RECORD OF DECISION
FOR
FORMOSA MINE SUPERFUND SITE
OPERABLE UNIT 1
DOUGLAS COUNTY, OREGON

April 2016

PREPARED BY

U.S. ENVIRONMENTAL

PROTECTION AGENCY, REGION 10

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RECORD OF DECISION

FOR

FORMOSA MINE SUPERFUND SITE

OPERABLE UNIT 1

DOUGLAS COUNTY, OREGON

Part 1
Declaration

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Site Name and Location

The Formosa Mine Superfund Site (Site) (U.S. Environmental Protection Agency [EPA] identification number ORN001002616) is an abandoned mine located in southwest Oregon in Douglas County, approximately 25 miles south of Roseburg, Oregon and 7 miles south of Riddle, Oregon on Silver Butte Mountain.

Statement of Basis and Purpose

This decision document presents EPA's Selected Remedy for Operable Unit (OU) 1. The remedy selected in this Record of Decision (ROD) was chosen according to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and, to the extent practicable, the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). The decision is based on the Administrative Record for the Site. This document is issued by EPA Region 10, the lead agency. The U.S. Department of the Interior Bureau of Land Management (BLM) and the Oregon Department of Environmental Quality (ODEQ) are the support agencies. The support agencies concur with the Selected Remedy.

Assessment of Site

The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants into the environment. Such a release or threat of release may present an imminent and substantial endangerment to public health, welfare, or the environment.

Description of Selected Remedy

The Selected Remedy will provide protection of human health and the environment by eliminating or reducing exposure of mine materials to water and oxygen through containment, thus, mitigating the migration of contaminants (cadmium, copper, and zinc) affecting surface waters at the Site. The Selected Remedy will provide protection of human health by removing, containing, and preventing human exposure to soil contaminated primarily with arsenic in localized areas at the Site.

The remedial action will address releases from mine waste outside the mine that are leaching metals to surface and groundwater and causing unacceptable risks to aquatic receptors. The Selected Remedy's containment of mine materials reduces the long-term risk of exposure to chemicals within mine materials by eliminating complete exposure pathways to ecological receptors using excavation, consolidation, and/or covering of mine materials. This approach results in ecological receptors having limited exposure to chemicals from mine materials, thus reducing potential adverse effects to these receptors. In addition, the consolidation and containment of mine materials will result in isolation of these materials from precipitation and surface water, reducing leaching of metals and mining-influenced water (MIW) into surface water and groundwater. The Selected Remedy achieves the remedial objectives for managing mine materials by containment, which reduces migration of cadmium, copper, and zinc to adjacent surface waters to acceptable levels for aquatic receptors. The beneficial effect to the aquatic environment will be measured and documented through monitoring of the OU2 remedy. There are no principal threat wastes addressed by this ROD.

The Selected Remedy includes the following approaches and components:

1. Excavate approximately 140,000 cubic yards (CY) of mine materials that directly affect the headwaters near the Site or in areas with currently unstable slopes.

2. Cover approximately 55,000 CY of mine materials not in close proximity to headwaters near the Site and in areas with currently stable slopes.

3. Continue to maintain simple submergence of tailings as stored within the former water and tailings storage pond and contain them under a new cover.

4. Consolidate and place excavated mine materials in up to two disposal facilities. The facilities may be designed as one unit.

    a. Proposed facility within the primary mine disturbance area (PMDA) would be located at the encapsulation mound (EM).

    b. Proposed facility outside the PMDA may be located east of the PMDA boundary but on Formosa Exploration Inc. (FEI) property. The final location will be determined during the design phase.

5. Reclaim excavated areas, areas disturbed during construction, and roads affected by construction as necessary to provide stability and continuity of access through the Site.

6. If needed, pave existing roadways constructed with mine waste material or implement additional drainage controls to prevent water infiltration through the roadbed.

7. Implement institutional controls (ICs), including administrative controls, and community awareness activities, as necessary, to protect the disposal facilities and containment areas.

8. Maintain and monitor the remedy components, including disposal facilities and containment areas, so exposure of mine materials and associated chemicals does not occur and covers remain effective at reducing or eliminating migration of chemicals to surface water and groundwater.

The Selected Remedy is estimated to take 2 years to construct. Total estimated net present value costs (discounted at 7 percent) for the Selected Remedy are $12.44 million, of which capital costs are $11.96 million, and operation and maintenance (O&M) plus 5-year review costs are approximately $1.082 million. The Selected Remedy is intended to be the final remedial action for OU1 of the Formosa Mine Site.

Statutory Determinations

The Selected Remedy is protective of human health and the environment. It complies with all federal and state requirements that are applicable or relevant and appropriate to the remedial action, is cost effective, and utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

The remedy does not satisfy the statutory preference for treatment as a principal element of the remedy. The NCP emphasizes the expectation that treatment will be used to address the principal threats posed by a site whenever practicable. Principal threat waste is defined in EPA guidance as source material that is highly toxic or highly mobile and that generally cannot be contained in a reliable manner. Mine materials present in OU1 do not represent a principal threat. Mine materials within the OU1 areas of the Site constitute source materials because they act as a reservoir for migration of contamination to groundwater and surface water. Although present in large volumes, mine materials within OU1 can be reliably contained and present only a low risk in the event of release.

Because the Selected Remedy will result in hazardous substances, pollutants, or contaminants remaining onsite above levels that would allow for unlimited use and unrestricted exposure, a statutory review will be conducted within 5 years after initiation of remedial action to ensure the remedy is, or will be, protective of human health and the environment.

ROD Data Certification Checklist

The following information is included in the Decision Summary section (Part 2) of this ROD. Additional information can be found in the administrative record file for the Site.

- Chemicals that cause adverse effects and their respective concentrations (Section 5 – Summary of Site Characteristics)
- Current and reasonably anticipated future land use assumptions used in the baseline risk assessment (Section 6 – Current or Potential Future Land and Resource Uses) and potential future beneficial uses of groundwater used in the baseline risk assessment
- Baseline risks and adverse effects represented and chemicals identified (Section 7 – Summary of Site Risks)
- Cleanup levels established and the basis for the levels (Section 8 – Remedial Action Objectives)
- How source materials constituting principal threats are addressed (Section 12 – Selected Remedy)
- Potential land and groundwater use that will be available at the Site as a result of the Selected Remedy (Section 12 – Selected Remedy)
- Estimated capital, annual O&M, and total present value (worth) costs, discount rate, and the number of years over which the remedy cost estimates are projected (Section 12 – Selected Remedy)
- Key factors that led to selecting the remedy (Section 12 – Selected Remedy)

Authorizing Signature

Cami Grandinetti

Cami Grandinetti, Manager
Office of Environmental Cleanup

4/18/16

Date

RECORD OF DECISION

FOR

FORMOSA MINE SUPERFUND SITE

OPERABLE UNIT 1

DOUGLAS COUNTY, OREGON

Part 2
Decision Summary

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Acronyms

ABA	acid base accounting
ADD	average daily dose
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ARD	acid rock drainage
ATV	all-terrain vehicle
BERA	baseline ecological risk assessment
BLM	U. S. Department of the Interior Bureau of Land Management
BMI	benthic macroinvertebrate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CCC	criterion continuous concentration
CDM Smith	CDM Federal Programs Corporation or CDM Smith Inc.
CLP	Contract Laboratory Program
COI	chemical of interest
COC	chemical of concern
COPC	chemical of potential concern
CSF	cancer slope factor
CSM	conceptual site model
$CuFeS_2$	chalcopyrite
CUL	cleanup level
CY	cubic yard
DOC	dissolved organic carbon
DOGAMI	Oregon Department of Geology and Mineral Industries
DU	decision unit
EA	exposure area
Eco-SSL	ecological soil screening level
ELCR	excess lifetime cancer risk
EM	encapsulation mound
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPT taxa	BMI taxa considered sensitive to dissolved metals
ERA	ecological risk assessment
ESL	ecological screening level
FEI	Formosa Exploration Inc.
FeS_2	pyrite
FPXRF	field portable x-ray fluorescence
FRC	Formosa Resources Corporation
FS	feasibility study
ft	feet
gal	gallon
gpm	gallons per minute
GRA	general response action
H_2SO_4	sulfuric acid
HC	Hart Crowser Inc.
HDPE	high-density polyethylene
HHEBRA	human health and ecological baseline risk assessment
HHRA	human health risk assessment

HI	hazard index
HQ	hazard quotient
IC	institutional control
in	inch
IRAM	interim remedial action measure
IRIS	Integrated Risk Information System
LiDAR	light detection and ranging
LOI	Letter of Intent
mg/kg	milligram per kilogram
mg/kg-day	milligram of a chemical per kilogram of body weight per day
MA	Middle Creek sub-drainage A
MB	Middle Creek sub-drainage B
MC	Middle Creek sub-drainage C
MIW	mining-influenced water
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NPL	National Priorities List
NRWQC	National Recommended Water Quality Criteria
NTCRA	non-time critical removal action
O&M	operation and maintenance
ODEQ	Oregon Department of Environmental Quality
OAR	Oregon Administrative Rules
ORS	Oregon Revised Statutes
OU	operable unit
PMDA	primary mine disturbance area
PREDATOR	Predictive Assessment Tool for Oregon
PRP	potentially responsible party
PUR	Partnership for the Umpqua Rivers
QSP	quartz sericite pyrite phyllite
QST	quartz sericite tuff
RAO	remedial action objective
RD	remedial design
RfC	reference concentration
RfD	reference dose
RG	remedial goal
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RSL	regional screening level
SAP	sampling and analysis plan
SFA	South Fork A drainage
Site	Formosa Mine Superfund Site
SLERA	screening level ecological risk assessment
SPLP	synthetic precipitation leaching procedure
su	standard units
TAG	Technical Assistance Grant
TAL	target analyte list
TDS	total dissolved solids
TPH-d	total petroleum hydrocarbon – diesel range
TRV	toxicity reference value
µg/L	micrograms per liter

UCL	upper confidence level
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WRD	waste rock dump
ZnS	sphalerite

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Section 1 – Site Name, Location, and Description

This section summarizes general information about the Formosa Mine Superfund Site.

1.1 Introduction

The Formosa Mine Superfund Site (Site) (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Information System number ORN001002616) is located approximately 25 miles south of Roseburg, Oregon and 7 miles south of Riddle, Oregon.

The Site is an abandoned hard rock mine managed as two operable units (OUs). OU1 includes source materials, and OU2 includes the aquatic environment.

The specific remedial actions for OU1, as presented in this ROD, are discretely separate from OU2. Additional investigation of the nature and extent of contamination and evaluation of cleanup options for OU2 will be performed separately, and a remedy for OU2 will be selected in a future decision document.

The U.S. Environmental Protection Agency (EPA) is the lead agency for the remedial actions at OU1, and the U.S. Department of the Interior Bureau of Land Management (BLM) and the Oregon Department of Environmental Quality (ODEQ) are supporting EPA in the investigation and cleanup. Long-term operation and maintenance (O&M) of the remedy implemented by EPA will be the responsibility of ODEQ.

EPA's detailed investigation and evaluation of conditions at OU1 included completion of a remedial investigation (RI)/feasibility study (FS) for OU1. The RI report for OU1 includes a comprehensive description of past investigative and removal actions at the Site, provides a detailed characterization of the nature and extent of contamination, and presents results from the OU1 human health risk assessment (HHRA) and ecological risk assessment (ERA). The OU1 FS performs a systematic analysis to determine the need for and scope of remedial alternatives to address the risk posed by OU1 contamination. The steps leading up to the ROD included numerous opportunities for public involvement, a Proposed Plan released on January 6, 2015, a public meeting, and a 30-day public comment period.

1.2 Site Name and Location

The Site is an abandoned mine located in southwest Oregon in Douglas County. Specifically, the Site is located within Sections 23, 26, and 27, Township 31 South, and Range 6 West Willamette Meridian. Locally, it is situated in the Coast Range Klamath Mountains at elevations between 3,200 and 3,700 feet (ft) above mean sea level (amsl) on Silver Butte Peak (3,973 ft amsl). The mine itself is located within Section 26, Township 31 South, Range 6 West Willamette Meridian.

The overall Site boundary has not been distinctly defined. The PMDA for OU1 is the portion of the Site that has been affected by deposition of mine materials as a result of mining-related activities. The Site includes the PMDA and surface water drainages emanating from the PMDA, specifically Middle Creek, and South Fork Middle Creek.

1.3 Key Features of the Site

1.3.1 General Site Features

Hazardous substance releases at the Site are caused by generation of acid rock drainage (ARD), which is an environmental problem caused by weathering of strongly mineralized rock. ARD problems are commonly associated with mining sites because the mining process exposes strongly mineralized rock to the surficial weathering environment, as a result of the following Site-specific mining-related activities:

- ***Mineral extraction:*** underground tunneling, blasting, and excavation to remove ore containing payable metals
- ***Mineral beneficiation:*** particle size reduction by crushing and grinding and separation of payable metals by flotation to create copper and zinc concentrates for smelting
- ***Mine materials management:*** deposition of waste rock, tailings, ore, construction rock, and concentrates, either on the surface or within the underground workings

At the Formosa Mine, a massive sulfide ore body was mined for primarily copper and zinc and some trace gold and silver. The massive sulfide ore body primarily contained the mineral pyrite (FeS_2) as well as the minerals chalcopyrite ($CuFeS_2$) and sphalerite (ZnS) that were mined for payable copper and zinc. Other trace sulfide minerals are also present in the ore body along with natural enrichments of trace metals and metalloids. Two periods of mining occurred from 1926 to 1937 and 1990 to 1993, and the mining process brought broken rock containing ore to the surface. The ore was then crushed and processed to separate payable metals (e.g., copper), and waste mine materials were deposited on the surface and back in the mine workings. These waste mine materials, especially those that contain sulfide minerals (e.g., pyrite), generate ARD when exposed to water, oxygen, and bacteria. MIW is a term used to describe ARD once it is generated and transported from the source. The materials left on the surface are exposed to rain and snowmelt and create MIW, which is very acidic and contains heavy metals. Site contaminants are attributable to the sulfide mineralization and natural enrichments of metals and metalloids in the rock. The process of ARD generation results in mobilization of contaminants into downslope soils, surface water, and groundwater at the Site. Contaminant sources are further discussed in Section 5.2.1.

The Site has been extensively disturbed by mining and mineral processing operations, and features associated with mining remain. General Site features are shown on Figure 1-1. There were originally five portals to the underground mine workings within the main Site area: the Silver Butte 1; Formosa 1, Formosa 2, and Formosa 3 Adits; and the 1090 raise. These portals were closed in 1994 and were reclaimed (e.g., backfilled). On the far southwest portion of the Site and along the ore body strike, the 404 and K1G Adits are not reclaimed but cannot be entered because of natural collapse of the portal. Site features are summarized in the subsections below.

- Mine materials
- Watersheds and drainages
- Other historic mining features

1.3.1.1 Mine Materials

OU1 mine materials are located in several areas throughout the Site, were subject to study during the RI, and generate ARD. These materials, hereafter referred to mine materials, are present in areas where waste rock, ore, tailings, construction rock, and co-mingled waste rock and soils were placed or disturbed during operation and after closure of the mine. Mine materials also include surface exposed ARD generating bedrock outcrops; however, only those bedrock outcrops modified as part of mining are included as mine materials. Natural outcrops not modified by mining are excluded from CERCLA authority (CERCLA Section 104(a)(3)(A)). Mine materials addressed by this ROD are generally identified as:

- Formosa 1 Adit waste rock dump (WRD)
- Formosa 2 Adit, Formosa 3 Adit, and 1090 raise WRDs
- Silver Butte 1 Adit WRD
- 404 Adit WRD
- East and west (Exhibit 1-1) encapsulation mound WRDs (sloped areas)
- Encapsulation mound (flat top area) (Exhibit 1-2), former milling facility area, and former shop facility area

Exhibit 1-1. West encapsulation mound WRD

- Former ore storage and water storage areas (e.g., former million-gallon tank and primary water storage)
- Illegal dump area
- Surface exposed rock surfaces
- Miscellaneous road areas constructed of co-mingled construction rock and soils

Exhibit 1-2. Encapsulation mound area 3D view, looking from south

These areas are identified on Figure 1-1; however, boundaries for the individual areas or WRDs are not delineated. Figure 1-1 shows the extent of mine materials (e.g., the PMDA). The extent of mine materials has been developed based on RI sampling data (CDM 2012).

1.3.1.2 Watersheds and Drainages

Four drainages have headwaters near the Site (Figure 1-2) although only the Upper Middle Creek and the South Fork Middle Creek drainages are known to be contaminated by MIW (based on historic data and RI sampling data). Several contaminated groundwater seeps/springs discharge to surface water in areas downslope from mine material and contaminated soil areas that have resulted in widespread contamination to the Middle Creek subwatershed. The area of contaminated surface water identified based on historic data and RI sampling data with concentrations above freshwater aquatic criteria extends for the entire length of South Fork Middle Creek (approximately 5 miles) and for the entire length of Middle Creek (approximately 13 miles).

For Upper Middle Creek, contaminated groundwater seeps (acidic pH, high total dissolved solids [TDS], and high metals concentrations) are observed starting at approximately 200 horizontal ft and 100 vertical ft from the main Site road (Road 30-6-35.1; Figure 1-1). The causes for these seeps are a result of leaching from the Formosa 1 Adit WRD and contaminated road areas, Formosa 1 Adit MIW that is not currently collected by the Adit water diversion system, and potentially contaminated bedrock groundwater. The Adit water diversion system (shown on Figure 1-1) is intended to capture MIW draining from the Formosa 1 and Silver Butte 1 Adits and divert it away from the headwaters of Upper Middle Creek and into a dispersion drainfield. The Silver Butte 1 Adit rarely flows, but the Formosa 1 Adit (Exhibit 1-3) has recorded flows as high as 190 gallons per minute (gpm) (Hart Crowser Inc. [HC] 2002). Over the years, however, clogging of the pipes by iron precipitate has required ongoing maintenance and reconfiguration of the system. Over time, the changing diversion system configurations have resulted in soil contamination over an approximately 0.6-acre area as a result of the acidic and metal-bearing MIW discharge. This area was evaluated as Exposure Area 3 (EA-3) in the summary of Site risks discussed in Section 7.

Exhibit 1-3. Formosa 1 Adit water diversion system

For South Fork Middle Creek, contaminated groundwater seeps (acidic pH, high TDS, and high metals concentrations) are observed starting at approximately 575 horizontal ft and 320 vertical feet below the top of the encapsulation mound. The causes for these seeps are a result of leakage from the encapsulation mound, east encapsulation mound WRD and illegal dump area, and contaminated bedrock groundwater below the encapsulation mound.

1.3.1.3 Other Historic Mining Features

Several other historic features are shown on Figure 1-1 that were associated with operation of the mine. These include features that are either removed from the Site or buried within the various WRDs.

- Former crusher, shop, and milling facilities
- Former primary water storage and million-gallon tank
- Former water and tailings storage pond
- Former runoff water diversions and water dispersion system
- Former tailings line from mill
- Historic roads
- Historic crib walls

Some of these features that have remnants buried beneath mine materials include the milling facility concrete foundation, the water and tailings storage pond, some intact crib walls, dispersed and demolished crib wall materials, and several partially reclaimed road areas.

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Section 1
Figures

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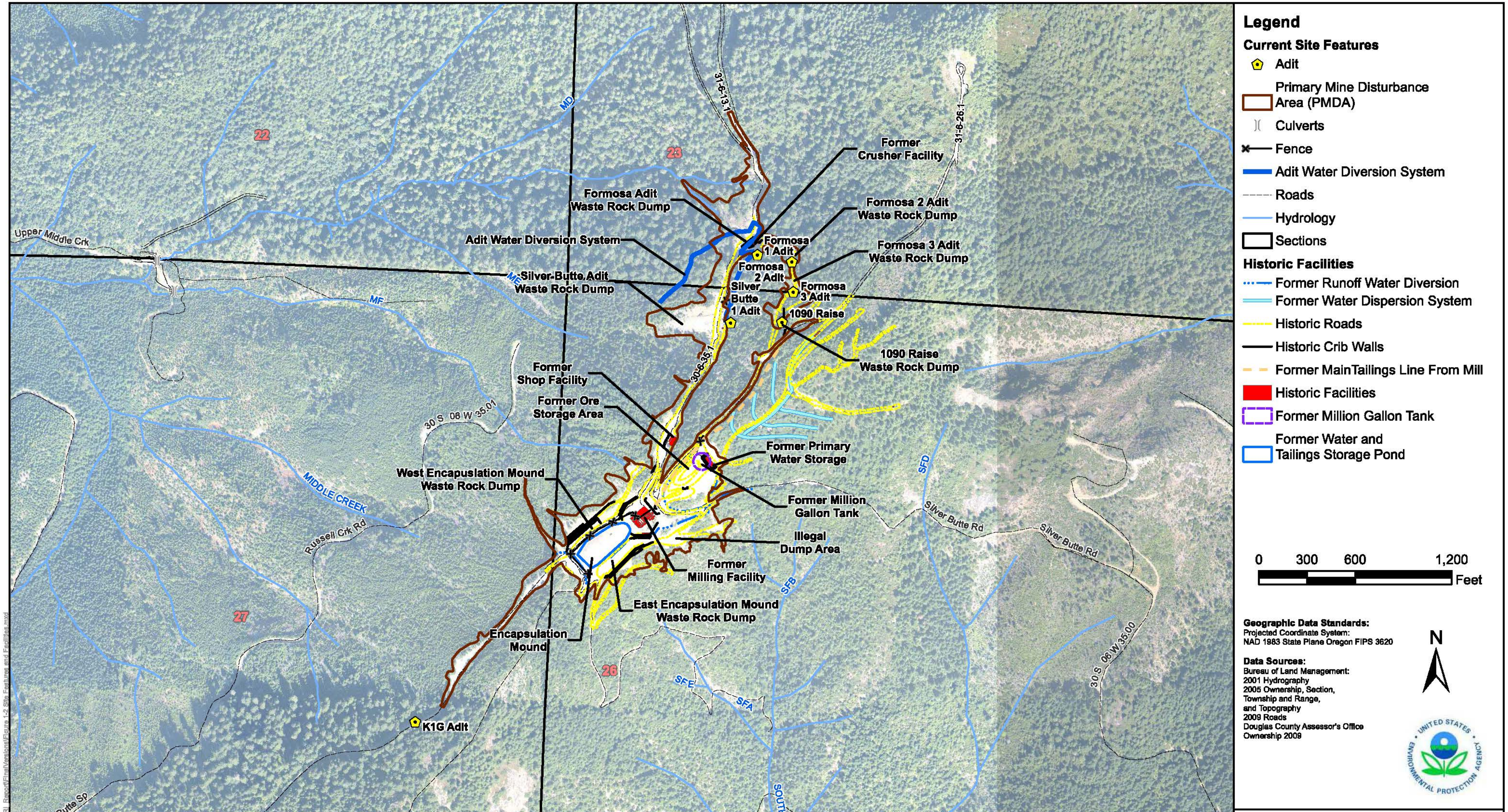

Figure 1-1

Site Features and Historic Facilities

Formosa Mine
Douglas County, Oregon

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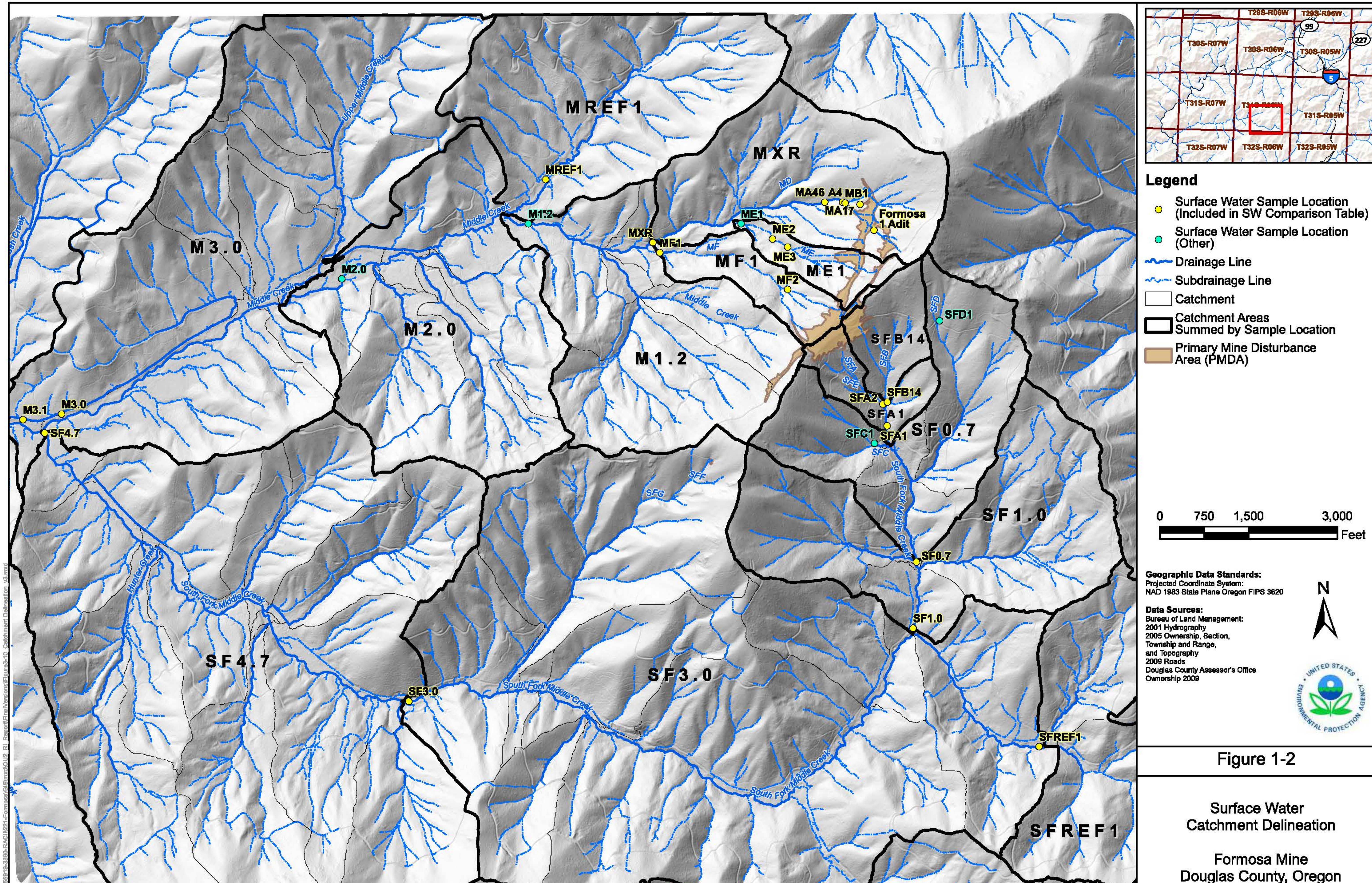

Figure 1-2

Surface Water Catchment Delineation

Formosa Mine
Douglas County, Oregon

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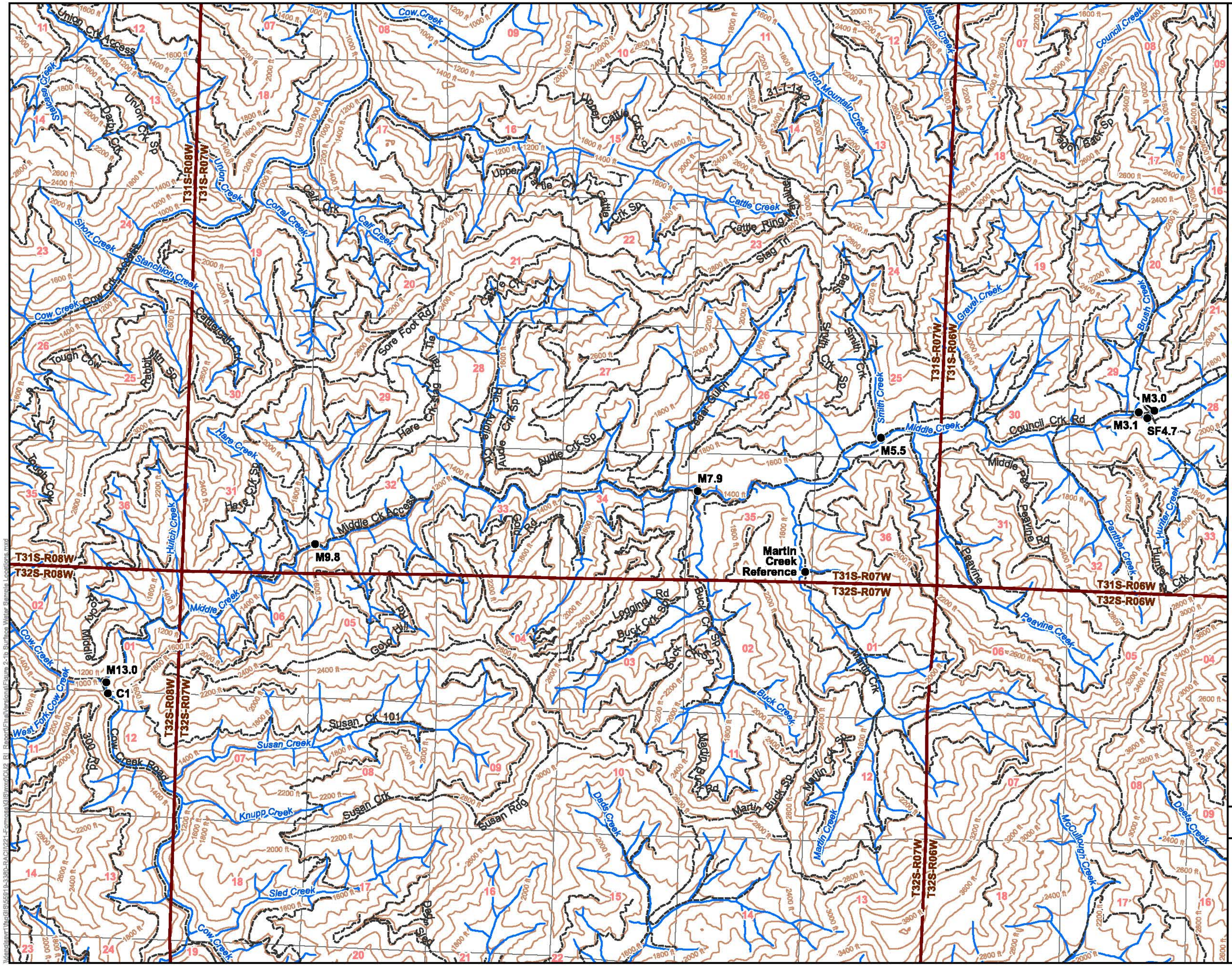

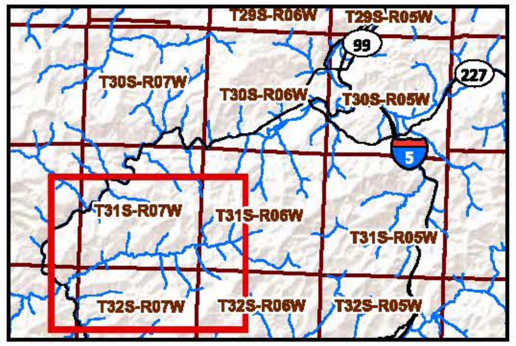

Legend

Surface Water Sample Locations

- Type 1 (similar to Formosa adit discharge)
- Type 2
- Type 3
- Type 4
- Not Designated
- Road
- Stream
- Contours (200 ft)
- Township/Range
- Sections
- Primary Mine Disturbance Area (PMDA)

0 2,000 4,000 8,000 Feet

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS 3620

Data Sources:
Bureau of Land Management:
2001 Hydrography
2005 Ownership, Section, Township and Range, and Topography
2009 Roads
Douglas County Assessor's Office
Ownership 2009

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Figure 1-3

Additional Surface Water Sample Locations

Formosa Mine
Douglas County, Oregon

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Section 2 – Site History and Response Actions

This section summarizes the history of the Formosa Mine Superfund Site in general and OU1 in particular and previous investigations and removal activities that have occurred at OU1 prior to the start of the RI/FS.

2.1 Site History

2.1.1 Early Mining and Exploration

Geologic exploration activities in the area of the Formosa and Silver Butte were first conducted in 1910. Development of the underground mine began in the early 1920s, and by 1926, the Oregon Exploration Company commenced underground mining and shipping of ore. No further mineral extraction occurred after 1937 until modern mining began in the 1990s (Section 2.1.3).

During this early period of mining, waste rock was disposed on the hillsides adjacent to the Adit portals and roads, as was typical during that era of mining. Waste rock dumps from this era of mining are reported to be present beneath the current road and along the angle of repose slopes adjacent to the Formosa 1 and Silver Butte 1 Adits. All mining was conducted above the Formosa 1 Adit elevation, so that all new workings could be drained of water by gravity through the Formosa 1 Adit.

2.1.2 Modern Exploration

In May 1987, Formosa Resources Corporation (FRC) (incorporated in Canada) established a subsidiary company called Formosa Exploration Inc. (FEI) based in Roseburg, Oregon to further conduct exploration activities. In July 1987, the mineral claims owned by FRC and the mineral lease and option to purchase agreement with Silver Butte Mining and Milling Company were assigned to FEI.

2.1.3 Modern Mining

This section presents a summary of the baseline environmental study and modern mining activities after the study was completed.

2.1.3.1 Baseline Environmental Study

As part of the permitting process, FEI's contractor (Norecol) conducted a baseline environmental study between 1988 and 1989 to document conditions before initiation of modern mining activities (Norecol 1989). The study concluded that there were increases of metals and low pH water entering the headwaters of Middle Creek during winter precipitation events. However, fish and benthic macroinvertebrate (BMI) sampling in Middle Creek and South Fork Middle Creek did not show adverse effects at the time.

2.1.3.2 Modern Mining Activities

In spring of 1990, the Oregon Department of Geology and Mineral Industries (DOGAMI) approved FEI's conditional use permit. Underground mining was conducted by FEI from early summer 1990 until August 1993. During this modern period of mining, FEI mined copper and zinc ore at a rate of 350 to 400 tons per day. About 62,000 tons of ore and 25,000 tons of waste rock were removed from the Silver Peak Mine during this period of mining.

Ore was crushed, screened, and sent to an onsite flotation mill. Waste tailings from the flotation process were stored onsite within the 2-acre lined water and tailings storage pond and were backfilled into the underground mine workings as part of normal operation and later as part of reclamation activities.

The tailings consisted of finely ground (i.e., less than 400 mesh size) pyrite and gangue minerals such as quartz, barite, and sericite. FEI's permit required backfilled tailings to be mixed with cement for stabilization before placement; however, it has been reported that cement was not used during backfill of some of the workings.

Onsite inspections in 1993 revealed several violations of FEI's permit conditions. In January and July 1993, DOGAMI issued a Notice of Violation to FEI for numerous violations of permit conditions. By August 1993, DOGAMI had issued a Closure Notice for failing to correct the problems identified in the Notice of Violation within the 30-day compliance period. On August 1, 1993, the mine officially ceased operations and began closure and reclamation activities.

2.2 Investigations/Removal/Remedial Activities

Mine reclamation occurred in 1993 and 1994 by FEI. When mine operations ceased in 1993, the reclamation plan and bond money originally set forth in the 1990 operating permit was determined inadequate for current conditions at the Site. As a result, the reclamation bond administered by DOGAMI was increased from $500,000 to $980,000. Reclamation was conducted as a cooperative effort between DOGAMI, ODEQ, and BLM. The overall dollars spent by FEI is reported to be over $1,000,000, and the amount spent over the reclamation bond came from FEI's Japanese investors.

Several former Site features associated with modern mining activities and reclamation are shown on Figure 1-1. Summaries of reclamation activities are described below.

Removal of crusher facility – The crusher and foundation (Exhibit 2-1) were removed from its location next to the Formosa 1 Adit.

Exhibit 2-1. Crusher facility conveyor and crushed ore stockpile near Formosa 1 Adit during mining

Removal of stockpiled ore – A large amount of crushed ore was stockpiled in the ore storage area at the time of mine closure. Most of this material was backfilled into the underground mine workings. Low-grade ore also was located in the million-gallon tank area; this material was excavated and backfilled into the water and tailings storage pond. Remaining material was regraded, amended with straw and lime, and seeded. This work was completed by January 1994.

Removal of zinc concentrate dumpsite –During mining, the concentrate was stored in a covered shed on the northwest side of the water and tailings storage pond and then later dumped over an embankment on the southeast side of the mill site. The dumped concentrate was then removed during reclamation and placed in the underground mine workings as described below.

Cleanup of diesel fuel spills –Approximately 1,200 cubic yards (CY) of diesel-contaminated soil was excavated from various spill areas and piled on the former million-gallon tank area. The pile was treated using a bioremediation process from approximately 1994 to 1997 to break down the diesel fuel; however, the effectiveness of this process was slow because of the low soil pH. Limestone was added to the pile at various phases to increase pH and increase the degradation reaction rate. Concentrations were reported to have decreased to 200 milligrams per kilogram (mg/kg) total petroleum hydrocarbon diesel range (TPH-d) although the cleanup target was 100 mg/kg TPH-d. Maximum concentrations of soil originally excavated were about 13,000 mg/kg TPH-d. The pile was placed near the former mill site area, amended with biosolids and lime, and seeded after bioremediation.

Removal of sulfide tailings from Upper Middle Creek – During mining operation, finely ground pyrite (FeS_2) and other sulfide tailings materials had washed from the crusher area and road into the Upper Middle Creek headwaters. Approximately 20 tons of sulfide tailings materials were estimated to have spilled into Upper Middle Creek. The approach to remove the sulfide materials included removal of down timber and brush, raking and washing the stream sediment into a funnel, and then transporting by 4-inch (in) pipe to a collection basin near the sampling location MXR (Figure 1-2). In the upper portions of the creek, tailings and mixed soil materials were hand excavated (Exhibit 2-2), placed in drums, and removed from the area. The flatter stream gradient and road access at MXR provided conditions needed to build an adequate collection basin. Materials were then removed from the collection basin and trucked back up to the mine for disposal. The cleanup process was completed by May 6, 1994.

Exhibit 2-2. Hand excavation of tailing and alluvium to a pipe collection system that drains to MXR pond, March 1994

Backfill of underground mine workings – Crushed ore stockpiled on the surface was placed in the workings below the Formosa 1 Adit level. Zinc concentrate stockpiled at an illegal dumpsite was removed and backfilled into the 1090 raise. The mine openings above the Formosa 1 Adit were filled mostly with tailings. Sulfide tailings materials collected from the Upper Middle Creek cleanup were also backfilled into the underground mine workings. All backfill operations were completed by July 15, 1994.

Exhibit 2-3. Closure of an Adit portal with rebar and concrete, July 1994

Reclamation of mine portals – Backfill at the Formosa 1 and Silver Butte 1 Adit portals (Exhibit 2-3) consisted of the following materials (in order of placement): a wooden and burlap bulkhead, crushed limestone backfill, an 8-in acid-resistant concrete cap, and an outer rock cover. Three-inch high-density polyethylene (HDPE) drainpipes were placed along the entire base of the backfill structures and were fitted with perforated cross drains spaced periodically along the pipelines. On the inside of the wooden bulkhead, vertical riser pipes with an open top were installed. Drainage pipes were constructed of 2-in HDPE that directed Adit water out of the Adits, beneath the road, and over the embankment into drainfield areas. The drainfield areas were located downslope of the Formosa 1 and Silver Butte 1 Adits. The backfill structure was similar for the Formosa 2 and Formosa 3 Adits; however, no drainage pipe or bulkheads were installed in these Adits, and no limestone backfill was placed for the Formosa 3 Adit. The fifth portal, the 1090 raise, was backfilled with zinc concentrate, non-reactive waste rock (non-acid generating), a 3-ft bentonite seal, a 6-in steel reinforced acid-resistant concrete cap, and a soil cover. All mine portal reclamation work was completed by August 4, 1994. The access road constructed to access all of the upper workings was also regraded and revegetated.

Exhibit 2-4. Crib wall structures on northwest side of Silver Butte ridge

Removal of crib wall fill and wood wall structures – Various crib wall structures (Exhibit 2-4) were built on the slopes on both sides of the mill site, water, and tailings storage pond to increase the available surface area for mine operations. The walls were built of wood and steel rebar, and fill material was placed behind the wall. The crib wall fill originated from the water and tailings storage pond excavation. The fill was also mixed with mine waste during placement in the crib walls. During reclamation, the crib walls were removed, and the fill was excavated, placed over the mill foundation, and used as the encapsulation mound cover. Since mine waste was mixed with the crib wall fill, this material may be acid generating. After the fill and wall material was removed, slopes were revegetated by adding straw, paper mulch, tackifier, and seed.

Removal of the mill building and all processing equipment – The process to remove the mill building and equipment began in 1994, and all material was sold or removed from the Site by June 1995.

Backfilling and capping of water and tailings storage pond – During mining, the volume of underground mine workings available for backfilling was consistently smaller than the volume of tailings generated. As a result, significant amounts of tailings were stored in the water storage pond (now referred to as the encapsulation mound). During reclamation, the majority of tailings were hydraulically transported into the underground mine workings; however, some tailings remained in the pond. These remaining tailings were spread on the pond liner to protect the liner from damage during rock backfilling. Seventeen thousand tons of low-grade ore was backfilled onto the remaining tailings (Exhibit 2-5), followed by a Bentomat™ cover, and a 5- to 7-ft thick soil/rock cover. Approximately 20 tons per acre limestone (one quarter finely ground agricultural limestone and three quarter crushed limestone) were mixed into the top of the soil/rock cover in an attempt to prevent acid generation.

After limestone amendment, approximately 42,000 gallons (gal) of biosolids from the Riddle wastewater treatment plant were tilled into the top of the cover, and the area was mulched (straw), seeded, and planted with blackberry cuttings and Douglas fir saplings. Down logs were also placed sporadically on the cover. Wood from the crib walls also was incorporated into the top of the cover. The encapsulation mound cover was completed in August 1994.

Million-gallon tank removal – The million-gallon tank was built in spring 1993 and was used to store process water during milling operations. The foundation for the tank was built on crushed ore. The tank was subsequently removed and sold during reclamation.

Exhibit 2-5. Backfill of low-grade ore over tailings during encapsulation mound construction, May 1994

2.2.1 Adit Water Diversion System Observation and Maintenance (1995 – 1999)

By February 1995, the Formosa 1 Adit water diversion pipeline was documented to be plugged, and seeps were observed flowing out of the fill rock covers of both the Formosa and Silver Butte Adits. The high iron content of the adit water resulted in formation of iron precipitate scale in the drainage pipes, which soon became a difficult maintenance problem. Attempts to clean out the scale proved to be futile, and flow eventually ceased in the Formosa 1 Adit pipeline.

FEI officially abandoned the Site in April 1996. The amount of money left in the reclamation bond at this time was $40,370. The remaining bond money was used for additional monitoring and repair to the Formosa 1 Adit water diversion system, which was rebuilt in the fall of 1996. In April 1999, the collection system had become completely plugged with scale, and a large flow of adit seep water was discharging directly into Upper Middle Creek.

