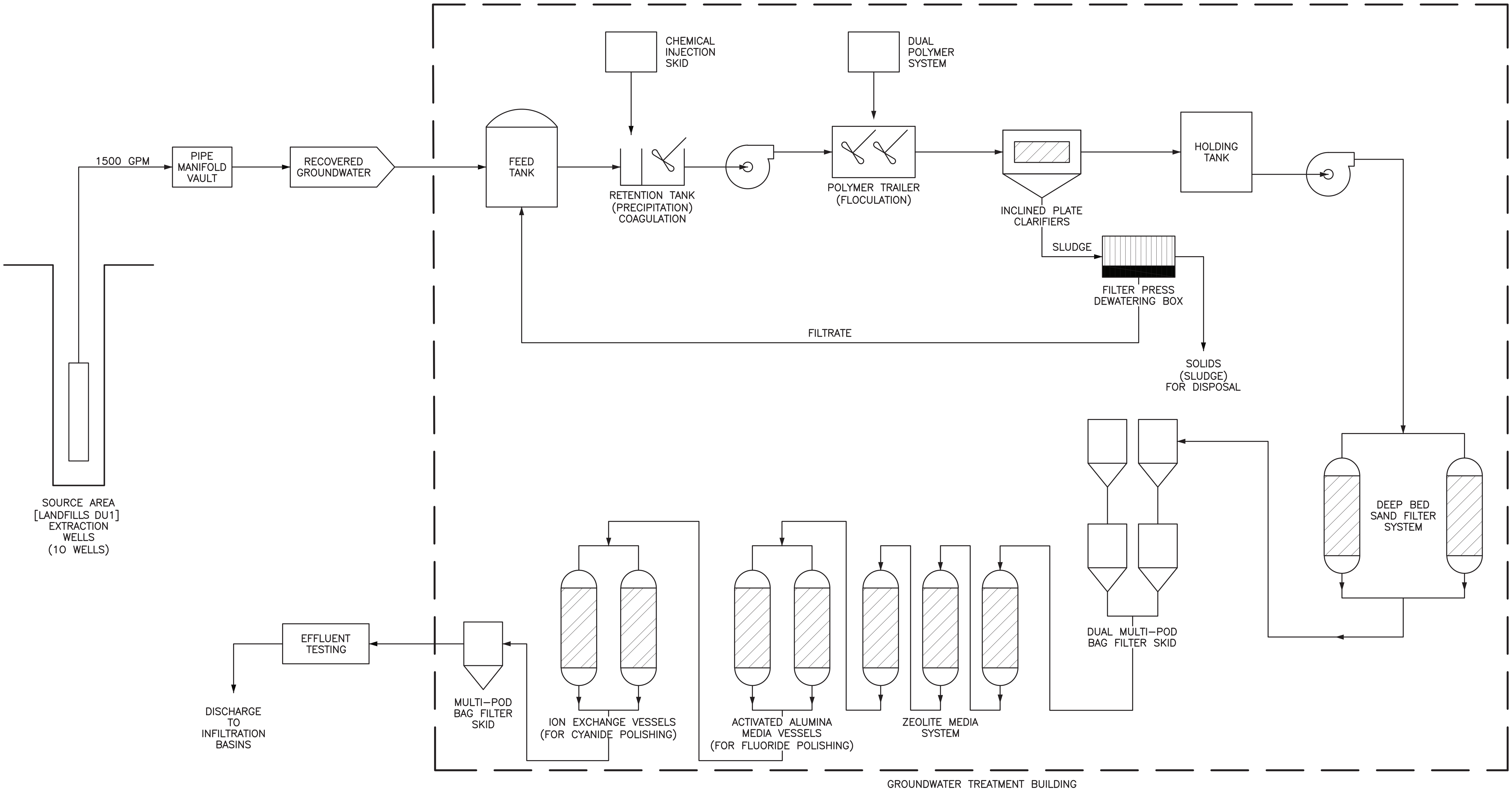

Title:

CONCEPTUAL PROCESS FLOW DIAGRAM FOR GROUNDWATER TREATMENT - CYANIDE AND FLUORIDE REMOVAL

2000 ALUMINUM DRIVE, COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY

ROUX

Compiled by: R.P.	Date: 28AUG20	FIGURE
Prepared by: G.M.	Scale: NONE	E14
Project Mgr: A.B.	Project: 2476.000Y010	
File: 2476.0001Y271.01.DWG		

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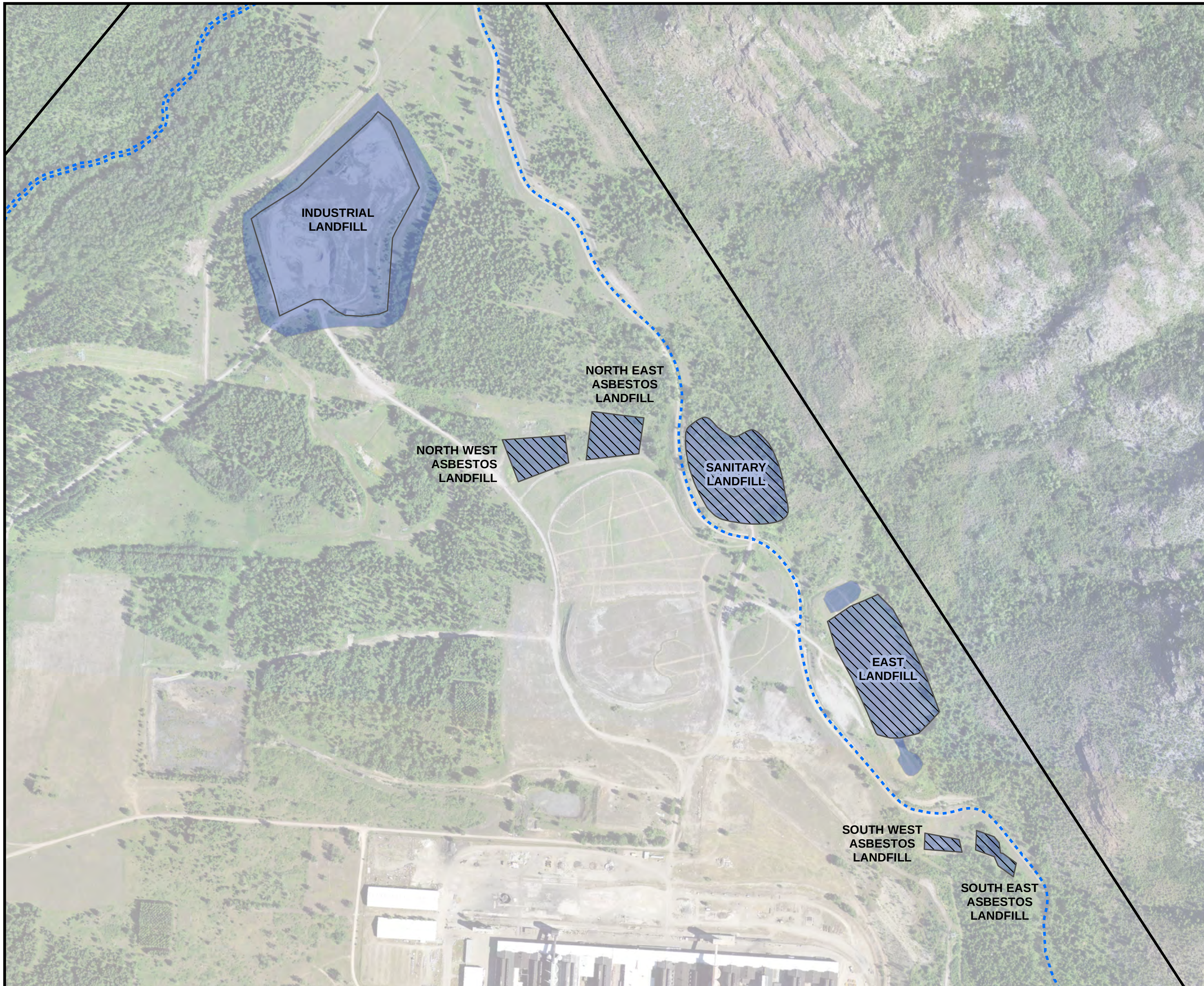
APPENDIX F

Figures Depicting Landfills DU2 Alternatives



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LEGEND

LANDFILLS DU2

SITE FEATURES WITHIN LANDFILLS DU2

MAINTAIN EXISTING CAPS AT THE EAST LANDFILL AND SANITARY LANDFILL AND MAINTAIN EXISTING SOIL COVERS AT THE ASBESTOS LANDFILLS

NOTE

1. AREAS OF LANDFILLS DU2 SITE FEATURES:
   EAST LANDFILL - 2.4 ACRES
   INDUSTRIAL LANDFILL - 12.4 ACRES
   SANITARY LANDFILL - 3.8 ACRES
   ASBESTOS LANDFILL - 3.4 ACRES

500 0 500'

Title:

LANDFILLS DECISION UNIT 2
ALTERNATIVE LDU2-1:
NO ACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 11/03/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	
Project Mgr: C.S.	Project: 2476.0001Y010	F1
File: 2476.0001Y271.F1.mxd		

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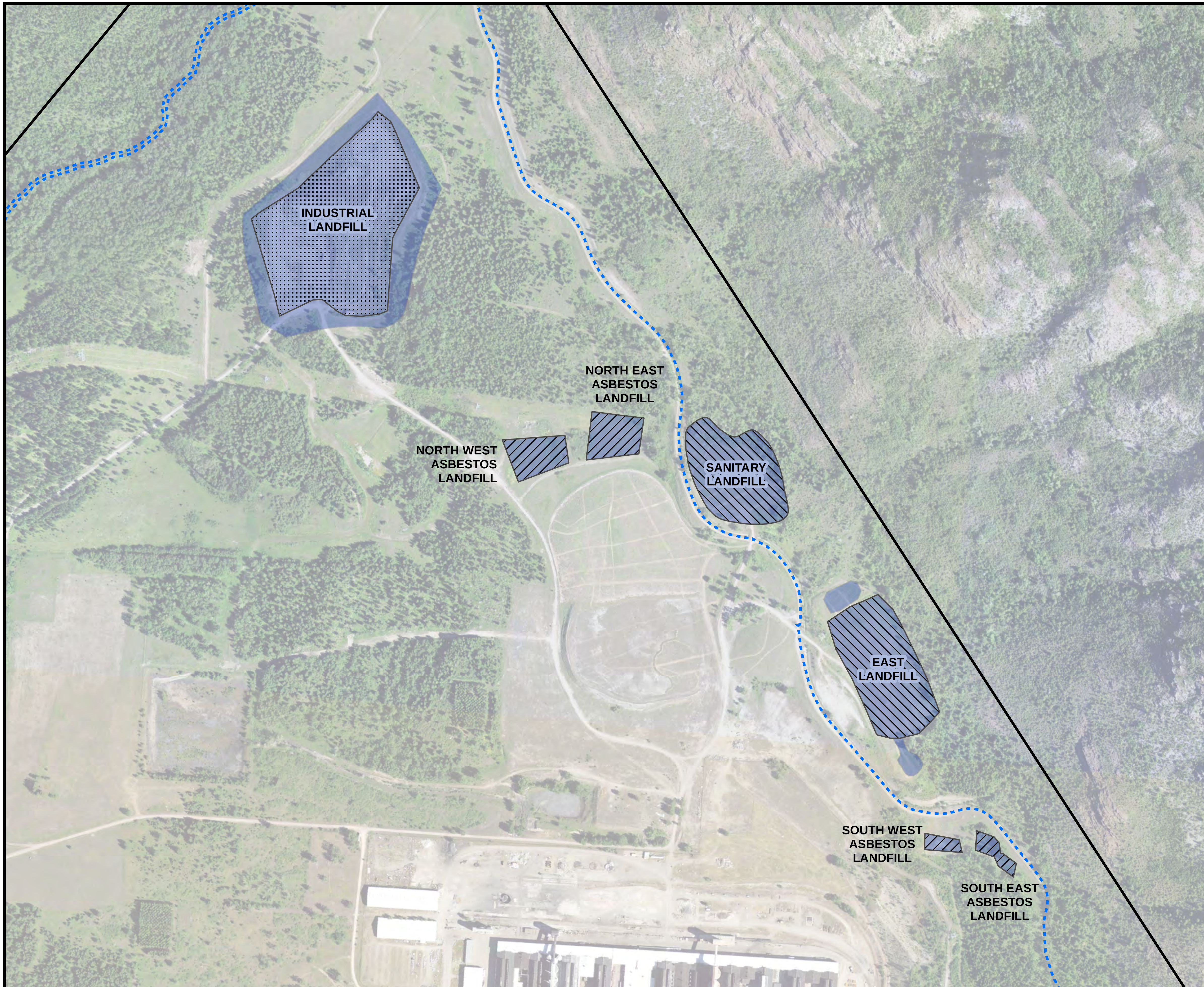

N

LEGEND

- LANDFILLS DU2
- SITE FEATURES WITHIN LANDFILLS DU2
- MAINTAIN EXISTING CAPS AT EAST LANDFILL AND SANITARY LANDFILL
- INSTALL IMPERMEABLE MEMBRANE CAP OR GCL CAP AT THE INDUSTRIAL LANDFILL
- IMPROVE EXISTING SOIL COVERS AT ASBESTOS LANDFILLS

NOTE

1. AREAS OF LANDFILLS DU2 SITE FEATURES:
   EAST LANDFILL - 2.4 ACRES
   INDUSTRIAL LANDFILL - 12.4 ACRES
   SANITARY LANDFILL - 3.8 ACRES
   ASBESTOS LANDFILL - 3.4 ACRES

500 0 500'

Title:

LANDFILLS DECISION UNIT 2 ALTERNATIVE LDU2-2: CONTAINMENT VIA CAPPING

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	F2
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File: 2476.0001Y271.F2.mxd		

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APPENDIX G

Figures Depicting Soil DU Alternatives

G1. Soil Decision Unit Alternative SO-1: No Action

G2. Soil Decision Unit Alternative SO-2: Covers with Hotspot Excavation

G3. Soil Decision Unit Alternative SO-3: *In Situ* Treatment with Hotspot Excavation

G4. Soil Decision Unit Alternative SO-4: Excavation with Onsite Consolidation

LEGEND

- AREAS OF CONCERN
- SOIL DECISION UNIT
- SITE FEATURES WITHIN SOIL DU
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. AOCS APPLY TO SURFICIAL AND SHALLOW SOIL (0-0.5 AND 0.5-2 FT-BLS, RESPECTIVELY)
2. AOCS AS DRAWN CAPTURE ALL EXCEEDANCES OF SMALL RANGE RECEPTOR PRGS AND LOCATIONS RESULTING IN EXCEEDANCES OF HUMAN HEALTH OR ECOLOGICAL PRGS, AS DESCRIBED IN SECTION 3.3.
3. ESTIMATED AREAS OF SOIL DU AOCS

   AOC A - 0.12 ACRES
   AOC B - 0.86 ACRES
   AOC C - 1.60 ACRES
   AOC D - 2.78 ACRES
   AOC E - 1.86 ACRES
   AOC F - 0.59 ACRES
   AOC G - 0.15 ACRES

Title:

SOIL DECISION UNIT ALTERNATIVE SO-1 : NO ACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX	
Prepared by: M.S.R.	Scale: AS SHOWN		G1
Project Mgr: C.S.	Project: 2476.0001Y010		
File: 2476.0001Y271.G1.mxd			

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LEGEND

- AREAS OF CONCERN
- SOIL DECISION UNIT
- SITE FEATURES WITHIN SOIL DU
- AREA OF PROPOSED EXCAVATION
- AREA OF PROPOSED SOIL COVER
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. AOCS APPLY TO SURFICIAL AND SHALLOW SOIL (0-0.5 AND 0.5-2 FT-BLS, RESPECTIVELY)
2. AOCS AS DRAWN CAPTURE ALL EXCEEDANCES OF SMALL RANGE RECEPTOR PRGS AND LOCATIONS RESULTING IN EXCEEDANCES OF HUMAN HEALTH OR ECOLOGICAL PRGS, AS DESCRIBED IN SECTION 3.3.
3. ESTIMATED AREAS OF SOIL DU AOCS

   AOC A - 0.12 ACRES
   AOC B - 0.86 ACRES
   AOC C - 1.60 ACRES
   AOC D - 2.78 ACRES
   AOC E - 1.86 ACRES
   AOC F - 0.59 ACRES
   AOC G - 0.15 ACRES

4. ESTIMATED VOLUMES FOR EXCAVATION BY AOC:

   AOC A - 390 CY
   AOC B - 2,770 CY
   AOC F - 1,900 CY
   AOC G - 480 CY

Title:

SOIL DECISION UNIT ALTERNATIVE SO-2 : COVERS WITH HOTSPOT EXCAVATION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	G2
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File: 2476.0001Y271.G2.mxd		

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LEGEND

- AREAS OF CONCERN
- SOIL DECISION UNIT
- SITE FEATURES WITHIN SOIL DU
- AREA OF PROPOSED EXCAVATION
- AREA OF PROPOSED PHYTOREMEDIATION
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. AOCS APPLY TO SURFICIAL AND SHALLOW SOIL (0-0.5 AND 0.5-2 FT-BLS, RESPECTIVELY)
2. AOCS AS DRAWN CAPTURE ALL EXCEEDANCES OF SMALL RANGE RECEPTOR PRGS AND LOCATIONS RESULTING IN EXCEEDANCES OF HUMAN HEALTH OR ECOLOGICAL PRGS, AS DESCRIBED IN SECTION 3.3.
3. ESTIMATED AREAS OF SOIL DU AOCS

   AOC A - 0.12 ACRES
   AOC B - 0.86 ACRES
   AOC C - 1.60 ACRES
   AOC D - 2.78 ACRES
   AOC E - 1.86 ACRES
   AOC F - 0.59 ACRES
   AOC G - 0.15 ACRES

4. ESTIMATED VOLUMES FOR EXCAVATION BY AOC:

   AOC A - 390 CY
   AOC B - 2,770 CY
   AOC F - 1,900 CY
   AOC G - 480 CY

200 0 200'

Title:

SOIL DECISION UNIT ALTERNATIVE SO-3 : IN SITU TREATMENT WITH HOTSPOT EXCAVATION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	G3
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.G3.mxd		

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N

LEGEND

- AREAS OF CONCERN
- SOIL DECISION UNIT
- SITE FEATURES WITHIN SOIL DU
- AREA OF PROPOSED EXCAVATION
- CREEK FEATURES
- SITE BOUNDARY

NOTES

1. AOCS APPLY TO SURFICIAL AND SHALLOW SOIL (0-0.5 AND 0.5-2 FT-BLS, RESPECTIVELY)
2. AOCS AS DRAWN CAPTURE ALL EXCEEDANCES OF SMALL RANGE RECEPTOR PRGS AND LOCATIONS RESULTING IN EXCEEDANCES OF HUMAN HEALTH OR ECOLOGICAL PRGS, AS DESCRIBED IN SECTION 3.3.
3. ESTIMATED AREAS OF SOIL DU AOCS

   AOC A - 0.12 ACRES
   AOC B - 0.86 ACRES
   AOC C - 1.60 ACRES
   AOC D - 2.78 ACRES
   AOC E - 1.86 ACRES
   AOC F - 0.59 ACRES
   AOC G - 0.15 ACRES

4. ESTIMATED VOLUMES FOR EXCAVATION BY AOC:

   AOC A - 390 CY
   AOC B - 2,770 CY
   AOC C - 5,160 CY
   AOC D - 8,970 CY
   AOC E - 6,000 CY
   AOC F - 1,900 CY
   AOC G - 480 CY

200 0 200'

Title:

SOIL DECISION UNIT ALTERNATIVE SO-4 : EXCAVATION WITH ONSITE CONSOLIDATION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	G4
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.G4.mxd		

