ENGINEERING EVALUATION/COST ANALYSIS FOR THE MIKE HORSE DAM AND IMPOUNDMENT TAILINGS, LOWER MIKE HORSE CREEK, BEARTRAP CREEK AND THE UPPER BLACKFOOT RIVER FLOODPLAIN REMOVAL AREAS UPPER BLACKFOOT MINING COMPLEX

LEWIS AND CLARK COUNTY, MT

- FINAL -

Prepared For:

U.S.D.A. Forest Service
Region 1
P.O. Box 7699
Missoula, MT 59807

ASARCO LLC
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Osburn, ID 83849

JULY 2007

Hydrometrics, Inc.
Consulting Scientists and Engineers

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ABA	Acid-Base-Accounting
AMSL	Above Mean Sea Level
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
ARCO	Atlantic Richfield Company
ASARCO	ASARCO, LLC
CECRA	State of Montana Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CoCs	Chemicals of Concern
CPT	Cone Penetrometer Testing
CSM	Conceptual Site Model
DI	Deionized
DOE	U.S. Department of Energy
EA	Environmental Assessment
EAP	Emergency Action Plan
Eco-SSLs	Soil Screening Levels (also referred to as SSLs)
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
FWP	Montana Department of Fish, Wildlife and Parks
GWIC	Montana Department of Natural Resources and Conservation Groundwater Information Center
HDPE	High Density Poly-Ethylene
HELP	Hydrologic Evaluation of Landfill Performance
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
MAP	Mean Annual Precipitation
MBMG	Montana Bureau of Mines and Geology
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDEQ	Montana Department of Environmental Quality (formerly MDHES)
MDEQ-AMRB	Montana Department of Environmental Quality-Abandoned Mine Reclamation Bureau
MDHES	Montana Department of Health and Environmental Sciences (now MDEQ)
MHM&MC	Mike Horse Mining and Milling Company
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFS	National Forest System
NOAA	National Oceanographic and Atmospheric Administration
O&M	Operations and Maintenance
PMF	Probable Maximum Flood
PLP	Potentially Liable Person
PMP	Probable Maximum Precipitation
PVC	Poly Vinyl Chloride
RAO	Removal Action Objective
RI/FS	Remedial Investigation and Feasibility Study
SACM	Superfund Accelerated Cleanup Model
SSLs	Soil Screening Levels (also referred to as Eco-SSLs)

Su	Unconfined Shear Strength
TMDL	Total Maximum Daily Load
UBMC	Upper Blackfoot Mining Complex (also referred to as the Heddleston Mining District or the Mike Horse Mine)
UCL	Upper Confidence Level
USFS	U.S. Department of Agriculture, Forest Service
VCRA	Voluntary Cleanup and Redevelopment Act
bgs	below ground surface
cfs	cubic feet per second
cm/sec	centimeters per second
cy	cubic yard
ft	feet
gpm	gallon per minute
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
oz/sq yd	ounce per square yard
pcf	pounds-per-cubic-foot
psf	pounds-per-square-foot
T	tons
µg/L	micrograms per liter
µm	micrometer
°F	degrees fahrenheit

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1.0 INTRODUCTION

The Upper Blackfoot Mining Complex site (UBMC) is an area of historic mining near the headwaters of the Blackfoot River in Lewis and Clark County, Montana. The UBMC has also been referred to as the Heddleston Mining District or the Mike Horse Mine, although the Mike Horse Mine is only one of several individual mines located within the district. This document presents an Engineering Evaluation/Cost Analysis (EE/CA) for portions of the UBMC, and has been prepared by Hydrometrics, Inc. for ASARCO LLC (ASARCO), and in cooperation with the United States Department of Agriculture-Forest Service (USFS). The EE/CA provides an evaluation of appropriate removal actions for mining-related impacts primarily on certain lands within the National Forest System (NFS) at the UBMC (the EE/CA area). This EE/CA has been prepared pursuant to an Administrative Order on Consent (AOC) entered into voluntarily by the USFS and ASARCO.

This EE/CA has been prepared in accordance with the Non-Time-Critical Removal Action process described in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Non-time-critical removal actions represent a primary tool in the Superfund Accelerated Cleanup Model (SACM), which has been developed by the U.S. Environmental Protection Agency (EPA) to allow site cleanups to proceed in a more timely and efficient manner, while achieving prompt risk reduction through a continuous process of assessing site conditions and the need for removal actions (EPA, 1993). Although the UBMC is not a federal National Priorities List site, the EE/CA process is being invoked for possible removal actions on lands within the NFS through the USFS's CERCLA authority. CERCLA and the NCP define removal actions to include "the cleanup or removal of released hazardous substances from the environment; such actions as may necessarily be taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or the threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release" (EPA, 1993). Non-time-critical removal actions refer to actions where implementation is not required within six months.

This EE/CA has been developed in accordance with the guidance for conducting non-time-critical removal actions under CERCLA published by the U.S. Environmental Protection Agency (EPA, 1993). The EE/CA covers only a portion of the UBMC located on lands within the NFS. Specifically, the EE/CA evaluates actions applicable to mining-related impacts within portions of Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot River drainage bottoms, and the Mike Horse Tailings Impoundment (Figure 1-1). Mining-related impacts on private lands located adjacent to and upgradient of the EE/CA coverage area are being addressed under separate response actions. Although mitigation of mining impacts on public and private lands are being addressed through separate programs, successful reclamation of the UBMC as a whole will require a high level of coordination to assure that overall site reclamation is completed as effectively and efficiently as possible. Also considered in development of this EE/CA are the Total Maximum Daily Loads (TMDLs) completed for the Blackfoot Headwaters TMDL Planning Area (MDEQ, 2003 and 2004). The UBMC is also listed as a high priority site under the State of Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA).

1.1 PURPOSE AND OBJECTIVES

The purpose of this EE/CA is to provide a process and rationale for developing, screening, and evaluating potential response actions designed to address mining-related impacts on those portions of the UBMC included within the EE/CA. An overview of removal actions considered in this evaluation were presented in two alternatives technical memoranda; one presenting preliminary removal options for Lower Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River drainage bottoms (Hydrometrics, 2005a), and the other presenting options for the Mike Horse Tailings Impoundment (USFS, 2006). The removal actions were also presented in the draft EE/CA (Hydrometrics, 2006a), which has undergone public and agency review. The objective of the EE/CA is to develop and present removal action alternatives that may be used to reduce or eliminate potential human health and environmental risks posed by mining-related impacts on certain lands within the NFS at the UBMC, and to present a comparative analysis of alternatives based on their relative effectiveness, implementability, and costs.

This EE/CA represents one of a series of response actions that the USFS has or will be conducting in response to the releases of hazardous substances at the UBMC. The removal alternatives evaluated under this EE/CA may be implemented in more than one future response action and do not necessarily constitute a final remedy.

1.2 REPORT ORGANIZATION

Section 2 of this document presents a brief overview and history of the UBMC area in terms of site development, mining history, and previous reclamation actions. Section 3 presents the site characterization, including natural site conditions and extent of mining-related impacts. Section 4 includes a streamlined risk evaluation, outlining both human health and ecological risks posed by the site for use in removal action planning, while Section 5 presents the removal action scope, proposed removal action objectives, and ARAR-based (Applicable or Relevant and Appropriate Requirements) and risk-based goals for the site.

Section 6 includes a description of removal options considered for each geographic sub-area included in the EE/CA, and five site-wide alternatives encompassing select removal options from each sub-area. Section 7 includes a comparative analysis of the removal action alternatives, with each alternative evaluated for effectiveness, implementability, and cost. Section 8 includes a list of references cited in this document. The majority of figures and tables are included at the end of the report, although smaller tables and figures are embedded within the text. Supplemental information is included as appendices.

Numerous other reports have been prepared for the UBMC over the past several years including a comprehensive data compilation report (Hydrometrics, 2005b), numerous annual monitoring reports, and annual construction and reclamation reports (see Section 8, References). The reader is referred to these existing reports for additional information on the UBMC site characteristics, extent of mining-related impacts, and previous removal actions/reclamation activities completed on privately owned property at the UBMC. These reports are included as part of the Administrative Record File for this project which can be reviewed at the Helena National Forest Supervisor's office, 2880 Skyway Drive in Helena, and at the Lincoln Ranger District Office in Lincoln, Montana, or at http://www.fs.fed.us/r1/helena.

2.0 SITE DESCRIPTION AND HISTORY

The UBMC is located at the headwaters of the Blackfoot River in Lewis and Clark County, Montana, and includes a mix of private property (patented mining claims and fee lands) and lands within the NFS (Figure 1-1). Although the UBMC includes both private and public lands, this EE/CA primarily addresses mining-related impacts on lands within the NFS only (the EE/CA area). Specifically, the EECA area includes lands within the NFS along the drainage bottoms of portions of Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River, as well as the Mike Horse tailings Impoundment (Figure 1-1). In addition, removal actions on two patented mining claims (the Flossie and Louise claims) along the Beartrap Creek drainage bottom are addressed in this EE/CA (see Section 6.2.2.2). Implementation of removal actions on these two patented claims would require the USFS to partner with other agencies/entities to effect removal.

As previously stated, the four general sub-areas addressed in the EE/CA include:

- The Mike Horse Tailings Impoundment (including the Mike Horse dam and tailings impounded behind the dam);
- Lower Mike Horse Creek drainage bottom from the National Forest boundary downstream to the confluence with Beartrap Creek;
- Beartrap Creek drainage bottom from the Mike Horse Tailings Impoundment downstream to the confluence with Anaconda Creek; and
- The Upper Blackfoot River drainage bottom from the confluence of Anaconda Creek and Beartrap Creek downstream to a large marsh system near the confluence with Pass Creek (Figure 1-1).

Following is a summary of site characteristics and information relevant to this EE/CA. Detailed descriptions of the UBMC are provided in a number of existing reports, including Hydrometrics (2005b) and GCM (1993). Also included in this section is a summary of past site characterization programs providing information utilized in development of this EE/CA.

2.1 SITE DESCRIPTION

The UBMC is characterized by heavily forested, steep mountainous terrain, with elevations ranging from 5,200 feet above mean sea level (AMSL) at the confluence of Pass Creek and the Blackfoot River (near the head of a major marsh system, Figure 2-1), to over 7,500 feet AMSL in the drainage headwaters along the continental divide. Mining activity at the UBMC began with the discovery of silver, lead, and zinc bearing ores in the late 1800s (GCM, 1993). Individual historic mines at the UBMC include the Mike Horse Mine, the Anaconda Mine, the Edith Mine, the Paymaster Mine, the Carbonate Mine, and the smaller Capitol and Consolation Mines (Figure 2-1). Sporadic development and production occurred at these various mines between the late 1800s and the 1940s with the most significant production occurring at the Mike Horse Mine in the late 1930s and 1940s. Mining activities ceased at the UBMC by the mid-1950s although exploration activities continued beyond the 1950s. Other smaller mines and mining prospects are located within the UBMC area (see GCM, 1993), as well as throughout the Blackfoot River drainage.

The Mike Horse Tailings Impoundment was constructed on Beartrap Creek drainage in 1941 for disposal of tailings from the Mike Horse Mine mill. An October 1964 annual inspection of the dam by the USFS noted that the principal spillway pipe was plugged and an overflow spillway had been dozed around the east dam abutment in the spring of that year to accommodate runoff (USFS, 1964).

The inspection report notes the presence of headcutting (erosion) at the spillway outlet. Subsequent to the 1964 inspection, a surface water diversion ditch was constructed to divert Beartrap Creek flows around the west side of the impoundment.

In June 1975, heavy precipitation, along with blockage of a surface water diversion ditch by mudslide debris, caused the Mike Horse Tailings Impoundment to be breached. As a result, tailings were washed downstream and deposited on the Beartrap Creek and Upper Blackfoot River floodplain. Several field investigations conducted in the past have focused on the effects of the tailings dam breach.

2.1.1 Hydrology

Significant streams in the EE/CA area include from upstream to downstream, Beartrap Creek, Mike Horse Creek, Anaconda Creek, the Blackfoot River, Stevens Gulch, Shave (or Shaue) Creek, Paymaster Creek, and Pass Creek (Figure 2-1). The Blackfoot River is formed by the confluence of Beartrap Creek and Anaconda Creek. Other significant features include a large marsh system on the Blackfoot River immediately downstream of the site, and the Mike Horse Tailings Impoundment on Beartrap Creek (Figure 2-1). The marsh system starts near the confluence of the Blackfoot River and Pass Creek and extends several miles downstream. Drainage areas for the streams mentioned above are listed in Table 2-1.

Envirocon (1993) completed a detailed floodplain analysis of the UBMC area as part of ASARCO's and Atlantic Richfield Company's early site characterization program. The study included stream cross-section surveys, bankfull width/elevation, and peak flow (100-year) determinations at various locations on the Blackfoot River and tributaries. Additional hydrologic modeling was completed to aid in conceptual design of removal options presented in this EE/CA (Appendix A). Bankfull elevations and peak flows determined from these two exercises are included in Table 2-1. The Envirocon study determined the extent of the 100-year flood plain, and predicted that sites within the UBMC which would be affected by the 100-year peak flows included the Lower Anaconda Mine waste piles, the Paymaster Mine waste piles, and the Swamp Gulch Mine (Carbonate Mine) waste piles. All of these mine waste piles have been removed and the sites reclaimed by ASARCO.

The Mike Horse Tailings Impoundment forms a reservoir impounded behind the Mike Horse Tailings Dam on Beartrap Creek, and has been in existence since 1941. During normal Beartrap Creek flows, water accumulates in the reservoir and is released (seasonally) as seepage through the earthen dam. During high stream flows resulting primarily from spring runoff and/or high intensity spring storms, reservoir water discharges through an emergency overflow spillway pipe downstream to Beartrap Creek via Lower Mike Horse Creek. The pond storage capacity is about 69 acre-feet at the spillway pipe invert elevation (5481 feet AMSL), and about 160 acre-feet at the dam crest elevation of 5491 feet AMSL (Figure 2-2). The highest pond elevation recorded since 1975 is about 5483 feet, or only two feet deep at the head of the 54-inch diameter spillway pipe. Under typical conditions, the impounded water seeps through the sandy embankment until the pond surface is two or more feet lower in elevation than the spillway pipe invert. At this elevation the dam impounds a storage capacity of about 50 acre-feet or less.

2.1.2 Meteorology

Climatic conditions at the UBMC are typical of intermediate to high elevation regions of the Northern Rocky Mountains with long, cold winters and short, moderately hot summers. Based on climatic records from the National Oceanographic and Atmospheric Administration (NOAA) weather station at Rogers Pass (approximately two miles northeast of the UBMC), average monthly minimum and maximum temperatures recorded at the Rogers Pass Station average 13.4 °F in January, and 81.5 °F in July, respectively (Table 2-2). A record cold temperature of –70 °F was recorded on January 20, 1954 (Envirocon, 1993).

Average monthly precipitation for the period of record ranges from 0.65 inches in February, to 3.10 inches in June. Annual precipitation for the period of record is 17.99 inches, with the highest annual precipitation (31.4 inches) occurring in 1975 and the lowest annual precipitation (13.9 inches) occurring in 1988. The greatest one-day storm event recorded since 1964 occurred on June 19, 1975, resulting in 2.98 inches of precipitation (Envirocon, 1993).

Average climatic data from the Lincoln Ranger Station weather station located about 14 miles west of the UBMC are similar to that from the Rogers Pass station. This indicates that weather patterns are relatively uniform throughout the UBMC area and are reasonably well represented by the Rogers Pass data.

2.1.3 Vegetation and Ecology

Vegetation

As reported in Western Technology and Engineering, Inc., (1993a), vegetation of the UBMC area is typical of the northern Rocky Mountains, although it has been modified by mining and timber harvesting. Coniferous forest, dominated primarily by lodgepole pine, spruce and Douglas fir, covers mesic slopes above drainage bottoms. Drier slopes are dominated by mountain big sagebrush and fescue grassland. Several riparian/wetland vegetation communities are present along streams and the floodplain of the Blackfoot River, including plant communities dominated by coniferous or deciduous tree species, shrubs or herbaceous species. Additional detail on the UBMC area vegetation is available in Western Technology and Engineering, Inc., 1993a.

Ecology

The ecology of the UBMC area is diverse in terms of biological species. Portions of the UBMC are located in federally designated grizzly bear and gray wolf recovery areas, and bald eagles, peregrine falcons, and whooping cranes may sometimes enter the UBMC (Western Technology and Engineering, Inc., 1993b). The Blackfoot River is considered to be a substantial fisheries resource below USFS's Aspen Grove Campground (approximately 12 miles downstream of the EE/CA area), and the Montana Department of Fish, Wildlife and Parks (FWP) considers the UBMC to include viable trout and big game habitats. Genetically pure westslope cutthroat trout have been identified in Anaconda Creek above the Anaconda Mine site (McCulley, Frick and Gilman, 1996). Cutthroat trout have also been identified by the USFS in Shave Gulch although this population has not undergone genetic testing.

Bull trout is a Montana *species of special concern* and *threatened* under the Endangered Species Act. The portion of the Upper Blackfoot River downstream from the EE/CA area is considered to be Bull trout core recovery area.

2.1.4 Site Demographics

The UBMC and surrounding area is sparsely populated and rural in character. According to the U.S. Census Bureau (http://factfinder.census.gov), the population density of the surrounding area is approximately one person per square mile. Based on an aerial photo survey, one residence is located along Beartrap Creek approximately 0.6 miles upstream of the Mike Horse Tailings Dam, and four residences are located within two miles downstream (west) of the confluence of the Blackfoot River and Pass Creek. The closest of these residences is located along Highway 200 approximately 0.75 miles from the Blackfoot River/Pass Creek confluence.

A search of the Montana Department of Natural Resources and Conservation Groundwater Information Center (GWIC), revealed three private drinking water wells within a one-mile radius of the UBMC area (one-mile radius of the Mike Horse Tailings Dam, and one-mile radius of the confluence of Blackfoot River and Pass Creek). All three wells are located west of the site, with the closest well approximately 0.75 miles from the Blackfoot River/Pass Creek confluence and north of Highway 200.

2.2 SITE GEOLOGY

The geology of the UBMC area is characterized by various bedrock units, with unconsolidated materials restricted to relatively thin accumulations of alluvium along drainage bottoms. Numerous reports have been published on the local and regional geology as referenced below. Following is a summary of the geology of the UBMC area.

2.2.1 Bedrock Units

Three general bedrock units are found at the UBMC, including the Belt Series Spokane Formation, a diorite sill, and a series of Tertiary-age igneous intrusive bodies (Figure 2-3). The Precambrian Spokane Formation includes massive, light to dark gray quartzite and argillite at the bottom, grading upward to maroon to green argillite at the top (Miller, 1973). The bedding planes dip from 5° to 30° north. The Spokane Formation is generally devoid of mineralization, except along margins of mineralized veins intruded into fractures within the argillite.

The Spokane metasedimentary rocks are intruded by a flat lying, diorite (gabbro) sill of Proterozoic age (McClave, 1998). The sill is tabular in form and cuts across bedding planes of the Spokane Formation at a slight angle. The sill is well exposed in the northern two thirds of the area (upper Anaconda Creek and Shave Gulch drainages) where it reaches a thickness of 500 feet, but occurs primarily subsurface to the south (Upper Mike Horse, Stevens, and Paymaster Creek drainages) where the thickness decreases to 200 feet due to vertical displacement by faulting. The top of the sill dips gently northward and strikes SW-NE. The diorite sill contains abundant chalcopyrite (copper-iron sulfide) and pyrite (iron sulfide), with the highest copper concentrations in soils within the Heddleston District occurring above suboutcrops of the diorite as opposed to above mineralized veins or ore zones (McClave, 1998).

A number of igneous intrusive stocks were emplaced within the older Spokane argillite and diorite sill in the central portion of the site. The igneous complex is quartz monzonite porphyry of Tertiary age. The quartz monzonite also forms linear dikes extending radially outward from the central stock, where molten rock intruded along faults and fracture zones within the country rock. Heat associated with the quartz porphyry at the time of emplacement caused hydrothermal solution to circulate through the country rock, producing the Heddleston District mineralization. The radial dikes extending outward from the central stock produced the mineralized veins first targeted for development in the district, including those at the Mike Horse, Anaconda, Paymaster, Carbonate, and other individual mines, while low grade, disseminated mineralization formed within the intrusive stock itself. Both the mineralized veins and zone of disseminated mineralization extend from south to north across the Blackfoot River drainage bottom (Figure 2-3).

2.2.2 Bedrock Structure

Two principal fault systems have been identified at the UBMC including the Mike Horse fault system and the Blackfoot fault system. Both systems trend northwest-southeast, and predate emplacement of the porphyry intrusive. The Mike Horse fault system is the southern-most of the two, and extends from east of Mike Horse Creek drainage, westward through Paymaster Creek drainage (Figure 2-3). The mineralized veins exploited at the Mike Horse Mine occur within subsidiary faults associated with the Mike Horse fault system. The second fault system (The Blackfoot Fault) is located approximately 4,000 feet to the north and trends subparallel to the Blackfoot River drainage bottom. Numerous smaller northwest-trending structures occur within the UBMC, as well as older northeast trending structures. Due to the control these structures play in mineral vein emplacement, the historic mines at the UBMC, including the Mike Horse, Anaconda, Paymaster and Carbonate, generally are located along these fault zones.

2.2.3 Mineralization

Multiple episodes of bedrock mineralization/alteration have occurred at the UBMC, with all mineralization related to the Tertiary-age intrusive complex. Early mineralization includes a network of base and precious metal veins (characterized as quartz/pyrite/chalcopyrite veins), occurring within the porphyry intrusive body and extending radially outward. These radial veins, which are typically fault controlled with considerable bedrock fracturing along vein margins, were the targets of early mine development in the district. Examples include the northwest-southeast trending Mike Horse, Intermediate, and Little Nell veins, which were the targets of underground development at the Mike Horse Mine. All three vein structures dip steeply (~75°) south. Pardee and Schrader (1933) report that mineralized veins at the Mike Horse Mine average five feet in thickness.

Imprinted upon this fault-controlled vein mineralization and surrounding bedrock are localized, disseminated deposits of supergene enriched copper-molybdenum mineralization (copper-moly ore zones). Two distinct copper-moly orebodies have been identified within the UBMC, including the “Number 3 Tunnel Ore Zone” located south of the Blackfoot River, and the “North Ore Zone” located north of the river (Figure 2-3). These two ore zones were the focus of an extensive mineral exploration program conducted by the Anaconda Company in the 1960s and 1970s.

2.3 HYDROGEOLOGY

Groundwater in the UBMC area occurs with the fractured metasediment and igneous bedrock units and within unconsolidated alluvium occupying drainage bottoms. Primary bedrock porosity and permeability are believed to be low, with groundwater flow occurring predominantly through secondary fractures, joints, and fault zones. The general pattern of groundwater flow at the UBMC is from higher elevation areas where the bedrock groundwater system is recharged primarily by snowmelt, towards the local drainage bottoms (Beartrap Creek, Anaconda Creek, the Upper Blackfoot River), recharging the alluvial groundwater system and local stream flows. The bedrock groundwater system ultimately sustains baseflow in the area streams. This bedrock groundwater/ alluvial groundwater/surface water interaction is typical of steep mountainous terrains like the UBMC.

Based on extensive drilling and completion of monitoring wells at the UBMC, the bedrock permeability is considered to be low. Wells completed in bedrock at the UBMC are invariably of low yield (a few gallons per minute or less), indicating low permeability. This is supported by the relatively low baseflow discharge from the Mike Horse Mine adit. Although the Mike Horse Mine workings include more than 30,000 feet of tunnels, drifts, raises and winzes, baseflow discharges from the mine are typically less than 25 gallons per minute (gpm). Groundwater flow through bedrock is further constrained due to the proximity of the UBMC to the continental divide, which limits the area of available recharge to the UBMC watershed. Based on the predominance of gravel and cobbles in the larger UBMC drainages (Beartrap Creek, Anaconda Creek, and the Upper Blackfoot River), the alluvium has a much higher permeability than the bedrock. Additional information on the site hydrogeology is presented in Hydrometrics, 2005b.

2.4 MINING AND REGULATORY HISTORY

2.4.1 Mining History

Individual mines within the Heddleston Mining District (or UBMC) include the Mike Horse Mine, Anaconda Mine, Paymaster Mine, Carbonate Mine, and numerous smaller mines and prospects. The Heddleston district was named for William Heddleston who, with his partner George Padbury, discovered the Calliope lode in 1889. The two miners took out $11,000 worth of gold ore before the vein ran out a few years later. The Mike Horse, Carbonate, Paymaster, Midnight, and Anaconda mines were also started during these early years but the district's development was hampered by the difficult access (GCM, 1993).

The Heddleston district differed from the common pattern of other mining districts, in that it never went through an early gold and/or silver boom. Although gold and silver were steadily produced as by-products from the district's mines, the preponderance of the district's mineral wealth has come from the production of base metals such as lead and zinc. With the exception of the limited gold production from the Calliope Mine, no other gold deposits of any consequence were found or operated. Prior to 1915, prospectors discovered a number of lodes containing lead, zinc, and copper, including the Mike Horse, which was discovered in 1898. Due to the lack of suitable roads into the district, only minor shipments of smelting ore were made. The district saw a revival of mining activity in 1915 when the Mike Horse Mine was taken over by the Sterling Mining and Milling Company of Ellensburg, Washington. A major lead deposit was developed at the Mike Horse Mine and in 1919 a concentrating mill was built to process the mine's ores, as well as the ore from the nearby Anaconda and Paymaster mines. The deposit continuously produced lead/zinc ore containing some silver, for the next decade, but produced a modest amount of ore and concentrate by the end of the 1920s (GCM, 1993).

The Mike Horse Mine was idle until 1938 when it was leased to the Mike Horse Mining and Milling Company (MHM&MC) and the following year a 150 ton-per-day flotation mill was built. In 1941, the Mike Horse Dam was constructed across Beartrap Creek (just upstream of the confluence with Mike Horse Creek) to serve as an impoundment for the tailings from the newly constructed Mike Horse Mine flotation mill. Sufficient ore was mined at the Mike Horse, Little Nell, and Intermediate veins to keep the mill operating until mid-1945. At this point, stock and assets of the MHM&MC were purchased by ASARCO, which kept the Mike Horse Mine operating until 1955, when it was closed due to declining metals prices and near exhaustion of the orebody. The Rogers Mining Company of Helena leased and operated the mine sporadically from 1958 until early 1964 when the Anaconda Company of Butte acquired lease rights to the Mike Horse Mine from ASARCO through an assignment of the Rogers lease. The Anaconda Company conducted exploration activities in the 1960s and 1970s in the Heddleston District (although not on the Mike Horse Mine claims), including detailed geologic mapping; geochemical sampling; drilling of 340 churn, diamond, and reverse circulation drill holes; and driving of two bulk sampling adits (one north of the Blackfoot River between Shave Creek and Pass Creek, and one south of the river between Stevens Gulch and

Paymaster Creek, Figure 2-1). This exploration work defined the substantial copper/molybdenum porphyry orebody described in Section 2.2. The interests that Anaconda acquired through transfer of the Rogers lease were transferred back to ASARCO by deed on November 19, 1981.

Although the Mike Horse was the mainstay of the district, other small mining operations were also active in the district during the twentieth century. The Paymaster was in operation early in the 1900s but had closed by the mid-1920s. The Anaconda Mine was developed early in the 1900s and produced minor amounts of ore containing gold, silver, copper, and lead intermittently through 1940. Both properties were purchased by the Anaconda Company in the mid-1960s, and subsequently acquired by ASARCO. Other smaller mines in the district include the Edith, Midnight Hill, and Mary P Mines, among others. Additional detail on the history of mining at the UBMC is provided in Hydrometrics, 2005a.

2.4.2 Overview of Regulatory History

Regulatory activities at the UBMC commenced in 1987 when the Montana Legislature allocated funds to the Montana Department of State Lands (now part of DEQ) for reclamation of the Mike Horse Mine under the State's abandoned mine reclamation program. Additional funding was allocated in 1989. MDSL performed site characterization activities and reclamation planning from 1987 through 1990, including mine waste removal and water treatment designs. In 1990 however, authority for the site was officially transferred to the Montana Department of Health and Environmental Sciences (MDHES, now DEQ) and it was determined that potentially liable persons (PLPs) may exist for the Mike Horse site.

In June 1991, ASARCO and Atlantic Richfield Company (Atlantic Richfield) were identified by MDHES as liable persons for hazardous or deleterious substance contamination at the UBMC (identified in the Special Notice Letter (MDHES, 1992) as portions of Sections 16, 17, 18, 19 20, 21, 22, 27, 28, 29, 31, 32, 33 and 34, Township 15N, Range 6W), under CECRA. Required response actions identified by MDHES included development of a Remedial Investigation and Feasibility Study (RI/FS), and implementation of a remedy to be determined by MDHES.

Between February 1992 and May 1993, ASARCO and Atlantic Richfield met with MDHES regarding implementation of a voluntary remediation program at the UBMC in lieu of the formal RI/FS process. Terms and conditions of an agreed upon voluntary remediation program are outlined in a May 26, 1993 letter from MDHES, including preparation and submittal of annual work plans and other documents for MDHES review (although not necessarily formal approval). Site reclamation activities proceeded under this agreement until 1998, with certain reclamation activities, namely reclamation of the Paymaster Mine and No. 3 Tunnel area in 1996 and 1997 completed under the newly established Montana Voluntary Cleanup and Redevelopment Act (VCRA) program.

In 1999, ASARCO petitioned the Montana Board of Environmental Review for adoption of temporary water quality standards in portions of three streams at the UBMC (Hydrometrics, 1999). Temporary standards were requested in portions of Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River. The temporary standards were approved by the Board and were established in the Montana Surface Water Quality regulations (ARM 17.30.630) in June 2000. The temporary standards temporarily modify the water quality standards for a number of metals, including cadmium, copper, iron, lead, manganese and zinc, as well as pH, until 2008. As part of the temporary standards petitioning process, ASARCO developed a conceptual plan for mitigation of all "water quality limiting factors" identified in the temporary standards support document, referred to as the Temporary Standards Implementation Plan (Hydrometrics, 2000).

In November 2002, ASARCO voluntarily entered into an Administrative Order on Consent (AOC) with the US Department of Agriculture (Forest Service) for performance of this EE/CA for certain public lands at the UBMC. The AOC covers lands within the NFS along portions of Mike Horse Creek, Beartrap Creek (including the Mike Horse tailings impoundment), and the upper Blackfoot River upstream of the confluence with Pass Creek (Figure 1-1), which may have been impacted by operation of the Mike Horse Mine and tailings impoundment. The objective of the AOC was for ASARCO to develop removal action alternatives for evaluation through development of an EE/CA.

In 2003, DEQ brought legal action against ASARCO and Atlantic Richfield to recover costs DEQ had incurred and will continue to incur in connection with remedial action activities associated with contamination and threats of contamination at and resulting from the UBMC. DEQ is also seeking a declaratory judgment to establish liability for all future remedial action costs, including cleanup, which DEQ will incur in connection with the UBMC.

Due to delays in implementation of the Temporary Water Quality Standards Implementation Plan, the Board of Environmental Review initiated rulemaking to rescind the temporary standards in May 2006, and the temporary standards were rescinded in December 2006.