2.2.2 Baseline Remedial Investigation and Interim Remedial Action Measure

Starting in June 1999, BLM, in cooperation with ODEQ, began an extensive baseline RI at the Site. Through North American Regional Science Council funding, BLM also hired Dynamac Corp. to conduct a site assessment in October 1999.

In March 2000, ODEQ declared the Site a State Orphan site, which is a designation in the State of Oregon for sites contaminated by a release of hazardous substances that pose serious threats to human health or the environment and where the parties responsible for the contamination are either unknown – or unable or unwilling – to pay for needed remedial actions. HC was hired by ODEQ to conduct an investigation at the Site and design and build the interim remedial action measure (IRAM) adit water diversion and treatment system. A removal assessment report was prepared by HC in September 2000, and construction of the adit water diversion system portion of the IRAM began in the fall of 2000 and was completed by November. The IRAM construction completed in 2000 consisted of the following elements:

- Excavation of a 20-ft by 15-ft receiving basin at 5-ft deep, lined with bentonite and a layer of limestone. Both the Formosa 1 and Silver Butte 1 Adit flows were directed into the basin.
- Installation of four gravity draining aeration tiers downgradient of the receiving basin, constructed of open top 24-in HDPE pipe, each placed with about 4- to 5-ft drop in elevation. Flow at the last tier transitioned to a 120-ft limestone drain constructed of closed 12-in HDPE pipe.
- Construction of two concrete vaults for collection of precipitate placed in series along the flow path after the limestone drain. The first vault can hold 5,460 gal of water, and the second vault can hold 3,870 gal of water.
- Construction of the remainder of the drainage pipes to the new drainfield using 12-in HDPE. Flow was directed under the road after the second concrete vault and then along the hillside (minimum slope of 10 percent) down to a drainfield further to the south than the previous drainfield.
- Regrading of the encapsulation mound [EM] and placement of a geotextile layer and 10-mil thick plastic liner (10 one-thousandths of an inch). Silt fence was placed along the eastern edge, and stormwater ditches were constructed on both the north and south ends draining to the east.

After approximately 6 months of operation of the system, an IRAM report was prepared. Within a short time, the limestone channel became coated with iron precipitates and was no longer effective in raising pH. Over the following years, precipitate formation and plugging of the diversion pipeline remained a problem due to the high iron content of the adit water. The following observations and maintenance actions occurred:

- In October 2003, it was observed that the adit water diversion pipeline had clogged with precipitate before the first concrete vault, and a section of pipe after the concrete vaults had been severed because of falling rocks. This resulted in approximately 5 gpm of adit water flowing into Upper Middle Creek. Precipitate was subsequently removed from the plugged pipe sections and vaults, and the broken section of pipe was repaired. The limestone drain section of pipe was also removed and replaced with a new pipe that did not contain limestone.
- In October 2004 and September 2005, repair and maintenance was conducted on the adit water diversion pipeline. Further details on these maintenance visits are unavailable.
- In November 2005, rocks were removed from the adit water diversion pipeline.
- In January 2006, it was observed that runoff from recent rains had breached a surface water runoff control berm, allowing surface water runoff to flow from the road down the hillside, causing a 3-ft deep gully to form beneath the adit water diversion pipeline. A support system was subsequently constructed along the eroded section beneath the pipeline, and repairs to the erosion berm and ditches along the road were made.
- In April 2006, it was observed that a pipeline joint had become separated, resulting in discharge of up to 48 gpm of adit water to Upper Middle Creek. The pipeline joint was subsequently repaired, and additional support posts were added to the section of pipeline where the joint had failed.

- In December 2006, maintenance was conducted to repair a section of pipeline and clean out precipitate. Further details on this maintenance visit are unavailable.

Additional maintenance and repairs have since been conducted by EPA's removal program and by BLM. In 2005, citizens petitioned the EPA to consider adding the Site to the National Priorities List (NPL). In 2006, the Site was proposed for listing on the NPL, and was officially added to the NPL in 2007. After the Site was added to the NPL, the EPA Region 10 Emergency Response Unit took over maintenance of the adit water diversion system. An emergency response action was conducted in June 2008, which included some piping repairs and replacements and removal of iron precipitates from piping.

During a March 2009 Site visit by BLM and others, significant plugging of the adit diversion system was observed at the concrete vaults. Adit water was overflowing out of the top of the first concrete vault, onto the main road, and down past where the Middle Creek A (MA) sub-drainage crosses the road. As a result of very high flows, a new drainage channel was cut through the woods to the north of MA, termed Middle Creek C (MC) sub-drainage. Significant erosion and iron staining of the soils in this channel were observed. This channel eventually intersected MA just before the confluence of Middle Creek B (MB) sub-drainage.

Because of this overflow and direct discharge of adit water into Upper Middle Creek, EPA Region 10 conducted emergency response action in March 2009. This action involved removal of the iron precipitate obstruction at the concrete vault, repair of the pipe, and overall inspection of the diversion system. Additional maintenance on the adit water diversion system has been conducted since March 2009 by BLM. This work includes routine cleaning of precipitates, pipe replacement, or repair (patching), and structural repairs on the pipe trestle near the MB drainage.

2.2.3 Additional Investigation and Site Status

A supplemental RI for the entire Site was conducted by HC after the BLM/ODEQ RI was completed in May 2000. The supplemental RI continued until June 2002, and the supplemental RI report was prepared. While the initial RI sampling was conducted in 2000, and after installation of the IRAM adit water diversion system, interim data were also reported separately in a data evaluation report. After the Supplemental RI was completed, HC completed a FS and a human health and ecological baseline risk assessment (HHEBRA). Both the HHEBRA and FS were completed, and their associated reports were published in 2004.

EPA, under CERCLA authority, initiated characterization of the nature and extent of mine materials and soils for the OU1 RI in October 2009; these activities were completed in November 2010. The first sampling and analysis plan (SAP) was prepared in 2009 (CDM 2009) and the second SAP in 2010 (CDM 2010). Both SAPs include components of OU1 and OU2. The OU1 RI included defining the horizontal and vertical extent of mine materials and soil, the potential for the mine materials to generate ARD and related chemicals, and human health and ecological risk assessment. Surface water and groundwater sampling are being conducted as part of ongoing efforts to characterize OU2 and understand the effects of mine materials on surface water and groundwater beyond OU1. OU1 RI results were presented in January 2012, with the FS completed in January 2013.

2.2.4 BLM Removal Activities

BLM is planning to conduct a non-time critical removal action (NTCRA) at the Formosa 1 Adit. The goal of the action is to control, treat, reduce, or eliminate uncontrolled releases of hazardous substances (metals and acidity) from Formosa 1 Adit, thereby minimizing human and ecological risk exposure. The purpose of reopening the Formosa 1 Adit will be to evaluate the feasibility of permanently closing the Adit using hydraulic adit plugs and provide information for the EPA and interagency technical team to support analysis of hydrology, hydrogeology, mineralogy, and rock mechanics to aid in overall solutions for the Site during the selection of a remedy for OU2. BLM is conducting this NTCRA because the Formosa 1 Adit and associated portal are on BLM-administered property, and pursuant to CERCLA 120 and Executive Order 12580, BLM is the lead agency for CERCLA actions on federal property under their jurisdiction.

2.3 Enforcement Activities

EPA conducted activities to identify potentially responsible parties (PRPs) who may have contributed to the contamination at the Site. Information request letters were sent to various parties from 2006 to 2014. A general notice letter, which provided notification of the recipient's opportunity to comment on the Proposed Plan, was sent in September 2014 to one PRP but was returned because the PRP had since ceased operations.

Section 3 – Community and Tribal Participation

EPA has maintained a program of community and tribal participation at the Site since 2007. The following engagement activities were conducted at the Site:

- Prepared the community involvement plan
- Conducted government to government discussions between EPA and the Cow Creek Band of Umpqua Indians
- Conducted community interviews
- Established a local information repository
- Engaged in frequent personal communications with Site residents
- Participated in community meetings, small group meetings, and availability sessions
- Hosted meetings and information sessions with the Partnership for the Umpqua Rivers (PUR)
- Awarded Technical Assistance Grants and performed a Technical Assistance Needs Assessment
- Engaged in Environmental Education opportunities with the Riddle School District
- Maintained and used postal and e-mail contact lists to distribute Site update materials
- Published notices in the Roseburg News Review and worked with local news media to share accurate information about the cleanup
- Maintained a project website and onsite access to information
- Issued the Proposed Plan for OU1, held a public meeting on January 20, 2015, and developed the ROD, including the Responsiveness Summary for OU1

3.1 Interviews, Community Involvement Plans

In August 2007, EPA conducted community interviews with affected stakeholders to find out general information about the properties, community concerns, and how best to communicate with the public during time-critical response actions. Using the information from those interviews, a community involvement plan was prepared and distributed in May 2009.

3.2 Local Information Repository

The administrative record, which includes the RI and FS and other documents that form the basis of EPA's Selected Remedy, is housed at the EPA Superfund Records Center located at 1200 Sixth Avenue, Suite 900, ECL-076 Seattle, Washington 98101 with the telephone number 206-553-4494 or toll-free at 1-800-424-4372. An information repository containing a subset of documents from the administrative record is located at the Riddle Public Library in Riddle located at 637 First Street, Riddle, Oregon 97469-0033 with the telephone number 541-874-2070.

3.3 Public Meetings and Availability Sessions

EPA hosted and participated in a number of public and organization meetings in Riddle and Roseburg between September 2007 and January 2014. Project staff provided updates to the Riddle City Council, Partnership for Umpqua Rivers, the Cow Creek Band of Umpqua Indians, and the Douglas County Commissioners and staff. Staff offered open availability to interested community members when visiting the Site. In addition, EPA and DEQ hosted tours of the Formosa Mine site for the public and media in August 2007, October 2009, and August 2010.

EPA held specific meetings with the Umpqua Indian tribe in 2013, 2014, and 2015. A technical briefing and site tour with Senator DeFazio was conducted on April 17, 2014. In addition, EPA provided a tour for Senator DeFazio's aid in August 2013.

3.4 E-Mail and Postal Updates

EPA maintained a mailing list of all interested stakeholders that included a base list of residents derived from Douglas County property ownership information. Most Site residents and stakeholders preferred e-mail updates, and several e-mails were sent to this list each year to provide information about removal activities, sampling results, and the availability of draft documents.

3.5 Paid Notices and Media Coverage

Articles about the Formosa Mine Superfund Site occasionally appeared in the Roseburg News Review and Eugene Register Guard between 2006 and 2015. Roseburg and Medford television stations regularly covered RI sampling activities and public meetings. The Jefferson Exchange (Northwest Public Radio) and local Roseburg radio stations also provided media coverage about the Site. Paid notices were placed in the Roseburg News Review when required for availability of Technical Assistance Grants and administrative records.

3.6 Project Website

EPA established a project website to provide access to documents and information about the Site: http://yosemite.epa.gov/r10/cleanup.nsf/sites/Formosa.

3.7 Technical Assistance Grants

EPA advertised the availability of a Technical Assistance Grant (TAG) in 2007. In fall 2008, a Letter of Intent (LOI) was received from PUR, and the TAG was awarded. In 2011, the TAG was completed. Subsequently new LOI's were received from Umpqua Watersheds and South Umpqua Rural Community Partnership, but a new grant was not issued. In 2014, a Technical Assistance Needs Assessment was conducted.

3.8 Environmental Education

As an outgrowth of the Community Interview process, EPA and ODEQ explored environmental education opportunities with the Riddle School District. In 2008, EPA and ODEQ presented Site information to teachers and staff. In April 2009, EPA staff met with each class in the school district and made age appropriate presentations to elementary, middle, and high school students.

3.9 Proposed Plan

EPA issued a Proposed Plan for OU1 on January 6, 2015, and a notice was published in the Roseburg News Review on January 6, 2015. An e-mail containing a link to the plan and information on how to submit comments was sent to the distribution list. A postcard containing the same information was mailed to the regular mail list. Paper copies of the Proposed Plan were mailed out by request. A public meeting for the Proposed Plan was held on the evening of January 20, 2015, at which EPA gave a brief presentation, and the public had an opportunity to provide oral or written comment. At this meeting, representatives from EPA and BLM were available to answer questions about problems at the Site and the remedial alternatives. As part of this public meeting, EPA received input from a cross-section of community regarding the reasonably anticipated future land use and potential beneficial groundwater uses at the Site. The 30-day public comment period closed on February 5, 2015. EPA received comments from nine individuals and organizations during the public comment period. The comments are summarized by topic with EPA's responses in the Responsiveness Summary, which is Part 3 of this document.

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Section 4 – Scope and Role of Operable Unit

The Site includes areas affected by mining, namely the PMDA consisting of approximately 25 acres, and groundwater and surface water drainages emanating from the PMDA, specifically Middle Creek and South Fork Middle Creek. The Site is being addressed by two OUs. This approach allows remediation of the source materials and then evaluation of those effects on the aquatic environment. OU1 includes source materials, and OU2 includes the aquatic environment.

OU1 includes all surface and subsurface mine materials deposited outside of the underground mine workings and considered "source materials" for the Site. These include materials excavated during construction and operation of the mine such as waste rock, ore, tailings, construction rock, road surfaces, and contaminated soils. These soils are co-mingled with waste rock, affected by dispersion of contaminants from mine materials, and/or affected by MIW discharges. These mine materials exist within the PMDA. Mine materials were defined in Section 4 of the OU1 RI by the following four criteria:

- Visual observation: Based on lithology, mineralogy, and alteration. Mine materials were identified based on the presence of micaceous and fissile fragments of quartz sericite pyrite phyllite (QSP) and quartz sericite tuff (QST), particles of massive sulfides, pyrite, or jarosite alteration minerals.
- Field paste pH: Values of less than 4.6 standard units (su).
- Field portable x-ray fluorescence (FPXRF): Values exceeding 190 mg/kg for copper or 288 mg/kg for zinc.
- Light detection and ranging (LiDAR): Topographic and photographic analysis.

Visual observation and field paste pH are the primary methods for delineating mine-impacted materials requiring remedial action. Volume of material and distance from stream headwaters will also influence the categorization of mine-impacted materials requiring remedial action. Thicker deposits and material located within headwater drainages will be prioritized for remedial action.

OU2 includes all remaining media and Site contamination areas, including surface water, stream sediment, groundwater, underground workings, and adit water drainage. Mine materials present within the underground workings are defined as OU2 mine materials.

While the two OUs are defined separately for purposes of administering the CERCLA process at the Site, the overall Site objectives for protection of ecological receptors require a Site-wide approach. The phasing of remediation will be conducted at the Site by addressing mine materials first, followed by remediation of remaining contaminated aqueous media, such as surface water and groundwater in OU2, as part of a final remedy for the Site, if necessary. The specific remedial actions to be conducted at OU1 as a result of this ROD are intended to be a final remedy to address the mine materials that are a contributing source of MIW and are discretely separate from OU2, which will specifically address contaminated aqueous media. The OU1 remedial action builds on the numerous removal actions already implemented at the Site as mentioned in Section 2 and summarized later in this section.

The EPA is the lead agency for the remedial actions at OU1. The BLM and ODEQ support EPA in investigation and cleanup of the Site and will continue to provide support via concurrence on this

ROD. In addition, BLM manages a portion of the land that includes the Site and they are responsible for a portion of the cleanup. The Formosa 1 Adit and the northern extent of the PMDA are within BLM-managed lands. The eastern portion of the PMDA, which includes the illegal dump area, the upper South Fork Middle Creek drainage, and the southern portion of the PMDA, including the 404 Adit, are either within or are in close proximity to lands designated General Forest Management Area. These lands are privately held by FEI. Long-term O&M of the OU1 remedy implemented by EPA will be the responsibility of ODEQ. The overall cleanup strategy is generally as follows:

- Minimize the generation of ARD to reduce effects to surface water and groundwater and prevent direct exposure to remaining areas of contamination within OU1 through a combination of excavation/onsite disposal in covered facilities and/or in place containment.
- Protect ecological receptors and people that might use the Site for recreational and commercial (logging) purposes within OU1.
- Use engineering controls and institutional controls (ICs) to protect the remedy and prevent disturbance of the deeper remaining contamination within OU1.
- Address OU2 separately from implementation of the Selected Remedy at OU1. The remedy at OU1 is expected to be implemented before the remedy at OU2. Although groundwater is not directly addressed by the OU1 remedial action, the reduction of ARD generation from the mine materials in OU1 is expected to have a positive effect on groundwater and surface water and overall contribute to achieving final Site-wide cleanup levels. Addressing the contributory sources first, followed by the associated impacts, is an adaptive management strategy. After the OU1 remedy is implemented and the effectiveness of the remedy is determined, a final remedy to address risk posed by contaminated surface water and groundwater, and any other risks, will be developed and selected for OU2.
- Develop a final remedy for OU2 that is consistent and compatible with past responses, planned removal actions, and OU 1 actions.

Section 5 – Summary of Site Characteristics

This section contains narrative overview of the Site in general, OU1 in particular, and the conceptual site model (CSM). Detailed information on sampling results and risks are presented in tables in Section 7.

5.1 Site Overview

5.1.1 Surface Features and Size

The Site is located in the Coast Range Klamath Mountains at elevations between 3,200 and 3,700 ft amsl in Douglas County, Oregon, approximately 25 miles south of Roseburg, Oregon and 7 miles south of Riddle, Oregon. The PMDA area that contains mine materials (approximately 24.4 acres) is surrounded by heavily forested and steep mountainous areas and several watershed drainages.

The Site is accessible by improved gravel and natural surface roads, which are maintained by BLM and private timber companies. The majority of the Site (e.g., PMDA) can be accessed off Shoestring Road, using either Silver Butte Road (Road 30-6-35.1) or Road 30-6-35.0 followed by Road 31-6-13.1. These roads are readily accessible by vehicle throughout the year, with the exception of winter months when snow may hinder vehicular travel.

General Site features are summarized below and shown on Figure 1-1.

Surface piles of mine materials are predominantly waste rock and construction rock, which have been comingled in many areas. Mine materials are present at all Adit portals, on the east and west sides of the encapsulation mound (EM), on road surfaces, and in other areas disturbed by mining such as the former ore storage area, illegal dump area, former million gallon tank area, former shop facility, and former crusher facility.

The **underground mine and associated mine adits** were constructed over various periods of operation. Currently, all underground mine workings are inaccessible because attempts were made to seal the portals as part of early reclamation activities in the early 1990s. However, MIW discharges from the Formosa 1 Adit on a perennial basis. Four additional reclaimed portals formerly accessed the underground mine but do not generally discharge ARD. Two small isolated Adits (404 and K1G) are also present south of the Site (Figure 1-1).

The **Adit Water Diversion System** has been reconstructed several times since mine reclamation. This facility is designed to collect MIW discharging from the Formosa 1 and Silver Butte 1 Adits and divert this water in a pipeline to a discharge point located just north of the Silver Butte WRD. Adit drainage affected soils are included as part of mine materials.

The **historic mining features** were present during modern mining but later removed or reclaimed such as the former crusher, shop, milling, water and tailings storage areas, and the EM. Some of these features that have remnants buried beneath mine materials include the milling facility concrete foundation, some intact crib walls, dispersed and demolished crib wall materials, and several partially reclaimed road areas. The EM was constructed from a former water and tailings storage pond during mine reclamation activities. The EM contains tailings and low grade ore within the pond and mounded low-grade ore above the pond liner elevation. As part of the reclamation activities, a geosynthetic clay cover and vegetated cover soil were constructed over the mounded low-grade ore.

Because of a lack of available storage in the underground mine workings during operation of the mine, tailings from the mill were placed into the former water and tailings storage pond that is referred to as the **encapsulation mound**. During reclamation of the mine, the majority of tailings were placed into the underground mine workings, but some tailings remained and were spread on the liner to protect it from damage during low-grade ore backfilling. Low-grade ore was then backfilled over these tailings. During excavation of the tailings material on the south portion of the pond, both the upper and lower pond liners were reportedly ripped, but no documentation was provided on whether the rips were repaired. During OU1 RI investigations, it was noted that materials backfilled into the EM are saturated for nearly the entire depth of the repository. Additional information regarding construction and contents of the EM can be found in Sections 3.1.2.2 and 4.1 and Tables 4.1-5 and 4.1-6 of the Final Formosa OU1 RI Report (CDM 2012).

5.1.2 Climate

The climate of the Klamath Mountains is characterized by hot dry summers followed by wet winters of low to moderate temperatures. Precipitation varies between 15 and 70 inches per year. November through March are the wettest months of the year, with median precipitation of 4.48, 5.75, 5.02, 3.58, and 3.35 inches, respectively. The higher precipitation during these months causes high surface water flow in area streams that generally peaks in March and declines during spring, summer, and fall. Precipitation during winter may fall as snow in higher elevations, especially above 3,200 feet amsl. The warmest months are July and August when the high temperatures average around 76°F. The coldest month is January when the high averages around 41°F and a low of 31°F.

5.1.3 Geology

The geology of the Site is characterized by weakly metamorphosed volcanic rocks, which lie within an accommodation zone between two regional thrust faults, the Silver Butte Thrust and the Coast Range Thrust. The rocks strike generally northeast and dip toward the east. The volcanic rock units include a variety of basaltic flows and tuffs. A thin veneer of unconsolidated colluvial and alluvial sediments overlies the metavolcanic bedrock, which are mixtures of rock fragments and soil that are transported downslope by gravity from parent bedrock. In areas of vegetation, the top surface of colluvial material contains a higher fraction of organic matter and rootlets.

A series of massive sulfide lenses are present within the metavolcanic rocks. These massive sulfide lenses are concordant with bedding of the metavolcanic rocks and crop out along a northeastern trend, extending from the EM area toward the Formosa 2 and 3 Adits. Natural enrichment of metals and metalloids, including arsenic, cadmium, copper, lead, and zinc, are associated with these massive sulfide deposits. Massive sulfide deposits containing economic concentrations of copper and zinc were the target of mining activities at Formosa. The massive sulfide deposits and surrounding rocks contain high concentrations of pyrite, an ARD-generating mineral, and other sulfide, sulfosalt, and sulfate minerals.

5.1.4 Surface Water

The Site is located near the top of Silver Butte at the drainage divide among four major drainages (Figures 1-1 and 1-2). The west and southeast portions of the Site are drained by Upper Middle Creek and South Fork Middle Creek, perennial streams that are tributaries to Middle Creek. These streams are adversely affected by MIW. The north and northeast portions of Silver Butte are drained by Russell Creek and Upper West Fork Canyon Creek, respectively.

Russell Creek, West Fork Canyon Creek, and Middle Creek all drain into Cow Creek, a major regional watershed that supplies municipal drinking water to the town of Riddle as well as several private drinking and irrigation water intakes. Flow in Cow Creek is significantly higher than the tributary drainages of Russell Creek, Canyon Creek, and Middle Creek.

When including the sections of the Upper Middle Creek and the South Fork of Middle Creek, the total perennial stream length from waters closest to the Site to intakes is shown in Table 5.1-1. Future surface water use is expected to be similar to the current uses.

5.1.5 Groundwater

The groundwater system at the Site is differentiated into two groundwater systems: the alluvial system and the bedrock system. The importance of the alluvial groundwater system in transporting MIW to surface water was recognized during detailed seep and spring surveys on and around the Site. Alluvial aquifers are present within unconsolidated alluvial and colluvial sediments located within tributary drainages. These aquifers coalesce in the downstream direction and convey water to the major drainages of Upper Middle Creek, South Fork Middle Creek, Russell Creek, and West Fork Canyon Creek.

The bedrock aquifer is located within metavolcanic rocks, which exhibit relatively lower permeability as compared to unconsolidated sediments that host the alluvial groundwater system. Observation of bedrock outcrops and water movement through those outcrops during spring and seep surveys shows that the primary porosity of the bedrock rock units is low and that groundwater is conveyed predominantly through fractures and other discontinuities. The overall permeability of the bedrock aquifer and the degree of inter-connectedness of individual fracture zones within the bedrock aquifer is unknown.

5.1.6 Encapsulation Mound Water

As discussed in Section 5.1.1, during OU1 RI activities, it was noted that materials backfilled into the EM are saturated for nearly the entire depth of the repository. As a result, MIW is also present within the EM. This water was considered as subsurface or vadose zone water in the OU1 FS, rather than groundwater (CDM Smith 2013). Pressure transducer data from piezometers within the EM indicate increases in water level during the wet season and decreases in water level during the dry season. The increase in water level indicates infiltration through the clay cover and mounded low-grade ore occurs in response to increased precipitation, whereas the decrease in water level indicates leakage of water from the existing repository liner. Water levels in the piezometers have varied by up to 1 foot throughout the period of record, indicating periodic infiltration and leakage occurs. However, the water level never decreased below approximately 3,342.4 ft amsl, which suggests the leakage from the pond is occurring at that elevation. With the encapsulation pond bottom liner elevation at 3,314 ft amsl and top liner elevation at approximately 3,346 ft amsl, the encapsulation pond water appears to be contained and seems to be overflowing at the top, presumably associated with infiltration of precipitation.

These observations document leaking water from the liner, which can have effects on both bedrock groundwater and alluvial groundwater in the EM and South Fork Middle Creek area but also indicate mine materials within the pond are generally stored under saturated conditions. Because the water level within the pond does not appear to decrease to below the top level of the pond liner, it is suspected the encapsulation mound facility leaks at the interface between the liner and the overlying low-permeability cover, but that the liner is relatively intact.

5.1.7 Surface Water/Groundwater Interactions

Discharge of groundwater to surface water was observed in many tributary drainages during the wet season seep and spring survey. Most of the observed locations were areas where groundwater discharges to surface water from alluvial aquifers. Discharge areas were commonly located at intersections of roads with the tributary drainages where the road cut excavation truncated the alluvial aquifer, forcing groundwater to the surface. Often this water flowed over the surface for a short distance downstream of the road before re-infiltrating into the alluvial groundwater system within undisturbed portions of the tributary drainages.

Discharge of MIW to surface water was observed within both the Upper Middle Creek and South Fork Middle Creek drainages. Within Upper Middle Creek, discharge of MIW from groundwater to surface water is extensive in a tributary located approximately 300 feet downgradient from the Formosa 1 Adit. This discharge causes severe effects to surface water quality and was observed during both the wet season and dry season spring and seep surveys, suggesting MIW discharge in this area is perennial. Discharge from the alluvial aquifer system is thought to be a major contributor to MIW discharge from groundwater to surface water in the Upper Middle Creek drainage; however, discharges from the bedrock aquifer to surface water may also occur. MIW also was observed to be discharging from the alluvial aquifer to the South Fork Middle Creek drainage. These discharges occur where road cuts truncate the alluvial groundwater system and MIW re-infiltrated downstream of the road cuts. The observed discharges were intermittent and may be associated with both the alluvial and/or bedrock groundwater systems.

5.1.8 Ecology

The PMDA is largely devoid of vegetation in many areas; however, thick vegetative cover is located in surrounding areas. Upland vegetation in and around the Site consists primarily of coniferous forest dominated by Douglas fir. Golden chinkapin and Pacific madrone also commonly occur in drier areas while western red cedar and western hemlock occur in wetter areas or on north aspects. Canyon live oak occasionally is found in open, drier areas on rocky soils. Forest age in and around the Site varies from old-growth stands to younger successional forest and areas of recent timber harvest. Old-growth forest is present on BLM-managed land located near the Formosa Adits.

The areas surrounding the mine provide habitat for a variety of wildlife, including Roosevelt elk, black tailed deer, coyote, western grey squirrel, black bear, and numerous bird species. Winter steelhead and resident rainbow trout, fall and spring Chinook salmon, Coho salmon, and cutthroat trout have been documented by the Oregon Department of Fish and Wildlife using the Lower Cow Creek Watershed Analysis Unit (BLM 2002), which includes unaffected portions of the watershed.

There are 11 federally threatened or endangered species with the potential to occur in Douglas County (U.S. Fish and Wildlife Service [USFWS] 2011). Of these, seven are marine species or are associated with coastal habitats not found close to the Site. The remaining four species proximate to the Site are the Northern spotted owl (*Strix occidentalis caurina*) and three plants (Gentner's fritillary [*Fritillaria gentneri*], Kincaid's lupine [*Lupinus sulphureus ssp. kincaidii*], and rough popcornflower [*Plagiobothrys hirtus*]). In addition, two species, the fisher (*Martes pennant*) and North American wolverine (*Gulo gulo luscus*), are candidates for listing. Only the Northern spotted owl (federally threatened) has a high likelihood of occurrence near the Site and has critical habitat areas identified. Forest areas within Connectivity/Diversity Block and General Forest Management Area designated BLM-managed lands and private lands adjacent to the PMDA are potential habitat for the northern spotted owl. The two matrix land use allocations are described in Section 6.1. All other species have a low likelihood or are unlikely to occur near the Site because of lack of habitat or range characteristics. Upper Middle Creek and South Fork Middle Creek are adversely affected by MIW discharge from the Site, affecting habitats for aquatic species. The affected aquatic areas include habitat for protected species discussed in Section 7.2.3.2.

5.2 Conceptual Site Model

The CSM is a basic description of how contaminants enter the environment, how they are transported, and what routes of exposure to organisms and humans occur. It also provides a framework for assessing risks from contaminants, developing remedial strategies, and determining source control requirements and methods to address unacceptable risks. Figure 5-1 is a diagrammatic figure illustrating these components for both OU1 and OU2. In addition, Figures 5-2 (Formosa 1 Adit area and Upper Middle Creek) and 5-3 (the EM area and South Fork Middle Creek) present graphic representations of the contaminant generation, transport, and fate mechanisms for two representative locations of the Site.

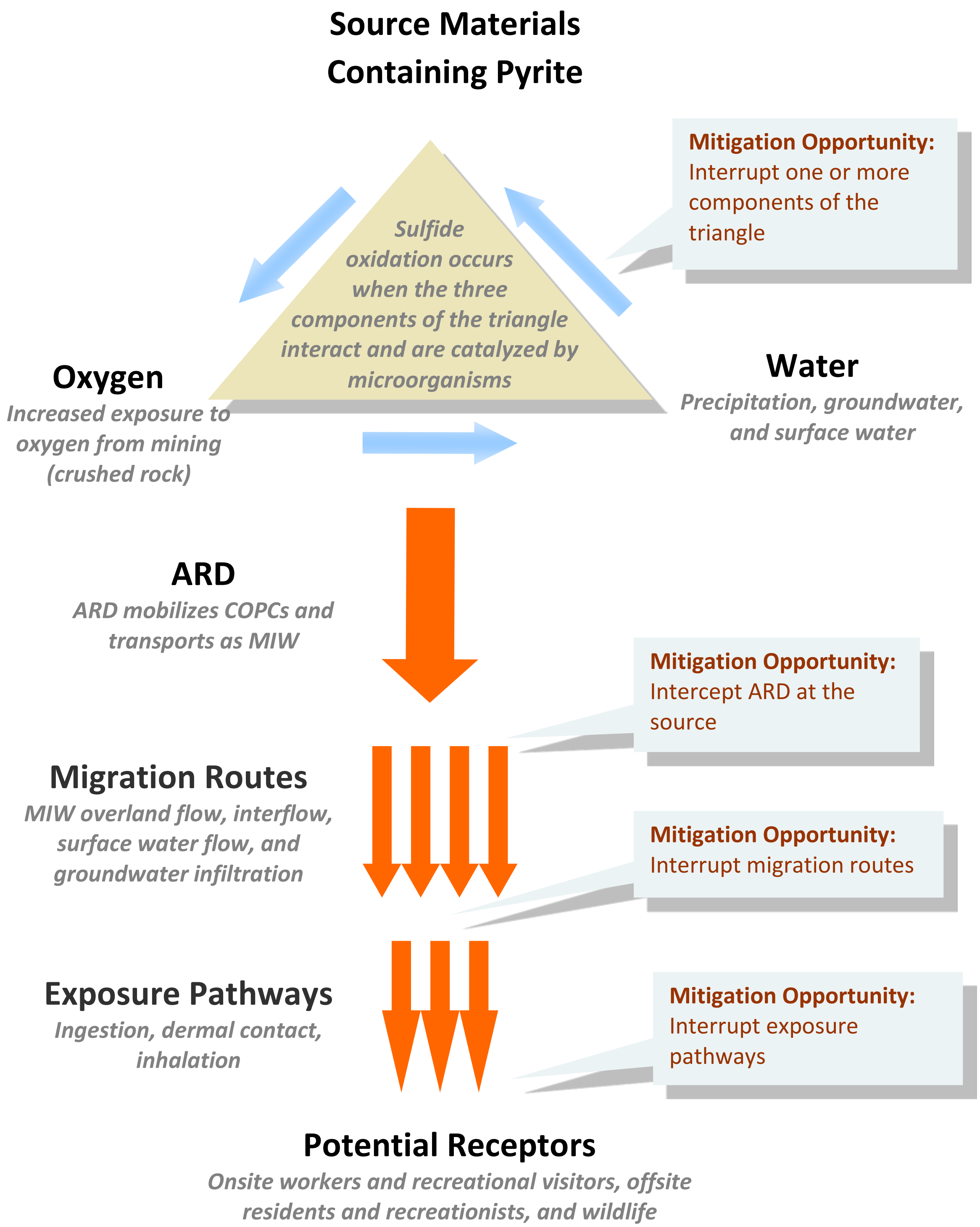
5.2.1 Contaminant Sources

The Formosa Mine exploited an ore body called a volcanogenic massive sulfide, a natural deposit of rock enriched in metals, metalloids, and sulfide minerals. The mining process exposed these rocks to surface weathering through construction of tunnels and haulage of broken rock to the surface, crushing and grinding rocks to separate payable metals, and deposition of waste materials at the surface. The primary contaminant sources at the Site are mine materials that contain sulfide minerals (e.g., pyrite), which generate ARD when exposed to precipitation and oxygen. The process of sulfide oxidation and subsequent release of dissolved metals and metalloids is the dominant contaminant release mechanism at the Site.

Chemicals include sulfur present in various forms that generate ARD, dissolved sulfate present in MIW, and several toxic metals and metalloids present in rocks and in MIW such as arsenic, cadmium, copper, and zinc. The term chemicals of potential concern (COPCs), as used in this ROD, is intended to represent the group of inorganic contaminants as a whole. The RI nature and extent evaluation identified chemicals of potential concern (COPCs) based upon a comparison to chemical criteria, followed by the risk assessment, which narrowed the list of chemicals to those that were estimated to cause unacceptable risks, referred to as chemicals of concern (COCs, a subset of the COPCs). Metals are included in the COPCs list; however only four metals/metalloids (arsenic, cadmium, copper, and zinc) are COCs for the Formosa Mine Site due to their unacceptable risk posed to site receptors.

The primary cause of ARD generation at the Site is oxidation of the mineral pyrite. Oxidation of pyrite forms sulfuric acid (H_2SO_4), which decreases the pH of water that interacts with the acid generating rocks and increases the solubility of metals and metalloids. Pyrite is widespread in rock exposed by mining at the Site, and acid generation occurs from numerous source materials that are widespread over the PMDA. Primary source materials are ARD generating mine materials such as a waste rock, ore, tailings, and co-mingled natural soils and waste rock. ARD generation from pyrite requires three primary components, oxygen, water, and pyrite, as shown in Exhibit 5-1.

Exhibit 5-1. ARD Generation, Migration, and Mitigation



The pyrite oxidation process is catalyzed by a consortium of microorganisms, which affect the rate of oxidation. In addition to oxygen and water, the overall ARD generation process is controlled by a number of interrelated factors, including concentration of pyrite in the rock, grain size, and crystal habit of the pyrite, particle size of the rock, and presence of minerals that have the ability to buffer changes in pH caused by pyrite oxidation. At the Site, these interrelated factors result in production of strongly acidic drainage containing concentrations of toxic metals that exceed acceptable standards by several orders of magnitude. For mine materials, particle size factors are particularly important with respect to fine-grained tailings and the widespread waste rock materials that have undergone weathering processes at the surface. The finer the particle size, the higher the surface area of potential exposed pyrite, and the higher the potential rate of oxidation of pyrite. Concentrations of COPCs are further discussed in Section 7.

MIW is defined as the water generated by processes that result in liberation of mine material contaminants from the solid phase to the dissolved or suspended phase. The term MIW is utilized to describe the sum of all of the processes that create water affected by mining activities that is potentially toxic to the environment regardless of the water pH. For instance, MIW can be acidic or it can be circum-neutral pH with elevated concentrations of COPCs. The use of the term ARD is intended to describe the primary oxidation process by which contaminants are released from rock sources. MIW is used to describe the migration of ARD once it is generated.

Mine materials that contain secondary products of ARD generation, such as efflorescent iron sulfate minerals, are also primary source materials. Mine materials containing these secondary products are widespread within the PMDA as a result of seasonal fluctuations in precipitation, stream flow, and groundwater levels. The secondary minerals are geochemically unstable once formed, highly soluble even under neutral pH conditions, and able to generate acid upon dissolution when contacted by water. Therefore, these minerals represent a source of secondary acidity that can increase COPC concentrations and adverse effects to the environment.

5.2.2 Affected Media

Mine Materials

Mine materials consist of waste rock, ore, tailings, construction rock, road construction material, and contaminated soils. Waste rock, ore, and tailings are the primary source materials that contain natural enrichments of various metals and metalloids, which have the potential to generate ARD. Tailings are present in the EM and within the underground mine but are generally not observed on the surface. Waste rock is common within mine materials, and unfortunately, waste rock management practices during mining and reclamation resulted in extensive comingling of waste rock with construction rock, road surfaces, and other soils. Because of the extensive comingling of these materials, they are evaluated together and referred to as “mine materials.”

Mine materials were characterized using a weight of evidence approach by comparing data to several different screening criteria. The screening criteria include:

- Target analyte list (TAL) metals screening criteria based on background incremental soil sample data
- Synthetic precipitation leaching procedure (SPLP) screening criteria based on State of Oregon groundwater and surface water standards

- Acid base accounting (ABA) screening criteria based on the metrics defined by the laboratory method
- Lithology screening criteria indicative of ARD-generating materials
- Field paste pH screening criteria based on paired comparison of field paste pH and SPLP data
- FPXRF screening criteria based on statistical evaluation of the FPXRF data populations

Mine materials were evaluated for these criteria to identify materials that may require mitigation based on the presence of COPCs that exceed the screening criteria (TAL metals, SPLP metals, and FPXRF metals), the potential to generate ARD, and the potential to leach COPCs to surface water and groundwater.

Mine materials are commonly strongly ARD-generating, as shown by field paste PH data, laboratory acid base accounting data, and lithological data. Modified SPLP data show that dissolved metals and acidity leach from mine materials at concentrations exceeding screening criteria. The SPLP extract solutions contain high concentrations of cadmium, copper, and zinc, which are indicators for MIW-affected waters. These indicators are also found in surface water and groundwater in close proximity to the mine materials. Evaluations of the maturity of the mine materials indicate these materials are not yet mature, and the materials would be expected to generate ARD with lower pH and higher concentrations of COPCs in the future. This indicates the downstream extent of effects to Upper Middle Creek and South Fork Middle Creek would be expected to increase in the future if the mine materials are not remediated.

It is estimated that the process of infiltration of precipitation into mine materials, ARD generation as the water percolates through the mine materials, and subsequent ARD discharge produces 4 to 13 million gallons of ARD in an average year. During particularly high-precipitation years, this volume is estimated to be between 9 and 15 million gallons per year. In contrast, a previous estimate of the volume of ARD that discharges from the Formosa 1 Adit is 5 million gallons per year. This illustrates the relative importance of mine materials in overall ARD generation at the Site. ARD produced by mine materials discharges to both groundwater and surface water. The dominant COPC transport pathway is discharge of ARD to groundwater, COPC migration in groundwater, and subsequent discharge of MIW from groundwater to surface water in Upper Middle Creek and South Fork Middle Creek.

Mine materials are present in WRDs located at the portals of all former openings into the underground mine and in piles on the east and west side of the EM. The depth of mine materials was delineated based on surface borings and excavator trenches. The thickness of mine materials averages 9.5 ft based on this subsurface data. The estimated volume of mine materials was 317,000 CY as published in the RI. As part of the FS process, these volumes were refined to support development and assessment of remedial alternatives. The revised estimated volume as published in the FS was 234,000 CY.

Potential Contaminated Soils

Soils located downslope from the mine materials are subject to both physical and hydrogeochemical dispersion of COPCs from the mine materials. Soils in these areas were evaluated using several methods to further define the downslope boundary of the mine materials and characterize soils downslope from that boundary, which may be affected by COPC dispersion. The downslope boundary of mine materials was delineated using a weight of evidence approach that incorporated visual observation, lithological logging, field paste pH/conductivity, and FPXRF. The downslope boundary of mine materials includes the visual extent of the mine materials and a narrow band of affected soils that was delineated based on paste pH/conductivity and FPXRF data.

Natural soils downslope from this delineated boundary may be affected by either physical dispersion or hydrogeochemical dispersion of contaminants. These soils are located within vegetated areas, including some old-growth forest on BLM land. COPC concentrations in these soils were evaluated by incremental sampling methods. Two areas of background soils were also sampled by incremental sampling to provide screening criteria to compare with the downslope soils. Comparison of the background data with the downslope data shows the downslope soils are enriched in numerous COPCs as compared to background. However, it is unknown if the relatively higher metal concentrations in the downslope soils reflect natural variability in background in this strongly mineralized area or if these relatively higher values result from downslope dispersion from mining–related contamination.

Several areas were identified in the downslope soils where hydrogeochemical dispersion was clearly responsible for metals enrichment. The most pronounced effects are present within the discharge areas for the adit water diversion system. Although delineation of contamination associated with the adit water diversion system discharge was not a data quality objective for the RI, opportunistic samples of affected soils and general observations were completed in the area visibly affected by adit water discharge. Two areas of thick accumulations of iron precipitates and anomalous arsenic concentrations are present in the direct vicinity discharge area. Although not delineated to date, it is thought that effects of contaminant dispersion for COPCs, such as cadmium, copper, and zinc, which precipitate and/or adsorb at higher pH, may be present downgradient from the Adit diversion discharge point. These effects of COPC dispersion may be present within soil, subsoil, or groundwater.

Several relatively small areas were also identified where MIW was discharging to soils from groundwater as seeps. These seep-affected soils exhibit high copper and zinc concentrations, which may be caused by adsorption of dissolved copper and zinc by organic matter in the soil. The sources for the seeps have not been identified and may relate to discharge of MIW from mine materials and from the alluvial and/or bedrock groundwater systems. These areas are very limited in scope and volume of discharge.

5.2.2.1 Sampling Activities

Surface and Subsurface Mine Materials

Surface and subsurface mine materials were characterized using a combination of field and laboratory analysis methods. Field methods included paste pH and conductivity measurements, lithologic logging, and other visual observations. Laboratory methods included total metals, SPLP, ABA, and mineralogical analyses. A summary of the samples collected are as follows:

- A total of 398 surface field samples were collected, with 60 of these field samples analyzed by the laboratory for total metals, SPLP, and ABA. A small fraction of these samples was studied for mineralogical analysis.
- A total of 184 subsurface locations were either excavated or advanced using a direct-push rig. At these locations, a total of 323 field samples were collected, with 47 of these field samples analyzed by the laboratory for total metals, SPLP, and ABA.