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APPENDIX H

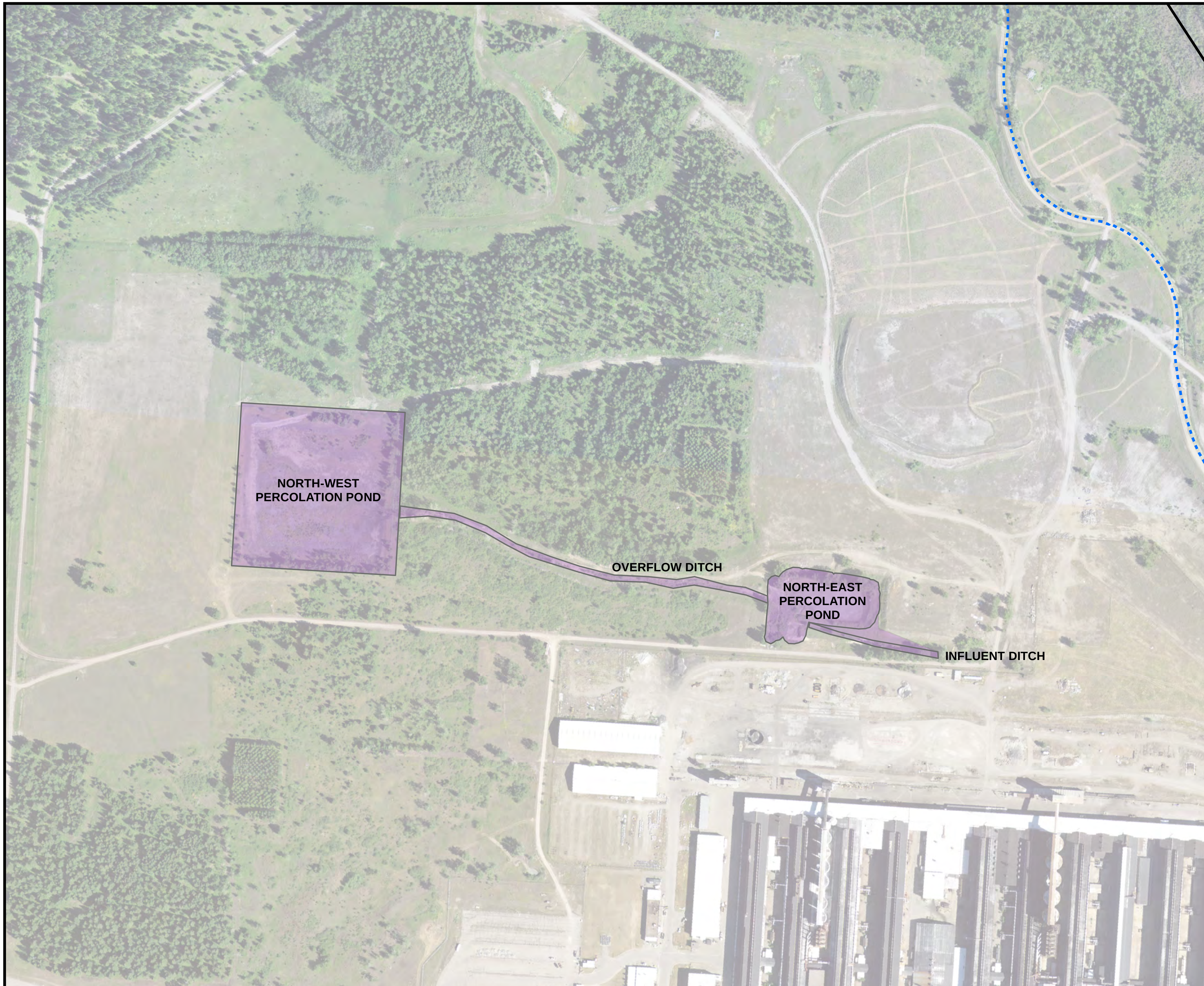
Figures Depicting North Percolation Pond DU Alternatives

H1. NPP Decision Unit Alternative NPP-1: No Action

H2. NPP Decision Unit Alternative NPP-2: Limited Excavation with Covers

H3. NPP Decision Unit Alternative NPP-3: Excavation with Cover

H4. NPP Decision Unit Alternative NPP-4: Excavation with Onsite Consolidation



LEGEND

- NORTH PERCOLATION POND DECISION UNIT
- SITE FEATURES WITHIN NPP DU

NOTE

1. AREAS OF NPP DU SITE FEATURES:
   NORTH-EAST PERCOLATION POND – 2.0 ACRES
   NORTH-WEST PERCOLATION POND – 8.0 ACRES
   INFLUENT DITCH – 0.2 ACRES
   OVERFLOW DITCH – 0.4 ACRES

Title:

NPP DECISION UNIT ALTERNATIVE NPP-1 : NO ACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	H1
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.H1.mxd		

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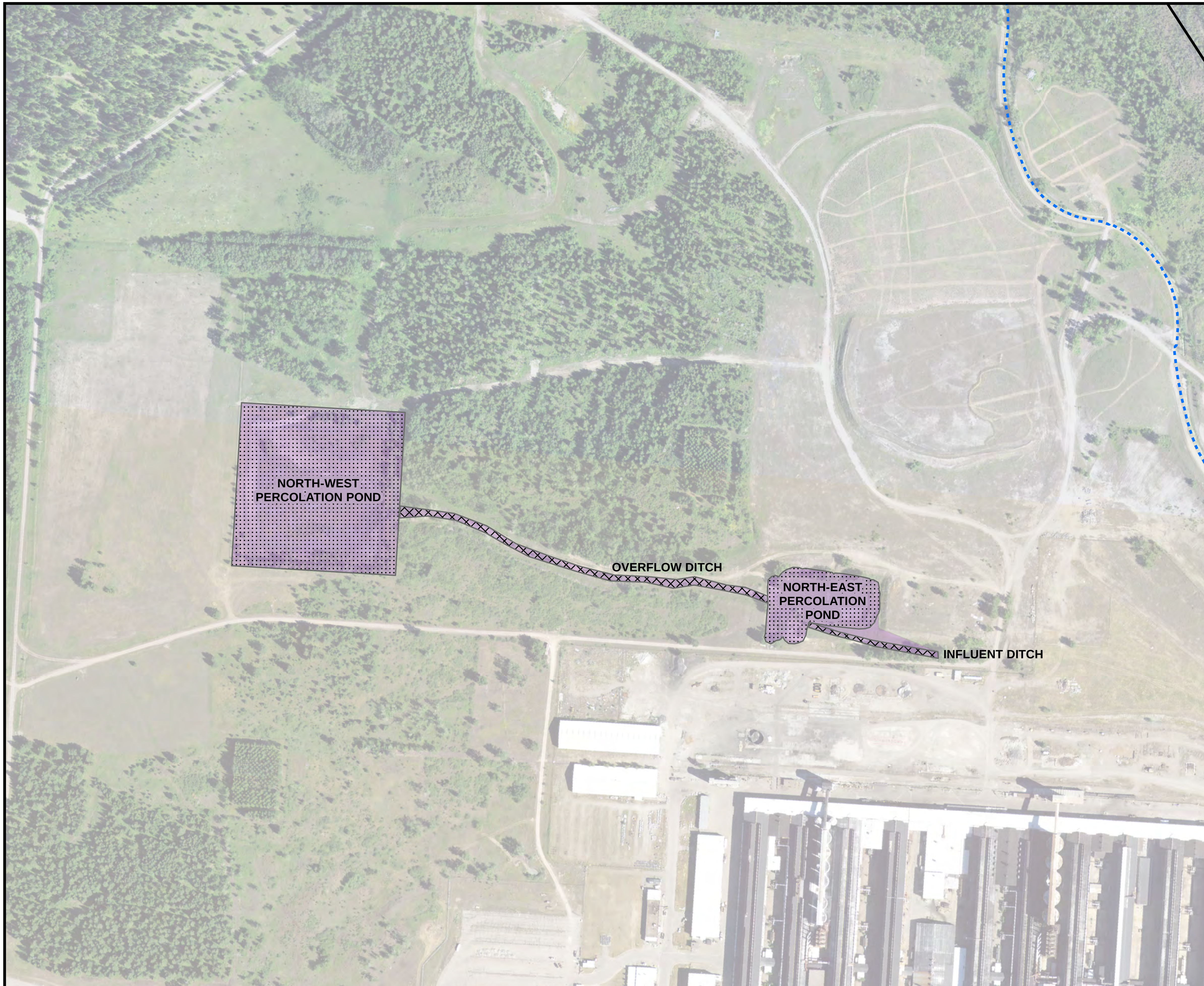

LEGEND

- NORTH PERCOLATION POND DECISION UNIT
- SITE FEATURES WITHIN NPP DU
- AREA OF PROPOSED EXCAVATION
- AREA OF PROPOSED SOIL COVER

NOTES

1. AREAS OF NPP DU SITE FEATURES:
   NORTH-EAST PERCOLATION POND – 2.0 ACRES
   NORTH-WEST PERCOLATION POND – 8.0 ACRES
   INFLUENT DITCH – 0.2 ACRES
   OVERFLOW DITCH – 0.4 ACRES
2. ESTIMATED RANGE OF VOLUMES FOR EXCAVATION BY NPP DU SITE FEATURE:
   INFLUENT DITCH – 160 TO 960 CY
   OVERFLOW DITCH – 320 TO 1,920 CY

350 0 350'

Title:

NPP DECISION UNIT ALTERNATIVE NPP-2 : LIMITED EXCAVATION WITH COVERS

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	H2
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.H2.mxd		

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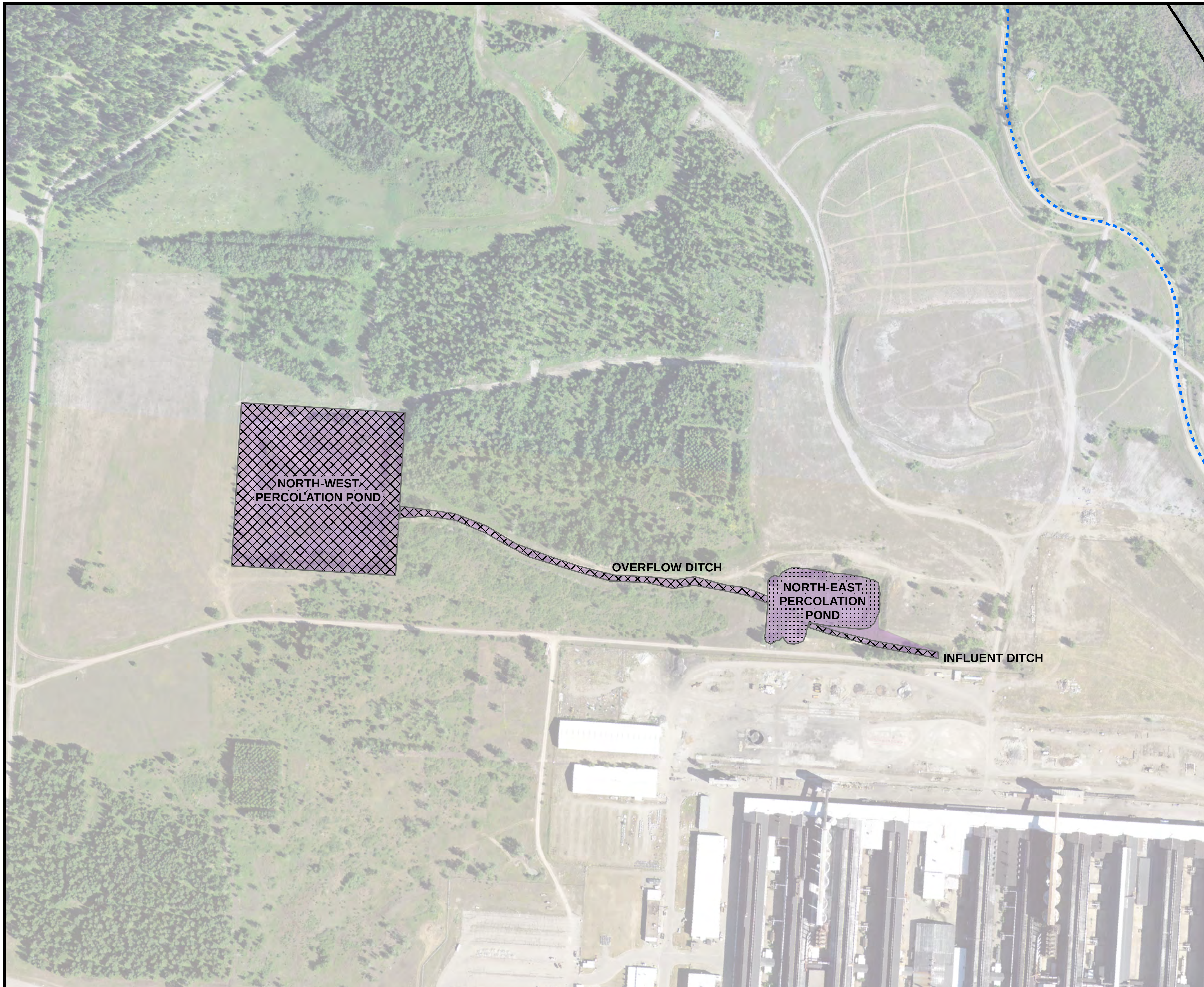

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LEGEND

- NORTH PERCOLATION POND DECISION UNIT
- SITE FEATURES WITHIN NPP DU
- AREA OF PROPOSED EXCAVATION
- AREA OF PROPOSED SOIL COVER

NOTES

1. AREAS OF NPP DU SITE FEATURES:
   NORTH-EAST PERCOLATION POND – 2.0 ACRES
   NORTH-WEST PERCOLATION POND – 8.0 ACRES
   INFLUENT DITCH – 0.2 ACRES
   OVERFLOW DITCH – 0.4 ACRES
2. ESTIMATED RANGE OF VOLUMES FOR EXCAVATION BY NPP DU SITE FEATURE:
   NORTH-WEST PERCOLATION POND – 4,850 TO 19,400 CY
   INFLUENT DITCH – 160 TO 960 CY
   OVERFLOW DITCH – 320 TO 1,920 CY

350 0 350'

Title:

NPP DECISION UNIT ALTERNATIVE NPP-3: EXCAVATION WITH COVER

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	H3
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.H3.mxd		

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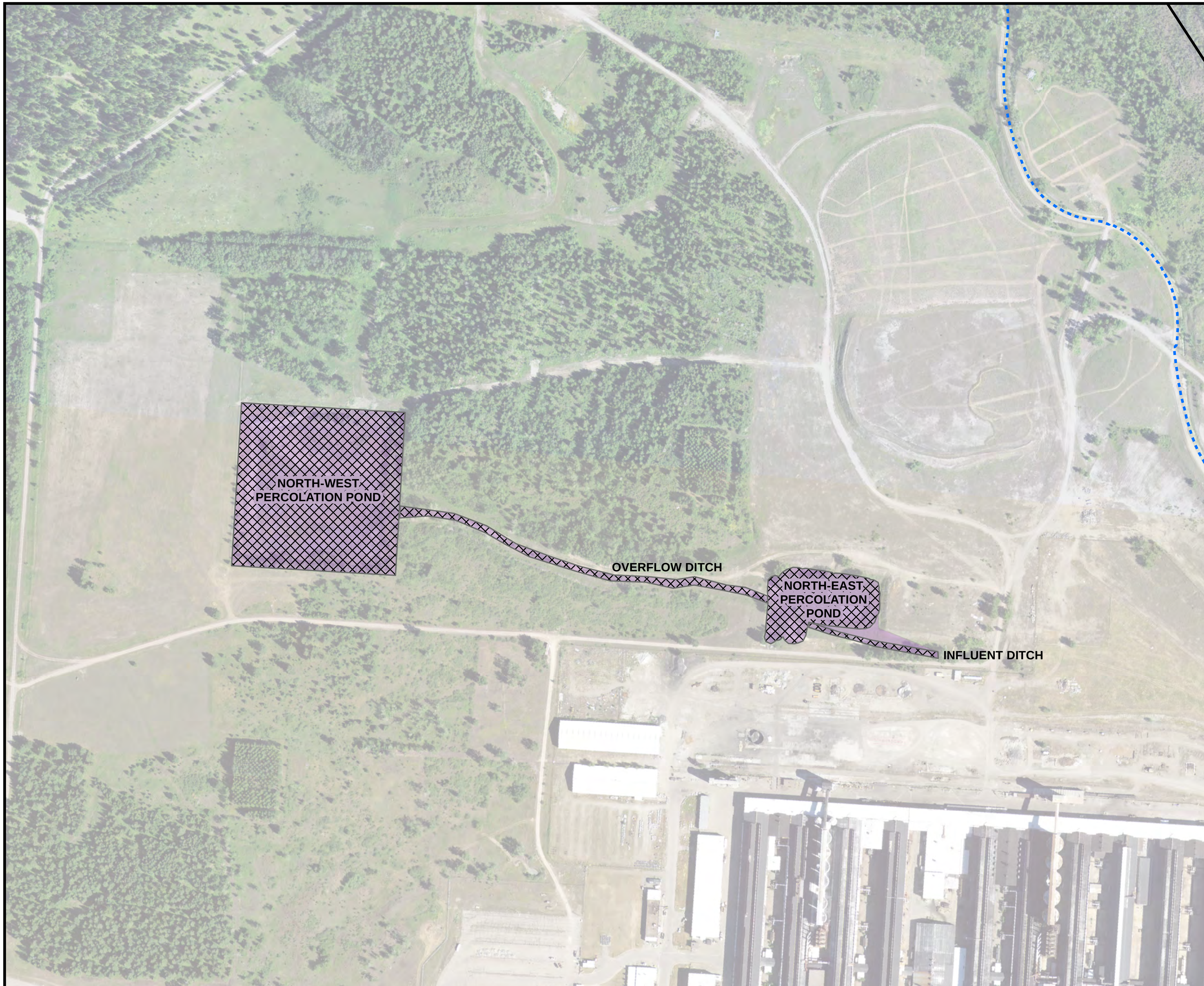

LEGEND

NORTH PERCOLATION POND DECISION UNIT

SITE FEATURES WITHIN NPP DU

AREA OF PROPOSED EXCAVATION

NOTES

1. AREAS OF NPP DU SITE FEATURES:
   NORTH-EAST PERCOLATION POND – 2.0 ACRES
   NORTH-WEST PERCOLATION POND – 8.0 ACRES
   INFLUENT DITCH – 0.2 ACRES
   OVERFLOW DITCH – 0.4 ACRES
2. ESTIMATED RANGE OF VOLUMES FOR EXCAVATION BY NPP DU SITE FEATURE:
   NORTH-EAST PERCOLATION POND – 4,850 TO 12,900 CY
   NORTH-WEST PERCOLATION POND – 4,850 TO 19,400 CY
   INFLUENT DITCH – 160 TO 960 CY
   OVERFLOW DITCH – 320 TO 1,920 CY

Title:

NPP DECISION UNIT ALTERNATIVE NPP-4 : EXCAVATION WITH ONSITE CONSOLIDATION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/29/20	APPENDIX	
Prepared by: M.S.R.	Scale: AS SHOWN		H4
Project Mgr: C.S.	Project: 2476.0001Y010		
File: 2476.0001Y271.H4.mxd			

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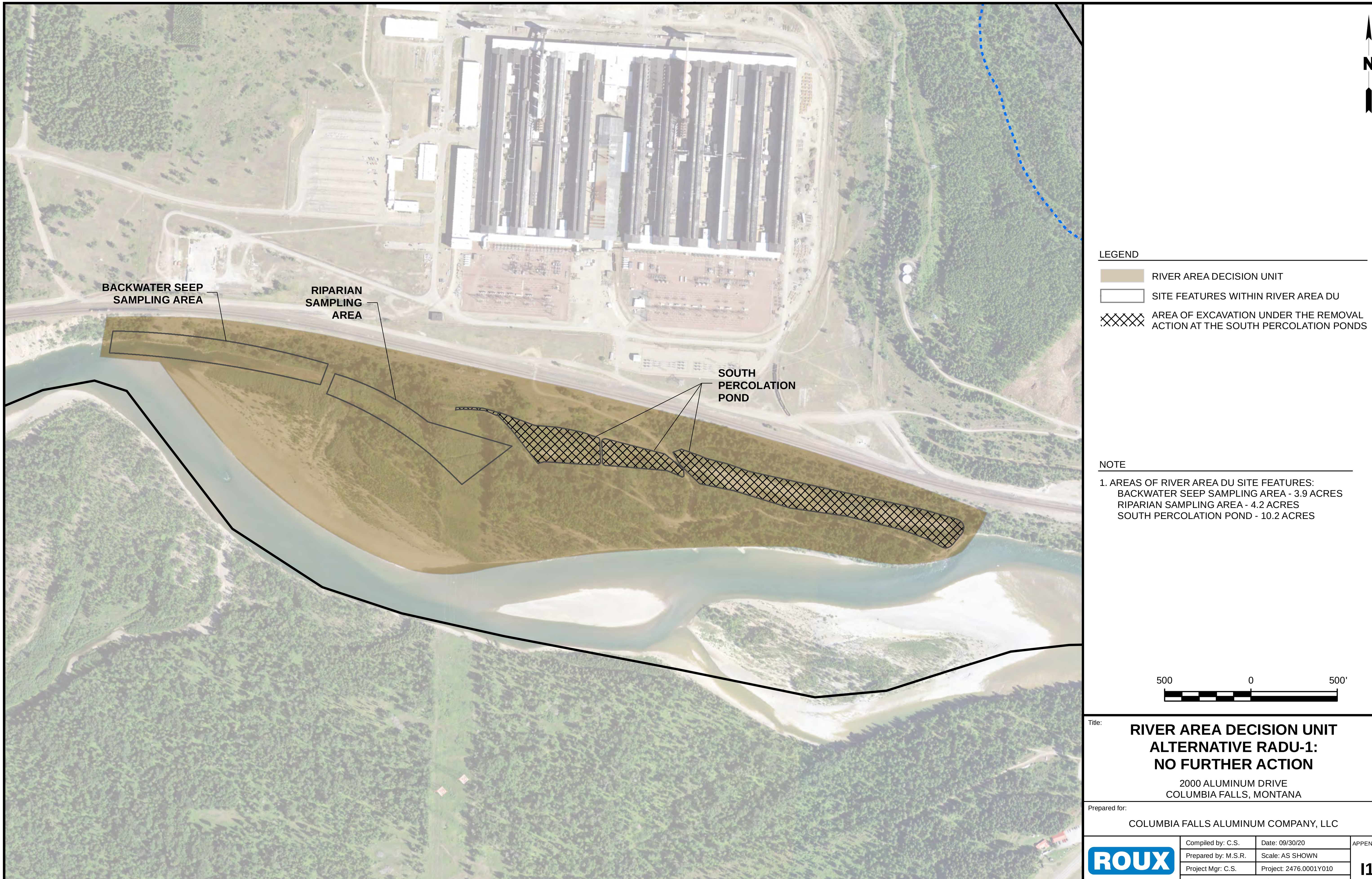
APPENDIX I