2.5 HISTORY OF MIKE HORSE TAILINGS IMPOUNDMENT

The Mike Horse Tailings Impoundment, which includes the Mike Horse dam, reservoir and impounded tailings, was constructed in 1941 by the Mike Horse Mining and Milling Company (MHM&MC). At the time, MHM&MC held a lease to the Mike Horse Mine claims from Sterling Mining, (GCM, 1993). Initial dam construction involved placement of mine tailings across the Beartrap Creek drainage bottom to create a pond for tailings disposal and storage. The dam structure was progressively raised by hydraulic movement of tailings from the Mike Horse mill through a series of flumes. The original dam construction included a 24-inch concrete decant pipe which discharged impounded water from behind the dam to Beartrap Creek, and a west-side diversion ditch for routing flow in Beartrap Creek around the impoundment (USFS, 1975). An emergency spillway was excavated in soil and bedrock on the east end of the tailings dam embankment in 1964. In 1972 the flow control inlet structure at the head of the impoundment, which diverted Beartrap Creek flow around the impoundment, was rebuilt. The early (1940s) Mike Horse Tailings Impoundment is shown in Figure 2-4.

A 1964 U.S. Forest Service memorandum, referenced in a U.S. Forest Service report (USFS, 1975), contains one of the earliest references to the condition of the impoundment stability. The engineering report and cover letter included the following observations:

1. The structure was 110 feet high and 400 feet long.
2. There was a 2’x2’ square concrete conduit extending from the downstream dam face up the creek bed for 800 feet.
3. From the upstream end of the square conduit, a 24-inch pipe rose on an incline to an open ditch to a point 1000 feet upstream and fifteen (15) feet below the dam crest.
4. The emergency spillway effectively conducted flows resulting from a 1964 high runoff event, although some headwall cutting was reported from that event.

On June 19, 1975, heavy runoff from a spring storm, coupled with rapid snowmelt, resulted in high flows in Beartrap Creek. A combination of events related to the storm runoff, including blockage of the Beartrap Creek diversion ditch from a mudslide, blockage of the reservoir decant pipe by runoff debris, and the high reservoir inflow rate, caused the reservoir level to rise and overtop the dam. The resulting breach released an estimated 100,000 tons of tailings and fill/colluvial material into the streams downstream of the impoundment (Dames and Moore, 1975). In response to the dam breach, various repair options were evaluated by the Anaconda Company and an environmental analysis (EA) report prepared by the USFS for repair of the dam (USFS, 1975). The EA proposed to reconstruct the dam, repair the existing decant tube and install a 54-inch concrete pipe spillway.

Repairs and modifications to the Mike Horse Dam were essentially completed by the Anaconda Company in November 1975 (Dames & Moore, 1975 and 1976). Dam repairs and modifications included:

- Excavation of dam fill and placement of a clay core in the breach area. The clay core has a 15-foot wide crest, 1:1 downstream slope and a 2.5:1 upstream slope, and is keyed into the original embankment;
- Reducing the dam slope to 3 horizontal to 1 vertical on the downstream slope, and 5 horizontal to 1 vertical on the upstream slope;
- Installation of a 54-inch diameter reinforced concrete spillway pipe with a design capacity of 418 cubic feet per second (cfs);
- Extension of the decant pipe outlet to the toe of the new embankment slope;
- Placement of erosion protection (rock) on the downstream dam face; and
- The dam crest was raised approximately two feet in elevation in 1980.

Four piezometers were also installed within the dam for monitoring the water level, or phreatic surface, within the dam fill. The number of piezometers within the dam fill has since been increased to eight.

In 2001, ASARCO completed a preliminary assessment of the Mike Horse Tailings Dam with the objectives of determining if the design, construction, and operation of the dam meets applicable USFS and State of Montana Dam Safety Requirements, and providing a preliminary evaluation of the overall stability and integrity of the embankment structure. Findings of the preliminary assessment were submitted to the USFS and MDEQ in an August 20, 2001 memorandum (Hydrometrics, 2001a). The preliminary evaluation concluded that the observed phreatic surface was well within the elevation range recommended by Dames & Moore for structural stability, and concluded that a new slope stability analysis was not needed. However, hydrologic modeling completed as part of the 2001 assessment determined that the spillway capacity was 179 cfs as opposed to the 418 cfs identified in Dames & Moore's analysis (1975). The updated analysis indicated that the tailings dam could be overtopped by the ½ probable maximum flood (PMF), the U.S. Forest Service inflow design standard. The report recommended an emergency overflow spillway be constructed to increase the impoundment outflow capacity and attain the U.S. Forest Services spillway standard. The 2001 memorandum provided hydrologic modeling results including the reservoir response to the ½ probable maximum precipitation (PMP) event that produced a peak inflow of 850 cfs.

In 2004, ASARCO contracted with Montana State University to conduct seismic piezocone, or cone penetrometer (CPT) testing at the tailings dam. The CPT data, as well as piezometer data dating back to the early 1980s, was evaluated by the USFS. The USFS concluded that seepage through joints in the bedrock beneath the original portion of the dam was piping material from the embankment, creating voids as detected by the CPT testing (USFS, 2005). The USFS report also notes that the phreatic surface in the western portion of the dam appears to be depressed (based on piezometer readings), which may indicate rapid drainage through the dam foundation. Highly fractured bedrock was encountered in the east abutment during the 1975 dam repairs, with significant groundwater inflow from bedrock encountered at an elevation of 5437 (Dames and Moore, 1976). The USFS also concluded that the resulting acceleration force from a 2500-year earthquake could cause liquefaction concerns for the dam and that these problems compromised the dam structure and stability. As a result, the USFS recommended that the dam be "taken out of service."

In 2005 ASARCO prepared an Emergency Action Plan (EAP) for the tailings impoundment, and revised it in February 2006 (Hydrometrics, 2006b). The purpose of this plan is to prevent the loss of human life and minimize environmental damage to the Upper Blackfoot River drainage and nearby property in the event of flooding caused by a failure of the Mike Horse Tailings Dam.

3.0 PREVIOUS SITE INVESTIGATION RESULTS

This section provides an overview of past site characterization programs and results relevant to EE/CA development. Field sampling efforts and results are presented separately for the Mike Horse Tailings Impoundment, Lower Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River. Sampling results are presented in a general sense, with more detailed discussions of field sampling methodologies and results provided in numerous existing reports (Hydrometrics, 2001b, 2002, 2005a and 2005b). All water and soil/sediment data referenced in this section are included in Appendix B. Surface water and groundwater monitoring sites established by ASARCO and Atlantic Richfield during their site characterization activities are shown on Figure 3-1. Also provided in this section is a generalized site conceptual model intended to facilitate risk evaluation and removal action development.

3.1 MIKE HORSE TAILINGS IMPOUNDMENT

The Mike Horse Tailings Impoundment includes three features: an earthen dam constructed in part of tailings and in part of clean earthen fill, approximately 325,000 cubic yards of tailings impounded behind the dam, and an approximately 69 acre-foot pond created by the dam. The earthen dam is located in the Beartrap Creek drainage just upstream of the confluence of Beartrap Creek and Mike Horse Creek. Seepage occurs at various locations along the base of the dam, with the rate of seepage varying seasonally (higher rates in the spring, lower rates the remainder of the year). In addition to this seasonal seepage, flow through the dam occurs year-round in the Beartrap Creek seepage channel on the east side of the dam, and through an overflow spillway pipe on the west side of the dam during spring when the pond level increases. The seasonal seepage at the dam toe flows either into the Beartrap Creek or Mike Horse Creek near the confluence with Beartrap Creek. Following is a summary of investigations conducted at the Mike Horse Tailings Impoundment, and a brief review of the results of these investigations.

3.1.1 Previous Investigations

Previous site characterization activities at the Mike Horse Tailings Impoundment have consisted of routine seasonal and supplemental monitoring events implemented by ASARCO over the past 15 years, as well as a 1997 site characterization conducted by the Montana Bureau of Mines and Geology (MBMG). Data collection by ASARCO has included:

- Seasonal water quality sampling (surface water and groundwater) from 1991 through the present;
- Seepage water quality sampling at the seasonal seepage areas present at the toe of the tailings impoundment, in May 2001, May 2003, and April, May, and June 2004;
- Sampling of impounded tailings and mine waste, from the beach area along the impoundment (four samples collected in 2000) and from sediments located at depth within the pond itself (three samples collected in 2005); and
- Sampling of soils along the dam face (four samples collected in 1995), conducted to support direct revegetation planning.

The 1997 MBMG investigation included sampling of water and soils in the vicinity of the tailings impoundment. Sample collection included two tailings pond sediment samples, one sediment sample from lower Mike Horse Creek and one from Beartrap Creek, two soil samples near the base of the dam, and surface water samples from upstream, downstream, and within the impoundment, and four samples of seepage flow at the base of the dam.

3.1.2 Impoundment Area Soil/Mine Waste Sampling

The soil and mine waste sampling in the vicinity of the tailings impoundment has included samples of tailings material (pond sediments), as well as soil samples from the tailings dam face (embankment). Pond sediment sampling events conducted by ASARCO have included sampling in September 2000, conducted at several sites along the tailings impoundment beach using hand tools to excavate shallow test pits; and a more comprehensive sampling program implemented in February 2005, designed to provide an estimate of the tailings thickness at various locations within the tailings pond. The 2005 sampling involved augering through the ice layer at the pond surface and hand-driving PVC pipe or direct-push type plastic core tubes (macroliners) into the bed sediments, then retrieving the cores for logging and potential laboratory analysis. Analysis for acid-base accounting (ABA) parameters and total metals concentrations were performed on all the 2000 sediment samples; three of the samples collected in 2005 were analyzed for total metals concentrations. Two additional pond sediment samples from locations near the north shore (outlet end) of the tailings pond were collected by MBMG during their 1997 investigation, and analyzed for total metals concentrations.

Soil samples from the north face of the tailings dam were collected by ASARCO in 1995 as part of planning activities for potential direct revegetation trials. Two locations were sampled in 1995; at each location, samples from 0-6 and 6-12 inches were collected and analyzed for total metals and extractable metals concentrations.

Summary statistics for these tailings impoundment area samples are presented in Table 3-1, and the complete dataset is in Appendix B. Also in Table 3-1 for comparison are results from background area UBMC soil samples collected by the Montana Department of Health and Environmental Sciences (MDHES, now MDEQ) in 1993 as part of CERCLA site investigation activities. As shown in Table 3-1, all soil/sediment samples collected at the Mike Horse Tailings Impoundment are considered shallow samples for the purposes of assessing risk (see Section 4.0).

The data in Table 3-1 indicate that metals concentrations are generally higher in the tailings material impounded behind the tailings dam than in the surface soils present along the downstream dam face. Average metals concentrations in both the tailings samples and dam embankment samples are greater than the maximum MDHES background values, with the exception of aluminum (Table 3-1). The tailings material is also potentially acid-generating, with acid-base potentials ranging from –95 to –193 tons $CaCO_3$/1000 tons for the four samples collected in 2000 (Appendix B). The pH values obtained for the three beach tailings samples, however, were near neutral (6.6-7.1). Only the sample of exposed mine waste collected above the west shore of the pond showed a moderately acidic pH of 4.8 (Appendix B). pH values for the embankment soil samples ranged from 4.2 to 4.7.

3.1.3 Impoundment Area Surface Water Quality

Surface water in Beartrap Creek upstream of the tailings impoundment (represented by sampling site BRSW-1) and within the tailings impoundment (represented by sampling site BRSW-2) is generally of good quality (sampling locations are shown in Figure 3-1). Observed concentration ranges for metals at these two sites are shown in Table 3-2, and the complete dataset is in Appendix B. Results for twelve samples collected at BRSW-1 from 1991 through 1998 showed no detectable total or total recoverable arsenic, cadmium, copper, lead, or manganese, and low concentrations of iron (<0.03 to 0.042 mg/L) and zinc (<0.008 to 0.022 mg/L) (Table 3-2). Tailings impoundment water sampled at site BRSW-2 from 1991 through 1996 (fifteen samples) show slightly higher metals concentrations, with no detectable cadmium, and relatively low concentrations of other metals (Table 3-2), including arsenic (<0.003 to 0.005 mg/L), copper (<0.005 to 0.010 mg/L), iron (<0.05 to 0.58 mg/L), manganese (<0.008 to 0.096 mg/L), lead (<0.003 to 0.033 mg/L), and zinc (<0.01 to 0.17 mg/L). Of these 15 samples, the only documented exceedance of numeric water quality criteria is for lead in one sample (lead was below the analytical detection limit in the majority of samples). The results obtained by MBMG during their 1997 investigation (MBMG, 1998), are consistent with the extensive seasonal monitoring results obtained by ASARCO.

Surface water downstream of the tailings impoundment in Beartrap Creek was historically sampled at site BRSW-3 just upstream of the confluence with Mike Horse Creek. In 2000, site BRSW-3 was designated BRSW-3A, and site BRSW-3B, located where the creek emerges from the base of the dam, was added to the monitoring program to evaluate the potential effects of surface seepage entering the creek between these two sites. Water quality has been monitored at these sites from 1991 to the present; metals concentration ranges for BRSW-3/3A are summarized in Table 3-2, with results for individual samples included in Appendix B. As shown in Appendix B, metals concentrations increased between BRSW-3B and 3A during the majority of monitoring event, although decreasing metals concentrations are not uncommon along this short stream reach. The data in Appendix B suggest that higher concentrations at sites BRSW-3/3A are associated with spring monitoring events, when the phreatic surface in the dam is at or near its high point. During lower water level periods of the year (fall monitoring events), metals concentrations in samples from BRSW-3/3A are lower. The metals concentrations in Beartrap Creek seepage channel water are higher than those in the tailings pond (BRSW-2) or the upstream Beartrap Creek monitoring site (BRSW-1), indicating that dam materials have some impact on water chemistry.

As noted previously, the seasonal seepage at the base of the Mike Horse Dam was sampled five times by ASARCO from 2001 through 2004, as well as by MBMG in 1997. The seepage can be generally characterized by appearance: those seeps exhibiting staining (white, yellow, orange precipitates near the seep) have higher metals concentrations, while concentrations are lower in the seepage areas without staining (clear seeps). In addition, the clear seepage accounts for the majority (>80%) of the seepage flow observed at the dam toe. Table 3-3 summarizes the metals concentrations obtained for the two types of seepage, based on the ASARCO 2001-2004 sampling results. Complete seep water quality results are in Appendix B.

The variable chemistry of the seepage at the dam toe is indicative of different sources. The clear, better quality seepage emerges near shallow alluvial well TDMW-1, which is a seasonally flowing well (flows only during springtime) with water quality similar to the clear seeps. This suggests that the higher volume, clear seepage derives from discharge of clean alluvial groundwater. The lower volume seepage from discolored areas at the toe presumably derives from seepage through the dam, which reacts with tailings to yield poorer-quality water.

3.1.4 Impoundment Area Groundwater Quality

Three wells were installed at the toe of the Mike Horse Tailings Dam in 2001 to evaluate groundwater quality immediately downgradient of the dam, and the potential for subsurface seepage through the tailings dam or through the tailings pond bottom to impact groundwater quality below the dam. The three wells TDMW-1, TDMW-2S, and TDMW-2D are all completed above bedrock in unconsolidated material (locations are shown on Figure 3-1). Seasonal sampling of these wells by ASARCO from 2001 through the present indicates that groundwater quality is similar among all three wells, with low dissolved metals concentrations as summarized in Table 3-4. Results for individual groundwater samples collected at these wells are in Appendix B.

With the exception of relatively low concentrations of manganese and zinc, metals concentrations in the tailings dam monitoring wells are typically below laboratory reporting limits (Appendix B). The generally good quality of the groundwater at the toe of the tailings dam indicates the absence of significant subsurface seepage from the impoundment to groundwater. The elevated metals concentrations present in certain surface seeps at the tailings dam toe (the discolored or stained-area seeps) are not apparent in groundwater from the three monitoring wells at the toe of the dam.

The presence of a seasonally flowing well (well TDMW-1) at the tailings dam toe, along with the differences in seepage, groundwater chemistry, and the seasonal nature of the seepage all suggest the conceptual model of tailings dam hydrology discussed in Section 3.5.

Five wells were installed along the west side of the impoundment in August 2006 to provide additional information on the impoundment area groundwater resources. Wells TDMW-3D and TDMW-4D are completed in bedrock along the west pond shoreline, and TDMW-5 is completed in bedrock along Mike Horse County Road, about 150 feet west of the impoundment (Figure 3-1). TDMW-3S and 4S are shallow wells completed above bedrock in unconsolidated colluvium/alluvium and paired with the deeper bedrock wells 3D and 4D. TDMW-3D, 4D and 5 were sampled in November 2006, and TDMW-3D, 4D, 4S and 5 were sampled in May 2007. TDMW-3S was dry in May and both shallow wells were dry in November. Similar to the tailings dam toe area wells, dissolved metals concentrations in the west impoundment wells are very low or less than the analytical detection limits (Table 3-4). Groundwater resources in the vicinity of the tailings impoundment are discussed further in Section 3.5.4.

3.2 LOWER MIKE HORSE CREEK

Lower Mike Horse Creek is a steep, highly incised channel impacted by historic mining activities. Mine waste materials (waste rock and tailings) cover a significant portion of the drainage bottom and sides. The mine waste occurs as both discrete mine waste piles, and as more dispersed deposits spread along the drainage bottom. Results of extensive surface water and mine waste sampling completed by ASARCO indicate that these mine waste materials are acidic, contain elevated concentrations of metals, and act as a source of metals loading to Lower Mike Horse Creek. Following is a summary of recent site characterization activities for Lower Mike Horse drainage.

3.2.1 Previous Investigations

Previous investigations in Lower Mike Horse Creek have included:

- Seasonal surface water and groundwater sampling conducted by ASARCO at surface water sites BRSW-22 and BRSW-35, and wells MHMW-8 and MIGW-1;
- Detailed synoptic surface water sampling conducted by ASARCO during the rising limb of the stream hydrograph in April and May 2001 to delineate early season metals loading trends;
- Soil and mine waste characterization activities in the drainage conducted by ASARCO in 2000 and 2001;
- Samples collected in 1995 to support direct revegetation planning; and
- Miscellaneous site investigations by others, including MBMG (1998), Moore (1990), Menges (1997), and PTI (1994).

3.2.2 Lower Mike Horse Creek Soil/Mine Waste Sampling

ASARCO completed soil and mine waste characterization activities in Lower Mike Horse Creek drainage in 2000 and 2001 (Hydrometrics, 2001b and 2002). Eight general mine waste areas (LMH-1 through LMH-8) were delineated by ASARCO in 2000 through detailed mapping and sampling. The 2000 sampling included collection and testing of nine mine waste samples from the 0 to 18-inch depth interval to assess the shallow mine waste characteristics. Additional sampling was conducted in 2001 utilizing a backhoe for sampling of the deeper mine waste and underlying native soils. The 2000 and 2001 mine waste and soil sampling results are summarized in Table 3-5, for all samples combined and for shallow samples only. The combined sample results are subsequently used in the risk assessment (see Section 4.1). Results for individual samples are in Appendix B.

The 2000 and 2001 sampling programs indicated that about 10,000 to 15,000 cubic yards of mine waste is present within and adjacent to the Lower Mike Horse Creek channel. Overall, metals concentrations are moderate to high for mineralized areas, with iron and lead occurring at the greatest concentrations (Appendix B; Table 3-5). Metals concentrations invariably were greater in the deeper 2001 mine waste samples as compared to the shallower 2000 samples (Appendix B). Many of the samples of underlying native soil materials also contained elevated metals concentrations and, in few cases exceeded concentrations in the overlying mine waste. The sampling results also show the Lower Mike Horse drainage mine waste to be potentially acid generating, with a maximum acid-base potential of –328 tons $CaCO_3$/1000 tons, and mine waste pH values ranging from 2.2 to 7.4.

3.2.3 Lower Mike Horse Creek Surface Water Quality

Seasonal surface water sampling on Lower Mike Horse Creek has been conducted since 1993. Surface water site BRSW-22 is located near the county road crossing at the upstream end of the Lower Mike Horse Creek area, and site BRSW-35 is located at the downstream end of the area, just upstream of the confluence with Beartrap Creek (Figure 3-1). Surface water quality at these locations is summarized in Table 3-6, which shows concentration ranges observed for recent samples collected at sites BRSW-22 and BRSW-35 from 2000-2004. Complete water quality results for these two Beartrap Creek monitoring sites are in Appendix B.

As shown in Table 3-6, metals concentrations (except arsenic) are elevated throughout this reach of Mike Horse Creek, with concentrations at the downstream site slightly higher than those at the upstream site. In general, metals concentrations in Lower Mike Horse Creek reach a seasonal peak during the early spring runoff, and decrease throughout the spring and summer to reach annual lows during the fall and winter.

Detailed surface water monitoring in Lower Mike Horse Creek was conducted in 2001 to further investigate loading sources and trends within this portion of the UBMC. The detailed surface water monitoring results reported in the 2001 Monitoring Activities Report (Hydrometrics, 2002) led to the following conclusions:

1. During early spring runoff, mine waste materials likely act as the main sources of metals loading to the creek, as oxidized metals are flushed out during snow melt.
2. Later in the spring, loading from waste materials probably decreases, and the influence of seepage from the Mike Horse Dam and/or groundwater may increase as tailings pond levels and observable quantities of surface seepage also increase.

3.2.4 Lower Mike Horse Creek Groundwater Quality

Groundwater quality in the Lower Mike Horse Creek area has historically been monitored at two locations, monitoring wells MHMW-8 (12 samples collected from 1994 through 2001) and MIGW-1 (2 samples collected in 2001). MHMW-8 is completed in bedrock on private property upgradient of the NFS boundary and the EECA area, and MIGW-1 is completed in alluvium on lands within the NFS in the EE/CA area. Monitoring locations are shown on Figure 3-1. Dissolved metals concentrations observed at these two wells are summarized in Table 3-7. Complete analytical results for the two Lower Mike Horse monitoring wells are in Appendix B.

As shown in Table 3-7, well MHMW-8 (bedrock groundwater) typically shows poor water quality relative to well MIGW-1 (alluvial groundwater well located on the opposite (south) side of Mike Horse Creek). A metals loading analysis and trilinear diagram presented in the 2001 Monitoring Activities Report (Hydrometrics, 2002), provided evidence for a conceptual model of potential groundwater impacts to the lower reach of Mike Horse Creek. Metals-bearing bedrock groundwater (MHMW-8) may provide the primary source of some metals (cadmium and zinc) to the creek on a seasonal basis, with the groundwater contribution to total flow (and metals concentrations) in the creek at a minimum during spring runoff events. High flow metals concentrations in the creek are more likely influenced by upstream sources in Upper Mike Horse Creek, and/or by contributions from mine waste piles within and adjacent to the creek.

3.2.5 Lower Mike Horse Creek Sediment Data

Stream sediment sampling in Lower Mike Horse Creek has been limited to four discrete samples collected during four separate investigations:

- One sample collected by MBMG in 1997;
- One sample collected by Hydrometrics in 1991;
- One sample collected by Moore (1990); and
- One sample collected by Menges (1997).

The sediment metals concentrations observed in Lower Mike Horse Creek are summarized in Table 3-8 for bulk samples, fine fraction samples (<63 µm), and all samples considered together. Individual sample results are in Appendix B.

Stream sediment metals concentrations in Lower Mike Horse Creek are elevated, and in most cases are higher than metals concentrations in the mine waste piles located along the drainage (Table 3-5). Metals in stream sediments may be derived from eroded and redeposited mine waste along the stream channel, from metals that have precipitated out of solution, and/or from metals that have adsorbed from the aqueous phase onto stream sediments.

Comparison of the fine fraction (<63 µm) sample results with the bulk sample results for the Lower Mike Horse Creek stream sediments shows that for arsenic, cadmium, copper, and zinc concentrations were higher in the fine fraction samples, while lead and manganese showed the opposite relationship. Typically, fine fraction samples show higher metals concentrations due to the higher adsorptive surface area of the fine fraction.

3.3 BEARTRAP CREEK

The Beartrap Creek drainage bottom between the tailings dam and Anaconda Creek consists of a relatively wide, flat floodplain with limited vegetative cover. The drainage bottom varies in width from about 60 feet to over 200 feet through most of this reach, but widens to approximately 300 feet upstream of the confluence with Anaconda Creek. Steep, heavily forested hillsides border both sides of the drainage bottom, clearly demarcating the drainage bottom area. Geomorphic features include the active Beartrap Creek channel (approximately ten feet wide), a recent alluvial terrace three to four feet higher in elevation than the active channel, and remnants of an older higher terrace bench along the margins of the drainage bottom. This older bench is forested as opposed to the predominately rocky, barren nature of the lower terrace bench. The majority of the drainage bottom, particularly in the upper half of the drainage, is comprised of the recent alluvial terrace.

3.3.1 Previous Investigations

Previous investigation conducted in the Beartrap Creek drainage have included the following:

- Seasonal surface water and groundwater sampling conducted by ASARCO at surface water sites BRSW-23 and BRSW-38, and well BCMW-10;
- Groundwater monitoring at piezometers installed during mine waste/soil sampling of Beartrap Creek floodplain sediments;
- Soil and mine waste characterization activities in the drainage conducted by ASARCO in 2000 and 2001; and
- Stream sediment sampling conducted by PTI (1994) and MBMG (1998).

In addition to these investigations, one background sediment sample was collected from Beartrap Creek by the Montana Department of Health and Environmental Sciences (MDHES, now MDEQ) in 1993 as part of CERCLA site investigation activities (MDHES, 1994). However, this sample was collected upstream of the tailings impoundment and upstream of the various UBMC orebodies, meaning it may not accurately reflect background or baseline sediment chemistry for mineralized portions of the UBMC.

3.3.2 Beartrap Creek Mine Waste Sampling

Based on detailed mapping and mine waste sampling, mine waste within Beartrap Creek drainage occurs in three general forms:

- Relatively small isolated surficial deposits of highly concentrated, oxidized mine tailings (concentrated tailings);
- Tailings intermixed with varying proportions of native sediments (intermixed or dispersed tailings); and
- A discrete mine waste pile located on the Flosse and Louise Mine claims near the middle of the Beartrap Creek stream reach.

Based on mapping and sampling of the concentrated tailings in 2001, the total volume of concentrated tailings in the Beartrap Creek drainage bottom is estimated to be between 3,000 and 4,000 cubic yards. The volume of intermixed tailings/native sediments is estimated to be on the order of 50,000 cubic yards, based on drainage bottom dimensions of 2,800 feet by 100 feet (average), and an inferred average depth of intermixed tailings of four feet. The total volume of the Flosse and Louise Mine waste rock pile is estimated to be 1,500 cubic yards.

The concentrated tailings deposits are relatively small in size and distinguishable by their sandy texture, yellow/orange color, and lack of vegetation. Based on the appearance, the concentrated tailings appear to be highly oxidized from exposure to the atmosphere. The tailings may have been deposited during the 1975 tailings dam breach. The dispersed or intermixed tailings occur as fine to medium sand-sized pyritic tailings intermixed with native floodplain alluvium. The intermixed tailings/alluvium is believed to occupy the majority of the Beartrap Creek drainage bottom.

The Flosse and Louise Mine waste dump is a discrete mine waste pile associated with the former Flosse and Louise Mine. The dump is comprised of mine waste rock (as opposed to tailings) extracted from a mine tunnel driven into the Beartrap Creek drainage wall. The waste rock dump consists of two separate lobes that together measure approximately 100 feet long by 50 feet wide. The dump is located, at least in part, on the privately owned Flosse and Louise patented mine claims.

ASARCO conducted extensive soil and mine waste sampling in Beartrap Creek drainage in 2000 and 2001 (Hydrometrics, 2001b and 2002). The 2000 sampling activities focused on characterization of shallow mine waste, while 2001 activities involved more extensive mine waste mapping and sampling utilizing backhoe test pits to access the deeper mine waste. Mine waste sampling results are summarized in Table 3-9. Results for individual samples are in Appendix B.

The Beartrap Creek sampling results show that the concentrated tailings are more acidic and have a greater acid-generating potential than the dispersed tailings. The average acid-base potential for the concentrated tailings was -306 tons $CaCO_3$/1000 tons ($TCaCO_3$/1000T) compared with a dispersed tailings average of -133 $TCaCO_3$/1000T. Similarly, the average pH of the concentrated tailings was 2.2 while the average pH of the dispersed tailings was 6.4. Metals concentrations in the Beartrap Creek mine waste were generally moderate to high for mineralized areas. In some cases, average metals concentrations are higher in the dispersed tailings compared with the concentrated tailings (Table 3-9). This trend may be due to differential weathering of the two types of deposits, with near-surface concentrated tailings undergoing more oxidation and leaching of metals than the deeper dispersed tailings.

As part of the Beartrap Creek 2001 supplemental evaluation of floodplain tailings, leach tests were performed on selected tailings samples from the Beartrap Creek drainage, and snowmelt/runoff samples were collected from areas of concentrated tailings or adjacent to discrete mine waste areas (i.e., the Flosse and Louise Mine waste piles). The objective of leach testing and snowmelt/runoff sample collection was to identify the relative potential for different types and areas of tailings or mine waste to contribute to metals loading in Beartrap Creek through a leaching pathway.

In general, samples of concentrated tailings generated higher metals concentrations and lower pH values than dispersed tailings in deionized (DI) water extracts. Runoff and seepage samples collected from concentrated tailings areas in Beartrap Creek drainage showed metals concentrations generally similar to leach test concentrations, as summarized in the following table:

Parameter	Average Leach Test Concentration (mg/L)	Seepage/Runoff Sample Concentration Range (mg/L)
cadmium	0.044	0.0046 – 0.096
copper	2.87	0.002 – 0.11
iron	99	<0.05 – 4.2
lead	0.59	<0.003 – 0.25
manganese	16	<0.01 – 5.2
zinc	6.36	1.3 – 19

Although seepage/runoff sample concentrations were lower for copper and iron than leach test concentrations, other parameter concentrations were of the same order of magnitude. These results suggest that the leach test employed is an appropriate method for estimating concentrations in runoff that has contacted concentrated tailings and has not been subjected to significant dilution. The results of the Beartrap Creek tailings leach tests and snowmelt/runoff sampling suggest that of the three types of tailings material present, the concentrated tailings possess the greatest metals leaching capacity while the deep dispersed tailings possess the least, based on a unit mass basis. Seepage collected from a site at the base of the Flosse and Louise Mine waste piles showed significantly better water quality than other runoff/seepage samples, suggesting that this surface seepage is likely not a major source of metals loading to Beartrap Creek.

3.3.3 Beartrap Creek Surface Water Quality

Surface water quality in Beartrap Creek has been monitored seasonally since 1993. Monitoring site BRSW-23 is located at the upper end of the Beartrap Creek EE/CA area, downstream of the confluence with Mike Horse Creek (Figure 3-1). Site BRSW-38 is located at the downstream end of the area, upstream of the confluence with Anaconda Creek. A summary of metals concentrations observed at these two sites from 2000-2004 is shown below in Table 3-10. Complete analytical results for BRSW-23 and BRSW-38 are in Appendix B.

As shown in Table 3-10, metals concentrations are similar at the upstream and downstream ends of Beartrap Creek from the confluence with Mike Horse Creek to the confluence with Anaconda Creek. Cadmium, copper, lead, manganese, and zinc concentrations are all elevated, with higher concentrations occurring seasonally during spring runoff events. A significant portion of the metals load in Beartrap Creek is derived from upstream sources, particularly during spring runoff events; however, past investigations have noted increases in metals loading through this portion of Beartrap Creek (from BRSW-23 to BRSW-38) at other times of the year. These increases likely derive from interaction of surface water with areas of dispersed or concentrated mine waste/tailings, and/or due to mixing with shallow groundwater affected by such deposits (see Section 3.3.4).

3.3.4 Beartrap Creek Groundwater Quality

Groundwater quality in the Beartrap Creek drainage has been characterized through seasonal sampling of an alluvial monitoring well (BCMW-10) from 1994 through 1998, and by sampling of three piezometers installed in test pits during the 2001 mine waste/soil sampling investigation in Beartrap Creek drainage conducted by ASARCO (BTC-TP7, -TP8, and -TP9). The range of dissolved metal concentrations observed at these groundwater monitoring sites are summarized in Table 3-11. Complete analytical data for the Beartrap Creek groundwater monitoring sites is in Appendix B.