- A total of 202 FPXRF samples were collected, with 52 of these field samples analyzed by the laboratory for total metals.

Soils

Background soils and potentially affected soils downslope of mine materials were sampled using incremental and field sampling methods that included FPXRF, paste pH and conductivity, and lithological logging. As described above, a total of 202 FPXRF samples were collected. Some of these samples were from locations at the toe of WRDs, and some of these samples were from locations in soils downslope of WRDs.

Background incremental soil samples were collected from two different areas. The largest data set and most representative was BKG1, which represented the local mineralized soil conditions and was used in the screening comparison for metals in the RI report. The data set for BKG2 represented the non-mineralized soil and was not appropriate for screening soil from the downslope areas of the mining site. BKG1 was located along the general trend of the sulfide mineralized ore bodies. Screening criteria were developed based on data from BKG1 because OU1 is located in areas of known natural outcrops of massive sulfides and other strongly mineralized rocks. No massive sulfide outcrops or weathering products of massive sulfide outcrops were observed in or near the BKG1 sample area; however, the BKG1 sample area is located along the general mineralized trend and has greater potential to contain natural concentrations of elevated metals and metalloids compared to non-mineralized areas. Natural background concentrations in OU1 may have been higher than represented by sample BKG1 because mineralized outcrops are present within OU1.

Incremental soil samples collected downslope from mine materials were focused on select areas associated with the major WRDs. Four of these incremental sample locations were sampled with two distinct decision units (DUs): an upper DU located just below the downslope extent of mine materials and a lower DU located immediately below the upper DU. Three other downslope incremental samples were collected as a single DU only. These samples were located within major drainage valley areas downslope from the WRDs where the pathways of contaminant dispersion by erosion and hydrogeochemical processes are strongly controlled by topography (see Figure 2.3-4 in the RI).

5.2.3 Migration Routes

Contaminants can be transported from the Site via surface water, groundwater, and by physical dispersion. Figures 5-2 and 5-3 illustrate these migration routes for both OU1 and OU2. As ARD is generated and transported through the environment via surface water and groundwater pathways, the pH generally increases through interactions with soils and mixing with neutral-pH waters. The general term MIW is used to describe the migration of ARD once it is generated.

5.2.3.1 Surface Water

Releases of COPCs from mine materials to surface water occur from MIW runoff from exposed mine materials and from groundwater seeps discharging to surface water. Release of COPCs also occurs from leakage of the adit water diversion system at the Formosa 1 Adit (from OU2 mine materials). Runoff includes overland flow (over the land surface) and interflow (within the subsoil/near-surface fractured bedrock zone). In the upper reaches of the Upper Middle Creek subdrainages (MA and MB) and the South Fork of Middle Creek subdrainage (SFA see Figure 1-2), interflow conveys runoff into the alluvial groundwater systems and can discharge as seeps to surface water. The seep discharges may also be affected by movement of MIW from bedrock groundwater into the alluvial groundwater systems within the subdrainages.

5.2.3.2 Groundwater

Releases of COPCs from mine materials to alluvial and/or bedrock groundwater occur from infiltration of rain and snowmelt through mine materials, ARD generation, and transport of MIW through the alluvial and/or bedrock groundwater systems. As described above, MIW transports through the alluvial groundwater systems of the main subdrainages near the Site and discharges to surface water. MIW also transports from mine materials in the EM area to the bedrock groundwater system and subsequently to the alluvial groundwater system in the SFA subdrainage. For the Upper Middle Creek subdrainages MA and MB, discharge of MIW from underground workings is possible but has not been adequately characterized.

5.2.3.3 Physical Dispersion

Physical dispersion of mine materials also contributes to pollutant migration. Numerous areas of large-scale downslope movement of mine materials are present because of very steep topography and relatively high precipitation rates during some periods of the year. Erosion rills of up to approximately 5 ft deep are present in some WRDs, and downslope transport by erosion has displaced mine materials tens to hundreds of feet downslope in several areas. Physical dispersion by wind and traffic may occur, in particular along road areas. Wind dispersion of road materials has likely occurred onto roadside ditches and embankments, causing migration of COPCs. Wind dispersion of road materials is facilitated by vehicle traffic and has been observed during field events. However, it is not considered a significant transport mechanism at the Site.

5.2.4 Exposure Pathways

Human exposure pathways include dermal contact, incidental ingestion, and inhalation of mine materials. Exposure pathways for terrestrial ecological receptors include direct contact/dermal exposure, direct contact/uptake, inhalation, and ingestion of mine materials. Exposure pathways for aquatic/riparian ecological receptors include direct contact/dermal exposure and direct contact/uptake of mine materials. Section 7 provides more details on exposure pathways.

5.2.5 Potential Receptors

Human populations most likely to be exposed include current workers, visitors, and possible, but unlikely, offsite residents. Potential future receptors include construction and other workers, visitors, and offsite residents (although that is highly unlikely to be a significant exposure scenario). Visitors include hikers, campers, all-terrain vehicle riders, and hunters.

Ecological receptors include terrestrial vegetation and wildlife (including salamanders, anurans [frogs and toads], lizards, snakes, birds, and mammals, including bats) and aquatic/riparian vegetation and wildlife (including water column and benthic aquatic invertebrates, fish, and larval amphibians).

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Section 5
Tables

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Table 5.1-1
Total Flow Length to Sites of Interest
Formosa Mine Superfund Site, Douglas County, Oregon

Site of Interest	Distance from Upper Middle Creek headwaters closest to Site (miles)	Distance from South Fork Middle Creek headwaters closest to Site (miles)
Middle Creek Cow Creek Confluence	13	15.6
Chamber's Intake	23.2	25.8
USGS Gage Station 14310000	32.44	35.04
Mayberry Intake	32.5	35.1
Riddle Intake	37	39.6
South Umpqua Confluence	39	41.6

USGS – U.S. Geological Survey

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Section 5
Figures

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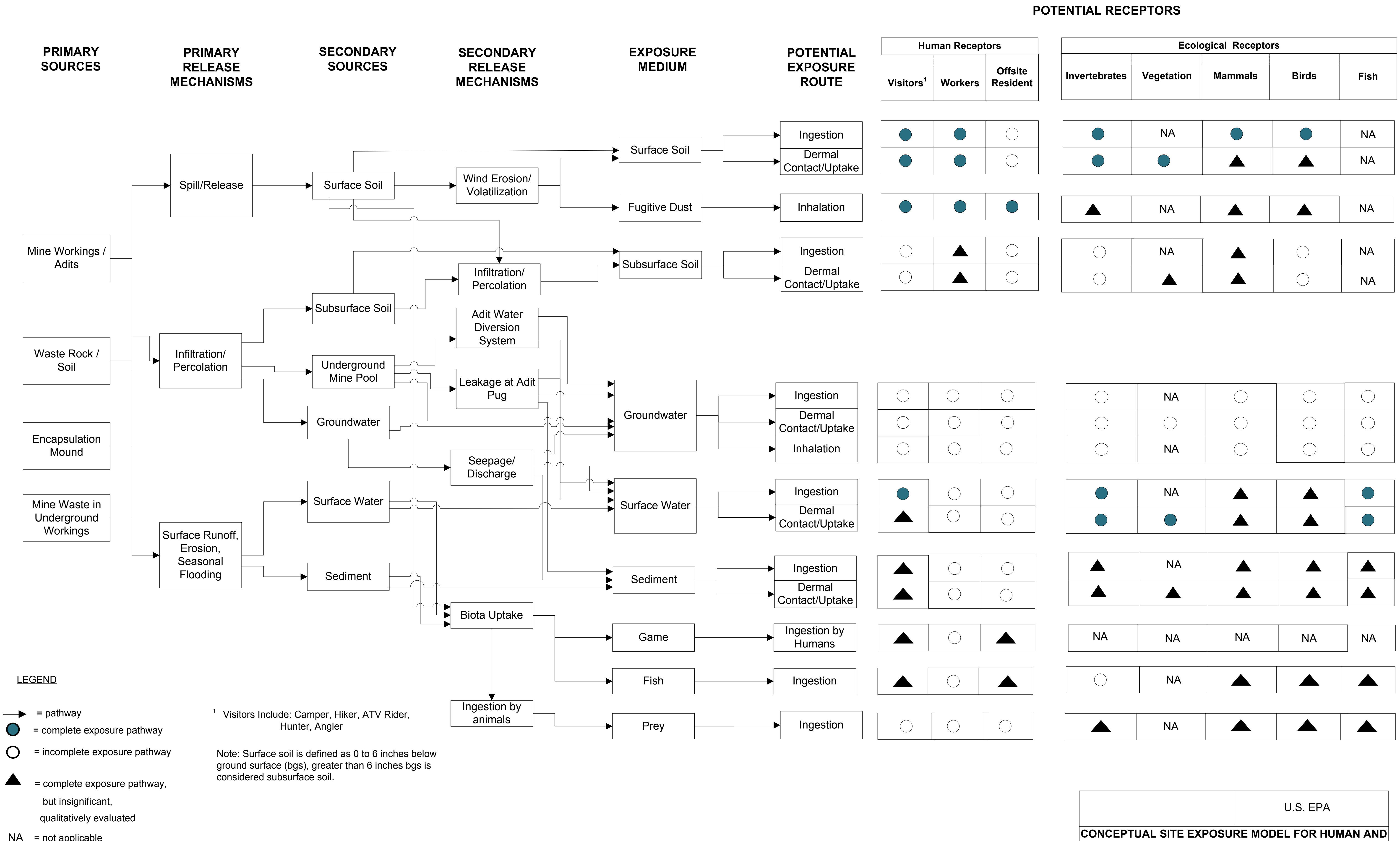

U.S. EPA

CONCEPTUAL SITE EXPOSURE MODEL FOR HUMAN AND ECOLOGICAL RECEPTORS

Formosa Mine

Douglas County, Oregon

FIGURE 5-1

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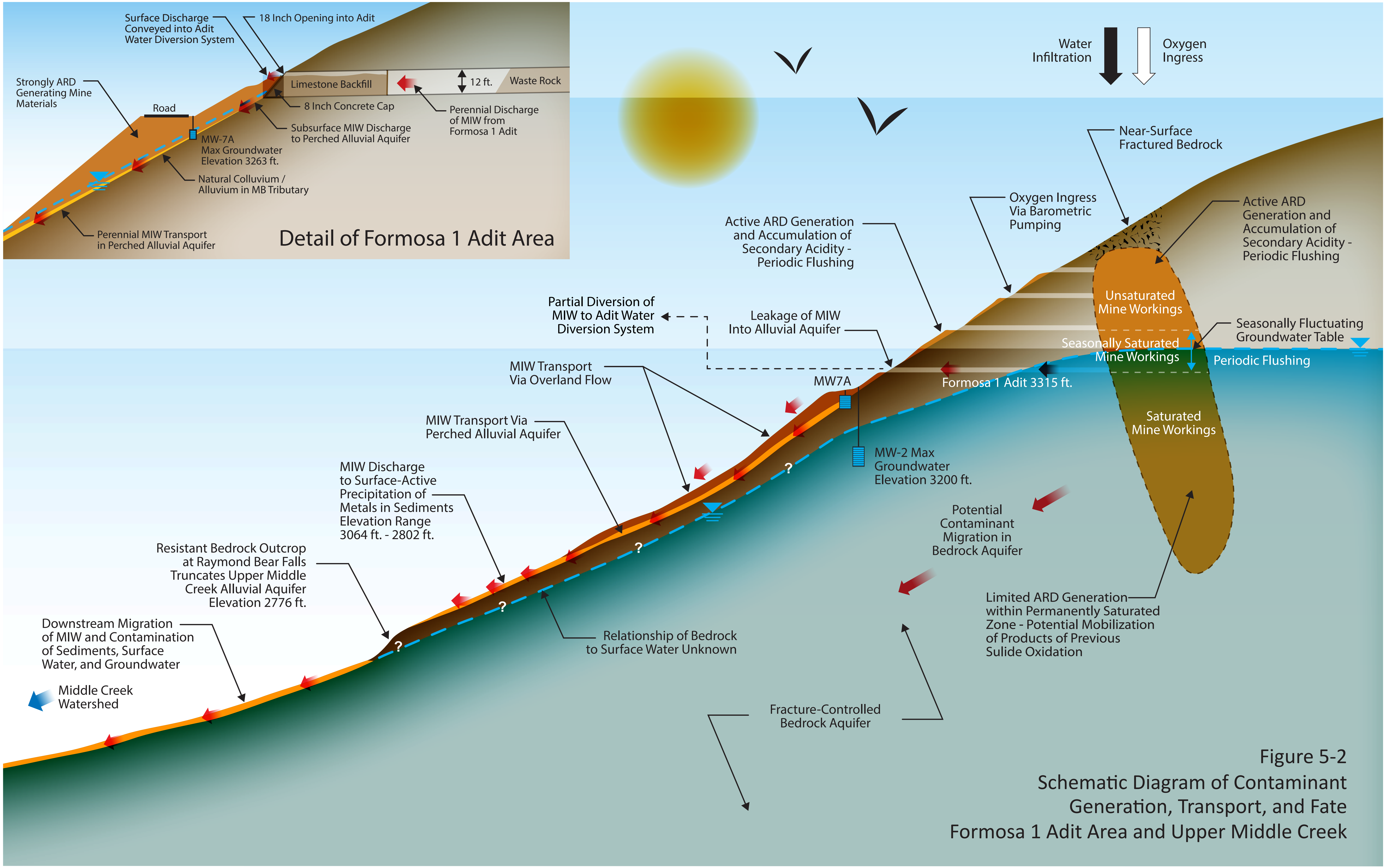

Figure 5-2
Schematic Diagram of Contaminant Generation, Transport, and Fate
Formosa 1 Adit Area and Upper Middle Creek

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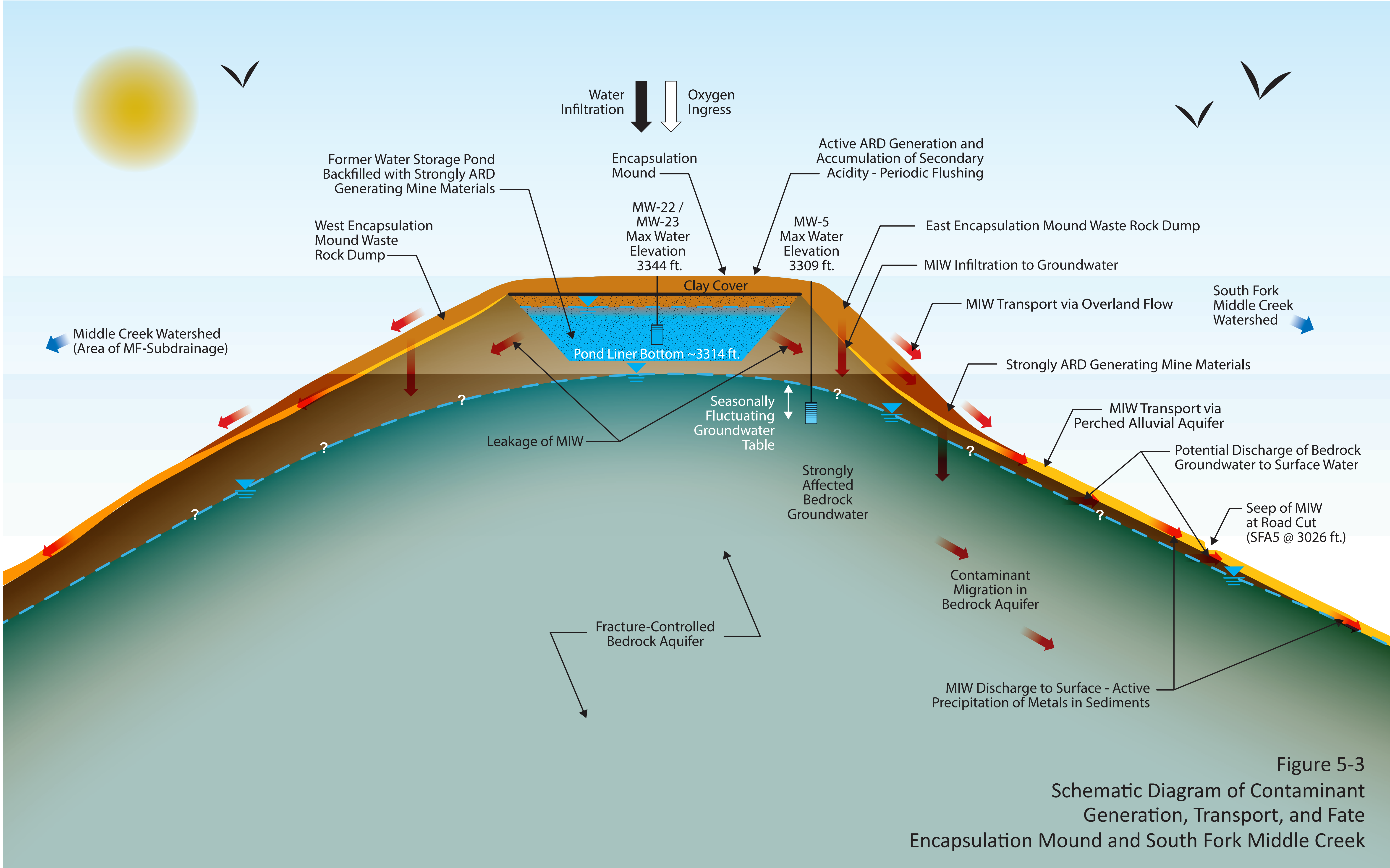

Figure 5-3
Schematic Diagram of Contaminant Generation, Transport, and Fate
Encapsulation Mound and South Fork Middle Creek

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Section 6 – Current and Potential Future Land and Resource Uses

6.1 Land Use

6.1.1 Current Uses

The former mine area of the Site is mostly located on private land owned by FEI, with some public land areas managed by BLM. Timber harvest is the predominant current and expected future land use in the area. The majority of land surrounding the OU1 area either is owned by private timber companies, chiefly Silver Butte Timber Company and Roseburg Resources, or is Oregon and California revested grant land managed by BLM. Private lands are designated as Timberland Resource following county zoning classifications that are based on requirements under state law. BLM land in the area is designated as one of the two Matrix Land use allocations, either as a General Forest Management Area or Connectivity/Diversity Block. The PMDA consists of approximately 25 acres. The Formosa 1 Adit and the northern extent of the PMDA are near or within BLM-managed lands, which are managed as Connectivity/Diversity Block land use allocation. The eastern portion of the PMDA, which includes the illegal dump area, the upper South Fork Middle Creek drainage, and the southern portion of the PMDA, including the 404 Adit, are either within or in close proximity to lands designated General Forest Management Area. In both cases, the land is available for timber harvest at varying frequencies, with the Connectivity/Diversity Block being more restrictive in terms of potential land use. In addition to timber and other forest commodities, the two Matrix Land use allocations provide connectivity between Late Successional Reserves, habitat, and ecologically valuable structural components such as down logs or large trees.

OU1 and adjacent areas are also used by recreational hikers, campers, hunters, and all-terrain vehicle riders. An active weather station and fire-lookout tower is located at the top of Silver Butte Peak, which is accessed via roads through the PMDA. There are also mining claims in the area although no mining is being conducted under a Notice or Plan of Operations.

Roads in the area and at the PMDA are open for public use, with exception to a locked gate on Road 31-6-26.1 that accesses the weather station/lookout tower. While timber harvest does not currently occur adjacent to the Site, the area is being managed as harvest and is part of a rotation, and harvest will occur within the life history of the Selected Remedy. Private timber companies have access agreements on roads within the PMDA area. Workers at the weather station also have access agreements for these onsite roads.

No residential use occurs at or adjacent to the Site. The nearest residents are approximately 3 miles to the north of the PMDA.

6.1.2 Reasonably Anticipated Future Land Uses

Future recreational activities at the Site might include snowmobiling, cross-country skiing, all-terrain vehicle (ATV) use, hiking, hunting, wildlife viewing, and fishing (within the Russell Creek, West Fork Canyon Creek, and Middle Creek drainages).

Based on current zoning of the Site, plausible future uses could include low-density residential use. However, residential use is highly unlikely due to the remote and steep terrain, controlled access by timber companies, ownership of the property, and risk of fire.

6.2 Groundwater Use

OU1 does not address groundwater contamination. Local groundwater is not used for potable supply. There are no privately owned wells or public water supply wells located in the OU1 boundary or within a several mile radius of this area. Future groundwater use within the Site boundaries is unlikely as it is not readily available and currently fails aesthetic values for taste due to high iron and very low pH. Because the State of Oregon has not specifically designated a groundwater beneficial use, the groundwater resource is considered a drinking water resource.

6.3 Surface Water Use

OU1 does not address surface water contamination. As previously mentioned, Russell Creek, West Fork Canyon Creek, and Middle Creek all drain into Cow Creek. There are the following three water intakes along Cow Creek, all greater than 25 miles from the mine (Table 5.1-1):

- ***Riddle public intake:*** Municipal water supply for the town of Riddle, located approximately 2 miles upstream of the South Umpqua confluence (see Figure 3.2-1 in the RI)
- ***Mayberry private intake:*** Drinking water source for a private community of residences, located approximately 6.5 miles upstream of the South Umpqua confluence
- ***Chamber's private intake:*** Irrigation water for agricultural use, located approximately 15.8 miles upstream of the South Umpqua confluence

Section 7 – Summary of Site Risks

Human health and ecological risk assessments for OU1 were conducted as part of the RI. This section provides a brief summary of the relevant portions of the risk assessments that provide the basis for taking remedial actions at OU1. A Draft Final Baseline Ecological Risk Assessment was also conducted for OU2 to evaluate risks to aquatic receptors and is relied upon in this ROD for showing effects on aquatic receptors from OU1 mine materials. The primary focus of this remedial action is to address Site risks associated with OU1 mine materials and reduce the effects they have to surface water and groundwater at OU2.

Methods used to evaluate human health and ecological risks are in accordance with EPA guidelines for evaluating risks at Superfund sites. Detailed explanations of the steps used to conduct the risk assessment are provided in the RI report, including background information, the basis for concern, the exposure model, a toxicity assessment, quantification of exposure and risk, and an evaluation of uncertainties.

Exposures to humans and ecological terrestrial receptors at OU1 were evaluated for the following three exposure EAs. These EAs are shown on Figure 7-1 along with excavation, grading, and capping areas, which will be discussed in Section 12-3.

- EA-1 – This exposure area represents the PMDA of the Site. These materials are classified as mine materials within the FS.
- EA-2 – This exposure area represents the area of potentially affected soils located immediately downslope of mine materials defined as EA-1. The area was characterized to determine whether effects are present beyond the mine materials boundary and sampled using an incremental sampling approach. The areas sampled were generally located below the Formosa 1 Adit WRD, Silver Butte 1 Adit WRD, west EM WRD, east EM WRD and illegal dump area, and two drainage areas west EM WRD. These materials are present in limited areas, thin layers, distributed amongst heavily forested areas, with cancer risk less than the threshold value of 10E-6, and therefore excluded from mine materials.
- EA-3 – This exposure area represents the visibly affected areas resulting from the Adit Water Diversion System pipeline and drainfields. This EA includes discharge areas associated with both the current pipeline and previous pipelines that discharged MIW in a drain field further upgradient from the current pipeline. These materials are classified as mine materials within the FS. Further delineation of the area comprising Adit drainage affected soils will be evaluated before implementation of the Selected Remedy.

7.1 Human Health Risk

A baseline HHRA was completed in January 2012 to assess potential risks to humans (both present and future) from Site-related contaminants present in mine materials (CDM 2012). The HHRA used "acceptable" risk and hazard values identified in CERCLA regulations and Oregon Administrative Rules (OAR 340-122-0115) to determine if the contamination at the Site poses an unacceptable risk to human health. EPA established an "acceptable" excess cancer risk range under CERCLA, from 1 in 10,000 [1E-04] to 1 in 1,000,000 [1E-06] of developing cancer from exposure to a site contaminant over a person's lifetime. The acceptable cancer risk for human exposure specified in OAR is 1 in 1,000,000 [1E-06] for exposure to an individual carcinogen and 1 in 100,000 [1E-05] for exposure to multiple carcinogens. For non-cancer effects, the established threshold below which non-cancer health effects are not expected is 1. The following sections summarize key steps performed in the HHRA.

7.1.1 Chemicals of Potential Concern

COPCs identified in the HHRA for mine materials were based on surface (0-6 inches), or subsurface soil samples (2-22 feet) and identified by EA. The data used in the risk assessment were collected during EPA's RI and were validated, evaluated, and determined to be usable in the HHRA. In surface soils antimony, arsenic, copper, iron, lead, and mercury were selected as COPCs in EA-1; arsenic and manganese were selected as COPCs in EA-2; and antimony, arsenic, and iron were selected as COPCs in EA-3. In mixed surface/subsurface soil, antimony, arsenic, chromium, cobalt, copper, iron, lead, manganese, and mercury were selected as COPCs in EA-1. Of these COPCs, only arsenic was retained as a COC, as discussed in Section 7.1.4.3. Table 7.1-1 shows the range of detected concentrations, the frequency of detection, the exposure point concentration (EPC), and the statistical measure for determining the EPC for the only COC identified in the HHRA.

7.1.2 Exposure Assessment

The exposure assessment identified scenarios through which a receptor could contact COPCs in Site media and estimated the extent of exposure. The CSM (Figure 5-1) illustrates sources, potentially impacted media, exposure routes, and exposed populations that were evaluated in the HHRA. The primary media of concern for human health are onsite soils. Exposure to chemicals detected in surface water was evaluated in a preliminary screening level risk assessment for OU1. Exposure to COPCs in surface and ground waters are addressed in OU2.

The HHRA evaluated human populations most likely to be exposed to site-related contamination. Because of lack of specific development plans, the HHRA evaluated possible exposure to workers (outdoor workers and construction workers) that may occupy the Site on a limited basis as well as others that may occasionally visit there. Several categories of recreational scenarios were considered, including trespassers, hikers, campers, ATV riders, and hunters. Additionally, the HHRA considered possible exposures via windblown dust to residents that do not occupy the Site but may live nearby. Current residents live at least 3 miles from the mine-affected areas and are therefore unlikely to be affected by windblown dust; however, they were included in the assessment to err on the side of protectiveness.

Exposure pathways evaluated for the receptors of concern are:

- Incidental ingestion of and dermal contact with soils (worker and recreational scenarios)
- Inhalation of dusts (worker, recreational, and offsite residential scenarios)

Area-specific EPCs along with site-specific and default exposure assumptions were used to estimate potential average daily doses (ADDs). Exposure assumptions for each receptor are presented on Table 7.1-2.

7.1.3 Toxicity Assessment

The toxicity assessment considered: (1) the types of adverse health effects associated with individual and multiple chemical exposure, (2) the relationship between magnitude of exposures and adverse effects, and (3) related uncertainties such as the weight of evidence for a chemical's potential carcinogenicity in humans. The human health toxicity assessment quantified the relationship between estimated exposure (dose) to a COPC and the increased likelihood of adverse effects.

Toxicity values are used to evaluate the potential for each COPC to cause adverse effects in exposed individuals and are numerical expressions of the relationship between dose (exposure) and response (adverse health effects). Adverse effects include both carcinogenic and non-carcinogenic health effects in humans, and these two types of effects are characterized differently. Risks of contracting cancer due to site exposures are evaluated using cancer slope factors [CSFs] and inhalation unit risk values developed by EPA, or, at times, other agencies. Quantification of non-cancer hazards relies on published reference doses (RfDs) or reference concentrations (RfCs).

CSFs are used to estimate the probability that a person would develop cancer during their lifetime given exposure to site-specific contamination. This site-specific risk is in addition to the risk of developing cancer due to other causes. Consequently, risk estimates generated in the risk assessment are frequently referred to as “excess lifetime” cancer risks.

RfDs are threshold values that represent a daily contaminant intake below which no adverse human health effects are expected to occur even for sensitive receptors (e.g., children or the elderly) exposed over long periods of time. To evaluate non-carcinogenic health effects, a hazard quotient (HQ) is calculated. A hazard quotient is the ratio of the site-specific exposure dose with the chemical-specific RfD.

The primary source of toxicological data used in the HHRA was the most current available at the time of the HHRA and from the following sources: (1) EPA's Integrated Risk Information System (IRIS), (2) EPA’s Provisional Peer Reviewed Toxicity Values, and (3) other sources of toxicity values (includes additional EPA and non-EPA sources of toxicity information). Table 7.1-3 provides the oral and dermal CSFs and inhalation unit risk values used to estimate cancer risks for the COCs, and Table 7.1-4 summarizes the RfDs and RfCs used to estimate non-carcinogenic effects for the COCs. Criteria used in the HHRA were obtained from the November 2010 online version of IRIS and sources listed in EPA regional screening level (RSL) table (www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm). As of April 2015, no changes have been made to toxicity criteria used in the HHRA.

7.1.4 Risk Characterization

Risk characterization is the final quantitative step in the risk assessment process. In this step, the results of the hazard identification, exposure assessment, and toxicity assessment are integrated to yield quantitative measures of cancer and non-cancer (threshold) risk.

7.1.4.1 Carcinogenic Risk Characterization

For potential carcinogens via the oral/dermal route of exposure, excess lifetime cancer risks (ELCRs) are obtained by the following equation:

ELCR = LADD x CSF

Where:
ELCR = Excess lifetime cancer risk associated with exposure to the chemical via the specified route of exposure (unitless)
LADD = Lifetime average daily dose (milligrams of a chemical per kilogram of body weight per day [mg/kg-day])
CSF = Cancer slope factor (mg/kg-day)-1

The estimated cancer risk is a unitless probability that an exposed individual will develop cancer as a result of exposure to a chemical by the age of 70. This risk is referred to as "excess lifetime cancer risk (ELCR)" because it would be in addition to the risks of cancer individuals face from other causes such as from smoking. An ELCR of 1E-06 indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. Excess cancer risks are summed for all COCs and across all exposure pathways that contribute to exposure of an individual in a given population. The level of total cancer risk that is of concern is a matter of personal, community, and regulatory judgment. EPA generally considers ELCRs below 1E-06 to be so small as to be negligible and risks above 1E-04 to be sufficiently large that some sort of remediation is warranted. ELCRs that range between 1E-04 and 1E-06 are generally considered to be acceptable although this is evaluated on a case-by-case basis. The acceptable cancer risk specified in OAR is 1 in 1,000,000 [1E-06] for exposure to an individual carcinogen and 1 in 100,000 [1E-05] for exposure to multiple carcinogens.

7.1.4.2 Non-carcinogenic Risk Characterization

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., lifetime) with an RfD derived for a similar exposure period. Non-carcinogenic hazards are measured in terms of an HQ for exposure to a single chemical and a hazard index (HI) for exposure to multiple chemicals. The HQ for oral/dermal exposures is defined by the equation:

HQ = ADD/RfD

Where:
HQ = Hazard quotient associated with the exposure via the specified exposure route (unitless)
ADD = Average daily dose (mg/kg-day)
RfD = Reference dose (mg/kg-day)

If the HQ for a chemical is equal to or less than 1, it is believed there is no appreciable risk that non-cancer health effects will occur. If an HQ exceeds 1, there is some possibility but not a certainty that non-cancer effects may occur. This is because of the margin of safety inherent in the derivation of all RfD values. The larger the HQ value, the more likely it is an adverse effect may occur.

If an individual is exposed to more than one chemical, a screening-level estimate of the total non-cancer risk is derived simply by summing the HQ values for that individual. This total is referred to as the HI. If the HI value is less than 1, non-cancer risks are not expected from any chemical, alone or in combination with others. If the screening level HI exceeds 1, it may be appropriate to perform a follow-on evaluation in which HQ values are added only if they affect the same target tissue or organ system (e.g., the liver). This is because chemicals that do not cause toxicity in the same tissues are not likely to cause additive effects.

7.1.4.3 Summary of Carcinogenic and Non-carcinogenic Risk

Current workers, visitors, and offsite residents were evaluated quantitatively for exposure to surface soils. Future construction workers, workers, visitors, and offsite residents were quantitatively evaluated for risks to surface as well as subsurface soils based on the assumption that surface and subsurface soils were disturbed in the future and subsequently intermixed. Visitors included hikers, campers, ATV riders, and hunters. Estimated cancer risks for all populations both current and future, are below 1E-06 for all COPCs except arsenic. Estimated cancer risks for arsenic exceed 1E -06 in some areas, and therefore only arsenic was retained as a COC. Estimated non-cancer hazards, segregated by target organ, are below the acceptable hazard benchmark of 1. Therefore, non-cancer health effects are not expected as a result of exposure to contaminants at the Site. Risks and hazards are summarized by EA below. Total risks for arsenic for OU1 soils are shown in Tables 7.1-5 through Table 7.1-7 for each of the receptors currently or potentially exposed to arsenic in the soils at the Site.

- EA-1. Estimated cancer risks for current and future onsite workers and construction workers in EA-1 are equal to 1E-05 or less (Table 7.1-5). Estimated cancer risks for current and future visitors (adult and child) in EA-1 are equal to 4E-06 or less. Estimated risks for offsite residents exposed via inhalation to windblown dusts from EA-1 are below the cancer risk benchmark of 1E-06. Estimated non-cancer hazards for current and future onsite workers, visitors, and offsite residents are below the acceptable hazard benchmark of 1. Estimated non-cancer hazard for future construction workers in the reasonable maximum exposure (RME) case is 2; however, when segregated by target organ, the individual hazard indices for each organ are below 1 (Table 7.1-6).

- EA-2. Estimated cancer risks for current and future visitors (adult and child) in EA-2 and offsite residents exposed via inhalation to windblown dusts from EA-2 are below the acceptable cancer risk benchmark of 1E-06. Estimated cancer risks for current and future workers were 2E-06 or less (Table 7.1-5). Estimated non-cancer hazards for these populations are below the acceptable hazard benchmark of 1 (Table 7.1-6).

- EA-3. Estimated cancer risks for current and future onsite workers in EA-3 are 6E-05 or less. Estimated cancer risks for current and future visitors (adult and child) in EA-3 are equal to 2E-05 or less. Estimated risks for offsite residents exposed via inhalation to windblown dust from EA-3 are 2E-06 or less (Table 7-1-5). Estimated non-cancer hazards for these populations are below the acceptable hazard benchmark of 1 (Table 7.1-6). Cancer risks and non-cancer hazards were based on maximum detected concentrations in EA-3 due to the small sample size.

In summary, human health risks greater than 1E-06 due to exposure to mine materials and soils are likely Site-related but limited to arsenic in soils. The maximum cancer risk was 6E-05 for workers in EA-3. All estimated non-cancer hazards segregated by target organ fall below EPA's benchmark of 1.0. Cancer risks and non-cancer hazards are summarized by EA in Table 7.1-7.

Groundwater and surface water exposures may also contribute to human health risk but will be examined quantitatively in the risk assessment conducted for OU2 and thus are not evaluated in the FS. Based on the OU1 human health screening level risk assessment, surface water posed no unacceptable cancer risk but does pose non-cancer risks greater than EPA's benchmark of 1 for cadmium, copper, and zinc.

7.1.5 Uncertainty Analysis

Methods used and assumptions made in assessing potential human health risks are subject to a certain degree of uncertainty. To compensate for uncertainty surrounding input variables, assumptions are made that tend to result in protective estimates of risk rather than underestimated risk. In cases where data are limited, assumptions may be based on professional judgment or subjective estimates that may under or overestimate risks. In general, the primary areas of uncertainty include the following:

- Environmental data
- Exposure parameter assumptions
- Toxicological data
- Risk characterization

Uncertainties important for understanding and using the risk estimates presented in the HHRA are discussed in the following sections.

7.1.5.1 Data Evaluation and Sample Representativeness

Soil sampling locations were distributed throughout the Site. Samples were collected from known and suspected areas of contamination (biased sampling) and areas representative of background to delineate the nature and extent of contamination. This sampling methodology provides data that are considered to accurately represent the current level of overall contamination at the Site. For areas that are anticipated to have a greater probability of having been impacted by historical mine operations, large datasets exist (i.e., EA-1 and EA-2). Data are more limited for EA-3 where the sampling was concentrated within the visibly affected Formosa Adit 1 drain field areas. The small sample size for EA-3 increases the uncertainty of the adequacy of data representativeness; however, little variability was observed in the available samples.

7.1.5.2 Exposure Assessment

There are two major areas of uncertainty associated with exposure parameter estimation. The first relates to the calculation of EPCs. The second relates to parameter values used to estimate chemical intake.

Uncertainties Associated with Exposure Point Concentrations

EPCs are calculated to reflect reasonable maximum exposures. Because the true mean cannot be calculated based on a limited set of measurements, EPA recommends that the exposure estimate be based on the 95 percent upper confidence limit (UCL) of the mean. When data are sparse or are highly variable, the exposure point concentration may be far greater than the mean of the available data, and risk is overestimated. In cases where fewer than 10 samples are available, the EPC is the maximum measured concentration. Generally, use of maximum detected concentrations will result in an overestimation of risk. In this assessment, maximum concentrations were used as EPCs only for EA-3.

Uncertainties in Chemical Absorption (Relative Bioavailability)

The risk from an ingested chemical depends on how much is absorbed from the gastrointestinal tract. This is important for metals in soil at mining sites because some metals exist in poorly absorbable forms. Failure to account for this may result in a substantial overestimation of exposure and risk. EPCs for arsenic used to evaluate both cancer and non-cancer health effects associated with exposure assume a bioavailability of 100 percent. However, a number of studies suggest arsenic from soil is less available for gastrointestinal and dermal absorption than previously assumed. EPA Region 10 has issued a policy statement regarding arsenic bioavailability (EPA 2000a). This statement suggests the use of default bioavailability for arsenic of 60 percent. While this may be a reasonable estimate for the Formosa Site, there is some uncertainty due to the high acidic nature of the soil. Therefore, to err on the side of public health, a bioavailability of 100 percent is assumed in this assessment as a conservative measure and is expected to overestimate the risk associated with arsenic exposure.

Uncertainties in Estimated Air EPCs

EPCs for indirect exposure, such as dust inhalation, are estimated by modeling air concentrations from soil concentrations. It should be noted this type of modeling is uncertain and hence contributes uncertainty to the risk estimates. In the case of offsite residents, a screening level assessment was performed to determine if adverse health effects were predicted. More detailed modeling could then be undertaken to refine the risk estimates. However, as adverse health effects were not expected, no refinement in the modeling was considered necessary.

Uncertainties in Exposure Parameters

Exposure assumptions for each exposure scenario were selected, with the intention of reflecting RME. It is unlikely any actual exposure would exceed the levels assumed based on these assumptions. The exposure pathways evaluated in the HHRA were identified based on current and anticipated future land use. If Site conditions change significantly in the future, exposure pathways and assumptions may require further evaluation.

7.1.5.3 Uncertainties in Toxicity Assessment

Toxicity information for many chemicals is often limited. Consequently, there are varying degrees of uncertainty associated with toxicity values (i.e., cancer slope factors, reference doses). For example, uncertainties can arise from extrapolation from animal studies to humans, from high dose to low dose, and from continuous exposure to intermittent exposure. In addition, some uncertainties exist not only in the dose response curve but also in the nature and severity of the adverse effects the chemical may cause. EPA typically deals with this uncertainty by applying an uncertainty factor of 10 to 100 to account for limitations in the database. Thus, in cases where available data do identify the most sensitive endpoint of toxicity, risk estimates will substantially overestimate true hazard. In general, uncertainty in toxicity factors is one of the largest sources of uncertainty in risk estimates at a site. Because of the conservative methods EPA uses in dealing with the uncertainties, it is much more likely the uncertainty will result in an overestimation rather than an underestimation of risk.

Due to limited information for some chemicals, EPA does not recommend assessing dermal exposure for those chemicals. Therefore, the lack of a dermal assessment for some chemicals may underestimate the exposure via this pathway. Conversely, as mentioned previously, because of reduced bioavailability, the dermal exposure for arsenic is likely overestimated.

7.1.5.4 Risk Characterization

In general, uncertainty is inherent in the risk characterization step by adding hazard indices and cancer risks across chemicals and media for each receptor. This assumption of additive risk from multiple chemical exposures may overestimate or underestimate risk since actual interactions among chemicals may be synergistic or antagonistic rather than additive.

In this assessment, unacceptable non-cancer exceedances are limited to the RME case of the future construction worker scenario and are due primarily to arsenic (61 percent). As discussed previously, arsenic is likely less bioavailable than the 100 percent assumed for this assessment, further lowering the expected health effects. Hazard indices, when segregated by target organ, are less than 1 for all tissues and organs. Therefore, Site-related non-cancer health effects seem unlikely for any receptors evaluated.

7.1.6 Summary of Human Health Risk

Current workers, visitors, and offsite residents were quantitatively evaluated for exposure to surface soils. Future construction workers, workers, visitors, and offsite residents were quantitatively evaluated for risks to surface as well as subsurface soils. Visitors included hikers, campers, ATV riders, and hunters.

Human health risks greater than 1E-06 due to exposure to mine materials and soils are likely Site-related but limited to arsenic. Estimated cancer risks associated with exposure to arsenic are above 1E-06 for several exposure scenarios and areas (Table 7.1-7). The maximum cancer risk was 6E-05 for workers in EA-3. EPCs for arsenic in all three EAs were above the background value of 12 mg/kg (ODEQ 2013a). Estimated non-cancer hazards segregated by target organ are below the acceptable hazard benchmark of 1.0 from exposure to soils.

Groundwater and surface water exposures may also contribute to human health risk but were not examined quantitatively in the OU1 HHRA. The OU1 screening level risk assessment for human health determined that surface water posed unacceptable non-cancer risks and concluded that a quantitative risk assessment would be included with the evaluations in the remedial investigation report for OU2. The OU 1 risk assessment focused on ecological risks due to the low exposure assumptions for human health. Human health risks for surface water exposure will be quantitatively evaluated in the risk assessment conducted for OU2.

7.2 Ecological Risk

ERAs evaluate the likelihood that adverse ecological effects may occur or are occurring at a site because of exposure to single or multiple chemical stressors. Risk of such effects results from contact between ecological receptors (e.g., plants and animals) and stressors (e.g., mining-related contaminants) that are of sufficient duration and intensity to elicit adverse effects. The primary purpose of an ERA is to identify, evaluate, and describe actual or potential conditions stemming from releases of site-related contaminants that can result in adverse effects to existing or future ecological receptors.

Two ERAs for the Site were conducted, a screening level ERA (SLERA) and a baseline ecological risk assessment (BERA). The SLERA focused primarily on terrestrial habitats and receptors potentially affected by contamination at the PMDA (identified as OU1) and, in a limited manner, aquatic habitats adjacent to the former mine site (CDM 2012). The SLERA concluded that mine materials are adversely affecting downgradient aquatic resources, based on migration routes identified in the CSM (Figure 5-

1) and concentrations of COCs measured in surface water. These results indicated the need to perform a BERA; the subsequent BERA (CDM Smith 2014) focused on aquatic habitats (identified as OU2) near the mine site to 13 miles downstream (Figure 1-2).