Figures Depicting River Area DU Alternatives

I1. River Area Decision Unit Alternative RADU-1: No Further Action

I2. River Area Decision Unit Alternative RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater



Title:

RIVER AREA DECISION UNIT
ALTERNATIVE RADU-1:
NO FURTHER ACTION

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/30/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	I1
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.I1.mxd		

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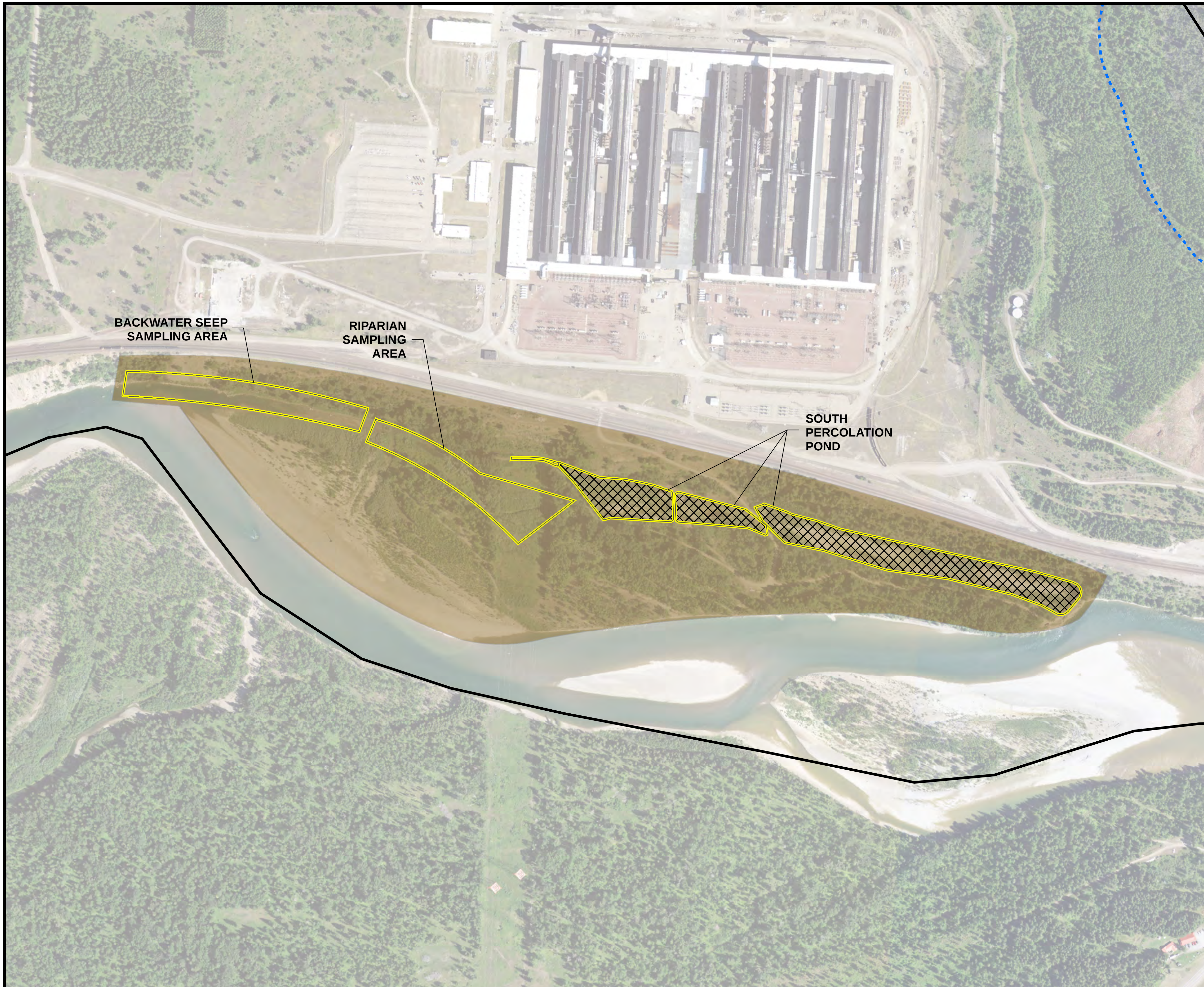

LEGEND

- RIVER AREA DECISION UNIT
- SITE FEATURES WITHIN RIVER AREA DU
- AREA OF EXCAVATION UNDER THE REMOVAL ACTION AT THE SOUTH PERCOLATION PONDS
- PROPOSED AREA OF LONG-TERM MONITORING OF SURFACE WATER AND SEDIMENT POREWATER

NOTES

1. AREAS OF RIVER AREA DU SITE FEATURES:
   BACKWATER SEEP SAMPLING AREA - 3.9 ACRES
   RIPARIAN SAMPLING AREA - 4.2 ACRES
   SOUTH PERCOLATION POND - 10.2 ACRES
2. EXISTING FLATHEAD RIVER SURFACE WATER STATIONS CFSWP-002 AND CFSWP-035 (LOCATED DOWNGRADIENT AND WEST OF THE BACKWATER SEEP SAMPLING AREA) MAY ALSO BE SAMPLED UNDER THIS ALTERNATIVE.

Title:

RIVER AREA DECISION UNIT ALTERNATIVE RADU-2: LONG-TERM MONITORING OF SURFACE WATER AND SEDIMENT POREWATER

2000 ALUMINUM DRIVE
COLUMBIA FALLS, MONTANA

Prepared for:

COLUMBIA FALLS ALUMINUM COMPANY, LLC

ROUX

Compiled by: C.S.	Date: 09/30/20	APPENDIX
Prepared by: M.S.R.	Scale: AS SHOWN	I2
Project Mgr: C.S.	Project: 2476.0001Y010	
File: 2476.0001Y271.I2.mxd		

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APPENDIX J

Feasibility Study Cost Estimates for Remedial Action Alternatives

Feasibility Study Cost Estimates for Remedial Action Alternatives

This appendix to the Feasibility Study documents the procedures, methods, and assumptions used in preparation of the cost estimates for each alternative under evaluation. The cost estimates have been prepared with the consideration of industry standard cost-estimating references, costs of similar projects, and quotes from contractors and equipment/process vendors. Assumptions used in developing cost estimates are provided with each individual remedial alternative cost table. The cost estimates are considered order-of-magnitude estimates with an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.

The cost estimates presented herein have been prepared for guidance in project evaluation and implementation and are based on information available at the time this document was prepared. The final project cost and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual Site conditions, final project scope, final design configuration, implementation schedule, and other variable factors. It is expected that the final project costs will vary from the estimated cost presented herein.

Cost Estimating Approach

Cost estimates are provided in this appendix for all Feasibility Study remedial alternatives undergoing detailed evaluation. Approximate cost estimates were developed for each remedial alternative based on the detailed descriptions and conceptual designs of the remedial alternatives. The descriptions of each alternative are presented in Section 5 of the Feasibility Study Report. Typically, the cost estimates presented in this FS are based on one or more of the following: quotes provided by vendors/contractors, cost data from the current operations at this Site or other similar sites, unit costs derived from remediation cost handbooks, and professional judgement and experience. Basis and assumptions for individual line items are provided in the notes attached to each cost estimate table. The cost estimates incorporate estimates of direct and indirect capital costs; operations, maintenance, and monitoring (OM&M) costs, and contingencies as appropriate. The cost estimates provide present worth cost in 2020 dollars. The cost spreadsheets in this FS utilize a template from the USEPA cost guidance document.

The estimated costs presented in this FS are contingent upon a large number of assumptions due to the uncertainties that exist for the Site. Examples of significant uncertainties include the lateral and vertical extent of the COC impacted areas at the Site, the extraction rates of groundwater, the estimated timeframes to achieve remedial objectives, etc. Fixed percentages were applied to capital costs to account for scope and bid contingency ranging from 20% to 30% for all alternatives. Additionally, a 5% to 10% contingency for indirect annual OM&M costs was typically applied to the alternatives. The percentages selected for contingency are consistent with the USEPA cost guidance document (USEPA, 2000).

Present worth costs of the remedial alternatives are estimated using a net discount rate of 7% over a timeframe of 30 years. Present worth costs were estimated using a net discount rate of 7% consistent with USEPA's policy stated in the NCP and Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 as summarized in USEPA guidance (USEPA, 2000).

Cost Estimate Tables

For each DU, the cost estimates sub-appendix includes a summary table which lists each remedial alternative evaluated for the DU and its capital cost, total OM&M (PV), and total cost (PV). The sub-appendix also includes detailed cost estimates for each remedial alternative. Each detailed cost estimate is comprised of a table followed by notes stating the basis of costs and accompanying assumptions.

The detailed cost estimate tables are generally divided into the following sections: a description of the alternative, capital costs, OM&M costs, and present worth analysis (i.e., net present value). Several alternatives within a DU are comprised of components also included in another alternative; costs for these common components are detailed in the cost estimate table for the first alternative, then summarized in the following cost tables in a single line item. The table/notes containing the detailed costs for these common components are referenced as appropriate.

Capital Costs

The capital cost section is divided into direct capital costs and indirect capital costs. Under direct capital costs, typical initial sections or line items include mobilization/demobilization/general conditions, erosion and sediment control, construction surveying, or other preliminary tasks. For mobilization/demobilization/general conditions, common lump sum estimated costs were used for most alternatives, which was based on the total capital cost (i.e., the size of the project). Costs for some preliminary tasks are based on lump sum estimates from experience with other projects of similar scope and/or estimates obtained from contractors/vendors.

Capital costs for key remedial components within each remedial alternative were detailed and subtotaled in separate sections, such as excavation, capping, or installation of slurry walls, permeable reactive barriers (PRB), or extraction wells. Each line item within these subsections utilize unit costs obtained from contractors, vendors, handbooks, or previous experience at the Site. Comments are provided within the notes for each cost estimate with assumptions of availability of onsite material versus import of offsite material. Unit costs obtained from contractors were typically an approximate range of unit pricing. In general, an average of the range of unit price was used. These unit prices were obtained between June 2020 and September 2020.

Ex situ groundwater treatment system (GWTS) capital costs for treating cyanide and fluoride in groundwater were based on recent quotes provided by vendors that specialize in groundwater treatment. Supplemental estimates for specific items were made using costing software. GWTS costs were based on a design flowrate derived from groundwater analytical capture calculations presented in Appendix A. The estimated flowrates for the remedial alternatives are provided in Tables 1 through 3 in Appendix A.

Indirect capital costs provided in the cost estimate tables include scope/bid contingency, project management, remedial design, construction management, and administrative costs. These costs provide an estimate for remedial design/engineering, overall management of remedial project components, USEPA oversight and regulatory coordination, community outreach, and more. These costs are based on a fixed percent of the total direct capital costs for each alternative. The fixed percentages applied to each alternative typically range from 5% to 15% (with a few exceptions for extreme high cost alternatives) and were based on Exhibit 5-8 from the 2000 USEPA guidance document; the selected percentage was based on the total capital cost of the project. Administrative costs were estimated as annual lump sums based on professional judgement.

Operations, Maintenance, and Monitoring Cost

Operations Maintenance, and Monitoring (OM&M) costs include annual costs for inspection, maintenance, operations, monitoring, and periodic repair of constructed remedies. Periodic costs were averaged and built into the annual estimated cost of OM&M. The costs are presented annually and are based on CFAC/Roux's prior experience, vendor quotes, and professional judgement with maintaining landfill caps, operating and maintaining groundwater treatment systems, repairing site facilities, or other remedial components. Annual OM&M costs for alternatives that contain a long-term treatment component (i.e., groundwater treatment system or leachate collection system) include costs for technical support, which were estimated as 5% to 10% of the annual OM&M cost.

Present Worth

Present worth cost section estimates the 30-year cost estimates for the 7% net discount rates. The present worth of this representative annual O&M cost, including the capital cost, is the total present worth cost.

References

FRTR, 2018. Federal Remediation Technologies Roundtable (FRTR), December 2018.

USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, October 1988.

USEPA and US Army Corp of Engineers, 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, July 2000.

Cost Estimates for Landfills DU1 and Groundwater DU Joint Alternatives

Feasibility Study Cost Estimate
Landfills DU1 / Groundwater DU Alternatives
Summary of Estimated Costs

Alternative	Capital Cost	Total OM&M (PV)	Total Cost (PV)
LDU1/GW-1: No Action	$ -	$ 769,050	$ 769,050
LDU1/GW-2: Containment via Capping and MNA	$ 11,478,683	$ 2,703,930	$ 14,182,613
LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall	$ 25,012,360	$ 2,703,930	$ 27,716,290
LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB	$ 75,093,899	$ 2,828,020	$ 77,921,920
LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction	$ 36,981,109	$ 25,277,465	$ 62,258,574
LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall	$ 38,999,937	$ 6,642,560	$ 45,642,497
LDU1/GW-4B: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient PRB	$ 89,081,476	$ 6,642,560	$ 95,724,036
LDU1/GW-4C: Containment via Capping, Fully-Encompassing Slurry Wall, and Downgradient Extraction	$ 49,025,609	$ 25,277,465	$ 74,303,074
LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area	$ 38,582,066	$ 28,685,981	$ 67,268,047
LDU1/GW-5B: Containment via Capping and Downgradient Extraction	$ 23,447,432	$ 25,277,465	$ 48,724,897
LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and Downgradient	$ 47,986,164	$ 50,497,352	$ 98,483,516
LDU1/GW-6: Excavation with Onsite Consolidation	$ 157,765,708	$ 7,825,141	$ 165,590,849

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Feasibility Study Cost Estimate
Alternative LDU1/GW-1: No Action

Description of Alternative:

- Maintenance of the existing caps on the West Landfill, Wet Scrubber Sludge Pond, and Center Landfill;
- Maintenance of the existing fence preventing access to these waste management units; and
- No additional actions.

This alternative is described in Section 5.1.1.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs (Capping Maintenance)				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 10,000	$ 10,000
Contingency	10%	% of Annual Costs		$ 4,500
			Subtotal of Direct OM&M Costs	**$ 49,500**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	5%	% of Direct OM&M Costs		$ 2,475
			Subtotal of Indirect OM&M Costs	**$ 12,475**
			Total OM&M Costs	**$ 61,975**
		Estimated Total 30-year OM&M Costs	**30**	**$ 1,859,250**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 769,050**
			TOTAL PRESENT VALUE COSTS	**$ 769,050**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Direct OM&M Costs

Annual Costs (Capping Maintenance)

- Cap Maintenance
  - Includes mowing, weed spraying, maintenance of stormwater conveyance systems.
  - Based on previous Site experience and professional judgement.
  - Includes maintenance of caps at West Landfill (7.8 acres), Wet Scrubber Sludge Pond (10.8 acres), and Center Landfill (1.8 acres).
- Site Maintenance
  - Repair of landfill perimeter fencing and roadways.
  - Based on previous Site experience and professional judgement.
- Reporting
  - Based on professional judgement.

Feasibility Study Cost Estimate
Alternative LDU1/GW-2: Containment via Capping and Monitored Natural Attenuation

Description of Alternative:
- Containment of source area waste management units via capping;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.2.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Mobilization/Demobilization/General Conditions	1	LS	$ 250,000	$ 250,000
Erosion and Sediment Control	1	LS	$ 30,000	$ 30,000
Construction Surveying	1	LS	$ 50,000	$ 50,000
Wet Scrubber Sludge Pond				
Settlement Study	1	LS	$ 100,000	$ 100,000
Pre-Load Backfill and Compaction of Onsite Soil	39,450	CY	$ 16	$ 631,200
Pre-Load Relocation of Onsite Soil	39,450	CY	$ 16	$ 631,200
Physical Solidification of Low-Strength Material	87,000	CY	$ 35	$ 3,045,000
Placement of Sand Layer (6" Layer)	8,900	CY	$ 35	$ 311,500
Surface Grading	54,000	SY	$ 2	$ 108,000
Installation of Geomembrane Layer (40 mil)	55,000	SY	$ 4.10	$ 225,500
Installation of Geocomposite Drainage Layer	55,000	SY	$ 6.35	$ 349,250
Backfill and Compaction of Imported Soil (18" layer)	27,000	CY	$ 27	$ 729,000
Backfill with Top Soil (6" layer)	8,900	CY	$ 35	$ 311,500
Installation of Stormwater Conveyance Swales/Ditches	1	LS	$ 300,000	$ 300,000
Perimeter Soil Berm	1,500	CY	$ 32	$ 48,000
Seeding/Vegetation	10.8	ACRES	$ 1,000	$ 10,800
Center Landfill				
Excavation of Existing Soil Cap to Stockpile (12" min)	2,900	CY	$ 9	$ 26,100
Surface Grading	8,700	SY	$ 2	$ 17,400
Installation of Geomembrane Layer	9,500	SY	$ 4.10	$ 38,950
Backfill and Compaction with Onsite Soil (12" layer)	3,100	CY	$ 8	$ 24,800
Backfill and Compaction with Imported Soil (6" layer)	1,550	CY	$ 27	$ 41,850
Backfill and Compaction with Top Soil (6" layer)	1,550	CY	$ 35	$ 54,250
Installation of Stormwater Conveyance Swales/Ditches	1	LS	$ 150,000	$ 150,000
Perimeter Soil Berm	600	CY	$ 32	$ 19,200
Seeding/Vegetation	1.8	ACRE	$ 1,000	$ 1,800
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Establish Groundwater Use Restrictions	1	LS	$ 20,000	$ 20,000
Establish ICs for Landfills and Deed Notices	1	LS	$ 20,000	$ 20,000
Fencing Around Perimeter of Landfills	5,500	LF	$ 8	$ 41,250
			Subtotal ICs and ECs Costs	**$ 81,250**
			Subtotal of Direct Capital Costs	**$ 7,565,550**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Project Management	5%	% of Total Direct Capital Costs		$ 490,542
Remedial Design	6%	% of Total Direct Capital Costs		$ 588,650
Construction Management	6%	% of Total Direct Capital Costs		$ 588,650
			Subtotal of Indirect Capital Costs	**$ 3,913,133**
			Total Capital Costs	**$ 11,478,683**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs (Capping Maintenance)				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 45,000	$ 45,000
Contingency	10%	% of Annual Costs		$ 18,000
			Subtotal of Direct OM&M Costs	**$ 198,000**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	5%	% of Direct OM&M Costs		$ 9,900
			Subtotal of Indirect OM&M Costs	**$ 19,900**
			Total OM&M Costs	**$ 217,900**
		Estimated Total 30-year OM&M Costs	**30**	**$ 6,537,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 2,703,930**
			TOTAL PRESENT VALUE COSTS	**$ 14,182,613**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Direct Capital Costs

Capping of Landfills

- Mobilization/Demobilization/General Conditions
  - Includes Site preparation activities such as mobilization/demobilization of construction equipment, construction of temporary facilities, installation of temporary sediment/erosion controls, etc.
  - Includes General requirements such as permitting, coordination with regulatory agencies, insurance requirements, etc.
  - Based on capital cost of job, see Introduction, Capital Costs section.
- Erosion and Sediment Control
  - Based on professional judgement.
- Construction Surveying
  - Drone surveying of landfills throughout various phases of the construction process.
  - Based on previous experience on similar projects.