The water quality data from the piezometers and well BCMW-10 is similar in terms of both major ion chemistry and metals concentrations, although iron and manganese concentrations are higher in the piezometer samples (Appendix B). As noted previously, dispersed tailings and relatively isolated “lenses” of more concentrated tailings are present throughout the Beartrap Creek floodplain. The groundwater data in Table 3-11 and Appendix B suggests that shallow alluvial groundwater in this drainage may be impacted by interaction with these tailings. Although groundwater metals concentrations in the Beartrap Creek drainage do not reach the levels observed further upstream in the Upper Mike Horse drainage, they are higher than those observed in the clean wells such as MIGW-1. The variability of metals concentrations in the piezometers may be attributable to the irregular distribution of tailings material throughout the drainage bottom, with higher concentrations corresponding to areas with a higher percentage of more reactive tailings material.

3.3.5 Beartrap Creek Sediment Data

Stream sediment data for Beartrap Creek within the EE/CA area is limited to two samples; one collected by PTI (1994) and the second collected by MBMG during their 1997 investigation of the Mike Horse Tailings Impoundment and the surrounding area. The metals concentrations obtained for stream sediments from these two samples are summarized in Table 3-12.

The sediment data for Beartrap Creek show elevated concentrations of metals, similar to the concentrations observed upstream in Mike Horse Creek, although maximum concentrations are generally lower. As in Mike Horse Creek, metals concentrations in stream sediments in the Beartrap Creek drainage are likely affected by deposition of eroding mine waste/tailings material, either from Lower Mike Horse Creek or from the Beartrap Creek floodplain, as well as by precipitation and adsorption of metals to the particulate phase from the water column.

3.4 UPPER BLACKFOOT RIVER

The Upper Blackfoot River portion of the UBMC EE/CA extends from the confluence of Beartrap and Anaconda Creeks, to the head of the large marsh system near the confluence with Pass Creek (Figures 1-1, 2-1). The drainage bottom in this area varies from a relatively narrow floodplain covered with coarse gravel and cobbles in the upper reaches (similar to Beartrap Creek), to a more wide open, lower gradient system characterized by finer grained sediments with willows and forested areas in the lower portion of the drainage. Notable features in this area include an area of concentrated fine-grained tailings referred to as the Shave Gulch Tailings, the water treatment system located on private property at the former Anaconda Mine site, and the large natural marsh system occupying the drainage bottom at the downstream boundary of the EE/CA area. Property along the drainage bottom is within the NFS (including unpatented mining claims), with privately held parcels (ASARCO patented claims) concentrated in the upper and lower portions of the drainage (Figure 1-1). Field characterization activities and results for the Upper Blackfoot River are described below.

3.4.1 Previous Investigations

Previous investigations conducted in the Upper Blackfoot River have included the following:

- Seasonal surface water and groundwater sampling conducted by ASARCO at surface water sites BRSW-9 and BRSW-12, and wells ANMW-3, ANMW-7, ANMW-9, MPP-4, EDMW-2, EDP-1, AND EDP-2;
- Groundwater monitoring at piezometers installed during mine waste/soil sampling at the Shave Creek concentrated tailings area;
- Soil and mine waste characterization activities in the drainage conducted by ASARCO in 2001; and
- Stream sediment sampling conducted by various investigators (Section 3.4.5).

3.4.2 Upper Blackfoot Drainage Mine Waste Sampling

ASARCO conducted mine waste mapping and sampling in the Upper Blackfoot drainage in 2001 (Hydrometrics, 2002). The field characterization program included identification and mapping of tailings deposits along the drainage bottom, delineation of tailings depths and physical characteristics through hand dug and backhoe test pits, and sampling and laboratory testing of tailings and underlying soils to determine chemical characteristics.

Based on this work, tailings along the Upper Blackfoot River floodplain occur in two general deposit types:

1. A relatively large area of concentrated, predominantly fine grained tailings located near the confluence of the Blackfoot River and Shave Creek.
2. Smaller, discrete deposits of both fine grained and coarse-grained tailings scattered along the floodplain from the confluence of Beartrap and Anaconda Creeks, to the head of the marsh.

The large area of concentrated tailings, referred to as the Shave Creek Tailings, represents a more or less continuous deposit of tailings approximately five acres in surface area. The tailings have a sandy texture, are yellow/orange in color, and are devoid of vegetation except for scattered willow hummocks, some small lodgepole pine, and sparse grass cover in limited areas. An old drainage channel, believed to be the former Blackfoot River channel, traverses the Shave Creek Tailings. Based on historic aerial photographs and current stream flooding patterns, it appears that the Blackfoot River previously flowed through the middle of the tailings area as opposed to its current location south of the tailings. Surface flow still occurs through this area on a seasonal basis due to overflow of the upstream Blackfoot River channel during high runoff events.

Other notable fine-grained tailings deposits (besides the Shave Creek deposit) include two areas of tailings located immediately downstream (west) of the Shave Creek Tailings, small pods of dispersed tailings further downstream near the head of the marsh, an area of tailings bisected by the Blackfoot River approximately 600 feet downstream of the Anaconda wetland treatment cells, and an area of tailings adjacent to the treatment cells. These deposits are generally shallow and are analogous to the concentrated tailings deposits identified in Beartrap Creek drainage (Section 3.3.2). Significant deposits of coarse tailings include a sizable deposit located approximately 600 feet upstream (east) of the Shave Creek Tailings, and an area of tailings bisected by the Blackfoot River immediately downstream of the Anaconda wetland treatment cells. In contrast to the thin deposits of fine tailings, the coarse tailings deposits are two to four feet thick.

Metals concentrations and summary statistics for the various mine waste material types identified and sampled along the Upper Blackfoot River are summarized in Table 3-13. Complete analytical results for the Upper Blackfoot River mine waste samples, including acid-base accounting results, are in Appendix B. The analytical data show that the Shave Creek Tailings are potentially acid generating, with acid-base potentials ranging from –5 to –100 $TCaCO_3$/1000T, and pH values ranging from 2.2 to 3.9. While metals concentrations are moderate to high for mineralized areas, they are notably less than those observed in the Lower Mike Horse drainage mine waste samples (Section 3.2.2). In some cases, underlying soils show higher metals concentrations than overlying waste material, presumably due to leaching and readsorption, and/or mixing of tailings with native sediments during deposition.

Dispersed mine waste samples are also potentially acid generating; fine-grained deposits show more potential for acid generation, with lower pH values and lower acid-base potentials (Appendix B). However, the coarse tailings sample showed significantly higher concentrations of all metals except iron, compared with the fine tailings. For example, the zinc concentration in the coarse sample was 22,663 mg/kg, compared with 871 and 869 mg/kg in the fine tailings samples. The higher metals concentrations in the coarse tailings most likely reflect lower metals recovery rates for the older jig mill (the source of the coarse tailings) compared with the later flotation mill that produced the fine tailings.

Two samples of snowmelt/precipitation runoff were collected in the Shave Creek concentrated tailings area in 2001 (similar to the samples collected in the Beartrap Creek drainage), for the purpose of evaluating the potential for leaching of metals from the tailings deposits to area groundwater and/or surface water. The following concentration ranges were observed for total recoverable metals at these two sites (UBR-1 and UBSM-1):

- TRC aluminum – 1.0 to 4.0 mg/L;
- TRC cadmium – 0.039 to 0.073 mg/L;
- TRC copper – 0.31 to 0.48 mg/L;
- TRC iron – 2.3 to 4.4 mg/L;
- TRC lead – 0.12 mg/L;
- TRC manganese – 6.8 to 10 mg/L; and
- TRC zinc – 6.5 to 13 mg/L.

In addition to elevated metals concentrations, the samples showed acidic pH values (4.1 to 5.6). These data suggest that, similar to the concentrated tailings areas in Beartrap Creek, areas of concentrated tailings along the Upper Blackfoot River are capable of generating elevated metals concentrations in runoff water contacting the tailings, and subsequently impacting area water quality.

3.4.3 Upper Blackfoot River Surface Water Quality

Surface water quality in the Upper Blackfoot River has been monitored as part of ASARCO's seasonal monitoring program since 1991. Monitoring sites BRSW-9 and BRSW-12 (Figure 3-1) are representative of water quality upstream and downstream (respectively) of the Shave Creek concentrated tailings area (Section 3.4.2). Metals concentrations observed at these monitoring sites from 2000-2004 are summarized in Table 3-14. Complete analytical data for sites BRSW-9 and BRSW-12 are in Appendix B.

The concentration ranges shown in Table 3-14 are similar for surface water sites BRSW-9 and BRSW-12, and show moderately elevated concentrations of metals (except arsenic). Metals loading trends and additional synoptic surface water monitoring in the area, conducted by ASARCO in 2000 and 2001, provided supplemental information on potential metals sources. Based on these loading analyses, the area of tailings deposited in the Shave Creek area along the Upper Blackfoot River appear to be a source of metals in surface water (via runoff and possibly shallow groundwater), particularly during spring high flow conditions. The occurrence of elevated metals concentrations at site BRSW-12 under low flow conditions also indicates that recharge from metals-bearing groundwater in this area may be a secondary source of metals to the river.

3.4.4 Upper Blackfoot River Groundwater Quality

Groundwater in the Upper Blackfoot River EE/CA area has been monitored by ASARCO in four general areas:

- Near the Anaconda Mine (wells ANMW-3, ANMW-7, ANMW-9);
- Near the Mary P prospect (piezometer MPP-4);

- In the Shave Creek concentrated tailings area (piezometers BFR-TP3, -TP11, and -TP13); and
- In the Edith Mine area (EDMW-2, EDP-1, and EDP-2).

Monitoring locations are shown on Figure 3-1. Summaries of dissolved metals concentrations observed in each of these areas are presented in Table 3-15. Analytical results for individual groundwater samples are in Appendix B.

The Anaconda Mine area wells show variable water quality; the well upgradient of the mine and the wetlands water treatment system (ANMW-9) and the well across the Blackfoot River from the mine (ANMW-3) exhibit good quality groundwater with metal concentrations near or below detection limits. Groundwater quality in well ANMW-9 represents alluvial underflow from the non-impacted Anaconda Creek drainage. Well ANMW-7 shows moderate metals concentrations, along with slightly acidic pH values. The Mary P and Edith Mine area wells also show variable but moderately elevated metals concentrations. It should be noted that Edith Mine groundwater samples were all collected prior to reclamation of the Edith Mine site.

The Shave Creek concentrated tailings area piezometers show the poorest groundwater quality observed in the Upper Blackfoot River EE/CA area. Water from all three piezometers is characterized by low pH (2.8 to 4.7), and a wide range of elevated metals concentrations. Higher metals concentrations were noted during the spring monitoring event (May) for the piezometers, compared with later summer monitoring conducted in July (Appendix B). The seasonal differences in metals concentrations for the piezometers suggest that concentrations increase as water levels rise and contact reactive tailings that are subject to seasonal wetting and drying cycles.

3.4.5 Upper Blackfoot River Sediment Data

Stream sediment samples have been collected from a number of sites within the Upper Blackfoot River EE/CA area, including two samples collected by the Montana Department of Health and Environmental Sciences (MDHES) (UBMC-SE-05 and SE-08), two samples collected by MFG (MH19 and MH20), two samples collected by Hydrometrics (BRSD-1 and BRSD-22), one sample collected by Nagorski et al. (MHM) (Nagorski et al., 2000), one sample collected by Menges (BF212.9), and three samples collected by Moore (BF212.9, BF211.8, and BF211.6). The samples collected by Nagorski, Menges, and Moore were sieved in the field to separate the fine (<63 µm) fraction. Table 3-16 summarizes the metals concentrations observed in Upper Blackfoot River stream sediment samples. Fine-fraction sediment samples are considered separately from bulk samples in Table 3-16. Individual sample results for the eleven stream sediment samples collected from the Upper Blackfoot River EE/CA area are in Appendix B.

The stream sediment samples from the Upper Blackfoot River area were collected over a relatively wide geographic area, from the confluence of Anaconda and Beartrap Creeks down to the head of the marsh area above the confluence with Pass Creek (over a mile of river distance). Thus, the variability in sediment metals concentrations shown in Table 3-16 is not unexpected. A review of the data in Table 3-16 and Appendix B show the following general trends in sediment metals concentrations in the Upper Blackfoot River:

- Metals concentrations are uniformly higher in the fine sediment (<63 µm) samples. As noted previously, this trend is common due to the greater adsorptive surface area of fine sediments compared to a similar mass of bulk sediment, and the tendency of metals to adsorb to surface complexation sites under near-neutral pH conditions.

- For the bulk sediment samples, the lowest metals concentrations were observed at sites further downstream in the Upper Blackfoot River EE/CA stream reach. Higher concentrations were observed in samples collected within or adjacent to the historic Anaconda Mine site near the confluence of Anaconda and Beartrap Creeks. The Anaconda Mine area was reclaimed in 1995 and 1996; no stream sediment samples have been collected from the Upper Blackfoot River near the mine site since reclamation was completed. Therefore, potential effects of the Anaconda Mine site reclamation on stream sediment metals concentrations have not been documented.

3.5 CONCEPTUAL SITE MODEL

Based on the site characterization data presented in the preceding sections, a conceptual site model has been developed for the EE/CA portions of the UBMC. A conceptual site model (CSM) typically includes a description of contaminant sources in the area of interest, a description of mechanisms responsible for release of contaminants to the environment, and a review of potential exposure pathways that may present risks to humans and the environment. In the case of the UBMC EE/CA, the CSM also describes the interaction of contaminants between the four sub-areas, and the interaction of contaminants originating outside the EE/CA area (i.e., upgradient sources) with the four EE/CA sub-areas. The CSM also includes a more detailed discussion of the Mike Horse Tailings Impoundment due to the more complex nature of groundwater/surface water/contaminant interactions at the impoundment as compared to the other three sub-areas. The contaminant source, release mechanisms and exposure pathway information is utilized in the streamlined risk evaluation presented in Section 4. The contaminant interaction and tailings impoundment discussions are intended to better familiarize the reader with the site-wide aspects of the UBMC. A map of the UBMC area delineating lands included in the EE/CA, the four EE/CA sub-areas, and upgradient contaminant sources, is shown in Figure 3-2. A site schematic delineating source areas, release mechanisms and potential exposure pathways is included in Figure 3-3.

3.5.1 Contaminants and Primary Contaminant Sources

Extensive site characterization activities at the UBMC dating back to at least 1991 identify arsenic (soil/mine waste only), aluminum, cadmium, copper, iron, lead, manganese and zinc (soil/mine waste and water) to be the main (but not necessarily the only) mining-related contaminants at the UBMC. Primary sources of these contaminants include mine waste materials (waste rock and tailings) located on public lands, and upgradient sources of metals loading to surface water (and potentially groundwater). Mine waste sources within the EE/CA area include:

1. The Lower Mike Horse Creek mine waste piles;
2. Concentrated tailings and, to a lesser extent the intermixed alluvium/tailings in the Beartrap Creek floodplain;
3. Fine grained and coarse grained concentrated tailings and, to a lesser extent dispersed tailings, in the Upper Blackfoot River floodplain; and
4. Tailings contained within the Mike Horse Tailings Impoundment and dam.

3.5.1.1 Upgradient Sources

In addition to the sources located within the EE/CA area, contaminants enter the EE/CA area from upgradient sources via surface water, sediment transport, and possibly groundwater. Documented upgradient sources include mine waste and possibly natural sources (although this has not been documented) located on both private and public lands. Contaminant sources are also located on privately owned lands interspersed throughout the EE/CA area. Internal upgradient sources (i.e., contaminant sources originating from private lands within the contiguous EE/CA area boundary) include fluvial tailings and mine waste located on privately owned portions of the drainage bottoms, and discharge to the Upper Blackfoot River from ASARCO's mine drainage water treatment system. The locations of these sources are shown on Figures 3-2 and 3-3.

The primary upgradient source contributing contaminants to the EE/CA area includes metals-impacted surface water inflow, sediment transport, and possibly groundwater inflow from Mike Horse Creek drainage upstream of the National Forest boundary. This area includes the Mike Horse Mine, which is currently undergoing reclamation. Documented metals loads in Stevens Gulch and Paymaster Creek surface waters also represent upgradient contaminant sources to the Blackfoot River EE/CA sub-area (Figure 3-2). As described in Section 3.4.3, streamflow and metals loading trends in this portion of the Blackfoot River (near surface water monitoring site BRSW-12) suggest that recharge to the stream from metals-bearing groundwater may be responsible in part for the metals load increases documented in this stream reach. This mineralized groundwater most likely originates from the steep mountainous areas drained by Stevens Gulch and Paymaster Creek where a large copper-molybdenum ore body is located (see Figure 2-3). This information, along with studies completed on water chemistry conditions in Paymaster Creek drainage (Furniss, 1995 and 1998; and summarized in Hydrometrics, 2005b, Section 5.1.6), suggests that upgradient bedrock groundwater may influence surface water quality on the UBMC EE/CA area to some extent.

3.5.2 Contaminant Release Mechanisms and Secondary Sources

Runoff/erosion of mine waste represents a release mechanism for contaminants to surface water throughout the EE/CA area, as depicted in Figure 3-3. Erosion of mine waste from storm water runoff (precipitation and snowmelt) and release to surface waters is evidenced by erosional rilling present on the surface of mine waste deposits located adjacent to surface water features. Release of contaminants to surface waters also occurs through scouring and undercutting of mine waste deposits located within stream banks. Erosion of surficial materials (soils, mine wastes, etc.) has also resulted in secondary sources of contaminants that are located within stream sediments.

Infiltration of storm water and leaching of contaminants may also contribute to contaminant transport from contaminant sources into subsurface soils and shallow groundwater. Detailed sampling has shown native soils underlying the mine waste to depths of one to two feet also contain elevated concentrations of some metals, indicating leaching and redeposition of metals from the mine waste sources. Leaching of metals from mine wastes has also been shown to occur through snowmelt runoff sampling in Beartrap Creek and Upper Blackfoot River drainages (Section 3.3). Infiltration/leaching is shown (Figure 3-3) to be a release mechanism for contaminants to the shallow alluvial groundwater system underlying the EE/CA area streams.

3.5.3 Potential Receptor Exposure

A receptor is a human or ecological entity (plants and animals) that may use the impacted areas in a particular manner and become exposed to contaminants. Routes of exposure by which humans and animals may be exposed include direct contact with contaminants, ingestion, and inhalation. Plants are exposed via direct contact with soils and via wet and dry deposition of contaminated wind-blown dust onto above ground plant surfaces.

The areas addressed by this EE/CA are located on lands within the NFS, which are accessible to the public (Figure 1-1). Accordingly, current human site use is limited to occasional recreation oriented visitors. Typical uses may include hiking, camping, fishing, biking, motor biking, hunting, prospecting, and other similar uses. There is no known survey of actual site use in this area, although long-time observations by USFS personnel indicate that site use is largely recreational, with the highest site use occurring in the fall during big game hunting season. ATV use (off road non-enclosed motorized vehicles), associated primarily with hunting, and rock and mineral collecting (rockhounding) are two activities that are specifically identified in the streamlined risk evaluation (Section 4) as likely site uses that might result in a reasonable upper end estimates of potential exposure to site contaminants. The topography and access to all four EE/CA sub-areas lends itself to potential ATV use (Figure 3-3). Rockhounding was only identified as a potential site use within the Lower Mike Horse area because this is the only area addressed in this EE/CA considered to have mine waste materials of sufficient size to interest a rock collector. Further evaluation of site use and potential exposure is provided in the Exposure Assessment section of the Streamlined Risk Evaluation (Section 4.2.1).

The area is also used by a broad range of plants and wildlife that typify forested areas of the northern Rocky Mountains. Plant growth has the potential to be adversely affected by contaminant concentrations in soil and water. Plant growth may also be adversely affected by the physical nature of the mine wastes (e.g. course material lacking growth nutrients). Soil invertebrates, fish, birds and mammals may be exposed to the contaminants through direct contact, ingestion, and inhalation pathways, as appropriate for the organism type. As shown in Figure 3-3, plants and wildlife have the potential for exposure to contaminants in all four EE/CA sub-areas. Further characterization of ecological exposure is provided in Section 4.3.1 of the Streamline Ecological Risk Evaluation.

3.5.4 Mike Horse Tailings Impoundment

Of particular interest for the UBMC EE/CA is the hydrogeology of the Mike Horse Tailings Impoundment area. The impoundment is of interest due to its location and volume of mine waste stored in the facility. The hydrogeology is of interest due to the potential interaction of the impounded tailings with the local groundwater system, and potential implications for removal actions at the impoundment, as well as current and future downgradient water quality. Due to the importance of the impoundment, this section presents current information and a conceptual site model of groundwater conditions peripheral to the impoundment. This information is utilized in the evaluation of potential repository locations presented in Section 6.1, and in evaluation of removal options for the impoundment (Section 6.2). A general description of the impoundment area hydrogeology based on previously available information is presented first. This is followed by a more detailed discussion focusing on EE/CA-related issues, and based on supplemental information collected in 2006/07 as part of the EE/CA process.

3.5.4.1 General Impoundment Hydrology

Figure 3-4 shows a generalized longitudinal cross-section through the Mike Horse Tailings Impoundment corresponding to the approximate location of the original Beartrap Creek channel. Key aspects of the figure include the seasonal variation in pond water levels relative to the 5476 foot AMSL (above mean sea level) elevation, groundwater flow patterns in the vicinity of the impoundment, the continuous nature of the former Beartrap Creek channel gravels beneath the impoundment, the seasonal seepage at the dam toe, and the presence of good quality groundwater immediately downgradient of the dam.

Figure 3-4 shows the phreatic surface, or upper limit of saturation within the dam while Figure 3-5 shows the locations of eight piezometers located in the dam embankment. Water levels have been monitored in the embankment piezometers for more than 30 years to assess hydrologic conditions within, and seepage through the dam (see USFS, 2005). As described in Section 3.1.3, a number of seeps which develop seasonally on the downstream side of the dam have also been monitored for flow and water quality to assess the tailings dam hydrology.

The phreatic surface represents seepage from the pond through the dam and, near the eastern abutment, may also be influenced by seepage from the adjacent bedrock into the dam. The monitoring data show that groundwater levels measured in piezometers P-2 and P-6, located on the dam crest near the east abutment (east end of the dam), track closely with the elevation of the tailings pond surface (see Figure 3-6B), indicating a good hydraulic connection with the pond through the east abutment. In addition, seepage through the east abutment daylights high on the downstream dam face when pond levels exceed elevation 5477 AMSL, and the seepage flow also tracks closely with reservoir levels. Based on seepage monitoring, the flow from the east abutment seep accounts for almost 30 percent of the total seepage at the dam toe during peak reservoir levels. Seepage of bedrock groundwater into the east abutment may account for a portion of the east abutment seepage flow.

Figure 3-4 also shows how the phreatic surface varies between the eastern half of the dam (which was repaired after the 1975 dam breach) and the original embankment in the western half of the dam. The concave phreatic surface in the western half of the dam suggests that the impounded tailings, and not the dam embankment, control seepage in this section of the dam, and that the dam embankment is relatively free-draining compared to the tailings. Conversely, the convex phreatic surface in the eastern half of the dam suggests that the repaired dam embankment contributes as much or more to seepage control than the impounded tailings and is not free-draining.

Water levels measured in the embankment piezometers indicate that as the pond level rises in the springtime, the phreatic surface rises within the dam embankment. When the reservoir level reaches approximately elevation 5477, seepage develops at the dam toe. However, the rise of the phreatic surface within the dam embankment does not occur simultaneously with the reservoir level rise. As previously mentioned, the water levels measured in the crest near the east abutment track very closely with reservoir rise. However, the two piezometers located in the downstream face of the dam, P-3 and P-4, take over 30 days to equilibrate following reservoir level peaks. This lag in the rise in the phreatic surface is a sign of a healthy embankment seepage and occurs because the embankment is acting like a large sponge and storing much of the flow within its pore spaces.

Similarly, other than near the east abutment, seepage flow measurements collected in weirs along the toe of the dam correlate roughly with the tailings pond levels but contain a lot of variation and scatter in their readings. The variation and scatter in the seepage flow readings may be partly due to the lag time required for embankment saturation, but also indicate that much of the seepage is likely the result of groundwater from other sources and not tied directly to seepage through the dam embankment. However, based on extensive monitoring of the pond elevations and seepage flow at the dam toe, it is apparent that surface seepage nearly ceases when the pond elevation falls below 5476 feet AMSL. Low permeability tailings line the reservoir bottom below this elevation and are thought to be the primary reason for the significant decrease in seepage below this pond level. This observation is significant in regards to seepage through the impoundment to downstream waters, and in the development of removal action options for the impoundment as presented in Section 6.

Also of interest is the nature of groundwater in the vicinity of the dam toe. Figure 3-1 shows the locations of three monitoring wells (TDMW-1, TDMW-2s and TDMW-2d) installed in 2001 to assess groundwater quality in the vicinity of the dam toe. All three wells are completed in unconsolidated materials above the bedrock surface, with TDMW-1 and TDMW-2d completed near the top of bedrock (approximately 30 feet below ground surface), and TDMS-2s completed in shallow fill 5 to 15 feet below ground surface. All groundwater samples collected from the three wells have been of good quality with trace metal concentrations near or below analytical detection limits (see Section 3.1.4, Table 3-4). Even when metals-bearing surface seepage is present near the wellhead, groundwater at TDMW-2s, completed only five feet below the surficial seepage, has been of good quality. This information indicates that seepage of metals-bearing water through the dam is primarily limited to the seasonal (May and June) surficial seepage documented at the dam toe, with seepage to underlying and downgradient groundwater being minimal or nonexistent.

Of further interest is the fact that well TDMW-1 becomes a flowing well in the spring (May/June), with the well flowing on the order of tens of gallons per minute of high quality alluvial groundwater. TDMW-1 is completed in an unconfined “water table” aquifer, meaning the water table in this area also rises above the local ground surface in the spring. The intersection of the water table with the ground surface is believed to be responsible for the majority of surface seepage observed at the dam toe in the springtime, with a lesser amount attributable to seepage of pond water through the dam. Based on extensive monitoring of the seepage quality and quantity, daylighting of the water table aquifer near the dam toe is believed to account for approximately 65% or more of the 400+ gpm of seepage observed at the dam toe during peak pond levels. As previously stated, seepage monitoring indicates that most of the remaining 35% is due to seepage around the east dam abutment, as opposed to flow through the dam fill. This conclusion is supported by observations that were documented during the 1975 dam repair (Section 2.5 and Dames and Moore, 1975).

Besides the seasonal seepage through the dam, seepage from the tailings impoundment is believed to occur from the upstream end of the pond. Unlike the northern two-thirds of the pond, the pond bottom at the upstream end is not covered with tailings, which act to seal the pond bottom and retard downward seepage where present. Instead, coarse gravel and cobble alluvium from Beartrap Creek is exposed at the upstream end of the pond. The alluvium acts as a drain for the pond water and likely forms a continuous drain beneath the impoundment, conveying seepage water from the head of the pond to downgradient Beartrap Creek. Besides the seasonal seepage through the dam, seepage through the Beartrap Creek channel gravels constitutes the other source of uncontrolled outflow from the pond. Controlled outflow occurs through the overflow spillway pipe when the pond surface elevation exceeds 5481 feet AMSL. Seepage from the head of the pond through the Beartrap Creek channel gravels is believed to be responsible for the continued decline in the pond water level below the 5476 elevation (below which seepage through the dam decreases significantly), although other seepage pathways from the pond may exist.

3.5.4.2 2006/07 Investigation Activities

Five groundwater monitoring wells were completed along the west side of the Tailings Impoundment in August 2006 to better define groundwater conditions in the impoundment area (Section 3.1.4). More detailed definition of groundwater conditions was necessary in this area to better assess the tailings impoundment removal options discussed in Section 6.2, and because the West Impoundment area is included in the EE/CA as a potential repository site (Section 6.1). The following discussion summarizes the 2006/07 groundwater investigation activities and results/conclusions relative to removal action and repository siting considerations. Of particular interest are the general subsurface conditions, depths to groundwater, general groundwater flow pathways, and potential interactions between the tailings/tailings pond and local groundwater system.

Well Completion and Subsurface Conditions

Of the five monitoring wells completed in August 2006, four wells are located along the west tailings pond shoreline and the fifth well is located about 150 feet west and uphill of the impoundment along Mike Horse County Road. The four shoreline wells were completed as paired wells with each pair including a deep well completed in bedrock and a shallower well completed in the overlying unconsolidated deposits. Well pair TDMW-3D/3S is located along the northwest shoreline near the emergency overflow pipe inlet, and well pair TDMW-4D/4S is located approximately 650 feet south of TDMW-3D/3S. TDMW-5, a single well, is competed uphill of the pond along the county road and approximately midway between the shoreline wells. The 2006 well locations, along with existing monitoring wells TDMW-1, 2S and 2D located near the toe of the dam, and the Mike Horse Dam piezometers are shown on Figure 3-5.

Shallow wells TDMW-3S and 4S are completed to depths of 30 and 22 feet below ground surface (bgs), respectively. These wells are completed near the bedrock/overburden contact and are intended to provide information on potential shallow groundwater within the unconsolidated material. Wells TDMW-3D and 4D are completed to 70 feet and 58 feet bgs, respectively (in Spokane Formation argillite), while well 5 is completed to a depth of 105 feet. Groundwater was not encountered in the two shallow shoreline wells indicating the unconsolidated material was unsaturated at the time of drilling. Groundwater was encountered at a depth of 34 feet bgs in TDMW-3D with increased fracturing and seepage noted from 42 to 49 feet. TDMW-3D yielded one to two gpm upon completion, and the static water level equilibrated at about 43 feet bgs. Groundwater was first encountered in TDMW-4D at 42 feet bgs, with significant water (up to 50 gpm) encountered from a fracture zone between 42 and 45 feet. The static water level in TDMW-4D equilibrated at 28 feet bgs. At TDMW-5, groundwater was first encountered at 99 feet bgs at a contact between Spokane Formation argillite and diorite bedrock. TDMW-5 made less than one gpm upon completion and the static water level equilibrated at about 70 feet bgs. Well completion logs are included in Appendix B.

Groundwater Levels and Flow Patterns

Static water levels, or depths to water, were measured in all impoundment area monitoring wells and piezometers from fall 2006 through spring 2007. Depths to groundwater for the five west impoundment wells, and groundwater elevations from all impoundment area wells and piezometers are shown in Figure 3-6. As shown in Figure 3-6A, depths to groundwater were relatively stable in the west impoundment wells from October 2006 through January 2007 and ranged from approximately 30 feet bgs at TDMW-4D to 70 feet at TDMW-5. Both shallow wells were dry throughout this period. Groundwater levels rose steeply in all wells from about mid March through April, and became relatively stable again in May and June. The May/June groundwater levels range from about 10 feet bgs at wells TDMW-4S and 4D, to about 50 feet at TDMW-5. Groundwater was first detected in shallow wells TDMW-3S and 4S on May 28th and April 12th, respectively. Of particular interest in Figure 3-6A is the close correlation in the timing of the water level fluctuations in the wells, particularly between TDMW-4D and 3D, and the relative magnitude of water level rise in the west impoundment wells (TDMW-4D and TDMW-5 both rose about 20 feet from January to May while TDMW-3D rose about 13 feet).