7.2.1 Ecological Resources at Risk

Terrestrial habitats that are directly affected by mine materials or have the potential to be affected by COCs via surface runoff from mine materials were evaluated in the SLERA (CDM 2012). The dominant fate and transport mechanism for COCs from the Site is transport via groundwater that discharges to surface waters in the upper reaches of the creeks. Therefore, terrestrial and riparian habitats upland of and adjacent to Middle Creek and South Fork are not expected to be adversely affected by mine-related materials.

Surface water quality in both Middle Creek and South Fork is affected by MIW from discharge at seeps and springs where groundwater discharges to surface water. Based on the findings of the OU1 RI (CDM 2012), the means of transport of MIW is via alluvial groundwater as a result of leaching and direct discharge from the Formosa 1 Adit and subsequent discharge to surface waters. Direct runoff of MIW from the mine materials typically occurs after intense but short-term precipitation or snowmelt events during late fall though winter.

Ecological sampling conducted in 2012 and 2013 found that fine-grained sediments are minimal within both Middle Creek and South Fork surface water drainages, particularly in higher gradient upper reaches and those dominated by cobble and boulder substrates. Small amounts of sediment are present within larger pools, typically located downstream of culverts. This indicates sediment transport downstream is not likely a significant means of transport of mine-related metals from the Site to the downstream aquatic systems. In addition, ecological data on BMI communities at several sampling locations in Middle Creek and South Fork are representative of riffle habitats that are generally lacking in fine-grained sediment. Since BMIs inhabit the areas that appear to be generally lacking fine-grained sediment, exposure to mine-related COCs in sediment is not expected to be a significant exposure pathway for BMIs or fish that consume BMIs. Therefore, the abiotic media of concern for aquatic habitats is limited to surface water.

7.2.2 Data Used in the ERAs

7.2.2.1 Soil and Mine Materials Data Used in the SLERA

Validated data collected during 2009 to 2010 sampling events conducted as part of the RI were used in the SLERA to evaluate the magnitude and distribution of chemicals in soil and mine materials. Soil samples included both discrete soil samples and multi-incremental samples (Tables 7.1-1 through 7.1-7).

7.2.2.2 Surface Water Data Used in the BERA

Validated data collected during multiple surface water sampling events from 2009 to 2013 were used to evaluate the magnitude and distribution of chemicals in surface waters of concern. Only surface water stream locations (i.e., not Adits or seeps) were included in the datasets used to evaluate exposure to aquatic receptors (Tables 7.2-1 and 7.2-2). For Middle Creek, sampling locations included in the EA chemical dataset are MXR, M3.0, M7.9, and M13.0. For South Fork, sampling locations included in the EA chemical dataset are SF1.0 and SF3.0. (Figures 1-2 and 1-3) Reference areas included in the EA chemical dataset are the Middle Fork reference location a (MREF) and the South Fork reference location (SFREF). Additional biological sampling locations in all EAs were included in the supporting lines of evidence datasets. Surface water data along with BMI and/or fish surveys indicate a decreasing trend in concentration and resulting ecological indicators with distance from the mine along both creeks.

More recent surface water data were collected in April 2014 after the BERA was completed. Analytical results for these data were compared to the dataset used in the BERA to evaluate if significant changes in water quality had occurred. The 2014 data represent an additional "dry season" sample dataset, supplementing the data from 2009 to 2013 for locations of ecological importance (e.g., M3.0, M7.9, SF1.0, SF3.0, SFREF, and MREF), and help to reduce any uncertainty in representativeness of the BERA exposure assessment (Figures 1-2 and 1-3). Higher concentrations of COCs observed in April 2014 compared to the 2009 through 2013 dataset indicate there may be short-term increases in COC concentrations; however, none of the April 2014 data would result in exceedances of chronic surface water criteria that were not already identified from the 2009 through 2013 dataset used in the BERA.

Surface water samples collected in April 2014 were specifically analyzed for dissolved organic carbon (DOC) to derive acute and chronic water quality criteria for copper using the Biotic Ligand Model. The purpose of this evaluation was to determine if the water quality criteria derived using hardness used in the BERA are sufficiently protective of aquatic life or if the Biotic Ligand Model, which requires analysis of DOC in addition to pH, hardness, and other parameters, would provide a different level of protectiveness. Based on this evaluation, risk estimates associated with exposure to dissolved copper in surface water are similar at most sampling locations or stream reaches whether the criteria used for those risk estimates are based on the hardness-only approach or the Biotic Ligand Model approach, indicating the use of the approved hardness-only method to derive water quality criteria in the BERA is sufficiently protective of aquatic life

7.2.3 Ecological Receptors

A variety of sources and surveys were used to identify ecological receptors for the Site, including biological site surveys, the Atlas of Oregon Wildlife (Csuti et al. 1997), and various USFWS sources and studies.

7.2.3.1 Terrestrial Receptors

Terrestrial receptors include those of the onsite and adjacent Douglas fir (*Pseudotsuga menziesii*) dominated forest habitats as well as the disturbed areas of the Site. Terrestrial receptors with potential to occur at the Site are briefly described below and listed in Tables 7.2-3 through 7.2-5. These tables provide information, including an evaluation of potential to occur onsite, listed and special concern species, and scientific names of species known or potentially occurring onsite. Site investigations concluded that wildlife and plant habitat quality is poor, and quantity of suitable habitat is limited within or near the PMDA.

Vegetation: Detailed descriptions of upland vegetation and riparian vegetation are provided in Section 3.7 of the OU1 RI (CDM 2012). Table 7.2-3 provides a list of plants found at the Site, and Table 7.2-4 provides a further list based on Csuti et al. 1997. In general, upland vegetation in and around the Site consists primarily of coniferous forest dominated by Douglas fir, and riparian areas are dominated by deciduous trees and shrubs.

Wildlife: Table 7.2-3 provides a list of wildlife found at the Site; a full list of species with ranges that could include the Site is provided in Table 7.2-4. A number of vertebrate species have potential to occur within the range of the Site, including salamanders, anurans (frogs and toads), lizards, snakes, birds, and mammals, including bats. A number of these species likely would use the coniferous forest ecosystems in the area occasionally or infrequently given the nearby disturbed areas. Some species more tolerant of disturbed conditions can occur within the PMDA more frequently; however, more suitable habitats for many of these species are the less disturbed coniferous and mixed forests adjacent to the Site.

7.2.3.2 Aquatic Receptors

Aquatic receptors include those found or are anticipated to be present in the EAs of Upper Middle Creek and South Fork Middle Creek of the Upper Middle Creek sub watershed. Ecological receptors of interest include aquatic plants, water column and BMI, fish, and larval amphibians. Fish species known to occur in the aquatic ecosystems include Coho salmon, steelhead/rainbow trout, cutthroat trout, and sculpin. Several amphibian species, including rough-skinned newt and Pacific giant salamander, are also known to occur in Middle Creek and South Fork and were observed during ecological sampling programs. Among the aquatic receptors considered most important are salmonid fish and the invertebrates and fish that serve as prey for salmonid fish.

Table 7.2-3 provides a list of aquatic wildlife and aquatic plants found at the Site, and Table 7.2-4 provides a further list based on Csuti et al. 1997.

7.2.3.3 Listed Species and Species of Special Concern

Federally threatened or endangered species, candidate species for listing, species of concern, and federally delisted species with the potential to occur in Douglas County are listed in Table 7.2-5.

Federally Threatened and Endangered Species: Detailed information on threatened and endangered species is provided in Section 3.7 of the OU1 RI (CDM 2012). Of the terrestrial animal species listed as threatened on Table 7.2-5, only the northern spotted owl may occur in the vicinity of the Site. BLM conducted a survey to determine if the northern spotted owl is present at or the near the Site. The survey concluded that there were no Northern Spotted Owls on BLM property. BLM property is the only mature forest adjacent to the Site. None of the threatened amphibians, reptiles, or invertebrates listed on Table 7.2-5 occurs on Site. Federally threatened plants listed on Table 7.2-5 have a low likelihood to occur on the Site. Coastal Coho salmon are the only federally threatened fish species likely to occur on or near the Site.

State Special Concern Species: There are a number of species listed as "special concern" for Douglas County. "Special concern" species have a conservation status that is of concern to the USFWS (many previously known as Category 2 candidates) but for which further information is still needed. For Douglas County, there are 13 birds, 10 mammals, 5 fish, 10 reptiles and amphibians, 5 invertebrates, and 17 plants that are listed as special concern. All special concern species for Douglas County are provided in Table 7.2-5. Species of concern with a high probability of occurring at the Site or that were observed during site surveys include band-tailed pigeon, mountain quail, Del Norte salamander, costal cutthroat trout, and Oregon Coast steelhead.

7.2.4 Media and Chemicals of Concern

7.2.4.1 Media of Concern

The primary abiotic media of interest for the SLERA includes surface soil and mine materials that are on the surface and may serve as surface soil from a terrestrial ecological exposure perspective. These media are considered important for two reasons. First, they can serve as exposure media for terrestrial ecological receptors occurring in or using the Site. Such exposures are considered limited given the disturbed nature and marginal habitat quality present at the Site. Site conditions suggest exposures would be infrequent and of short duration for a limited suite of ecological receptors tolerant of this environment. Secondly, surface soil and mine materials as potential sources of contamination to areas and media downgradient, including groundwater, surface waters, sediments, and possibly other media associated with the terrestrial environment.

Three EAs were defined for terrestrial receptors: EA-1 (PMDA), EA-2 (area immediately downgradient of the PMDA), and EA-3 (visibly affected areas resulting from the Adit Water Diversion System pipeline and drainfields). EA-2 was divided into several smaller decision units, including encapsulation mound east (upper and lower), encapsulation mound southeast (upper and lower), encapsulation mound west (upper and lower), Formosa Adit (upper and lower), encapsulation mound west drainage 1 and drainage 2, and Silver Butte (Figure 7-1).

The second type of abiotic medium of interest for the SLERA is surface water immediately downgradient of the former mine site. The screening evaluation of surface water was performed to determine if surface soil, mine materials, and other abiotic media (e.g., groundwater) have an adverse effect on surface water and related media (e.g., sediment and biota). The SLERA evaluated surface water by comparing dissolved concentrations of selected metals in surface water at seep and stream locations in the headwaters of Middle Creek and South Fork Middle Creek to chronic National Recommended Water Quality Criteria (NRWQC) established by EPA for the protection of aquatic life. Aquatic life is defined as aquatic plants, water column invertebrates, fish, and larval amphibians underlying the derivation of chronic water quality criteria. The SLERA identified several COCs for the aquatic ecosystems evaluated. Based on these findings, a BERA was conducted.

The primary media of interest for the BERA is surface water. Two surface water EAs are defined for the Site – Middle Creek and South Fork. These two EAs are most applicable to mobile receptors such as fish. In addition, each individual sampling location from Middle Creek, South Fork, and each reference area was considered an EA because location-specific EAs are most applicable to non-mobile or minimally mobile receptors such as BMI.

7.2.4.2 Chemical Screening and Selection of Final Chemicals of Concern for Terrestrial Habitats

Multiple steps were conducted in accordance with EPA Superfund Guidance (EPA 1997) to identify the final COCs for terrestrial receptors. First, all potentially hazardous chemicals detected were evaluated as chemicals of interest (COIs). Chemical properties, including persistence, bioavailability, bio concentration, and bioaccumulation potential, were evaluated to determine potential chemical stressors. Maximum detected concentrations of COIs in EA-1 and EA-3 were compared to ecological screening levels (ESLs); if the maximum detected concentration exceeded the ESL, indicating the potential for adverse ecological effects to exist, the COI was selected as a COC. Because incremental sampling and the collection of triplicate samples were conducted in EA-2, a confident arithmetic mean was generated. Therefore, the arithmetic mean was used to compare to ESLs to select COCs for EA-2.

At the conclusion of the SLERA, the COPCs with the greatest potential to cause or contribute to ecologically significant adverse effects were identified as ecological COCs by the hazard quotient method and carried forward for evaluation in the baseline ecological risk assessment. Final chemicals for surface soil and mine materials by EA are:

- EA-1 – Arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc
- EA-2 – Cadmium, copper, manganese, and zinc (location-specific)

- EA-3 – Arsenic, copper, vanadium, and zinc

Table 7.2-1 provides summary statistics by exposure area for COCs in surface soils evaluated for ecological effects in Section 7.2.7.1.

7.2.4.3 Chemical Screening and Selection of Final Chemicals of Concern for Aquatic Habitats

The maximum detected dissolved concentration for each detected chemical in surface water for each EA was selected as the EPC and compared to conservative ESLs to select final COCs and to derive preliminary risk estimates based on the HQ approach. ESLs used to select COCs include NRWQC criterion continuous concentrations (EPA 2013) and ODEQ Freshwater Water Quality Criteria (ODEQ 2013b) adjusted for site-specific hardness where appropriate.

Mercury was initially selected as a COC based on the screening described above and because the maximum detected concentration of mercury in surface water in Middle Creek (0.044J micrograms per liter [μg/L] at MXR) and South Fork (0.036J μg/L at SF1.0) exceeded the ODEQ ESL of 0.012 μg/L (ODEQ 2013b). An evaluation of mercury concentrations in creek surface water relative to historical mining operations and the water quality in the vicinity of the Site was conducted to determine if mercury is a mine-related COC and if food web modeling is warranted for evaluation of upper trophic level receptors such as piscivorous birds and mammals. The evaluation of mercury included a review of historical mining operations, low level analysis of mercury in select water samples, comparison of mercury concentrations in Middle Creek and South Fork relative to background locations and locations representing discharge of water from the mine that would have the highest metals concentrations based on proximity to the mine, the frequency of detection, and limited available biota tissue data. Based on the evaluation of these multiple lines of evidence, mercury was not considered a mine-related COC because of its low concentrations and therefore not evaluated further. The primary reason mercury was retained throughout the RI as a COPC was because the original analytical method (EPA Contract Laboratory Program [CLP] Inorganics ILM05.4) detection limit (0.2 μg/L) was above the ESL (.012 μg/L ODEQ criterion continuous concentration [CCC]) for mercury. Utilizing the low level mercury analysis (EPA Method 1631E) enabled us to definitively screen mercury out as a COPC because the results showed mercury was present below the ESL in surface water. The maximum mercury concentration detected was 0.0036 μg/L.

Based on the screening, maximum detected concentrations of three metals in surface water exceeded one or both of the selected ESLs in both Middle Creek and South Fork. The surface water COCs retained for evaluation are:

- Cadmium
- Copper
- Zinc

Table 7.2-2 provides summary statistics for COCs in surface water, and the estimated EPCs that are evaluated in Section 7.2.7.2.

7.2.5 Exposure Assessment

7.2.5.1 Exposure Pathways and Receptors

The ERAs focused on complete and significant exposure pathways; a few potentially complete exposure pathways (e.g., inhalation of COCs and dietary risks to birds and mammals with large foraging ranges) are considered insignificant and were not evaluated. Bioaccumulation of some metals (e.g., cadmium) is a concern for upper trophic level receptors that forage within the Site for a significant duration and/or with sufficient frequency. Such risks are assessed by comparing exposure concentrations to soil screening levels based on bioaccumulation and dietary food web transfer to upper trophic level birds and mammals. Based on the COCs selected for aquatic receptors, food web modelling was not required. Exposure pathways and receptor groups evaluated in the ERAs are shown in Table 7.2-6.

7.2.6 Effects Assessment

7.2.6.1 Ecological Screening Levels for Surface Soil and Mine Materials

ESLs for surface soil and mine materials were compiled for terrestrial plants, soil invertebrates, birds, and mammals. The preferred ESL for all four receptor categories is the receptor-specific ecological soil screening level (Eco-SSL) (EPA 2008). Eco-SSLs for birds and mammals are based on dietary exposures (i.e., exposures via food ingestion) and do not consider direct contact exposures. Where Eco-SSLs have not been derived, alternative ESLs are selected. For terrestrial plants, Oak Ridge National Laboratory Benchmark for Terrestrial Plants (Efroymson et al. 1997a) were used. For soil invertebrates, Oak Ridge National Laboratory Benchmark for Soil and Litter Invertebrates (Efroymson et al. 1997b) were used.

Where none of these sources provides an acceptable ESL for a particular receptor category, alternative ESLs are selected from multiple sources. These sources include site-specific values from other mining-related projects, more general ESLs applicable to a wide range of receptor types or generally applicable to ecological receptors (but undefined), or ESLs recommended by EPA regions.

7.2.6.2 Ecological Screening Levels for Surface Water and Fish

Criteria used to evaluate risks for aquatic receptors include the Oregon Chronic water quality criteria (ODEQ 2013b) and the chronic EPA NRWQC (EPA 2013), adjusted for hardness where applicable. These values are based on aquatic toxicity tests that generate criteria intended to protect all or most forms of aquatic life. Exceedance of these water quality values suggests unacceptable risks to sensitive components of aquatic communities. Table 7.2-7 presents the hardness adjusted surface water criteria used to evaluate COCs in surface water.

In addition, trout or salmonid-specific toxicity reference values (TRVs) adjusted for hardness were used to estimate risks for resident or migratory salmonid fish that occur in or frequent surface waters in the EAs evaluated. Table 7.2-8 presents the salmonid-specific TRVs used to evaluate COCs in surface water.

7.2.7 Risk Characterization

Several lines of evidence are used to evaluate ecological risks in the ERAs. These lines of evidence include risk estimates (hazard quotients) and observations of populations (BMI and fish) and community structure.

Following EPA guidance, risk estimates based on direct exposure (direct contact and ingestion) to COC-contaminated media are quantified by comparing EPCs (e.g., either the 95 percent UCL, arithmetic mean, or the maximum detected concentration for small datasets) to one or more effects concentrations (e.g., Eco-SSLs, NRWQC, TRVs for salmonids). These comparisons result in the derivation of HQs, as shown below:

HQ = Exposure Point Concentration/Effects Concentration or TRV

HQs equal to or greater than 1 indicate the potential for an adverse effect to occur. Where neither the threshold nor the low effect TRV is exceeded, risks are deemed acceptable or so low they can be considered insignificant. Higher HQs are not necessarily indicative of more severe effects, but instead, where confidence in TRVs is equal, suggest a greater likelihood of adverse effects.

7.2.7.1 Risks to Terrestrial Receptors

The SLERA identified chemicals in surface and subsurface soils that occur at concentrations that may cause adverse effects to terrestrial wildlife and vegetation. However, habitats at the Site have been highly disturbed from past mine-related activities. The degree of disturbance has resulted in these habitats becoming less attractive and usable for resident and migratory wildlife. Because there is no foraging or nesting habitat within the PMDA, calculated risks are considered an overestimation of actual effects for terrestrial wildlife in the area. Table 7.2-9 shows what the HQs by COC, receptor, and exposure area would be if there were suitable habitat within the PMDA. However, there is no suitable habitat, so the risks to terrestrial receptors were considered acceptable (besides arsenic, which poses an unacceptable risk to workers through application of OAR) and therefore only COPCs with adverse risks to aquatic receptors are considered COCs at OU1.

7.2.7.2 Risks to Aquatic Life (General)

Surface water COC concentrations were compared to national and state water quality criteria. These comparisons resulted in the derivation of HQs, which provide quantitative estimates of risk to a diverse group of aquatic receptors, including aquatic plants, invertebrates, fish, and larval amphibians.

Based on chronic exposures to metals in surface water, HQs for Middle Creek exceed the threshold value of 1 for cadmium, copper, and zinc at MXR and for cadmium at M3.0. All HQs were below 1 for all sampling locations downstream in Middle Creek and for the MREF reference location. HQs for South Fork exceed 1 for cadmium, copper, and zinc at SF1.0 and for copper at SF3.0 based on chronic exposures. All HQs were below 1 for the SFREF reference location. Risks by EA for aquatic life are shown in Table 7.2-10.

7.2.7.3 Risks to Salmonid Fish

COC concentrations were compared to trout- or salmonid-specific TRVs. Exceedance of salmonid-specific TRVs suggests unacceptable risks to resident or migratory salmonid fish that occur in or frequent the surface waters of EAs evaluated in the BERA. HQs based on salmonid-specific TRVs exceed 1 for cadmium, copper, and zinc at MXR. For South Fork, HQs exceed 1 for cadmium, copper, and zinc at SF1.0. Risks by EA for salmonid fish are shown on Table 7.2-11.

7.2.7.4 Supporting Lines of Evidence

Fish Presence/Absence

Fish presence/absence surveys were conducted by EPA in Middle Creek and South Fork in June and September 2012 and June and September 2013. Ecological sampling locations include eight locations in Middle Creek, four in South Fork, and three reference locations (Martin Creek Reference, Middle Creek Reference, and South Fork Reference). Fish surveys were conducted using backpack electroshocking, focusing on pools at the same locations where BMI sampling was conducted.

A qualitative evaluation of fish presence/absence at multiple locations downstream of the mine was conducted based on the results of these surveys. This evaluation was qualitative because the numbers of fish observed during surveys conducted during previous investigations by BLM were not directly comparable to numbers observed during surveys conducted by EPA. Several fish sampling events were conducted by BLM and the Oregon Department of Fish and Wildlife from 1991 through 2007 (BLM 2009). Recent EPA data suggest that reaches of Middle Creek and South Fork Middle Creek vary in their current ability to support fish.

Findings of the EPA fish surveys indicate fish are abundant in Middle Creek at M3.0 and further downstream. Fish are present upstream of M3.0, at M1.2, and M2.0 but in lower numbers. In South Fork, fish are abundant at SF3.0 and further downstream. Fish are present in lower numbers upstream of SF3.0, at SF1.0.

Fish are abundant in the Martin Creek Reference and South Fork Reference locations. No fish were observed in MREF during any of the survey events (stream location was not flowing during September events). Fish abundance and species observed at the Martin Creek Reference location were similar to those at M3.0 and M3.1. Fish abundance and species observed at the South Fork Reference location were similar to those at SF3.0.

Compared to historical data (2000 through 2007), relative numbers of fish appear to be increasing in both Middle Creek and South Fork when considering M3.0 and SF3.0, which are the locations that have been sampled most consistently.

Benthic Macroinvertebrate Community Metrics

BMI surveys were conducted by EPA in Middle Creek and South Fork in June and September 2012 and June and September 2013. BMI sampling locations included the same locations used in the fish survey. Quantitative BMI community sampling from a known area (144 square inches) was conducted via Surber samplers in riffle habitat following standardized protocols at all sampling stations to allow for comparisons of BMI relative abundance and diversity.

BMI community metrics from locations potentially affected by mine-related contamination were compared to similar metrics from reference locations unaffected by mine-related contamination. This evaluation provided insight into integrated conditions (e.g., physical habitat suitability, sediment quality, and water quality) at specific instream locations. The recent data collected suggest that reaches of Middle Creek and South Fork Middle Creek vary in their ability to support BMI.

The total number of BMI organisms increased with distance from the mine in both Middle Creek and South Fork. In both creeks, the total number of organisms was reduced at sampling locations near the mine compared to reference locations. The total number of BMI taxa in Middle Creek increased with distance from the mine and was reduced at all or most locations compared to the reference location. In South Fork, the total number of BMI taxa compared to reference (SFREF location) was reduced at all locations. The single exception was SF1.0 in September 2012 where a higher number of BMI taxa were observed than at the SFREF location.

The number of BMI taxa considered sensitive to dissolved metals, also known as EPT taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], Trichoptera [caddisflies]) increased with distance from the mine in Middle Creek and was reduced at all or most locations compared to reference. In South Fork, the number of EPT taxa was reduced at all locations compared to reference.

Based on the ODEQ Predictive Assessment Tool for Oregon (PREDATOR, ODEQ 2008), Middle Creek shows an impaired condition in upstream locations, with a transition zone from M3.0 to M5.5 and a zone of recovery downstream of M5.5. South Fork shows an impaired condition at all locations.

Previous ecological investigations within the OU2 BERA study area have included BMI sampling at over 20 locations in 1999 by BLM and ODEQ (BLM/ODEQ 2000). Data obtained during this sampling event were compared to earlier sampling conducted by the USFWS in 1982 and 1984 and DOGAMI yearly from 1994 through 1997 (DOGAMI 1990-1999). Subsequent BMI community sampling was conducted by BLM from 2000 to 2008.

Compared to historical data (2000 through 2008), there are increasing trends in total taxa and EPT taxa in Middle Creek at the locations that have been consistently sampled. In South Fork, there is an increasing trend in total taxa and EPT taxa only at SF1.0. Although there is an apparent improvement in BMI metrics during the time period the RI was conducted, various factors likely influence this observation. Key among these factors is the fluctuation of precipitation over time. Over the last few years, the Site has been in a drought cycle; a wet year could result in increased leaching of COCs, resulting in increased impacts. Other events, such as the diversion pipe blowout in 2009, likely produced temporal impacts on the BMI community, and the gradual recovery of the BMI community likely contributes to observations made during the RI, suggesting increasing trends.

The total number of BMI and EPT taxa observed at Middle Creek, South Fork, and reference locations from 1999 to 2013 is shown in Tables 7.2-12, 7.2-13, and 7.2-14 respectively.

7.2.7.5 Ecological Significance

As discussed above, several chemicals in surface soils, Adit and nearby surface waters have been measured at concentrations exceeding ESLs intended as thresholds for adverse effects in terrestrial and aquatic ecological receptors. Exceedance of such thresholds does not equate to confirmation of ecologically significant adverse effects. Even very high HQs do not necessarily suggest adverse effects are inevitable. The potential for ecological receptors exposed to mining-related chemicals to suffer adverse effects related to survival, growth, or reproduction is based only partly on exposure concentration and associated HQs. Also important to consider are the following:

- <u>Receptor Behavior and Exposure</u> – Non-mobile receptors (e.g., terrestrial plants) and receptors with limited mobility (e.g., soil invertebrates) have an increased potential to suffer adverse effects because exposure to soil and mine materials is more likely for these organisms than highly mobile receptors and those with large foraging ranges.
- <u>Habitat Quality and Quantity</u> – Poor quality or disturbed habitat, such as that dominating the PMDA, is unlikely to support abundant and diverse ecological communities. A large amount of higher quality habitat is found adjacent to the PMDA, which probably results in exposures that are comparatively more infrequent and of shorter duration than those associated with offsite habitats.

- Chemical Concentration, Chemical Form, and Data Availability – Some of the elevated HQs associated with surface soil and mine materials do not consider the form of chemical likely occurring in surface soil and mine materials. Some chemicals are found in forms that reduce toxicity compared to the forms on which the ESLs are based. Other inorganic chemicals often occur in forms that are generally considered toxic or have reasonable potential to be toxic under commonly encountered conditions.

For these reasons, it is expected that arsenic, cadmium, copper, lead, and zinc are more ecologically significant (regardless of HQs) than chemicals that are less well-studied, those with low confidence ESLs, and those for which toxicity data are generally lacking. Copper (dissolved) is designated as the single most hazardous chemical for surface water downgradient of the PMDA. These chemicals can be viewed as risk drivers or chemicals with the greatest potential to cause or contribute to ecologically significant adverse effects in exposed receptors.

- Population vs. Individual Effects – Calculated HQs primarily reflect potential for adverse effects to individual organisms. In some cases, these HQs can infer potential for population level effects because effects underlying the ESLs include reduced survival or impaired reproduction, both of which can affect population status. Most HQs, however, are best viewed as indicating potential for adverse effects at the organism and not at the population or community level.

- Representative Receptors vs. Species of Concern – Calculated HQs and qualitative discussions of risk are based primarily on receptor categories (e.g., terrestrial plants) and not on any particular species. Threatened or endangered species, or species of special concern, are not evaluated individually because data are lacking to make such evaluations. It is reasonable, however, to conclude that special concern species have the potential to be adversely affected if risks to representatives of the receptor category are at risk. Whether a particular species is actually at risk because of exposure to site-related contamination is best considered from a likelihood of exposure viewpoint. For the most part, the PMDA does not provide habitat suitable for plant or animal species of special concern; however, aquatic resources downgradient of the PMDA do provide habitat for species of special concern.

7.2.8 Uncertainty Analysis

All ERAs have a degree of uncertainty because of necessary simplifications and assumptions that must be made as part of the evaluation. Uncertainty associated with exposure assessment, effects assessment, and risk characterization is summarized below.

Uncertainties Related to Exposure

Major sources of uncertainty in the exposure assessment include the values used to represent the magnitude and distribution of media-specific contamination. Obviously, all media cannot be sampled at all locations, and data interpolation and/or extrapolation is necessary. The most likely causes of uncertainty in the exposure portion of this assessment are the chemical concentrations selected as EPCs for risk estimation. Contaminants in soils are most often unevenly distributed, and there are uncertainties in the mean, maximum, and 95 percent UCL values derived from soil sampling. It is believed, however, that sufficient samples have been collected and appropriately analyzed to adequately describe the nature and extent of chemical contamination within terrestrial EAs of the Site.

Descriptions of the magnitude and distribution of COCs within the surface waters potentially impacted by the mine and the reference areas are considered generally to be representative of current conditions within those areas. In spite of the overall confidence in exposure data, some data are clearly biased toward times of the year when sampling is easiest or most desirable. For example, data collected during storm events are limited and may not represent the wide range of conditions that may be seen during such events. Specifically, recent flows, storm events, degree and location of upwelling of groundwater, and other factors can affect surface water metals concentrations and associated EPCs. These biases may, in various ways, affect the EPC calculations. However, the surface water data used in the BERA are considered representative of the long-term average or "most likely" conditions to which aquatic receptors are exposed.

Where potential levels of uncertainty could adversely affect the results of the assessment, conservative approaches were taken that may result in over-protection of some local species. For example, commonly applied exposure assumptions often lead to predictions of risk, especially where receptors with large foraging ranges are assumed to forage predominately on site. The foraging behavior of individual organisms and even populations is sufficiently unknown to warrant a more conservative or protective approach. To err on the side of over-protection is considered prudent and follows regulatory guidance. Therefore, risks to birds and mammals were evaluated even though exposures for most avian and mammalian receptors are likely to be minimal given the degraded terrestrial habitat at the PMDA and may be influenced by other variables such as bioavailability or pH.

Uncertainties Related to Effects

Toxicity data and other information providing the basis for the majority of accepted ESLs are commonly based on effects experienced by individual organisms under controlled laboratory conditions. There is, therefore, considerable concern regarding the ability of these data to reflect or predict population-level or community-level effects in the field. Adequate field data are lacking for most chemical stressors and receptor species, and laboratory-based data are therefore used and accepted in most cases to estimate effects in the field. Effects to individuals in the laboratory may or may not be representative of effects that may be seen in populations and communities in the field. ESLs are by design conservative values that likely overestimate risk when used as thresholds for adverse effects.

ESLs and TRVs for surface water are considered to be associated with low levels of uncertainty while soil ESLs are likely more uncertain. Eco-SSLs are assumed to be associated with low uncertainty for most receptor categories, especially those linked to direct contact exposures. Because site-specific effects or toxicity-based biological data are unavailable, a weight-of-evidence approach is used to assess potential for ecological effects. The ERAs relied on ESLs and TRVs from a large variety of appropriate and relevant data sources, which should decrease the overall uncertainty compared to assessments based on only one or a few data sources.

Uncertainties Related to Risk Characterization

By definition, uncertainties in risk characterization are influenced by uncertainties in exposure assessment and effects assessment. Uncertainties in exposure assessment are considered to be minimized by the extensive recent sampling and analysis of surface soil and surface water. Descriptions of the magnitude and distribution of COCs within the Site are considered to be reasonably representative of actual conditions to which ecological receptors may be exposed.

Specific areas of concern with regard to uncertainties include the lack of useful ESLs or other ecotoxicity data for certain potential chemical stressors, limited data for other chemical stressors, and the effect of exposure to multiple chemical stressors. For example, ecotoxicity data are lacking for several frequently detected metals in surface soil. The effect of cumulative risks or effects from exposure to multiple chemical stressors are another area of uncertainty in the ERA. It is generally assumed that risks from individual chemical stressors are additive. This assumption is based on limited data where the effects of exposures to multiple chemicals were investigated. The actual effect of exposure to multiple chemical stressors on ecological receptors is unknown because additive toxicity has not been confirmed for most chemical combinations.

Another potential source of uncertainty is the biological data collected to support the BERA. For example, natural differences in BMI metrics among varying stream habitat types, along with potential seasonal differences, may be important sources of uncertainty when drawing conclusions from these data.

Finally, the risk characterization method itself can contribute to uncertainties in the ERAs. These uncertainties are reduced by not relying only on a single EPC or receptor category. The simple HQ method of expressing risk is a useful approach that may not be appropriate for more complete investigations. The HQ method is, however, considered appropriate as a primary line of evidence. When supplemented by site-specific observations and general habitat descriptions, these quantitative and qualitative data support a multiple line of evidence approach that provides a more meaningful and realistic evaluation of ecological conditions within the Site.

7.2.9 Summary of Ecological Risks

7.2.9.1 Risks to Terrestrial Receptors

The SLERA identified several COCs (arsenic, cadmium, copper, lead, and zinc) in surface soil and mine materials occurring at elevated concentrations potentially linked to adverse effects in exposed terrestrial receptors (mammals, birds, plants, invertebrates). However, poor quality or disturbed habitat that dominates the PMDA does not support ecological receptors. The resulting estimated risks are likely an overestimation of actual effects for terrestrial wildlife in the area because there is no exposure due to lack of forage or nesting habitat that would result in exposure.

The PMDA covers approximately 25 acres of land. This area is dominated by mine materials, which result in habitats that are mostly unsuitable for wildlife. Wildlife associated with the fir-dominated forests of the area surrounding the Site will not find suitable habitats for either foraging or breeding. There are a few patches of good quality forest within the primary mine disturbance area, and the estimated acreage of these forest patches is less than a half-acre. Small patches of forest provide habitats for species that can adapt to the types and degrees of disturbance currently associated with the PMDA, but species dependent on contiguous fir forests would not be expected in these areas.

7.2.9.2 Risks to Aquatic Receptors

Based on the evaluations conducted in the BERA, there is an unacceptable risk to aquatic life from exposure to dissolved concentrations of cadmium, copper, and zinc in both Middle Creek and South Fork. In Middle Creek, risks from cadmium, copper, and zinc are considered unacceptable at MXR, and risks from cadmium extend downstream to M3.0. In South Fork, risks from cadmium, copper, and zinc are unacceptable at SF1.0, and risks from copper extend downstream to SF3.0. Although these risks cannot be attributed solely to mine-related materials, there is a reasonable expectation that mine soils are contributing to the adverse impacts identified for aquatic receptors.

Based on salmonid-specific TRVs, risks are unacceptable at MXR and SF1.0 due to cadmium, copper, and zinc. It should be noted that the culvert just downstream of MXR presents a barrier to fish under most if not all flow conditions.

Fish survey observations and BMI community metrics also indicate impairment in the upstream sampling locations in Middle Creek and South Fork. The findings of these investigations support the conclusion of potentially significant ecological risk to aquatic receptors from elevated metals concentrations in these surface waters.

7.3 Basis of Action

The response action selected for OU1 in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants into the environment. Such a release or threat of release may present an imminent and substantial endangerment to public health, welfare, or the environment. A response action is necessary for the Site because:

- Ecological Risk: Cadmium, copper, and zinc in soils leach into surface and groundwater, causing unacceptable risks to aquatic receptors. Risks to salmonids, trout, and aquatic invertebrates are unacceptable. The OU1 action is a source control action to prevent continued releases of COCs into the aquatic environment.

- Human Health Risk: Cancer risks associated with exposure to arsenic in soil exceed 1E-06, and arsenic concentrations in soil are above background. Arsenic contamination is found in soils associated with EA-3 and co-located with mine materials. Mine materials that contain co-located arsenic contamination will be addressed as part of the cleanup of mine materials in soils within EA-3.

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Section 7
Tables

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Table 7.1-1
Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations
Formosa Mine Superfund Site, Douglas County, Oregon

Scenario Timeframe:	Current / Future											
Medium:	Soil											
Exposure Medium:	Soil											
Exposure Point	**Exposure Area**	**Chemical of Concern**	**Concentration Detected**				**Units**	**Frequency of Detection**		**Exposure Point Concentration**	**Exposure Point Concentration Units**	**Statistical Measure**
			Min		Max							
Surface Soil	EA-1	Arsenic	0.4	J	778	J	ppm	50 /	50	105.7	ppm	95% UCL
	EA-2	Arsenic	1.030		23.47		ppm	11 /	11	15.7	ppm	95% UCL
	EA-3	Arsenic	247.0		576		ppm	5 /	5	576	ppm	MAX
Mixed Soil	EA-1	Arsenic	0.4	J	778	J	ppm	92 /	92	89.9	ppm	95% UCL

ppm : parts per million

95% UCL : 95% upper confidence limit

J : estimated value

Table 7.1-2
Summary of Exposure Assumptions
Formosa Mine Superfund Site, Douglas County, Oregon

Exposure Parameter	Unit	Current/Future Recreational Visitor[1] (Adult)	Current/Future Recreational Visitor[1] (Child 7-16 years)	Current/Future ATV Rider	Current/Future Worker[1]	Future Construction Worker	Current/Future Offsite Resident
		RME	RME	RME	RME	RME	RME
Incidental Soil Ingestion Rate	mg/day	100 [A]	100 [K]	100 [A]	100 [A]	330 [A]	NA
Fraction Ingested from Contaminated Source	unitless	1 [C]	1 [C]	1 [C]	1 [C]	1 [C]	NA
Exposure Frequency	days/year	14 [D]	14 [D]	14 [D]	40 [E]	250 [M]	350 [A,B]
Exposure Duration	years	30 [A]	10 [F]	30 [A]	25 [A]	1 [A]	30 [A]
Body Weight	kg	70 [A]	43 [G]	70 [A]	70 [A]	70 [A]	70 [A]
Averaging Time (cancer)	days	25,550 [H]	25,550 [H]	25,550 [H]	25,550 [H]	25,550 [H]	25,550 [H]
Averaging Time (noncancer)	days	10,950 [I]	3,650 [I]	10,950 [I]	9,125 [I]	365 [I]	10,950 [I]
Exposed Skin Area	cm^2	5,700 [J]	4,000 [J]	5,700 [J]	3,300 [A]	3,300 [A]	NA
Adherence Factor	mg/cm^2	0.07 [J]	0.3 [J]	0.07 [J]	0.2 [A]	0.3 [M]	NA
Particulate Emission Factor	m^3/kg	calculated [A]	calculated [A]	calculated [A]	calculated [A]	calculated [A]	calculated [A]
Exposure Time	hour/day	24 [L]	24 [L]	8 [L]	8 [L]	8 [L]	24 [L]

Acronyms and Abbreviations:
NA - not applicable, exposure pathway incomplete
cm - centimeter
EPA - United States Environmental Protection Agency
kg - kilograms
m - meter
mg - milligram

RME - Reasonable Maximum Exposure

Notes:
[1] Exposure assumptions for recreational visitors and outdoor workers based on personal communication with Karl Ford, BLM.
A: EPA 2002: Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24.
B: EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
C: Assumes all exposure comes from the contaminated areas
D: Recreational scenario based on recreational user participating in activities onsite for 2 weeks per year, RME
E: Based on site-specific information for forestry workers
F: Assumes adolescent (7 to 16 years in age) recreational scenario
G: EPA 1997: Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.
H: Averaging time (cancer) = (70 year lifetime * 365 days per year)
:I Averaging time (noncancer) = (exposure duration * 365 days per year)
J: EPA 2004: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005.
K: EPA 2008: Child Specific Exposure Factors Handbook. EPA 600/R-06/096F.
L: EPA 2009: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment. EPA-540-R-070-002.
M: ODEQ 2010. Human Health Risk Assessment Guidance.
N: Professional judgment
Exposure time for recreational visitors is conservatively assumed to be 24 hours per day based on the camper scenario.
ATV riders are assumed to ride for 8 hours per day

Table 7.1-3
Cancer Toxicity Data Summary
Formosa Mine Superfund Site, Douglas County, Oregon

Pathway: Ingestion, Dermal							
Chemical of Concern	**Oral Cancer Slope Factor**	**Oral Cancer Slope Factor Units**	**Dermal Cancer Slope Factor (1)**	**Dermal Cancer Slope Factor Units**	**Weight of Evidence/ Cancer Guideline Description**	**Source**	**Date (MM/DD/YY)**
Arsenic	1.5E+00	$(mg/kg/day)^{-1}$	1.5E+00	$(mg/kg/day)^{-1}$	A	IRIS	04/18/11
Pathway: Inhalation							
Chemical of Concern	**Unit Risk**	**Units**	**Inhalation Cancer Slope Factor**	**Units**	**Weight of Evidence /Cancer Guideline Description**	**Source**	**Date (MM/DD/YY)**
Arsenic	4.3E-03	$(\mu g/m^3)^{-1}$	1.5E+01	$(mg/kg/day)^{-1}$	A	IRIS	04/18/11

IRIS: Integrated Risk Information System, U.S. EPA
(1) The dermal Cancer Slope Factor was assumed to equal the oral Cancer Slope Factor. No adjustment factor was applied.
(2) IRIS values were confirmed against the EPA's online database, April 2011.
No changes as of April 2015

EPA Group::
A - Human Carcinogen
B1 - Probable human carcinogen - indicates that limited human data are available.
B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans.
C - Possible human carcinogen
D - Not classifiable as human carcinogen
E - Evidence of noncarcinogenicity

Table 7.1-4
Non-Cancer Toxicity Data Summary
Formosa Mine Superfund Site, Douglas County, Oregon

Chemical of Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Dermal RfD (1)	Dermal RfD Units	Primary Target Organ	Combined Uncertainty /Modifying Factors	Source of RfD: Target Organ(s)	Dates of RfD: Target Organ (MM/DD/YY) (2)
Pathway: Ingestion, Dermal									
Arsenic	Chronic/ Subchronic	3.0E-04	mg/kg/day	3.0E-04	mg/kg/day	Skin	3	IRIS	04/18/11
Pathway: Inhalation									
Chemical of Concern	**Chronic/ Subchronic**	**Inhalation RfC**	**Inhalation RfC Units**	**Inhalation RfD**	**Inhalation RfD Units**	**Primary Target Organ**	**Combined Uncertainty /Modifying Factors**	**Source of RfC: Target Organ(s)**	**Dates of RfD: Target Organ (MM/DD/YY)**
INORGANICs									
Arsenic	Chronic/ Subchronic	1.5E-05	mg/m^3	NA	NA	Development/ cardiovascular system/ CNS	30	CalEPA	04/18/11

mg/m^3 = milligrams per cubic meter
CNS = central nervous system

CalEPA - California Environmental Protection Agency
IRIS = Integrated Risk Information System
RfC = Reference concentration
RfD = Reference dose
NA = Not available
(1) The dermal RfD was assumed to equal the oral RfD, unless an adjustment factor was found in Exhibit 4.1 of EPA 2004c.
(2) IRIS values were confirmed against the EPA's online database, April 2011.
No changes as of April 2015
(8) The RfD_o value for mercuric chloride was used as a surrogate
(9) The RfD_o is for nickel, soluble salts
(10) The RfD_o is based on infant exposure
(11) The RfD_o is for Uranium soluble salts