<u>Wet Scrubber Sludge Pond</u>

- Settlement Study
  - Geotechnical investigation of Wet Scrubber Sludge Pond to support remedial design and determine pre-load volume.
  - Based on professional judgement.
- Pre-Load Backfill and Compaction of Onsite Soil
  - Placement of pre-load material across 50% of the landfill footprint.
  - Assumes pre-load backfill volume is equivalent to volume required for a 3% slope. Based on preliminary cap design for the Wet Scrubber Sludge Pond.
  - Assumes pre-load material will be available onsite; unit cost for backfill and compaction is based on previous experience on similar projects.
- Pre-Load Relocation of Onsite Soil
  - Relocation of pre-load material to the remaining 50% of the landfill footprint.
  - Unit cost based on previous experience on similar projects.
- Physical Solidification of Low-Strength Material Wet Scrubber Sludge Pond
  - To improve load bearing capacity.
  - Assumes physical solidification of Wet Scrubber Sludge Pond by mixing the top 5 feet of existing material with amendments (e.g., cement kiln dust, lime dust, etc.) across the landfill footprint.
  - Unit cost based on quotes from contractors and previous experience on similar projects.
- Placement of Sand Layer (6” Layer)
  - Includes cost for import and placement of a 6-inch thick sand as a cushion layer atop onsite borrow material, prior to placement of geomembrane layer.
  - Material unit cost based on quote from local vendors.
  - Unit cost for backfill and compaction is based on previous experience on similar projects.
  - Assumes pre-load material can be used as backfill, and additional volume required for a 3% slope based on preliminary cap design for Wet Scrubber Sludge Pond would be met by this sand layer.
- Surface Grading
  - Assumes grading of the existing Wet Scrubber Sludge Pond surface will be required prior to cap placement.

- Includes preparation of anchor trench, 5 feet in width around the entire perimeter of the landfill.
- Unit cost based on previous experience on similar projects.

- Installation of Geomembrane Layer
  - Includes cost for material and installation of a 40-mil low permeability high density polyethylene (HDPE) geomembrane.
  - Geomembrane installed across entire landfill footprint, assuming a 2% increase in surface area to account for overlap of sheets and tied into anchor trench.
  - Material unit cost based on average of quotes from vendors.
  - Installation unit cost based on previous experience with similar projects.
- Installation of Geocomposite Drainage Layer
  - Geocomposite comprised of non-woven polypropylene geotextile fabric bonded to a geonet made from HDPE.
  - Geomembrane installed across entire landfill footprint, assuming a 2% increase in surface area to account for overlap of sheets and tied into anchor trench.
  - Material unit cost based on average of quotes from vendors.
  - Installation unit cost based on previous experience with similar projects.
- Backfill and Compaction of Imported Soil
  - Assumes 18 inches of soil barrier layer across the entire footprint.
  - Unit cost includes both material and installation cost.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the entire Wet Scrubber Sludge Pond to promote vegetation.
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Installation of Stormwater Conveyance Swales/Ditches
  - Includes installation of surface water drainage design measures, includes swales/ditches, to direct stormwater runoff away from landfill and provide erosion control.
  - Unit cost based on previous experience with similar projects.
- Perimeter Soil Berm
  - Assumes perimeter soil berm approximately 5 feet wide and 5 feet in height around entire landfill footprint.
  - Unit cost includes both cost for material and installation.
  - Material unit cost is equivalent to imported soil unit cost described above.
  - Installation unit cost based on previous experience with similar projects.
- Seeding/Vegetation
  - Assumes seeding for vegetation across entire Wet Scrubber Sludge Pond.
  - Unit cost based on based on previous experience with similar projects.

Center Landfill

- Excavation of Existing Soil Cap to Stockpile
  - Cost to excavate 12 inches of the existing till soil cap across 1.8 acres.
  - Excavated material will be stockpiled for reuse above Geomembrane.
- Installation of Geomembrane Layer
  - Assumptions for Center Landfill mirror those for the Wet Scrubber Sludge Pond.
- Backfill and Compaction with Onsite Soil
  - Cost to reuse excavated till as soil barrier layer above Geomembrane.
  - Assumes a 12 inches of soil cap across the entire 1.8 acres.
  - Unit cost is for backfill only based on previous experience with similar projects.
- Backfill and Compaction of Imported Soil
  - 6 inches of soil barrier layer across the entire footprint.
  - Assumptions for Center Landfill mirror those for the Wet Scrubber Sludge Pond.
- Surface Grading; Backfill and Compaction of Topsoil (6" Layer); Installation of Stormwater Conveyance Swales/Ditches; Perimeter Soil Berm Seeding/Vegetation
  - Assumptions for Center Landfill mirror those for the Wet Scrubber Sludge Pond.

ICs and ECs

- Establish Groundwater Use Restrictions
  - Based on previous experience with similar projects.
- Establish ICs for Landfills and Deed Notices
  - Institutional Controls (ICs) include prohibiting residential use as well as any activities that can comprise the integrity of the cap.
- Fencing Around Perimeter of Landfills
  - Fencing around perimeter of landfills as an engineering control (EC).
  - Based on RS Means software.

Direct OM&M Costs

Annual Costs

- Cap Maintenance; Site Maintenance; and Reporting
  - See Alternative LDU1/GW-1 Cost Estimate Notes.
- Groundwater Monitoring Natural Attenuation (MNA)
  - Based on previous Site-wide groundwater sampling events.
  - Sample a subset of monitoring wells that currently exist at the Site.
  - Analyze groundwater samples for target analyte list (TAL) metals (total and dissolved), total cyanide, dissolved total cyanide, fluoride, alkalinity, hardness, total dissolved solids (TDS), total suspended solids (TSS), nitrogen (ammonia), nitrogen (nitrate-nitrite), orthophosphate, total sulfide, total organic carbon (TOC), and dissolved organic carbon (DOC).
  - Includes costs for quality assurance/quality control (QA/QC) samples and data validation.

Feasibility Study Cost Estimate
Alternative LDU1/GW-3A: Containment via Capping and Upgradient Slurry Wall

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.3.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Upgradient Slurry Wall (1,950 ft. x 100-125 ft. x 2-3 ft.)				
Pre Design Investigation	1	LS	$ 315,000	$ 315,000
Mobilization/Demobilization/General Conditions	1	LS	$ 550,000	$ 550,000
Clearing and Grubbing	1	ACRE	$ 4,600	$ 4,600
Installation of Slurry Wall	1	LS	$ 8,000,000	$ 8,000,000
Disposal of Excess Soil at Onsite Repository	2,031	CY	$ 9	$ 18,281
Surveying	1	LS	$ 10,000	$ 10,000
			Subtotal Construction of Upgradient Slurry Wall Costs	**$ 8,897,881**
			Subtotal of Direct Capital Costs	**$ 16,463,431**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Upgradient Slurry Wall)	30%	% of Respective Capital Costs		$ 2,669,364
Project Management	5%	% of Total Direct Capital Costs		$ 1,068,904
Remedial Design	6%	% of Total Direct Capital Costs		$ 1,282,685
Construction Management	6%	% of Total Direct Capital Costs		$ 1,282,685
			Subtotal of Indirect Capital Costs	**$ 8,548,929**
			Total Capital Costs	**$ 25,012,360**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 45,000	$ 45,000
Contingency	10%	% of Annual Costs		$ 18,000
			Subtotal of Direct OM&M Costs	**$ 198,000**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	5%	% of Direct OM&M Costs		$ 9,900
			Subtotal of Indirect OM&M Costs	**$ 19,900**
			Total OM&M Costs	**$ 217,900**
		Estimated Total 30-year OM&M Costs	**30**	**$ 6,537,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 2,703,930**
			TOTAL PRESENT VALUE COSTS	**$ 27,716,290**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-3A Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Upgradient Slurry Wall

- Pre-Design Investigation
  - Based upon slurry wall contractor recommendations.
  - Assumes soil borings advanced along the proposed slurry wall spaced 50 feet apart (total of 40 borings) to target depth of 125 ft.
  - Assumes 1 ½ borings completed per day (27 days).
  - Assume sonic or hollow stem auger (HAS) rig: $50 per foot (5000 ft) plus, mobilization/demobilization, and geologist oversight
  - Assumes two test pits for soil test sampling.
  - Slurry wall compatibility/soil testing based on previous experience with similar projects.
- Mobilization/Demobilization/General Conditions
  - Based on preliminary cost estimate from subcontractor.
  - Estimated timeframe of one to two weeks.
- Clearing and Grubbing
  - Unit cost from RS Means software
  - Assumes 1 acre will need to be cleared.
- Installation of Slurry Wall
  - Soil bentonite slurry wall 1950 feet long by 2 to 3 feet wide by 100 to 125 feet deep (see Appendix Figure E3).
  - Installation method is trenching, mixing, and filling.
  - Assumes construction duration will take 80 to 100 days.
  - Based on quote from subcontractor.
- Disposal of Excess Soil at Onsite Repository
  - Assumes that 90% of excavated soil can be reused for soil/bentonite mixture and remaining 10% of excavated soil will be disposed at an onsite repository.
  - Unit cost for transporting and placing of excess excavated soil at onsite repository based on previous experience with similar projects.
- Surveying
  - Drone surveying of slurry wall location at surface.
  - Based on previous experience with similar projects.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW-3B: Containment via Capping and Upgradient Slurry Wall with Downgradient PRB

Description of Alternative:
- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.4.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Upgradient Slurry Wall (1,950 ft. x 100-125 ft. x 2-3 ft.)				
Tasks from LDU1/GW-3A	1	LS	$ 8,897,881	$ 8,897,881
			Subtotal Construction of Upgradient Slurry Wall Costs	**$ 8,897,881**
Installation of PRB (3,785 ft. x 130 ft. x 2-3 ft.)				
Pre-Design Investigation	1	LS	$ 525,000	$ 525,000
Mobilization/Demobilization/General Conditions	1	LS	$ 750,000	$ 750,000
Installation of PRB	1	LS	$ 31,000,000	$ 31,000,000
Disposal of Excess Soil at Onsite Repository	34,635	CY	$ 9	$ 311,719
Surveying	1	LS	$ 20,000	$ 20,000
Monitoring Well Installation	10	ea	$ 32,000	$ 320,000
			Subtotal Installation of PRB Costs	**$ 32,926,719**
			Subtotal of Direct Capital Costs	**$ 49,390,150**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Upgradient Slurry Wall)	30%	% of Respective Capital Costs		$ 2,669,364
Scope/Bid Contingency (PRB)	30%	% of Respective Capital Costs		$ 9,878,016
Project Management	5%	% of Total Direct Capital Costs		$ 3,209,141
Remedial Design	6%	% of Total Direct Capital Costs		$ 3,850,969
Construction Management	6%	% of Total Direct Capital Costs		$ 3,850,969
			Subtotal of Indirect Capital Costs	**$ 25,703,749**
			Total Capital Costs	**$ 75,093,899**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 45,000	$ 45,000
Contingency	10%	% of Annual Costs		$ 18,000
			Subtotal of Direct OM&M Costs	**$ 198,000**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 20,000	$ 20,000
Contingency	5%	% of Direct OM&M Costs		$ 9,900
			Subtotal of Indirect OM&M Costs	**$ 29,900**
			Total OM&M Costs	**$ 227,900**
		Estimated Total 30-year OM&M Costs	**30**	**$ 6,837,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 2,828,020**
			TOTAL PRESENT VALUE COSTS	**$ 77,921,920**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-3B Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Upgradient Slurry Wall

- See Alternative LDU1/GW-3A Cost Estimate Notes.

Installation of Downgradient PRB

- Pre-Design Investigation
  - Treatability study for PRB along portion of the planned alignment.
  - Assumes soil borings advanced along the proposed PRB spaced 50 feet apart (total of 67 borings) to target depth of 130 ft.
  - Assumes 1 ½ borings completed per day.
  - Assume sonic or hollow stem auger (HAS) rig: $50 per foot (5000 ft) plus, mobilization/demobilization, and geologist oversight.
  - Assumes two test pits for soil test sampling.
  - PRB compatibility testing based on previous experience with similar projects.
- Mobilization/Demobilization/General Conditions
  - Based on preliminary cost estimate from subcontractor.
- Installation of PRB
  - To be installed north of Burlington Northern Railroad for treatment of cyanide (see Appendix Figure E4).
  - Based on subcontractor preliminary lump sum cost estimate, assumes design life of 30 years.
  - Assumes PRB trenching/filling dimensions of 3,785 feet by 130 feet by 2 to 3 feet.
  - Assumes PRB substrate vertically spans from 60 ft-bls through 130 ft-bls.
  - Assumes the reactive media mixture would range from 20% zero valent iron (ZVI) and 80% sand mixture by volume.
  - Assumes dewatering of trench will not be required.
  - Assumes construction duration will take 200 days.
- Disposal of Excess Soil at Onsite Repository
  - Assumes 100% of excavated soil to be disposed of at an onsite repository.
  - Unit cost for transporting and placing of excavated soil at onsite repository based on previous Site experience.
- Surveying
  - Based on previous experience with similar projects.
- Monitoring Well Installation
  - Based on quote from subcontractor.
  - Assumes five monitoring well pairs (4-inch PVC) monitoring wells installed around PRB to 130 feet.
  - Includes well development and surface restoration.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-2 Cost Estimate Notes, PRB related monitoring will be included within the Groundwater MNA.

Feasibility Study Cost Estimate
Alternative LDU1/GW-3C: Containment via Capping and Upgradient Slurry Wall with Downgradient Extraction

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall immediately upgradient of the West Landfill;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), ex situ treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.5.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Upgradient Slurry Wall (1,950 ft. x 100-125 ft. x 2-3 ft.)				
Tasks from LDU1/GW-3A	1	LS	$ 8,897,881	$ 8,897,881
			Subtotal Construction of Upgradient Slurry Wall Costs	**$ 8,897,881**
Installation of Downgradient Extraction Wells				
Pre-Design Investigation	1	LS	$ 125,000	$ 125,000
Mobilization/Demobilization/General Conditions	1	LS	$ 40,000	$ 40,000
Installation of Extraction Wells	10	ea	$ 44,000	$ 440,000
Installation of Pumps and Electrical	10	ea	$ 12,000	$ 120,000
			Subtotal Installation of Downgradient Extraction Wells Costs	**$ 725,000**
Installation of *Ex Situ* Groundwater Treatment System (500 GPM)				
Bench-Scale Treatability Study	1	LS	$ 100,000	$ 100,000
Mobilization/Demobilization/General Conditions	1	LS	$ 250,000	$ 250,000
Site Preparation	1	LS	$ 50,000	$ 50,000
Piping (3") from Extraction Wells to Central Trench	3,300	LF	$ 25	$ 82,500
Piping (8") from Central Trench to GWTS	2,100	LF	$ 40	$ 84,000
Treatment Plant Building (70' x 70')	1	LS	$ 540,000	$ 540,000
Treament System Equipment	1	LS	$ 6,000,000	$ 6,000,000
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 7,106,500**
Installation of Effluent Discharge Piping				
Mobilization/Demobilization/General Conditions	1	LS	$ 20,000	$ 20,000
Piping from GWTS to Discharge	500	LF	$ 35	$ 17,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
			Subtotal of Direct Capital Costs	**$ 24,332,431**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Upgradient Slurry Wall)	30%	% of Respective Capital Costs		$ 2,669,364
Scope/Bid Contingency (Downgradient Extraction Wells)	30%	% of Respective Capital Costs		$ 217,500
Scope/Bid Contingency (Groundwater Treatment System)	30%	% of Respective Capital Costs		$ 2,131,950
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Project Management	5%	% of Total Direct Capital Costs		$ 1,580,389
Remedial Design	6%	% of Total Direct Capital Costs		$ 1,896,467
Construction Management	6%	% of Total Direct Capital Costs		$ 1,896,467
			Subtotal of Indirect Capital Costs	**$ 12,648,678**
			Total Capital Costs	**$ 36,981,109**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 60,000	$ 60,000
GWTS Operational Costs	263	MILLION GALLON	$ 3,500	$ 920,000
GWTS Maintenance and Repair Costs	1	LS	$ 120,000	$ 120,000
GWTS Power and Utilities	1	LS	$ 30,000	$ 30,000
GWTS Operator and Labor	260	Man-Days	$ 1,200	$ 312,000
Technical Support	10%	% of Annual Costs		$ 157,700
Contingency	10%	% of Annual Costs		$ 157,700
			Subtotal of Direct OM&M Costs	**$ 1,892,400**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 50,000	$ 50,000
Contingency	5%	% of Direct OM&M Costs		$ 94,620
			Subtotal of Indirect OM&M Costs	**$ 144,620**
			Total OM&M Costs	**$ 2,037,020**
		Estimated Total 30-year OM&M Costs	**30**	**$ 61,110,600**
			TOTAL PRESENT VALUE COSTS	**$ 62,258,574**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-3C Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Upgradient Slurry Wall

- See Alternative LDU1/GW-3A Cost Estimate Notes.

Installation of Downgradient Extraction Wells

- Mobilization/Demobilization/General Conditions
  - Based on previous quotes for onsite drilling.
- Pre-Design Investigation
  - Aquifer testing, 48 to 72-hour pump test at two extraction wells.
  - Assumes two-person field crew for 4 days in field.
  - Assumes portable treatment system to pre-treat extracted groundwater for discharge to aquifer.
- Installation of Extraction Wells
  - Based on quote from subcontractor.
  - Assumes installation of ten 6-inch extraction wells along railroad to 125 ft-bls (see Appendix Figure E5).
  - Includes discharge piping to surface grade (assumes additional 15 ft required)and a pitless adapter for frost protection for each extraction well.
  - Includes well development and surface restoration.
- Installation of Pumps and Electrical
  - Assumes ten submersible pumps capable of 75 gallons per minute (gpm).
  - Includes wiring for all pumps.

Installation of *Ex Situ* Groundwater Treatment System (500 GPM)

- Bench-Scale Treatability Study
  - Collection and analysis of groundwater samples from extraction wells to represent influent to Groundwater Treatment System (GWTS).
  - Lab-scale treatment of groundwater samples using proposed treatment methods for GWTS to evaluate removal efficiency.
  - Performing various trials to aid in design of GWTS.
  - Based on professional judgement.
- Mobilization/Demobilization/General Conditions
  - Based on professional judgement and previous experience with similar projects.
- Site Preparation
  - Based on professional judgement and previous experience with similar projects.
- Piping (3") from Extraction Wells to Central Trench; Piping (8") from Central Trench to Groundwater Treatment System (GWTS)
  - Unit cost per linear foot includes trenching, backfill, and compaction.
  - Assumes 3" pipes from ten extraction wells to a central trench and 8" piping from central trench to GWTS. The proposed location of the GTWS is shown on Appendix Figure E5.

- Pipe sizing based on flowrates.
- Treatment Plant Building (70' x 70')
  - Heated, one-story metal frame building, slab on grade foundation.
  - Based on cost estimating software.
- Treatment Equipment:
  - Equalization Tank, Mixing Tanks, Clarifier, Filters, Sludge Management System, Ion Exchange Unit.
  - Average of vendor quote and cost estimating software.

Installation of Effluent Discharge Piping

- Mobilization/Demobilization/General Conditions
  - Based on professional judgement and previous experience with similar projects.
- Piping from GWTS to Discharge
  - Unit cost per linear foot includes trenching, backfill, and compaction.
  - Assumes 6" to 8" piping from GWTS to the NPP.
  - Based on RS Means Software

Direct OM&M Costs

Annual Costs

- Cap Maintenance; Groundwater MNA; Site Maintenance; Reporting
  - See Alternative LDU1/GW-2 Cost Estimate Notes.
- GWTS Operational Costs
  - Assumes $0.0035/gallon for consumables (chemicals, materials, analytical testing, permitting, replacement and disposal of treatment media) associated with operating the GWTS.
  - Total gallons based on continuous flowrate of treatment system.
  - Unit rate based on quote provided by vendor.
- GWTS Maintenance and Repair Costs
  - Includes average anticipated cost per year for maintenance and repair of the GWTS, including the following tasks:
    - Equipment repair and replacement (electrical components, well and pumps, water level floats, etc.)
    - System cleaning / maintenance
    - Maintenance of infiltration basins
  - Assumes routine O&M site visits by one technician each month.
  - Assumes 50% of the GWTS components will be replaced over the 30-year timeframe.
  - Assume no off-gas air treatment or testing is required.
- GWTS Power and Utilities
  - Costs for power to the GWTS.
  - Based on estimate of kilowatt-hour required for operation of GWTS.
  - Industrial electricity rate in Montana averages 5.1 cents per kilowatt-hour.
  - Assumes well pumps run for 12 hours/day and plant pumps run for 3 hours per day.
- GWTS Operator and Labor
  - Labor for operation of GWTS, one technician for 8 hours per day, 5 days per week).
    - Based on professional judgement and previous experience on similar projects.

- Technical Support
  - Engineering support for the GWTS.
  - See Operations, Maintenance, and Monitoring Cost section of Introduction.