Groundwater elevations for all impoundment area wells, piezometers and the tailings pond surface are shown in Figure 3-6B. Interestingly, groundwater levels in all wells and piezometers, including the new wells located immediately adjacent to the pond shoreline, are lower in elevation than the tailings pond surface (the one exception is the water level in TDMW-5 on 5/28/07 which was 1.5 feet higher than the pond). The fact that the pond level is higher than the adjacent groundwater by 20 feet or more during much of the year suggests that the pond is “perched” and may not be in direct hydraulic connection with the adjacent aquifer. Instead, the groundwater system is believed to be connected to, and groundwater levels controlled by, the elevation of the Beartrap Creek alluvium buried beneath the impounded tailings.

Figure 3-7 shows the groundwater potentiometric surface and pond elevation for January 30 and May 16, 2007. The potentiometric surface contours represent lines of equal hydraulic head, or groundwater elevation, for the specified time. Based on the groundwater level data depicted on the maps, the generalized direction of groundwater flow throughout the impoundment area is to the north-northeast, although flow directions vary significantly on a localized basis. A dominant feature of both potentiometric maps is a low point or trough in the groundwater surface extending along the west side of the impoundment. This is consistent with previous observations of the phreatic surface within the dam, prior to the availability of the west shoreline groundwater information. This feature could be caused by a higher permeability zone located at depth beneath the west impoundment shoreline, acting as a drain and lowering groundwater levels in this area. Conversely, the phreatic surface may be the result of increased groundwater inflow from the east. During excavation for the 1975 dam repairs (Dames and Moore, 1976), 300 gpm or more of groundwater inflow was encountered at about 5437 feet AMSL from the east abutment bedrock near the current location of piezometer P-6 (Figure 3-7). It should also be stressed that the potentiometric maps in Figure 3-7 are based on groundwater level data from potentially different groundwater systems, including bedrock, alluvium and the dam fill, which may add to the complexity of the potentiometric surface configuration. Although grouping of groundwater level data from the various media may introduce some variability in the potentiometric surface, the consistent patterns observed for both January 30 and May 16 suggest that the maps provide a reasonable depiction of general groundwater levels and flow patterns in the impoundment area.

As previously discussed, the potentiometric maps also show that the tailings pond surface is higher in elevation than the surrounding groundwater. In January, the pond is 20 feet or more higher in elevation than the groundwater system, indicating the pond is perched above the groundwater. This concept of the pond being perched has implications for the tailings impoundment removal options and is discussed further below.

Groundwater Chemistry

On May 17, 2007, water samples were collected from west impoundment monitoring wells TDMW-3D, 4S, 4D, 5 and the tailings pond surface water for assessment of the general chemistry for each water type (TDMW-3S was dry at the time of sampling). The purpose of this sampling was to further evaluate possible connections between the bedrock groundwater system and the tailings pond water. As described above, groundwater levels along the west side of the impoundment are relatively stable, and are 20 feet or more lower in elevation than the tailings pond surface during the majority of the year. Groundwater levels in shoreline wells TDMW-4S and 4D however increase to within less than 10 feet of the ground surface in spring, while water levels in shoreline wells TDMW-3S and 3-D remain 30 feet or more below ground surface. The water chemistry data was collected to determine if the significant water level rise in wells TDMW-4D/4S may be the result of a direct hydraulic connection between the wells and the tailings pond water. The May 17, 2007 water chemistry data is included in Table 3-17.

As suspected, the water chemistry data show a strong correlation between the pond water and groundwater chemistry at wells TDMW-4D and 4S. This is particularly true for TDS, sulfate and calcium, which are nearly identical in the pond and TDMW-4 samples. Major ion concentrations are much higher in upgradient bedrock well TDMW-5, which is believed to represent bedrock groundwater chemistry with no influence from surface water. The chemistry at TDMW-3D appears to be a mixture of these two water types.

This information suggests that water chemistry, and thus groundwater levels at TDMW-4D and 4S may are influenced by surface water from the tailings pond/Beartrap Creek. As described above (and illustrated in Figure 3-4), surface water is believed to flow from the pond through the Beartrap Creek alluvium, which is exposed at the head of the pond and extends northward beneath the impounded tailings, acting like a buried drain. Water within the alluvium most likely backs up into wells 4D/4S through the highly permeable fracture system encountered at 40 to 45 feet bgs during drilling. This would account for the significant springtime water level rise observed in TDMW-4D/S as compared to the other wells and the similar pond/TDMW-4 water chemistry. Based on the groundwater chemistry data, the "surface water" intrusion does not extend to TDMW-5 due to its greater distance from the pond and higher elevation. Groundwater at TDMW-3, located along the pond shoreline about 650 feet north of TDMW-4, appears to be a combination of the bedrock groundwater observed at TDMW-5 and the pond-influenced groundwater observed at TDMW-4. Surface water intrusion to TDMW-3D is probably restricted by the lower bedrock permeability at TDMW-3D compared to TDMW-4D as indicated by the much lower well yield recorded during drilling (a few gpm at 3D as compared to 50 gpm or more at 4D).

Summary and Discussion

Groundwater levels near the Mike Horse Tailings Impoundment are lower in elevation as compared to the tailings pond during most of the year. This suggests that the tailings pond is a "perched" pond with limited hydraulic connection to the adjacent groundwater system. The pond is most likely perched atop the low permeability tailings, which limit seepage through the pond bottom and may limit saturation of the tailings. Instead of being directly connected to the pond, the groundwater system is most likely connected to the Beartrap Creek alluvial system buried beneath the tailings, which represents the original drain and control point for the adjacent groundwater system. Thus, the groundwater is believed to flow largely beneath the tailings to the buried alluvial gravels and cobbles, which then convey the groundwater beneath and downgradient of the impoundment. This conceptual model is illustrated in Figure 3-8.

Based on the water level fluctuation trends and water chemistry, TDMW-4D/4S appear to be recharged by pond water when the pond surface reaches a certain elevation. A likely mechanism for this is leakage from the pond to the underlying Beartrap Creek alluvium where the alluvium is exposed at the head of the pond (Figure 3-4). Surface water then flows through the alluvium and backs up into the bedrock through the high permeability fracture system encountered at 45 feet bgs in TDMW-4D. Based on the groundwater chemistry, the pond water does not affect the less densely fractured bedrock encountered in TDMW-3D. This suggests that if pond were removed, the springtime groundwater level rise at TDMW-4D and 4S would be similar to that observed at TDMW-3D, and groundwater levels would remain 20 feet or more bgs, as opposed to the groundwater depths of l0 feet or less observed in May/June 2007. This further suggests that if the tailings pond were removed, groundwater flow patterns may approximate those shown in Figure 3-8 during most or all times of the year thus limiting the potential interaction between groundwater and the impounded tailings. The implications of these findings are discussed where relevant in the repository siting and tailings impoundment removal option discussions in Section 6.

4.0 STREAMLINED RISK EVALUATION

This section presents a streamlined risk evaluation for the UBMC EE/CA. The streamlined risk evaluation addresses human health and ecological risks posed by historic mining impacts on those portions of the UBMC located on public lands and addressed in this EE/CA (portions of Lower Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River drainages, and the Mike Horse Tailings Impoundment). The risk evaluation utilizes site-specific environmental data to identify chemicals of concern (CoCs), estimate potential exposure to CoCs, and assess potential adverse human health and ecological effects of such exposure. This information is used to provide a rationale for conducting a removal action, define potential exposure pathways that need to be addressed, and to identify appropriate cleanup goals.

The primary source of elevated CoCs within the UBMC EE/CA area is mine waste (waste rock and tailings) and contaminated soils. Mine tailings are located within the Mike Horse Tailings Impoundment, and as both isolated concentrated deposits and dispersed deposits along the Lower Mike Horse Creek, Beartrap Creek, and Upper Blackfoot River drainage bottoms (Section 3). The mine wastes contribute CoCs to downgradient surface water, sediments, and surrounding soils (and possibly groundwater). Therefore, the streamlined risk evaluation addresses the health and ecological impacts associated with exposure to CoCs present within the mine waste, surrounding soils, and downgradient surface water and sediments. The risk evaluation does not specifically address groundwater since there are currently no groundwater users within the EE/CA area, nor is such use likely in the future since the EE/CA area is confined to those portions of the UBMC located on lands within the NFS.

Upgradient sources of CoCs currently affect surface water and possibly sediment quality within the EE/CA area, and may affect future surface water and sediment quality within the EE/CA removal areas. The impact of these upgradient sources, which are being addressed through a separate removal action program, is considered in the risk evaluation process and when applying the resulting risk-based action levels.

Guidance developed by the Montana Department of Environmental Quality-Abandoned Mine Reclamation Bureau (Tetra Tech, 1996 and 2004) was used for conducting the streamlined human health risk evaluation. The streamlined ecological risk evaluation relies on published screening level criteria for various media developed by EPA and from other sources as referenced below. The streamlined risk evaluation begins with the hazard identification, which identifies CoCs to be evaluated in the process. The hazard identification, as well as other portions of the risk evaluation, is presented below.

4.1 HAZARD IDENTIFICATION

Using the hazard identification process, CoCs that pose the greatest potential risk to human health are identified for further consideration in the human health and ecological risk evaluation. The selection of CoCs is based on generally accepted practices applied by the MDEQ-AMRB. The CoC selection criteria include: 1) contaminants that are associated with and present at the site; 2) contaminants with average concentrations at least three times average background levels; 3) contaminants with at least 20 percent of measured concentrations above analytical detection limits; and 4) data that is verified to meet applicable quality assurance/quality control guidelines.

Metals for which sufficient data has been collected to support this evaluation are aluminum, arsenic, cadmium, copper, lead, manganese, and zinc. While other metals are likely to be associated with the historic mining materials being evaluated in this EE/CA, DEQ guidance (Tetra Tech, 1996) and prior experience at other mine sites suggests that the metals included in this investigation are the metals that typically result in the greatest degree of potential risk. Based on site-specific data for the various environmental media (Section 3), primary contaminants of concern in mine waste, soils, sediment, and/or water at the UBMC include arsenic, cadmium, copper, lead, manganese and zinc (Table 4-1). Therefore, the streamlined risk evaluation focuses on these parameters. A presentation of the CoC screening process is included in a screening matrix in Appendix C.

This risk assessment utilizes the "combined" data presented in the Section 3 tables. This approach differs from a typical risk assessment that would distinguish between surface soil (defined by MDEQ as the upper two feet) and subsurface soil. Several factors were considered in making the decision to utilize the combined data set. The sampling effort focused on historic mine materials. Where these materials exist as tailings or waste rock piles, the materials sampled are relatively homogeneous. The CoC concentrations do not vary significantly (from a risk perspective) with depth as might be expected for natural soils comprised of soil horizons or in cases where trace level contamination affects 'surface soil' differently from 'subsurface soil.' Using the combined data therefore provides a larger data set from which an average CoC concentration for a material type (e.g. waste rock) can be estimated. Often within an exposure area (e.g. Mike Horse Tailings Impoundment) there are multiple material types. These material types can have substantially different CoC concentrations. Using the combined data set permits the estimation of the average concentration of CoCs that a receptor may be exposed to as they move randomly throughout the exposure area. In no cases are samples from unimpacted areas (i.e., area not containing mine related materials) included with mine impacted areas to 'dilute' or 'average-out' mine impacted areas of potential concern.

4.2 STREAMLINED HUMAN HEALTH RISK EVALUATION

In accordance with EPA guidance (1989), this human health risk assessment consists of three primary parts:

- Exposure Assessment;
- Toxicity Assessment; and
- Risk Characterization.

The Exposure Assessment (Section 4.2.1) evaluates the fate and transport of CoCs in the environment and establishes the routes of exposure for people. For each exposure scenario, calculations are made regarding a media (i.e., soil) concentration that is protective against unacceptable risk. The Toxicity Assessment (Section 4.2.2) identifies the source of the quantitative measures of toxicity for each CoC. Section 4.2.3 presents the quantitative Risk Characterization, whereby areas of the site exceeding safe concentrations, and the exposure pathways that contribute most significantly to potential risk, are identified.

4.2.1 Exposure Assessment

An exposure assessment describes how contaminants are transported through the environment and come into contact with people. A complete exposure pathway requires all of the following:

- A source of CoC release into the environment;
- A transport mechanism for CoC release and migration from the source;

- Contact of CoCs with a receptor; and
- A mechanism for CoC intake into the body.

There are multiple sources of CoC release within the UBMC (Section 3.5), including upgradient sources (i.e., Upper Mike Horse Creek drainage) located outside of the area addressed in this EE/CA. CoCs associated with these upgradient source areas may continue to adversely affect water quality and sediment quality within the EE/CA area. Therefore, a more complete remedy of water and sediment quality is not possible within the scope of this EE/CA. Accordingly, this risk evaluation does not quantitatively assess risks associated with ongoing water and sediment quality.

This EE/CA does address sources of CoC release to the watershed that are located on lands within the NFS. For purposes of assessing exposure and risk, four main geographically distinct source areas exist: tailings and mine waste rock located within the Blackfoot River drainage bottom, tailings and mine waste rock located within the Beartrap Creek drainage bottom, tailings and mine waste rock located within the Lower Mike Horse drainage bottom, and tailings impounded behind the Mike Horse Dam and within the dam itself.

Rainfall, snowmelt and upgradient surface water runon can cause CoCs within each of these four areas to be released into surface water and possibly groundwater. The mechanisms of release may include sediment erosion (by wind and water) and leaching (i.e., dissolving the CoCs into the water). People may come into contact with the CoCs either through direct contact with the mine waste materials, by breathing impacted dusts derived from mine waste materials, or by contacting impacted surface water.

DEQ guidance (Tetra Tech, 1996; Tetra Tech, 2004) identifies the types of human health site uses that are most likely to occur at remote mine sites and are expected to contribute the most to potential exposure and risk. The types of site use identified in the guidance are: fisherman, hunters, gold panners/rock hounds, and ATV/motorcycle riders (does not include pickup trucks or other enclosed vehicles). Using this guidance, the following types of exposure are considered likely to contribute to potential risk within each of the four main source areas:

- <u>Upper Blackfoot River Sub-Area:</u> As described in Section 3, tailings along the Upper Blackfoot River floodplain occur as localized concentrated deposits and as dispersed deposits. Based on site topography and access, these areas may be subject to limited use by ATV/motorcycle riders. The tailings are not expected to contain the types of minerals that would attract gold panners/rock hounds. Also, although fishing resources are limited in this section of river, some limited fishing use is possible and is considered in the risk evaluation.

- <u>Beartrap Creek Sub-Area floodplain tailings and mine waste rock:</u> Beartrap Creek drainage contains mine wastes dispersed along the drainage bottom from the tailings impoundment downstream to the mouth, and small, isolated lenses of concentrated tailings. This area is minimally accessible to ATV/motorcycle use, although some limited use is possible. Based on the dispersed nature of the materials, the Beartrap Creek mine waste is not expected to support gold panner/rock hound recreational use. Also, fishing resources are poor in this section of Beartrap Creek, and fishing use is considered to be nonexistent.

- <u>Lower Mike Horse Creek Sub-Area waste rock piles:</u> The Lower Mike Horse Creek area contains several discrete mine waste piles along the drainage sides and bottoms, with waste rock (as opposed to tailings) being the primary waste type. The area is moderately accessible to ATV/motorcycle recreationists, although such use is believed to be rare based on site observations dating back to 1991. The waste rock piles may contain the types of minerals that would attract rock hounds. Due to water quality and possibly geomorphic conditions, fishing resources are lacking in Mike Horse Creek.

- Mike Horse Tailings Impoundment impounded tailings and dam face: Tailings within the impoundment (along the pond shoreline) and the dam face earthen materials are moderately accessible to ATV/motorcycle recreationists. These materials are not expected to contain the types of minerals that would appreciably attract gold panners/rock hounds. Also, based on the favorable quality of the tailings pond water (Section 3), and past observations of fish within the pond, the potential exists for fishing resources to be present within the reservoir.

Hunting was not considered to be a significant site use because the area impacted by mining is small relative to the overall available habitat for game species, and hunters would not be expected to spend appreciable amounts of time within the relatively bare land that is typical of the areas impacted by mining. Based on site experience, observed site visit patterns, and the relatively remote site location, the frequency of site use is near the lower end of recreational usage rates for public lands in Montana. Therefore, the lower levels of exposure frequency are used in the human health risk evaluation. For fisherman, an exposure frequency of 7.9 days per year is used and for the ATV/motorcycle rider an exposure frequency of 15 days per year is used, consistent with DEQ guidance (Tetra Tech, 2004). An exposure frequency of 25 days per year is used for the gold panner/rock hound, which is one-half the default value identified in DEQ guidance (Tetra Tech, 2004).

These recreationists may be exposed to the CoCs through the following mechanisms:

- Dermal absorption of CoC associated with soils that adhere to the skin;
- Ingestion of soil through inadvertent hand-to-mouth activity; and
- Inhalation of wind-blown dust.

It is assumed that recreationists in this area would not routinely use the water for drinking; however, fisherman and gold panners/rock hounds are assumed to come into direct contact with surface water.

This assessment uses default DEQ values (as described in Tetra Tech, 1996 and 2004) to quantify the amount of CoC exposure that may occur through the exposure scenarios described above. In so doing, risk-based media concentrations are derived that are protective of the reasonable maximum levels of exposure that are expected to occur at the site. These risk-based concentrations are presented in the Risk Characterization (Section 4.2.3).

4.2.2 Toxicity Assessment

This risk evaluation uses toxicity factors (cancer slope factors for carcinogens and chronic reference doses for systemic toxins) developed by the EPA. The slope factors and chronic reference doses used in this assessment were obtained from the User's Guide (Tetra Tech, 2004), which in turn were obtained from EPA's Integrated Risk Information System (IRIS) at http://www.epa.gov/iris. Contaminant-specific information regarding toxicity characteristics and the basis for development of the toxicity factors are also described on IRIS.

A cancer slope factor is the upper bound estimate of the probability of a cancer response per unit intake of a chemical averaged over a lifetime. It is derived based on the relationship of exposure (dose) to cancer rates in laboratory studies using animals or epidemiological studies where exposure to humans has been documented. They are derived using statistical regression methods to extrapolate the observations in experimental studies to lower levels of exposure typically observed in environmental investigations such as this one. It is not conclusively known whether the relationship between dose and cancer rates observed in experimental studies is preserved when extrapolated to concentrations typical of most contaminated sites. The development and use of slope factors for risk assessment is a policy position by the EPA in the absence of complete scientific information. The slope factor is typically set at the 95% upper confidence level (UCL) of the dose-response relationship to provide a margin of safety against the unknown. However, the EPA has long acknowledged that actual toxicity may be much lower, and may be as low as zero (EPA, 1986).

For long-term exposure scenarios, all toxic effects other than cancer are evaluated using a reference dose approach. Unlike the cancer slope factor, implicit in the use of a reference dose is the fact that there are concentrations below which no toxic effects are known to occur. Uncertainty factors are used to make toxicity factors more protective when confronted with uncertainty (e.g. extrapolating experimental results for animals to effects in people). Reference doses are developed based on both acute (short-term) and chronic (long-term) exposures. Generally, as the exposure period gets longer, the value of the chronic reference dose becomes lower relative to the acute reference dose. These toxicity factors are intended to be protective of the most sensitive adverse effect known and provide margins of safety against the unknown. This assessment considers the possibility of repeated exposure over a lifetime; therefore, the more stringent chronic reference doses are used.

An alternative approach is available for the evaluation of lead toxicity. Both the U.S. EPA and the California EPA have developed models that predict the concentration of lead in blood as a result of exposure to lead in various environmental media. This approach considers the fact that lead is widespread in air, water, food and soil. This approach also allows lead exposure to be compared with blood-lead levels, which is a common measurement used for assessing lead toxicity in epidemiological and toxicological studies. Appendix C provides an alternative assessment for lead using the model developed by the California EPA.

4.2.3 Risk Characterization

Risk characterization is the process of quantifying the potential risk by comparing the amount of potential exposure to a chemical with the chemical's toxicity. The approach used in this streamlined evaluation is to use a Hazard Quotient (HQ) approach to compare concentrations in environmental media with concentrations previously determined in the exposure assessment to represent an acceptable degree of hazard. This is quantitatively described as follows:

HQ = Mean Concentration in Environmental Media / Safe Media Concentration

When the concentration in the environmental media, such as surface soil, exceeds the concentration determined to be safe, then the HQ will be greater than 1.0. An HQ greater than 1.0 indicates a *potential* for adverse health impacts for people who may be exposed to the soil at a frequency (number of times per year) and duration (number of years) that is equal to or greater than the assumptions used to determine the safe concentration. An HQ greater than 1.0 indicates a *potential* for adverse health impacts because the models used to determine a safe concentration include several conservative assumptions, such as soil ingestion rates and CoC bioavailability. Also, the toxicity factors used to calculate safe levels incorporate margins of safety. The conservative assumptions used in this evaluation are necessary to ensure health protectiveness because of the inherent uncertainty associated with the risk assessment process. Importantly, the conservative assumptions are consistent with general EPA guidance. While uncertainty in estimating the true risk exists, adhering to EPA guidelines provides a streamlined approach for risk estimation that is comparable to those used at other sites, and it thereby provides a consistent basis for making decisions about remediation priorities.

4.2.3.1 Soil

The human health risks for exposure to soil are characterized in Tables 4-2 to 4-6. The upper portion of the tables present the average soil concentrations within each of the exposure units described in Sections 4.1 and 4.2.1, as applies to each respective table. Since a person using the area would be expected to move around randomly within a particular area, over time they would be expected to receive an exposure level that is most likely estimated using the average concentration.

Immediately below the average soil values in each table are the risk-based criteria – i.e., the soil concentrations that correspond to acceptable risk using the exposure assumptions described in Section 4.2.1 and the toxicity factors described in Section 4.2.2. The risk-based criteria are based on an acceptable "target" risk of 1×10^{-5} for carcinogens and a "target" HQ of 1.0 for non-carcinogens. A risk level of 1×10^{-5} is within the 1×10^{-4} to 1×10^{-6} range of risks identified in the National Contingency Plan (EPA, 1990), which is generally applied to federal Superfund sites. 1×10^{-5} is also the risk level that is used by the State of Montana for establishing a surface water quality criterion for arsenic (MDEQ, 2006). The target risk level and HQ are both divided in half, based on DEQ (Tetra Tech, 2004) guidance, to account for exposure to multiple chemicals or exposure to chemicals via multiple pathways. Thus the risk based criteria are based on a risk level of 5×10^{-6} and a HQ of 0.5.

While the approach presented in the tables follows guidance, the estimated cancer risks for all of the exposure areas are dominated by arsenic and other chemicals are not known to contribute significantly to the incremental risk. Thus, the risk level of 5×10^{-6} may be overly conservative because it has been reduced to account for possible contributions from multiple carcinogens. Such conservatism must be balanced against the possibility that additional carcinogens may be present that were not analyzed. Overall, the methodologies and assumptions employed in this streamlined risk evaluation are appropriate for informing removal objectives.

The lower portion of Tables 4-2 to 4-6 presents the HQs. The HQs for arsenic exceed 1.0 in all geographic areas. At the tailing impoundment (Tables 4-5 and 4-6), the arsenic HQ exceeds 1.0 for both the impounded tailings and for the surficial material on the downstream dam face. Also, the HQ is exceeded in all areas for manganese except for the Mike Horse Tailings Impoundment Dam Face (Table 4-6) and the rock hound exposure scenario for the Lower Mike Horse Creek area (Table 4-4). The HQs for lead for the Lower Mike Horse area also exceed 1.0 for both the ATV and rock hound exposure scenario (Table 4-4). These findings indicate that unacceptable risk exists as a result of potential exposure to arsenic, manganese and/or lead in one or more of the exposure areas.

If a risk level of 1×10^{-5} is used to assess potential concern for arsenic the risk-based criteria would double and the HQ would decrease by half. A simple way to observe the implication of this change is to identify those exposure areas where the HQ, as presently reported in Tables 4-2 to 4-6, are greater than 2.0. The Mike Horse Tailings Impoundment Dam Face has the lowest HQ of 2.3. Thus, this dam face exceeds risk-based levels of concern at a risk level of 1×10^{-5}. Changing only the risk level of concern does not change conclusions to be made about potential risks.

However, different conclusions about the risk posed by arsenic may be reached if the risk-level of concern is considered in conjunction with other areas of uncertainty and variability in the risk assessment. Importantly, this risk assessment assumes that total metals concentrations measured in soil are bioavailable (absorbed into the blood stream upon exposure to metals-laden soil or mine waste particles). However, bioavailability can be dramatically lower for non-soluble chemical forms or when the metal is encased within this mineral structure of the particle. Lowney, et al., 2005, demonstrated negligible dermal absorption for arsenic from soil. If this phenomenon was demonstrated for materials derived from the Upper Blackfoot Mining Complex and the dermal pathway was removed from the derivation of the risk-based criteria, the criteria would increase almost two-fold. Additional adjustments might prove warranted for the soil ingestion component of the risk-based criteria. Thus, considerations of bioavailability combined with risk-based levels of concern of 1×10^{-5} would result in a four-fold or greater adjustment to the risk-based criteria. A simple way to observe the implication of these changes is to identify those exposure areas where the HQ, as presently reported in Tables 4-2 to 4-6, is 4.0 or greater for arsenic. This would eliminate concern for the Mike Horse Tailings Impoundment Dam Face[1], but not for other exposure areas that have HQs ranging from 6.26 to 10.24.

A couple of additional points may aid in further interpreting the HQ results. There is not necessarily a linear relationship between increases in the HQ above 1.0 and increases in potential adverse effects. Therefore, a HQ of 10 does not imply a 10-fold increase in risk. Also, a HQ that exceeds 1.0 indicates a *potential* for adverse health impacts. Because several conservative assumptions are used to protect against uncertainty inherent to the risk assessment process, the HQs are believed to be conservative estimates of the level at which most people would be expected to receive adverse health effects as a result of exposure at the site. Also, please refer to Appendix C, which provides an alternative evaluation of the potential hazards from lead exposure using the blood-lead level approach. This alternative approach indicates lower overall hazards from lead exposure than is indicated above using the reference dose approach.

4.2.3.2 <u>Water</u>

Fishing within the Mike Horse Tailings Impoundment and the Upper Blackfoot River is identified in Section 4.2.1 as a potential route of exposure. Table 4-7 presents the risk characterization results for the fisherman using the same methodology described for soils in Section 4.2.3.1. HQs were far below 1.0 for all constituents, indicating no potential for adverse health impacts for the exposure frequency and duration assumed for the scenario.

4.3 STREAMLINED ECOLOGICAL RISK EVALUATION

The approach used to conduct this streamlined ecological risk evaluation is consistent with the general methodology established by EPA (1997). More specifically, this evaluation uses the methodology described by DEQ (Tetra Tech, 1996), which in Section 9 describes a methodology for conducting risk evaluations for aquatic organisms that in turn heavily relies upon the Ambient Aquatic Life Criteria (MDEQ, 2006). This streamlined ecological risk evaluation also uses EPA guidance for identifying ecological soil screening levels (EPA, 2003).

4.3.1 Exposure Assessment

This exposure assessment builds upon the CoC fate and transport concepts presented in Section 4.2.1. The information in this exposure assessment is used to provide context for the Problem Formulation section that follows, wherein those particular aspects of ecological health that are to be evaluated are selected.

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[1]Potential concern based on ecological risk may remain however.

The environmental media that are impacted (refer to Section 3 for a summary of media concentrations) are summarized as follows:

Soil/Mine Waste
Soil/mine waste includes all solid media samples collected from the streambanks, floodplains, and drainage bottoms along the Mike Horse Tailings Impoundment, Lower Mike Horse Creek drainage, Beartrap Creek drainage downstream of the tailings impoundment, and the Blackfoot River drainage downstream to the head of the marsh system near Pass Creek (Figure 1-1).

Sediment
Sediment includes all fluvially deposited materials within the wetted stream channel and along stream banks. Floodplain materials, whether fluvially deposited or placed by man, are considered to be soil/mine waste.

Surface Water
Surface water includes reaches of the Upper Blackfoot River, Beartrap Creek, Mike Horse Creek, and the Mike Horse Tailings Impoundment within the EE/CA-area boundaries.

The following are identified as potential routes of exposure of ecological receptors to CoCs in the above mentioned media:

Terrestrial Environment

- Birds and mammals – incidental ingestion of soil or sediment with food.
- Terrestrial plants – uptake and direct contact with soils and sediment.
- Terrestrial invertebrates – ingestion and direct contact with soil and sediment.

Aquatic Environment

- Fish – ingestion and direct contact with sediment and surface water.
- Benthic invertebrates – ingestion and direct contact with sediment and surface water.
- Aquatic plants – uptake and direct contact with sediment and surface water.

4.3.2 Problem Formulation

Chemical toxicity varies between species. What may be toxic to humans at a given concentration may or may not be toxic to one or more ecological organisms. When approaching an ecological risk assessment, it is necessary to consider a broad range of possible species and the interrelationship of these species within the context of overall potential impacts to broader ecological integrity. For these reasons, EPA guidance recommends that a problem formulation step be included at the beginning of an ecological risk assessment. A primary objective of problem formulation is to define the assessment endpoints. The following text from EPA (1997; p. I-4) describes assessment endpoints:

> "The Agency defines assessment endpoints as explicit expressions of the actual environmental values (e.g. ecological resources) that are to be protected. Valuable ecological resources include those without which ecosystem function would be significantly impaired, those providing critical resources (e.g. habitat, fisheries), and those perceived as valuable by humans (e.g. endangered species and other issues addressed by legislation). Because assessment endpoints focus the risk assessment design and analysis, appropriate selection and definition of these endpoints are critical to the utility of a risk assessment. Assessment endpoints should relate to

statutory mandates (e.g. protection of the environment), but must be specific enough to guide the development of the risk assessment study design at a particular site. Useful assessment endpoints define both the valued ecological entity at the site (e.g. a species, ecological resource, or habitat type) and a characteristic(s) of the entity to protect (e.g. reproductive success, production per unit area, areal extent)."

This Problem Formulation considers these factors first in terms of aquatic life and then for terrestrial life.

4.3.2.1 Aquatic Assessment Endpoints

The Blackfoot River is generally recognized as a valuable cold water fishery. On this basis alone, the protection of the fishery would be an important assessment endpoint. Doing so also implies protection of aquatic invertebrates and plants that support the fishery food chain. Fishery quality may be adversely affected by elevated metals concentrations derived from the mine wastes and from physical habitat degradation. Moreover, there are upstream sources of release of metals that are expected to continue impacting many of the surface water bodies considered in this EE/CA. For this reason, fisheries impacts are not primary assessment endpoints for this EE/CA. Rather, an adaptive management approach is to be used. Metals which leach from the historic mine material can enter both the surface water bodies and their respective sediments. The removal of the mine materials will reduce the amount of metals that are available for leaching into surface water and sediments. Within the context of the adaptive management approach, water quality will continue to be monitored after the removal of mine materials. Any additional actions needed to improve fisheries will be considered at a later phase of the remediation efforts within the area which gives due consideration to upstream water quality improvement needs and possible natural sources of impaired surface water quality.

4.3.2.2 Terrestrial Assessment Endpoints

As for the aquatic habitat, the terrestrial habitat is possibly impacted by both the physical quality of the historic mine materials and the elevated metals concentrations in the mine materials. The lack of topsoil within the mine materials likely minimizes the potential for vegetative growth and therefore minimizes the overall habitat quality. The mine impacted areas receive relatively little use by both plant and animal species. Moreover, there is ample high quality ecological habitat on surrounding lands and along more downstream stream reaches. Therefore, any adverse health impacts which may (or may not) occur as a result of excessive metals exposure to individual organisms that live within or frequent the mine impacted areas would be muted within the broader context of ecosystem health for the region. That said, high quality terrestrial habitat along stream corridors is both aesthetically valued, ecologically productive, and may provide for a unique type of stream corridor ecological habitat. For these reasons, this screening level ecological risk evaluation considers assessment endpoints for soil invertebrates, plants, birds and mammals. The use of such general categories of organism types is consistent with the approach frequently used to conduct screening level assessment.