Table 7.1-5
Risk Characterization Summary - Carcinogens
Formosa Mine Superfund Site, Douglas County, Oregon

Scenario Timeframe: Current and Future (Surface Soil) / Future (Mixed Soil)								
Exposure Area	**Exposure Medium**	**Exposure Point**	**Chemical of Concern**	**Receptor**	**Carcinogenic Risk**			
					Ingestion	**Inhalation**	**Dermal**	**Exposure Routes Total**
EA-1	Soil/Dust	Surface Soil	Arsenic	Worker	9.E-06	2.E-08	2.E-06	1.E-05
				Recreational Visitor (Adult)	4.E-06	3.E-08	5.E-07	4.E-06
				Recreational Visitor (Child 7 to 16 years old)	2.E-06	9.E-09	7.E-07	3.E-06
				ATV Rider	4.E-06	4.E-08	5.E-07	4.E-06
				Offsite Resident	NA	7.E-07	NA	7.E-07
	Soil/Dust	Mixed Soil	Arsenic	Worker	8.E-06	2.E-08	2.E-06	9.E-06
				Construction Worker	6.E-06	5.E-09	6.E-07	7.E-06
				Recreational Visitor (Adult)	3.E-06	2.E-08	4.E-07	4.E-06
				Recreational Visitor (Child 7 to 16 years old)	2.E-06	8.E-09	6.E-07	2.E-06
				ATV Rider	3.E-06	4.E-08	4.E-07	4.E-06
				Offsite Resident	NA	6.E-07	NA	6.E-07
EA-2	Soil/Dust	Surface Soil	Arsenic	Worker	1.E-06	3.E-09	3.E-07	2.E-06
				Recreational Visitor (Adult)	6.E-07	3.E-09	7.E-08	6.E-07
				Recreational Visitor (Child 7 to 16 years old)	3.E-07	1.E-09	1.E-07	4.E-07
				Offsite Resident	NA	8.E-08	NA	8.E-08
EA-3	Soil/Dust	Surface Soil	Arsenic	Worker	5.E-05	6.E-08	1.E-05	6.E-05
				Recreational Visitor (Adult)	2.E-05	8.E-08	2.E-06	2.E-05
				Recreational Visitor (Child 7 to 16 years old)	1.E-05	3.E-08	5.E-08	1.E-05
				Offsite Resident	NA	2.E-06	NA	2.E-06

N/A : Route of Exposure is not applicable to this medium

Table 7.1-6
Risk Characterization Summary - Non-Carcinogens
Formosa Mine Superfund Site, Douglas County, Oregon

Scenario Timeframe: Current and Future (Surface Soil) / Future (Mixed Soil)									
						Non-Carcinogenic Hazard Quotient			
Exposure Area	**Exposure Medium**	**Exposure Point**	**Chemical of Concern**	**Primary Target Organ**	**Receptor**	**Ingestion**	**Inhalation**	**Dermal**	**Exposure Routes Total**
EA-1	Soil/Dust	Surface Soil	Arsenic	Skin	Worker	5.5E-02	9.0E-04	1.1E-02	0.07
					Recreational Visitor (Adult)	1.9E-02	9.7E-04	2.3E-03	0.02
					Recreational Visitor (Child 7 to 16 years old)	3.1E-03	9.7E-04	1.1E-02	0.02
					ATV Rider	1.9E-02	1.6E-03	2.3E-03	0.02
					Offsite Resident	NA	2.4E-02	NA	0.02
	Soil/Dust	Mixed Soil	Arsenic	Skin	Worker	4.7E-02	7.8E-04	9.3E-03	0.06
					Construction Worker	9.7E-01	1.7E-05	8.7E-03	0.98
					Recreational Visitor (Adult)	1.6E-02	8.2E-04	2.0E-03	0.02
					Recreational Visitor (Child 7 to 16 years old)	2.7E-03	8.2E-04	9.6E-03	0.01
					ATV Rider	1.6E-02	3.9E-06	2.0E-03	0.02
					Offsite Resident	NA	6.0E-05	NA	0.00006
EA-2	Soil/Dust	Surface Soil	Arsenic	Skin	Worker	8.2E-03	1.1E-04	1.6E-03	0.01
					Recreational Visitor (Adult)	2.9E-03	1.2E-04	3.4E-04	0.003
					Recreational Visitor (Child 7 to 16 years old)	4.7E-03	1.2E-04	1.7E-03	0.01
					Offsite Resident	NA	3.0E-03	NA	0.003
EA-3	Soil/Dust	Surface Soil	Arsenic	Skin	Worker	3.0E-01	2.7E-03	6.0E-02	0.4
					Recreational Visitor (Adult)	1.1E-01	2.8E-03	1.3E-02	0.1
					Recreational Visitor (Child 7 to 16 years old)	1.7E-01	2.8E-03	6.2E-02	0.2
					Offsite Resident	NA	7.1E-02	NA	0.07

N/A : Route of Exposure is not applicable to this medium

Table 7.1-7
Summary of Cancer Risks and Non-Cancer Hazards
Formosa Mine Superfund Site, Douglas County, Oregon

Scenario Timeframe: Current and Future (Surface Soil) / Future (Mixed Soil)						
Exposure Area	**Exposure Medium**	**Exposure Point**	**Chemical of Concern**	**Receptor**	**Carcinogenic Risk**	**Non-Carcinogenic Hazard Index**
EA-1	Soil/Dust	Surface Soil	Arsenic	Worker	1.E-05	7.E-02
				Recreational Visitor (Adult)	4.E-06	2.E-02
				Recreational Visitor (Child 7 to 16 years old)	3.E-06	2.E-02
				ATV Rider	4.E-06	2.E-02
				Offsite Resident	7.E-07	2.E-02
	Soil/Dust	Mixed Soil	Arsenic	Worker	9.E-06	6.E-02
				Construction Worker	7.E-06	1.E+00
				Recreational Visitor (Adult)	4.E-06	2.E-02
				Recreational Visitor (Child 7 to 16 years old)	2.E-06	1.E-02
				ATV Rider	4.E-06	2.E-02
				Offsite Resident	6.E-07	6.E-05
EA-2	Soil/Dust	Surface Soil	Arsenic	Worker	2.E-06	1.E-02
				Recreational Visitor (Adult)	6.E-07	3.E-03
				Recreational Visitor (Child 7 to 16 years old)	4.E-07	7.E-03
				Offsite Resident	8.E-08	3.E-03
EA-3	Soil/Dust	Surface Soil	Arsenic	Worker	6.E-05	4.E-01
				Recreational Visitor (Adult)	2.E-05	1.E-01
				Recreational Visitor (Child 7 to 16 years old)	1.E-05	2.E-01
				Offsite Resident	2.E-06	7.E-02

N/A : Route of Exposure is not applicable to this medium

Table 7.2-1

Summary Statistics for Chemicals in Surface Soils Carried Forward in the BERA

Formosa Mine Superfund Site, Douglas County, Oregon

Exposure Area	Number of Samples	Chemical Concentration Range (mg/kg)															
		Arsenic				Cadmium				Copper				Zinc			
		Min	Mean	Max	95% UCL	Min	Mean	Max	95% UCL	Min	Mean	Max	95% UCL	Min	Mean	Max	95% UCL
EA-1	50	0.4 J	83	778 J	106	0.11	3	29	5	25	771	6,860 J	165	21.4	741	6,190 J	1013
EA-2 Decision Units (a)																	
Encapsulation Mound East Lower	3	--	22	25	NC	--	1	1	NC	--	258	267	NC	--	236	246	NC
Encapsulation Mound East Upper	3	--	18	21	NC	--	2	3	NC	--	306	326	NC	--	408	680	NC
Encapsulation Mound Southeast Lower	3	--	2	2	NC	--	0.6	0.7	NC	--	94	98	NC	--	206	215	NC
Encapsulation Mound Southeast Upper	3	--	3	3	NC	--	0.8	0.9	NC	--	147	158	NC	--	233	246	NC
Encapsulation Mound West Lower	3	--	1	1	NC	--	ND (0.5)	ND (0.5)	NC	--	34	36	NC	--	99	101	NC
Encapsulation Mound West Upper	3	--	2	2	NC	--	0.6	0.6	NC	--	72	75	NC	--	140	143	NC
Encapsulation Formosa Adit Lower	3	--	5	5	NC	--	0.8	0.9	NC	--	292	294	NC	--	191	196	NC
Encapsulation Formosa Adit Upper	3	--	4	4	NC	--	2	2	NC	--	291	299	NC	--	264	266	NC
Encapsulation Mound Drainage 1	3	--	1	1	NC	--	0.6	0.6	NC	--	58	59	NC	--	187	191	NC
Encapsulation Mound Drainage 2	3	--	7	19	NC	--	ND (0.5)	ND (0.5)	NC	--	47	48	NC	--	105	114	NC
Encapsulation Mound Silver Butte	3	--	24	27	NC	--	1	2	NC	--	195	205	NC	--	256	282	NC
EA-3	5	247	421	576	NC	0.038 J	0.19	0.28	NC	268	362	491	NC	63.7	148	211	NC
Klamath Mountains	(b)	12			NC	0.52			NC	110			NC	140			NC

Notes: 1 mg/kg is equal to 1 ppm

1 mg/kg is equal to 1 ppm

NC – not calculated

ND – not detected

(a) Values for EA-2 are from incremental sampling. Each replicate sample is comprised of 30 or more distinct subsamples; therefore, 95% UCL calculations are not necessary.

(b) Klamath Mountains regional values from ODEQ Fact Sheet *Background Levels of Metals in Soils for Cleanups* (March 2013)

Table 7.2-2

Summary of Chemicals of Concern for Surface Water Analytical Dissolved Results and Medium Specific Exposure Point Concentrations

Formosa Mine Superfund Site, Douglas County, Oregon

Exposure Area	COC	ODEQ CCC Screening Level	National CCC Screening Level	Frequency of Detection	Minimum Detected Conc. (µg/L)	Average Detected Conc. (µg/L)	Maximum Detected Conc. (µg/L)
Middle Creek (1)	Cadmium	0.3	0.3	11/15	0.24J	3.16	14.2
	Copper	12	9.2	14/15	3.3	63	530
	Zinc	121	121	15/15	10.7	504	3260
Middle Creek Reference (2)	Cadmium	0.3	0.3	0/1	ND	ND	ND
	Copper	12	9.2	1/1	0.53J	0.53J	0.53J
	Zinc	121	121	1/1	3.1	3.1	3.1
South Fork Middle Creek (3)	Cadmium	0.2	0.2	8/10	1	3.6	7.6
	Copper	12	6.96	10/10	3.4	58	285
	Zinc	92	92	10/10	58.8	580	2120
South Fork Middle Creek (4)	Cadmium	0.2	0.2	0/2	ND	ND	ND
	Copper	12	7	1/2	0.83J	0.83J	0.83J
	Zinc	92	92	2/2	1.9J	3.4	4.8

Notes:

(1) Locations included in the Middle Creek dataset are MXR, M3.0, M7.9, M13.0.

(2) Locations included in the Middle Creek Reference dataset are MREF

(3) Locations included in the South Fork Middle Creek dataset are SF1.0, SF3.0

4) Locations included in the South Fork Middle Creek Reference dataset are SFREF

J = value qualified by laboratory or data validator as estimated

ND = Not detected

Table 7.2-3
Wildlife and Plants Found at the Formosa Mine Superfund Site and Vicinity
Formosa Mine Superfund Site, Douglas County, Oregon

	Scientific Name	Observed?	Notes
Birds			
Band-tailed pigeon	*Patagioenas fasciata*	Yes	Listed as SC
Black-capped chickadee	*Poecile atricapilla*	Yes	
Bushtit	*Psaltriparus minimus*	Yes	
Common raven	*Corvus corax*	Yes	
Great-horned owl	*Bubo virginianus*	heard only	
Mountain quail	*Oreortyx pictus*	Yes	
Red-breasted nuthatch	*Sitta canadensis*	Yes	
Red-tailed hawk	*Buteo jamaicensis*	Yes	
Rufous hummingbird	*Selaphorus rufus*	Yes	
Northern Spotted Owl	*Strix occidentalis caurina*	No	Likely to occur and listed as CH FT
Steller's jay	*Cyanocitta stelleri*	Yes	
Turkey vulture	*Cathartes aura*	No	Likely to occur
Violet-green swallow	*Tachycineta thalassina*	Yes	
Western screetch owl	*Megascops kennicotti*	Yes	
Wrentit	*Chamaea fasciata*	heard only	
Mammals			
American black bear	*Ursus americanus*	Yes	
Bobcat	*Lynx rufus*	sign	
Mule (black-tailed) deer	*Odocoileus hemionus*	Yes	
Coyote	*Canis latrans*	sign	
Mountain lion	*Felis concolor*	No	likely to occur in low numbers
Roosevelt elk	*Cervus canadensis roosevelti*	sign	
Western gray squirrel	*Sciurus griseus*	Yes	
Woodrat	*Neotoma* sp.	Yes	
Fish			
Black crappie	*Pomoxis nigromaculatus*	No	likely to occur in lower watershed
Bluegill	*Lepomis macrochirus*	No	likely to occur in lower watershed
Brown bullhead	*Ameiurus nebulosus*	No	likely to occur in lower watershed
Chinook salmon	*Oncorhynchus tshawytscha*	?	likely to occur in lower watershed
Coarse-scale sucker	*Catostomus macrocheilus*	No	likely to occur in lower watershed
Coho salmon	*Oncorhynchus kisutch*	?	likely to occur in lower watershed
Cutthroat trout	*Oncorhynchus clarki*	No	likely to occur in lower watershed
Longnose dace	*Rhinichthys cataractae dulcis*	No	likely to occur in lower watershed
Pacific lamprey	*Lampetra tridentata*	No	likely to occur in lower watershed and listed as SC
Rainbow trout	*Oncorhynchus mykiss*	No	likely to occur in lower watershed
Redside shiner	*Richardsonius balteatus hydrophlox*	No	likely to occur in lower watershed
River lamprey	*Lampetra ayresi*	No	Likely to occur in lower watershed
Salmon	Unknown	Yes	Observed unknown salmonid during C1 sampling
Sculpin	*Cottus spp.*	No	likely to occur in lower watershed
Smallmouth bass	*Micropterus dolomieu*	No	likely to occur in lower watershed
Speckled dace	*Rhinichthys osculus*	No	likely to occur in lower watershed
Umpqua pikeminnow	*Ptychocheilus oregonensis*	No	likely to occur in lower watershed
Reptiles and Amphibians			
Common garter snake	*Thamnophis sirtalis*	No	likely to occur
Pacific giant salamander	*Dicamptodon ensatus*	No	likely to occur
Pacific chorus (tree) frog	*Pseudacris regilla*	No	likely to occur
Rough-skinned newt	*Taricha granulosa*	Yes	
Western fence lizard	*Sceloporus occidentalis*	Yes	
Western skink	*Eumeces skiltonianus*	Yes	hibernaculum found during MIS sampling
Invertebrates			
Benthic invertebrates	Multiple Taxa	Yes	
Ground beetle	Family Carabidae	Yes	
Lorquin's admiral butterfly	*Limenitis lorquini*	Yes	
Water striders (skimmers)	Family Gerridae	Yes	
Yellow-spotted millipede	*Harpaphe haydeniana*	Yes	

Table 7.2-3
Wildlife and Plants Found at the Formosa Mine Superfund Site and Vicinity
Formosa Mine Superfund Site, Douglas County, Oregon

	Scientific Name	Observed?	Notes
Trees			
Bigleaf maple	*Acer macrophyllum*	Yes	
Black cottonwood	*Populus trichocarpa*	Yes	
California black oak	*Quercus kelloggii*	Yes	
Canyon live oak	*Quercus chrysolepis*	Yes	
Douglas fir	*Pseudotsuga menziesii*	Yes	
Golden chinkapin	*Chrysolepis chrysophylla*	Yes	
Incense cedar	*Calocedrus decurrens*	Yes	
Jeffrey pine	*Pinus jeffreyi*	Yes	
Oregon ash	*Fraxinus latifolia*	Yes	
Oregon myrtle	*Umbellularia californica*	Yes	
Oregon white oak	*Quercus garryana*	Yes	
Ponderosa pine	*Pinus ponderosa*	Yes	
Pacific madrone	*Arbutus menziesii*	Yes	
Red alder	*Alnus rubra*	Yes	
Sugar pine	*Pinus lambertiana*	Yes	
Tan oak	*Lithocarpus densiflorus*	Yes	
Vine maple	*Acer circinatum*	Yes	
Western hemlock	*Tsuga heterophylla*	Yes	
Western redcedar	*Thuja plicata*	Yes	
Western white pine	*Pinus monticola*	Yes	
Willow	*Salix* sp.	Yes	
Shrubs			
Manzanita	*Arctostaphylos* sp.	Yes	
Oregon grape	*Mahonia aquifolium*	Yes	
Western poison oak	*Toxicodendron diversilobum*	Yes	
Salal	*Gaultheria shallon*	Yes	
Western sword fern	*Polystichum munitum*	Yes	
Thimbleberry	*Rubus parviflorus*	Yes	
Wedgeleaf ceanothus	*Ceanothus cuneatus*	Yes	

Table 7.2-4
Species Whose Range Includes the Formosa Mine Superfund Site, from Atlas of Oregon Wildlife (Csuti et al. 1997)
Formosa Mine Superfund Site, Douglas County, Oregon

Salamanders	Flammulated owl	***Mammals (not including Bats)***
Northwestern salamander	Western screech owl	**Dusky-footed woodrat**
Long-toed salamander	Great horned owl	Bushy tailed woodrat
Pacific giant salamander	Northern spotted owl	**Western red-backed vole**
Clouded salamander	Northern pygmy owl	Red tree vole (arboreal)
Ensatina salamander	Barred owl	White footed vole
Dunn’s salamander	Northern saw whet owl	**Townsend's vole**
Del Norte salamander	***Corvid (jays/crows/ravens)***	Long-tailed vole
Western red-backed salamander	Bewicks wren- 5 acre home range	Creeping vole
Rough skinned newt	House wren	Muskrat
Frogs	Winter wren	Pacific jumping mouse
Western toad	Marsh wren	Lizard porcupine
Pacific chorus frog	Dipper	Coyote
Tailed frog	Swanson’s thrush	Red fox and gray fox
Red legged frog	Hermit Thrush	Black bear
Foothills yellow frog	**American Robin**	Ringtail and raccoon
Reptiles	**Varied thrush**	Martin
Western pond turtle	Green-tailed towhee	Fisher
Northern alligator lizard	**Spotted Towhee**	**Ermine**
Southern alligator lizard	**Dark-eyed junco**	Long-tailed weasel
Sagebrush lizard	***Mammals (not including Bats)***	Mink
Western fence lizard	**Vagrant shrew**	**Western spotted skunk**
Western skink	Towbridges shrew	Striped skunk
Rubber boa	**Shrew-mole**	Bobcat
Racer	**Townsends mole**	Mountain lion
Sharptail snake	Coast mole	***Bats***
Ringneck snake	Broad footed mole	California myotis
Common kingsnake	Brush rabbit	Yuma myotis
Pacific gopher snake	Snowshoe hare	Little brown myotis
Garter snake	Mountain beaver	Long-legged myotis
Western rattlesnake	Townsends chipmunk	Long-eared myotis
Birds (with most likely exposure)	Calififornia ground squirrel	Silver haired bat
Ring necked pheasant (introduced)	Golden mantled ground squirrel	Big brown bat
Blue grouse	Western gray squirrel	Hoary bat
Ruffed grouse	Douglas squirrel	Townsends big eared bat
Wild turkey (introduced)	Northern flying squirrel	Pallid bat
California quail	Western pocket gopher	
Mountain quail	Botta’s pocket gopher	
Band tailed pigeon	American beaver	
Mourning dove	Deer mouse	
Barn owl		

***Bold - Bold indicates possible receptors for terrestrial risk assessment for OU1 (J.Buck, USFWS)**

Table 7.2-5
Federally Listed, Candidate Species, and Species of Concern Under the Jurisdiction of the U.S. Fish and Wildlife Service (USFWS) Which May Occur within Douglas County, Oregon [1]
Formosa Mine Superfund Site, Douglas County, Oregon

	Latin name	Listing Status	Potential to Occur[2]
Birds			
Acorn woodpecker	*Melanerpes formicivorus*	SC	Low
American Peregrine falcon	*Falco peregrinus anatum*	DL	Low
Bald eagle	*Haliaeetus leucocephalus*	DL	Low
Band-tailed pigeon	*Patagioenas fasciata*	SC	High
Black oystercatcher	*Haematopus bachmani*	SC	None
Brown pelican	*Pelecanus occidentalis*	DL	None
Harlequin duck	*Histrionicus histrionicus*	SC	Low
Lewis' woodpecker	*Melanerpes lewis*	SC	Low
Marbled murrelet	*Brachyramphus marmoratus*	CH FT	Low
Mountain quail	*Oreortyx pictus*	SC	High
Northern goshawk	*Accipiter gentilis*	SC	Moderate
Northern spotted owl	*Strix occidentalis caurina*	CH FT	High
Olive-sided flycatcher	*Contopus cooperi*	SC	Moderate
Oregon vesper sparrow	*Pooecetes gramineus affinis*	SC	Low
Purple martin	*Progne subis*	SC	Low
Short-tailed albatross	*Phoebastria albatrus*	FE	None
Western burrowing owl	*Athene cunicularia hypugaea*	SC	None
Western snowy (coastal) plover	*Charadrius alexandrinus nivosus*	CH FT	None
White-headed woodpecker	*Picoides albolarvatus*	SC	Low
Yellow-breasted chat	*Icteria virens*	SC	Low
Mammals			
Fisher	*Martes pennanti*	Candidate	Moderate
Fringed myotis bat	*Myotis thysanodes*	SC	Moderate
Long-eared myotis bat	*Myotis evotis*	SC	Moderate
Long-legged myotis bat	*Myotis volans*	SC	Moderate
North American wolverine	*Gulo gulo luteus*	Candidate	#N/A
Pallid bat	*Antrozous pallidus pacificus*	SC	Low
Red tree vole	*Arborimus longicaudus*	SC	Moderate
Silver-haired bat	*Lasionycteris noctivagans*	SC	Moderate
Small-footed myotis bat	*Myotis ciliolabrum*	SC	Moderate
Townsend's western big-eared bat	*Corynorhinus townsendii townsendii*	SC	Moderate
White-footed vole	*Arborimus albipes*	SC	Moderate
Yuma myotis bat	*Myotis yumanensis*	SC	Moderate
Fish			
Coastal cutthroat trout	*Oncorhynchus clarki ssp.*	SC	High
Millicoma dace	*Rhinichthys cataractae ssp.*	SC	Moderate
Oregon Coast coho salmon	*Oncorhynchus kisutch*	CH FT	High
Oregon Coast steelhead	*Oncorhynchus mykiss*	SC	High
Pacific lamprey	*Lampetra tridentata*	SC	Low
River lamprey	*Lampetra ayresi*	SC	Moderate
Umpqua chub	*Oregonichthys kalawatseti*	SC	Moderate

Definitions:

Listed Species - An endangered species is one that is in danger of extinction throughout all or a significant portion of its range.
Threatened species - One that is likely to become endangered in the foreseeable future.
Candidate Species - Taxa for which the USFWS has sufficient biological information to support a proposal to list as endangered or
Species of Concern - Taxa whose conservation status is of concern to the USFWS (many previously known as Category 2 candidates), but for
Delisted Species - A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

Key:

FE - Federally Endangered
FT - Federally Threatened
CH - Critical Habitat has been designated for this species
DL - Federally Delisted
SC - Species of Concern

[1] United States Fish and Wildlife Service (USFWS). 2011. Federally Listed, Proposed, Candidate Species and Species of Concern under the
[2] Potential to occur based on range and habitats present at the Site. Shading indicates High potential to occur based on field observations

Table 7.2-5
Federally Listed, Candidate Species, and Species of Concern Under the Jurisdiction of the U.S. Fish and Wildlife Service (USFWS) Which May Occur within Douglas County, Oregon [1]
Formosa Mine Superfund Site, Douglas County, Oregon

	Latin name	Listing Status	Potential to Occur[2]
Reptiles and Amphibians			
California mountain kingsnake	*Lampropeltis zonata*	SC	Moderate
Cascades frog	*Rana cascadae*	SC	Moderate
Coastal tailed frog	*Ascaphus truei*	SC	Moderate
Common kingsnake	*Lampropeltis getula*	SC	Moderate
Del Norte salamander	*Plethodon elongatus*	SC	Low
Foothill yellow-legged frog	*Rana boylii*	SC	Moderate
Green sea turtle	*Chelonia mydas*	FT	None
Leatherback sea turtle	*Dermochelys coriacea*	FE	None
Loggerhead sea turtle	*Caretta caretta*	FE	None
Northern Pacific pond turtle	*Actinemys marmorata marmorata*	SC	Low
Northern red-legged frog	*Rana aurora aurora*	SC	Low
Olive (=Pacific) ridley sea turtle	*Lepidochelys olivacea*	FT	None
Oregon slender salamander	*Batrachoseps wrighti*	SC	Moderate
Southern torrent (seep) salamander	*Rhyacotriton variegatus*	SC	Moderate
Invertebrates			
Cascades apatanian caddisfly	*Apatania tavala*	SC	Moderate
Franklin's bumblebee	*Bombus franklini*	SC	Moderate
Mt. Hood primitive brachycentrid caddisfly	*Eobrachycentrus gelidae*	SC	Low
Tombstone Prairie farulan caddisfly	*Farula reaperi*	SC	Low
Sagehen Creek goeracean caddisfly	*Goeracea oregona*	SC	Low
Plants			
Bensoniella	*Bensoniella oregona*	SC	Moderate
Cliff paintbrush	*Castilleja rupicola*	SC	Moderate
Clustered lady's-slipper	*Cypripedium fasciculatum*	SC	Low
Cox's mariposa lily	*Calochortus coxii*	SC	Moderate
Fragrant kalmiopsis	*Kalmiopsis fragrans*	SC	Low
Frye's Limbella	*Limbella fryei*	SC	Low
Gasquet manzanita	*Arctostaphylos hispidula*	SC	Moderate
Gentner's fritillary	*Fritillaria gentneri*	FE	Low
Henderson's checker-mallow	*Sidalcea hendersonii*	SC	Low
Hitchcock's blue-eyed grass	*Sisyrinchium hitchcockii*	SC	Moderate
Kincaid's lupine	*Lupinus sulphureus ssp. kincaidii*	CH FT	Low
Koehler's rock-cress	*Arabis koehleri var. koehleri*	SC	Moderate
Pink sand-verbena	*Abronia umbellata ssp. breviflora*	SC	Low
Red-root yampah	*Perideridia erythrorhiza*	SC	Low
Rough popcornflower	*Plagiobothrys hirtus*	FE	Low
Shaggy horkelia	*Horkelia congesta ssp. congesta*	SC	Moderate
Thin leaved peavine	*Lathyrus holochlorus*	SC	Moderate
Umpqua mariposa-lily	*Calochortus umpquaensis*	SC	Low
Wayside aster	*Eucephalus vialis*	SC	Low
Whitebark pine	*Pinus albicaulis*	FC	Low
White meconella	*Meconella oregana*	SC	Moderate

Definitions:
Listed Species - An endangered species is one that is in danger of extinction throughout all or a significant portion of its range.
Threatened species - One that is likely to become endangered in the foreseeable future.
Candidate Species - Taxa for which the USFWS has sufficient biological information to support a proposal to list as endangered or
Species of Concern - Taxa whose conservation status is of concern to the USFWS (many previously known as Category 2 candidates), but for
Delisted Species - A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

Key:
FE - Federally Endangered
FT - Federally Threatened
CH - Critical Habitat has been designated for this species
DL - Federally Delisted
SC - Species of Concern

[1] United States Fish and Wildlife Service (USFWS). 2011. Federally Listed, Proposed, Candidate Species and Species of Concern under the

Table 7.2-6
Ecological Exposure Pathways of Concern
Formosa Mine Superfund Site, Douglas County, Oregon

Exposure Medium	Receptor	Exposure Routes	Assessment Endpoints	Measurements Endpoints
Soil	Terrestrial invertebrates	Ingestion/direct contact with chemicals in soil	Establishment and maintenance of healthy and diverse aquatic and riparian ecosystems	Comparison of EA specific chemical concentrations in soil to toxicity screening benchmarks for terrestrial receptors
	Terrestrial amphibians and reptiles		Protection of terrestrial amphibians (e.g., toads) and reptiles from the toxic effects (on survival, growth, or reproduction) of site-related chemicals present in surface soil	
	Soil-associated birds	Ingestion/direct contact with chemicals in soil, dietary[1]	Protection of omnivorous, herbivorous, invertivorous, and carnivorous avian receptors with small foraging ranges from the toxic effects (on survival, growth, or reproduction) of site-related chemicals present in prey (e.g., earthworms) and soil. This assessment endpoint also considers certain species of special concern, including individual northern spotted owls, based on the assumption that protection of species with small foraging ranges ensures protection of other species with larger foraging ranges	
	Small mammals	Ingestion/ inhalation[2]/ direct contact with chemicals in soil/dietary[1]	Protection of herbivorous, omnivorous, and insectivorous mammalian receptors with small foraging ranges (e.g., cottontail, deer mouse, and shrew) from the toxic effects (on survival, growth, or reproduction) of site-related chemicals present in food items and soil	
	Terrestrial plants	Direct contact/ uptake of chemicals via root systems	Protection of terrestrial plants (including individuals of special status species) and soil associated invertebrate communities from the toxic effects (on survival, growth, or reproduction) of site-related chemicals present in surface soil	
Surface Water/ Sediment	Benthic organisms	Direct contact/ ingestion	Protection of water-column and benthic invertebrate receptors from the toxic effects (on survival, growth, and reproduction) of site-related chemicals present in sediment and surface water	State and Federal Water Quality Criteria Contaminant concentration in surface water, abundance and
	Aquatic invertebrates			
	Fish		Protection of fish from the toxic effects (on survival, growth, and reproduction) of site-related chemicals present in surface water	State and Federal Water Quality Criteria Contaminant concentration in surface water, fish presence/absence
	Laval amphibians		Protection of larval amphibians from the toxic effects (on survival, growth, and reproduction) of site-related chemicals present in sediment and surface water	State and Federal Water Quality Criteria Contaminant concentration in surface water
	Aquatic plants	Direct contact/ uptake		
	Terrestrial Receptors	Drinking surface water/ consuming aquatic biota	Qualitative Evaluation	Not applicable
Prey	Upper trophic receptors	Ingestion/ bioaccumulation	Protection of insectivorous, piscivorous, and carnivorous avian receptors (e.g., belted kingfisher) and omnivorous and piscivorous mammalian receptors (e.g., raccoon and mink) from the toxic effects (on survival, growth, and reproduction) of site-related chemicals present in prey, sediment, and surface water.	Qualitative Evaluation

[1] Site related dietary risks for bird and mammals with large foraging ranges were not quantified because the Site is relatively small in comparison to the large amc

[2] Inhalation exposures were considered insignificant and therefore not quantified.

Table 7.2-7
Summary of Aquatic Life Screening Criteria
Formosa Mine Superfund Site, Douglas County, Oregon

Exposure Area	Middle Creek		South Fork Middle Creek	
COC	ODEQ CCC (µg/L)	National Criteria (µg/L)	ODEQ CCC (µg/L)	National Criteria (µg/L)
Cadmium	0.25	0.25	0.2	0.2
Copper	12	9.18	12	6.96
Zinc	121.09	121.09	92.03	92.03

Table 7.2-8
Summary of Chronic Surface Water Toxicity Reference Values – Hardness–Adjusted by Exposure Area
Formosa Mine Superfund Site, Douglas County, Oregon

COC	Original Toxicity Reference Value (TRV)	Middle Creek	Middle Creek Reference	South Fork Middle Creek	South Fork Middle Creek Reference
	Hardness in $CaCO_3$/L				
	100	103	51	74	57
	TRV (µg/L)				
Cadmium	3.45	4	2	3	2
Copper-dissolved	22	22	15	18	16
Zinc-dissolved	752	772	416	577	459

$CaCO_3$ = calcium carbonate

Table 7.2-9
Summary of Hazard Quotients for Terrestrial Receptors
Formosa Mine Superfund Site, Douglas County, Oregon

Terrestrial Exposure Area	COPC	Hazard Quotients By Receptor Group			
		Plants	Soil Invertebrates	Birds	Mammals
EA-1	Arsenic	6	2	3	2
	Cadmium	<1	<1	7	14
	Copper	14	13	36	21
	Lead	1	<1	15	3
	Mercury	11	33	--	--
	Nickel	5	<1	<1	1
	Selenium	5	<1	2	4
	Zinc	6	8	22	13
EA-2 (Maximum HQs of all DUs)	Cadmium	<1	<1	2	5
	Copper	4	4	11	6
	Manganese	7	4	<1	<1
	Zinc	3	3	9	5
EA-3	Arsenic	23	72	10	9
	Copper	5	5	13	7
	Zinc	<1	1	3	2

Table 7.2-10

Chronic Hazard Quotients for Aquatic Receptors

Formosa Mine Superfund Site, Douglas County, Oregon

COC	National CCC Criteria (µg/L)	EPC	HQ	EPC	HQ	EPC	HQ	EPC	HQ
Middle Creek Exposure Area									
		Hazard Quotients Based on Mean Concentrations							
	Location	**MXR**		**M3.0**		**M7.9**		**M13.0**	
Cadmium	0.25	8	**34**	1	**3**	ND	--	0.2	1
Copper	9.18	236	**26**	7	<1	4	<1	5	<1
Zinc	121.09	1851	**15**	100	<1	30	<1	36	<1
		Hazard Quotients Based on Maximum Detected Concentrations							
Cadmium	0.25	14	**57**	1	**3**	ND	--	0.2	1
Copper	9.18	530	**58**	8	<1	4	<1	5	<1
Zinc	121.09	3260	**27**	101	<1	35	<1	49	<1
South Fork Middle Creek Exposure Area									
		Hazard Quotients Based on Mean Concentrations				**Hazard Quotients Based on Maximum Detected Concentrations**			
	Location	**SF1.0**		**SF 3.0**		**SF1.0**		**SF 3.0**	
Cadmium	0.2	4	**18**	ND	--	8	**38**	ND	--
Copper	6.96	108	**16**	7	1	285	**41**	11	**2**
Zinc	92.03	1087	**12**	72	<1	2120	**23**	86	<1

Bold Indicates the HQ is above the threshold value of 1

Table 7.2-11

Salmonid Specific Hazard Quotients

Formosa Mine Superfund Site, Douglas County, Oregon

COC	TRV	EPC	HQ	EPC	HQ	EPC	HQ	EPC	HQ
Middle Creek Exposure Area									
		HQs Based on Mean Concentrations							
	Location	**MXR**		**M3.0**		**M7.9**		**M13.0**	
Cadmium	4	8	**2**	1	<1	ND	--	0.2	<1
Copper	22	236	**11**	7	<1	4	<1	5	<1
Zinc	772	1851	**2**	100	<1	30	<1	36	<1
		HQs Based on Maximum Detected Concentrations							
Cadmium	4	14	**4**	1	<1	ND	--	0.2	<1
Copper	22	530	**24**	8	<1	4	<1	5	<1
Zinc	772	3260	**4**	101	<1	35	<1	49	<1
South Fork Middle Creek Exposure Area									
		HQs Based on Mean Concentrations				**HQs Based on Maximum Detected Concentrations**			
	Location	**SF1.0**		**SF 3.0**		**SF1.0**		**SF 3.0**	
COC	**TRV**	**EPC**	**HQ**	**EPC**	**HQ**	**EPC**	**HQ**	**EPC**	**HQ**
Cadmium	3	4	**1**	ND	--	8	**3**	ND	--
Copper	18	108	**6**	7	<1	285	**16**	11	<1
Zinc	577	1087	**2**	72	<1	2120	**4**	86	<1

Bold Indicates the HQ is above the threshold value of 1

Table 7.2-12
Benthic Macroinvertebrate Community Numbers at Middle Creek Sampling Locations
Formosa Mine Superfund Site, Douglas County, Oregon

Total Number of BMI Taxa at Middle Creek Sampling Locations								
Date	**M1.2**	**M2.0**	**M3.0**	**M3.1**	**M5.5**	**M7.9**	**M9.8**	**M13**
Jun-99	NS	NS	4	7	NS	12	15	17
Oct-99	NS	NS	11	14	NS	20	17	23
Jul-00	NS	NS	10	9	NS	19	18	17
Jul-01	NS	NS	10	15	NS	15	16	20
Oct-01	NS	NS	13	11	NS	19	14	14
Jul-02	NS	NS	12	10	NS	14	17	16
Nov-02	NS	NS	8	13	NS	15	21	10
Jun-07	NS	NS	13	11	19	22	24	NS
Jul-08	NS	NS	10	24	NS	37	47	NS
Jun-12 (EPA)	12	18	19	16	27	26	25	21
Sep-12 (EPA)	16	17	21	23	NS	28	NS	NS
Jun-13 (EPA)	10	14	15	16	NS	27	NS	NS
Total Number of EPT Taxa at Middle Creek Sampling Locations								
Date	**M1.2**	**M2.0**	**M3.0**	**M3.1**	**M5.5**	**M7.9**	**M9.8**	**M13**
Jun-99	NS	NS	1	4	NS	7	10	11
Oct-99	NS	NS	7	10	NS	12	12	12
Jul-00	NS	NS	4	5	NS	11	12	12
Jul-01	NS	NS	6	10	NS	10	11	13
Oct-01	NS	NS	9	8	NS	10	8	8
Jul-02	NS	NS	8	7	NS	9	11	9
Nov-02	NS	NS	7	8	NS	10	16	8
Jun-07	NS	NS	7	8	14	14	15	NS
Jul-08	NS	NS	1	12	NS	19	20	NS
Jun-12 (EPA)	5	7	11	7	15	14	13	11
Sep-12 (EPA)	6	10	12	12	NS	16	NS	NS
Jun-13 (EPA)	3	7	6	6	NS	17	NS	NS

Table 7.2-13
Benthic Macroinvertebrate Numbers at South Fork Middle Creek Sampling Locations
Formosa Mine Superfund Site, Douglas County, Oregon

Total Number of BMI Taxa at South Fork Middle Creek Sampling Locations					
Date	**SF0.7**	**SF1.0**	**SF1.7**	**SF3.0**	**SF4.7**
Jun-99	NS	0	1	4	8
Oct-99	NS	4	5	12	13
Jul-00	NS	2	5	14	11
Jul-01	NS	0	11	10	14
Oct-01	NS	6	8	13	12
Jul-02	NS	0	6	8	8
Nov-02	NS	1	10	10	11
Jun-07	NS	NS	NS	6	8
Jun-12 (EPA)	6	16	NS	12	16
Sep-12 (EPA)	NS	29	NS	18	NS
Jun-13 (EPA)	NS	13	NS	9	NS

Total Number of EPT Taxa at South Fork Middle Creek Sampling Locations					
Date	**SF0.7**	**SF1.0**	**SF1.7**	**SF3.0**	**SF4.7**
Jun-99	NS	0	0	2	4
Oct-99	NS	2	4	6	8
Jul-00	NS	1	2	7	6
Jul-01	NS	0	4	6	10
Oct-01	NS	3	7	9	9
Jul-02	NS	0	4	6	6
Nov-02	NS	1	8	7	8
Jun-07	NS	NS	NS	4	5
Jun-12 (EPA)	1	4	NS	4	9
Sep-12 (EPA)	NS	12	NS	10	NS
Jun-13 (EPA)	NS	5	NS	4	NS

Table 7.2-14
Benthic Macroinvertebrate Numbers at Reference Sampling Locations
Formosa Mine Superfund Site, Douglas County, Oregon

Total Number of BMI Taxa at Reference Sampling Locations			
Date	**Martin Creek REF**	**MREF**	**SFREF**
Jun-99	NS	28	27
Oct-99	NS	32	33
Jul-00	NS	29	26
Jul-01	NS	31	32
Oct-01	NS	31	30
Jul-02	NS	25	23
Nov-02	NS	30	25
Jun-07	36	NS	NS
Jul-08	54	NS	NS
Jun-12 (EPA)	30	38	36
Sep-12 (EPA)	36	NS	24
Jun-13 (EPA)	32	38	27

Total Number of EPT Taxa at Reference Sampling Locations			
Date	**Martin Creek REF**	**MREF**	**SFREF**
Jun-99	NS	20	19
Oct-99	NS	19	22
Jul-00	NS	18	18
Jul-01	NS	20	22
Oct-01	NS	20	19
Jul-02	NS	15	23
Nov-02	NS	19	19
Jun-07	22	NS	NS
Jul-08	26	NS	NS
Jun-12 (EPA)	15	20	20
Sep-12 (EPA)	19	NS	9
Jun-13 (EPA)	19	20	13

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Section 7
Figures

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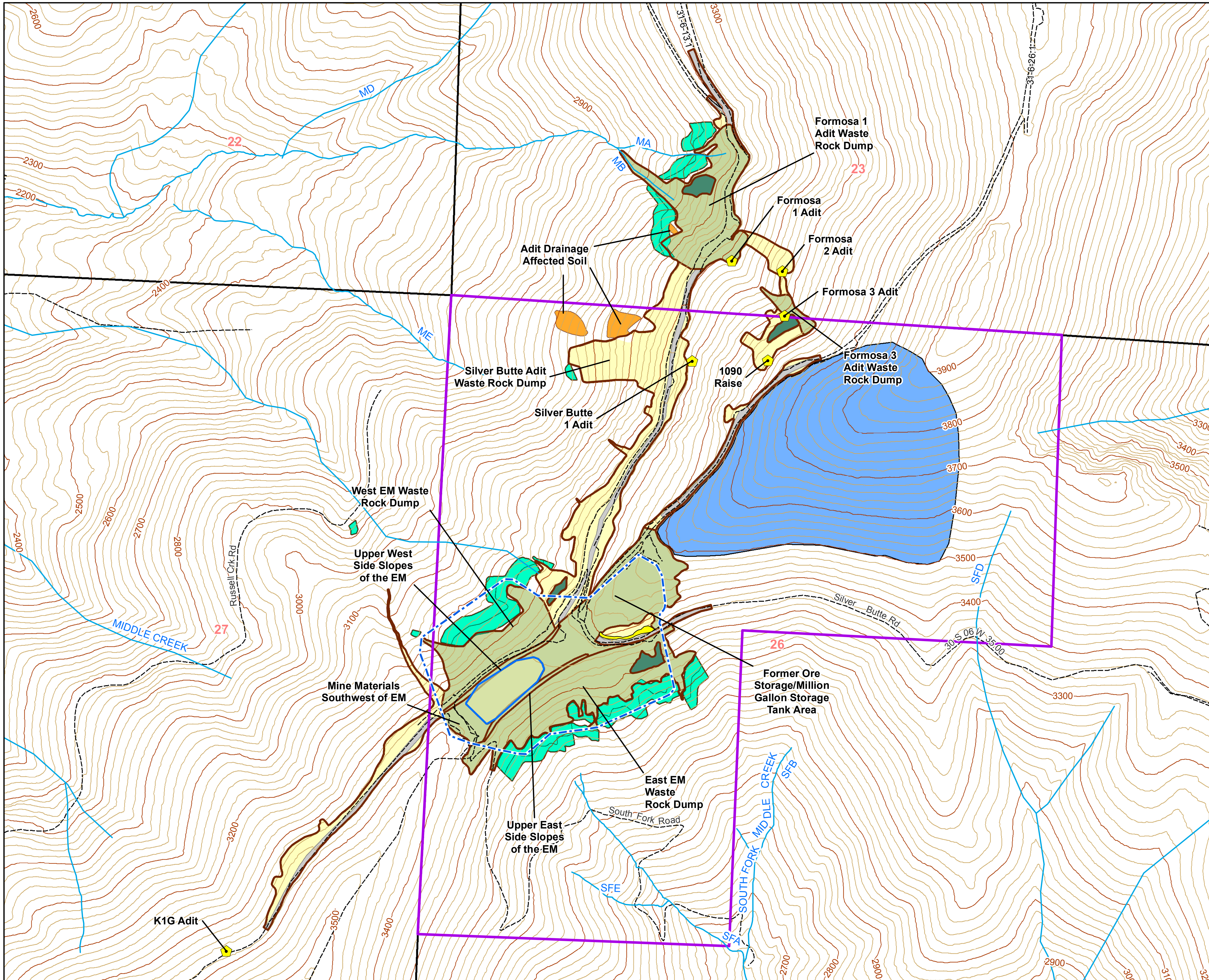

Legend

- Adit
- Primary Mine Disturbance Area (EA-1)
- Downslope Soils (EA-2)
- Acid Drainage Affected Soil (EA-3), to be excavated
- ARD Generating Bedrock Outcrops
- Unaffected Area (no visible mine waste)
- Approximate Extent of Exposure Barriers
- Approximate Extent of Excavations
- Encapsulation Mound (EM)
- Approximate Extent of Roadway Cover
- Approximate Extent of Proposed Facility within PMDA
- Roads
- Topographic Line (100 Ft.)
- Topographic Line (20 Ft.)
- Sections
- Approximate Maximum Extent of Proposed Facility Outside PMDA
- Formosa Exploration Inc. Property Boundary

Notes:
1. Within areas indicated for excavation, mine materials would be removed for consolidation and disposal as indicated in Table 2.
2. The location and extent of the proposed disposal facilities within and outside of the PMDA are conceptual and would be evaluated during remedial design.
3. "EA" = "Exposure Area"

0 200 400 800 Feet

N

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS Zone 3602

Data Sources:
Bureau of Land Management:
2001 Hydrography
2005 Township, Range, and Topography

Figure 7-1

Excavation, Grading, and Capping Areas

Formosa Mine
Douglas County, Oregon

Section 8 – Remedial Action Objectives

8.1 Remedial Action Objectives

In accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), EPA developed remedial action objectives (RAOs) to describe what the selected OU1 remedy is expected to accomplish to protect human health and the environment. These RAOs are based on results of the human health and ecological risk assessments described in Section 7 and identified applicable or relevant and appropriate requirements (ARARs). RAOs are media-specific and source-specific goals to be achieved through completion of a remedy that is protective of human health and the environment. These objectives are typically expressed in terms of the chemicals, the concentration of the chemicals, and the exposure routes and receptors. In addition to the narrative RAOs, the selected remedial action typically must meet contaminant-specific cleanup levels. OU1 is a source control action. This ROD describes the criteria that will be used to define attainment of the OU1 RAOs.