Feasibility Study Cost Estimate
Alternative LDU1/GW-4A: Containment via Capping and Fully-Encompassing Slurry Wall

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.6.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Fully-Encompassing Slurry Wall (3,700 ft. x 100-125 ft. x 2-3 ft.)				
Pre-Design Investigation	1	LS	$ 570,000	$ 570,000
Mobilization/Demobilization/General Conditions	1	LS	$ 750,000	$ 750,000
Clearing and Grubbing	2	ACRE	$ 4,600	$ 9,200
Installation of Slurry Wall	1	LS	$ 15,000,000	$ 15,000,000
Disposal of Excess Soil at Onsite Repository	3,859	CY	$ 25	$ 96,484
Surveying	1	LS	$ 20,000	$ 20,000
Monitoring Well Installation	11	ea	$ 25,000	$ 275,000
Installation of Pumps and Electrical (If needed)	8	ea	$ 12,000	$ 96,000
			Subtotal Installation of Fully-Encompassing Slurry Wall Costs	**$ 16,816,684**
Installation of *Ex Situ* Groundwater Treatment System (20 GPM)				
Bench-Scale Treatability Study	1	LS	$ 100,000	$ 100,000
Mobilization/Demobilization/General Conditions	1	LS	$ 100,000	$ 100,000
Site Preparation	1	LS	$ 20,000	$ 20,000
Piping (3") from Extraction Wells to Central Trench	500	LF	$ 25	$ 12,500
Piping (4") from Central Trench to GWTS	250	LF	$ 30	$ 7,500
Treatment Plant Building (20' x 40')	1	LS	$ 100,000	$ 100,000
Treatment System Equipment	1	LS	$ 900,000	$ 900,000
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 1,240,000**
Installation of Effluent Discharge Piping				
Tasks from LDU1/GW-3C	1	LS	$ 37,500	$ 37,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
			Subtotal of Direct Capital Costs	**$ 25,659,734**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Fully-Encompassing Slurry Wall)	30%	% of Respective Capital Costs		$ 5,045,005
Scope/Bid Contingency (Treatment System)	30%	% of Respective Capital Costs		$ 372,000
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Project Management	5%	% of Total Direct Capital Costs		$ 1,666,664
Remedial Design	6%	% of Total Direct Capital Costs		$ 1,999,997
Construction Management	6%	% of Total Direct Capital Costs		$ 1,999,997
			Subtotal of Indirect Capital Costs	**$ 13,340,203**
			Total Capital Costs	**$ 38,999,937**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 60,000	$ 60,000
GWTS Operational Costs	11	MILLION GALLON	$ 3,500	$ 37,000
GWTS Maintenance and Repair Costs	1	LS	$ 35,000	$ 35,000
GWTS Power and Utilities	1	LS	$ 13,000	$ 13,000
GWTS Operator and Labor	104	Man-Days	$ 1,200	$ 125,000
Technical Support	10%	% of Annual Costs		$ 40,500
Contingency	10%	% of Annual Costs		$ 40,500
			Subtotal of Direct OM&M Costs	**$ 486,000**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 25,000	$ 25,000
Contingency	5%	% of Direct OM&M Costs		$ 24,300
			Subtotal of Indirect OM&M Costs	**$ 49,300**
			Total OM&M Costs	**$ 535,300**
		Estimated Total 30-year OM&M Costs	**30**	**$ 16,059,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 6,642,560**
			TOTAL PRESENT VALUE COSTS	**$ 45,642,497**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-4A Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Fully-Encompassing of Slurry Wall

- Pre-Design Investigation
  - See Alternative LDU1/GW-3A Cost Estimate Notes.
  - Total of 75 borings.
- Mobilization/Demobilization/General Conditions
  - See Alternative LDU1/GW-3A Cost Estimate Notes.
- Clearing and Grubbing
  - See Alternative LDU1/GW-3A Cost Estimate Notes.
  - Assumes 2 acres will need to be cleared.
- Installation of Slurry Wall
  - Soil bentonite slurry wall 3,705 feet long by 2 to 3 feet wide by 100 to 125 feet deep (see Appendix Figure E6).
  - Installation method is trenching, mixing, and filling.
  - Assumes construction duration will take 160 to 180 days.
- Disposal of Excess Excavated Soil at Onsite Repository
  - See Alternative LDU1/GW-3A Cost Estimate Notes.
- Surveying
  - Based on previous experience with similar projects.
- Monitoring Well Installation
  - Based on quote from subcontractor.
  - Assumes 8 pairs of monitoring wells (4-inch PVC to depth of 100 feet) will be utilized around perimeter of slurry wall. 5 existing monitoring wells can be used; therefore 11 new wells will be installed.
  - Includes well development and surface restoration.
  - The 8 interior monitoring wells could be converted to extraction wells if needed for gradient control.

Installation of *Ex Situ* Groundwater Treatment System (20 GPM)

- Bench-Scale Treatability Study
  - See Alternative LDU1/GW-3C Cost Estimate Notes.
- Mobilization/Demobilization/General Conditions; Site Preparation; Piping (3") from Extraction Wells to Central Trench; Piping (4") from Central Trench to GWTS;
  - See Alternative LDU1/GW-3C Cost Estimate Notes.
- Treatment System Building (20' x 40')
  - Portable, prefabricated and heated enclosure to house treatment equipment.
  - Based on professional judgement.

- Treatment System Equipment:
  - Equalization Tank, Mixing Tanks, Filters, Sludge Management System, Adsorption Vessels, Ion Exchange Unit.
  - Based on quote provided by subcontractor.

Installation of Effluent Discharge Piping

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW 4B: Containment via Capping and Fully-Encompassing Slurry Wall and Downgradient PRB

Description of Alternative:

- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Installation of a permeable reactive barrier north of the Burlington Northern Railroad;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.7.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Fully-Encompassing Slurry Wall (3,700 ft. x 100-125 ft. x 2-3 ft.)				
Tasks from LDU1/GW-4A	1	LS	$ 16,816,684	$ 16,816,684
			Subtotal Installation of Fully-Encompassing Slurry Wall Costs	**$ 16,816,684**
Installation of *Ex Situ* Groundwater Treatment System (20 GPM)				
Tasks from LDU1/GW-4A	1	LS	$ 1,240,000	$ 1,240,000
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 1,240,000**
Installation of Effluent Discharge Piping				
Tasks from LDU1/GW-3C	1	LS	$ 37,500	$ 37,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
Installation of PRB (3,785 ft. x 130 ft. x 2-3 ft.)				
Tasks from LDU1/GW-3B	1	LS	$ 32,926,719	$ 32,926,719
			Subtotal Installation of PRB Costs	**$ 32,926,719**
			Subtotal of Direct Capital Costs	**$ 58,586,453**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Fully-Encompassing Slurry Wall)	30%	% of Respective Capital Costs		$ 5,045,005
Scope/Bid Contingency (Treatment System)	30%	% of Respective Capital Costs		$ 372,000
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Scope/Bid Contingency (PRB)	30%	% of Respective Capital Costs		$ 9,878,016
Project Management	5%	% of Total Direct Capital Costs		$ 3,806,901
Remedial Design	6%	% of Total Direct Capital Costs		$ 4,568,281
Construction Management	6%	% of Total Direct Capital Costs		$ 4,568,281
			Subtotal of Indirect Capital Costs	**$ 30,495,023**
			Total Capital Costs	**$ 89,081,476**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 60,000	$ 60,000
GWTS Operational Costs	11	MILLION GALLON	$ 3,500	$ 37,000
GWTS Maintenance and Repair Costs	1	LS	$ 35,000	$ 35,000
GWTS Power and Utilities	1	LS	$ 13,000	$ 13,000
GWTS Opertor and Labor	104	Man-Days	$ 1,200	$ 125,000
Technical Support	10%	% of Annual Costs		$ 40,500
Contingency	10%	% of Annual Costs		$ 40,500
			Subtotal of Direct OM&M Costs	**$ 486,000**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 25,000	$ 25,000
Contingency	5%	% Direct OM&M		$ 24,300
			Subtotal of Indirect OM&M Costs	**$ 49,300**
			Total OM&M Costs	**$ 535,300**
		Estimated Total 30-year OM&M Costs	**30**	**$ 16,059,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 6,642,560**
			TOTAL PRESENT VALUE COSTS	**$ 95,724,036**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-4B Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Fully-Encompassing Slurry Wall

- See Alternative LDU1/GW-4A Cost Estimate Notes.

Installation of *Ex Situ* Groundwater Treatment System (20 GPM)

- See Alternative LDU1/GW-4A Cost Estimate Notes.

Installation of Effluent Discharge Piping

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of PRB (3,785 ft. x 130 ft. x 2-3 ft.)

- See Alternative LDU1/GW-3B Cost Estimate Notes.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW-4C: Containment via Capping and Fully-Encompassing Slurry Wall and Downgradient Extraction

Description of Alternative:
- Containment of source area waste management units via capping;
- Construction of a slurry wall fully-encompassing the West Landfill and Wet Scrubber Sludge Pond;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), ex situ treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs..

This alternative is described in Section 5.1.8.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Fully-Encompassing Slurry Wall (3,700 ft. x 100-125 ft. x 2-3 ft.)				
Tasks from LDU1/GW-4A	1	LS	$ 16,816,684	$ 16,816,684
			Subtotal Installation of Fully-Encompassing Slurry Wall Costs	**$ 16,816,684**
Installation of Downgradient Extraction Wells				
Tasks from LDU1/GW-3C	1	LS	$ 725,000	$ 725,000
			Subtotal Installation of Downgradient Extraction Wells Costs	**$ 725,000**
Installation of *Ex Situ* Treatment System (500 GPM)				
Tasks from LDU1/GW-3C	1	LS	$ 7,106,500	$ 7,106,500
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 7,106,500**
Installation of Effluent Discharge Piping				
Tasks from LDU1/GW-3C	1	LS	$ 37,500	$ 37,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
			Subtotal of Direct Capital Costs	**$ 32,251,234**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Fully-Encompassing Slurry Wall)	30%	% of Respective Capital Costs		$ 5,045,005
Scope/Bid Contingency (Downgradient Extraction Wells)	30%	% of Respective Capital Costs		$ 217,500
Scope/Bid Contingency (Groundwater Treatment System)	30%	% of Respective Capital Costs		$ 2,131,950
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Project Management	5%	% of Total Direct Capital Costs		$ 2,095,111
Remedial Design	6%	% of Total Direct Capital Costs		$ 2,514,134
Construction Management	6%	% of Total Direct Capital Costs		$ 2,514,134
			Subtotal of Indirect Capital Costs	**$ 16,774,374**
			Total Capital Costs	**$ 49,025,609**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 60,000	$ 60,000
GWTS Operational Costs	263	MILLION GALLON	$ 3,500	$ 920,000
GWTS Maintenance and Repair Costs	1	LS	$ 120,000	$ 120,000
GWTS Power and Utilities	1	LS	$ 30,000	$ 30,000
GWTS Operator and Labor	260	Man-Days	$ 1,200	$ 312,000
Technical Support	10%	% of Annual Costs		$ 157,700
Contingency	10%	% of Annual Costs		$ 157,700
			Subtotal of Direct OM&M Costs	**$ 1,892,400**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 50,000	$ 50,000
Contingency	5%	% of Direct OM&M Costs		$ 94,620
			Subtotal of Indirect OM&M Costs	**$ 144,620**
			Total OM&M Costs	**$ 2,037,020**
		Estimated Total 30-year OM&M Costs	**30**	**$ 61,110,600**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 25,277,465**
			TOTAL PRESENT VALUE COSTS	**$ 74,303,074**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-4C Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Fully-Encompassing of Slurry Wall

- See Alternative LDU1/GW-4A Cost Estimate Notes.

Installation of Downgradient Extraction Wells

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of *Ex Situ* Groundwater Treatment System (500 GPM)

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of Effluent Discharge Piping

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW-5A: Containment via Capping and Hydraulic Control at the Source Area

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1), ex situ treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.9.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1-GW 2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1-GW 2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Source Area Extraction Wells				
Pre-Design Investigation	1	LS	$ 175,000	$ 175,000
Mobilization/Demobilization/General Conditions	1	LS	$ 40,000	$ 40,000
Installation of Extraction Wells	10	ea	$ 51,000	$ 510,000
Installation of Pumps and Electrical	10	ea	$ 12,000	$ 120,000
			Subtotal Installation of Source Area Extraction Wells Costs	**$ 845,000**
Installation of *Ex Situ* Groundwater Treatment System (1,500 GPM)				
Bench-Scale Treability Study	1	LS	$ 200,000	$ 200,000
Mobilization/Demobilization/General Conditions	1	LS	$ 500,000	$ 500,000
Site Preparation	1	LS	$ 75,000	$ 75,000
Piping (6") from Extraction Wells to Central Trench	1,200	LF	$ 35	$ 42,000
Piping (12") from Central Trench to GWTS	250	LF	$ 45	$ 11,250
Treatment Plant Building (100 x 100')	1	LS	$ 1,100,000	$ 1,100,000
Treatment System Equipment	1	LS	$ 15,000,000	$ 15,000,000
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 16,928,250**
Installation of Effluent Discharge Piping				
Mobilization/Demobilization/General Conditions	1	LS	$ 20,000	$ 20,000
Piping from GWTS to Discharge	200	LF	$ 131	$ 26,200
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 46,200**
			Subtotal of Direct Capital Costs	**$ 25,385,000**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Source Area Extraction Wells)	30%	% of Respective Capital Costs		$ 253,500
Scope/Bid Contingency (Groundwater Treatment System)	30%	% of Respective Capital Costs		$ 5,078,475
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 13,860
Project Management	5%	% of Total Direct Capital Costs		$ 1,648,806
Remedial Design	6%	% of Total Direct Capital Costs		$ 1,978,568
Construction Management	6%	% of Total Direct Capital Costs		$ 1,978,568
			Subtotal of Indirect Capital Costs	**$ 13,197,066**
			Total Capital Costs	**$ 38,582,066**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
GWTS Operational Costs	254	MILLION GALLON	$ 3,500	$ 890,000
GWTS Maintenance and Repair Costs	1	LS	$ 270,000	$ 270,000
GWTS Power and Utilities	1	LS	$ 50,000	$ 50,000
GWTS Operator and Labor	325	Man-Days	$ 1,200	$ 390,000
Reporting	1	LS	$ 60,000	$ 60,000
Technical Support	10%	% of Annual Costs		$ 179,500
Contingency	10%	% of Annual Costs		$ 179,500
			Subtotal of Direct OM&M Costs	**$ 2,154,000**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 50,000	$ 50,000
Contingency	5%	% of Direct OM&M Costs		$ 107,700
			Subtotal of Indirect OM&M Costs	**$ 157,700**
			Total OM&M Costs	**$ 2,311,700**
		Estimated Total 30-year OM&M Costs	**30**	**$ 69,351,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 28,685,981**
			TOTAL PRESENT VALUE COSTS	**$ 67,268,047**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-5A Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Source Area Extraction Wells

- Pre-Design Investigation
  - Aquifer testing, 48 to 72-hour pump test at two extraction wells.
  - Assumes two-person field crew for 4 days in field.
  - Assumes portable treatment system to pre-treat extracted groundwater for discharge to aquifer.
- Mobilization/Demobilization/General Conditions
  - Based on previous quotes for onsite drilling.
- Installation of Extraction Wells
  - Based on quote from subcontractor.
  - Assumes installation of ten 6-inch extraction wells downgradient of West Landfill and Wet Scrubber Sludge Pond to 100 ft-bls (see Appendix Figure E9).
  - Includes 100 ft of pipe to surface grade and a pitless adapter for frost protection for each extraction well.
  - Includes well development and surface restoration.
- Installation of Pumps and Electrical
  - Assumes ten submersible pumps capable of 175 gallons per minute (gpm).

Installation of *Ex Situ* Groundwater Treatment Systems (1,500 GPM)

- Bench-Scale Treatability Study
  - Collection and analysis of groundwater samples from extraction wells to represent influent to Groundwater Treatment System (GWTS).
  - Lab-scale treatment of groundwater samples using proposed treatment methods for GWTS to evaluate removal efficiency.
  - Performing various trials to aid in design of GWTS.
  - Based on professional judgement.
- Mobilization/Demobilization; Site Preparation; Piping (6”) from Extraction Wells to Central Trench; Piping (12”) from Central Trench to GWTS; Treatment Plant Building (100’ x 100’);
  - See Alternative LDU1/GW-3C Cost Estimate Notes
- Treatment System Equipment
  - See Alternative LDU1/GW-4A Cost Estimate Notes

Installation of Effluent Discharge Piping

- Mobilization/Demobilization/General Conditions
  - Based on professional judgement and previous experience with similar projects.
- Piping from GWTS to Discharge
  - The proposed location of the GWTS is shown on Appendix Figure E9.
  - Unit cost per linear foot includes trenching, backfill, and compaction. Assumes 12” piping from GWTS to the NPP

Direct OM&M Costs

Annual Costs

- Cap Maintenance; Groundwater MNA; Site Maintenance; GWTS Operational Costs; GWTS Maintenance and Repair Costs; GWTS Power and Utilities; Reporting; Technical Support
  - See Alternative LDU1/GW-3C Cost Estimate Notes.
- GWTS Operational Costs
  - Assumes $0.0035/gallon for consumables (chemicals, materials, analytical testing, permitting, replacement and disposal of treatment media) associated with operating the GWTS.
  - Total gallons based on flowrate of 1,500 gpm for 90 days and 110 gpm for remainder of the year.
  - Unit rate based on quote provided by vendors.
- GWTS Operator and Labor
  - Labor for operation of GWTS two technicians for 8 hours per day, 5 days per week for 90 days during full flow GWTS operation and one technician for 8 hours per day, 5 days per week for remainder of year.
  - Based on professional judgement and previous experience on similar projects.

Feasibility Study Cost Estimate
Alternative LDU1/GW-5B: Containment via Capping and Downgradient Extraction

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of downgradient groundwater (i.e., north of the Burlington Northern Railroad), ex situ treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.10.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1/GW-2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1-GW 2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Downgradient Extraction Wells				
Tasks from LDU1-GW 3C	1	LS	$ 725,000	$ 725,000
			Subtotal Installation of Downgradient Extraction Wells Costs	**$ 725,000**
Installation of *Ex Situ* Groundwater Treatment System (500 GPM)				
Tasks from LDU1-GW 3C	1	LS	$ 7,106,500	$ 7,106,500
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 7,106,500**
Installation of Effluent Discharge Piping				
Tasks from LDU1-GW 3C	1	LS	$ 37,500	$ 37,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
			Subtotal of Direct Capital Costs	**$ 15,434,550**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Downgradient Extraction Wells)	30%	% of Respective Capital Costs		$ 217,500
Scope/Bid Contingency (Groundwater Treatment System)	30%	% of Respective Capital Costs		$ 2,131,950
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Project Management	5%	% of Total Direct Capital Costs		$ 1,002,027
Remedial Design	6%	% of Total Direct Capital Costs		$ 1,202,432
Construction Management	6%	% of Total Direct Capital Costs		$ 1,202,432
			Subtotal of Indirect Capital Costs	**$ 8,012,882**
			Total Capital Costs	**$ 23,447,432**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
GWTS Operational Costs	263	MILLION GALLON	$ 3,500	$ 920,000
GWTS Maintenance and Repair Costs	1	LS	$ 120,000	$ 120,000
GWTS Power and Utilities	1	LS	$ 30,000	$ 30,000
GWTS Operator and Labor	260	Man-Days	$ 1,200	$ 312,000
Reporting	1	LS	$ 60,000	$ 60,000
Technical Support	10%	% of Annual Costs		$ 157,700
Contingency	10%	% of Annual Costs		$ 157,700
			Subtotal of Direct OM&M Costs	**$ 1,892,400**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 50,000	$ 50,000
Contingency	5%	% of Direct OM&M Costs		$ 94,620
			Subtotal of Indirect OM&M Costs	**$ 144,620**
			Total OM&M Costs	**$ 2,037,020**
		Estimated Total 30-year OM&M Costs	**30**	**$ 61,110,600**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 25,277,465**
			TOTAL PRESENT VALUE COSTS	**$ 48,724,897**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-5B Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Downgradient Extraction Wells

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of *Ex Situ* Groundwater Treatment System (500 GPM)

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of Effluent Discharge Piping

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW-5C: Containment via Capping and Hydraulic Control at the Source Area and Downgradient

Description of Alternative:

- Containment of source area waste management units via capping;
- Extraction of source area groundwater (i.e., immediately downgradient of Landfills DU1) and downgradient groundwater (i.e., north of the Burlington Northern Railroad), ex situ treatment of extracted groundwater, and discharge of treated groundwater;
- Monitored natural attenuation; and
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.11.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Tasks from LDU1-GW 2	1	LS	$ 7,484,300	$ 7,484,300
			Subtotal Capping of Landfills Costs	**$ 7,484,300**
ICs and ECs				
Tasks from LDU1-GW 2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Installation of Downgradient Extraction Wells				
Tasks from LDU1/GW-3C	1	LS	$ 725,000	$ 725,000
			Subtotal Installation of Downgradient Extraction Wells Costs	**$ 725,000**
Installation of *Ex Situ* Groundwater Treatment System (500 GPM)				
Tasks from LDU1-GW 3C	1	LS	$ 7,106,500	$ 7,106,500
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 7,106,500**
Installation of Source Area Extraction Wells				
Tasks from LDU1/GW-5A	1	LS	$ 845,000	$ 845,000
			Subtotal Installation of Source Area Wells Costs	**$ 845,000**
Installation of *Ex Situ* Groundwater Treatment System (1,500 GPM)				
Tasks from LDU1/GW-5A	1	LS	$ 16,928,250	$ 16,928,250
			Subtotal Installation of Ex Situ Groundwater Treatment System Costs	**$ 16,928,250**
Installation of Effluent Discharge Piping				
Tasks from LDU1/GW-3C	1	LS	$ 37,500	$ 37,500
			Subtotal Installation of Effluent Discharge Piping Costs	**$ 37,500**
			Subtotal of Direct Capital Costs	**$ 33,207,800**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 2,245,290
Scope/Bid Contingency (Extraction Wells)	30%	% of Respective Capital Costs		$ 471,000
Scope/Bid Contingency (Groundwater Treatment System)	30%	% of Respective Capital Costs		$ 5,078,475
Scope/Bid Contingency (Effluent Discharge Piping)	30%	% of Respective Capital Costs		$ 11,250
Project Management	5%	% of Total Direct Capital Costs		$ 2,050,691
Remedial Design	6%	% of Total Direct Capital Costs		$ 2,460,829
Construction Management	6%	% of Total Direct Capital Costs		$ 2,460,829
			Subtotal of Indirect Capital Costs	**$ 14,778,364**
			Total Capital Costs	**$ 47,986,164**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	20	ACRE	$ 1,000	$ 20,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
GWTS Operational Costs	517	MILLION GALLON	$ 3,500	$ 1,810,000
GWTS Maintenance and Repair Costs	1	LS	$ 390,000	$ 390,000
GWTS Power and Utilities	1	LS	$ 80,000	$ 80,000
GWTS Operator and Labor	585	Man-Days	$ 1,200	$ 700,000
Reporting	1	LS	$ 75,000	$ 75,000
Technical Support	10%	% of Annual Costs		$ 319,000
Contingency	10%	% of Annual Costs		$ 319,000
			Subtotal of Direct OM&M Costs	**$ 3,828,000**
Indirect OM&M Costs				
Administrative Costs	1	LS	$ 50,000	$ 50,000
Contingency	5%	% of Direct OM&M Costs		$ 191,400
			Subtotal of Indirect OM&M Costs	**$ 241,400**
			Total OM&M Costs	**$ 4,069,400**
		Estimated Total 30-year OM&M Costs	**30**	**$ 122,082,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 50,497,352**
			TOTAL PRESENT VALUE COSTS	**$ 98,483,516**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-5C Cost Estimate Notes

Direct Capital Costs

Capping of Landfills

- See Alternative LDU1/GW-2 Cost Estimate Notes.