4.3.3 Toxicity Reference Values

The EPA and the U.S. Department of Energy (DOE) have developed soil screening levels (Eco-SSLs, or simply SSLs) that are appropriate for use in completing screening level ecological risk evaluations. The following EPA (2003) text addresses the derivation and application of the SSLs:

> "The Eco-SSLs are concentrations of contaminants in soil that are protective of ecological receptors that commonly come into contact with soil or ingest biota that live in or on soil. These values can be used to identify those contaminants of potential concern in soils requiring further evaluation in a baseline ecological risk assessment. The Eco-SSLs should be used during Step 2 of the Superfund Ecological Risk Assessment process, the screening-level risk calculation. The Eco-SSLs are not designed to be used as cleanup levels and EPA emphasizes that it is inappropriate to adopt or modify these Eco-SSLs as cleanup standards.
>
> EPA derived the Eco-SSLs in order to conserve resources by limiting the need for EPA and other risk assessors to perform repetitious toxicity data literature searches and data evaluations for the same contaminants at every site. This effort should also allow risk assessors to focus their resources on key site-specific studies needed for critical decision-making. EPA also expects that the Eco-SSLs will increase consistency among screening risk analyses and decrease the possibility that potential risks from soil contamination to ecological receptors will be overlooked."

The SSLs selected for this assessment are presented in Table 4-8. Where available, the recently revised criteria from the EPA were selected. Criteria established previously by the DOE were used where criteria established by the EPA were not available.[2]

4.3.4 Risk Characterization

As was done for the human health risk assessment, this screening level ecological risk evaluation compares the arithmetic average concentrations in soil with the SSLs using a HQ approach. The HQs are presented in Tables 4-9 to 4-13 for each of the exposure units.

Tables 4-9 to 4-13 indicate widespread exceedances of the SSLs. HQs less than 1.0, indicating minimal potential for ecological risk, only occur sporadically across the exposure units and organism types for cadmium, copper, lead and zinc.

As previously stated, the elevated HQs indicate a potential for ecological risk to individual organisms that may live within or frequent the impacted areas. The standards are based on the most sensitive adverse effect observed among those species for which toxicological information is available. The screening criteria are intended for application nationwide, and are therefore conservatively derived to

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[2] As stated above, the SSLs are intended for use in completing screening level ecological risk evaluations, which this is. In lieu of developing site-specific cleanup levels through completion of a conventional risk assessment, the SSLs are used as preliminary cleanup goals in this EECA (see Section 5), with the adequacy of associated removal actions determined through follow-up monitoring. This adaptive management approach to site cleanup will expedite actual site cleanup, as opposed to spending significant time and funding on development of site specific cleanup standards, without compromising the level of cleanup ultimately attained.

Also, for reasons stated in Section 4.3.2.1, The State of Montana surface water quality criteria are not used in the Streamlined Ecological Risk Evaluation. The surface water quality criteria are used in Section 5 to inform remedial action decisions. These criteria are based on total recoverable concentrations (rather than dissolved concentrations) in surface water. Total recoverable metals concentration may over predict toxicity in waters that have elevated TSS, TDS, or other water quality conditions that tend to inhibit the uptake of the CoCs by aquatic organisms. This effect may be minimal for the Upper Blackfoot River and headwaters because of low TSS, TDS, and generally equal concentrations for dissolved and total recoverable metals concentrations (see Tables B-2, B-6, B-10 and B-14).

apply to a large variety of species (but not necessarily all species). Also, there is no simple relationship between potential adverse health impacts to individual species and overall ecological integrity. Because of the relative abundance of surrounding high quality ecological habitat in the region, an elevated HQ does not permit conclusive statements about potential adverse impacts to the ecological integrity of the region. Rather, the results may be more applicable to the need to re-establish stream corridor habitat, particularly as may apply to rare, threatened or endangered species that may (now or when reclaimed) inhabit such habitat, or other ecological considerations along this line of thought.

4.4 SUMMARY AND CONCLUSIONS

Regarding the potential for human exposure to surface soil, ATV/motorcycle use was assumed for all exposure units. Additionally, a gold panner/rock hound exposure scenario was applied to the evaluation of the Lower Mike Horse Area. HQs exceed 1.0 for multiple metals in each of the exposure units. Unacceptable risk exists for the ATV/motorcycle user as a result of potential exposure to arsenic, manganese and/or lead in one or more of the exposure areas. (Note that the blood-lead approach presented in Appendix C indicates that lead does not pose an unacceptable risk for the ATV/motorcycle user.) Unacceptable risk exists for the gold panner/rock hound as a result of potential exposure to arsenic and lead in one or more of the exposure areas. (Note that the blood-lead approach presented in Appendix C indicates that lead may pose an unacceptable risk to small children, but it does not pose an unacceptable risk for adult gold panners/rock hounds.)

Fishing within the Mike Horse Tailings Impoundment pond and the Upper Blackfoot River is considered a potential route for human exposure to metals. The HQs were far below 1.0 for all constituents, indicating no potential for adverse health impacts for exposure to metals in surface water and fish at the assumed fish ingestion rate (113 grams/day), exposure frequency (7.9 days/year), and exposure duration (30 years).

Regarding potential ecological risks, this screening level evaluation indicates widespread exceedances of the eco-SSLs. HQs less than 1.0, indicating minimal potential for ecological risk, only occur sporadically across the exposure units and organism types for cadmium, copper, lead and zinc. These results indicate a potential for adverse health impacts to species that live within or may otherwise frequent the impacted areas; however, these results cannot be generalized to make conclusive statements about potential ecological impacts throughout the broader region.

5.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

The streamlined human health and ecological risk evaluations presented in Section 4 concluded that mine waste/soils and surface water at the UBMC pose potential risks to both human health and the environment. Specifically, potential risks to recreational site users are posed by arsenic, lead, and/or manganese in one or more of the four EE/CA areas. The screening level ecological risk evaluation shows that arsenic, cadmium, copper, lead, manganese, and zinc all pose potential risks to various ecological receptors in one or more of the EE/CA areas.

The primary goal of removal actions described in this EE/CA is protection of human health and the environment through minimization of direct contact with contaminants, and minimization of migration and mobility of contaminants to the environment. The following sections describe the rationale for the removal actions, Preliminary Removal Action Objectives, and Applicable or Relevant and Appropriate Requirements.

5.1 REMOVAL ACTION RATIONALE

Site data and the risk evaluation performed for the UBMC indicate that mine waste rock, tailings, and impacted soils located along the tailings impoundment, Lower Mike Hose Creek, Beartrap Creek, and/or the Upper Blackfoot River pose potential risk to human health and the environment, and therefore qualify for response actions under 40 CFR 300.415 of the NCP. According to 40 CFR 300.415(b)(2) of the NCP, the appropriateness of a removal action can be determined by one or more of the following factors:

1. Actual or potential exposure of nearby human populations, animals, or food chain to hazardous substances, pollutants, or contaminants;
2. Actual or potential contamination of drinking water supplies or sensitive ecosystems;
3. Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release;
4. High levels of hazardous substances, pollutants, or contaminants in soils largely at or near the surface with the potential for migration;
5. Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or be released;
6. Threat of fire or explosion;
7. The availability of other appropriate federal or state response mechanisms to respond to the release; and/or
8. Other situations or factors that may pose threats to public health or welfare or the environment.

The appropriateness of and rationale for mine waste removal actions in Lower Mike Horse Creek, Beartrap Creek, the Upper Blackfoot River, and the Mike Horse Tailings Impoundment are related primarily to items 1, 2, 4, 5, 7 and 8 above.

5.2 REMOVAL ACTION OBJECTIVES

The overall objective of the removal action as defined under CERCLA and the NCP is to reduce the current and/or threatened release of potentially hazardous substances to the environment. The primary media of concern at the site (soil/mine waste, surface water and sediment, and potential human health and ecological exposure pathways) have been identified. As stated above, the overall goal of the removal actions described in this EE/CA is the protection of human health and the environment through minimization of contact with contaminants, and minimization of the migration and mobility of contaminants in the environment. Specific objectives of the removal actions include:

- Reduce the potential for contaminant migration from mine waste (waste rock/tailings), soils and sediments that would result in unacceptable risk to human health and the environment;
- Reduce potential for unacceptable risk to human health through ingestion of mine waste, soils and sediment and/or inhalation of dust;
- Improve water quality in Lower Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River to the extent possible accounting for the presence of upgradient sources;
- Improve watershed functionality in the Blackfoot Headwaters area to promote a more stable, natural hydrologic system; and
- Reduce long-term potential for failure of the Mike Horse dam and the associated increase in migration and mobility of contaminants that would result.

These objectives should be achieved through attainment of the ARAR-based and risk-based goals presented below.

In addition to these primary removal action objectives, a number of secondary objectives have been identified by the USFS. Secondary removal action objectives include:

- Minimize effects to significant historic features at the site;
- Enhance future recreational opportunities for the site; and
- Improve overall site aesthetics.

As previously mentioned, attainment of certain removal action objectives (RAOs) may be dependent in part on factors outside of the control of the EE/CA actions. Specifically, metals loading sources in Upper Mike Horse Creek drainage may influence the magnitude of water quality improvements that may be achieved through the EE/CA removal actions alone. The ultimate water quality in EE/CA area streams will be dependent in part on the completion of reclamation actions and water quality mitigation measures being implemented by ASARCO on private land holdings at the UBMC. It is also possible that natural sources of metals loading to area streams are present at the UBMC due to the presence of mineralized bedrock. Therefore, the removal process administered on lands within the NFS through this EE/CA will focus on source control, where known or suspected sources of contaminant loading to area streams (such as the Lower Mike Horse mine waste piles) are addressed through removal or other means, and the effects on water quality determined through post-removal monitoring. This adaptive management approach, where removal actions are completed, the environmental response is monitored, and the need for additional actions evaluated, is consistent with principles of the restoration plan included in the Blackfoot Headwaters area metals TMDL document (MDEQ, 2003).

5.3 ARAR-BASED GOALS

Applicable requirements are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal or State laws that specifically address a hazardous substance, constituent, removal action, location, or other circumstance found at a site. Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requires that on-site remedial actions attain or waive Federal environmental ARARs (Applicable or Relevant and Appropriate Requirements), or more stringent State environmental ARARs, upon completion of the remedial action. The 1990 National Oil and Hazardous Substances

Pollution Contingency Plan (NCP) also requires compliance with ARARs during remedial actions and during removal actions to the extent practicable (http://www.epa.gov/superfund). Relevant and appropriate requirements, while not applicable to a hazardous substance, pollutant, contaminant, removal action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the site (40 CFR 300.5). In addition to ARARs, many Federal and State Environmental and public health programs also have criteria, advisories, and guidance that are not legally binding but may provide useful information or recommended procedures. These To-Be-Considered standards and ARARs are identified for use in guiding removal actions. A compilation of ARARs is included in Appendix D.

ARAR-based cleanup goals for the UBMC are limited to surface water and groundwater since no contaminant-specific ARARs exist for soils and mine waste. ARARs for surface water and groundwater are discussed below.

5.3.1 Surface Water

Surface water ARARs include established aquatic life and human health water quality standards which specify concentrations of a specific constituent deemed protective of human health and the environment. The human health water quality standards assume that 2 liters of water per day are consumed and that fish are consumed at the national average fish consumption rate over a lifetime. These assumptions result in much higher levels of exposure and therefore much lower human health standards than those determined for the fisherman scenario in the human health risk screening (Section 4.2.3.2). For certain constituents, including some UBMC CoCs, the aquatic life standards include both acute and chronic criteria. The chronic criteria are applicable for long-term exposure and were selected for this ARAR evaluation. The more stringent of the applicable human health or aquatic water quality standards is taken to be the ARAR-based goal for surface water. The ARAR-based goals for surface water are listed in Table 5-1.

5.3.2 Groundwater

Groundwater at the site is not currently used as a drinking water source, nor is it likely to be used as such in the future based on the undeveloped nature of the site, historic use of the area, and the fact that all areas addressed in this EE/CA are on public lands. Although the removal actions addressed through this EE/CA do not specifically address groundwater (since groundwater poses no direct risk), the removal actions have the potential to improve groundwater quality through removal of potential sources of groundwater contamination.

ARAR-based goals for groundwater are the State of Montana human health standards and are listed in Table 5-2.

5.4 RISK-BASED GOALS

The streamlined risk evaluation (Section 4.0) determined that arsenic, lead and manganese in soils/mine waste exceed acceptable risk levels for occasional recreational users of the site. In addition to these metals, cadmium, copper, and zinc pose potential environmental threats to the various ecological receptors. Therefore, risk-based cleanup levels have been developed to further guide the removal action process at the UBMC.

Table 5-3 presents the basis for the recommended risk-based soil cleanup goals for both carcinogenic and non-carcinogenic CoCs. The risk-based goals are based on results of the streamlined human health and ecological risk evaluation and typical background soil concentrations at mine sites in Montana. The recommended risk-based cleanup goals are based on the lowest risk-based soil concentrations for human or ecological receptors; however, the recommended cleanup goals are not less than background concentrations. Some additional consideration regarding potential background concentration may be necessary during final removal design or other future phases of the project, since background concentrations at the site may vary from state-wide average concentrations as reflected by the maximum state-wide background concentrations shown in Table 5-3. Importantly, the Screening Level Ecological Risk Evaluation (see Section 4.3.3) indicates that the eco-SSLs are not to be used as cleanup standards. While we chose to use them as cleanup goals, there remains a considerable degree of uncertainty and most likely a high degree of conservatism in these values as they may apply to the site. For example, many metals toxicity studies on plants are related to the application of municipal sewage sludge as fertilizer for agricultural crops. The species of concern, climate, soil and other factors in agricultural studies have little in common with the alpine conditions at the site. Regarding soil invertebrates, these species are important for a healthy ecosystem; however, compromising invertebrate abundance within specific areas at the site will have limited ecological impact to the broader region. For these reasons, a range of possible cleanup recommendations is provided that both includes and excludes toxicity factors for plants and soil invertebrates.

Table 5-4 presents the basis for the recommended risk-based surface water cleanup goals. These goals consider the ongoing removal actions on private property upgradient of the site, which may affect future site use and thus the actual risks for potential future site users. The goals also consider the more limited site use by fisherman rather than the ARARs-based human health standards presented in Table 5-1; however, the chronic aquatic life criteria presented in Table 5-1 are utilized. As for soils, the lower of both the fisherman and chronic aquatic life standards could be applied in the future to select the risk-based cleanup goals, provided that the risk-based values are not lower than upstream concentrations. Strict adherence to these goals for selection of final removal actions may not be appropriate until the final upstream water quality is determined. Similarly, sediment criteria relevant to ecological risk should be considered at that time. Since upstream surface water quality and sediment quality is expected to improve over time as cleanup progresses in these areas, the risk-based cleanup goals for these media should also be reassessed periodically, consistent with an adaptive management approach for improving ecological health in the Blackfoot River.

Consistent with EPA guidance (EPA, 1993), the risk-based goals and ARARs are considered further in Section 7.0 along with the balancing criteria of effectiveness, implementability, and cost to support final recommendations regarding the remediation approach.

6.0 PRESENTATION AND EVALUATION OF SITE-WIDE ALTERNATIVES

This EE/CA addresses removal actions for mining-related impacts on lands within the NFS and within portions of Lower Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River drainage bottoms, and the Mike Horse Tailings Impoundment. Removal action options have been developed for each of these sub-areas, and were previously presented in two alternative technical memoranda (Hydrometrics, 2005b; USFS, 2006). This section provides descriptions and conceptual details for each sub-area removal options. Based on comments provided on the mine waste removal alternatives technical memorandum, and more detailed evaluation of the options, Beartrap Creek Option 3 and Blackfoot River Option 3 (both of which included partial mine waste removal and in-place amendment of remaining mine waste) have been omitted from further consideration and therefore are not included in the following discussion. Following presentation of sub-area removal options, selected options from each sub-area are combined into a number of site-wide alternatives for evaluation. This evaluation will form the basis for selection of a preferred site-wide alternative by the USFS for the UBMC EE/CA area.

Section 6.1 includes an overview of potential mine waste repository locations and a conceptual repository cap design. Sections 6.2 through 6.5 present removal options for the four sub-areas, and Section 6.6 presents design elements and construction considerations common to all removal options. The site-wide removal alternatives are presented in Section 6.7. The site-wide alternatives are screened through a comparative analysis of effectiveness, implementability and cost in Section 7.

6.1 REPOSITORY OPTIONS

A number of locations have been identified as potential repository sites for permanent disposal of soil/mine waste excavated through implementation of removal actions identified in this EE/CA. The repository sites fall under two categories, in-drainage sites and out-of-drainage sites. In-drainage sites refer to those located within the EE/CA area, or generally within the Upper Blackfoot drainage upstream of the confluence with Pass Creek (Figure 1-2). In-drainage sites include the Paymaster Mine area, the West Impoundment area, and the Old Townsite area. Two potential out-of-drainage repository sites have been identified and are located within First Gulch drainage area and Horsefly Creek drainage. Other out-of-drainage locations may be considered as well if the First Gulch or Horsefly Creek sites prove to be unsuitable, or if more suitable locations are identified through ongoing evaluation of potential repository sites. Assuming suitable sites can be identified, use of in-drainage repositories is preferred due to the reduced hauling distance involved (and associated cost and safety benefits of eliminating off-site hauling), and to avoid disturbance of additional lands outside the EE/CA area.

Each potential repository site is described below. Repository locations are shown in Figure 6-1 and a qualitative comparison of repository sites is included in Table 6-1. Two Repository Siting Investigations, a screening level investigation completed by the USFS for potential in-drainage repository locations and a screening level investigation completed by MDEQ for potential out-of-drainage locations within 20 road miles of the Mike Horse Dam, along with site characterization evaluations performed by the USFS at Fist Gulch and by MDEQ at Horsefly Creek, are included in Appendix E. Additional investigation will be conducted in 2007 at all repository locations identified for potential use through the EE/CA process.

6.1.1 In-Drainage Repository Locations

6.1.1.1 Paymaster Mine Area

The Paymaster Repository site is located on private property (owned by ASARCO) in Township 15N, Range 6W, Section 20 (Figure 6-1). The potential repository site occupies the north facing hillside bounded by Paymaster Creek drainage on the east and Meadow Creek drainage on the west. The area slopes to the north at about 20% to 25% and is covered by a lodgepole pine forest. The Paymaster area is the location of an existing repository constructed by ASARCO in 1996/97, with additional material placed in the existing repository in 2006. The new repository location would be immediately west of the existing repository, and would be within 2.5 road miles of the tailings impoundment with distances to the other sub-areas less than this. Suitable haul roads currently exist to the Paymaster area, with minimal additional road building necessary. All hauling would occur on county and USFS roads, with no highway hauling necessary.

Based on information collected during design and construction of the existing repository, subsurface conditions at the site include one foot of silty topsoil, silty to clayey sand and gravel (SC-GC) from one to six feet below ground surface, and well graded sand and gravel from six feet to greater than 10 feet below ground surface (McCulley, Frick and Gilman, 1996). Groundwater level data collected from three test pits between 1994 and 1996 showed groundwater levels to be greater than 10 feet bgs. Bulk soil samples collected from the 0 to 1.0-foot, 5 foot and 10-foot intervals were tested for grain size distribution, organic matter content, compaction, direct shear, and/or permeability. Shelby tube soil samples were also collected from each pit at a depth of 5 feet for direct shear testing. Details of the 1994-1996 testing are presented in MFG, 1996 and the testing results are included in Appendix E.

In addition to the soil testing, a slope stability analysis was performed by MFG (1996) using the PCSTABL5M computer program. Soil parameters for the slope stability analysis were obtained from direct shear tests performed on bulk samples taken from test pits. The direct shear tests indicated internal friction angles ranging from 28° to 30° for repository fill and 47° for the subgrade. The stability analysis showed the minimum static factor of safety for the repository slopes to be 3.2 and the minimum seismic factor of safety was 1.9 (MFG, 1996). These values are well in excess of the minimum recommended static design factor of 1.5 and the minimum recommended seismic design factor of 1.0 (USEPA, 1993). Details of this analysis are presented in MFG, 1996 and are included in Appendix E.

Information obtained from three bedrock monitoring wells drilled at the existing Paymaster Repository in 2006 show the area to be underlain by hard intrusive bedrock (diorite sill), with a quartz-sulfide vein encountered in one of the wells. Depths to groundwater ranged from 24 to 44 feet below ground surface in August 2006 and from 19 to 31 feet in May/June 2007. The generalized bedrock groundwater flow direction is north-northwest towards the Blackfoot River. Test pit logs, well logs and other relevant information from the Paymaster Repository area is included in Appendix E. Conditions at the nearby EE/CA repository site are expected to be similar to those described above for the existing repository, although it is not currently known if any mineralized veins transect the proposed repository area. Based on preliminary field surveys, there are no surface water features such as streams, springs/seeps, or wetlands within the potential repository area. The closest surface water would be a marshy area in the Blackfoot River drainage bottom about 200 feet to the north of the repository site. Additional site investigations will take place in 2007/08 if the Paymaster Repository site is retained for further consideration in the site-wide plan.

Based on a topographic survey performed by the USFS, the Paymaster Repository site has an estimated mine waste storage capacity of between 200,000 and 300,000 cubic yards (cy) assuming a low profile structure similar to the existing Paymaster Repository (i.e., fill thickness of approximately 15 feet or less and minimum buttressing at the toe to lessen visual impacts) and a repository footprint area of about six acres. The repository capacity could be increased to accommodate 500,000 cy or more with a more engineered structure including a 20-foot high toe retaining berm to increase the repository fill thickness, and the repository footprint was increased to about ten acres in area. Drawing 5, Appendix F shows one potential repository configuration for the larger 500,000 cy capacity option. Other potential configurations will be evaluated if the Paymaster Repository site is included in the selected site-wide alternative.

6.1.1.2 West Impoundment Area

The West Impoundment Repository site is located along the west side of the Mike Horse Tailings Impoundment in Township 15 N, Range 6W, Section 27, and is located entirely on lands within the NFS (Figure 6-1). The hillside slopes northward at about 33% and is crossed by the Mike Horse county road. Below the county road, the hillside has been extensively reworked with an old road bed and the former Beartrap Creek diversion ditch forming two benches. Above the county road, the hillside is relatively undisturbed with moderate forest cover. Based on the location immediately adjacent to the tailings impoundment and Lower Mike Horse Creek removal areas, little if any additional haul road construction would be necessary.

In 2006, five monitoring wells were drilled in the proposed repository area for characterization of groundwater conditions. Depths to groundwater within the bedrock ranged from about 30 to 70 feet below ground surface from late summer through winter, and increased to within 10 feet of the ground surface in two of the shoreline wells in spring 2007. As described in Section 3.5.4, the large rise in groundwater levels observed in the two wells is believed to be related to backing up of pond water into the bedrock system, and may not occur if the pond is eliminated. Thus, groundwater conditions in this area may be suitable for construction of a repository in the absence of the pond although additional information would be required to confirm this. Groundwater conditions will continue to be evaluated in 2007/08 to assess the groundwater level response to tailings impoundment dewatering and the suitability of the West Impoundment site for repository construction if the West Impoundment Repository is retained for further consideration in the site-wide plan.

There are no surface water features such as streams, springs/seeps or wetlands within the proposed repository area. Following implementation of tailings impoundment options 3 or 4 (the only two options under which the West Impoundment Repository site would be considered) the closest surface water body (Mike Horse Creek) would flow approximately 150 feet from the repository toe.

Two general designs are considered for the West Impoundment Repository depending on the extent of tailings removal selected for the impoundment. For tailings impoundment removal option 3 (described in Section 6.2.3), the repository would be constructed atop tailings to be left and closed in-place (repository Scenario 1). For the more extensive tailings removal proposed under option 4, the repository design would include a higher level of engineering and construction to maximize the repository capacity (repository Scenario 2), which would also increase the level of technical difficulty associated with repository construction. Each of these designs is described below with additional detail presented in Section 6.2 under the applicable impoundment removal option discussions.

Scenario 1

Repository Scenario 1 is designed specifically for use with impoundment removal Option 3, which includes partial removal of the impoundment tailings with the remainder of tailings to be closed in place. Under Scenario 1, the repository would be constructed on top of the tailings left in place. The hillside between the impoundment and the county road would be stripped of vegetation and the ground surface prepped for repository development. Following dewatering, material excavated from the impoundment would be placed in lifts atop the prepped surface for compaction and incorporation into the repository. The repository, which would include the tailings left in place and the excavated tailings stacked on top, would be capped as described in Section 6.1.3. Based on a detailed topographic survey, the West Impoundment Repository would have a storage capacity of about 180,000 cy under Scenario 1, and could receive all of the material to be removed from the impoundment under the partial removal option (up to 60,000 cy), plus all or most of the material to be removed from Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot River. The repository layout is shown in Drawing 3, Appendix F with a schematic representation shown in Figure 6-2.

Scenario 2

Under Scenario 2, the West Impoundment Repository design would include a higher level of engineering to increase the repository capacity. Scenario 2 would be considered only for Tailings Impoundment removal Option 4 (although this is not the only repository location considered for this option), which includes total removal of the tailings dam and impoundment from the drainage bottom to the extent practicable. Besides the additional excavated material requiring disposal under Option 4 (up to 350,000 cy), the engineering measures are needed to compensate for less space being available for repository construction (due to the complete removal of tailings from the impoundment and loss of the flat surface of the in-place tailings to build upon) as compared to Scenario 1.

Under this scenario, the repository design would include over-excavation of the repository subgrade and incorporation of a toe berm to increase repository capacity. Over-excavation of the subgrade would increase the repository capacity by lowering the repository bottom elevation, and the toe berm would allow the repository thickness and slope to be increased. The subgrade would be excavated into benches to increase repository stability. The subgrade excavation would have the added benefit of providing excess earthen material for use as earthen fill and/or repository/removal area cover material for use throughout the EE/CA area. An earthen berm would be constructed along the toe of the repository area prior to placement of the dewatered tailings in the repository.

Based on the repository design and results of a slope stability evaluation (Section 6.2.1.7), the completed repository face would have a slope of 2.65 to 1 and would be covered with an engineered cap as described in Section 6.1.3. The estimated capacity of the West Impoundment Repository with a 15-foot high toe berm would be about 245,000 cy. Additional subsurface investigation would be required to further quantify hydrologic and geotechnical conditions in the west impoundment area before the Scenario 2 repository could be selected.

6.1.1.3 Old Townsite Area

The third in-drainage repository site is the Old Mike Horse Townsite located 500 feet north of the tailings impoundment on lands within the NFS (Township 15N, Range 7W, Section 27, Figure 6-1). The Old Townsite is a large flat benched area located between the Mike Horse County Road and Mike Horse/Beartrap Creeks where the Mike Horse Mine employee housing use to be located. All structures were removed several years ago and the site was revegetated in 1996 and now supports a healthy grass cover. The potential repository site extends from the townsite bench, uphill (westward) to an old borrow pit just uphill of the county road. Overall the site slopes about 25% from top to bottom and other than the grass cover on the reclaimed bench, the site is mostly devoid of vegetation. All portions of the site are readily accessed by existing roads.

The lower bench measures approximately 100 feet by 350 feet and ranges from about 20 to 40 feet in elevation above Mike Horse/Beartrap Creek. From the back of the bench, the ground slopes steeply upward about 40 feet to the Mike Horse county road, which forms a second flat bench, and then slopes upward at about 33% through the old borrow area. The borrow pit area consists largely of bedrock outcrops (argillite), while the county road and lower bench surfaces are comprised of unconsolidated fill. There are no streams, springs/seeps or wetlands present at the site. The closest surface water bodies would be Mike Horse and Beartrap Creeks, both located less than 100 feet from the lower bench. No information is currently available on depths to groundwater or other subsurface conditions beneath the site.

In order to maximize the repository capacity, the repository design would include removal of some fill material below the county road (if testing shows the fill to be suitable for use as reclamation backfill or cover). Based on estimated depths to bedrock below the road, approximately 16,000 cy of material would be excavated for possible use as cover/fill material. An earthen berm would be constructed along the outer edge of the repository to retain the repository fill material and allow the repository fill to be placed at a greater thickness than would otherwise be possible. The repository fill (dewatered tailings and other earthen material from the impoundment and possibly other removal areas) would then be placed in the repository in lifts and compacted to construction specifications. The repository would be covered with an engineered cap as described in Section 6.1.3. Based on a 15-foot high toe berm and a 3.6:1 slope for the repository face (see slope stability evaluation in Section 6.2.6.2), the Old Townsite Repository would have a capacity of 125,000 cy. A preliminary design drawing for the Old Townsite Repository is shown in Drawing 13, Appendix F.

Advantages of the Old Townsite location include the proximity to the tailings impoundment, Lower Mike Horse and Beartrap Creek removal areas, the fact that the site is within the UBMC area and is already disturbed, and avoidance of hauling on heavily traveled roads or highways. Development of this site would require the county road be relocated around the repository or across the repository face. Other existing infrastructure, such as a water conveyance pipeline buried beneath the existing road bed may also require relocation. As with the other potential repository locations, additional investigation would be required to confirm the suitability of the Old Townsite as a repository location and better assess the potential repository capacity.

6.1.2 Out-of-Drainage Repository Locations

Two potential out-of-drainage repository locations have been identified for consideration should the in-drainage sites prove to be unsuitable or provide insufficient capacity for disposal of all excavated material. Both sites are located west of the EE/CA area and would require mine wastes to be hauled on state Highway 200. The first site is in the First Gulch area and the second is in Horsefly Creek drainage (Figure 6-1). Each of these sites is described below.

6.1.2.1 First Gulch Area

First Gulch is a tributary to the Blackfoot River located west of the Mike Horse Road/Highway 200 junction. The potential repository site is located on lands within the NFS in Township 15N, Range 7W, Section 14. The site is situated on the east side of First Gulch drainage, and on the west flank of the ridge separating First Gulch on the west from Second Gulch to the east (Figure 6-1). The site slopes to the west at 20% to 25% and is covered by small (10-foot tall) lodgepole pine. The repository site is 6.5 road miles from the Mike Horse Tailings Impoundment, including 2.5 miles on Mike Horse county road between the impoundment and Highway 200, 2.75 miles on Highway 200, and 1.25 miles of existing dirt road leading north from Highway 200 to the repository site. No new road construction would be necessary to access the repository site, although access road upgrades would be necessary.

Subsurface conditions at the site are as follows. Six test pits excavated in November 2006 and five more excavated in May 2007 (see Drawing 14, Appendix F), show soils to be silty loam to loam texture with considerable coarse rock content. Neither bedrock nor groundwater were encountered in any of the 6 to 10-foot deep pits, although the coarse rock content increased to over 50% near the bottom of each pit, suggesting that depths to bedrock are not much greater than the pit depths. Two monitoring wells were also drilled along the site access road near the proposed repository toe (Drawing 14, Appendix F). Well FGMW-1 encountered unconsolidated material to six feet, which was underlain by moderately hard, buff colored bedrock believed to be volcanic tuff from six to 66 feet, and Spokane Formation argillite from 66 to 80 feet. FGMW-2 encountered 22 feet of unconsolidated colluvium, and Spokane Formation argillite from 22 to 80 feet. Groundwater was first encountered at about 60 feet bgs in both wells, and stabilized in mid June at 60 feet bgs in FGMW-1 and 55 feet bgs in FGMW-2. The monitoring well logs, test pit logs and soil testing results are included in Appendix E.

Based on preliminary field inspections, no streams, springs/seeps or wetlands are present. The closest surface water body, First Gulch drainage, is located about 300 feet from the proposed repository toe. Additional investigation would be required to evaluate the site suitability for repository construction if the First Gulch site is retained for further consideration through the EE/CA process.