The OU1 RAOs are described further below:

RAO 1: Manage mine materials to minimize and control effects to human health and ecological receptor populations and communities and individuals of threatened and endangered species from direct contact with mine materials.

Risks to ecological receptors will be reduced through removal and containment of mine materials with concentrations of cadmium, copper, and zinc that have the potential to adversely affect exposed aquatic receptors. These include mine materials in EA-1, potentially contaminated soils in EA-2, and contaminated soils in EA-3. Human health risks will be reduced through removal and containment of arsenic in soils associated with EA-3 and co-located with mine materials that exceed background concentrations.

RAO 2: Minimize the generation of acid rock drainage to reduce releases of COCs to surface water and groundwater.

Mine materials are primary source materials, and the process of ARD generation and MIW migration causes ongoing releases of COCs from mine materials into the environment. These COCs are subsequently transported via groundwater and surface water pathways to downstream ecosystems where they cause adverse effects to aquatic biota and potentially to other upper trophic level consumers (e.g., piscivorous [fish eating] birds and mammals). Managing mine materials in a manner that prevents ARD generation and subsequent transport of the COCs via groundwater and surface water will prevent ongoing releases of COCs from mine materials and the associated deleterious effects to downstream ecosystems from MIW.

The goal of the OU1 remedy is to reduce to the extent practicable the amount of ARD generated, which will reduce the risk of uncontrolled release of ARD. As discussed in the OU1 RI report and described in more detail in Section 12, identification of mine materials is based on a weight of evidence approach because there is no test that can fully define the propensity for a rock to generate ARD. Treatment of contaminated surface water and groundwater will be addressed under OU2. Although surface water and groundwater are not directly addressed under OU1, it is anticipated the surface water and groundwater quality will improve due to consolidation and containment of mine materials and reduction of ARD. Improvement of surface water quality will address risks to aquatic life. Progress toward this objective will be measured by monitoring the BMI community in surface water and monitoring the alluvial aquifer for reductions in cadmium, copper, zinc, and acidity. OU2 will fully address surface and groundwater and provide cleanup levels for those media.

EPA intends to use an overall framework for adaptive management as part of final remedial action for the Site. Since the greatest risks from contamination by mine materials are to ecological receptors, with some human health risks due to arsenic as discussed in Section 7, an adaptive management approach is anticipated for OU 2 to focus largely on biological receptor information (such as population trends). The remedial approaches and performance requirements, such as cleanup levels (CULs), for addressing remaining sources of MIW contamination throughout the Site will be developed as part of an adaptive management framework to be determined as part of the final remedy for the Site (OU2). Thus, cleanup criteria for OU1 are not based on final Site-wide CULs to be developed in OU2 but rather using OU1-specific cleanup criteria as discussed in Section 8.2.

8.2 Cleanup Levels

CULs for OU1 are based on physical and chemical characteristics as measured by methods developed in the OU1 RI. These physical and chemical characteristics, including arsenic, with specific values and/or descriptions, are described in the OU1 RI report where they were used for identifying mine materials requiring remedial action. Specific test methods and qualitative and quantitative criteria, such as mineral composition of the rock, paste pH, neutralization potential/acid potential ratio (NP/AP), and FPXRF, were developed, and used during the OU1 RI to delineate the extent of mine materials from surrounding soil and rock. The depths of the contaminated mine materials across this area were estimated during the OU1 RI using information gathered from drilling and trenching investigations.

These data and properties for mine material extent were used in the OU1 FS to determine volume of mine materials requiring cleanup to meet RAOs. The test methods, field procedures, and specific values developed in the OU1 RI to define mine materials designated for removal will be used during the remedial design phase to identify and delineate on site the contaminated mine materials. The areal extent of the mine materials for OU1 is shown on Figure 1-1. These materials designated for removal will be identified during the RD phase using land survey methods and LiDAR topographic maps to establish the extent of mine materials for removal.

The CULs presented in this OU1 ROD are quantitative values and physical descriptions intended to describe materials safe to remain after cleanup. These CUL values are derived, but quantitatively different, from the values used to define contaminated materials to be removed. The CULs in Table 8.2-1 describe properties for materials left in place and ensure the mine materials have been managed adequately to meet RAOs.

Statistical analyses completed and reported in the OU1 RI document that copper and zinc are high confidence indicators of soils and mine materials contaminated with all COCs that may be a source of ARD. The CUL values for copper and zinc (see Table 8.2-1) will be applied to confirm achievement of RAOs. Additionally, arsenic contamination associated with EA-3 and co-located with mine materials, exceed the acceptable risk threshold of 1E-06 for individual carcinogens and will be addressed by the Selected Remedy. As documented, the region-specific natural background concentration for arsenic in soils is 12 mg/kg (ODEQ 2013a). Because the naturally occurring arsenic concentration is greater than the arsenic concentration that equates to a 1E-06 cancer risk, in conformance with the NCP, the CUL for arsenic is the background value of 12 mg/kg.

Table 8.2-1 Confirmation Parameters used for Cleanup Levels at Formosa Mine OU1

Contaminant	Cleanup Criteria or Value	Method based upon OU1 RI	Basis/Rationale
Copper	190 mg/kg	FPXRF by EPA Method 6200 or equivalent	Used in a statistical evaluation of measurements to confirm achieving RAO 1 for protection of ecological receptors.
Zinc	288 mg/kg	FPXRF by EPA Method 6200 or equivalent	Used in a statistical evaluation of measurements to confirm achieving RAO 1 for protection of ecological receptors.
Arsenic	12 mg/kg	EPA Statement of Work (SOW) ISM01.3 – Multi-media, Multi-concentration Inorganic Analysis (or current equivalent method)	Used in a statistical evaluation of measurements to confirm achieving RAO 1 for human receptors. Based upon naturally occurring background concentrations (ODEQ 2013a).*
ARD Potential	Equal to or greater than 4.6 su	Field paste pH	Used in field screening data collection in a statistical evaluation of measurements to confirm achieving RAO 2.
ARD Potential	NP/AP Ratios equal to or greater than 1	ABA with neutralization ratios	Used in field screening data collection in a statistical evaluation of measurements to confirm protection by achieving RAO 2.
ARD Potential	Removal areas free from lithology, mineralogy, and mineralogical alterations that are indicators of mine materials; including noting the absence of micaceous and fissile fragments of QSP and QST, particles of massive sulfides, pyrite, or jarosite alteration minerals.	Visual observations	Confirm protection by achieving RAO 2.
ARD Potential	Bedrock: Presence of intact bedrock that has not been disturbed by mining activities and thus is excluded from remediation under CERCLA.	Visual observations	Confirm protection by achieving RAO 2.

*Oregon Department of Environmental Quality (ODEQ). 2013a. Development of Oregon Background Metals Concentrations in Soil Technical Report. Oregon Department of Environmental Quality, Land Quality Division Cleanup Program, Portland Oregon, March 2013.

QSP quartz sericite pyrite phyllite
QST quartz sericite tuff

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Section 9 – Description of Alternatives

This section describes the remedial alternatives developed and evaluated in the FS for OU1. It is organized into two subsections: common elements of alternatives and description of remedy components, distinguishing features, and expected outcomes for each alternative. The detailed evaluation and comparative analysis of alternatives described in this section is summarized in Section 10.

GRAs, remedial technologies, and process options that were potentially useful to address the RAOs for contaminated media were identified for OU1 and screened in accordance with the NCP. The purpose of this identification and screening process was to retain representative technologies and process options that could be assembled into remedial alternatives. To simplify FS evaluations and alternative descriptions, the contaminated media (OU1 mine materials and soil), all low level threat wastes were grouped together and defined as mine materials. The GRAs identified to address OU1 mine materials included the following:

- No action/no further action
- Institutional controls
- Removal, transport, and disposal
- Reuse, reclamation, recovery
- Treatment
- Monitoring
- Containment

Remedial technologies and process options were identified for each of the GRAs and broadly evaluated using a two-step screening process. The first screening step evaluated overall technical implementability and suitability of the technology for treatment of Site-wide contamination. Remedial technologies and process options that were retained from the first step were further evaluated for effectiveness, Implementability, and relative cost.

The remedial technologies and process options retained after the screening process described in the FS are listed in Table 9.0-1. These remedial technologies and process options were used to assemble remedial alternatives that could comprehensively address ecological risks posed by OU1 mine materials. The information in brackets was added to correspond with the terminology used for the alternative descriptions in this ROD.

Remedial alternatives were assembled by combining the retained remedial technologies and process options from the technology screening process. Table 9.0-2 provides a list of the major remedy components derived from retained remedial technologies/process options that were used to develop each remedial alternative. The fundamental Site assumptions and factors were also considered during development of the remedial alternatives.

The FS initially identified and screened 6 alternatives. Further explanations of the screening determinations for alternatives 1 through 6 can be found in the FS. The remedial alternatives retained for detailed evaluation for OU1 are described below:

Alternative 1: No Further Action

Alternative 2: In-Place Containment, Continued Submergence of Tailings within EM, and Limited Excavation/Disposal of Mine Materials at Proposed Facility within PMDA

Alternative 3: Limited In-Place Containment, Chemically Reduced Submergence of Tailings within EM, and Excavation/Disposal of Mine Materials at Proposed Facilities within and outside PMDA

Alternative 4: Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine materials at Proposed Facilities within and outside PMDA

Alternative 5 (Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine Materials at Existing and Proposed Facilities within and outside PMDA) was eliminated because it would pose additional short-term risks, would be complex to implement, and would have excessive costs relative to the other screened alternatives.

Alternative 6: Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine Materials at Proposed Facilities outside PMDA

Section 9.1 provides general descriptions of the common elements and distinguishing features of the remedial alternatives; Section 9.2 gives a description of the remedy components and expected outcomes for each of the alternatives retained for detailed evaluation in the FS.

9.1 Description of Remedy Components

The following subsections provide general descriptions and the expected outcomes of the alternatives retained for detailed evaluation in the FS. Complete descriptions of the retained alternatives and the results of the alternative screening that led to evaluation of these alternatives are provided in the OU1 FS.

9.1.1 Alternative 1 – No Action

- Estimated capital cost: $0
- Estimated total O&M costs (first 30 years): $0
- Estimated total periodic costs (first 30 years): $300,000
- Estimated total present value cost: $115,000
- Estimated construction timeframe: None
- Estimated time to achieve RAOs: Will never achieve RAOs

Alternative 1 would not include any remedial action activities at OU1 to address migration of contaminants and MIW from mine materials or otherwise mitigate the associated risks to human health and the environment.

Mine materials within the PMDA would remain exposed to the environment generating ARD. Acid-generating mine materials on steep slopes adjacent to the headwaters of South Fork and Middle Creek would continue to migrate contaminants and MIW to those drainages. Adit diversion system soils would continue to allow migration of MIW to surface water and groundwater.

The existing cover constructed over the EM would continue to erode and expose mine materials and allow infiltration of precipitation into the EM. Mine materials could become exposed at the surface and allow migration of MIW to surface water and groundwater. Tailings within the former water and tailings storage pond would continue to remain submerged in the short term, but changes in conditions within the EM could result in further discharge of contaminants and MIW to groundwater in the future.

The only actions that would be implemented for Alternative 1 are completion of 5-year site reviews as required by the NCP and monitoring (specifically non-intrusive visual inspections) only as required to support conclusions made in the 5-year site reviews.

<u>Summary of Major Remedial Components and Associated Quantities for Alternative 1:</u> None (no further action taken)

<u>Key ARARs:</u>

- None, no action does not trigger compliance with ARARs.

<u>Expected outcomes:</u>

- Mine materials would remain exposed to oxygen and water, and acid generation would continue.
- Unlimited use and unrestricted exposure would not be allowed due to presence of mine materials beneath covers.

9.1.2 Alternative 2 – In-Place Containment, Continued Submergence of Tailings within Encapsulation Mound, and Limited Excavation/Disposal of Mine Materials at Proposed Facility within PMDA

- Estimated capital cost: $5,075,000
- Estimated total O&M costs (first 30 years): $750,000
- Estimated total periodic costs (first 30 years): $330,000
- Estimated total present value cost: $5,553,000
- Estimated construction timeframe: 1 year
- Estimated time to achieve RAOs: 1 year

A summary of the major remedial components for Alternative 2 is provided in Table 9.1-1. Limited excavation would be conducted to address highly acid-generating mine materials at headwaters of creek areas and other targeted areas. Targeted mine materials directly affect the headwaters of South Fork Middle Creek and Upper Middle Creek and/or affect the stability of the EM. These areas include the east EM WRD, illegal dump area, the Formosa 1 and Formosa 3 Adit WRDs, mine materials along the upper side slopes of the EM, and adit drainage affected soils. The total targeted volume of mine materials to be excavated for Alternative 2 is approximately 72,000 CY.

All excavated materials would be disposed of within a proposed facility located within the PMDA. For the purpose of cost estimating, the proposed facility within the PMDA was assumed to span primarily from the EM to the ore storage area and would have an approximate capacity of 60,000 to 80,000 CY, depending on the degree of potential development of onsite overburden and rock borrow source to the southwest of the EM area. Development of this area to obtain uncontaminated soil and rock for cover construction and reclamation would expand the available volume for consolidation of mine materials. The facility was assumed to include a geosynthetic multi-layer cover system placed over consolidated mine materials.

The proposed facility within the PMDA would contain the EM in place, including the former water and tailings storage pond. Tailings currently stored in the pond would continue to remain submerged under the newly constructed geosynthetic multi-layer cover system. Submergence of tailings would continue to mitigate ARD generation, assuming the existing liner remains intact and holds water.

A combination of multi-layer geosynthetic covers, pavement covers, and exposure barriers would be implemented for remaining mine materials not targeted for excavation to mitigate unacceptable exposure risks to humans and reduce ARD generation. Pavement covers would be constructed over mine materials within existing road alignments. Multi-layer geosynthetic covers would be constructed in areas of mine materials outside of the proposed facility and road alignments on level areas and shallow slopes (for cost purposes, assumed to be less than 3H:1V). Both types of covers are capable of mitigating ARD generation as well as addressing human exposure to contaminants.

Exposure barriers were assumed to only be used on remaining mine materials with slopes steeper than 3H:1V. The mine material surface would be regraded, neutralized as needed to successfully establish exposure barriers to underlying mine materials, and covered with a vegetated or rock surface layer. The specific type of exposure barriers would be determined during the remedial design based on slopes and availability of sufficient quantities of suitable fill materials. Geotechnical stability of regraded areas would be evaluated during the RD, which may indicate the need for retaining structures to stabilize mine materials left in place. These types of covers would address human exposure to contaminants but would have a minimal effect on mitigating ARD.

Excavated areas or areas disturbed during construction that do not have mine materials would be regraded and reclaimed with a rock armor or a vegetative layer, depending on the steepness of resulting slopes. Roads within the PMDA affected by excavations would be reconstructed as necessary to restore access.

ICs include administrative, legal, and/or informational instruments intended to control or prevent present and future use or access to mine materials and inform and warn of dangers associated with these materials. These controls, combined with access controls (engineered controls, i.e., barriers, fences), would be implemented, as needed, to maintain the integrity of the remedy for OU1. Monitoring would consist of visual inspections to document maintenance needs for the remedy. Maintenance of the proposed disposal facility and containment areas would be performed as necessary to maintain protectiveness and integrity of the covers systems.

Five-year site reviews would be required because mine materials under covers would remain at the site that do not allow for unlimited use and unrestricted exposure.

Key ARARs:

- Oregon Hazardous Substance Remedial Action Rules
- Oregon Revised Statute 459 – Solid Waste Management

Expected outcomes:

- All mine materials would be addressed through removal and/or containment.
- Generation of ARD would be reduced significantly as a result of mine materials reduction in surface water and oxygen exposure.
- Unlimited use and unrestricted exposure would not be achieved due to presence of mine materials beneath covers.

9.1.3 Alternative 3 – Limited In-Place Containment, Chemically Reduced Submergence of Tailings within Encapsulation Mound, and Excavation/Disposal of Mine Materials at Proposed Facilities within and outside PMDA

- Estimated capital cost: $8,878,000
- Estimated total O&M costs (first 30 years): $553,000
- Estimated total periodic costs (first 30 years): $330,000
- Estimated total present value cost: $9,275,000
- Estimated construction timeframe: 2 years
- Estimated time to achieve RAOs: 2 years

A summary of the major remedial components for Alternative 3 is provided in Table 9.1-1. Alternative 3 includes limited in-place containment of mine materials at the EM area, excavation of all other mine materials, and disposal of mine materials at proposed facilities within and outside the PMDA. Disposal of all excavated materials would take place at two proposed facilities: one within the PMDA as described in Alternative 2 and one outside of the PMDA at a location to be determined.

The proposed facility within the PMDA would contain the EM in place, including the former water and tailings storage pond. Chemically reduced submergence would be implemented for tailings within the former water and tailings storage pond by adding liquid organic reagents to enhance in situ biological treatment.

The proposed facility outside of the PMDA would be sized to contain the remainder of excavated mine materials (approximately 125,000 CY) and constructed to meet pertinent ARARs for the selected location. Excavated areas or areas disturbed during completion of the remedy (including roads within the PMDA) would be restored or regraded and reclaimed, as described for Alternative 2.

ICs, access controls, maintenance, and monitoring for the proposed disposal facilities would be performed as described for Alternative 2; however, additional maintenance requirements, such as leachate collection and treatment, may be needed for the proposed facility outside of the PMDA, depending on the selected location and configuration. Components associated with the collection and storage facilities for leachate likely will need to be installed during construction activities; however, this will be addressed during the RD phase. The FS did not include evaluation of subsequent leachate water management (i.e., treatment). It is assumed subsequent management and disposal of leachate would take place during the remedial action addressing aquatic media (OU2), because it is difficult to make a facility-specific determination of leachate characteristics (i.e., quantity and quality).

Five-year site reviews would be required because mine materials under covers would remain at the sites that do not allow for unlimited use and unrestricted exposure.

Key ARARs:

- Oregon Hazardous Substance Remedial Action Rules
- Oregon Revised Statute 459 – Solid Waste Management

Expected outcomes:

- Mine materials would be addressed through removal and/or containment. In addition, tailings within the former water and tailings pond would receive treatment.
- Generation of ARD would be reduced significantly as a result of mine materials reduction in surface water and oxygen exposure.
- Unlimited use and unrestricted exposure would not be achieved due to presence of mine materials beneath covers.

9.1.4 Alternative 4 – Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine Materials at Proposed Facilities within and outside PMDA

- Estimated capital cost: $10,010,000
- Estimated total O&M costs (first 30 years): $553,000
- Estimated total periodic costs (first 30 years): $330,000
- Estimated total present value cost: $10,407,000
- Estimated construction timeframe: 2 years
- Estimated time to achieve RAOs: 2 years

A summary of the major remedial components for Alternative 4 is provided in Table 9.1-1. Alternative 4 includes excavation and disposal of mine materials, including EM tailings, at proposed facilities within and outside the PMDA. Disposal of all excavated materials would take place at two proposed facilities: one within the PMDA and one outside of the PMDA as described for Alternative 3.

The tailings within the former water and tailings storage pond (approximately 19,000 CY) would be dewatered and treated by pozzolan- or cement-based stabilization/solidification before disposal. A treatment additive, such as Portland cement or other types of stabilization agents, would be added to bind the contaminants in the tailings and reduce their mobility from leaching.

Since the EM area will be excavated and disposed of rather than contained in place, the targeted disposal volume for the proposed facility within the PMDA would increase to 109,000 CY. Excavated areas or areas disturbed during completion of the remedy (including roads within the PMDA) would be restored or regraded and reclaimed as described for Alternatives 2 and 3. ICs, access controls, maintenance, monitoring, and 5-year site reviews would be implemented as described for Alternative 3.

Key ARARs:

- Oregon Hazardous Substance Remedial Action Rules
- Oregon Revised Statute 459 – Solid Waste Management

Expected outcomes:

- Mine materials would be addressed through removal and containment within disposal facilities. In addition, tailings within the former water and tailings pond would receive pozzolan- or cement-based stabilization/solidification before disposal.
- Generation of ARD would be reduced significantly as a result of mine materials reduction in surface water and oxygen exposure.
- Unlimited use and unrestricted exposure would not be achieved due to presence of mine materials beneath covers.

9.1.5 Alternative 6 – Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine Materials at Proposed Facility outside PMDA

- Estimated capital cost: $10,092,000
- Estimated total O&M costs (first 30 years): $553,000
- Estimated total periodic costs (first 30 years): $330,000
- Estimated total present value cost: $10,489,000
- Estimated construction timeframe: 3 years
- Estimated time to achieve RAOs: 3 years

A summary of the major remedial components for Alternative 6 is provided in Table 9.1-1. Alternative 6 includes excavation of mine materials, including EM tailings, as described for Alternative 3 and disposal of all excavated material at a proposed facility outside the PMDA.

The tailings within the former water and tailings storage pond (approximately 19,000 CY) would be dewatered and treated as described for Alternative 4. Since the EM area will be excavated and disposed of rather than contained in place, the targeted disposal volume for the proposed facility outside of the PMDA would increase to 234,000 CY. Excavated areas or areas disturbed during completion of the remedy (including roads within the PMDA) would be restored or regraded and reclaimed as described for Alternatives 2 and 3.

ICs, access controls, maintenance, monitoring, and 5-year site reviews would be implemented as described for Alternative 3 except that 5-year site reviews would not be required for OU1 within the PMDA once ARD generating mine materials are no longer present.

Key ARARs:

- Oregon Hazardous Substance Remedial Action Rules

- Oregon Revised Statute 459 – Solid Waste Management

Expected outcomes:

- Mine materials would be addressed through removal and containment within disposal facilities. In addition, tailings within the former water and tailings pond would receive pozzolan- or cement-based stabilization/solidification before disposal.
- Generation of ARD would be reduced significantly because of mine materials reduction in surface water and oxygen exposure.
- Unlimited use and unrestricted exposure would be achieved within the PMDA due to removal of ARD generating mine materials.

9.1.6 Selected Remedy Description

The Selected Remedy for the cleanup of mine materials at OU1 comprises Alternative 3 with two elements from Alternative 2 and consists of the following remedy components:

- Excavation and consolidation of mine materials at two proposed disposal facilities, as described in Alternative 3, limited in-place containment, and excavation/disposal of mine materials at proposed facilities within and outside the PMDA.
- In-place containment, as described in Alternative 2, continued submergence of tailings within Encapsulation Mound without addition of chemical treatment, and limited excavation/disposal of mine materials at proposed facility within the PMDA.
- Continued submergence of tailings within encapsulation mound, as described in Alternative 2 existing tailings continue simple submergence without addition of chemicals.

The difference from Alternative 3 is the repositories all will be built on FEI property within the Site and without chemical treatment of tailings within the EM as evaluated in Alternative 3. The Selected Remedy results in modified waste volumes by adopting the limited excavation of Alternative 2, eliminates additional waste handling by adapting the simple submergence of Alternative 2, without chemical addition, and reduces access issues related to building a repository outside of the Site. The Selected Remedy is sufficiently similar to Alternative 3 that the discussion in the nine-criteria analysis for Alternative 3 applies to the Selected Remedy, and the CERCLA ranking is the same as for Alternative 3, with the exception of three of the balancing criteria as described in Section10. A description of the Selected Remedy is presented in Section 12. Key features and areas are shown on Figure 9-1.

9.2 Common Elements and Distinguishing Features of Each Alternative

Common elements and distinguishing features in how mine materials at OU1 are addressed under remedial alternatives 1, 2, 3, 4, and 6 are discussed below. These common elements and distinguishing features were derived from the retained remedial technologies and process options presented in Table 9.2-1.

9.2.1 Multi-layer Geosynthetic Covers, Exposure Barriers, and Pavement Covers

Covers are a common element of Alternatives 2, 3, 4, and 6. The purpose and degree of covering varies from alternative to alternative. Alternative 2 uses in-place covering to address the majority of mine materials, with the remaining material being covered after consolidation. Alternatives 3, 4, and 6 use covering at the disposal facilities located within and outside the PMDA after excavation of mine materials.

Multi-layer geosynthetic covers would be installed over mine materials to remain in place on level areas and shallow slopes (for cost purposes, assumed to be at areas less than 3H:1V). A typical multi-layer geosynthetic cover is assumed to consist of a low permeability layer, drainage layer, barrier layer, and vegetative layer. The vegetative layer would be amended with organics, lime, and fertilizer and then seeded. Erosion control would be provided as necessary. Multi-layer geosynthetic covers would also be installed over the proposed disposal facilities located within and outside the PMDA.

Where multi-layer geosynthetic covers may not be implementable, soil or rock exposure barriers may be used. Placement of different types of exposure barriers is dependent on Site conditions and cover objectives. For soil barriers, the upper layer (growth media) would be amended with organics, lime, and fertilizer and then seeded. Rock barriers are assumed to be constructed of coarse rock generated from nearby borrow sources. Additional erosion control features would be provided as necessary to stabilize covered areas.

For Alternative 2 only, existing roads in areas not targeted for excavation and outside of the proposed facility area within the PMDA would be covered with a pavement cover. These areas are assumed to be excavated to a depth of 1 foot below grade and then regraded as necessary to accommodate the thickness of a pavement cover. An aggregate gravel base is assumed to be installed, followed by an asphalt cover. Management of runoff from pavement cover areas would also be necessary and incorporated into the cover system. A combination of drainage channels/ditches and culverts may be implemented to route runoff from the paved areas and into runoff channels at selected areas along the road.

9.2.2 Excavation of Mine Materials

Mine materials would be excavated at varying degrees for the alternatives. Alternative 2 would only target highly acid-generating mine materials at the headwaters of creek areas. Alternative 3 would excavate all mine materials within the PMDA except for those already contained with the EM. Alternatives 4 and 6 would excavate all mine materials, including the materials within the EM. Mine materials would be distributed to the proposed disposal facilities located within and/or outside the PMDA.

The ARD-generating bedrock beneath mine materials that was altered previously by mining activities on the southeast side of the ore storage area and within a portion of the illegal dump area would be reshaped using blasting or other means, covered with a rock or vegetative soil layer to the extent possible, and water diversions installed around these areas to mitigate exposure to stormwater.

Other excavated areas or areas disturbed during completion of the remedy would be regraded and covered with a growth media layer or rock layer to stabilize steep slopes. Areas with growth media would be amended with organic matter, lime, and fertilizer as necessary and then seeded. Erosion control features, such as silt fences, straw bales, erosion control blankets, and down logs/slash from clearing and grubbing, would be installed. The FS indicated a tree-planting program may be implemented in areas that have adequate soil materials (some areas would be excavated to bedrock); however, tree-planting costs were not included in the FS.

Roads removed during excavation would be re-constructed using primarily native overburden and clean road gravel cover except for areas of road where the pavement cover has been applied. Because native overburden is comprised of mine materials, and these materials would be removed, the road may need to be installed above or below the existing grade.

9.2.3 Treatment of Tailings within Encapsulation Mound

Under Alternative 2, the proposed facility within the PMDA would contain the EM in place, including the former water and tailings storage pond. Tailings currently contained within the pond would continue to remain submerged under the newly constructed geosynthetic multi-layer cover system to mitigate ARD generation, assuming the existing liner remains intact and holds water. However, during construction of the proposed facility within the PMDA, partial removal of the EM sides (including the upper portion of the pond liner) would occur because the ARD-generating fill used to create the berm would be unstable for construction of the proposed disposal facility within the PMDA. After excavation of the fill materials that support the upper portion of the pond liner, excavated mine materials from other areas can be disposed within this area.

Under Alternative 3, chemically reduced submergence would be applied to the tailings currently contained within the former water and tailings storage pond by adding liquid organic reagents to enhance in situ biological treatment within the existing cover system. This approach would mitigate ARD generation, assuming the existing liner remains intact and holds water. Chemically reduced submergence within the EM would promote the precipitation of dissolved COCs, as solid-phase sulfide minerals, as long as saturated conditions are maintained within the EM. Excavation of the sides of the EM and upper portion of the pond liner would be conducted as described for Alternative 2.

Under Alternatives 4 and 6, the tailings within the EM (approximately 19,000 CY) would be removed and treated by pozzolan- or cement-based stabilization/solidification. This approach would reduce the ARD-generating potential and improve transportation and compaction of tailings. However, treatment of tailings with cement would increase the volume of materials necessary for disposal, thereby increasing the size requirement for disposal facilities. Treated tailings material would be disposed within the proposed facility within the PMDA. Prior to treatment of tailings, the pore water present within the EM would be removed to the extent possible via extraction or other methods.

9.2.4 Proposed Facilities

Alternative 2 utilizes a proposed disposal facility within the PMDA. Alternative 6 utilizes a proposed disposal facility outside of the PMDA. Alternatives 3 and 4 utilize proposed disposal facilities both within and outside of the PMDA. Alternative 6 utilizes a proposed disposal facility outside of the PMDA.

For the purpose of cost estimating, the proposed facility within the PMDA was assumed to span primarily from the EM to the ore storage area and would have an approximate capacity of 60,000 to 80,000 CY, depending on the degree of potential development of onsite overburden and rock borrow source to the southwest of the EM area. The proposed facility within the PMDA was assumed to be constructed with 3H:1V side slopes, contain a geosynthetic multi-layer cover system (including low permeability layer, drainage layer, barrier layer, and vegetative layer) over consolidated mine materials, and would include surface water run-on/runoff controls. Existing Site roads would be removed in the EM and ore storage area to accommodate the disposal facility. Roads would be reclaimed to maintain current access routes in conjunction with the disposal facility construction although alignments of new road areas may differ from the current alignments.

As evaluated in the FS, the proposed facility outside the PMDA would be located between approximately 1 to 5 miles (haul distance) from the PMDA and would have an approximate capacity of 125,000 CY. The repository area would be cleared and grubbed as necessary and existing overburden removed to bedrock for mine material consolidation. Overburden would be processed (screened and amended) to create materials for the cover system construction. Additional soil and rock materials may be required from other near-site borrow areas. Consolidation of excavated mine materials would be conducted to create stable side slopes and geomorphic shapes that promote runoff. The facility would be constructed with 3H:1V side slopes, contain a geosynthetic multi-layer cover system (including low permeability layer, drainage layer, barrier layer, and vegetative layer) over consolidated mine materials, and would include surface water run-on/runoff controls. Since this facility would be constructed on an existing sloped area, run-on channels at the upper end of the facility would be necessary, which would route stormwater around the repository. Runoff channels would also be constructed at the slope toe of the repository area, along with potential for bench/runoff channels space along the long axis of the repository slope. Exact configurations of run-on and runoff controls would be evaluated during the RD.

Although the location and configuration of the disposal facility outside of the PMDA is unknown, it was assumed a liner and leachate collection system would be installed at the bottom of the repository to protect groundwater and surface water by collecting leachate from the overlying mine materials. The liner and leachate collection system construction would be determined during RD in accordance with ARARs. The leachate collection system would drain to a central leachate collection point such as a detention basin or treatment system. The RD would evaluate the necessity and approach for leachate collection treatment; however, treatment approaches for leachate were not included in the FS. It was assumed subsequent management and disposal of leachate would take place under OU2 operations, as it is difficult to make a facility-specific determination of leachate characteristics (i.e., quantity and quality).

9.2.5 Institutional Controls

ICs are non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. There are four categories of IC instruments: governmental controls, proprietary controls, informational devices, and enforcement tools. ICs may be selected and employed individually or used in a layering manner with other land use controls, consistent with the concept promoted by the EPA (EPA 2000b). ICs may also be applicable on a parcel basis or for specific components of the Selected Remedy.

All remedial alternatives, with the exception of Alternative 1, include the use of ICs to achieve remedial objectives. Consistent with the NCP, none of the remedies rely exclusively on ICs to achieve protectiveness. The ICs at OU1 will consist of governmental controls, proprietary controls, and informational devices, including community awareness activities such as information sessions and educational programs to enhance awareness of potential hazards if disturbances occur that adversely affect the remedial action at OU1. These ICs will control or prevent present and future use or access to mine materials, inform and warn of dangers associated with these materials, and maintain the integrity of the disposal facilities and containment areas constructed as part of the Selected Remedy (EPA 2012). Land use controls will be developed specifically for the land ownership and local regulatory jurisdictions and tailored for different components of the Site. For example, ICs would be selected to prevent excavation or damage of repositories or capped or graded waste piles.

The following subsections provide descriptions of specific legal and administrative instruments of ICs that are adaptable to meet the RAOs of the OU1 Selected Remedy and are consistent with the local jurisdiction of the Formosa Mine.

Governmental Controls

Governmental controls impose land or resource restrictions under the authority of an existing unit of government. Such controls may include use or changes in local zoning, permits, codes, or regulations.

The Formosa Mine OU1 is located in Douglas County, Oregon, which has demonstrated legal authority to pass ordinances respecting the use and development of land. Such authority might also be used to pass ordinances requiring the safe access and/or management of the mine materials containment facility. Consistent with Oregon law (ORS Chapter 195), the Douglas County Board of Commissioners maintains jurisdiction over specific local land use decisions with legal authority to approve proposed changes in zoning that may be necessary to accommodate the Selected Remedy and ensure the protectiveness of the containment facility. Governmental controls may be implemented and enforced during construction of the Selected Remedy as well as post-construction for long-term maintenance of the installed remedy components, especially if it becomes difficult to implement other IC instruments.

Proprietary Controls

Proprietary controls are various legal instruments based on state law, such as easements or covenants, which prohibit activities that could pose an unacceptable risk from exposure to contamination or compromise the effectiveness of remedy components.

Consistent with State of Oregon property law, land use restrictions may be effected by the use of an Easement and Equitable Servitude. Creation of such legal instruments can be facilitated through use of a standard form developed for such purpose by ODEQ. Through such instruments, an owner of property (grantor) may convey to another party (grantee) an easement for access. In the past, ODEQ has agreed to serve as a grantee for purposes of effecting an Equitable Servitude. Grantors may also simultaneously accept placement of Equitable Servitudes upon the property. Such Equitable Servitudes may include restrictions on land use such as prohibitions of residential or agricultural use. An Easement and Equitable Servitude may prohibit future owners of such properties from disturbing covers over contaminated materials buried in place or otherwise within the area of real property subject to the instrument.

An executed Easement and Equitable Servitude may be filed with the county records and run with the land to subject future owners of the property to the conditions of the instrument. Through such instruments, grantees, including ODEQ, may hold perpetual rights to enforce the conditions and restrictions of such instrument. It is uncertain whether an Easement and Equitable Servitude could be established for Formosa Mine OU1.

Informational Devices

Informational notices, community outreach, and risk communications also may be utilized to provide notice of contamination on the property and to discourage uses that could lead to unacceptable exposures to such contamination.

In the State of Oregon, informational notices may take the form of a Notice of Environmental Contamination, which ODEQ may issue unilaterally, consistent with ORS 465.200 et seq. Consistent with ORS 205.130(2), such notices may be presented by ODEQ to the county clerk for recording in the county records. It is uncertain whether Notice of Environmental Contamination could be issued for Formosa Mine OU1.

Community awareness activities include informational and educational programs to inform the public about Site risks and the activities being performed to reduce these risks. For OU1, onsite signage warning against trespassing and digging through caps and covers may be posted around the boundary of all caps and covers.

Implementation and Enforcement of Institutional Controls

States often play a major role in implementing and enforcing ICs. The NCP requires the state to ensure that any ICs implemented as part of the OU1 Selected Remedy are in place and reliable and will remain in place after the remedial action is complete and the post-remedial action monitoring occurs. CERCLA and the NCP do not specify a role for local governments in implementing the IC instruments identified for the Selected Remedy. However, a local government is often the only entity that has the legal authority to implement, monitor, and enforce certain types of ICs, particularly governmental controls such as zoning changes. Additionally, difficulties implementing ICs may be encountered because the property is not owned by the EPA and would require coordination with the property owner and/or adjacent property for access, implementation, and operations of the Selected Remedy.

9.2.6 Access Controls

Implementation of access controls is a component of the all alternatives. These engineered and constructed physical controls include barriers, fencing, riprap, and placement of large boulders and/or logs to prevent access. In some applications, the placement of logs and rock may enhance habitat in the vicinity in addition to restricting access to the containment facility. Access controls (specifically engineered/constructed barriers) would be implemented primarily at the proposed facilities within and outside the PMDA. These controls would be designed to maintain the integrity of the disposal facilities and restrict access that would be detrimental to the protectiveness goals of the remedial action. The nature of these barriers would be further developed in the remedial design phase. O&M would be required to maintain and repair access controls damaged by weather or vandalism.

9.2.7 Monitoring and Five-Year Reviews

Five-year site reviews would be performed for Alternatives 2, 3, and 4 because mine materials remaining at the PMDA under covers would not allow for unlimited use and unrestricted exposure under the current and potential future land uses. Non-intrusive visual inspections (i.e., surface inspections) would be performed in support of the 5-year site review. Monitoring would be performed at all locations with mine materials left in place within the PMDA. In addition, monitoring of covers and leachate collection systems at the proposed facilities would take place for Alternatives 3, 4, and 6.