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Installation of Downgradient Extraction Wells

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of *Ex Situ* Groundwater Treatment System (500 GPM)

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Installation of Source Area Extraction Wells

- See Alternative LDU1/GW-5A Cost Estimate Notes.

Installation of *Ex Situ* Groundwater Treatment System (1,500 GPM)

- See Alternative LDU1/GW-5A Cost Estimate Notes.

Installation of Effluent Discharge Piping

- See Alternative LDU1/GW-3C Cost Estimate Notes.

Direct OM&M Costs

Annual Costs

- See Alternative LDU1/GW-3C and Alternative LDU1/GW-5A Cost Estimate Notes.

Feasibility Study Cost Estimate
Alternative LDU1/GW-6: Excavation with Onsite Consolidation

Description of Alternative:

- Excavation of wastes previously disposed within the source area waste management units;
- Characterization of soils beneath waste and removal as necessary to eliminate source material;
- Construction of an onsite repository meeting RCRA Subtitle C requirements for disposal of excavated material;
- Containment of the Center Landfill via capping;
- Monitored natural attenuation;
- Establishment of ICs and ECs.

This alternative is described in Section 5.1.12.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
ICs and ECs				
Tasks from LDU1/GW-2	1	LS	$ 81,250	$ 81,250
			Subtotal ICs and ECs Costs	**$ 81,250**
Capping of Center Landfill				
Mobilization/Demobilization/General Conditions	1	LS	$ 100,000	$ 100,000
Erosion and Sediment Control	1	LS	$ 30,000	$ 30,000
Construction Surveying	1	LS	$ 20,000	$ 20,000
Excavation of Existing Soil Cap to Stockpile (12" min)	2,900	CY	$ 9	$ 26,100
Surface Grading	8,700	SY	$ 2	$ 17,400
Installation of Geomembrane Layer	9,500	SY	$ 4	$ 38,950
Backfill and Compaction with Onsite Soil (12" layer)	3,100	CY	$ 8	$ 24,800
Backfill and Compaction with Imported Soil (6" layer)	1,550	CY	$ 27	$ 41,850
Backfill and Compation with Top Soil (6" layer)	1,550	CY	$ 35	$ 54,250
Installation of Stormwater Conveyance Swales/Ditches	1	LS	$ 150,000	$ 150,000
Perimeter Soil Berm	600	CY	$ 32	$ 19,200
Seeding/Vegetation	1.8	ACRE	$ 1,000	$ 1,800
			Subtotal Capping of Landfills Costs	**$ 524,350**
Waste Excavation				
Mobilization/Demobilization/General Conditions	1	LS	$ 750,000	$ 750,000
Erosion and Sediment Control	1	LS	$ 50,000	$ 50,000
Pre-Design Investigation	1	LS	$ 364,000	$ 364,000
Construction Surveying	1	LS	$ 60,000	$ 60,000
<u>Wet Scrubber Sludge Pond</u>				
Physical Solidification of Low-Strength Material	523,000	CY	$ 35.00	$ 18,305,000
Waste Excavation	523,000	CY	$ 9.00	$ 4,707,000
Waste Transportation	719,000	CY	$ 5.00	$ 3,595,000
Sloping/Benching of Excavation	78,500	CY	$ 9.00	$ 706,500
Dewatering System for Excavation	1	LS	$ 500,000	$ 500,000
<u>West Landfill</u>				
Waste and Underlying Impacted Soil Excavation	818,000	CY	$ 9	$ 7,362,000
Waste and Underlying Impacted Soil Transportation	1,020,000	CY	$ 5	$ 5,100,000
Sloping/Benching of Excavation	153,000	CY	$ 9	$ 1,377,000
Dewatering System for Excavation	1	LS	$ 2,000,000	$ 2,000,000
Backfilling, Compaction of Former WMUs with Onsite Material	532,000	CY	$ 8	$ 4,256,000
Backfilling, Compaction of Former WMUs with Imported Fill	572,000	CY	$ 27	$ 15,444,000
Seeding/Vegetation	18.6	ACRE	$ 1,000	$ 18,600
			Subtotal Waste Excavation	**$ 64,595,100**
Construction of RCRA Subtitle C Landfill				
Mobilization/Demobilization/General Conditions	1	LS	$ 750,000	$ 750,000
Construction Surveying	1	LS	$ 60,000	$ 60,000
Subgrade Grading	211,000	SY	$ 2	$ 422,000
Installation of Geosynthetic Clay Liner	216,000	SY	$ 8.73	$ 1,885,680
Installation of Leak Detection Geocomposite Drainage Layer	216,000	SY	$ 6.35	$ 1,371,600
Installation of Geomembrane Layer	216,000	SY	$ 4.10	$ 885,600
Installation of Leachate Collection System	1	LS	$ 2,900,000	$ 2,900,000
Placement of Sand Layer (12" Layer)	70,200	CY	$ 35	$ 2,457,000
Waste Placement and Compaction in Lifts	1,400,000	CY	$ 20	$ 28,000,000
Installation of Geosynthetic Clay Liner	216,000	SY	$ 8.73	$ 1,885,680
Installation of Geomembrane Layer	216,000	SY	$ 4.10	$ 885,600
Installation of Geocomposite Drainage Layer	216,000	SY	$ 6.35	$ 1,371,600
Backfill and Compaction of Imported Soil (18" layer)	105,000	CY	$ 27	$ 2,835,000
Backfill and Compaction of Topsoil (6" layer)	35,000	CY	$ 35	$ 1,225,000
Installation of Stormwater Conveyance Swales/Ditches	1	LS	$ 900,000	$ 900,000
Perimeter Soil Berm	3,400	CY	$ 32	$ 108,800
Monitoring Well Installation	10	ea	$ 25,000	$ 250,000
Seeding/Vegetation	43.5	ACRES	$ 1,000	$ 43,496
			Subtotal Construction of RCRA Subtitle C Landfill Costs	**$ 48,237,056**
			Subtotal of Direct Capital Costs	**$ 113,437,756**
Indirect Capital Costs				
Scope/Bid Contingency (Capping of Center Landfill)	30%	% of Respective Capital Costs		$ 157,305
Scope/Bid Contingency (Waste Excavation)	30%	% of Respective Capital Costs		$ 19,378,530
Scope/Bid Contingency (Construction of RCRA C Landfill)	30%	% of Respective Capital Costs		$ 14,471,117
Project Management	1%	% of Total Direct Capital Costs		$ 1,474,000
Remedial Design	2%	% of Total Direct Capital Costs		$ 2,949,000
Construction Management	4%	% of Total Direct Capital Costs		$ 5,898,000
			Subtotal of Indirect Capital Costs	**$ 44,327,952**
			Total Capital Costs	**$ 157,765,708**

OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs				
Cap Maintenance	45	ACRE	$ 1,000	$ 45,000
Groundwater MNA	1	LS	$ 100,000	$ 100,000
Site Maintenance	1	LS	$ 20,000	$ 20,000
Reporting	1	LS	$ 45,000	$ 45,000
LCS O&M Costs	1	LS	$ 72,000	$ 72,000
LCS Power and Utilities	1	LS	$ 13,000	$ 13,000
LCS Operator and Labor	1	LS	$ 125,000	$ 125,000
Technical Support	10%	% of Annual Costs		$ 42,000
Contingency	20%	% of Annual Costs		$ 84,000
			Subtotal of Direct OM&M Costs	**$ 546,000**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 30,000	$ 30,000
Contingency	10%	% of Direct OM&M Costs		$ 54,600
			Subtotal of Indirect OM&M Costs	**$ 84,600**
			Total OM&M Costs	**$ 630,600**
		Estimated Total 30-year OM&M Costs	**30**	**$ 18,918,000**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 7,825,141**
			TOTAL PRESENT VALUE COSTS	**$ 165,590,849**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative LDU1/GW-6 Cost Estimate Notes

Direct Capital Costs

ICs and ECs

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Capping of Center Landfill

- See Alternative LDU1/GW-2 Cost Estimate Notes.

Waste Excavation

- Mobilization/Demobilization/General Conditions
  - See LDU1/GW-2 Cost Estimate Notes.
  - Includes undercutting of the proposed landfill footprint.
- Erosion and Sediment Control; Construction Surveying
  - See Alternative LDU1/GW-2 Cost Estimate Notes.
- Pre-Design Investigation
  - Site investigation to delineate depth of wastes and underlying impacted soil that requires excavation.
  - Assumes soil borings advanced at Wet Scrubber Sludge Pond to 50 feet and West Landfill to 100 feet, at 4 borings per acre (total 72 borings).
  - Assumes 4 ½ borings completed per day (16 days).
  - Assume two sonic or hollow stem auger (HAS) rig: $50 per foot (5000 ft) plus, mobilization/demobilization, and geologist oversight.
- Construction Surveying
  - See Alternative LDU1/GW-2 Cost Estimate Notes.
- <u>Wet Scrubber Sludge Pond</u>
  - Physical Solidification of Low-Strength Material
    - See Alternative LDU1/GW-2 Cost Estimate Notes.
    - Assumes physical solidification of all waste removed from Wet Scrubber Sludge Pond prior to landfilling.
  - Waste Excavation
    - Includes cost for excavation of waste within the Wet Scrubber Sludge Pond, based on the dimensions below:
      - Wet Scrubber Sludge Pond (10.8 acres with waste thickness of 30 feet).
    - Based on quotes from contractors and previous Site experience.
    - Does not include excavation of underlying soils.
  - Waste Transportation
    - Includes cost for transportation of waste to the onsite repository.
    - Assumes 10% increase in volume of solidified waste and 25% increase in volume of excavated waste from fluff factor for trucking purposes.
    - Based on quotes from contractors and previous Site experience.
  - Sloping/Benching of Excavation
    - Sloping and benching would be completed to maintain stability of the sidewalls.
    - Assumes 15% of excavation volume for staging and reuse as backfill in the excavation.
  - Dewatering System for Excavation
    - Based on previous experience with similar projects.

        - Includes construction water dewatering of excavations and management of construction water (does not include groundwater).
        - Includes construction of pre-fabricated corrugated metal dewatering sumps as needed at low elevation areas within excavations to allow for water removal. Adequately sized pumps and hoses will transfer collected water from the sump to a construction water management system.
        - Assumes the construction water management system will consist of storage tanks, transfer pumps, bag filtration, liquid phase carbon adsorbers and a totalizing flow meter.
        - See Alternative LDU1/GW-2 Cost Estimate notes for assumptions on backfill/compaction.

- <u>West Landfill</u>
    - Waste and Underlying Impacted Soil Excavation
        - Includes cost for excavation of waste based on 7.8-acre footprint, waste depth of 35 ft extending on average approximately 20 ft-bls below surrounding grade, and excavation of underlying soils from 20 to 50 ft below grade.
        - Based on quotes from contractors and previous Site experience.
    - Waste and Underlying Impacted Soil Transportation
        - See notes for Wet Scrubber Sludge Pond.
        - Assumes 25% increase in volume from fluff factor.
    - Sloping/Benching of Excavation; Dewatering System for Excavation
        - See notes for Wet Scrubber Sludge Pond above.
- Backfilling, Compaction of Former WMU's with Onsite Material
    - Includes cost to backfill and compact the open excavations at the former Waste Management Units (WMUs) using material available onsite.
    - Includes material excavated for sloping/benching and 300,000 CY of coarse-grained material available from the onsite permitted borrow pit.
    - Assumes excavation will be backfilled to restore the area to the grade and topography currently surrounding the waste management units.
    - See Alternative LDU1/GW-2 Cost Estimate notes for assumptions on backfill/compaction.
- Backfilling, Compaction of Former WMUs with Imported Fill
    - Includes cost to backfill and compact the open excavations at the former landfill using imported fill material.
    - Assumes 50% of excavation volume will be backfilled.
    - See Alternative LDU1/GW-2 Cost Estimate notes for assumptions on backfill/compaction.
- Seeding/Vegetation
    - Includes cost for seeding the footprint of the former waste management unit.
    - Based on previous experience on similar projects.

Construction of RCRA Subtitle C Landfill

- Mobilization/Demobilization/General Conditions
    - See notes for Waste Excavation, and Capital Costs section of the Introduction.
- Construction Surveying
    - See Alternative LDU1/GW-2 Cost Estimate Notes.
- Subgrade Grading
    - Assumes an average landfill height of 20 feet.

- Landfill footprint is based on volume of waste required for disposal (assumptions detailed below under Waste Placement and Compaction in Lifts; fluff factor not included for this volume).
- Includes excavation of 5-foot wide anchor trench around landfill footprint.
- Unit cost based on previous experience with similar projects.

- Installation of Geosynthetic Clay Liner
  - Unit cost includes both cost for material and installation of a low permeability geosynthetic clay liner (GCL) atop the compacted subgrade across entire landfill footprint. Area of installation assumes 2% greater than landfill footprint to account for overlap of sheets and additional 5 ft along perimeters to tie into anchor trench.
  - Assumes GCL is comprised of bentonite composites sandwiched between two layers of geotextile.
  - Material and Installation unit cost based on previous experience with similar projects.
- Installation of Leak Detection Geocomposite Drainage Layer
  - Includes cost for material and installation of leak detection layer consisting of high permeability Geocomposite layer.
  - See Alternative LDU1/GW-2 Cost Estimate Notes for Geocomposite notes.
- Installation of Geomembrane Layer
  - Includes cost for material and installation of a secondary HDPE 40-mil geomembrane liner atop GCL.
  - See Alternative LDU1/GW-2 Cost Estimate Notes for Geomembrane notes.
- Installation of Leachate Collection System
  - Leachate Collection System (LCS) assumes installation of perforated lateral piping spaced 50 feet apart across entire landfill footprint.
  - Assumes installation of header piping with cleanouts to connect laterals and leak detection drainage to sumps.
  - Includes 5 sumps with pumps and side slope risers that direct leachate to a force main that outlets to a leachate storage area.
- Placement of Sand Layer
  - Includes cost for import and placement of a 12-inch thick high-permeability sand layer atop leachate collection piping.
  - See Alternative LDU1/GW-2 Cost Estimate Notes.
  - Does not include excavation of underlying soils.
- Waste Placement and Compaction in Lifts
  - Includes cost to backfill waste excavated from Wet Scrubber Sludge Pond, Center Landfill, and West Landfill and compact in 2-foot lifts.
  - Assumes an additional 10% of volume excavated from Wet Scrubber Sludge Pond due to addition of amendments for solidification.
- Installation of GCL; Installation of Geomembrane Layer; Installation of Geocomposite Drainage Layer; Backfill and Compaction of Imported Soil (18" Layer); Backfill and Compaction of Topsoil (6" Layer); Installation of Stormwater Conveyance Swales/Ditches; and Perimeter Soil Berm
  - See Alternative LDU1/GW-2 Cost Estimate Notes
- Monitoring Well Installation
  - Based on quote from subcontractor.
  - Assumes ten monitoring wells installed around RCRA Subtitle C Landfill to approximately 100 feet.
  - Includes well development and surface restoration.
- Seeding/Vegetation

    - Includes cost for seeding the entire footprint of the newly construction RCRA Subtitle C Landfill.

Indirect Capital Costs

- Scope/Bid Contingency; Project Management; Remedial Design
    - See Introduction, Capital Costs section.
- Construction Management
    - Construction duration anticipated to occur for 10 years or more, based on low capacity for pre-treatment of K088 Listed Hazardous Waste.

Direct OM&M Costs

Annual Costs

- Cap Maintenance
    - Based on professional judgement and previous experience with similar projects.
    - Includes maintenance of the cap at the newly constructed, RCRA Subtitle C onsite repository.
- Groundwater MNA; Site Maintenance; and Reporting.
    - See Alternative LDU1/GW-2 Cost Estimate Notes.
- LCS O&M Costs; LCS Power and Utilities; LCS Operator and Labor
    - Assumed similar OM&M of the LCS as those for 20 gpm GWTS (See LDU1/GW 4A Alternative cost estimate notes).
- Technical Support
    - Engineering support for the LCS.
    - See Operations, Maintenance, and Monitoring Cost section of Introduction.

Cost Estimates for Landfills DU2 Alternatives

Feasibility Study Cost Estimate
Landfills DU2 Alternatives
Summary of Estimated Costs

Alternative	Capital Cost	Total OM&M (PV)	Total Cost (PV)
LDU2-1: No Action	$ -	$ 797,715	$ 797,715
LDU2-2: Containment via Capping	$ 6,169,608	$ 797,715	$ 6,967,323

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Feasibility Study Cost Estimate
Alternative LDU2-1: No Action

Description of Alternative:

- Maintenance of the existing caps on the East Landfill and Sanitary Landfill;
- Maintenance of the existing soil covers on the Asbestos Landfills;
- Maintenance of the existing fences where present to limit access to these waste management units; and
- No additional actions.

This alternative is described in Section 5.2.1.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs (Capping)				
Cap Maintenance	22	ACRE	$ 1,000	$ 22,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 10,000	$ 10,000
Contingency	10%	% of Annual Costs		$ 4,700
			Subtotal of Direct OM&M Costs	**$ 51,700**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	5%	% of Direct OM&M Costs		$ 2,585
			Subtotal of Indirect OM&M Costs	**$ 12,585**
			Total OM&M Costs	**$ 64,285**
		Estimated Total 30-year OM&M Costs	**30**	**$ 1,928,550**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 797,715**
			TOTAL PRESENT VALUE COSTS	**$ 797,715**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Direct OM&M Costs

Annual Costs (Capping Maintenance)

- Cap Maintenance
  - Includes mowing, weed spraying, maintenance of stormwater conveyance systems.
  - Based on previous Site experience and professional judgement.
  - Includes maintenance of caps at East Landfill (2.4 acres), Industrial Landfill (12.4 acres), Sanitary Landfill (3.8 acres), and Asbestos Landfills (3.4 acres).
- Site Maintenance
  - Repair of landfill perimeter fencing and roadways.
  - Based on previous Site experience and professional judgement.
- Reporting
  - Based on professional judgement.

Feasibility Study Cost Estimate
Alternative LDU2-2: Containment via Capping

Description of Alternative:

- Maintaining the existing caps on the East Landfill and Sanitary Landfill;
- Containment of the Industrial Landfill via capping;
- Improving the existing soil covers at the Asbestos Landfill;
- Establishment of ICs and ECs.