Preliminary repository design includes a footprint area of 700 feet by 850 feet or approximately 13.5 acres, and a toe berm to maximize repository capacity (Drawing 14, Appendix F). Based on a 10-foot high toe berm, a slope of 3.5 to 1 for the repository face, and an average fill thickness of 30 feet, the repository capacity would be about 500,000 cy, roughly equivalent to the combined volume for total removal at each of the EE/CA removal areas. A minimally engineered repository with no toe berm, a 3.5 to 1 slope, and average fill thickness of 20 feet would have a fill capacity of about 300,000 cy. Thus, the First Gulch repository site may provide a range of disposal options for mine waste materials excavated from the EE/CA area.

As stated above, some information is currently available regarding subsurface conditions at the First Gulch site. Although site conditions, such as groundwater depths and slope stability properties are expected to be acceptable for a properly designed and engineered repository, these issues and other site characteristics would have to be verified through additional site testing and a detailed site survey.

6.1.2.2 Horsefly Creek Area

Horsefly Creek is a tributary to the Blackfoot River located approximately six miles west of the Mike Horse tailings impoundment. MDEQ has identified a potential repository site immediately north of Horsefly Creek and about 0.6 miles south of the Blackfoot River in Township 14N, Range 7W, Section 3 (Figure 6-1). The potential repository site totals 70 acres in area and is located entirely on Stimson Lumber Company-owned land. The site slopes between 5% and 12% to the southwest (towards Horsefly Creek) and is generally open due to recent logging. The site is about 10 road miles from the tailings impoundment with the haul route including 2.5 miles on Mike Horse county road, 6.0 miles on Highway 200, and approximately 1.5 miles of new access road that would have to be constructed from Highway 200 to the site. In addition to the 1.5 miles of new haul road, a bridge crossing would have to be constructed on the Blackfoot River for site access and mine waste hauling.

Based on a December 2006 site investigation conducted by MDEQ, site soils are described as light brown clayey gravel and sand with some silt, cobbles and boulders with a permeability of 2.5×10^{-5} cm/sec (see 12/06 Site Investigation memo, Appendix E). Seepage was detected from the wall of one of the test pits at a depth of four feet during the December investigation. Based on preliminary site evaluations conducted by MDEQ, there are no streams, springs/seeps or wetlands present within the proposed repository area. The closest surface waterbody, Horsefly Creek, is located about 200 feet from the proposed repository. MDEQ has proposed additional investigations in 2007, including installation of one or more monitoring wells to better characterize site conditions.

Based on preliminary repository designs provided by MDEQ, the repository footprint would be approximately 535 feet by 535 feet square (6.5 acres) with an average fill thickness of about 40 feet. The preliminary design would provide a total repository capacity of about 500,000 cy, with the ability to increase the capacity by expanding the repository area. The repository would slope outward from the center towards all four sides (pyramid shape) at a 4.5:1 grade. For purposes of cost estimating and for comparability to the other repository options, a cap similar to that described in Section 6.1.3 is assumed for the Horsefly Creek repository. The area of new disturbance, not including the 1.5 miles of new road, would be about 15 acres. As with the other sites, additional information on subsurface conditions is needed for full evaluation of the site suitability. Other considerations specific to this site include the relatively long haul involved (10 miles), the considerable haul distance on Highway 200 (six miles) and associated safety concerns, and the fact that the property is privately owned. A land ownership exchange and/or access agreements for the repository site, as well as for adjacent privately owned lands, would be required for site access and repository development.

6.1.3 Conceptual Cap Design for All Repository Sites

For purposes of evaluation, the repository design for each potential site includes an engineered composite cap to be placed over the compacted mine waste. The purpose of the cap would be to minimize potential contact of incident precipitation (storm water and snowmelt) with the repository fill and associated contaminant migration via erosion and leaching. The cap would also eliminate potential human contact (via direct contact or airborne dust) with the mine waste fill. The cap design would also apply to the tailings to be left in place under Option 3 for the Mike Horse Tailings Impoundment.

The engineered cap includes, from bottom to top, a low permeability synthetic liner, overlain by a 200-mil drainage net layer, overlain by 24 inches of soil. The low permeability liner would be comprised of suitable material such as 60-mil high density polyethylene (HDPE), which has a permeability on the order of 10^{-12} cm/sec. The purpose of the liner would be to restrict downward percolation into the underlying repository fill. The plastic liner would be keyed into anchor trenches at both the top and bottom of the repository.

A high permeability drainage layer would be placed over the low permeability liner in order to convey infiltration water downslope and away from the repository. A typical drainage layer would include 200 mil drainage net with a permeability on the order of 10 cm/sec, and bonded with a 6 oz/sq yd. nonwoven geotextile. The geotextile would prevent the overlying soil from infilling and plugging the drainage net. The extreme contrast between the liner and drainage net permeabilities would cause virtually all water infiltrating the overlying soil layer flow through the drainage net to the repository toe, and prevent excessive head from building up on top of the plastic liner.

The coversoil layer would consist of approximately 18 inches of subsoil and 6 inches of topsoil. The repository surface would be mulched, fertilized and seeded to promote vegetation establishment. The vegetation would prevent erosion of the soil cover, and promote evapotranspiration of incident precipitation falling on the repository surface.

HELP modeling results for the engineered cap indicate that infiltration through the cap liner to the repository fill would be less than 0.1% of mean annual precipitation (Appendix G). This equates to approximately 0.2 ft^3/day, or less than 0.001 gpm of water contacting the repository fill per acre of repository.

6.2 SUB-AREA REMOVAL OPTIONS

This section presents various removal options being considered for implementation at each of the four EE/CA sub-areas. The sub-area removal options form the basis for the site-wide removal alternatives presented in Section 6.3. Consistent with the EE/CA process, the removal action descriptions presented below are largely conceptual in nature with the level of detail sufficient for: 1) demonstration of the feasibility of each option, and 2) allow for comparative analysis of the options based on implementability, effectiveness and costs. Detailed engineering designs and cost estimates will be prepared for those options included in the site-wide removal alternative selected for implementation by the USFS. Additional information is provided in Appendix H on conceptual construction planning and sequencing for the tailings impoundment and the site as a whole.

Certain terms used in describing the sub-area removal options warrant some elaboration. The term "complete" or "total removal" as used in tailings impoundment Options 4 and 5, and in other sub-area removal options, refers to removal of all mining-related wastes (waste rock, tailings and metals-contaminated soils) from a sub-area, to the extent practicable. Although removal of all mining-related waste is the intent of this option, potential complications inherent to total removal of mining-related contaminants for projects on the scale of the UBMC (an entire mining district) must be recognized. Also, as described in Section 6.1, the term in-drainage and out-of-drainage is used to describe potential repository locations. "In-drainage" refers to those areas in the Upper Blackfoot River drainage upstream of the confluence with Pass Creek and "out-of-drainage" refers to locations downstream of this point. Sub-area removal options, starting with the Mike Horse Tailings Impoundment, are presented below.

6.2.1 Mike Horse Tailings Impoundment Removal Options

Five options are included for the Mike Horse Tailings Impoundment, ranging from No Action (Option 1) to complete removal of the Mike Horse Dam and impounded tailings, and restoration of a functioning Beartrap Creek channel and floodplain through the removal area (Option 5). With the exception of Option 4, the impoundment options are essentially the same as those presented in the draft EE/CA (Hydrometrics, 2006a) and the tailings impoundment alternatives technical memorandum (USFS, 2006), with relatively minor refinements. Option 4 has been modified to a greater extent from that proposed in the draft EE/CA with the Paymaster Mine area now being the preferred repository site (instead of the West Impoundment Repository), to maximize the quantity of mine waste material that can be disposed of in the Paymaster Repository, and to minimize the potential for post-removal interaction of groundwater with mine wastes. All five tailings impoundment options are summarized in Table 6-2 with additional detail on construction planning presented in Appendix H. Impoundment dewatering and slope stability issues are discussed in Sections 6.2.1.6 and 6.2.1.7. Reprocessing and chemical stabilization of the tailings was not evaluated due to technical impracticability and excessive cost, with little anticipated improvement in effectiveness.

6.2.1.1 Option 1: No Action

The No Action option would leave the tailings impoundment in its current state with no removal or modifications. The No Action option would not achieve the removal action objectives presented in Section 5, nor would it comply with ARARs. Metals-bearing seepage would continue to occur at the toe of the dam. In addition, the impoundment would continue to lack the spillway capacity to handle flows resulting from the ½ probable maximum flood (½ PMF), which is the USFS dam safety criteria for this dam. The primary purpose of Option 1 is to provide a baseline condition for comparison to other removal options.

Under Option 1, monitoring would continue under the current monitoring program, including regular inspections of the dam and impoundment, monitoring of seepage quantity and quality at the dam toe, and groundwater quality monitoring downgradient of the dam. The Emergency Action Plan (Hydrometrics, 2006b) would also remain in effect.

6.2.1.2 Option 2: In-Place Dam Stabilization/Seepage Reduction

Option 2 is intended to address concerns regarding the stability of the Mike Horse Dam while leaving the dam and impoundment in place. Specific objectives include:

- Prevent uncontrolled overtopping of the dam resulting from sustained flows in excess of the existing spillway pipe capacity (approximately 180 cfs) and up to the ½ PMF (approximately 850 cfs).
- Address potential dam stability concerns through lining the interior dam face to reduce seasonal seepage through the dam (Figure 3-2), thereby lowering the phreatic surface and reducing the potential for piping of dam fill.
- Eliminate or reduce the release of metals to the environment resulting from seasonal seepage through the dam and resulting metals-bearing seepage at the dam toe.
- Address possible water quality impacts by minimizing seasonal fluctuations in the tailings pond level to minimize seasonal wetting and drying of tailings located along the pond shoreline.
- Address potential human health risks posed by the pond shoreline tailings (Section 4) by either removing shoreline tailings or covering the tailings with clean soil.
- Address potential human health risks posed by soils on the downstream dam face (Section 4) by covering the dam face with clean soil.

In order to meet these objectives, several modifications would be made to the existing structure, including construction of an emergency overflow spillway and lining of the interior dam face. The emergency spillway would be constructed on the west side of the dam, and would be approximately 100 feet wide at the top, 30 feet wide at the bottom, and 15 feet deep (Drawing 2, Appendix F). In accordance with US Forest Service standards, the emergency spillway would be designed to handle ½ of the PMF, or approximately 850 cfs. This is equivalent to the peak flow from at least a 1000-year flood.

The emergency spillway would need to be protected from erosion with engineered riprap, bedding stone, and a separation filter. The armored spillway channel would be constructed through the dam crest near the west abutment and down the dam face near the gently sloping west groin to safely convey spillway overflow to lower Mike Horse Creek. The spillway invert elevation would be about 5486 ft AMSL, or about six feet higher than the existing spillway pipe invert and one foot higher than the spillway pipe crest. Flow would occur through the emergency spillway only when inflow to the impoundment exceeds the capacity of the existing spillway pipe, a condition that has not occurred since the spillway pipe was constructed in 1975, and may only occur from the 150-year or larger flood event. Approximately 13,000 cy of tailings/dam fill material would be excavated during construction of the spillway and placed in an in-drainage repository, such as the Paymaster or Old Townsite, for disposal.

In order to eliminate or reduce seepage of pond water through the dam, the interior face of the dam would be covered with a low permeability liner (Drawing 2, Appendix F). A plastic liner such as 60 mil HDPE or similar material would be used, with a protective cushion layer (fabric) and six to 12 inches of earthen material placed over the liner. The liner would extend from the dam crest, down the interior face to elevation 5476. The bottom edge of the liner would terminate in a five-foot deep anchor trench, extending the liner coverage down to 5471 ft AMSL (Drawing 2, Appendix F). The liner bottom edge elevation is based on results of extensive monitoring, which show that the seepage at the dam toe ceases once the pond level drops below an elevation of 5476 ft AMSL (Section 3.5).

Although the liner is intended to prevent or reduce seasonal seepage through the dam, saturated conditions would continue near the dam toe on a seasonal basis due to discharge of alluvial and bedrock groundwater (Section 3.5). This "clean" groundwater is believed to account for up to 75% of the peak seepage rates of 400+ gpm measured at the dam toe. Option 2 includes installation of a dam toe drain in order to prevent saturation of the dam toe and improve dam stability. The drain system would include a series of trenches excavated to several feet below ground surface, containing perforated pipes and drain rock (see additional detail in Appendix H). The drains would capture and divert shallow groundwater coming from the east and west abutments to Lower Mike Horse Creek and/or Beartrap Creek.

Other elements of Option 2 include covering the downstream dam face with clean soil to address potential human health risks identified in the streamlined risk evaluation (Section 4), and removing and/or covering tailings located along the pond shoreline to address potential human health risks and possible water quality impacts resulting from the seasonal wetting and drying of shoreline tailings. The dam face would be covered with one foot of clean soil and seeded. The pond shoreline tailings would either be covered with one foot of soil, or excavated and disposed of in an in-drainage repository. The volume of tailings potentially requiring removal is not currently known, but is expected to be on the order of a few thousand cubic yards (cy). Depending on the volume of material, it may be possible to place all of the excavated shoreline tailings beneath the liner to be installed on the interior dam face. Pond dewatering requirements for Option 2 would be minimal and are discussed in Section 6.2.1.6. Additional information on construction planning and sequencing is included in Appendix H.

Although it would not be completely eliminated, Option 2 would greatly reduce the potential for a catastrophic dam failure due to overtopping of the dam. As stated above, the proposed spillway would safely pass all flow through the pond resulting from the ½ PMF, which would result from a flood with an estimated recurrence interval of more than 1,000 years. In its current condition (Option 1), the dam may be overtopped by runoff from the 150-year flood event. Lining the interior dam face would reduce seepage through the dam, thereby reducing the potential of dam failure through piping or slumping. Covering the dam face with soil would address potential human health concerns identified in the streamlined risk evaluation for the impoundment soils, as would covering or removing the exposed shoreline tailings. Option 2 would have a positive effect on water quality by reducing seepage through the dam and reducing contact of incident precipitation with mine waste/soils. As described in Section 3.5.4, existing information suggests that groundwater flow through the impounded tailings may be limited in scope by the relatively deep groundwater levels (as compared to the pond level), thus limiting potential impacts to groundwater quality from the impounded tailings. Seasonally high groundwater levels would continue to occur under Option 2 in the vicinity of well TDMW-4 however due to backing up of pond water into the Beartrap Creek alluvium and bedrock fracture system (Section 3.5.4). However, the full effect of Option 2 on downgradient water quality cannot be determined at this time due to the potential for groundwater flow through portions of the tailings and associated metals leaching to occur.

Operation and Maintenance (O&M) requirements for Option 2 would be similar to those listed for Option 1 with a few exceptions. Monitoring would continue under the current monitoring program, including regular inspections of the dam and impoundment, monitoring of seepage quantity and quality at the dam toe, and groundwater quality monitoring downgradient of the dam. The Emergency Action Plan (Hydrometrics, 2006b) would also remain in effect. In addition, both the primary and emergency spillways would need to be inspected and maintained on a regular basis, and vegetation monitoring would be required on the dam face and other areas to be seeded. Monitoring would also be required at the selected repository location, including groundwater, surface water and storm water monitoring, vegetation monitoring, and routine site inspections.

6.2.1.3 <u>Option 3: Partial Removal with Engineered Channel</u>

Option 3 includes partial removal of the dam and impoundment tailings, and construction of an engineered Beartrap Creek channel through the impoundment area. The excavated tailings would be placed in an in-drainage repository to be located along the west side of the impoundment. Details of Option 3 are shown on Drawing 3, Appendix F.

Primary objectives of Option 3 include:

- Remove dam from service to eliminate the potential for future dam failure.
- Provide a channel to safely convey the Beartrap Creek flow through the impoundment area.
- Cover all soils/tailings that may pose a risk to human health or the environment per the streamlined risk evaluation (Section 4).
- Minimize seepage through the tailings and associated release of metals to the environment by eliminating the Mike Horse reservoir.

In order to remove the dam from service, the dam would be breached on the east side and the dam fill excavated down to native ground. A channel corridor would be excavated down to native ground along the east side of the impoundment, providing a conveyance pathway for Beartrap Creek flows through the impoundment area. The west side of the excavation would be sloped back to a 3.65 horizontal to 1 vertical slope (3.65:1), whereas the east side of the excavation would be taken down to native ground. Locating the breach and channel corridor along the extreme east side of the impoundment would minimize the volume of material requiring removal, since the dam fill and impounded tailings are shallowest on the east side. Figure 6-2 shows a schematic cross section through the Mike Horse Dam for Option 3.

Following excavation, an engineered channel would be constructed to convey the Beartrap Creek flow through the impoundment area. The channel would be designed to safely convey the 500-yr flow event, which was calculated to be approximately 766 cfs (Appendix A). The conveyance would be a trapezoidal channel with a bottom width of 8 feet and 3:1 side slopes. The water depth resulting from the 100 yr and 500 yr flow events would be 2.2 and 3.4 feet, respectively, with corresponding flow velocities of 9.5 and 12.2 ft/sec (Appendix A). The channel would be lined with riprap, and would include a drop structure at the downstream end to safely transition from the constructed channel to downstream Beartrap Creek. Under Option 3, the constructed channel through the impoundment area would be designed to provide a safe conveyance for Beartrap Creek flows, and would not be designed to function as a live stream or accommodate fish passage.

As described in Section 3.5.5, current information suggests that groundwater flow through the tailings may be limited in magnitude and areal extent. Instead, groundwater from the hillsides surrounding the impoundment may flow beneath (or through the lower portion of tailings only) towards the Beartrap Creek alluvium, which acts as a drain beneath the impoundment. If so, excavating into the tailings to the proposed depths (as much as 45 feet at the downstream end of the proposed channel) may not result in long-term seepage from the west excavation wall (which would be comprised of tailings), and thus should not create any long-term seepage-related slope stability or water quality concerns. However, additional information would be required to better define groundwater flow conditions in the vicinity of the impoundment. In the event that more detailed evaluation shows that groundwater flow through the tailings could result in long-term seepage from the east excavation wall and potential stability and water quality concerns, the depth of excavation could be reduced so that the engineered channel would be above the zone of saturated tailings. This would require the channel to be widened (to compensate for the reduced channel gradient and flow velocity), and the channel to be lined since it would be constructed on tailings instead of native ground. The more detailed evaluation of groundwater flow will occur through monitoring of piezometer-area groundwater levels during diversion and dewatering of the impoundment in 2007 and/or 2008. Based on the evaluation results, a suitable design would be developed for Option 3 that would prevent unacceptable seepage from the excavation walls into the engineered channel, while allowing the dam to be taken out of service.

The excavated material would be placed in an in-drainage repository such as the West Impoundment or Paymaster sites. If the West Impoundment repository site was utilized, the excavated material would be placed on top of the tailings to be left in place and would be capped with an engineered composite cap (Section 6.1). Based on an evaluation using the HELP model (Schroeder et al., 1994), the engineered cap would reduce infiltration into the repository fill to less than 0.1% of MAP, or less than 0.001 gpm/acre of repository (Appendix G). The cap would encompass the repository area (the area where excavated tailings are placed), as well as the tailings and the portion of the dam to be left in place (Drawing 3, Appendix F and Figure 6-2). The northern extent of the cap in the vicinity of Mike Horse Creek would be dependent in part on the removal option selected for Lower Mike Horse Creek. One advantage of Option 3 is that the West Impoundment Repository would have a total capacity of approximately 180,000 cy (as shown in Drawing 3, Appendix F), compared to an estimated removal volume of 66,000 cy for Option 3. This means that approximately 120,000 cy of material removed from Lower Mike Horse Creek, Beartrap Creek, and/or the Upper Blackfoot River could be placed in the Option 3 West Impoundment Repository if desired. Also of note is the fact that, of the 66,000 cy of material currently proposed for excavation under Option 3, up to 40,000 cy would be natural earthen fill material used in the 1975 dam reconstruction as opposed to tailings. Pending testing, the fill material may be segregated from the tailings and disposed of separately or used as soil cover material (see borrow soil source discussion, Appendix H).

The potential for dam failure (breaching, piping or slumping) would be greatly reduced under Option 3 since the dam would be taken out of service (water would not be stored behind the dam). Potential human health issues associated with the impoundment mine waste and soils would be addressed through capping of all materials to be left in place. Water quality impacts from seepage through the dam and precipitation runoff would be addressed through the capping and removal of the dam from service. The potential for groundwater flow through the impounded tailings to negatively affect water quality would remain, although current information suggests groundwater flow through the tailings may be limited in magnitude by the relatively deep groundwater levels around the impoundment most of the year. Based on current information, eliminating the tailings pond would also eliminate the seasonally high groundwater levels observed near well TDMW-4 in the springtime (Section 3.5.4). However, the full effect of Option 3 on downgradient water quality cannot be fully quantified at this time. The potential for groundwater flow to occur through the in-place tailings and potential affects to downstream water quality has not been definitively determined, and will be evaluated further in conjunction with the 2007/08 diversion and dewatering of the impoundment and in the final design phase of the project. Option 3 would also minimize repository construction costs and would minimize disturbance of currently undisturbed areas for repository construction as compared to the higher removal level options. Option 3 would not fully achieve the removal action objective of improving watershed functionality to promote a more stable, natural hydrologic system.

Monitoring/O&M requirements would be similar to Option 2 and would include regular inspections of the impoundment area including the engineered channel and repository cap, groundwater monitoring downgradient of the dam, and vegetation monitoring. Monitoring of potential seepage along the west side of the channel from the in-place tailings would also be required to evaluate the possible short-term release of pore water from the tailings, or possible groundwater flow through the lower portion of the tailings. Based on this fact, and hydrologic modeling performed on the engineered composite cap, the need for a seepage collection system is not anticipated. The Emergency Action Plan would no longer be in effect. Monitoring would also be required at the repository, including groundwater, storm water and surface water monitoring, vegetation monitoring, and routine site inspections. Pond dewatering and water management considerations are discussed in Section 6.2.1.6.

6.2.1.4 Option 4: Removal of Dam and Impounded Tailings with Disposal in In-Drainage Repository and Construction of Functioning Beartrap Creek Channel and Floodplain

Option 4 includes total removal of the impoundment mine waste and impacted soils from the Beartrap Creek drainage bottom and consolidation in an in-drainage repository. A new Beartrap Creek channel would be constructed through the removal area and the drainage bottom restored to premining conditions to the extent practicable. Option 4 conceptual details are shown on Drawing 4, Appendix F. General objectives of Option 4 include:

- Remove the dam, impounded tailings and impacted soils from the Beartrap Creek drainage bottom.
- Isolate mine waste through covering with engineered cap to minimize exposure to the environment and potential metals leaching.
- Utilize in-drainage repository to minimize hauling requirements and off-site disturbance.
- Connect upstream and downstream segments of Beartrap Creek with hydrologically and biologically functioning channel and floodplain.
- Restore the drainage bottom to premining conditions to the extent practicable.

Under Option 4, all tailings and mine waste would be removed from the Beartrap Creek drainage bottom along with an estimated one to two feet of underlying soil. The estimated removal volume ranges from 350,000 to 370,000 cy, including 20,000 to 40,000 cy of underlying soils (one and two feet overexcavation, respectively), 40,000 cy earthen dam fill, and 290,000 cy tailings. A functioning stream channel and floodplain would be created to approximate the natural drainage system, and the riparian area restored through native grass and shrub plantings. One foot of clean soil would be spread over the entire removal area if necessary to provide suitable growth medium for site revegetation. Based on a surface area of 580,000 square feet for the Option 4 removal, approximately 22,000 cy of soil would be required to provide a one-foot thick growth medium. The post-excavation ground surface may be amended with lime products to neutralize acidity, or with organic material and/or nutrients to reduce the quantity of coversoil required. A stream channel and floodplain system would be developed through the former impoundment area, with the channel and floodplain designed to function as a natural stream system and allow for fish migration through the former impoundment area. The excavated material would be disposed of at an in-drainage repository, such as the Paymaster Mine area (Drawing 5, Appendix F), or at an out-of-drainage repository such as First Gulch (Drawing 14, Appendix F) if a suitable in-drainage site cannot be secured.

Complete removal under Option 4 would eliminate the potential for failure of the dam through overtopping, piping or slope failure. Option 4 would also address potential human health concerns associated with the impoundment soils and mine waste identified in the streamlined risk evaluation, and potential water quality issues, through removal and encapsulation of mine waste and soils in a suitable repository location. In addition, the potential for groundwater flow through the impounded tailings to negatively affect water quality would also be eliminated.

Monitoring/O&M requirements for Option 4 would be less than for Option 3 since all mine waste would be removed from the drainage bottom and covered with an engineered cap. Monitoring would include regular inspections of the impoundment area including the constructed channel and floodplain, and monitoring for revegetation success. Monitoring would also be required at the selected repository site including groundwater, storm water and possibly surface water monitoring, and routine site inspections. The Emergency Action Plan would no longer be in effect. Pond dewatering and water management considerations are discussed in Section 6.2.1.6. Construction planning details are provided in Appendix H.

6.2.1.5 <u>Option 5: Complete Removal of Dam and Impounded Tailings</u>

Similar to Option 4, Option 5 includes removal of all tailings and dam fill material and restoration of the impoundment area to as close to premining conditions as practicable. Under Option 5 however, all excavated material would be hauled out of the drainage to a new repository location approximately 10 miles west of the UBMC near Horsefly Creek or to the First Gulch site located 6.5 miles west of the UBMC. Objectives of Option 5 would be identical to those listed for Option 4 with the exception that objective 3 (utilize in-drainage repositories to minimize hauling requirements and off-site disturbance) would not apply.

Similar to Option 4, all tailings and mine waste would be removed along with one to two feet of underlying soil if necessary. The estimated removal volume would be about 350,000 to 370,000 cy (for one and two feet of overexcavation, respectively), with 20,000 to 40,000 cy being underlying soils, 40,000 cy earthen dam fill, and 290,000 cy tailings. A functioning stream channel and floodplain would be created to approximate the natural drainage system, and the riparian area restored through native grass and shrub plantings. One foot of clean soil would be spread over the entire removal area to provide suitable growth medium for site revegetation. Based on a surface area of 580,000 square feet for the Option 5 removal, approximately 22,000 cy of soil would be required to provide a one-foot thick growth medium. The post-excavation ground surface may be amended with lime products to neutralize acidity, or with organic material and/or nutrients if necessary, to reduce the quantity of coversoil required. Option 5 conceptual details are shown on Drawing 4, Appendix F.

MDEQ has identified a potential repository location (Horsefly Creek site) approximately 6.5 air miles and 10 road miles from the impoundment. Based on preliminary evaluation by MDEQ, the site may be suitable for permanent storage of all materials excavated from the impoundment, as well as all other removal materials from the Lower Mike Horse Creek, Beartrap Creek and Upper Blackfoot River sub-areas. As described in Section 6.1, development of the Horsefly Creek site would require construction of 1.5 miles of new haul roads and a temporary bridge crossing on the Blackfoot River, and would entail 15 acres of new disturbance outside of the EE/CA area. Other special considerations pertaining to Option 5 are included in Section 6.1 (repository considerations), and Appendix H.

Alternatively, excavated materials could be relocated to the First Gulch out-of-drainage repository site. The First Gulch repository location is approximately 6.5 road miles from the impoundment. As discussed in Section 6.1, the site may be suitable for all materials excavated from the impoundment, as well as all other removal materials from the Lower Mike Horse Creek, Beartrap Creek and Upper Blackfoot River sub-areas. No new road construction would be necessary to access the repository site, although access road upgrades would be necessary. It would entail approximately 13 acres of new disturbance outside the drainage area.

Complete removal under Option 5 would achieve a similar degree of site improvement as Option 4. The potential for dam failure through overtopping, piping or slope failure would be eliminated. Potential human health concerns associated with the impoundment soils and mine waste, and potential water quality issues, would be addressed through removal and encapsulation of mine waste and soils in a suitable repository location.

Removal area monitoring requirements under Option 5 would be less than those for the other impoundment options since all mine waste and fill would be removed. Monitoring would likely consist of surface water and groundwater quality monitoring, vegetation monitoring, and inspections of the removal area to identify possible erosion or other indicators of site stability concerns. Additional monitoring would be required at the Horsefly Creek repository, including groundwater, storm water and possibly surface water monitoring, vegetation monitoring, and routine site inspections.

6.2.1.6 Conceptual Impoundment Dewatering/Water Management

With the exception of Option 1, all options being considered for the Mike Horse Tailings Impoundment would require the diversion of inflow to the reservoir around the impoundment and dewatering of the impoundment to some degree. Diversion of Beartrap Creek around the impoundment is scheduled to occur in summer/fall 2007 to allow for collection of important hydrologic information on the tailings and surrounding groundwater system, and to allow for removal actions to begin as early as 2008. The level of diversion would vary depending upon the specific option (extent of removal activities), and the dewatering needs will vary depending upon the bottom elevation of the proposed removal. The following paragraphs describe a conceptual plan for management of impoundment inflow and pond level and for dewatering the impoundment sufficiently for implementation of each of the options described above.

Inflow Diversion and Bypass

With the exception of Option 1, all removal options for the impoundment will require diversion of Beartrap Creek around the impoundment so that the tailings pond level can be controlled. Design of a diversion around the impoundment requires that some magnitude of flow be chosen for design, and an appropriate level of risk established. For options with shorter construction durations (such as Option 2), a smaller design flow can provide an acceptable level of risk, whereas a larger design flow may be appropriate for options requiring longer construction periods. Therefore, the design flow utilized for diversion design should be commensurate with the action, or option being considered.

One option for diverting Beartrap Creek around the impoundment would be to collect Beartrap Creek surface flow (and possibly alluvial groundwater) at a point upgradient of the impoundment and pipe or ditch it around the impoundment for downstream discharge (via gravity) to Lower Mike Horse or Beartrap Creek. For a pipe installed at a 1% slope, the inflow diversion would need to be at an elevation of about 5512 feet AMSL for gravity drainage of Beartrap Creek flows over the dam crest (elevation 5491). However, if the diversion pipe were routed through the existing spillway pipe (invert elevation 5481) instead of over the dam crest, the upstream diversion point could be lowered about eleven feet to 5501. The diversion would include a small dam placed across the Beartrap Creek channel upstream of the impoundment to raise the water surface elevation to that required for diversion, and possibly a cutoff wall in the alluvium if site investigation determines that capture and diversion of alluvial groundwater if warranted. The diverted water would then be routed around the impoundment through a pipe or ditch.

Assuming the tailings can be excavated in a reasonable amount of time, Impoundment Options 2 and 3 could most likely be accomplished within a single construction season. Therefore, it may be appropriate to design the diversion and bypass structures for as little as the 2-year maximum flow event, or about 16 cfs (excluding alluvial groundwater). A 20-inch PVC or HDPE pipe could convey as much as 18 cfs at a 1% slope. Therefore for Options 2 and 3, design and construction of the diversion could be relatively straightforward and limited in scope.

Options 4 and 5 are expected to take more than one construction season to complete. Therefore, the diversion and bypass structures would need to be designed for a higher flow in order to avoid exposing the project to unacceptable risks during construction. The diversion and bypass may need to handle up to the 5-year peak inflow, or about 40 cfs. A 28-inch PVC or HDPE pipe can provide a capacity of as much as 44 cfs at a 1% slope. Therefore, for Options 4 and 5 the design and construction of the diversion and bypass will be more complicated than what would be required for Options 2 and 3 but are still very feasible.

Dewatering

Options 3, 4, and 5 require the tailings impoundment to be significantly dewatered. For these options, not only will the impoundment pool need to be emptied, but the tailings will need to be dewatered to the planned excavation depths, which is least for Option 3 and greatest for Option 5. Although dewatering is less of an issue for Option 2, it may require some dewatering of the tailings, although to a lesser degree.