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Section 9
Tables

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Table 9.0-1
Retained Remedial Technologies and Process Options Used to Develop Remedial Alternatives
Formosa Mine Superfund Site, Douglas County, Oregon

Remedial Technology	Process Option
Physical and/or Chemical Monitoring	Non-Intrusive Visual Inspection (i.e., surficial inspection)
	Intrusive Visual Inspection (i.e., inspection using excavations or boreholes)
	Sample Collection and Analysis
Institutional Controls	Governmental Controls, Proprietary Controls, and Informational Devices
Community Awareness Activities	Informational and Educational Programs
Access Controls	Fencing and Posted Warnings
Surface Source Controls	Grading
	Revegetation
	Exposure Barrier
	Geosynthetic Multi-Layer Cover
	Pavement Cover
Subsurface Source Controls	Liner System
	Submergence
Barriers	Retaining Structures
Removal	Mechanical Removal (Excavation)
	Hydraulic Excavation (Slurry Pumping)
Transport	Mechanical Transport (Hauling/Conveying)
	Hydraulic Transport (Slurry Pumping)
Disposal	Disposal at Proposed Facility within PMDA
	Disposal at Proposed Facility outside PMDA
	Disposal at Existing Facility
Biological Treatment	Chemically Reduced Submergence
Chemical/Physical Treatment	Neutralization
	Pozzolan- or Cement-Based Stabilization/Solidification

Table 9.0-2
Remedy Components Used in Site Remedial Alternatives
Formosa Mine Superfund Site, Douglas County, Oregon

	Remedial Alternative					
Remedy Component Used	1	2	3	4	5	6
Five-year site reviews and monitoring	●	●	●	●	●	●
ICs, community awareness activities, access controls		●	●	●	●	●
Partial in-place covering of mine materials		●	●			
Containment of tailings within encapsulation mound by submerging in place		●				
Treatment of tailings within encapsulation mound by submerging in place with the introduction of additives			●			
Excavation and treatment of tailings outside of encapsulation mound				●	●	●
Excavation and consolidation/disposal of mine materials within PMDA		●	●	●	●	
Excavation and consolidation/disposal of mine materials outside PMDA			●	●	●	●
Excavation and consolidation/disposal of mine materials at existing permitted facility					●	

Shaded alternative (5) was eliminated from consideration prior to detailed analysis

Table 9.1-1
Summary of Major Remedial Components and Associated Quantities, by Alternative
Formosa Mine Superfund Site, Douglas County, Oregon

Alternative	Remedial Component	Unit	Estimated Quantity
2	Mine materials to remain in place	BCY	162,000
	Mine materials to be excavated and consolidated at proposed facility within the PMDA	BCY	72,000
	Surface area of excavations	Acres	6.8
	Surface area of proposed repository within the PMDA	Acres	4.4
	Surface area of exposure barriers	Acres	11.1
	Surface area of multi-layer geosynthetic covers	Acres	1.2
	Surface area of pavement covers	Acres	2
3	Mine materials to remain in place	BCY	40,000
	Mine materials to be excavated and consolidated at proposed facility within the PMDA	BCY	69,000
	Mine materials to be excavated and consolidated at proposed facility outside the PMDA	BCY	125,000
	Volume of tailings to be treated with chemical submergence	BCY	19,000
	Surface area of proposed repository within the PMDA	Acres	4.4
	Surface area of proposed repository outside of the PMDA	Acres	3.5
	Surface area of excavations	Acres	24.9
4	Mine materials to be excavated and consolidated at proposed facility within the PMDA	BCY	109,000
	Mine materials to be excavated and consolidated at proposed facility outside the PMDA	BCY	125,000
	Volume of tailings to be treated with pozzolan- or cement-based solidification/stabilizatior	BCY	19,000
	Estimated volume of water to be removed from EM during tailings removal	GAL	632,000
	Surface area of proposed repository within the PMDA	Acres	4.4
	Surface area of proposed repository outside of the PMDA	Acres	3.5
	Surface area of excavations	Acres	24.9
6	Mine materials to be excavated and consolidated at proposed facility outside the PMDA	BCY	234,000
	Volume of tailings to be treated with pozzolan- or cement-based solidification/stabilizatior	BCY	19,000
	Estimated volume of water to be removed from EM during tailings removal	GAL	632,000
	Surface area of proposed repository outside of the PMDA	Acres	5.4
	Surface area of excavations	Acres	24.9

Notes:

BCY = bank cubic yards

PMDA = primary mine disturbance area

GAL = gallons

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Section 9
Figures

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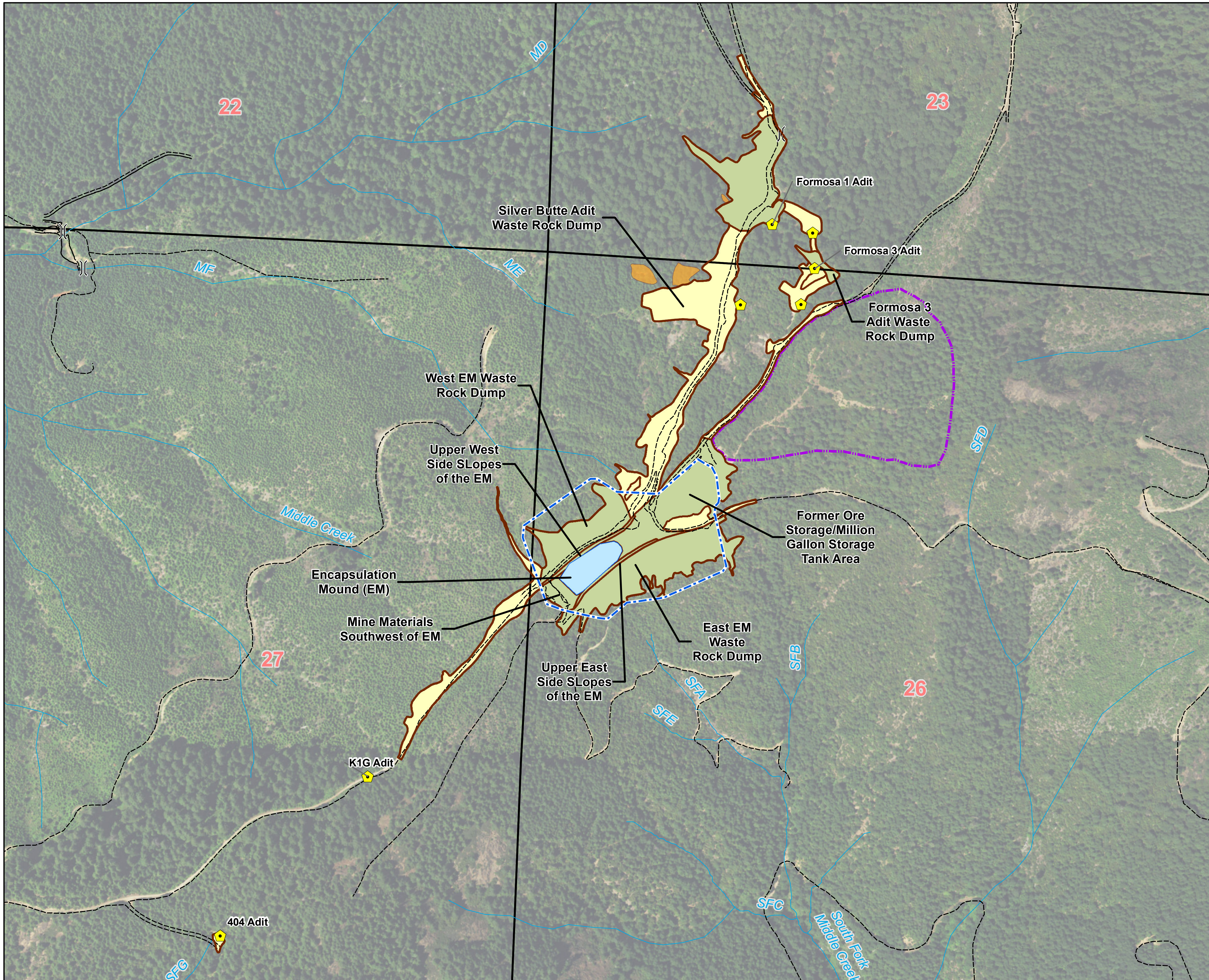

Legend

- Adit
- Culverts
- Roads
- Streams
- Primary Mine Disturbance Area (EA-1)
- Adit Drainage Affected Soil (EA-3)
- Approximate Extent of Exposure Barriers
- Approximate Extent of Excavations
- Approximate Extent of Proposed Facility within PMDA [1]
- Approximate Extent of Proposed Facility Outside PMDA [1]
- Encapsulation Mound (EM)
- Sections
- 26 Section Number

Note(s):
1. The location and extent of the proposed disposal facilities within and outside of the PMDA are conceptual. Evaluation during remedial design, such as facility design capacity and slope, would determine if the facilities would be developed separately or combined for containment of excavated mine materials.
2. "EA" = "Exposure Area"

0 250 500 1,000 Feet

Geographic Data Standards:
Projected Coordinate System:
NAD 1983 State Plane Oregon FIPS Zone 3602

Data Sources:
Bureau of Land Management:
2001 Hydrography
2005 Township, Range, and Topography
2010 ESRI World Imagery Service Layer

N

Figure 9-1

Key Features of the Selected Remedy

Formosa Mine
Douglas County, Oregon

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Section 10 – Comparative Analysis of Alternatives

Alternative 5 (Excavation, Stabilization/Solidification of Tailings, and Disposal of Mine Materials at Existing and Proposed Facilities within and outside PMDA) was eliminated during the screening evaluation. The remaining alternatives (1, 2, 3, 4, and 6) were retained for detailed analysis in the FS against two **threshold** criteria and five **balancing** criteria.

Threshold Criteria:

The following two threshold criteria are the most important and must be satisfied by any alternative in order to be eligible for selection:

- ***Overall protection of human health and the environment*** requires that an alternative eliminates, reduces, or controls unacceptable threats to public health and the environment through ICs, engineering controls, treatment, and/or other remedial actions.

- ***Compliance with ARARs*** evaluates whether the alternative meets federal and state environmental and facility siting statutes that pertain to OU1 or whether a waiver is justified.

Balancing Criteria:

The following five balancing criteria are used to make comparisons and to identify the major tradeoffs between alternatives:

- ***Long-term effectiveness and permanence*** considers the ability of an alternative to maintain protection of human health and the environment over time.

- ***Reduction of toxicity, mobility, or volume through treatment*** evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, the contaminant's ability to move in the environment, and the amount of contamination remaining after remedy implementation.

- ***Short-term effectiveness*** considers the length of time needed to implement an alternative and the risk the alternative poses to workers, residents, and the environment during implementation.

- ***Implementability*** considers the technical and administrative feasibility of implementing the alternative, including factors such as the availability of materials and services.

- ***Cost*** includes estimated capital, annual operations and maintenance, and periodic costs, as well as present value cost. Present value cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates for detailed analysis of alternatives are expected to be accurate within a range of +50 to -30 percent of actual cost.

A full comparative analysis of the remedial alternatives against the threshold and balancing criteria and highlights the key tradeoffs between them can be found in Section 7 and Appendix G of the OU1 FS (CDM Smith 2013).

Modifying Criteria:

After the Site Proposed Plan was released in January 2015, EPA received comments from nine individuals and organizations from the community on the Proposed Plan and preferred alternative. With state and community input in hand, EPA was able to complete the final evaluation of the remedial alternatives using the following modifying criteria. These criteria can prompt modification of the preferred remedy that was presented in the Proposed Plan:

- ***State acceptance*** considers whether the state agrees with EPA's analyses and recommendations, as described in the RI/FS and Proposed Plan.

- ***Community acceptance*** considers whether the local community agrees with EPA's analyses and preferred alternative. Comments received on the Proposed Plan are an important indicator of community acceptance.

A discussion of how the modifying criteria affected the Selected Remedy is provided in Section 10.2.

10.1 Comparative Analysis of Remedial Alternatives against Threshold and Balancing Criteria

The OU1 FS evaluated the five retained remedial alternatives discussed in this section against the two threshold criteria and five balancing criteria. The results of the detailed analysis for each remedial alternative were provided in the OU1 FS. Comparative analysis for the remedial alternatives using the threshold and balancing criteria has been put into narrative form in the following subsections. Only significant comparative differences between alternatives are presented; the full set of rationale for the qualitative ratings is provided in Appendix E of the OU1 FS (CDM Smith 2013).

10.1.1 Overall Protection of Human Health and the Environment

Of the five retained alternatives, only the no further action alternative (i.e., Alternative 1) would fail to provide protection for human health and the environment and would not meet the RAOs for OU1. Alternative 1 will not be discussed further in this ROD as it does not meet the threshold criteria of Protection of Human Health and the Environment.

Varying combinations of excavation and containment of mine materials and ICs provide long-term effectiveness and permanence to all alternatives. ICs prohibit excavation. Alternative 2 meets the RAOs primarily through in-place containment of mine materials as the predominant approach, with limited excavation and disposal of targeted mine materials at a proposed facility within the PMDA. Tailings stored in the EM remain submerged in the former water and tailings storage pond under a newly constructed geosynthetic multi-layer cover system. In-place containment using covers would provide a barrier that reduces generation of ARD.

Alternative 3 meets the RAOs primarily through excavation of mine materials and disposal of mine materials at proposed facilities within and outside the PMDA, limited in-place containment of mine materials at the EM area, and implementation of chemically reduced submergence for tailings within the former water and tailings storage pond. Excavation of mine materials and disposal in proposed disposal facilities within and outside the PMDA would provide a barrier that reduces generation of ARD. Tailings stored in the EM would be contained in place under a newly constructed geosynthetic multi-layer cover system, and chemically reduced submergence of the tailings in the former water and tailings storage pond would provide further protection from generation of ARD and MIW migration to groundwater.

As noted in Section 9.1.6., the Selected Remedy is Alternative 3 with two elements from Alternative 2. It is sufficiently similar to Alternative 3 that the discussion in the nine criteria analysis for Alternative 3 applies to the Selected Remedy and the CERCLA ranking is the same as for Alternative 3. The Selected Remedy utilizes continued simple submergence (i.e., without addition of chemicals) of mine tailings within the EM, which would have a similar effect as chemically enhanced submergence utilized in Alternative 3.

Alternative 4 meets the RAOs primarily through excavation of mine materials, stabilization/ solidification of tailings, and disposal at proposed facilities within and outside the PMDA. Excavation of mine materials and disposal in proposed disposal facilities within and outside the PMDA would provide a barrier that reduces generation of ARD. Tailings stored in the EM would be excavated and treated using stabilization/solidification prior to disposal that would provide further protection from generation of ARD and MIW migration to groundwater.

Alternative 6 meets the RAOs primarily through excavation of mine materials, stabilization/ solidification of tailings, and disposal at a proposed facility outside the PMDA. Alternative 6 would provide similar protection of human health and the environment as Alternative 4 except that mine materials would be completely excavated at OU1 and placed at a proposed facility outside of the PMDA.

10.1.2 Compliance with ARARs

ARARs are provided in Appendix A.

Alternatives 2, 3, the Selected Remedy, 4, and 6meet ARARs through in-place containment or excavation and disposal of mine materials in proposed facilities. Specifically, these alternatives comply with chemical-specific ARARs such as OAR 340-122 by addressing arsenic that is present at concentrations that exceed the state threshold of 1E-06 excess lifetime cancer risk for an individual carcinogen, or background concentrations, whichever is higher. Location- and action-specific ARARs will be addressed during excavation and transport of mine materials and in selection and construction of proposed facilities for disposal of mine materials.

10.1.3 Long-Term Effectiveness and Permanence

For all remaining alternatives, varying combinations of excavation and containment of mine materials and ICs would be used to provide long-term effectiveness and permanence. In addition, ICs would be used to prohibit excavation and access to specific areas and the containment facility by unauthorized vehicles.

Alternative 2 provides long-term effectiveness and permanence primarily through in-place containment of mine materials with limited excavation and disposal of targeted mine materials at a proposed facility within the PMDA. With proper construction, the covers would limit direct exposure to mine materials by humans, provide a reduction in infiltration, and mitigate ARD generation and MIW migration. However, mine materials still remain beneath covers across a large extent of OU1 and could pose risks if the covers are compromised. Because mine materials would remain in place on steep slopes, long-term effectiveness and permanence is not as certain as for alternatives that excavate contaminated mine materials and dispose of them in proposed facilities constructed with shallower slopes. Thus, this alternative was given a rating of “low to moderate.”

Alternative 3 and the Selected Remedy provide long-term effectiveness and permanence primarily through excavation and disposal at proposed facilities within and outside PMDA. Excavation and disposal outside of PMDA increases the long-term effectiveness and permanence of the alternative because mine materials are relocated and placed within proposed disposal facilities constructed with shallower slopes than are currently present. The proposed facility outside of the PMDA includes bottom liners as well as cover liners, which would increase the isolation of the mine materials. Although mine materials are left in place at the EM area under Alternative 3 and the Selected Remedy, exposure to these materials would be addressed through in-place containment. The proposed facility within the PMDA would contain the EM in place, including the former water and tailings storage pond. For Alternative 3, chemically reduced submergence would be implemented for tailings within the former water and tailings storage pond to enhance biological treatment and reduce generation of ARD and migration of MIW. Thus, Alternative 3 was given a rating of "moderate." The Selected Remedy, with some components similar to Alternative 2, would receive a "moderate to low" rating for long-term effectiveness and permanence because the excavated volumes are less than Alternative 3, and the tailings would be submerged under water, without added chemicals, but would still be submerged, preventing oxidation that would result in ARD generation. Overall, the long-term effectiveness for the Selected Remedy is similar to or slightly greater than Alternative 3 because the disposal facility constructed within the PMDA is more stable as a result of improving the slopes and lowering the profile exposed to adverse weather.

Alternatives 4 and 6 provide long-term effectiveness and permanence primarily through excavation and disposal of mine materials at proposed facilities within and outside PMDA as described for Alternative 3. The tailings within the former water and tailings storage pond would be dewatered and treated by pozzolan- or cement-based stabilization/solidification prior to disposal. Excavation and disposal of mine materials in the EM area, along with additional treatment of tailings, increases the long-term effectiveness and permanence of the remedy compared to remedies without additional treatment. This would provide further protection from generation of ARD and MIW migration to groundwater when treated tailings are disposed at the proposed facilities.

Excavated mine materials would be disposed at the proposed facilities within and outside of PMDA under Alternative 4. Thus, Alternative 4 was given a rating of "moderate." Alternative 6 has a greater potential for long-term effectiveness and permanence than Alternatives 2, 3, the Selected Remedy, and 4 because mine materials would be disposed at a single proposed facility outside the PMDA. The proposed facility outside the PMDA could be designed to be fully contained and capable of collecting leachate for treatment and sited at a more environmentally favorable location than the PMDA to enhance permanence. The use of one disposal facility outside of the PMDA, coupled with the removal of mine materials from the PMDA, would also increase long-term effectiveness by decreasing the environmental footprint (measured by surface area) of mine materials as compared to Alternative 4. Thus, Alternative 6 was given a rating of "moderate to high." The Selected Remedy would receive a moderate rating, similar to Alternatives 3 and 4, because the repositories would have a single location that allows for effective, permanent maintenance but not a "moderate to high" rating as Alternative 6 received because the proposed disposal location would not be located in as environmentally friendly location as Alternative 6.

10.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 2, 3, Selected Remedy, 4, and 6 provide varying and small degrees of reduction in toxicity, mobility, and volume through treatment of tailings. Under Alternative 2 and the Selected Remedy, tailings currently contained within the former water and tailings storage pond would continue to be submerged under the newly constructed cover system to mitigate ARD generation. The tailings, however, are a relatively small percentage of the volume of mine materials existing at OU1. Thus, Alternative 2 and the Selected Remedy were given a rating of "low" because containment and simple submergence does not provide the same level of permanent and irreversible treatment as chemically reduced submergence in Alternative 3.

With Alternative 3 chemically reduced submergence as treatment, would be implemented for tailings within the former water and tailings storage pond by adding liquid organic reagents to enhance in situ biological treatment. Although chemically reduced submergence is not part of the Selected Remedy, for Alternative 3, it may provide a further reduction of toxicity and mobility of contaminants from the tailings. The tailings, however, are a relatively small percentage of the volume of mine materials existing at OU1; therefore, tailings are not considered principal threat wastes. Thus, Alternative 3 was given a rating of “low to moderate.”

With Alternatives 4 and 6, tailings would be treated by stabilization/solidification prior to disposal. Treatment would provide additional protection to groundwater from generation of ARD and migration of MIW from pyrite-rich tailings. The tailings, however, are a relatively small percentage of the volume of mine materials existing at OU1 and are not principal threat wastes. Thus, these alternatives were given a rating of “moderate.”

10.1.5 Short-Term Effectiveness

Potential additional risks to workers, the community, and the environment would occur during the implementation of the targeted excavation of mine materials in Alternative 2, the Selected Remedy, and the more comprehensive excavation of mine materials in Alternatives 3, 4, and 6. Alternative 2 and the Selected Remedy limit short-term risks to workers, the community, and the environment primarily through in-place containment of mine materials and having less excavated volumes to haul. In addition, Alternative 2 and the Selected Remedy have less short-term risk because they do not involve addition of chemicals to the submerged tailings as in Alternative 3. ICs could be implemented quickly to address potential exposure to mine materials. Trucks used to haul materials for covers as well as for reclamation within the PMDA slightly increase short-term risks to the community. Transportation and placement of borrow materials have potential environmental effects from equipment emissions and disturbance of borrow location outside of PMDA. Limited excavation of mine materials and disposal at the proposed facility within PMDA would require disturbance of mine materials. While limited excavation of mine materials and construction of covers would involve surface disturbance of mine materials, short-term risks to workers would be mitigated through the use of safety measures such as personal protective equipment. Short-term risks to workers, the community, and the environment could be mitigated through measures such as water-based dust suppression and use of fuel-efficient vehicles. Thus, Alternative 2 and the Selected Remedy were given a rating of “moderate to high.”

Alternative 3 requires disturbance of a larger amount of mine materials across OU1 and a longer duration of construction than Alternative 2 and the Selected Remedy, which poses increased short-term risks to workers and the community than the predominately surface disturbance activities within Alternative 2 and the Selected Remedy. Construction of a new proposed facility outside of the PMDA would increase the extent of the affected areas as compared to Alternative 2. Hauling of mine materials to the proposed facility outside of the PMDA as well as transport of materials for covers and for reclamation to the PMDA increases truck traffic and related risks to workers and the community as compared to Alternative 2. Excavation and transport of mine materials to the proposed facility outside of the PMDA as well as transport and placement of borrow materials have potential environmental effects from equipment emissions and disturbance of the borrow location outside of the PMDA. While limited excavation of mine materials and construction of covers would involve surface disturbance of mine materials, short-term risks to workers would be mitigated through the use of safety measures such as personal protective equipment. Short-term risks to workers, the community, and the environment would be mitigated through measures such as water-based dust suppression and use of fuel-efficient vehicles. Thus, this alternative was given a rating of “moderate.”

The Selected Remedy is considered "moderate to high" for short-term protectiveness because it will reduce the distance travelled for creating the repository outside of the PMDA and does not include adding a chemical to alter the chemical conditions within the tailings in the EM. There are less significant effects from the Selected Remedy to the community and environment from truck traffic since disposal of mine materials is limited to the boundaries of the former FEI property. This would reduce fuel costs and related engine emissions for transportation and minimize transportation-related safety issues. The proposed facility in the Selected Remedy is adjacent to the PMDA and thus has a smaller overall footprint and construction duration than what was proposed in alternatives 3, 4, and 6.

Alternative 4 poses similar short-term risks to workers and the community as Alternative 3. Alternative 4 requires disturbance of mine materials across OU1 and a longer duration of construction than Alternative 3, which poses more short-term risks to workers and the community than the less robust excavation activities under Alternative 2. However, with Alternative 4, there is an additional step of treating tailings by stabilization/solidification. This step involves additional contact by workers to mine materials during treatment as well as additional truck traffic to deliver the stabilization agent. Thus, this alternative was given a rating of "moderate."

Alternative 6 is similar to Alternative 4 except that mine materials would be disposed at a proposed facility outside the PMDA. Construction of a new proposed facility outside of the PMDA would increase truck traffic in the community due to the increased volume of mine materials to be disposed at the proposed facility. The additional hauling of mine materials to the proposed facility outside of the PMDA would result in additional environmental effects from equipment emissions. Thus, this alternative was given a rating of "low to moderate."

10.1.6 Implementability

Alternative 2 and the Selected Remedy include limited excavation and disposal of targeted mine materials at a proposed facility within the PMDA. Alternatives 3 and 4 include excavation, transport, and disposal of larger volumes of mine materials, a common construction practice, but this will result in a longer construction period and uses more construction equipment to complete than Alternative 2. The Selected Remedy is more implementable than Alternative 3 because it does not include introduction of a chemical additive to the EM. Adding chemicals would require additional equipment and expertise to mix the chemical with the tailings and prevent tearing the bottom liners of the EM. Alternative 6 includes transport of the largest quantities of mine materials for disposal at the proposed facility outside of the PMDA. Alternatives 3 and 4 include disposal of mine materials at two locations (proposed facilities within and outside of PMDA). Alternative 2 and the Selected Remedy include transport of mine materials a shorter distance to a proposed facility within and adjacent to the PMDA.

Alternatives 2, 3, Selected Remedy, 4, and 6 include import of construction resources, such as asphalt (Alternative 2, 3, and the Selected Remedy), pozzolan or cement (Alternatives 4 and 6), lime, organic materials, and geosynthetic materials. Uncontaminated borrow sources within or outside of the PMDA would need to be developed for these alternatives. Excavation of mine materials and placement of covers on steep slopes may require the use of specialty equipment and practices to ensure worker safety. Inspection, monitoring, and maintenance of the proposed facilities, cover systems, and access controls across OU1 would be relatively easy to implement.

Materials, equipment, and technical specialists needed for the chemically reduced submergence of tailings in Alternative 3 are specialized but available. Treatment of tailings using stabilization/ solidification for Alternatives 4 and 6 is relatively straightforward but may be difficult due to high concentrations of contaminants in the tailings, degree of saturation, and limited space for performing the stabilization/solidification. Treatability testing would be required to assess and optimize the performance of stabilization/solidification of the tailings.

Overall, Alternative 2 and the Selected Remedy are given a rating of “moderate to high.” Alternatives 3, 4, and 6 were given a rating of “moderate.”

10.1.7 Cost

Present value costs for all alternatives were evaluated over a 30-year period (Years 0 through 29). The present value cost for Alternative 1, approximately $115,000, was given a rating of “low.” The present value cost for Alternative 2, approximately $5,553,000, was given a rating of “low to moderate.” The present value costs for Alternatives 3, 4, and 6 were each given a rating of “moderate.” The present value costs for these alternatives are approximately $9,275,000 (Alternative 3), $12,440,000 (Selected Remedy), $10,407,000 (Alternative 4), and $10,489,000 (Alternative 6). The Selected Remedy appears more expensive, but its cost is more accurate than the other estimates because the refinement of the alternative (location and volume) results in a higher confidence than the +50 to -30 percent estimates for the other alternatives.

10.2 Modifying Criteria Evaluation

10.2.1 State Acceptance

Representatives of ODEQ provided input in the RI, FS, Proposed Plan, and ROD through review of these documents. ODEQ also provided formal comments on the Proposed Plan during the comment period. The State of Oregon, through ODEQ, has submitted a letter to EPA concurring with the Selected Remedy in this ROD and supports EPA’s preferred alternative for OU1. A copy of this concurrence letter is in Appendix B.

10.2.2 Public Acceptance

Public comments were received from nine citizens, citizen groups, and state agencies (via comment letters or during the Proposed Plan public hearing). While most individuals supported the Proposed Plan, each commenter raised one or more concerns or questions to EPA. These are addressed in the Responsiveness Summary. The comments are summarized by topic and a summary response is provided for each topic. The Administrative Record file contains the original comments of each individual. There were no changes due to public comments to the preferred alternative, as presented in the Proposed Plan.

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Section 11 – Principal Threat Wastes

Principal threat wastes are generally source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present significant risk to human health or the environment should exposure occur. Low-level threat wastes are those source materials that generally can be reliably contained and that would present only a low risk in the event of release. Source materials are materials that include or contain hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, surface water, or air or act as a source for direct exposure.

Based on those definitions and the determinations made in the HHRA and the OU1 FS, mine materials within the OU1 areas of the Site containing contaminants above their respective remedial criteria constitute source materials because they act as a reservoir for migration of contamination to groundwater and surface water. Mine materials, such as waste rock, tailings, and mixtures of waste rock with soils, are source materials for ARD generation; mitigation of the mine material sources is the focus of this OU1 ROD.

Mine materials, including tailings, at OU1 are not considered principal threat waste for the following reasons:

- Contaminants in mine materials at OU1 are not highly toxic.
    - The contaminants present are not in forms or at concentrations that would result in designation of characteristic hazardous waste due to toxicity (i.e., through the Toxicity Characteristic Leaching Procedure) if it were otherwise not exempt from regulation by the Bevill amendment.
- Contaminants in mine materials at OU1 are not highly mobile.
    - The contaminants present at this Site are inorganics that are generally bound as part of mineral assemblages within the solid mine materials and are only mobile when in contact with acidic water over time.
- Contaminants in mine materials at OU1 can be reliably contained.
    - The contaminants present at this Site are inorganics generally bound as part of mineral assemblages within the mine materials. Solid mine materials are particularly amenable to containment strategies that also isolate the contaminants with water, resulting in leaching and migration.
- Contaminants in mine materials at OU1 would not present a significant risk to human health should exposure occur as evidenced by the HHRA.
    - Exposure to metals concentrations (cadmium, copper, and zinc) within these mine materials through ingestion or inhalation does not pose an unacceptable risk to human receptors. The only human receptor slightly exceeding EPA's cancer risk range was a worker and was only exceeded for arsenic in EA-3.

Mine materials at the Formosa Mine Site are thus considered a low-level threat waste. Mine materials have large volumes but low overall contaminant concentrations, and due to their solid matrix and ability to be isolated from water to minimize generation of ARD, are particularly amenable to containment. Conversely, the large volumes of materials and low contaminant concentrations, as well as the heterogeneity of the materials, are generally detrimental to and not compatible with treatment technologies. Treatment technologies were evaluated within the OU1 FS, and most were eliminated from further consideration in screening due to low implementability and high costs. Although not identified as principal threat wastes, the only materials indicated as amenable to treatment were the tailings currently contained within the pond in the EM because of their limited volume, relative homogeneity, and relatively higher contaminant concentrations. Additional discussion in Section 13.4 describes the statutory preference for treatment and subsequent exclusion of treatment as a principal element of the remedy.

Section 12 – Selected Remedy

Based on consideration of the CERCLA requirements, the detailed analysis of remedial alternatives, a preferred remedial alternative was identified and presented in the OU1 Proposed Plan. After receiving state and public comments (see Part 3, Responsiveness Summary), EPA has determined the preferred remedial alternative presented in the Proposed Plan for OU1 is the Selected Remedy for the Site. The title of the Selected Remedy is **In-Place Containment of Mine Materials, Continued Submergence of Tailings within Encapsulation Mound, and Excavation/Disposal of Targeted Mine Materials at Proposed Facilities inside PMDA and outside PMDA on FEI Property**. The Selected Remedy protects human health and the environment through the combination of targeted removals and in-place covering of OU1 mine materials. One of the primary methods to mitigate ARD is to limit infiltration of water into the source materials. Soil covers are an effective means for limiting water infiltration. The Selected Remedy includes ICs and access controls to limit activities that can interfere with the integrity of the Selected Remedy.

The Selected Remedy is Alternative 3 with two refinements. First, the repositories for the Selected Remedy will all be built on FEI property, and second (as described in Alternative 2), there will be no chemical treatment of tailings within the EM. This results in modified waste volumes, eliminates additional waste handling (chemical addition to EM), and eliminates access issues for building a repository outside of the Site. The Selected Remedy for the cleanup of mine materials at OU1 consists of the remedy components discussed in Section 9.1.6 and summarized in Section 12.2.

12.1 Rationale for the Selected Remedy

The Selected Remedy achieves the threshold criteria and provides the best balance of tradeoffs among the alternatives for balancing criteria than other Site-wide alternatives that were evaluated for OU1. The Selected Remedy is a comprehensive cleanup of OU1 that will protect human health and the environment and complies with ARARs (described more fully in Section 13.2). It has long-term effectiveness and permanence because it reliably contains mine materials and consolidates more than half of the estimated volume of mine materials in disposal facilities either within or outside the PMDA.

The covers will be designed to reduce or eliminate exposure of mine materials to surface water and oxygen. Consolidation of mine materials achieves substantial exposure reduction, as it will reduce the contamination footprint by consolidating mine materials into disposal facilities. The Selected Remedy is feasible and implementable, does not require offsite transport and disposal of mine materials, and has long-term cost-effectiveness. Excavation and covering of mine materials are remedy components that have been selected and performed at mine sites similar to the Formosa Mine Site.

The Selected Remedy also includes requirements for ICs, monitoring (visual inspections), access controls, and maintenance of the covers to prevent exposure of mine materials and maintain protectiveness. EPA will review the protectiveness of the remedy at least every 5 years after the remedy has been initiated.

The primary reasons the Selected Remedy was chosen over other alternatives in the FS were:

1. There are less significant effects to the community and environment from truck traffic since disposal of mine materials is limited to the boundaries of the former FEI property. This would reduce fuel costs and related engine emissions for transportation and minimize transportation-related safety issues.

2. The long-term effectiveness is greater because the disposal facility constructed within the PMDA is more stable as a result of improving the slopes and lowering the profile exposed to adverse weather.

3. The use of former FEI property lessens administrative activities, such as acquiring property and meeting substantive permit requirements, during selection and design of a disposal facility outside of the PMDA.

4. It simplifies development of borrow sources for proposed facility construction, cover, and reclamation materials due to use of former FEI property.

5. Location of the disposal facility within or in close proximity to the PMDA would simplify future O&M activities because the facility would be adjacent to mine workings (addressed under OU2) that may also require O&M.

12.2 Detailed Description of the Selected Remedy

The Selected Remedy includes in-place containment of approximately 55,000 CY mine materials not in close proximity to affected surface waters that have a relatively higher potential for long-term geotechnical and geochemical stability. Excavation and consolidation of mine materials will be targeted to those in close proximity to adversely affected surface water drainages and that have a lower potential for long-term geotechnical and geochemical stability. Key features of the Selected Remedy including, proposed excavation, grading, capping, and disposal facilities, are shown on Figure 9-1. Disposal of all excavated materials will take place at two proposed facilities: one within the PMDA located primarily around the EM and one outside of the PMDA located just east of the EM. Both proposed facilities will be located on FEI property. The specific locations and configurations of the repositories will be determined during the RD. For depiction Figure 9-1, the location and extent of the proposed disposal facilities within and outside the PMDA are conceptual pending remedial design. Resolving design capacity, compatible slopes, and other factors will determine whether the facilities are combined or developed separately.

Mine materials targeted for excavation and disposal directly affect the headwaters of the South Fork Middle Creek and Upper Middle Creek and/or affect stability of the EM. These areas (Figure 7-1) include the east EM WRD (which includes the illegal dump area), the Former Ore Storage and Million Gallon Tank Area, the Formosa 1 Adit and Formosa 3 Adit WRDs, overburden placed on top of the EM, mine materials along the upper side slopes of the EM, and Adit drainage affected soils (Figure 1-1). In addition, the west EM WRD is being targeted to lower the profile of the EM and reduce the slopes to the extent practical. The total targeted volume of mine materials to be excavated and disposed on the FEI property is approximately 140,000 CY.

The facility within the PMDA will be located primarily around the EM. The objective of the reconfiguration of the EM area is to remove mine materials affecting stability of side slopes and reduce the overall vertical profile of the EM without additional consolidation of mine materials. The expected volume of material to be located at the facility within the PMDA is 67,000 CY. The consolidation of mine materials at the proposed facility within the PMDA could affect long-term geotechnical stability, so the volume of consolidation will be dependent on the degree of consolidation performed outside the PMDA. Mine materials closest to the EM targeted for excavation likely will be consolidated at the proposed disposal facility within the PMDA. These include the overburden placed on top of the EM, mine materials along the upper side slopes of the EM, the Former Ore Storage and Million Gallon Tank

Area, and the west EM WRD. The overburden on top of the EM to be removed varies in thickness between 4 and 7 feet above the existing Bentomat™ cover. The existing Bentomat™ cover will remain in place over the tailings and low-grade ore within the EM. The area surrounding the EM will be regraded to stabilize the proposed facility within the PMDA.

The facility outside of the PMDA will be sized to contain the remainder of excavated mine materials and constructed to meet pertinent ARARs for the selected location. The remaining mine materials are in close proximity to the proposed facility outside of the PMDA and include the Formosa 1 Adit and Formosa 3 Adit WRD, mine materials southwest of the EM, adit drainage affected soils, mine material volumes removed from road areas to accommodate pavement cover, and the east EM WRD.

Both disposal facilities will be contained using multi-layer vegetated or rock geosynthetic covers, depending on final configuration and geotechnical stability. Multi-layer geosynthetic covers will be implemented to mitigate unacceptable exposure risks to humans and reduce ARD generation.

The facility within the PMDA will contain the EM in place, including the former water and tailings storage pond. Tailings currently stored in the pond will continue to remain submerged under the newly constructed geosynthetic multi-layer cover system. Submergence of tailings will continue to mitigate ARD generation, assuming the existing liner remains intact and holds water.

A combination of multi-layer geosynthetic covers, pavement covers, and exposure barriers will be implemented for remaining mine materials not targeted for excavation to mitigate unacceptable exposure risks to humans and reduce generation of ARD. Pavement covers will be constructed over mine materials within existing road alignments. Multi-layer geosynthetic covers could be constructed on a limited basis in areas of mine materials outside of the proposed disposal facility where specific conditions warrant. Both types of covers are capable of mitigating ARD generation as well as addressing human exposure to contaminants.

Excavated areas or areas disturbed during construction that do not have mine materials will be regraded and reclaimed with a rock armor or a vegetative layer, depending on the steepness of resulting slopes. Roads within the PMDA affected by excavations will be reconstructed as necessary to restore access. For cost estimating, exposure barriers were assumed to be used only on remaining mine materials with slopes steeper than 3H:1V. The mine material surface will be regraded, neutralized as needed to successfully establish exposure barriers to underlying mine materials, and covered with a vegetated or rock surface layer. The specific type of exposure barriers will be determined during the remedial design based on slopes and availability of sufficient quantities of suitable fill materials. Evaluation of geotechnical stability of regraded areas will be evaluated during the RD, which may indicate the need for retaining structures to stabilize mine materials left in place. These types of covers will address human exposure to contaminants but will have a minimal effect on mitigating ARD.

The ICs for the Selected Remedy involve administrative, legal, and/or informational measures intended to control or prevent present and future use or access to mine materials and inform and warn of dangers associated with these materials. In addition to ICs, access controls or physical engineered and constructed means, such as barriers, boulders, riprap, and use of timbers/logs, are components of the alternatives to inhibit access and activities that are not compatible with the Selected Remedy. These controls will be implemented as needed to maintain integrity of the proposed disposal facilities and containment areas and provide the public with community awareness tools to enhance awareness of potential hazards and the remedy for OU1. Monitoring will consist of visual inspections to document the degree of protectiveness to human health and the environment and determine maintenance needs for the proposed facilities and containment areas. Maintenance of the proposed disposal facilities and containment areas will be performed as necessary to maintain protectiveness and integrity of the covers systems.

Additional maintenance requirements, such as leachate collection and treatment, may be needed for the proposed facility outside of the PMDA, depending on the selected disposal facility location and configuration. The evaluation of the alternative for the Selected Remedy in the FS did not include evaluation of subsequent leachate water management (i.e., treatment). It is assumed subsequent management and disposal of leachate will take place under OU2 operations, as it is difficult to make a facility-specific determination of leachate characteristics (i.e., quantity and quality). Similarly, it is assumed monitoring of groundwater around the proposed facilities will be completed under OU2 operations.

Five-year site reviews will be required since mine materials under covers will remain at the site and the remedy does not allow for unlimited use and unrestricted exposure.

12.3 Estimated Cost of the Selected Remedy

The present value cost of the Selected Remedy is approximately $12,440,000. Differences from the costs in the OU1 FS are discussed in Section 12.5. The estimated capital costs are $11,960,000, and O&M and 5-year review costs (for the first 30 years) are $1,082,000. The construction timeframe is estimated to be two construction seasons (May to October), assuming full funding, maximized productivity, and no substantial delays after initiation. Table 12.4-1 presents the cost estimate summary for the Selected Remedy, including the present value analysis, on a year-by-year basis, assuming a real discount rate of 7 percent.

The information in Table 12.4-1 is based on the best available information regarding the anticipated scope of the Selected Remedy. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the Selected Remedy. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost. Because the Selected Remedy underwent more detailed evaluation and refinement of travel distance and volume of excavation, it presumably has a narrower range of estimated costs than the other alternatives. Changes may be documented in the form of a memorandum in the Administrative Record file, an Explanation of Significant Difference, or a ROD amendment.

12.4 Selected Remedy Evaluation Differences from Feasibility Study

It should be noted there are some fundamental differences in alternative component definition for the Selected Remedy that influence the comparison using the screening criteria to the other alternatives within the Final Formosa OU1 FS (CDM Smith 2013). Unlike the six remedial action alternatives evaluated in the Final Formosa OU1 FS, the Selected Remedy identifies a specific locale (FEI property) for construction of the proposed facility outside of the PMDA for OU1 mine materials. Including a specific disposal facility location for this alternative affected several factors used in the final FS for the alternative screening and cost estimate. For example, the implementability evaluation included some location-specific information associated with the FEI property for the disposal facility outside of the PMDA. Location-specific information was not evaluated or considered for other alternatives screened in the final FS that included disposal outside of the PMDA. Similarly, quantities (for instance, areas and volumes) assumed for disposal facility construction outside of the PMDA were refined for the Selected Remedy to account for the location-specific conditions. Although other alternatives in the FS included generic assumptions for construction of a disposal facility outside of the PMDA, they were not adjusted for a specific location as was done for the Selected Remedy. The factors having the most significant effects to comparability of the cost estimate for the Selected Remedy to other alternatives in the FS include:

- Horizontal footprint of the disposal facilities – The evaluation of other alternatives in the FS assumed ideal placement conditions would be used where mine materials could be placed in an optimum configuration. The FEI property, while suitable, likely would require a larger footprint to place the mine materials in a suitable configuration due to the narrow ridgetop and hillside topography. A larger footprint results in higher cover construction costs.
- Slope stability – The evaluation of other alternatives in the FS assumed that mine materials at the disposal facility within the PMDA would be placed on top of the EM, raising the profile of the ridgetop. The Selected Remedy would remove additional material at the ridgetop and regrade the area to stabilize the base for the proposed facility within the PMDA. Additional costs to enhance stability would be incurred by removing and relocating these materials for disposal. This will result in a more stable repository.
- Haul distance – The distance assumed within the evaluation of other alternatives in the FS for the proposed disposal facility outside of the PMDA was greater than the distance to FEI property immediately adjacent to the PMDA. A shorter haul distance reduces hauling costs but is offset by larger volumes required of mine materials and cover materials as discussed for the previous two factors.

This added analysis of the Selected Remedy results in a more refined cost estimate than the alternatives received during the FS, likely reducing the range of variation in the remedy compared to the FS, which is on the order of +50 percent to -30 percent costs.

12.5 Expected Outcomes of the Selected Remedy

The Selected Remedy will achieve acceptable exposure risks through a combination of consolidation and containment of mine materials, which directly affect the headwaters near the Site or that are unstable on their current slope. The remedy is expected to address the most significant mine materials in terms of potential for generation of ARD. Exposure to mine materials at remaining areas of the Site will be controlled through in-place coverings.

The Selected Remedy also will have a major effect on contaminated water at and beyond the Site. Treatment of contaminated water will be addressed under OU2; however, the OU1 Selected Remedy will greatly reduce the amount of ARD generated, which will reduce ARD collection needs and treatment requirements as well as the risk of uncontrolled release of ARD. It is anticipated the surface water quality will improve due to consolidation and containment of mine materials. Although groundwater is not directly addressed under OU1, the reduction of ARD generation from the OU1 mine materials onsite is expected to also have a positive effect on Site groundwater. As a result, the OU1 Selected Remedy will likely enhance the ability to achieve reduction of risks to human health and the environment in the OU2 remedy.

This ROD (Section 8.2) defines CULs for contaminant sources at OU1 that will be used to measure the overall effectiveness of the remedy over the long term. The OU1 CULs are linked directly to the long-term protection of human health and the environment from COCs present at the Mine Site and include the final ARARs for the Site. CULs for OU1 are quantitative values and physical descriptions that are characteristic of materials safe to remain after cleanup. The methods and procedures for measuring the CUL values are the same as developed in the OU1 RI. The CULs include arsenic, which has a concentration for natural occurring background that is based on Oregon State region-specific background concentrations (ODEQ 2013a). Specific information is provided in Table 8.2-1.

The Selected Remedy will allow the Site to be used for low-intensity recreational visitors and commercial workers. ICs and access controls comprising physical barriers, such as rock landforms timbers/logs, and/or fencing, will be considered during the remedial design phase. The ICs and access controls would restrict activity that could be detrimental to the integrity of the covers used. Acceptable low-intensity recreational activities could include hiking, hunting, fishing, and cross-country skiing. EPA has determined it is not practical to remediate the Site to meet residential use criteria because of Site conditions (i.e., groundwater contamination, steep terrain, remoteness, fire danger). Thus, ICs will be implemented to limit residential development onsite and access to contaminated water sources.