This alternative is described in Section 5.2.2.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Capping of Landfills				
Mobilization/Demobilization/General Conditions	1	LS	$ 250,000	$ 250,000
Erosion and Sediment Control	1	LS	$ 20,000	$ 20,000
Construction Surveying	1	LS	$ 30,000	$ 30,000
Industrial Landfill				
Backfill with Onsite Material for Grading	58,000	CY	$ 8	$ 464,000
Surface Grading	60,000	SY	$ 2	$ 120,000
Backfill and Compaction of Sand (6" Grading Layer)	10,000	CY	$ 27	$ 270,000
Installation of Geomembrane Layer	61,000	SY	$ 4.10	$ 250,100
Installation of Geocomposite Drainage Layer	61,000	SY	$ 6.35	$ 387,350
Backfill and Compaction of Imported Soil (18" Layer)	30,000	CY	$ 27	$ 810,000
Backfill and Compaction of Topsoil (6" Layer)	10,000	CY	$ 35	$ 350,000
Installation of Stormwater Conveyance Swales/Ditches	1	LS	$ 450,000	$ 450,000
Perimeter Soil Berm	1,900	CY	$ 32	$ 60,800
Seeding/Vegetation	12.4	ACRE	$ 1,000	$ 12,400
Asbestos Landfills				
Backfill and Compaction of Topsoil (8" Layer)	11,000	CY	$ 27	$ 297,000
Surface Grading	16,000	SY	$ 2	$ 32,000
Limited Stormwater Conveyance Swales/Ditches	1	LS	$ 118,000	$ 118,000
Seeding/Vegetation	3.4	ACRE	$ 1,000	$ 3,400
			Subtotal Capping of Landfills	**$ 3,925,050**
ICs and ECs				
Establish ICs for Landfills and Deed Notices	1	LS	$ 20,000	$ 20,000
Fencing Around Perimeter of Landfills	8,264	LF	$ 8	$ 61,979
			Subtotal ICs and ECs Costs	**$ 81,979**
			Subtotal of Direct Capital Costs	**$ 4,007,029**
Indirect Capital Costs				
Scope/Bid Contingency (Capping)	30%	% of Respective Capital Costs		$ 1,177,515
Project Management	5%	% of Total Direct Capital Costs		$ 259,227
Remedial Design	8%	% of Total Direct Capital Costs		$ 414,764
Construction Management	6%	% of Total Direct Capital Costs		$ 311,073
			Subtotal of Indirect Capital Costs	**$ 2,162,578**
			Total Capital Costs	**$ 6,169,608**
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Annual Costs (Capping)				
Cap Maintenance	22	ACRE	$ 1,000	$ 22,000
Site Maintenance	1	LS	$ 15,000	$ 15,000
Reporting	1	LS	$ 10,000	$ 10,000
Contingency	10%	% of Annual Costs		$ 4,700
			Subtotal of Direct OM&M Costs	**$ 51,700**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	5%	% of Direct OM&M Costs		$ 2,585
			Subtotal of Indirect OM&M Costs	**$ 12,585**
			Total OM&M Costs	**$ 64,285**
		Estimated Total 30-year OM&M Costs	**30**	**$ 1,928,550**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 797,715**
			TOTAL PRESENT VALUE COSTS	**$ 6,967,323**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Direct Capital Costs

Capping of Landfills

- Mobilization/Demobilization/General Conditions
  - Includes Site preparation activities such as mobilization/demobilization of equipment and construction of temporary facilities.
  - Includes General Requirements such as permitting, coordination with regulatory agencies, insurance requirements, etc.
  - Based on capital cost of job, see Introduction, Capital Costs section.
- Erosion and Sediment Control
  - Based on professional judgement.
- Construction Surveying
  - Drone surveying of landfills throughout various phases of the construction process.
  - Based on previous experience on similar projects.

<u>Industrial Landfill</u>

- Backfill with Onsite Material for Grading
  - Assumes 78,000 CY of material required for subgrade, to allow for a 3% slope. Based on a capacity analysis completed for South Percolation Ponds Removal Action.
  - Assuming 20,000 CY of material will be placed from South Percolation Ponds Removal Action, 58,000 CY of material would be required for grading.
  - Excludes import costs, assuming import is included under the Soil and North Percolation Pond DUs.
  - Unit rate based on previous experience on similar projects.
- Surface Grading
  - Assumes grading of the existing Industrial Landfill surface will be required to meet minimum slope requirements of final cap.
  - Unit cost based on previous experience on similar projects.
- Backfill and Compaction of Onsite Material
  - Assumes 6 inches of sand required to allow for smooth subgrade and prevent protrusion that may penetrate geomembrane.
  - Assumes sand will be imported to the Site.
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Installation of Geomembrane Layer
  - Includes cost for material and installation of a 40-mil low permeability HDPE geomembrane.
  - Geomembrane installed across entire landfill footprint, assuming a 2% increase in surface area to account for overlap of sheets and tied into anchor trench.
  - Material unit cost based on average of quotes from vendors.
  - Installation unit cost based on previous experience with similar projects.
- Installation of Geocomposite Drainage Layer
  - Geocomposite comprised of non-woven polypropylene geotextile fabric bonded to a geonet made from HDPE.
  - Geomembrane installed across entire landfill footprint, assuming a 2% increase in surface area to account for overlap of sheets and tied into anchor trench.

- Material unit cost based on average of quotes from vendors.
- Installation unit cost based on previous experience with similar projects.

- Backfill and Compaction of Imported Soil
  - Assumes 18 inches of soil barrier layer across the entire footprint.
  - Unit cost includes both material and installation cost.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the entire Industrial Landfill footprint to promote vegetation.
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Installation of Stormwater Conveyance Swales/Ditches
  - Includes installation of surface water drainage design measures, includes swales/ditches, to direct stormwater runoff away from landfill and provide erosion control.
  - Unit cost based on previous experience with similar projects.
- Perimeter Soil Berm
  - See Alternative LDU1/GW-2 Cost Estimate Notes.
- Seeding/Vegetation
  - Assumes seeding for vegetation across entire landfill footprint.
  - Unit cost based on based on previous experience with similar projects.

<u>Asbestos Landfills</u>

- Backfill and Compaction of Topsoil
  - Minimum of 12 inches of soil cover required.
  - Assumes an average of 4 inches of existing soil cover across the Asbestos Landfills, therefore an additional 8 inches of imported topsoil required.
  - Backfill and compaction assumptions mirror those for the Industrial Landfill.
- Surface Grading
  - Assumptions for Asbestos Landfills mirror those for the Industrial Landfill.
- Limited Stormwater Conveyance Swales/Ditches; Seeding/Vegetation
  - Includes limited installation of surface water drainage design measures, as necessary, to direct stormwater runoff away from landfills and provide erosion control.
- Seeding/Vegetation
  - Assumptions for Asbestos Landfills mirror those for the Industrial Landfill.

ICs and ECs

- Establish ICs for Landfills and Deed Notices
    - ICs include prohibiting residential use as well as any activities that can comprise the integrity of the cap.
- Fencing Around Perimeter of Landfills
    - Fencing around perimeter of landfills as an EC.
    - Based on RS Means software.

Direct OM&M Costs

Annual Costs

- Cap Maintenance
    - Includes mowing, weed spraying, maintenance of stormwater conveyance systems.
    - Based on previous Site experience and professional judgement.
    - Includes maintenance of caps at East Landfill (2.4 acres), Industrial Landfill (12.4 acres), Sanitary Landfill (3.8 acres), and Asbestos Landfills (3.4 acres).
- Site Maintenance
    - Repair of landfill perimeter fencing and roadways.
    - Based on previous Site experience and professional judgement.
- Reporting
    - Based on professional judgement.

Cost Estimates for Soil DU Alternatives

Feasibility Study Cost Estimate
Soil DU Alternatives
Summary of Estimated Costs

Alternative	Capital Cost	Total OM&M (PV)	Total Cost (PV)
SO-1: No Action	$ -	$ -	$ -
SO-2: Covers with Hotspot Excavation	$ 1,267,440	$ 338,866	$ 1,606,306
SO-3: *In Situ* Phytoremediation with Hotspot Excavation	$ 775,851	$ 396,097	$ 1,171,948
SO-4: Excavation and Onsite Consolidation	$ 1,237,989	$ -	$ 1,237,989

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Feasibility Study Cost Estimate
Alternative SO-2: Covers with Hotspot Excavation

Description of Alternative:

- Install a soil cover for select areas of spatially concentrated COC distribution within the Soil DU.
- Establish ICs in cover areas and land use restrictions for the DU to allow for commercial or industrial use, only.
- Excavation of discontinuous, isolated soil hotspots outside of cover footprints, as needed. Excavated materials could be consolidated underneath covers, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

This alternative is described in Section 5.3.2.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 100,000	$ 100,000
***In situ* Pre-Characterization Sampling**				
Pre-characterization Sampling Labor	10	Days	$ 1,200	$ 12,000
Analysis of Copper for AOC A	8	Samples	$ 79	$ 630
Analysis of PAHs for AOCs C through G	84	Samples	$ 189	$ 15,876
Hotspot Excavation				
Excavation and Staging of Impacted Material from AOC B	2,770	CY	$ 9	$ 24,930
Relocation of Material from AOC B to Onsite Repository	3,500	CY	$ 5	$ 17,500
Excavation of Impacted Material from AOCs A, F, and G; Consolidation in Another AOC Underneath Soil Cover	2,770	CY	$ 9	$ 24,930
Confirmatory Endpoint Sampling				
Analysis of Copper for AOC A	2	Samples	$ 79	$ 158
Analysis of PAHs for AOCs F and G	4	Samples	$ 189	$ 756
Soil Cover Construction				
Backfill and Compaction of Imported Soil (18" Layer)	15,100	CY	$ 27	$ 407,700
Backfill and Compaction of Topsoil (6" Layer)	5,000	CY	$ 35	$ 175,000
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	1,400	CY	$ 35	$ 49,000
Seeding/Vegetation	8	Acres	$ 1,000	$ 7,960
			Subtotal of Direct Capital Costs	**$ 836,440**
Indirect Capital Costs				
Scope/Bid Contingency	20%	% of Direct Capital Cost		$ 168,000
Project Management	6%	% of Direct Capital Cost		$ 61,000
Remedial Design / Construction Completion Reporting	12%	% of Direct Capital Cost		$ 121,000
Construction Management	8%	% of Direct Capital Cost		$ 81,000
			Subtotal of Indirect Capital Costs	**$ 431,000**
			Total Capital Costs	**$ 1,267,440**
OPERATION MAINTENANCE AND MONITORING				
Direct OMM Costs				
Annual Costs				
Cover Maintenance	6	acres	$ 300	$ 1,900
Cover Inspections & Reporting	1	LS	$ 15,000	$ 15,000
Contingency	20%	% of Annual Costs		$ 3,380
			Subtotal of Direct OMM Costs	**$ 20,280**
Indirect OMM Costs				
Administrative Costs	1	LS	$ 5,000	$ 5,000
Contingency	10%	% of Direct OM&M Costs		$ 2,028
			Subtotal of Indirect OMM Costs	**$ 7,028**
			Total OMM Costs	**$ 27,308**
			Estimated Total 30-year OMM Costs	**$ 819,240**
			Estimated PV Total 30-year OMM Costs	**$ 338,866**
			TOTAL PRESENT VALUE COSTS	**$ 1,606,306**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Direct Capital Costs

Costs for establishment of ICs under this alternative are assumed to be incorporated under IC costs for other DUs.

Site Preparation

- Mobilization/Demobilization/General Conditions
  - Includes Site preparation activities as needed such as mobilization/demobilization of construction equipment, construction of temporary facilities, installation of temporary sediment/erosion controls, etc.
  - Includes General requirements as needed such as permitting, coordination with regulatory agencies, insurance requirements, etc.
  - Based on capital cost of job, see Introduction, Capital Costs section.

***In Situ* Pre-Characterization Sampling**

- Pre-characterization Sampling Labor
  - In situ pre-characterization soil sampling for AOC A through G, assuming delineation of AOCs by stepping out from samples resulting in exceedances of PRGs in 50 ft intervals, for a total of 92 soil samples. Number of samples dependent on sample results.
  - Includes labor cost to perform the sampling event, assuming 10 samples collected per person per day.
  - Unit rates based on previous Site experience.
- Analysis of Copper for AOC A
  - Laboratory analytical costs for soil sample analysis of TAL metals.
  - Unit costs based on quote from vendor.
- Analysis of PAHs for AOCs C through G
  - Laboratory analytical costs for soil sample analysis of PAHs.
  - Unit costs based on quote from vendor.

Hotspot Excavation

- Excavation and Staging of Impacted Material from AOC B
  - Includes cost for excavation of soil to a depth of 2 feet within AOC B and staging of the material.
  - Unit cost based on quotes from contractors and previous Site experience.
- Relocation of Material from AOC B to Onsite Repository
  - Includes cost for transportation of soil to an onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).
  - Assumes 25% increase in volume of excavated soil from fluff factor for trucking purposes.
  - Based on quotes from contractors and previous Site experience.
- Excavation of Impacted Material from AOCs A, F, and G; Consolidation in Another AOC Underneath Soil Cover
  - Includes cost for excavation of soil to a depth of 2 feet in AOCs A, F, and G and directly placing this material within another AOC.
  - Assumes re-handling of material will not be required.
  - Based on quotes from contractors and previous Site experience.

Confirmatory Endpoint Sampling

- Analysis of Copper for AOC A
  - See notes for In Situ Pre-Characterization Sampling – Analysis of Copper for AOC A above.
  - Assumes 2 endpoint samples will be collected per AOC.

- Analysis of PAHs for AOCs F and G
  - See notes for In Situ Pre-Characterization Sampling – Analysis of PAHs for AOCs C through G above.
  - Assumes 2 endpoint samples will be collected per AOC.

Soil Cover Construction

- Backfill and Compaction of Imported Soil
  - Assumes 18 inches of soil cover across areas that do not include soil removal (i.e., AOCs C through E).
  - Unit cost includes both material and installation cost.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across areas that do not include soil removal (i.e., AOCs C through E).
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil cover across hotspots that include soil removal (i.e., AOCs A, B, F, and G).
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Seeding/Vegetation
  - Assumes seeding for vegetation for all disturbed areas (i.e., AOCs A through G)
  - Unit cost based on based on previous experience with similar projects.

Direct OM&M Costs

Annual Costs

- Cover Maintenance
  - Includes mowing, weed spraying, and reseeding of all areas with covers (approximately 6 acres total).
  - Assumes 30% of area will require reseeding each year to maintain health of vegetated cover.
  - Based on previous Site experience and professional judgement.
- Cover Inspections and Reporting
  - Includes routine inspections of soil covers and reporting.
  - Based on professional judgement.

Feasibility Study Cost Estimate
Alternative SO-3: *In Situ* Phytoremediation with Hotspot Excavation

Description of Alternative:

- *In situ* treatment of spatially concentrated PAH-impacted soils via phytoremediation.
- Establish ICs for areas of phytoremediation until treatment is completed, and land use restrictions for the DU to allow for commercial or industrial use, only.
- Excavation of discontinuous, isolated soil hotspots outside of treatment footprints, as needed. Excavated materials could be consolidated within treatment areas, if appropriate, or disposed of at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).

This alternative is described in Section 5.3.3.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 100,000	$ 100,000
***In situ* pre-characterization sampling**				
Pre-characterization Sampling Labor	10	Days	$ 1,200	$ 12,000
Analysis of Copper for AOC A	8	Samples	$ 79	$ 630
Analysis of PAHs for AOCs C through G	84	Samples	$ 189	$ 15,876
Hotspot Excavation				
Excavation and Staging of Impacted Material from AOC A and AOC B	3,160	CY	$ 9	$ 28,440
Repository	4,000	CY	$ 5	$ 20,000
Excavation of Impacted Material from AOC F and AOC G; Consolidation in Another AOC within Phytoremediation Treatment Areas	2,380	CY	$ 9	$ 21,420
Confirmatory Endpoint Sampling				
Analysis of Copper for AOC A	2	Samples	$ 79	$ 158
Analysis of PAHs for AOCs F and G	4	Samples	$ 189	$ 756
***In situ* Phytoremediation**				
Bench Scale Treatability Study	1	LS	$ 30,000	$ 30,000
Backfill and Compaction of Topsoil (6" Layer)	5,000	CY	$ 35	$ 175,000
Establish Vegetation in Treatment Areas	6	Acres	$ 4,840	$ 30,202
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	1,390	CY	$ 35	$ 48,650
Seeding/Vegetation	2	Acres	$ 1,000	$ 1,720
			Subtotal of Direct Capital Costs	**$ 484,851**
Indirect Capital Costs				
Scope/Bid Contingency	20%	% of Direct Capital Cost		$ 97,000
Project Management	8%	% of Direct Capital Cost		$ 47,000
Remedial Design / Construction Completion Reporting	15%	% of Direct Capital Cost		$ 88,000
Construction Management	10%	% of Direct Capital Cost		$ 59,000
			Subtotal of Indirect Capital Costs	**$ 291,000**
			Total Capital Costs	**$ 775,851**
OPERATION MAINTENANCE AND MONITORING				
Direct OMM Costs				
Annual Costs				
Maintenance of Phytoremediation Treatment Areas	6	acres	$ 1,450	$ 9,048
Rhizosphere Soil Monitoring Sampling Labor	1	Days	$ 1,200	$ 1,200
Analysis of PAHs and Soil Chemistry	12	Samples	$ 296	$ 3,688
Inspections & Reporting	1	LS	$ 25,000	$ 25,000
Contingency	20%	% of Annual Costs		$ 7,787
			Subtotal of Direct OMM Costs	**$ 46,723**
Indirect OMM Costs				
Administrative Costs	1	LS	$ 5,000	$ 5,000
Contingency	10%	% of Direct OM&M Costs		$ 4,672
			Subtotal of Indirect OMM Costs	**$ 9,672**
			Total OMM Costs	**$ 56,395**
			Estimated Total 10-year OMM Costs	**$ 563,953**
			Estimated PV Total 10-year OMM Costs	**$ 396,097**
			TOTAL PRESENT VALUE COSTS	**$ 1,171,948**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative SO-3 Cost Estimate Notes

Direct Capital Costs

Costs for establishment of ICs under this alternative are assumed to be incorporated under IC costs for other DUs.

Site Preparation

- Mobilization/Demobilization/General Conditions
  - See Alternative SO-2 for Cost Estimate Notes.

***In Situ* Pre-Characterization Sampling**

- Pre-characterization Sampling Labor; Analysis of Copper for AOC A; Analysis of PAHs for AOCs C through G
  - See Alternative SO-2 for Cost Estimate Notes.

Hotspot Excavation

- Excavation and Staging of Impacted Material from AOC A and B; Relocation of Material from AOC A and B to Onsite Repository; Excavation of Impacted Material from AOC F and AOC G; Consolidation in Another AOC within Phytoremediation Treatment Areas
  - See Alternative SO-2 for Cost Estimate Notes.

Confirmatory Endpoint Sampling

- Analysis of Copper for AOC A; Analysis of PAHs for AOCs F and G
  - See Alternative SO-2 for Cost Estimate Notes.

***In Situ* Phytoremediation**

- Bench Scale Treatability Study
  - Perform lab-scale treatability study to evaluate plant compatibility and root growth and to determine if additional nutrients are required to promote growth.
  - Performing various trials to aid in treatment design.
  - Based on professional judgement.
- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil for seed layer across phytoremediation areas (i.e., AOCs C through E).
  - See Alternative SO-2 for Cost Estimate Notes.
- Establish Vegetation in Treatment Areas
  - Assumes seeding for growth of various prairie grasses at AOCs C through E.
  - Assumes $1 per square yard.
  - Unit cost based on based on previous experience with similar projects.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - See Alternative SO-2 for Cost Estimate Notes.
- Seeding/Vegetation
  - Assumes seeding for vegetation across hotspots that include soil removal (i.e., AOCs A, B, F, and G).
  - Unit cost based on based on previous experience with similar projects.

Direct OM&M Costs

Annual Costs

- Maintenance of Phytoremediation Treatment Areas
  - Assumes 30% of treatment areas will require reseeding each year to maintain treatment efficiency.
  - Based on professional judgement.
- Rhizosphere Soil Monitoring Sampling Labor
  - Includes labor cost to perform one sampling event each year, assuming 10 samples collected per person per day.
  - Unit rates based on previous Site experience.
- Analysis of PAHs and Soil Chemistry
  - Laboratory analytical costs for rhizosphere soil sample analysis of PAHs, pH, and key plant nutrients.
  - Assumes 2 samples per acre.
  - Unit costs based on quote from vendor.
- Inspections & Reporting
  - Includes routine inspections of phytoremediation treatment areas and reporting.
  - Based on professional judgement.

Feasibility Study Cost Estimate
Alternative SO-4: Excavation and Onsite Consolidation

Description of Alternative:

- Excavate impacted soil in the Soil DU with disposal at an existing onsite repository (i.e., Industrial Landfill or Wet Scrubber Sludge Pond).
- Establish land use restrictions for the DU to allow for commercial or industrial use, only.