At full pool, the Mike Horse Tailings Impoundment contains approximately 40 acre-feet of water. Following diversion of inflows, this pool will need to be dewatered for removal options 2, 3, 4, and 5. Removal of this water can be accomplished either by pumping or siphoning the water from the pool into the spillway pipe or over the dam. Options 3, 4, and 5 will require additional dewatering to facilitate excavation of the tailings.

Because the finer grained tailings covering the pond bottom have a relatively low permeability (Section 3.5.4), complete dewatering may be difficult. Furthermore, the fine-grained nature of the tailings are expected to have very low strength, especially when saturated. Therefore, dewatering and excavation of the tailings may need to be done in stages, using a grid of excavated trenches across the work site that drain to one or more sumps. Once the tailings have been sufficiently dewatered, this layer of tailings can be excavated and a new trench network installed to a greater depth. This process can be repeated as often as needed to excavate the tailings to the required depth. However, the depth of each layer may be limited by the low shear strength of the tailings, which may limit the depth of trench that will remain open. Therefore, dewatering for Options 3, 4, and 5 will be significantly more challenging than for Option 2.

Based on past water quality sampling, the Mike Horse Tailings Pond water contains very low concentrations of CoCs (Section 3), and should be suitable for direct discharge to downgradient Mike Horse or Beartrap Creek. Dewatering flows will be routed through one or more settling basins prior to downstream discharge to reduce sediment and turbidity levels, with a final filtration step added if necessary. In the event that dissolved contaminants (i.e., metals, acidity) make the dewatering water unsuitable for discharge, advanced water treatment may be incorporated into the tailings dewatering plan. Advanced treatment may include chemical precipitation of metals through pH adjustment (or other means) followed by filtration, or mechanical treatment such as ion exchange or reverse osmosis technologies using a portable packaged water treatment plant. A tailings dewatering plan detailing dewatering methods and water treatment requirements will be developed once a removal option is selected for the Mike Horse Tailings Impoundment.

6.2.1.7 Slope Stability Evaluation

Physical properties and possible saturated conditions could cause slope stability concerns for excavation of tailings and placement in a repository. Of particular interest is the maximum slope that can be safely maintained while excavating tailings from the impoundment under Options 2 through 5, the maximum slope that can be maintained long-term in the west excavation wall under Option 3, and the maximum slope at which the tailings can be placed within a repository. These questions were evaluated through performance of a slope stability analysis for the tailings.

Stability analyses were performed using PCSTABL (Purdue University, 1982) software. These analyses required that the density and shear strength of the Mike Horse tailings be determined. Material properties of the tailings were determined from core samples that had previously been collected from the impoundment area and frozen. Because the material to be removed from the impoundment area will consist mainly of fine-grained tailings, unconfined shear strength (Su) was used as the key strength property for analysis of the excavation and repository side slopes. A Torvane shear device was used to estimate the unconfined cohesive shear strength of the tailings. This test was performed on several undisturbed samples collected from within the impoundment area. In addition, the moisture content of each sample was measured. A Proctor test was performed on a combined sample of the tailings to determine the maximum density likely to be achieved by compaction of the tailings in the repository. During the Proctor test, a Torvane shear test was performed at each moisture content used to define the Moisture-Density Curve in order to determine how cohesive strength varies with compaction. Measured cohesive strengths ranged from 300 to 500 pounds-per-square-foot (psf) for the undisturbed samples and 500 to 2500 psf for the compacted samples.

The unconfined shear strength of the undisturbed tailings appears to change quickly with small changes in moisture content. Therefore, for this analysis the minimum cohesive measured strength of 300 psf was used for the unconfined shear strength of soils in the tailings excavation. Typically a compaction requirement of 95% of maximum Proctor Density is specified for tailings placed in a repository. At this degree of compaction, the tailings will weigh approximately 119 pounds-per-cubic-foot (pcf). To achieve this degree of compaction the tailings moisture content may range between 8 to 18.5 percent. Within this range of moisture content, the unconfined cohesive strength of the tailings may be as low as 500 psf. Therefore, this value was used in the stability analyses as the cohesion strength of the compacted repository tailings. The unconfined shear strengths used for the tailings in this analysis are considered very conservative values because cohesive strengths measured using a Torvane typically vary from 0.3 to 0.7 of the actual cohesive strength. Figure 6-3 shows results of this testing.

Using these densities and shear strengths (cohesion), slope stability analyses were run to determine how steep the excavated cut through the tailings and the face of the repository pile could be constructed and still produce an acceptable factor of safety of 1.5 or greater. Using PCSTABL, the slope of the repository was varied until a suitable slope was determined that gave a factor of safety of 1.5. Next, with the repository slope fixed, the slope of the excavated cut below the repository was varied in a similar fashion. Figure 6-4 shows the results of these analyses.

Results of this analysis show that for initial planning purposes, cut slopes no steeper than 3.65:1 (H:V) should be proposed in the Mike Horse tailings impoundment. Tailings may be compacted in the repository at slopes of 2.65:1 (H:V) unless the slopes become so long that an unacceptable tension stress is placed on the cap liner. If excessive repository slope lengths are proposed, breaks or benches would be required. Conversely, the tension stress may limit slopes to about 3.5:1 (H:V) with no breaks or benches.

6.2.2 BEARTRAP CREEK

The 2,800-foot long Beartrap Creek drainage bottom between the Mike Horse Tailings Impoundment and Anaconda Creek consists of a relatively wide, flat floodplain with limited vegetative cover. The drainage bottom varies in width from about 60 feet to over 200 feet through most of this reach, but widens to approximately 300 feet upstream of the confluence with Anaconda Creek. Steep, heavily forested hillsides border both sides of the drainage bottom, clearly demarcating the drainage bottom area included in the EE/CA.

Five preliminary removal options were initially evaluated for Beartrap Creek drainage in the mine waste removal alternatives technical memorandum (Hydrometrics, 2005a), with the five options shown in Table 6-2. Option 3 was eliminated from further consideration through the alternatives tech memo review process, due to redundancy with other options, and anticipated difficulties associated with the floodplain soil amendment component. The remaining four options are described below, with the original option numbers retained for consistency with the alternatives tech memo.

6.2.2.1 <u>Option 1: No Action</u>

The No Action option would leave Beartrap Creek drainage in its current state with no removals or modifications. The No Action option would not achieve the removal action objectives presented in Section 5, nor would it comply with ARARs. Metals leaching and erosion of mine waste would continue to impact surface water quality and pose potential risks to recreationists and to the ecosystem. Option 1 is included in the EE/CA to provide a baseline condition for comparison to other removal options.

Under Option 1, a certain level of maintenance and monitoring would be required for Beartrap Creek. Maintenance and monitoring may include surface water and groundwater quality monitoring, monitoring for erosion and implementing necessary erosional controls, weed control, and other potential O&M requirements.

6.2.2.2 <u>Option 2: Remove Concentrated Tailings and Place in On-Site Repository</u>

Under this Option, only the isolated deposits of concentrated tailings would be removed from the drainage bottom. As shown on Drawing 6 in Appendix F, the Beartrap Creek concentrated tailings include six individual deposits totaling about 5,300 cy in volume. The tailings deposits are relatively thin, generally one to two feet in thickness, and the 5,000 cy volume includes one foot of underlying soil. In addition to the concentrated tailings, two mine waste piles located on the Flossie and Louise patented mining claims would be removed from the drainage bottom. Removal of the mine waste piles would require the cooperation of the property owner. The Flossie and Louise dumps total about 1,200 cy in volume, bringing the total removal volume to about 6,500 cy for Option 2. Since this waste is located on patented mining claims not associated with the ASARCO claims, the USFS would only conduct the evaluation of removal options. MDEQ or the EPA would be the lead agency for removal of the Flosse and Louise mine waste piles.

Following excavation, the removal areas would be covered with clean soil (if necessary) to restore the areas to a suitable grade and to serve as growth medium. The post-excavation soil surfaces may also be amended to neutralize potential residual acidity in the soils or to improve agronomic properties such as organic matter content. The removal areas would then be seeded to promote revegetation of the removal sites. Option 2 would not include removal of the intermixed tailings present within the Beartrap Creek drainage bottom alluvium, nor would the existing stream channel be modified. Option 2 is intended to address the most problematic materials present in the Beartrap Creek removal area, which is based on leaching tests and runoff sampling as described in Section 3. Follow-up monitoring would then be performed to determine if additional removal actions are warranted based on the response in surface water quality and the status of upgradient sources of metals loading. This adaptive management approach to removal is consistent with the restoration approach outlined in the Blackfoot Headwater TMDL document (MDEQ, 2003).

The excavated mine waste would be placed in an on-site repository, most likely either the Paymaster Area Repository or the West Impoundment Repository. The West Impoundment Repository could only be used if Option 3 is selected for the Mike Horse Tailings Impoundment. Repository details are included in Section 6.1.

6.2.2.3 Option 4: Remove all Concentrated Tailings; Remove Intermixed Tailings Within an Active Stream Channel Migration Corridor; Placement of Removed Materials in an In-Drainage Repository

Option 4 would include removal of the concentrated tailings deposits and Flossie and Louise mine waste dumps as described under Option 2, plus removal of all intermixed tailings and alluvium within an active Beartrap Creek channel migration corridor. Option 4 is intended to address the more reactive mine waste materials as proposed in Option 2, plus eliminate contact between the creek and the less reactive intermixed tailings/alluvium. This would decrease the potential for metals leaching from the intermixed tailings/alluvium to Beartrap Creek, and entrainment of tailings into the creek through channel migration and associated bank erosion.

All concentrated tailings deposits and mine waste dumps would be excavated from the drainage bottom as described under Option 2. In addition, a band of the intermixed tailings/alluvium would be removed down the length of the drainage to accommodate a floodplain and meander belt for Beartrap Creek free of tailings (Drawing 7, Appendix F). Based on the hydrologic modeling described in Appendix A, the 100-year floodplain in lower Beartrap Creek would range from 25 feet to 45 feet wide, depending on the drainage gradient and channel depth, and would average 30 feet. The existing tailings/alluvium would be excavated from the floodplain area to a depth of approximately four feet, which past field investigations have shown to be the average depth to clean native sediments (Section 3). The total volume of intermixed tailings/alluvium to be removed is estimated to be 26,000 cy. Including the concentrated tailings, the combined removal volume for Option 4 is approximately 32,500 cy.

Following mine waste removal, a new stream channel and floodplain would be created from the Mike Horse Tailings Dam to the confluence with Anaconda Creek. The channel system would be designed to properly function (from a hydrologic standpoint) under the maximum 100-year flow of 298 cfs. The channel would average about eight feet wide with a depth of 2.2 to 3.4 feet (Appendix A). Soft armoring, such as vegetation, boulders, root wads, and other suitable material would be placed along the floodplain margins to prevent undercutting of, and stream migration into, the surrounding intermixed tailings. Riprap would likely be required in some areas to further stabilize the stream migration corridor. Additional riprap would be placed above the 100-year floodplain to protect the removal area from flows up to the 500-year flow of 766 cfs. Clean backfill/soil would be imported to the site to restore the removal area to a suitable grade and to promote revegetation of the riparian and floodplain areas.

Peak flows and corresponding stream channel floodplain widths determined through the hydrologic modeling performed for the EE/CA are based on the Mike Horse Tailings Dam either being taken out of service (Impoundment Options 3 or 4), or removed (Option 5). If the dam were to remain in place (Impoundment Option 2), the peak flows in downstream Beartrap Creek would be less than those presented here, although the difference is not expected to be significant for the 100-year and 500-year flows. Additional hydrologic modeling will be required once a site-wide removal action alternative is selected.

The excavated soil/mine waste would be placed in one of the potential on-site repository locations. If Option 3 is selected for the Tailings Impoundment, then the Beartrap Creek mine waste could be placed in the West Impoundment Repository. Otherwise it would go in the Paymaster Area Repository or other potential on-site repository. Based on the high coarse rock content in the intermixed tailing/alluvium, it may be possible to reduce the volume of material to be placed in a repository by screening the coarse rock out prior to hauling off-site. Screening out the coarse rocks, which range up to eight inches or more in diameter and consist primarily of Belt rock or other "non-mine waste-related" materials, could reduce the volume of intermixed tailings material requiring disposal (26,000 cy) by approximately 50%. The over-screened material could likely be used for backfill, riprap, or other construction materials in the floodplain/stream channel reconstruction.

6.2.2.4 Option 5: Complete Mine Waste Removal and Placement in an On-Site Repository

Under Option 5, all mine waste within the Beartrap Creek drainage bottom, including the concentrated tailings, Flossie and Louise waste rock piles, and intermixed tailings/alluvium, would be removed from the Beartrap Creek drainage bottom. The objective of Option 5 would be to remove all mine waste materials and restore the segment of Beartrap Creek between the tailings dam and Anaconda Creek to as close to pre-mining conditions as practicable.

Mine waste excavation would extend down to the clean (tailings free) underlying sediments, or three to four feet below existing ground surface based on field investigation results (Section 3). Based on the drainage bottom dimensions and an estimated average dispersed tailings thickness of four feet, the total volume of dispersed tailings is on the order of 60,000 cubic yards, including removal of one foot of underlying soil. The post-removal drainage bottom topography is shown in Drawing 8, Appendix F. All of the removed mine waste would be placed in an on-site engineered repository as discussed for Option 2. As described for Option 4, it may be possible to reduce the volume of material requiring disposal in a repository by up to 50% if the non-mine waste-related coarse rock is separated from the finer grained tailings and impacted soils by screening the excavated soils prior to hauling to the repository. The over-screened material (clean rock) could be used in restoration of the drainage bottom.

Clean backfill/soil would be imported to the site to restore the removal area to a suitable grade (if needed) and to promote revegetation of the riparian and floodplain areas. Since much of the material that would be removed is foreign to the drainage bottom (i.e., the mine waste), restoring the drainage bottom to its current elevation would not be necessary, nor would it likely be desirable. Prior to the aggradation of mine waste in the drainage bottom, the elevation of the creek channel and flood plain most likely was lower than it is today. Therefore, the amount of clean fill required likely would be less than the quantity of mine waste removed. The quantity of fill required would be dependent on the depth of mine waste excavation, and the desired final stream elevation and grade. Determining the desired channel elevation and grade through Beartrap Creek drainage would depend in part on the removal options selected for the upgradient tailings impoundment and Lower Mike Horse Creek, and would be determined following selection of a site-wide removal action alternative.

Following mine waste removal, the drainage bottom would be restored to a functioning stream system. Final site restoration would include construction of a new stream channel and associated floodplain and riparian area. Stream channel and floodplain design would follow that described under Option 4, except that riprap protection for the 500-year flow event would not be required since all mine waste would be removed and the channel would be allowed to meander across the entire drainage bottom. Final restoration details would depend on the scope of upgradient removal actions performed under this EE/CA as well as future water quality conditions entering the site from upstream sources. If future water quality conditions necessitate, restoration of Beartrap Creek could be designed to optimize downstream water quality by developing a series of wetlands along the drainage bottom. These wetlands could remove trace amounts of contaminants in Beartrap Creek (if present after removal actions are completed) thereby improving downstream water quality to the point that the Blackfoot River below the confluence of Beartrap Creek and Anaconda Creek could support fish. This would serve to connect the isolated cutthroat trout population in Anaconda Creek with the downstream Blackfoot River fishery.

6.2.3 LOWER MIKE HORSE CREEK

For purposes of the EE/CA, Lower Mike Horse Creek includes the lower 900 feet of stream and drainage bottom located on lands within the NFS (Figure 1-1). A number of mine waste piles located along the Lower Mike Horse Creek drainage bottom have been shown to impact surface water quality in Mike Horse Creek and downstream drainages (Section 3). The streamlined risk evaluation (Section 4) shows these wastes to also pose potential risks to recreational site users and the ecosystem. The upstream portion of Mike Horse Creek drainage has previously undergone reclamation by ASARCO, with additional reclamation scheduled to occur in 2006.

Removal options considered for Mike horse Creek include No Action (Option 1), partial mine waste removal (Option 2), and complete mine waste removal (Option 3). The Lower Mike Horse Creek removal options are described below.

6.2.3.1 Option 1: No Action

The No Action option would leave Lower Mike Horse drainage in its current state with no removals or modifications. The No Action option would not achieve the removal action objectives presented in Section 5, nor would it comply with ARARs. Metals leaching and erosion of mine waste would continue to impact surface water quality and pose potential risks to recreationists and to the ecosystem. Option 1 is included in the EE/CA to provide a baseline condition for comparison to other removal options.

Under Option 1, a certain level of maintenance and monitoring would be required for Lower Mike Horse Creek. Maintenance and monitoring may include surface water and groundwater quality monitoring, monitoring for erosion and implementing necessary erosional controls, weed control, and other potential O&M requirements.

6.2.3.2 Option 2: Partial Mine Waste Removal

Option 2 would include removal of mine waste from the drainage bottom and partial removal from the drainage walls (to increase slope stability), and in-place reclamation of surrounding mine waste. The removal area and mine waste left in place would be covered with soil and seeded. The objective of this option would be to eliminate direct contact of mine waste with surface water, minimize erosion of soil/mine waste from unstable slopes, and address potential human health and ecological risks associated with site soils (Section 4). Option 2 details are shown on Drawing 9, Appendix F.

Prior to conducting removal actions, the Mike Horse Creek flow would be diverted around the removal area to allow work to take place in the creek channel and drainage bottom. A temporary dam would be constructed in Mike Horse Creek upstream of the removal area for diversion of flow around the work area. The streamflow would most likely be diverted to Beartrap Creek below the confluence with Mike Horse Creek through an HDPE or similar pipe. The water would be routed through a settling basin for sediment removal prior to discharge to the creek. Since Option 2 should be implementable in a relatively short time period, the diversion structure may be sized to handle a relatively small flow such as the 2-year maximum flow event. A temporary settling basin would also be constructed at the mouth of Mike Horse Creek to help remove sediment which may be transported downstream with any seepage or precipitation runoff that may occur within the removal area.

Mine waste materials would be removed from the drainage bottom down to approximately one-foot below the top of native sediment/soils or clean fill, or to bedrock. Discrete mine waste piles along the drainage sides would also be removed and side slopes reshaped to a more stable configuration. A total of about 5,000 cy of mine waste and contaminated soil would be excavated under Option 2. The excavated mine waste would be placed in an on-site repository (the Paymaster Area, West Impoundment Area, or other potential on-site repository). The West Impoundment Repository could only be used if Option 3 was selected for the Tailings Impoundment.

Mine waste/contaminated soils left in place above the high water mark would be regraded to simulate a more natural topography. The upper one-foot of material may be amended with acid-neutralizing material such as lime, and then covered with one foot of clean soil to serve as a cap and as growth medium. The removal area would then be seeded to promote revegetation, and erosion control measures installed to temporarily stabilize site soils until vegetative cover is established. Over-excavated areas would be backfilled with clean soil as needed to maintain a consistent longitudinal profile to the creek channel and stable embankment slopes.

The creek channel will be reconstructed to pass the 100-year flow event, and safely convey the flow resulting from a 500-year event. Based on the naturally steep gradient of lower Mike Horse Creek (approximately to 10%), and to prevent future undercutting and sloughing of mine waste remaining in the drainage walls, the reconstructed Mike Horse Creek would be a riprapped channel designed to prevent lateral migration and downcutting. The primary channel design criteria would be based on creation of a stable channel and safe conveyance of design flows, as opposed to aquatic and riparian habitat conditions. The channel would be about 30 feet wide, with approximately 3:1 side slopes (Drawing 9, Appendix F). Approximately 1,300 linear feet of stream channel would be constructed from the upgradient National Forest boundary to the confluence with Beartrap Creek.

6.2.3.3 Option 3: Complete Removal of Mine Waste and Placement in an On-Site Repository

Under Option 3, all mine waste and contaminated soils in the Lower Mike Horse removal area would be excavated and placed in an on-site repository. The primary difference between Options 2 and 3 is that mine waste within the drainage walls and immediately surrounding area would not be left in place under Option 3.

Water management under Option 3 would be similar to that described above for Mike Horse Creek Option 2. The Mike Horse Creek flow would be diverted around the removal area in a pipe and discharged through a settling basin to Beartrap Creek. A temporary settling basin would also be constructed at the mouth of Mike Horse Creek to remove sediment transported downstream through the removal area.

All mine waste within the stream channel, drainage walls and immediately surrounding area would be excavated and placed in an in-drainage repository. This includes all of the discrete mine waste piles located in Lower Mike Horse Creek drainage, (Drawing 10, Appendix F), and approximately one to two feet of soil along the entire drainage bottom and walls. The removal boundaries would encompass portions of the existing Mike Horse Dam access road, with portions of the access road relocated slightly to the south from its current location. Excavation depths would extend to the native ground surface, or to clean earthen fill beneath the dam access road, with one to two feet of underlying native material removed as well. The estimated removal volume for Option 3 would be 15,000 cy.

Following mine waste removal, clean soil would be imported to the site and placed to a thickness of one foot over the entire removal area. The cover soil would serve as a growth medium with the entire removal area seeded, and would also aid in final site grading to provide a more natural appearance and more stable site configuration. An estimated 3,500 cy of cover soil would be required to obtain an average one-foot of cover over the entire Lower Mike Horse removal area. Additional clean backfill may also be required for any localized areas requiring overexcavation.

Channel reconstruction for Option 3 would be identical to that described for Option 2. An engineered channel would be constructed to pass the 100-year flow event, and safely convey the 500-year flow. The channel would be about 30 feet wide, 1,300 feet long, with approximately 3:1 side slopes (Drawing 10, Appendix F). The channel design objectives would focus on stabilization of the active channel as opposed to aquatic habitat or fish migration. However, if Option 5 is selected for the Tailings Impoundment (complete removal and site restoration), a more natural channel design and reconstruction may be adopted for Lower Mike Horse Creek.

6.2.4 BLACKFOOT RIVER

The Upper Blackfoot River portion of the EE/CA area extends from the confluence of Beartrap Creek and Anaconda Creek, to the head of the natural marsh system in the east half of Section 20, Township 15N, Range 6W (Figure 1-1). The Blackfoot River drainage bottom includes lands within the NFS interspersed with ASARCO-owned patented mining claims. Similar to Beartrap Creek, this segment of Blackfoot River has been impacted by historic mining activities and the 1975 tailings dam breach, including deposition of mine waste within the floodplain and degradation of the stream channel structure and associated aquatic habitat. Previous reclamation activities in the Upper Blackfoot River drainage include reclamation of the Anaconda mine (removal of approximately 25,000 cubic yards of mine waste and placement in a repository, and capture and treatment of discharge water from the Anaconda adit and shaft), and removal of approximately 10,000 cubic yards of mine waste from the Edith Mine area and placement in a repository (Hydrometrics, 2005b). A constructed wetlands-based water treatment system is located at the site of the reclaimed Anaconda Mine and currently treats discharge waters from the Anaconda adit/shaft and the Mike Horse Mine adit.

Two general types of mine waste are present within the Upper Blackfoot River floodplain including fine-grained pyritic tailings, and coarser grained tailings (coarse sand to fine gravel size). The fine tailings most likely originated from operation of the flotation mill constructed at the Mike Horse Mine around 1941 and may have been deposited along the floodplain, at least in part, as a result of the 1975 tailings dam breach. Production of the coarse tailings predates the fine tailings with the coarse tailings produced from operation of the older jig mill(s). Both types of tailings have been sampled and characterized as discussed in Section 3.

Four preliminary removal options were initially evaluated for the Upper Blackfoot River drainage in the mine waste removal alternatives technical memorandum (Hydrometrics, 2005a), with the four options shown in Table 6-2. Option 3 was eliminated from further consideration through the alternatives tech memo review process, due to redundancy with other options, and anticipated difficulties associated with the floodplain soil amendment component. The remaining three options are described below, with the original option numbers retained for consistency with the alternatives tech memo. Although extensive field characterization activities have been completed in the Upper Blackfoot drainage (Section 3), additional field characterization will be necessary for final evaluation of the removal options outlined below. Additional data needs include a detailed topographic survey of the area, and detailed sampling of Blackfoot River alluvium between the confluence of Anaconda and Beartrap Creeks downstream to surface water monitoring site BRSW-9 (Figure 2-1).

6.2.4.1 Option 1: No Action

The No Action option would leave the Upper Blackfoot River drainage in its current state with no removals or modifications. The No Action option would not achieve the removal action objectives presented in Section 5, nor would it comply with ARARs. Metals leaching and erosion of mine waste would continue to impact surface water quality and pose potential risks to recreationists and to the ecosystem. Option 1 is included in the EE/CA to provide a baseline condition for comparison to other removal options.

Under Option 1, a certain level of maintenance and monitoring would be required for the Upper Blackfoot River. Maintenance and monitoring may include surface water and groundwater quality monitoring, monitoring for erosion and implementing necessary erosional controls, weed control, and other potential O&M requirements.

6.2.4.2 Option 2: Remove Shave Creek Concentrated Tailings and Larger Dispersed Tailings Deposits and Place in an In-Drainage Repository

Under this scenario, all of the Shave Creek concentrated tailings and other significant tailings deposits located on lands within the NFS would be removed and placed in an in-drainage repository. Other significant tailings deposits include fine grained tailings deposits UBDT-100 and UBDT-101 located downstream of the Shave Creek Tailings, the area of fine tailings bisected by the Blackfoot River approximately 600 feet downstream of the Anaconda wetland treatment cells, the area of tailings adjacent to the treatment cells, coarse-grained tailings deposit UBDT-102, and the two lobes of coarse tailings immediately downstream of the Anaconda wetland treatment cells (Drawing 11, Appendix F). The objective of this alternative would be to remove the largest and most accessible of the identified tailings deposits located on lands within the NFS. Portions of these tailings deposits, most notably the area of tailings located adjacent to the Anaconda wetland water treatment cells lay in part on private property. Complete removal of these tailings may require coordination between the EE/CA program, and reclamation activities being conducted primarily by ASARCO on private lands at the UBMC.

The concentrated tailings and larger dispersed tailings deposits identified on Drawing 11 would be excavated along with underlying soils to a depth of approximately one foot below the tailings/native sediment interface. The post-excavation soil surface would then be tested to determine if additional soil removal and/or soil amendment is warranted. Once soil removal is completed, clean earthen fill would be placed in the excavation areas as needed to maintain an appropriate grade across the site. The excavation areas would then be covered with one foot of clean soil and revegetated with a suitable suite of grasses and shrubs. Under Option 2, modifications to the Blackfoot River channel would be limited to those necessary to address channel disturbance caused by the removal action.

Based on existing information, including detailed mapping and sampling of the Shave Creek concentrated tailings (Section 3), the Shave Creek deposit contains an estimated 16,000 cubic yards of tailings, with the tailings generally two feet or less in thickness, except for a narrow band corresponding to a former stream channel where the tailings reach five feet in thickness. Tailings areas UBDT-100 and 101 contain a total of about 2,500 cubic yards, and the coarse-grained tailings areas contain about 3,500 cubic yards. Total removal volumes for these areas, including one foot of underlying soil, are estimated to range between 30,000 and 35,000 cubic yards. No other mine waste removal would occur under this option.

The excavated mine waste would be placed in one of the potential in-drainage repositories. The Upper Blackfoot mine waste could be placed in the West Impoundment Repository if Tailing Impoundment Option 3 is selected, and depending on options selected for Lower Mike Horse and Beartrap Creek. Alternatively, the Upper Blackfoot River mine waste would be placed in the Paymaster Area Repository or other suitable on-site repository. The repository design would include an engineered composite cap consisting of a plastic liner, drainage net, and two feet of cover soil (Section 6.1). Based on HELP modeling results, the engineered cap would reduce infiltration to less than 0.1% of MAP (Section 6.1, Appendix G).

6.2.4.3 Option 4: Complete Mine Waste Removal and Placement in an In-Drainage Repository

Under Option 4, all mine waste within the Upper Blackfoot River floodplain, including the concentrated and dispersed tailings slated for removal under Option 2, would be removed and placed in an in-drainage repository. Additional elements on Option 4 as compared to Option 2 include removal of a series of small, isolated fine tailings deposits located downstream (west) of deposit UBDT-100, removal of additional mine waste that may be intermixed with alluvium throughout the floodplain, relocation of river to what is believed to be its original location (through the Shave Creek concentrated tailings area), and restoration of the floodplain and riparian zone throughout the Upper Blackfoot River removal area. The merits of, and appropriate location for the Blackfoot River realignment would be based on a detailed topographic survey to be conducted in 2007. A portion of the County road (Mike Horse Road) may also be relocated under Option 5 to reduce the overall road length and minimize the length of road falling within the riparian zone. Option 4 conceptual details are shown on Drawing 12, Appendix F.

Mine waste removal under Option 4 would follow that described for Option 2. Excavation would extend to about one-foot below the native soil/mine waste interface, with the total volume of material to be excavated estimated at 45,000 cy. This estimated volume might change pending detailed floodplain soil sampling to be performed in 2007 or 2008. Over-excavated areas backfilled with clean earthen fill to maintain a suitable grade through the removal area. Since the majority of mine waste present within the Upper Blackfoot River drainage bottom was deposited on top of the original ground surface, removal of the mine waste should restore the original topography and grade of the affected areas. Therefore, backfill material would only be necessary to replace over-excavated areas. The actual quantity of fill required would be dependent on the depth of mine waste excavation, and the desired final stream and floodplain elevation and grade. Removal areas would also be covered with six to 12 inches of clean soil and seeded to promote revegetation. Excavated mine waste/soils would be placed in an in-drainage repository such as the Paymaster Area, or an out-of-drainage location depending on the removal actions selected for the other subareas.

Following mine waste removal, the drainage bottom would be restored to a functioning stream/floodplain system. If appropriate, the Blackfoot River channel would be relocated to what is believed to be the original channel location through the Shave Creek concentrated tailings area (Drawing 12). The channel and floodplain design would be based on the modeled 100-year maximum flow of 920 cfs (Appendix A). The stream channel and floodplain dimensions, as well as the exact location for the new stream channel, would be determined following the detailed topographic survey to be completed in 2007. Final restoration would also include restoration of the riparian area to provide suitable aquatic habitat and stream channel stabilization.

As with Beartrap Creek, hydrologic modeling performed to determine the 100-year (and 500-year) flows for the Upper Blackfoot River ignore effects on site hydrology of the Mike Horse Dam. If the dam were to remain in place (Impoundment Option 2), the peak flows in downstream Beartrap Creek would be less than those presented here, although the difference is not expected to be significant for the 100-year and 500-year flows. Additional hydrologic modeling will be required once a site-wide removal action alternative is selected to account for the final upstream hydrologic conditions resulting from removal actions at the Mike Horse Tailings Impoundment, Lower Mike Horse Creek and Beartrap Creek.

6.3 SITE-WIDE REMOVAL ACTION ALTERNATIVES

Five site-wide removal action alternatives have been developed for the EE/CA area with each alternative comprised of selected sub-area removal options presented in Section 6.2. Each of the alternatives is described and assessed for consistency with the primary and secondary removal action objectives presented in Section 5. In accordance with EE/CA guidance (EPA, 1993), alternatives are assessed for effectiveness, implementability and relative cost. The effectiveness criterion addresses an alternatives ability to meet the removal action objectives (outlined in Section 5), overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness. The implementability criterion assesses the technical and administrative feasibility and availability of required services and materials for each alternative. The cost criterion includes direct and indirect construction costs, and post-removal operation and maintenance (O&M) costs. As specified by the USFS, the post-removal O&M costs are based on a net present worth cost for a 100-year O&M period.