12.6 Protection of Threatened Species

Northern spotted owl (federally threatened) has a high likelihood of occurrence near the Site and has critical habitat areas identified. Forest areas within Connectivity/Diversity Block and General Forest Management Area designated BLM-managed lands and private lands adjacent to the PMDA are potential habitat for the northern spotted owl. Protection of the species and habitat will be considered during implementation of the Selected Remedy. Coastal Coho salmon is the only federally threatened fish species likely to occur in or near lower reaches of Middle Creek, approximately 6 miles downstream of the Site.

Section 12
Tables

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Table 12.4-1
Cost Estimate Summary for Selected Remedy
Formosa Mine Superfund Site, Douglas County, Oregon

Year[1]	Capital Costs (Administrative Controls)	Capital Costs (Earthwork)	Annual O&M Costs	Periodic Costs	Total Annual Expenditure[2]	Present Value[3]
0	$301,000	$11,659,000	$0	$0	$11,960,000	$11,960,000
1	$0	$0	$42,000	$0	$42,000	$39,253
2	$0	$0	$41,000	$0	$41,000	$35,809
3	$0	$0	$39,000	$0	$39,000	$31,836
4	$0	$0	$39,000	$55,000	$94,000	$71,713
5	$0	$0	$39,000	$0	$39,000	$27,807
6	$0	$0	$23,000	$0	$23,000	$15,325
7	$0	$0	$23,000	$0	$23,000	$14,322
8	$0	$0	$23,000	$0	$23,000	$13,386
9	$0	$0	$23,000	$55,000	$78,000	$42,424
10	$0	$0	$23,000	$0	$23,000	$11,691
11	$0	$0	$23,000	$0	$23,000	$10,927
12	$0	$0	$23,000	$0	$23,000	$10,212
13	$0	$0	$23,000	$0	$23,000	$9,545
14	$0	$0	$23,000	$55,000	$78,000	$30,248
15	$0	$0	$23,000	$0	$23,000	$8,335
16	$0	$0	$23,000	$0	$23,000	$7,790
17	$0	$0	$23,000	$0	$23,000	$7,282
18	$0	$0	$23,000	$0	$23,000	$6,806
19	$0	$0	$23,000	$55,000	$78,000	$21,567
20	$0	$0	$23,000	$0	$23,000	$5,943
21	$0	$0	$23,000	$0	$23,000	$5,555
22	$0	$0	$23,000	$0	$23,000	$5,191
23	$0	$0	$23,000	$0	$23,000	$4,851
24	$0	$0	$23,000	$55,000	$78,000	$15,374
25	$0	$0	$23,000	$0	$23,000	$4,237
26	$0	$0	$23,000	$0	$23,000	$3,961
27	$0	$0	$23,000	$0	$23,000	$3,701
28	$0	$0	$23,000	$0	$23,000	$3,459
29	$0	$0	$23,000	$55,000	$78,000	$10,967
TOTALS:	**$301,000**	**$11,659,000**	**$752,000**	**$330,000**	**$13,042,000**	
					TOTAL PRESENT VALUE OF SELECTED ALTERNATIVE	**$12,440,000**

Notes:

[1] The alternative is expected to require cost expenditures for perpetuity since soils under covers and structures would have mine materials that would not allow for unlimited use and unrestricted exposure under the current and potential future land uses. However, the period of analysis was assumed to be 30 years (Years 0 through 29).

[2] Total annual expenditure is the total cost per year with no discounting.

[3] Present value is the total cost per year, including a 7 percent real discount factor for that year.

[4] Total present value is rounded to the nearest $1,000. Inflation and depreciation are excluded from present value cost. Costs presented are expected to have accuracy between -30 to +50 percent of actual costs, based on the scope. They are prepared solely to facilitate facilitate relative comparisons between alternatives for FS evaluation and remedy selection.

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Section 13 – Statutory Determinations

Under CERCLA Section 121 and the NCP, EPA must select a remedy that is protective of human health and the environment, complies with or appropriately waives ARARs, is cost effective, and utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that include treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as a principal element. The following sections discuss how the Selected Remedy meets these statutory requirements.

13.1 Protection of Human Health and the Environment

The Selected Remedy includes components to address human health and environmental risks associated with OU1 mine materials. Unacceptable human health or environmental risks identified in the risk assessment process will be addressed. Risks to future workers will be reduced to acceptable levels by excavating and containing mine materials with elevated arsenic levels. Risks to aquatic receptors will be reduced through the prevention of ARD generation by excavating, containing, and capping ARD producing mine materials. The Selected Remedy will be monitored and maintained through comprehensive programs using ICs, access controls, monitoring, and maintenance. There are no short-term threats associated with the Selected Remedy that cannot be readily controlled through applicable health and safety requirements, monitoring, and standard construction practices. In addition, no adverse cross-media effects are expected from the Selected Remedy. Risks posed by exposure from mine-impacted water will be addressed in the OU2 Selected Remedy.

13.2 Compliance with ARARs

ARARs are determined based on analysis of which requirements are applicable or relevant and appropriate to the distinctive set of circumstances and actions contemplated at a specific site. The NCP requires that ARARs be attained during implementation and at completion of the remedial action. A summary of federal and state ARARs for the OU1 ROD is provided in Appendix A. The Selected Remedy will address the chemical-, location-, and action-specific ARARs described in Appendix A through adherence to those ARARs during implementation of the remedial action. When the mine materials are excavated and/or covered as described in Section 12, EPA has determined the Selected Remedy will meet ARARs while providing the greatest protection to human health and the environment.

13.2.1 ARARs Affecting Protectiveness Determinations

The provisions of the following ARARs were identified as significantly affecting protectiveness determinations for the Selected Remedy identified in this ROD. The Oregon Environmental Cleanup Law (ORS 465.200 through ORS 465.900) and the Oregon Hazardous Substance Remedial Action Rules (OAR 340-122) provide the state's regulatory framework for the determination of removal and remedial action necessary to assure protection of the present and future public health, safety and welfare, and the environment in the event of a release or threat of a release of a hazardous substance. These state laws and regulations have been identified as ARARs, and thus, compliance with the substantive requirements of these laws and regulations is required.

CERCLA and the NCP form the federal laws and regulations that were the basis for determining the need for a response action and guide the process through which a response is performed in the event of a release or threat of a release of a hazardous substance from an abandoned site. Once the need for action is determined and the remedial decision is being followed per the CERCLA and NCP requirements, the actions must meet the threshold criteria for complying with the substantive provisions of applicable or relevant and appropriate regulatory requirements. Generally, the substantive portions of the Oregon Environmental Cleanup Law and Oregon Hazardous Substance Remedial Action Rules provide standards similar to those within CERCLA and the NCP. However, a few major differences fundamentally affect the determination of protectiveness.

Specifically, the NCP indicates the following regarding carcinogens:

- For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 1E-04 and 1E-06 using information on the relationship between dose and response. The 1E-06 risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure. (Section 300.430(e)(2)(i)(A)(2)).

The Oregon Hazardous Substance Remedial Action Rules indicate the following:

- "Acceptable risk level for human exposure to individual carcinogens" means, for deterministic risk assessments, an excess lifetime cancer risk of less than or equal to one per one million (1E-06) for exposure to an individual carcinogen as described in statute and regulation ORS 465.315, OAR 340-122-0115 (2) (a).

The maximum carcinogenic risk was 6E-05 to an onsite worker exposed to arsenic in by direct ingestion of soil at EA-3. The cancer risk for the individual carcinogen, arsenic, exceeds the State of Oregon threshold risk value of 1E-06 for an individual carcinogen and region-specific background. Mine wastes in OU1 with arsenic concentrations that exceed the 1E-06 risk levels and above background are addressed in the Selected Remedy.

One location-specific ARAR that is applicable to OU1 is the National Historic Preservation Act as well as the analogous State of Oregon statutes and regulations designed to encourage historic, archeological, and antiquities preservation (contained within ORS 358 and OAR 736-050 and 736-051 as indicated in Appendix A). These ARARs will be met by the Selected Remedy through consultation with the historical preservation agencies in remedial design and implementation of remedial action consistent with the outcome of that consultation

13.2.2 Surface Water and Groundwater

Surface water and groundwater are not addressed by this action but will be addressed in OU 2.

13.3 Cost Effectiveness

In EPA's judgment, the Selected Remedy is cost effective. In making this determination, the following definition was used: "A remedy shall be cost effective if its costs are proportional to its overall effectiveness" [NCP §300.430(f)(1)(ii)(D)]. This was determined by evaluating the overall effectiveness of the Selected Remedy and comparing that effectiveness to the overall costs. Effectiveness was evaluated by examining how the remedy meets three criteria: long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness. Overall effectiveness of the remedial alternatives was then compared to costs to determine cost effectiveness. The relationship of the overall effectiveness of the Selected Remedy was determined to be proportional to its cost, and hence, this remedy represents a reasonable value for the cost to be incurred.

The present value cost of the Selected Remedy is approximately $12,440,000. It was selected over less costly alternatives because it results in greater long-term effectiveness and permanence by consolidating and covering more of the mine materials than less costly alternatives. Compared to the other alternatives, the Selected Remedy is expected to have greater short-term effectiveness, with a lower level of risk to the community, cleanup workers, and the environment. The Selected Remedy appears more expensive than other alternatives, but its cost is more accurate than the other estimates because the Selected Remedy has refinements for the disposal facility location and volume that provides a higher confidence than the +50 to -30 percent cost estimates for the other alternatives.

13.4 Utilization of Permanent Solutions and Alternative Treatment (or Resource Recovery) Technologies to the Maximum Extent Practicable

The Selected Remedy provides the best balance of trade-offs among the alternatives with respect to the balancing criteria set forth in NCP §300.430(f)(1)(i)(B). It represents the maximum extent to which permanence and treatment can be practicably utilized at OU1 of the Site. NCP §300.430(f)(1)(ii)(E) provides that the balancing shall emphasize the factors of "long-term effectiveness" and "reduction of toxicity, mobility, or volume through treatment" and shall consider the preference for treatment and bias against offsite disposal. The modifying criteria were also considered in making this determination.

EPA has determined that the Selected Remedy represents the maximum extent to which permanent solutions and treatment technologies can be used in a cost-effective manner at OU1. Of the alternatives evaluated that are protective of human health and the environment and comply with ARARs, EPA has determined the Selected Remedy provides the best balance of trade-offs in terms of the five balancing criteria, while also considering the statutory preference for treatment and bias against offsite treatment and disposal, and considering state and community acceptance.

13.5 Preference for Treatment as a Principal Element

The Selected Remedy does not satisfy the statutory preference for treatment as a principal element. The NCP establishes the expectation that treatment will be used to address principal threat wastes whenever practicable (40 CFR 300.430[a][1][iii][A]). Principal threat wastes are those source materials that are considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner or will present a significant risk to human health and the environment should exposure occur. Mine materials are generally of large volume and low toxicity, which are difficult to treat effectively. As discussed in Section 11 of this ROD, EPA has determined that mine materials, including tailings, at OU1 are not highly toxic or highly mobile, can be reliably contained, do not present a significant risk should exposure occur, and thus do not represent a principal threat. In addition, technical difficulties prevent effective treatment or recovery/reuse of various metals. Thus, active treatment and recovery/reuse were screened out as a potential option for the contaminant sources, and long-term effectiveness is achieved through consolidation, containment, ICs, access controls, maintenance, and monitoring.

13.6 Five-Year Reviews

Because the Selected Remedy results in hazardous substances, pollutants, or contaminants remaining onsite (although under covers) above levels that allow for unlimited use and unrestricted exposure, 5-year reviews will be conducted pursuant to CERCLA §121(c) and NCP §300.430(f)(5)(iii)(C). EPA will conduct a review of remedial actions no less often than each 5 years after the initiation of such remedial action to ensure the remedy is, or will be, protective of human health and the environment.

13.7 Use of Green Remediation Practices

To the extent practicable, the remedial action should be carried out consistent with EPA Region 10's Clean and Green policy (EPA 2009), including the following practices:

- Use renewable energy and energy conservation and efficiency approaches, including Energy Star equipment.
- Use cleaner fuels such as low-sulfur fuel or biodiesel, diesel emissions controls and retrofits, and emission reduction strategies.
- Use water conservation and efficiency approaches including Water Sense products.
- Use locally sourced materials when available and financially competitive (bio char)
- Use reused or recycled materials within regulatory requirements.
- Minimize transportation of materials and use rail rather than truck transport to the extent practicable.

Section 14 – Documentation of Significant Changes from Preferred Alternative of Proposed Plan

The preferred alternative in the OU1 Proposed Plan remains unchanged and is the Selected Remedy. During the public comment period, EPA received nine comments from individuals, citizen groups, and state agencies. Addressing these comments resulted in no modifications.

A common technical topic raised by commenters pertained to considering using locally produced "biochar" for revegetation at the Site. Utilization of biochar will be evaluated during the RD. Biochar is a soil amendment made through pyrolysis. Depending upon the feedstock, it has attributes to sequester metals, raise pH, and introduce a long term, stable carbon source. Cost and availability are the primary considerations that will be evaluated during the RD.

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RECORD OF DECISION

FOR

FORMOSA MINE SUPERFUND SITE

OPERABLE UNIT 1

DOUGLAS COUNTY, OREGON

Part 3
Responsiveness Summary

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Section 1 – Introduction

This section responds to comments received on the Proposed Plan for OU1 of the Formosa Mine Superfund Site. The Proposed Plan was available for public comment from January 6 to February 5, 2015. A public meeting was held to take spoken comments on January 20, 2015. EPA received comments from nine individuals and organizations.

Some commenters stated either support or opposition for the EPA preferred alternative, and several made suggestions to add to or modify the Proposed Plan. Most commenters requested clarification or asked questions on topics, including cost, methods of work, use of volunteers, effectiveness, and ease of implementation.

Section 2 – Responses to Specific Comments

The Responsiveness Summary provides each substantive comment (or a synopsis of each) received during the public comment period, followed by EPA's response. EPA received a total of fifteen comments from nine individuals and organizations during the comment period. The original comments are in the Administrative Record. The comments are listed in bold font, and EPA's responses are provided after each comment.

Comment: Biochar

EPA received multiple comments indicating a desire to utilize biochar for site remediation. Commenters suggested the use of biochar might help in various ways, including: immobilize metals and toxics, raise the pH of contaminated soil, stabilize soil, assist in soil fertility, assist in tree growth, and provide local economic opportunities.

EPA Response:

Biochar was not a specific technology or process option evaluated in the FS. EPA will include the evaluation of utilizing biochar as a soil amendment during design of the remedy to enhance plant growth, sequester metals, and raise the pH of soils.

Comment: Community Training and Jobs

One commenter expressed: "What we do want to see from this project, is that these funds that are coming here to fix the problem that has been caused, not by any individual here, go to develop community to make sure that the jobs stay in this area. If we need to put together a hazardous waste training program so that all of the people can work on the site, well that is just what we are going to do, is put together those programs."

EPA Response:

EPA will utilize local materials and labor to the extent allowed through the Federal Acquisition Regulations.

Comment: Phyto-mining and Mycological Remediation

One commenter expressed: "What we are looking at is doing phyto-mining and mycological remediation. So that we can get ahead of it, reduce the acid levels and issues we are having and start the first phase of coming in before you get into the engineering fix. That takes years of works that has to be resolved. Right now we can start a process of saying how many tons are we dealing with? How many thousands of yards are we dealing with? How many thousands or millions of gallons of material are we dealing with here that we can't comprehend. This could be continuous over decades and decades. In the first phase, mushrooms will help us. Phyto-mining is another way that we can resolve these issues and reduce the acids. Until we do the project now with permissions, permits, interfaces, working with BLM and EPA look at experimental phase. Nothing is bad about using biosystems. The chemical alterations and other activities, yes. Engineering, moving materials, it's a major watershed issue that we need to resolve. That is where the local interface comes into play."

EPA Response:

EPA concluded during the Remedial Investigation/Feasibility Study stage that phytoremediation was not technically feasible for site application because of high contaminant concentrations, large extent, and volume of mine materials and soils, excessive depth of contamination, and the heterogeneous nature of the mine materials matrix. (See Table 4-1, page 2 of 3, of OU 1 Feasibility Study Report, January 31, 2013).

Comment: Integration of EPA and BLM Plans

One commenter expressed: "I agree in concept with the need to cap waste rock to stop Acid Mine Drainage, however I believe there needs to better integration of the two plans. The one plan that EPA is rolling out for capping makes sense to me, the other phase of the plan involving the mine adit drainage on BLM lands concerns me. I see little or no integration between the two plans or phases of the same plan and that concerns me."

EPA Response:

EPA and BLM have been coordinating the actions considered by their respective agencies for this Site. Although EPA's OU1 remedy proposal does not elaborate upon BLM's planned Non-Time-Critical Removal Action (NTCRA) to control the discharge of water from the Formosa 1 Adit, EPA has considered it in planning for the overall site remediation process. BLM's proposed action is a potential remedy for OU2. OU2 will characterize releases and evaluate risks posed to surface water and groundwater. EPA intends to evaluate the results from BLM's NTCRA and determine the need for any further response action. If BLM does not implement its NTCRA, EPA will continue with characterization and remedy evaluation at OU2.

Comment: Fish Impacts

One commenter expressed: "The Department would recommend further investigation of fish populations and individual fish as they may continue to be impacted. Fish tissue samples should be collected and analyzed by the responsible parties to determine risks as there is the potential for warm water and some anadromous fish species to be caught and consumed near Middle Creek."

EPA Response:

Fish and benthic macro invertebrates will be monitored throughout the remediation process. EPA acknowledges there are threatened Coho salmon present in Middle and Southfork Middle Creek. At this time, EPA does not think it is necessary to collect tissue samples as there are no bioaccumulative metals that are being released from the Site. If tissue data is determined to be a data gap during the completion of the RI for OU2, tissue samples may be obtained.

Comment: Consumption of Terrestrial Game Species

One commenter expressed: "The Department is also concerned with terrestrial game species present in the area immediately around the site, specifically near Exposure Area 1(EA1). Mammal and bird species located in the vicinity of the mine and available for harvest include: Roosevelt Elk (*Cervus elaphus roosevelti*), **Black-tailed Deer (***Odocoileus hemionus),* **Black Bear** (*Ursus americanus),* **Dusky Grouse (***Dendragapus obscures),* **Sooty Grouse (***Dendragapus fuliginous),* Ruffed Grouse (*Bonasa umbellus),* **Mountain Quail** (*Oreortyx pictus), and* **California Quail** (*Callipepla californica).* There is some concern that species hunted and consumed in the nearby area could be contaminated. The Department does not have direct data on hunting pressure near the Formosa Mine; however, some general data is available for the Powers Unit, which includes this site. There are other hunts in this unit as well, that we do not have numbers for, such as spring bear, cougar, and game bird hunts.

EPA Response:

The Draft Final OU2 Human Health Risk Assessment determined that consuming game meat, including organ meat, would not pose an unacceptable risk to humans.

Comment: Terrestrial Receptors Impacts

One commenter expressed: "The Department suggests there may be other non-game species occasionally using the area around EA1 currently or into the future. Species such as Northern Red-legged Frog (*Rana auror)*, Western Pong Turtle (*Actinemys marmorata)*, Western Gray Squirrel (*Sciurus griseus)*, and Ringtail (*Bassariscus astutus)* are listed on the Department's Sensitive Species List. Several other species not on the Department's list may also come into contact with the site. Specific attention should be given to those species that may forage immediately next to the site on forbs or insects that may have been contaminated.

The Proposed Plan suggests there is a lack of forage or habitat for any terrestrial species. Is the investigation and evidence for this suggestion available? The Department suggests monitoring of some of the local game or other terrestrial species may be warranted to provide certainty toward this concern. Species that would most likely bioaccumulate the types of heavy metals on site would be the best candidates. A detailed plan for this proposal would need to be developed."

EPA Response:

The OU1 Baseline Ecological Risk Assessment evaluated potential impacts to terrestrial receptors and determined there was no unacceptable risk, primarily due to lack of habitat (forage and shelter). As part of the remedy for OU1, surface soils will be covered to prevent exposure and provide for revegetation. Upon completion of the remedy there will not be exposed mine impacted materials which would be available to terrestrial receptors, so EPA does not intend to monitor terrestrial organisms. EPA plans to continue monitoring aquatic organisms to evaluate the effectiveness of the selected remedy.

Comment: Vegetative Cover

One commenter expressed: "It would seem wise to try to establish vegetation on areas of barren soil. This would initiate the process of succession towards better habitat as well as limit the production and movement of airborne toxic dust."

EPA Response:

EPA concurs with the comment. EPA plans to establish a vegetative cover on the planned repositories for containing the mining waste.

Comment: Monitoring of Macroinvertebrates

One commenter expressed: "The record shows that aquatic macroinvertebrates remain severely impacted by conditions at this site. Macroinvertebrates are an important link near the bottom of the food chain. EPA should consider monitoring the status of macoinverts to determine progress toward clean-up goals."

EPA Response:

EPA concurs with the comment. The purpose of taking action at Formosa Mine Site is to improve water quality in Middle Creek and South Fork Middle Creek to allow the benthic macro invertebrate to reestablish itself and support the endemic fisheries that existed in those creeks. EPA will monitor aquatic receptors during and after implementation of the remedial action.

Comment: Naturally Occurring Acidity

One commenter expressed: "This water was very acidic due to the geology of the area interacting with hydrologic processes, rain, percolation, and ground water. The geology of the area consists of igneous related mineralization with a very high sulfur content. Rain percolates down through these minerals and becomes sulfuric acid. *This process is naturally occurring and has nothing to do with mining.*

As the assistant exploration geologist explored above and below ground in an approximately 25 square mile area. Within this area are a number of other adits, I have been in or attempted entry into many of them. Few of them were dry and most had water dammed up within them or had water running out of them. Given the geology of the area I find it quite likely that those waters too were acidic."

EPA Response:

EPA's investigation found that conditions at the mine after the 1990's phase of mining were significantly different than when commenter visited the Site in the late 1980s. EPA concurs that the geology of the area naturally results in the release of metals due to high sulfur content of the rocks, but the 1990s mining activities dramatically increased the surface area of these minerals below the groundwater table in Silver Butte Mountain. The historic mining that occurred in the 1920s and 1930s did not extend significantly below groundwater and did not backfill the mine with finely crushed waste rock and ore. The combination of mining below the water table and backfilling the tailings and other material without treatment that took place from 1990-1994 greatly exacerbated the leaching.

Comment: Over irrigation and Climatic Conditions

One commenter expressed: "There have been no reports of mammals or birds found sick or dead in the area. I believe there were reports of fish dying in Middle or Cow Creek. I can recall that this was nearly an annual event each summer due to low oxygen levels in the water due to low water levels most likely caused by a combination of over irrigation and climatic conditions."

EPA Response:

The OU2 Baseline Ecological Risk Assessment included a review of historic aquatic surveys and conducted fish presence/absence surveys and benthic macro invertebrates diversity surveys. These surveys documented reductions of benthic macro invertebrates and fish in both Middle Creek and South Fork Middle Creek from the late 1980s to the present. The most significant activity during this time period was the resumption of mining in 1990. Coastal Coho Salmon are a threatened species and were once present in higher numbers in both creeks. Impacts from over irrigation are not expected within Middle Fork or South Fork Middle Creek because there is no irrigation within these drainages. Climatic conditions can have an impact on stream flows. These two factors may have impacts to Cow Creek, but these factors are independent of and unlikely to be affected by implementing the Selected Remedy at OU 1.

Comment: Third-Party Review

One commenter expressed: "Since we do not have the expertise to provide a professional assessment of EPA's proposed remedies or the current contamination risks--we feel it would be valuable to have an independent third party evaluate the main EPA findings and obtain an opinion on the merits of Alternative 3. We would like to determine if this remedy is sufficient to address the problems at the Formosa Mine. We request that EPA provide us with administrative guidance on how this third-party review could be funded and completed."

EPA Response:

EPA will use the Technical Assistance Services (TASC) Contract to provide technical assistance to the community. In 2014, the TASC contractor completed a Technical Assistance Needs Assessment (TANA), which recommended written updates, public meeting, services of technical advisor and, follow-up on employment opportunities.

Comment: Site Restoration

A commenter expressed: "The South Umpqua Rural Community Partnership, it's collaborative partners and other community members wants to see the PMDA land restored to its former vegetative condition and proper ecological function. EPA should provide a clear plan of action to restore the site—with a plan to mitigate wildlife impacts *when* the site is restored. Capping it with rocks, keeping it as a moonscape, and hoping that deer and other wildlife do not move in—seems an inadequate course of action."

EPA Response:

The Selected Remedy includes restoration of the PMDA to the extent practical. Relatively flat areas will be revegetated, steep slopes will be armored with rock, and EPA will evaluate the utilization of biochar as a soil amendment to enhance vegetative growth for all areas. However, the Selected Remedy for caps and repositories does not anticipate allowing large woody plants to colonize the repositories as growth would compromise the integrity of the caps and repositories by preventing infiltration of precipitation.

Comment: Modification to Proposed Plan

A commenter requested that EPA modify Exhibit 8 in the Proposed Plan.

EPA Response:

The Proposed Plan is an instrument to provide the public with a summary of the nature and extent of contamination and EPA's preferred remedy to clean up that contamination. EPA does not plan to revise the Proposed Plan.

Comment: Letter of Support

A commenter requested that EPA write a letter of support indicating that EPA is willing to cooperate with SURCP and other members of community to further explore biochar as a mitigation activity at Formosa Mine in addition to the initial testing of biochar efficacy to address issues highlighted in the OU1 document.

EPA Response:

EPA will incorporate the evaluation of biochar as a soil amendment in the design of the remedy. EPA considers this Responsiveness Summary as equivalent as a "letter of support from the agency indicating that EPA is willing to cooperate with SURCP and other members of community to further explore biochar as a mitigation activity at Formosa Mine".

Section 3 – Technical and Legal Issues

The resolution of land ownership for the FEI mining property is being resolved through EPA Region 10 Office of Legal Counsel. No other technical or legal concerns are pertinent to the decision process. Preliminary design and remedial design phases of work will address engineering and geotechnical aspects.

Appendix A
Summary of Compliance with Federal and State Applicable or Relevant and Appropriate Requirements

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Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs) for the Selected Remedy at the Formosa Mine Superfund Site, OU1

Authority	Medium	Requirement[1]	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement	Chemical-Specific	Location-Specific	Action-Specific
Federal regulatory requirement	Cultural	National Historic Preservation Act (NHPA) [16 U.S.C. 470, 36 CFR Part 800, 40 CFR 6.301(b)]	Applicable	Statute and implementing regulations require federal agencies to take into account the effect of a response action upon any district, site, building, structure, or object included in or eligible for the National Register of Historic Places (generally, 50 or more years old). NHPA requires federally funded projects to assess if cultural resources on or eligible for the National Register are present, determine if there will be an adverse effect and, if so, how the effect may be minimized/mitigated, in consultation with the appropriate State Historic Preservation Office.	It is possible the mine itself or remnants of the first mining activities are of historic interest; however, no property/resources at the Site are currently included in the National Register and no building in the project area was constructed prior to 1950, a date typically used as an initial screen for determining eligibility for the Register. See also state ARAR requirements below.		✓	
Federal regulatory requirement	Cultural	Historic Sites, Buildings, and Antiquities Act of 1935 [16 U.S.C. 461-467]	Applicable	For areas designated as historic sites, the RA should avoid undesirable impacts on landmarks and encourage the long-term preservation of nationally significant properties that illustrate or commemorate the history/prehistory of the US. In conducting an environmental review of a proposed action, the responsible official shall consider the existence and location of natural landmarks using information provided by the National Park Service pursuant to 36 CFR § 62.6(d) to avoid undesirable impacts on such landmarks.	Determine if any areas of the Site are eligible for listing on the Historic Site, Building, Objects, and Antiquities Register and assess whether the Selected Remedy will affect those areas. Record assessment results or if no areas area affected.		✓	
Federal regulatory requirement	Cultural	Executive Order 11593 Protection and Enhancement of the Cultural Environment [36 CFR 8921]	Applicable	Requires federal agencies to consider the existence and location of potential and existing cultural landmarks to avoid undesirable impacts on them.	Applicability will be determined in conjunction with NHPA and other cultural statutes.		✓	

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs) for the Selected Remedy at the Formosa Mine Superfund Site, OU1

Authority	Medium	Requirement[1]	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement	Chemical-Specific	Location-Specific	Action-Specific
Federal regulatory requirement	Cultural	Archaeological and Historic Preservation Act (AHPA) [16 U.S.C. 469, 40 CFR 6.301(c)] Archaeological Resources Protection Act of 1979, as amended 1988 [16 U.S.C. 470aa-470mm]	Applicable	The statutes and implementing regulations require federally approved projects to evaluate and preserve significant scientific, prehistoric, historic, and archaeological data which may be irreparably lost or destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. The data must be preserved by the agency undertaking the project, or the DOI if requested by the agency.	The Site underwent extensive excavations and disturbances during mining activities and is unlikely to contain potential scientific, prehistoric, historic, or archaeological data/resources; however, not all of the area has been previously surveyed. If any remedy components are to be located in a previously undisturbed area, conduct a Phase I archaeological survey.		✓	
Federal regulatory requirement	Hazardous Waste	Resource Conservation and Recovery Act (RCRA): Subtitle C – Exemption for Extraction, Beneficiation, and Processing Mining Waste [40 CFR 261.4(b)(7)]	Applicable	EPA exempts mining wastes from the extraction, beneficiation, and some processing of ores and minerals, in accordance with the Bevill amendment to RCRA.	None – RCRA Bevill Amendment applies because all OU1 mining wastes are from the extraction and beneficiation processes. Bevill exempts mining wastes from Subtitle C of RCRA	✓		✓
Federal regulatory requirement	Hazardous Waste	RCRA: Subtitle D – Criteria for Classification of Solid Waste Disposal Facilities and Practices [42 U.S.C. 6901 et seq., 40 CFR 257]	Relevant and Appropriate	Certain criteria are required to be met by solid waste disposal facilities and disposal practices. Relevant criteria such as not restricting the base flow of the floodplain, not taking threatened or endangered species, and not causing a discharge to navigable waters, may be useful for siting and design of a disposal facility.	Relevant, substantive provisions will be addressed during pre-design activity for the Selected Remedy.			✓
Federal regulatory requirement	Hazardous Waste	RCRA: Subtitle D – Disposal of Nonhazardous Solid Waste [42 U.S.C. 6901 et seq., 40 CFR Part 258]	Relevant and Appropriate	Provides criteria for cover material, run-on/runoff control systems, access control, restrictions on disposal of liquid wastes.	Substantive provisions will be identified during pre-design activity.			✓
Federal regulatory requirement	Hazardous Waste	Hazardous Waste Operations and Emergency Response [29 CFR 1910.120, 40 CFR 311]	Applicable	Worker protection during hazardous waste cleanup and CERCLA removal actions	Substantive provisions will be identified during pre-design and construction planning activity.	✓		✓

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)
and To Be Considered Information (TBCs)
for the Selected Remedy at the Formosa Mine Superfund Site, OU1

Authority	**Medium**	**Requirement[1]**	**Status**	**Synopsis of Requirement**	**Action to be Taken to Attain Requirement**	**Chemical-Specific**	**Location-Specific**	**Action-Specific**
Federal regulatory requirement	Waste	Disposal of Solid Waste Criteria for Classification of Solid Waste Disposal Facilities and Practices [42 U.S.C. 6901 et seq., 40 CFR 257]	Relevant and Appropriate	Establishes criteria for determining which solid waste disposal practices pose threats to human health and the environment.	Substantive provisions will be identified and incorporated as appropriate for the disposal facility or repository located "onsite."			✓
Federal regulatory requirement	Habitat	Endangered Species Act (ESA) [16 U.S.C. 1531] Responsible official requirements [40 CFR 6.302(h)] Endangered and threatened wildlife and plants [50 CFR 17] Interagency cooperation – ESA of 1973, as amended [50 CFR 402]	Applicable	Statute and implementing regulations require that federal activities not jeopardize the continued existence of any threatened or endangered species. Section 7 of the ESA requires consultation with the USFWS to identify the possible presence of protected species and mitigate potential impacts on such species.	None – to date, no threatened or endangered species have been identified in the PMDA area of the Site.		✓	
Federal regulatory requirement	Habitat	Migratory Bird Treaty Act [16 U.S.C. 703, et seq.] List of Migratory Birds [50 CFR 10.13]	Relevant and Appropriate	The Act makes it unlawful to "hunt, take, capture, kill," or take other various actions adversely affecting a broad range of migratory birds, without the prior approval of the Department of the Interior (DOI).	The Selected Remedy will be implemented in a manner to avoid adversely affecting migratory bird species, including individual birds or their nests.		✓	

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)
and To Be Considered Information (TBCs)
for the Selected Remedy at the Formosa Mine Superfund Site, OU1

Authority	Medium	Requirement[1]	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement	Chemical-Specific	Location-Specific	Action-Specific
Federal regulatory requirement	Water	Clean Water Act / Water Pollution Control Act [33 U.S.C. 1251] - Sections 301-302 – Effluent Limitations - Section 303 – Water Quality Standards - Section 304 – Federal Water Quality Criteria - Section 306 – National Performance Standards Section 307(a) – Toxic Pollutant Standards - Section 401—Water Quality Certification - Section 402 – National Pollutant Discharge Elimination System (NPDES)	Relevant and Appropriate	These regulations govern water quality, including water discharged as part of a remedial process. - Section 401— requires the state to provide EPA with a water quality certification that discharges to navigable waters will comply with the state's water quality standards (if a federal permit was required) - Section 402— The NPDES program establishes a comprehensive framework for addressing processing water and stormwater discharges under the program and requires that point-source discharges not cause exceedance of surface water quality standards outside the mixing zone. Also specifies requirements under 40 CFR 122.26 for point-source discharge of stormwater from construction sites to surface water and provides for Best Management Practices such as erosion control for removal and management of sediment to prevent run-on and runoff.	The Selected Remedy for OU1 addresses only mine materials; however, the substantive provisions are relevant and appropriate to the materials. The regulations include standards of control and other substantive environmental protection requirements that address situations similar to the circumstances of the Selected Remedy and are well suited to the conditions of the Site.			✓
Federal	Waste	BLM Abandoned Mine Lands Handbook	TBC	BLM Policies Management of Abandoned Mine Lands including, but not limited to, Section 9.4.7.2. Repositories	None – The handbook can be used during design of a disposal facility, if desired, to provide useful guidance for cleanup decisions or methods.			
Federal	Land	Resource Management Plan [Northwest Forest Plan FSEIS, 1994 and ROD, 1994]	TBC	This is the applicable approved Resource Management Plan for the area of BLM Managed Lands. The plan is non-promulgated and therefore not legally binding.	Plan may provide useful guidance if BLM land is part of the disposal facility or borrow source.			
State regulatory requirement	Soil and Water	Removal or Remedial Action [ORS 465.200-465.900 Oregon Hazardous Substance Remedial Action Rules[2], OAR 340-122 et seq.]	Relevant and Appropriate	Sets standards for degree of cleanup required. Establishes acceptable risk levels for human health at 1E-6 for individual carcinogens and 1E-5 for multiple carcinogens; a Hazard Index of 1 for non-carcinogens; and protection of ecological receptors at the individual level for threatened or endangered species and the population levels for all others.	State cleanup requirements will be used where the substantive cleanup standard is more stringent than federal requirements.	✓		✓

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs) for the Selected Remedy at the Formosa Mine Superfund Site, OU1

Authority	Medium	Requirement[1]	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement	Chemical-Specific	Location-Specific	Action-Specific
State regulatory requirement	Hazardous Waste	Oregon Hazardous Waste Management Act [ORS 466.005-225 Hazardous Waste Management Rules; OAR 340-100 et seq.]	Not an ARAR	Establish a regulatory structure for the generation, transportation, treatment, storage, and disposal of hazardous wastes. OAR Chapter 340, Divisions 100 to 106, 109, 111, 113, 120, 124, and 142 incorporate, by reference, hazardous waste management regulations of the federal program, included in 40 CFR Parts 260 to 266, 268, 270, 273, and Subpart A and Subpart B of Part 124, into OAR.	Oregon adopted and implements the RCRA Bevill Amendment, therefore, substantive standards are not more stringent than federal requirements.			
State regulatory requirement	Waste	Solid Waste Management Solid Waste: General Provisions [ORS 459.005–418, OAR 340.093-097]	Relevant and Appropriate	Regulations under this statute establish a regulatory structure for the collection, transportation, treatment, storage, and disposal of solid wastes.	For onsite management and disposal of contaminated soil, groundwater, and mine materials, state cleanup requirements will be used where the substantive cleanup standard is more stringent than federal requirements.			✓
State regulatory requirement	Waste	Solid Waste Management [ORS 459, OAR 340-095 Land Disposal Sites Other than Municipal Solid Waste Landfills]	Applicable	Governs the management of solid wastes and land disposal sites, other than municipal solid waste landfills.	For onsite management of mine materials, state cleanup requirements will be used where the substantive cleanup standard is more stringent than federal requirements.			✓
State regulatory requirement	Assessment	Final Guidance for Use of Institutional Controls [OAR 340-122 ODEQ, April 1998]	TBC	Guidance for selection or approval of institutional controls as part or all of a remedy.	Consider for the Selected Remedy at this Superfund site but only where consistent with overall EPA guidance and policy.			✓

1 = Statute/Regulation/Standard/Policy (and appropriate citations) used to identify general category of ARAR/TBC. This listing does not indicate acceptance of the entire statute/regulation/standard/policy as an ARAR/TBC; specific ARARs/TBCs are addressed in the table for each general heading. Only substantive provisions of the specific requirement are considered potential ARARs/TBCs.

2 = The preamble to the NCP indicates that state regulations that are components of a federally authorized or delegated state program are generally considered federal requirements and potential federal ARARs for the purposes of ARARs analysis (55 Fed. Reg. 8666, 8742 [1990]). The ODEQ received final authorization for the regulation of hazardous wastes on August 15, 1995 (Federal Register Volume 60, Number 116 [Friday, June 16, 1995]).

Substantive RCRA requirements are applicable to response actions on CERCLA sites if the waste is a RCRA hazardous waste, and either: the waste was initially treated, stored, or disposed after the effective date of the particular RCRA requirement (1976 for RCRA, and 1984 for the amendments including land disposal restrictions); or the activity at the CERCLA site constitutes treatment, storage, or disposal as defined by RCRA

EPA 1988a CERCLA Compliance With Other Laws Manual, Draft Guidance (Part I). Interim Final EPA/540/G 89/006, Office of Emergency and Remedial Response, Washington, D.C. August.

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs)
and To Be Considered Information (TBCs)
for the Selected Remedy at the Formosa Mine Superfund Site, OU1

EPA 1989a. CERCLA Compliance With Other Laws Manual: Part II – Clean Air Act and Other Environmental Statutes and State Requirements, EPA/540/G-89/009, OSWER Directive 9234.1-02, Office of Solid Waste and Emergency Response, Washington, D.C. August.

Acronyms

AHPA	Archaeological and Historic Preservation Act
ARAR	Applicable or Relevant and Appropriate Requirement
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOI	United States Department of Interior
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FSEIS	Final Supplemental Environmental Impact Statement
NAAQS	National Ambient Air Quality Standards
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rules
ODEQ	State of Oregon Department of Environmental Quality
ORS	Oregon Revised Statutes
OSWER	Office of Solid Waste and Emergency Response
OU1	Operable Unit 1
PMDA	Primary mine disturbance area
RA	Remedial action
ROD	Record of Decision
RCRA	Resource Conservation and Recovery Act
SMCRA	Surface Mining Control and Reclamation Act
TBC	To Be Considered (information)
TSDF	Treatment, Storage, and Disposal Facility
U.S.C.	United States Code
USFWS	United States Fish and Wildlife Service

Appendix B
State Letter of Concurrence on ROD

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Oregon
Kate Brown, Governor

Department of Environmental Quality
Western Region Eugene Office
165 East 7th Street
Eugene, OR 97401
(541) 686-7838
FAX (541) 686-7551
TTY 711

February 22, 2016

Dennis McLerran, Regional Administrator
Office of Environmental Cleanup
U.S. Environmental Protection Agency, Region 10
1200 Sixth Avenue
Seattle, WA 98102

Re: State Concurrence with the Formosa Mine Superfund Site Record of Decision for Operable Unit 1

Dear Mr. McLerran:

The Oregon Department of Environmental Quality has reviewed the U.S. Environmental Protection Agency Region 10 proposed Record of Decision for final cleanup of Operable Unit 1 of the Formosa Mine Superfund Site. Heavy metals in mine wastes and mine-impacted water from the abandoned Formosa Mine site threaten human health and the environment, including salmonid fish in two drainages near the site.

On January 9, 2007, Oregon Governor Theodore R. Kulongoski concurred with EPA's decision to add the Formosa Mine site to the National Priorities List. DEQ recommended state concurrence because it recognized that the significant environmental impacts from the abandoned mine would not likely be successfully mitigated without federal Superfund status.

DEQ believes that EPA's remedy decision complies with state laws that are applicable or relevant and appropriate to the site, and will provide for remedial action that is protective of human health and the environment. Pursuant to CERCLA and 40 CFR 300.515(e), I am pleased to advise you that the State of Oregon, by and through DEQ, concurs with EPA's Operable Unit 1 Record of Decision.

DEQ believes the selected Operable Unit 1 remedy will contain and isolate mine materials at the Formosa Mine site from precipitation and surface water, reducing leaching of metals and mine-influenced water into nearby salmonid fish-bearing waterways. DEQ understands that beneficial effects of the Operable Unit 1 remedy on restoration of these waterways will be measured and monitored through planning and implementing a future remedy for Operable Unit 2, including source materials and contaminated groundwater within the underground mine workings.

DEQ understands that the Bureau of Land Management will be contributing significant funds towards Operable Unit 1 remedial action costs. DEQ also understands that the state's CERCLA-required cost-sharing of remedial action costs will be limited to EPA's capital costs for remedy implementation, not including BLM's expenditures.

DEQ appreciates EPA's significant efforts to consult and coordinate with state interests throughout the Remedial Investigation/Feasibility Study process leading up to the Record of Decision for Operable Unit 1. DEQ looks forward to continuing this cooperative effort during the upcoming Remedial Design/Remedial Action process that is expected over the next three to four years on the Formosa Mine project.

The appropriate DEQ contact is Mr. Greg Aitken who can be reached at (541) 687-7361.

Sincerely,

Dick Pedersen
Director

Cc: Sheila Fleming, EPA Region 10 Acting Director of Environmental Cleanup
Davis Zhen, EPA Region 10 Site Cleanup Unit 2 Manager
Christopher Cora, EPA Region 10 Site Cleanup 2 Remedial Project Manager
Richard Whitman, Oregon Natural Resources Policy Director
Joni Hammond, DEQ Deputy Director
Keith Andersen, DEQ Western Region Administrator
Lydia Emer, DEQ Operations Administrator
Bruce Gilles, DEQ Cleanup and Emergency Response Manager
Michael Kucinski, DEQ Western Region Cleanup and Emergency Response Manager
Gary Vrooman, Oregon Department of Justice