This alternative is described in Section 5.3.4.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 100,000	$ 100,000
***In situ* pre-characterization sampling**				
Pre-characterization Sampling Labor	10	Days	$ 1,200	$ 12,000
Analysis of Copper for AOC A	8	Samples	$ 79	$ 630
Analysis of PAHs for AOCs C through G	84	Samples	$ 189	$ 15,876
Excavation and Onsite Consolidation				
Excavation and Staging	25,670	CY	$ 9	$ 231,030
Relocation to Onsite Repository	32,100	CY	$ 5	$ 160,500
Confirmatory Endpoint Sampling				
Analysis of Copper for AOC A	2	Samples	$ 79	$ 158
Analysis of PAHs for AOCs C through G	15	Samples	$ 189	$ 2,835
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	6,400	CY	$ 35	$ 224,000
Seeding/Vegetation	8	Acres	$ 1,000	$ 7,960
			Subtotal of Direct Capital Costs	**$ 754,989**
Indirect Capital Costs				
Scope/Bid Contingency	30%	% of Direct Capital Cost		$ 227,000
Project Management	6%	% of Direct Capital Cost		$ 59,000
Remedial Design / Construction Completion Reporting	12%	% of Direct Capital Cost		$ 118,000
Construction Management	8%	% of Direct Capital Cost		$ 79,000
			Subtotal of Indirect Capital Costs	**$ 483,000**
			Total Capital Costs	**$ 1,237,989**
			TOTAL PRESENT VALUE COSTS	**$ 1,237,989**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative SO-4 Cost Estimate Notes

Direct Capital Costs

Costs for establishment of ICs under this alternative are assumed to be incorporated under ICs cost for other DUs.

Site Preparation

- Mobilization/Demobilization/General Conditions
  - See Alternative SO-2 for Cost Estimate Notes.

***In Situ* Pre-Characterization Sampling**

- Pre-characterization Sampling Labor; Analysis of Copper for AOC A; Analysis of PAHs for AOCs C through G
  - See Alternative SO-2 for Cost Estimate Notes.

Excavation and Onsite Consolidation

- Excavation and Staging
  - Includes cost for excavation of soil to a depth of 2 feet for all AOCs and staging of the material.
  - Unit cost based on quotes from contractors and previous Site experience.
- Relocation to Onsite Repository
  - See Alternative SO-2 for Cost Estimate Notes.

Confirmatory Endpoint Sampling

- Analysis of Copper for AOC A
  - See Alternative SO-2 for Cost Estimate Notes.
- Analysis of PAHs for AOCs C and G
  - See Alternative SO-2 for Cost Estimate Notes.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil cover across all disturbed areas (i.e., AOCs A through G).
  - See Alternative SO-2 for Cost Estimate Notes.
- Seeding/Vegetation
  - Assumes seeding for vegetation for all disturbed areas (i.e., AOCs A through G)
  - Unit cost based on based on previous experience with similar projects.

Cost Estimates for North Percolation Pond DU Alternatives

Feasibility Study Cost Estimate
North Percolation Pond DU Alternatives
Summary of Estimated Costs

Alternative	Capital Cost	Total OM&M (PV)	Total Cost (PV)
NPP-1: No Action	$ -	$ -	$ -
NPP-2: Limited Excavation with Covers	$ 2,493,668	$ 635,343	$ 3,129,010
NPP-3: Excavation with Cover	$ 1,972,829	$ 373,264	$ 2,346,093
NPP-4: Excavation and Onsite Consolidation	$ 2,286,195	$ -	$ 2,286,195

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Preliminary Feasibility Study Cost Estimate
North Percolation Pond DU, Alternative NPP-2: Limited Excavation with Covers

Description of Alternative:

- Excavate impacted material in the influent and effluent ditches and consolidate in the North-East Percolation Pond;
- Install soil covers at the North-East and North-West Percolation Ponds with physical solidification as needed;
- Establish ICs and ECs, including land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.2.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 200,000	$ 200,000
Decommission influent stormwater pipes	1	LS	$ 10,000	$ 10,000
Excavation and Onsite Consolidation				
Excavation and Relocation to North-East Percolation Pond	2,880	CY	$ 9	$ 25,920
Physical Solidification of Viscous, Carbonaceous Material	12,740	CY	$ 35	$ 445,900
Soil Cover Construction				
Backfill and Compaction of Imported Soil (18" Layer)	24,200	CY	$ 27	$ 653,403
Backfill and Compaction of Topsoil (6" Layer)	8,067	CY	$ 35	$ 282,334
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	484	CY	$ 35	$ 16,940
Seeding/Vegetation	11	Acres	$ 1,000	$ 10,600
Confirmatory Endpoint Sampling				
Sampling & Analysis of NPP DU Soil / Sediment COCs	10	Samples	$ 268	$ 2,570
			Subtotal of Direct Capital Costs	**$ 1,647,668**
Indirect Capital Costs				
Scope/Bid Contingency	20%	% of Direct Capital Cost		$ 330,000
Project Management	6%	% of Direct Capital Cost		$ 119,000
Remedial Design / Construction Completion Reporting	12%	% of Direct Capital Cost		$ 238,000
Construction Management	8%	% of Direct Capital Cost		$ 159,000
			Subtotal of Indirect Capital Costs	**$ 846,000**
			Total Capital Costs	**$ 2,493,668**
OPERATION MAINTENANCE AND MONITORING				
Direct OMM Costs				
Annual Costs				
Cover Maintenance	10	acres	$ 2,000	$ 20,000
Cover Inspections & Reporting	1	LS	$ 15,000	$ 15,000
Contingency	20%	% of Annual Costs		$ 7,000
			Subtotal of Direct OMM Costs	**$ 42,000**
Indirect OMM Costs				
Administrative Costs	1	LS	$ 5,000	$ 5,000
Contingency	10%	% of Direct OM&M Costs		$ 4,200
			Subtotal of Indirect OMM Costs	**$ 9,200**
			Total OMM Costs	**$ 51,200**
			Estimated Total 30-year OMM Costs	**$ 1,536,000**
			Estimated PV Total 30-year OMM Costs	**$ 635,343**
			TOTAL COSTS	**$ 3,129,010**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative NPP-2 Cost Estimate Notes

Direct Capital Costs

Costs for establishment of ICs under this alternative are assumed to be incorporated under ICs cost for other DUs.

Site Preparation

- Mobilization/Demobilization/General Conditions
  - Includes Site preparation activities as needed such as mobilization/demobilization of construction equipment, construction of temporary facilities, installation of temporary sediment/erosion controls, etc.
  - Includes General requirements as needed such as permitting, coordination with regulatory agencies, insurance requirements, etc.
  - Based on capital cost of job, see Introduction, Capital Costs section.
- Decommission Influent Stormwater Pipes
  - Includes abandonment of influent pipes by cutting and sealing with flowable fill.
  - Based on professional judgement.

Excavation and Onsite Consolidation

- Excavation and Relocation to North-East Percolation Pond
  - Includes cost for excavation of soil/sediment from the influent and overflow ditches to an average depth of 3 feet.
  - Assumes handling of material at excavation location.
  - Unit cost based on quotes from contractors and previous Site experience.
- Physical Solidification of Viscous, Carbonaceous Material
  - Assumes physical solidification of 50% by volume of the material within the North-East Percolation Pond, the influent ditch, and the overflow ditch; and 25% by volume of the material within the North-West Percolation Pond by mixing with amendments (e.g., cement kiln dust, lime dust, etc.).
  - Assumes average depth of 4 feet for North-East Percolation Pond and 2 feet for North-West Percolation Pond.
  - Unit cost based on quotes from contractors and previous experience on similar projects.

Soil Cover Construction

- Backfill and Compaction of Imported Soil
  - Assumes 18 inches of soil cover across the North-East and North-West Percolation Ponds.
  - Unit cost includes both material and installation cost.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.
- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the North-East and North-West Percolation Ponds.
  - Unit cost includes both cost for material and installation.
  - Material unit cost based on quote from local vendors.
  - Installation unit cost based on previous experience with similar projects.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the influent and overflow ditches.
  - See notes above for Soil Cover Construction

- Seeding/Vegetation
    - Assumes seeding for vegetation for all disturbed areas.
    - Unit cost based on based on previous experience with similar projects.

Confirmatory Endpoint Sampling

- Sampling & Analysis of NPP DU Soil / Sediment COCs
    - Assumes 1 endpoint sample collected in influent and overflow ditches per 200 linear feet for analysis of metals and PAHs.
    - Unit cost based on quote from vendor.

Direct OM&M Costs

Annual Costs

- Cover Maintenance
    - Includes mowing, weed spraying, and reseeding of all areas with covers.
    - Based on previous Site experience and professional judgement.
- Cover Inspections and Reporting
    - Includes routine inspections of soil covers and reporting.
    - Based on professional judgement.

Preliminary Feasibility Study Cost Estimate
North Percolation Pond DU, Alternative NPP-3: Excavation with Cover

Description of Alternative:

- Excavate impacted material in the North-West Percolation Pond, influent ditch, and effluent ditch;
- Consolidate excavated materials and install soil cover at the North-East Percolation Pond with physical solidification as needed;
- Establish ICs and ECs, including land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.3.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 200,000	$ 200,000
Decommission influent stormwater pipes	1	LS	$ 10,000	$ 10,000
Excavation and Onsite Consolidation				
Excavation and Relocation to North-East Percolation Pond	22,280	CY	$ 9	$ 200,520
Physical Solidification of Viscous, Carbonaceous Material	12,740	CY	$ 35	$ 445,900
Soil Cover Construction				
Backfill and Compaction of Imported Soil (18" Layer)	4,840	CY	$ 27	$ 130,681
Backfill and Compaction of Topsoil (6" Layer)	1,613	CY	$ 35	$ 56,467
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	6,937	CY	$ 35	$ 242,808
Seeding/Vegetation	11	Acres	$ 1,000	$ 10,600
Confirmatory Endpoint Sampling				
Sampling & Analysis of NPP DU Soil / Sediment COCs	26	Samples	$ 268	$ 6,854
			Subtotal of Direct Capital Costs	**$ 1,303,829**
Indirect Capital Costs				
Scope/Bid Contingency	20%	% of Direct Capital Cost		$ 261,000
Project Management	6%	% of Direct Capital Cost		$ 94,000
Remedial Design / Construction Completion Reporting	12%	% of Direct Capital Cost		$ 188,000
Construction Management	8%	% of Direct Capital Cost		$ 126,000
			Subtotal of Indirect Capital Costs	**$ 669,000**
			Total Capital Costs	**$ 1,972,829**
OPERATION MAINTENANCE AND MONITORING				
Direct OMM Costs				
Annual Costs				
Cover Maintenance	2	acres	$ 2,000	$ 4,000
Cover Inspections & Reporting	1	LS	$ 15,000	$ 15,000
Contingency	20%	% of Annual Costs		$ 3,800
			Subtotal of Direct OMM Costs	**$ 22,800**
Indirect OMM Costs				
Administrative Costs	1	LS	$ 5,000	$ 5,000
Contingency	10%	% of Direct OM&M Costs		$ 2,280
			Subtotal of Indirect OMM Costs	**$ 7,280**
			Total OMM Costs	**$ 30,080**
			Estimated Total 30-year OMM Costs	**$ 902,400**
			Estimated PV Total 30-year OMM Costs	**$ 373,264**
			TOTAL COSTS	**$ 2,346,093**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative NPP-3 Cost Estimate Notes

Direct Capital Costs

Costs for establishment of ICs under this alternative are assumed to be incorporated under ICs cost for other DUs.

Site Preparation

- Mobilization/Demobilization/General Conditions; Decommission Influent Stormwater Pipes
  - See Alternative NPP-2 Cost Estimate Notes.

Excavation and Onsite Consolidation

- Excavation and Relocation to North-East Percolation Pond
  - Includes cost for excavation of soil/sediment from the North-West Percolation Pond to an average depth of 2 feet and excavation of the influent and overflow ditches to an average depth of 3 feet.
  - Assumes handling of material at excavation location.
  - Unit cost based on quotes from contractors and previous Site experience.
- Physical Solidification of Viscous, Carbonaceous Material
  - See Alternative NPP-2 Cost Estimate Notes.

Soil Cover Construction

- Backfill and Compaction of Imported Soil; Backfill and Compaction of Topsoil
  - Assumes 18 inches of imported soil cover plus 6 inches of imported topsoil cover across the North-East Percolation Pond.
  - See notes above for Alternative NPP-2.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the North-West Percolation Pond, the influent ditch, and the overflow ditch.
  - See notes above for Alternative NPP-2.
- Seeding/Vegetation
  - See Alternative NPP-2 Cost Estimate Notes.

Confirmatory Endpoint Sampling

- Sampling & Analysis of NPP DU Soil / Sediment COCs
  - Assumes 1 endpoint sample per acre collected in the North-West Percolation Pond and 1 endpoint sample collected in the influent and overflow ditches per 200 linear feet for analysis of metals and PAHs.
  - Unit cost based on previous Site experience.

Direct OM&M Costs

Annual Costs

- Cover Maintenance; Cover Inspections and Reporting
  - See Alternative NPP-2 Cost Estimate Notes.

Preliminary Feasibility Study Cost Estimate
North Percolation Pond DU, Alternative NPP-4: Excavation and Onsite Consolidation

Description of Alternative:

- Excavate impacted material in the North-East Percolation Pond, North-West Percolation Pond, influent ditch, and effluent ditch;
- Consolidate excavated materials at the Wet Scrubber Sludge Pond with physical solidification as needed;
- Establish land use restrictions for the DU to allow for commercial or industrial use, only; and
- Decommission stormwater influent pipes.

This alternative is described in Section 5.4.4.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Site Preparation				
Mobilization/Demobilization/General Conditions	1	LS	$ 200,000	$ 200,000
Decommission influent stormwater pipes	1	LS	$ 10,000	$ 10,000
Excavation and Onsite Consolidation				
Excavation and Staging	35,180	CY	$ 9	$ 316,620
Relocation of Material to Onsite Repository	43,975	CY	$ 5	$ 219,875
Physical Solidification of Viscous, Carbonaceous Material	12,740	CY	$ 35	$ 445,900
Post Removal Response Action				
Backfill and Compaction of Topsoil (6" Layer)	8,551	CY	$ 35	$ 299,275
Seeding/Vegetation	11	Acres	$ 1,000	$ 10,600
Confirmatory Endpoint Sampling				
Sampling & Analysis of NPP DU Soil / Sediment COCs	30	Samples	$ 268	$ 7,925
			Subtotal of Direct Capital Costs	**$ 1,510,195**
Indirect Capital Costs				
Scope/Bid Contingency	20%	% of Direct Capital Cost		$ 303,000
Project Management	6%	% of Direct Capital Cost		$ 109,000
Remedial Design / Construction Completion Reporting	12%	% of Direct Capital Cost		$ 218,000
Construction Management	8%	% of Direct Capital Cost		$ 146,000
			Subtotal of Indirect Capital Costs	**$ 776,000**
			Total Capital Costs	**$ 2,286,195**
			TOTAL COSTS	**$ 2,286,195**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative NPP-4 Cost Estimate Notes

Direct Capital Costs

Site Preparation

- Mobilization/Demobilization/General Conditions; Decommission Influent Stormwater Pipes
  - See Alternative NPP-2 Cost Estimate Notes.

Excavation and Onsite Consolidation

- Excavation and Staging
  - Includes cost for excavation of all impacted soil/sediment from the North Percolation Pond DU. Assumes excavation of North-East Percolation Pond to an average depth of 4 feet, the North-West Percolation Pond to an average depth of 2 feet, and the influent and overflow ditches to an average depth of 3 feet.
  - Assumes material will be staged.
  - Unit cost based on quotes from contractors and previous Site experience.
- Relocation of Material to Onsite Repository
  - Includes cost for transportation of soil to an onsite repository (i.e., the Wet Scrubber Sludge Pond).
  - Assumes 25% increase in volume of excavated soil from fluff factor for trucking purposes.
  - Based on quotes from contractors and previous Site experience.
- Physical Solidification of Viscous, Carbonaceous Material
  - See Alternative NPP-2 Cost Estimate Notes.

Post Removal Response Action

- Backfill and Compaction of Topsoil
  - Assumes 6 inches of topsoil across the North-East Percolation Pond, the North-West Percolation Pond, and the influent and overflow ditches.
  - See notes above for Alternative NPP-2.
- Seeding/Vegetation
  - See Alternative NPP-2 Cost Estimate Notes.

Confirmatory Endpoint Sampling

- Sampling & Analysis of NPP DU Soil / Sediment COCs
  - Assumes 1 endpoint sample per acre collected in the North-East Percolation Pond and North-West Percolation Pond and 1 endpoint sample collected in the influent and overflow ditches per 200 linear feet for analysis of metals and PAHs.
  - Unit cost based on previous Site experience.

Cost Estimates for River Area DU Alternatives

Feasibility Study Cost Estimate
River Area DU Alternatives
Summary of Estimated Costs

Alternative	Capital Cost	Total OM&M (PV)	Total Cost (PV)
RADU-1: No Further Action	$ -	$ -	$ -
RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater	$ -	$ 1,401,725	$ 1,401,725

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Feasibility Study Cost Estimate
Alternative RADU-2: Long-Term Monitoring of Surface Water and Sediment Porewater

Description of Alternative:

- Implementation of Removal Action at the South Percolation Ponds, including:
  - o Decommissioning the influent pipe from which stormwater enters the South Percolation Pond system; and
  - o Excavating impacted sediment in the South Percolation Ponds with disposal at an existing onsite repository (i.e., Industrial Landfill).
- Comprehensive long-term monitoring of cyanide in the River Area DU surface water and sediment porewater.
- Monitoring of metals1, fluoride, and PAHs2 in the River Area DU surface water as identified in the Surface Water RAO and PRGs until concurrence to cease monitoring is obtained from the agencies (e.g., multiple sampling rounds demonstrate compliance with ARARs)

1 Aluminum, arsenic, barium, copper, iron, lead, mercury, and thallium
2 Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-C,D)pyrene

This alternative is described in Section 5.5.2.

Description	Estimated Quantities	Unit	Unit Cost	Total Cost
CAPITAL COSTS				
Direct Capital Costs				
Removal Action				
Removal Action is currently being implemented pursuant to an Administrative Order on Consent; therefore costs associated with the Removal Action are not evaluated as a part of this FS.				
OPERATION MAINTENANCE AND MONITORING				
Direct OM&M Costs				
Long-Term Monitoring				
Boat Rental	1	Event	$ 19,000	$ 19,000
Labor and Equipment	1	Event	$ 19,000	$ 19,000
Analysis of Surface Water Samples	20	Sample	$ 800	$ 16,000
Analysis of Sediment Porewater Samples	20	Sample	$ 200	$ 4,000
Reporting	1	LS	$ 20,000	$ 20,000
Contingency	20%	% of Annual Costs		$ 15,600
			Subtotal of Direct OM&M Costs	**$ 93,600**
Indirect OM&M and Contingency Costs				
Administrative Costs	1	LS	$ 10,000	$ 10,000
Contingency	10%	% of Direct OM&M Costs		$ 9,360
			Subtotal of Indirect OM&M Costs	**$ 19,360**
			Total OM&M Costs	**$ 112,960**
		Estimated Total 30-year OM&M Costs	**30**	**$ 3,388,800**
		Estimated PV Total 30-year OM&M Costs	**7%**	**$ 1,401,725**
			TOTAL PRESENT VALUE COSTS	**$ 1,401,725**

Notes:
1. The information in this preliminary cost estimate is based on available information regarding Site conditions and the anticipated scope of this remedial alternative. Changes in the cost elements are likely to occur as a result of the engineering design of the remedial alternative. This cost estimate represents an expected accuracy of -30 to +50 percent in accordance with CERCLA guidance.
2. See attached cost estimate notes for basis of costs and accompanying assumptions.

Alternative RADU-2 Cost Estimate Notes

Direct Capital Costs

Removal Action

- Removal Action at the South Percolation Ponds was performed in accordance with the requirements of the Administrative Order on Consent effective July 21, 2020, between CFAC and USEPA (CERCLA Docket No. 08-2020-0002); therefore costs associated with the Removal Action are not evaluated as a part of this FS.

Direct OM&M Costs

Long-Term Monitoring

- Boat Rental
  - Includes labor for two boat engineers, fuel, and boat rental fee for one sampling event each year.
  - Assumes 1 sampling event will take 5 days to complete.
  - Based on quote provided by local vendor.
- Labor and Equipment
  - Includes labor and equipment costs to perform one sampling event each year, assuming 8 samples collected per day.
  - Unit rates based on previous Site experience.
- Analysis of Surface Water Samples
  - Laboratory analytical costs for surface water sample analysis of the following parameters: metals (total and dissolved), fluoride, PAHs, total cyanide, free cyanide, and dissolved cyanide (total and free).
  - Includes data validation of sampling results.
  - Unit costs based on previous Site experience and quote from vendor.
- Analysis of Sediment Porewater Samples
  - Laboratory analytical costs for sediment porewater sample analysis of the following parameters: total cyanide, free cyanide, and dissolved cyanide (total and free).
  - Includes data validation of sampling results.
  - Unit costs based on previous Site experience and quote from vendor.
- Reporting
  - Based on professional judgement.