The five site-wide removal action alternatives include:

- Alternative 1: No Action
- Alternative 2: In-place stabilization of the Mike Horse Tailings Impoundment (Option 2), partial removal from Lower Mike Horse sub-area (Option 2), removal of concentrated tailings from Beartrap Creek sub-area (Option 2), and removal of concentrated tailings and larger dispersed tailings deposits from Blackfoot River sub-area (Option 2).
- Alternative 3: Removal of Mike Horse dam from service and partial removal of impounded tailings (Option 3), total mine waste removal from Lower Mike Horse sub-area (Option 3), removal of concentrated tailings from Beartrap Creek sub-area (Option 2), and removal of concentrated tailings and larger dispersed tailings deposits from Blackfoot River sub-area (Option 2). Relocation of excavated materials to in-drainage repository.
- Alternative 4: Total removal of Mike Horse dam and impounded tailings (Option 4), total mine waste removal from Lower Mike Horse sub-area (Option 3), removal of all concentrated tailings deposits and intermixed tailings adjacent to the stream channel for Beartrap Creek sub-area (Option 4), and total mine waste removal from Blackfoot River sub-area (Option 4). Relocation of excavated materials to in-drainage repository if necessary, or to First Gulch repository site if suitable in-drainage site not available.
- Alternative 5: Total removal of Mike Horse dam and impounded tailings (Option 5), total mine waste removal from Lower Mike Horse sub-area (Option 3), total mine waste removal from Beartrap Creek sub-area (Option 5), and total mine waste removal from Blackfoot River sub-area (Option 4). Relocation of all excavated materials to Horsefly Creek, First Gulch, or other out-of-drainage repository.

The site-wide removal action alternatives are summarized in Table 6-3 and are described below. Detailed cost estimates are provided for each sub-area option in Appendix I.

6.3.1 Alternative 1: No Action

Alternative 1 includes no mine waste removal or other mitigative measures at any of the EE/CA sub-areas. Although no removal actions would occur, it is possible that water quality conditions would improve in the EE/CA area streams due to continued remediation of upgradient source areas by ASARCO. These reductions in upgradient metals loading rates are expected to improve water quality at least in portions of the EE/CA area, however, the improvements are not expected to result in attainment of the Removal Action Objectives (RAOs) outlined in Section 5. Therefore, Alternative 1 ranks low for effectiveness, including overall protectiveness of human health and the environment, compliance with ARAR- and risk-based goals (Section 5), long-term effectiveness and permanence, and short-term effectiveness. Alternative 1 would not meet any of the contaminant mobility, human health risk, surface water quality, or watershed functionality RAOs presented in Section 5. For implementability, Alternative 1 would rank high for technical feasibility and availability of services and materials since no construction would be done, but low for administrative feasibility since it would not address the human health and environmental issues associated with the site as described in Sections 3 and 4.

Alternative 1 would include continued monitoring at the tailings impoundment and other sub-areas, including water quality monitoring and routine site inspections. The emergency action plan would also remain in effect at the impoundment. The net present worth cost for O&M activities over 100 years would be approximately $2,448,000 (Appendix I).

6.3.2 Alternative 2: Dam Stabilization and Removal of Select Mine Wastes

Alternative 2 includes stabilization of the Mike Horse Tailings Impoundment by constructing an emergency overflow spillway in the dam to meet USFS dam design requirements, lining the upstream dam face to reduce seepage through the dam, and construction of subsurface drains at the dam toe to lower the water table (Impoundment Option 2). The downstream dam face would be covered with soil and shoreline tailings either relocated to a repository or covered in place. Removal actions in Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot sub-areas would include partial mine waste removal, with the more concentrated mine waste deposits targeted for removal (Option 2 for each sub-area, Section 6.2). The combined mine waste removal volume would be approximately 60,000 cy with all excavated material placed in one in-drainage repository at the Paymaster, Old Townsite or West Impoundment locations (Figure 6-1).

The overall effectiveness of Alternative 2 would be low to moderate. Although several site improvements would occur under Alternative 2, including a substantial reduction in the potential for the Mike Horse Dam to be overtopped, mine waste would remain along drainage bottoms at all sub-areas. Overall protection of human health and the environment would be moderate based on the potential for leaching and erosion of floodplain wastes to affect surface water quality, and the continued potential for direct contaminant contact or inhalation by recreational site users. Alternative 2 most likely would not comply with surface water quality-related ARARs. Short-term effectiveness would be moderate since tailings within the impoundment would undergo minimal dewatering, but extensive construction and materials handling would occur along floodplains. Long-term effectiveness and permanence would be moderate for the same reasons cited above for protection of human health and the environment, and because the tailings dam would remain in place and in service. Alternative 2 may not meet the contaminant mobility, human health risk, surface water quality, and improved watershed functionality RAOs listed in Section 5, but would at least partially meet the RAO for reducing the long-term potential for failure of the Mike Horse Dam.

Alternative 2 ranks moderate to high for implementability. Technical feasibility would be high since construction activities would involve standard construction practices. Availability of required services and materials would be moderate since coversoil (approximately 13,000 cy) may need to be imported from an offsite location such as First Gulch. Administrative feasibility would be low to moderate since all ARARs may not be met, and some human health and environmental issues associated with floodplain mine wastes and impoundment tailings would not be addressed.

Alternative 2 would require continued site-wide monitoring and routine site inspections (for the assumed 100-year O&M period), and continued implementation of the tailings dam emergency action plan. The Alternative 2 costs are estimated at $5,221,000 (Appendix I).

6.3.3 Alternative 3: Remove Dam from Service and Removal of Select Mine Wastes

Alternative 3 includes breaching the Mike Horse Dam and construction of an engineered Beartrap Creek channel through the impoundment to remove the dam from service (Impoundment Option 3). Portions of the impoundment tailings and remnants of the dam would be capped in place. All mine waste would be removed from Lower Mike Horse Creek (Option 3), while only the concentrated tailings deposits would be removed from the Beartrap Creek sub-area (Option 2). In the Blackfoot River sub-area, the concentrated tailings and larger dispersed tailings deposits would be removed, but smaller less accessible deposits left in place (Option 2). The combined removal volume would be approximately 125,000 cy (Table 6-3). The excavated mine waste would be placed in one of the in-drainage repository sites with the West Impoundment site being the preferred location due to its proximity to the area of greatest removal volume (the impoundment).

Alternative 3 ranks moderate for overall effectiveness, with the level of effectiveness greater than that for Alternative 2 based on removal of the dam from service and total mine waste removal in Lower Mike Horse Creek. Overall protection of human health and the environment would be moderate due to the continued presence of floodplain mine waste along Beartrap Creek and the Upper Blackfoot River, and potential for water quality impacts or human exposure, and the large volume of impoundment tailings remaining in the drainage bottom and possibly subject to metals leaching from groundwater through-flow. For these same reasons, compliance with ARARs and long-term effectiveness would be moderate. Short-term effectiveness would be low to moderate based on the extensive dewatering and excavation of tailings that would occur at the impoundment, and the potential for short-term seepage from the west wall of the tailings impoundment excavation area due to compaction and gravity drainage of the tailings left in place. Based on available site information including the hydrogeology of the impoundment area, Alternative 3 may meet the contaminant mobility, human health risk, and surface water quality RAOs outlined in Section 5, would at least partially meet the RAO for improved watershed functionality and stabilization, and would met the RAO for reducing the long-term potential for failure of the Mike Horse Dam.

Overall implementability would be moderate for Alternative 3. Technical feasibility and availability of services and materials would be moderate based on extensive dewatering of the tailings required, and the need for excavation and handling of potentially wet tailings. Availability of coversoil at the impoundment and other removal areas could also be a concern since coversoil may have to be imported from an offsite location such as First Gulch. Up to 35,500 cy of coversoil would be required under Alternative 3. Administrative feasibility would be moderate based on the likelihood of continued water quality impacts and potential human health affects from mine waste materials left in place.

Alternative 3 would include site-wide water quality monitoring and routine site inspections for an assumed 100-year O&M period. Costs for Alternative 3 would be low to moderate, with construction and O&M costs totaling $7,778,000.

6.3.4 Alternative 4: Removal of Tailings Impoundment and Dam, Removal of Lower Mike Horse and Blackfoot River Mine Wastes, and Removal of Select Mine Wastes from Beartrap Creek drainage with Placement in In-Drainage Repositories

Alternative 4 includes total removal of the Mike Horse Dam and impounded tailings (Option 4), total mine waste removal from Lower Mike Horse Creek (Option 3), removal of all concentrated mine waste deposits and intermixed mine waste adjacent to the active stream channel in the Beartrap Creek subarea (Option 4); and total mine waste removal from the Upper Blackfoot River sub-area (Option 4). The combined removal volume would be approximately 455,000 cy. The storage capacity of the Paymaster Mine area repository would be maximized through use of a toe berm and steepened repository grade so that all wastes could be permanently stored in-drainage. If the Paymaster Mine site is found to be unsuitable for repository construction for physical or logistical reasons, removal materials would be relocated to the First Gulch site repository.

Overall effectiveness for Alternative 4 would be high. Protection to human health and the environment would be high based on the removal of all mine waste from the impoundment, Lower Mike Horse and Blackfoot River sub-areas. Removal of all concentrated tailings deposits and intermixed tailings within the stream migration corridor should address water quality and human health issues associated with the floodplain mine wastes as well. Placement of mine wastes in a repository with a composite plastic liner/earthen cap as described in Section 6.1 would greatly reduce infiltration through, and potential metals leaching from, the mine waste. Hydrologic modeling has shown that consolidation and capping of the mine waste as proposed would reduce infiltration through the mine waste to approximately 0.001 gpm per acre of repository, or 0.006 gpm for a six-acre repository on an annual average basis. This is approximately two orders of magnitude lower than estimated infiltration rates for surficial mine wastes such as those exposed along the Beartrap Creek floodplain. Compliance with ARARs and long-term effectiveness would be high for these same reasons. Short-term effectiveness would be moderate due to the extensive tailings dewatering, excavation and handling required, and in-stream work required at the other sub-areas. All project RAOs as listed in Section 5 would be attainable under Alternative 4 provided mine wastes are placed in a suitably located and designed repository.

Implementability would be moderate to high. Technical feasibility and availability of required services and materials would be moderate due to the extensive dewatering and materials handling requirements, and the possible need to import approximately 50,000 cy of coversoil/fill required for Alternative 4 (not counting the repository cap soils which would be available through repository site stripping/preparation), from an offsite soil borrow source. Administrative feasibility should be high based on the total or near total removal proposed at all sub-areas, as long as a suitable repository site is selected.

Monitoring requirements would include site-wide water quality monitoring and regular inspections of all removal areas and repository sites. Based on a 100-year O&M period, the cost of Alternative 4 would be about $19,224,000, based on development of the Paymaster Repository.

6.3.5 Alternative 5: Removal of Tailings Impoundment and Dam, Removal of Lower Mike Horse Creek, Beartrap Creek and Blackfoot River Mine Wastes, and Placement in Out-of Drainage Repository

Alternative 5 is similar to Alternative 4 except that all mine waste would be removed from the Beartrap Creek sub-area (Option 5) instead of just the concentrated tailings deposits and intermixed tailings from the stream migration corridor, and all removed mine wastes would be taken to the Horsefly Creek, First Gulch, or other out-of-drainage repository site. The combined removal volume under Alternative 5 would be approximately 490,000 cy.

Similar to Alternative 4, overall effectiveness for Alternative 5 would be high. Overall protection to human health and the environment would be high based on the removal of all mine waste from all four sub-areas. Placement of mine wastes in a repository with a composite plastic liner/earthen cap as described in Section 6.1 would greatly reduce infiltration through, and potential metals leaching from, the mine waste. Hydrologic modeling has shown that consolidation and capping of the mine waste as proposed would reduce infiltration through the mine waste to approximately 0.001 gpm per acre of repository, or 0.006 gpm for a six-acre repository on an annual average basis. Compliance with ARARs and long-term effectiveness would be high for these same reasons. Short-term effectiveness would be moderate due to safety concerns and a higher potential for material spillage, as compared to Alternative 4, due to the longer haul (10 miles), six miles of which would occur on Highway 200. The moderate rating for short-term effectiveness also reflects the extensive tailings dewatering, excavation and handling required, and in-stream work required at the other sub-areas. Similar to Alternative 4, all project RAOs would be attainable under Alternative 5 provided mine wastes are placed in a suitably located and designed repository.

Overall implementability would be moderate for Alternative 5. Technical feasibility would be moderate based on the need for significant dewatering and materials handling, and hauling on a state highway. Availability of required services and materials would be moderate due to the need to import a significant quantity of fill/coversoil, which would total over 55,000 cy for the removal areas, not counting the repository cap soils (the repository coversoil would be available through repository site stripping/preparation). Administrative feasibility would also be moderate due to additional regulatory requirements associated with hauling on a public highway and the significant land disturbance that would occur in a currently uncontaminated area (15 to 20 acres for the repository and 1.5 miles of new road). Administrative feasibility is also rated moderate due to the fact that the Horsefly Creek property is not in federal, state, or ASARCO control or ownership, and a property transfer or other access arrangements would be required before the repository site could be considered for use. Administrative feasibility would be higher if the First Gulch repository site was used instead of Horsefly Creek due to distance, access and property control considerations.

The estimated cost for Alternative 5 is $30,550,000 based on use of the Horsefly Creek repository site. Besides the relatively long haul distance, this value reflects a number of cost items which are specific to Alternative 5, such as construction of new roads and river crossings, the need to repair Highway 200 after hauling is completed, and the cost for purchasing the Horsefly Creek area property (20 acres at $800/acre) which is currently owned by Stimson Lumber Company.

7.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

In Section 6.3, five site-wide removal action alternatives were introduced and evaluated for effectiveness, implementability and cost. To supplement the alternative-specific analysis provided in 6.3, this section provides a head to head comparison of the five alternatives for relative performance under each of the evaluation criteria. Results of the comparative analysis are summarized in Table 7-1 and are described below.

7.1 COMPARATIVE ANALYSIS FOR EFFECTIVENESS

The effectiveness criterion includes: overall protection of human health and the environment; short-term effectiveness; long-term effectiveness and permanence; reduction of contaminant toxicity, mobility or volume; and compliance with ARARs. Short-term effectiveness addresses potential environmental and human health effects of the alternative during implementation and before the removal action objectives are met, while the long-term effectiveness and permanence criterion addresses potential effects after implementation.

Alternative 1 ranks low for overall effectiveness since no removal actions would occur. Overall protection of human health and the environment, short-term effectiveness, long-term effectiveness and reduction in toxicity/mobility/volume all rank low since there would be no change in site conditions. Although improvements to water quality may occur within the EE/CA area due to reclamation activities on upgradient private lands, this most likely would not result in EE/CA area surface waters meeting applicable water quality standards, and compliance with ARARs would be low. Alternative 1 would not meet the project RAOs listed in Section 5.

Alternative 2 ranks low to moderate for overall effectiveness due to the volume of mine waste that would be left in-place and exposed to the elements in all four sub-areas. Overall protection of human health and the environment, short-term effectiveness would all rank moderate due to construction of a spillway in the Mike Horse dam and associated reduction in the potential for overtopping of the dam, and removal of the more reactive mine wastes in Lower Mike Horse Creek, Beartrap Creek and Blackfoot River sub-areas. Reduction of toxicity/mobility/volume and compliance with ARARs rank low to moderate based on the volume of mine waste left exposed to the environment, especially at the tailings impoundment. Long-term effectiveness and permanence rank low to moderate due to the large amount of mine waste left in place, and the continued potential for future failure of the dam (although failure through overtopping would be substantially reduced with construction of the spillway).

Alternative 3 ranks moderate for overall effectiveness, with the higher effectiveness rating (as compared to Alternative 2) attributable to the dam being removed from service and removal of all mine waste from Lower Mike Horse Creek. Overall protection of human health and the environment, long-term effectiveness, reduction of toxicity/mobility/volume, and compliance with ARARs all rank moderate since all mine waste in the impoundment and Lower Mike Horse Creek sub-areas would either be relocated to a repository or capped in-place, but some mine waste would be left in it's current state in Beartrap Creek and Blackfoot River sub-areas. Also, portions of the impoundment tailings to be capped in-place may be exposed to groundwater through-flow and possible metals leaching. Short-term effectiveness would be low to moderate due to the extensive dewatering and excavation of tailings that would occur at the impoundment, and the potential for short-term seepage from the west wall of the tailings impoundment excavation area due to drainage from the tailings to be left in place. Alternative 3 would meet the project RAO for reducing the long-term potential for failure of the Mike Horse dam, and would partially meet the improved watershed functionality RAO. Alternative 3 may meet the contaminant mobility, human health risk, and surface water quality RAOs, depending in part on the nature of post-dewatering groundwater flow through the impoundment area and interaction of groundwater with the tailings closed in-place.

Alternatives 4 and 5 both rank high for effectiveness since virtually all mine waste would be removed from the drainage bottoms and placed in a capped repository. The relatively small volume of intermixed tailings to be left in-place in the Beartrap Creek sub-area under Alternative 4 (as compared to the total removal of Beartrap mine waste in Alternative 5) is not expected to have a significant impact on human health or the environment based on the streamlined risk evaluation (Section 4). Overall protection of human health and the environment, long-term effectiveness, reduction of toxicity/mobility/volume, and compliance with ARARs all rank high for Alternatives 4 and 5 assuming appropriate repository sites are chosen. Short-term effectiveness would be moderate for Alternative 4 and 5 due to the significant volume of material requiring excavation and handling (especially at the tailings impoundment), and the large amount of in-stream work required. Short-term effectiveness would be somewhat lower for Alternative 5 if the Horsefly Creek repository site were used (as compared to use of the First Gulch site) based on the ten mile haul distance (six miles of which is on Highway 200), and the need for 1.5 miles of new road and a stream crossing on the Blackfoot River to access Horsefly Creek. Likewise, long-term effectiveness and reduction in toxicity/mobility/volume would be reduced to moderate for Alternative 4 if the West Impoundment Repository site is used and shallow seasonal groundwater conditions persisted after impoundment dewatering. These criteria would continue to rank high however if another in-drainage location like Paymaster Creek, or an out of drainage repository site (First Gulch) were used in lieu of the West Impoundment. Both Alternatives 4 and 5 would meet all project RAOs listed in Section 5 assuming the removed material was placed in an appropriately located and designed repository.

7.2 COMPARATIVE ANALYSIS FOR IMPLEMENTABILITY

The implementability criterion includes technical feasibility, availability of required services and materials, and administrative feasibility. Alternative 1 (No Action) ranks high for technical feasibility and availability of services and materials since no removals would occur (Table 7-1). Administrative feasibility would be low since the current regulatory concerns associated with the site would remain.

Overall implementability is moderate to high for Alternative 2. Technical feasibility is high since all removals under Alternative 2 could be completed using standard construction practices and equipment. Availability of required services and materials would be moderate since coversoil (approximately 13,000 cy) may need to be imported from an offsite location. Administrative feasibility would be low to moderate since all ARARs may not be met, and some human health and environmental issues associated with floodplain mine wastes and impoundment tailings would not be addressed.

Technical feasibility, availability of services and materials, and administrative feasibility are all moderate for Alternative 3. Although construction techniques are readily available for removals such as those proposed in Alternative 3, dewatering and excavation/handling of potentially saturated tailings at the impoundment would require special construction practices and measures. Availability of services and materials would be affected by these same issues, and by the need to procure a borrow site for up to 35,500 cy of coversoil. Administrative feasibility would be moderate based on the potential for continued water quality impacts and potential human health affects from mine waste materials left in place at all sub-areas except Lower Mike Horse Creek.

Overall implementability is moderate to high for Alternative 4. Technical feasibility and availability of required services and materials are both considered to be moderate due to the extensive dewatering and materials handling requirements, potential site preparation requirements for construction of the West Impoundment Repository, and the possible need to import approximately 50,000 cy of fill/coversoil for the removal areas. Administrative feasibility should be high based on the total or near total removal proposed at all sub-areas and placement in a capped repository, as long as a suitable repository site is selected. If the First Gulch repository site were used, administrative feasibility may decrease somewhat due to regulatory requirements associated with hauling on a public highway.

Alternative 5 ranks moderate for overall implementability (Table 7-1). Similar to Alternative 4, technical feasibility is moderate based on the need for significant dewatering and handling of potentially saturated materials at the impoundment and other sub-areas. Technical feasibility is also affected by the required hauling of approximately 500,000 cy of mine waste on state Highway 200. Availability of required services and materials is moderate based on the need to import approximately 55,000 cy of fill/coversoil for the removal areas. Administrative feasibility would be moderate to high (depending on the repository location) due to additional permitting requirements associated with hauling on a public highway and with "out-of-drainage" disposal of mine waste, and the significant land disturbance that would occur in a currently uncontaminated area (15 to 20 acres at the out-of-drainage location). Administrative feasibility would be at the moderate end of the range if the Horsefly Creek site were used based on the fact that the Horsefly Creek property is privately owned and a property transfer or other access arrangements would be required before the repository site could be considered for use, and 1.5 miles of new road and a Blackfoot River crossing would have to be constructed for mine waste hauling. Administrative feasibility would be high if the First Gulch repository site were used due to the shorter highway haul distance (2.5 miles vs. 6 miles) and elimination of the need for new roads and river crossings.

7.3 COMPARATIVE ANALYSIS FOR COST

Cost estimates for each site-wide alternative were introduced in Section 6.3 and are detailed in Appendix I. Alternative cost estimates include direct and indirect construction costs, and post-removal operation and maintenance (including monitoring) costs (EPA, 2000). As requested by the USFS, the O&M costs are based on a net present worth cost for a 100-year O&M period, and a discount rate of 4.86% (Brattle Group, 2007). Based on inherent uncertainties in material volumes and actual construction costs, and keeping with conventional cost estimating guidance, the estimates provided should be considered accurate to within +50%/-30%.

As shown in Table 7-1, total cost estimates (construction and O&M) on a net present value basis for individual alternatives include:

- $2,448,000 for Alternative 1;
- $5,221,000 for Alternative 2;
- $7,778,000 for Alternative 3;
- $19, 224,000 for Alternative 4; and
- $30,550,000 for Alternative 5.

The cost estimate presented above for Alternative 4 is based on relocation of the majority of excavated mine waste to the Paymaster repository site. As described in Section 6.3, this is the preferred repository location under Alternative 4 based on its in-drainage location, property ownership, and the currently disturbed nature of the Paymaster area. However, if this site proves unsuitable for repository construction, the excavated waste would be disposed at the First Gulch repository location. If the First Gulch Repository site were used, the Alternative 4 cost estimate would increase to $26,000,000.

8.0 REFERENCES

Brattle Group, 2007. Expert Report Concerning Cost Estimating of the Present Value of Expected Costs in the ASARCO LLC Chapter 11 Bankruptcy Matter Case No. 05-21207. May 4, 2007.

Dames & Moore, 1975. Design Report on Repair of Tailings Embankment, Mike Horse Mine Near Lincoln, Montana. September 18, 1975.

Dames & Moore, 1976. Report on Construction Inspection, Mike Horse Dam and Spillway Near Lincoln, Montana. January 1976.

Envirocon, 1993. Flood Plain Analysis for the Blackfoot River and Tributaries in the Vicinity of the Upper Blackfoot Mining Complex. August 1993.

Furniss, G., 1995. Memorandum RE: History and character of "Stevens Creek", a drainage south of the Blackfoot River between Paymaster Creek and Mike Horse Creek. Addressed To Bob Anderson (Hydrometrics) and Chris Pfahl (ASARCO). June 15, 1995.

Furniss, G., 1998. Holocene ferricrete of Paymaster Creek reveals natural acid drainage history, Heddleston Mining District, Lewis and Clark County, Montana. *Northwest Geology* 28: 21-25.

GCM Services, Inc., 1993. Cultural Resource Inventory and Evaluation of the Upper Blackfoot Mining Complex in the Heddleston Mining District, Lewis and Clark County, Montana. Prepared for ASARCO, Inc. and ARCO. August 1993.

Hydrometrics, Inc., 1999. Support Document and Implementation Plan for Temporary Modification of Water Quality Standards for a Portion of Mike Horse Creek, a Portion of Beartrap Creek, and a Portion of the Upper Blackfoot River. Prepared for ASARCO Incorporated. October 1999.

Hydrometrics, Inc., 2000. Revised Implementation Plan in Support of Adoption of Temporary Water Quality Standards, Upper Blackfoot Mining Complex. Prepared for ASARCO Incorporated. August 2000.

Hydrometrics, Inc., 2001a. Mike Horse Mine Tailings Impoundment Investigation. Memorandum submitted to U.S. Forest Service and Montana Department of Environmental Quality. August 20, 2001.

Hydrometrics, Inc., 2001b. 2000 Monitoring Activities Report for the Upper Blackfoot Mining Complex, Lewis and Clark County, Montana. Prepared for ASARCO Incorporated. March 2001.

Hydrometrics, Inc., 2002. 2001 Monitoring Activities Report for the Upper Blackfoot Mining Complex, Lewis and Clark County, Montana. Prepared for ASARCO Incorporated. May 2002.

Hydrometrics, Inc., 2005a. Alternatives Technical Memorandum for Mine Waste Removal at the Upper Blackfoot Mining Complex, Lewis and Clark County, Montana. Prepared for ASARCO Inc. January 2005.

Hydrometrics, Inc., 2005b. Comprehensive Data Summary Report for the Upper Blackfoot Mining Complex, Lewis and Clark County, Montana. Prepared for ASARCO Inc. December 2005.

Hydrometrics, Inc., 2006a. Draft Engineering Evaluation/Cost Analysis for the Mike Horse Dam and Impoundment Tailings, Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot River Floodplain Removal Areas, Upper Blackfoot Mining Complex. Prepared for USDA Forest Service and ASARCO LLC. July 2006.

Hydrometrics, Inc., 2006b. Emergency Action Plan, Mike Horse Dam, Upper Blackfoot Mining Complex, Lewis and Clark County, MT. February 24, 2006.

Lowney, Y.W., M.V. Ruby and R.C. Wester, 2005. Percutaneous Adsorption of Arsenic from Environmental Media. Toxicology and Industrial Health, V21, No. 10.

McClave, Michael A., 1998. The Heddleston Porphyry Copper-Molybdenum Deposit – An Update. Northwest Geology, V. 28.

McCulley, Frick and Gilman, 1996. Paymaster Mine and No. 3 Tunnel Areas Montana Voluntary Cleanup and Redevelopment Act (VCRA) Application.

Menges, J., 1997. Investigation of Temporal Changes of Heavy Metal Concentrations in Sediments and Water of the Blackfoot River, Montana. M.S. Thesis (Geology), University of Montana. March 1997.

Miller, R.N., Shea, E.P., Goddard, C.C. Jr., Potter, C.W., and Brox, J.B., 1973. Geology of the Heddleston Copper-Molybdenum Deposit, Lewis and Clark County, Montana: Pacific Northwest Metals and Minerals Conference, Coeur d'Alene, Idaho, A.I.M.E. Proceedings, p. 1-33.

MBMG, 1998. Water-Quality, Soil and Sediment Sampling at the Mike Horse Tailings Dam and Impounded Tailings. Montana Bureau of Mines and Geology. April 1998.

Montana Department of Environmental Quality, 2003. Water Quality Restoration Plan for Metals in the Blackfoot Headwaters Planning Area. June 2003.

Montana Department of Environmental Quality, 2004. Water Quality Restoration Plan for Sediment and Habitat in the Blackfoot Headwaters Planning Area

Montana Department of Environmental Quality, 2006. *Circular DEQ-7, Montana Numeric Water Quality Standards*, http://www.deq.state.mt.us/wqinfo/Standards/CompiledDEQ-7.pdf

Montana Department of Health and Environmental Sciences (MDHES), 1992. Special Notice Letter from Mr. Dennis Iverson to ASARCO Incorporated (Mr. F.D. Owsley). February 18, 1992.

Montana Department of Health and Environmental Sciences, 1994. Final Site Inspection Report, Upper Blackfoot Mining Complex Site, Lewis and Clark County, MT. CERCLIS ID No. MTD986069474. February 15, 1994.

Moore, 1990. Mine Effluent Effects on Non-point Source Contaminants in the Blackfoot River, Montana. Prepared for the Lewis and Clark City-County Health Department and the Montana Department of Health and Environmental Sciences, Water Quality Bureau, Helena, MT. University of Montana, Geology Department, Missoula, MT.

Nagorski, S.A., T.E. McKinnon, J.N. Moore and D.B. Smith, 2000. Geochemical Characterization of Surface Water and Streambed Sediment of the Blackfoot River, Montana, During Low Flow Conditions, August 16-20, 1998. USGS Open-File Report 00-003.

Pardee, J.T. and Schrader, F.C., 1933. Metalliferous Deposits of the Greater Helena Mining Region, Montana.

Purdue University, 1982. PCSTABL5M Slope Stability Package.

PTI, 1994. Upper Blackfoot Mining Complex, Phase I Data Report. Prepared for ASARCO, Inc. and ARCO. April 1994.

Schroeder, P.R., C.M. Lloyd, P.A. Zappi and N.M. Aziz, 1994. Hydrologic Evaluation of Landfill Performance Model, User's Guide for Version 3.01. USEPA 600-94158a. October 1994.

Tetra Tech, Inc. (Tetra Tech), 1996. *Risk-Based Guidelines for Abandoned Mine Sites*, Final Report, Submitted to the State of Montana, Department of Environmental Quality, Abandoned Mine Reclamation Bureau, February.

Tetra Tech, Inc. (Tetra Tech), 2004. *User's Guide: Risk-Based Guidelines for Abandoned Mine Sites*, Final Report, Submitted to the State of Montana, Department of Environmental Quality, Abandoned Mine Reclamation Bureau, July.

U.S. Environmental Protection Agency (EPA), 1986. *Guidelines for Carcinogen Risk Assessment*, EPA/600/8-87/045, Risk Assessment Forum, Washington, D.C., 1986.

U.S. Environmental Protection Agency (EPA), 1989. *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final*, July, and *Part B, Development of Risk-Based Preliminary Remediation Goals*.

U.S. Environmental Protection Agency (EPA), 1990. *National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule*, Federal Register 6670-8852, March 8, 1990.

U.S. Environmental Protection Agency (EPA), 1993. Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA. Publication # EPA540-R-93-057. August 1993.

U.S. Environmental Protection Agency (EPA), 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*, Interim Final, OSWER Directive 9285.7-25, Office of Solid Waste and Emergency Response, June.

U.S. Environmental Protection Agency (EPA), 2000. A Guide to Developing and Documenting Cost Estimates During Feasibility Studies. EPA 540-R-00-002, OSWER 9355.0-75. Office of Solid Waste and Emergency Response. July.

U.S. Environmental Protection Agency (EPA), 2003. *Guidance for Developing Ecological Soil Screening Levels*, OSWER Directive 92857-55, Office of Solid Waste and Emergency Response, November.

USFS, 1964. USFS Memorandum on October 14, 1964 Annual Inspection of the Mike Horse Dam. November 10, 1964.

USFS, 1975. Mike Horse Dam Reconstruction Environmental Analysis Report. Helena National Forest. August, 1975.

USFS, 2005. Evaluation of Mike Horse Dam, A Report Prepared for the USDA Forest Service by Stephen Romero, USFS Missoula. January 2005.

USFS, 2006. Draft Concept Alternatives Technical Memorandum for the Mike Horse Dam and Tailings Impoundment at the Upper Blackfoot Mining Complex, Lewis and Clark County, MT. Prepared by Helena National Forest. February 21, 2006.

Western Technology and Engineering, Inc., 1993a. Wetlands Inventory of the Upper Blackfoot Project Area, Lewis and Clark County, Montana. Prepared for ASARCO and ARCO. August 1993.

Western Technology and Engineering, Inc., 1993b. Upper Blackfoot Project Area Threatened and Endangered Species Reconnaissance. Prepared for ASARCO and ARCO. August 1993.