Engineering Evaluation/Cost Assessment (EE/CA) for the Union-Zaar Mine Six Rivers National Forest Del Norte County, California

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Submitted by:

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Acronyms and Abbreviations

ARAR	Applicable or Relevant and Appropriate Requirements
bgs	below ground surface
BLM	Bureau of Land Management
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COPC	contaminants of potential concern
DWR	California Department of Water Resources
EE/CA	Engineering Evaluation/Cost Assessment
EPA	U.S. Environmental Protection Agency
ERRG	Engineering/Remediation Resources Group, Inc.
ESL	Environmental Screening Level
FDEP	Florida Department of Environmental Protection
Forest Service	U.S. Department of Agriculture, Forest Service Region 5
HRS	Hazard Ranking Score
MCL	Maximum Contaminant Levels
mg/kg	milligrams per kilogram
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRA	National Recreation Area
OSC	On-Scene Coordinator

Acronyms and Abbreviations *(continued)*

PEC	probable effects concentrations
PEL	probable effects level
PPE	probable point of entry
PA/SI	Preliminary Assessment/Site Investigation
PRAG	preliminary removal action goal
PRAO	preliminary removal action objective
PRG	Preliminary Remediation Goal
QC	quality control
RAP	remedial action plan
RWQCB	Regional Water Quality Control Board
SPLP	Synthetic Precipitation Leaching Procedure
SRE	Streamlined Risk Evaluation
Tetra Tech	Tetra Tech, EM Inc
TEC	threshold effect concentration
TEL	threshold effects level
USGS	U.S. Geological Survey

Executive Summary

The Union-Zaar Mine is an inactive copper mine located in Section 35, T18N, R1E, within the Smith River National Recreation Area in the Six Rivers National Forest, about 25 miles northeast of Crescent City, in Del Norte County, California. The 20-acre site includes roads, adits, and mine waste piles located along the banks of Copper Creek. Copper Creek, a tributary to the Smith River, runs north through the middle of the site. A number of sensitive environments exist at the site and downstream from the site, including habitat known to be used by the following species listed by the federal government as Endangered: McDonald's Rock Cress, Coho salmon, cutthroat and steelhead trout.

The waste rock piles associated with the mine site are in direct contact with Copper Creek. Investigations conducted at the mine site from 1991 to 2007 indicate that the mine waste piles along the creek are the source of the metals contamination observed in the sediments of Copper Creek. The primary pathway for contaminants to migrate from source materials (mine waste piles) to sediment in Copper Creek is via physical erosion of the waste piles where they are in contact with Copper Creek. Materials eroded from the underwater portions of the mine waste piles are transported downstream and re-deposited as sediment in Copper Creek. High creek flow during the Winter and Spring likely contributes more significantly to erosion of the waste piles than low flow during Summer/Fall. The concentrations of metals in sediment decrease with distance downstream from the waste piles, indicating that natural sediments are likely being deposited with contaminated sediments and diluting the effects of the metals-impacted sediment.

Surface water quality in Copper Creek in the vicinity of the Union-Zaar Mine Site has not been affected by metals in mine waste piles, likely as a result of a natural buffering effect of the slightly alkaline native surface and groundwater. Groundwater and surface water are not considered exposure pathways for contaminants from this site.

A streamlined risk evaluation (SRE) was conducted to evaluate potential risks to human health and the environment. The SRE concluded surface water at the Union Zaar Mine site does not pose unacceptable risk to human health or the environment, but that sediment in Copper Creek may pose unacceptable risk to ecological receptors and source materials (mine waste piles) may pose unacceptable risk to human health and the environment.

Humans who come in contact with the mine waste piles at the Union-Zaar mine site (through extended recreational activities such as camping) may be exposed to arsenic at concentrations that pose a

significant health risk. Ecological receptors may also be exposed to arsenic, copper, and mercury in the mine waste piles and downstream sediments at concentrations that pose unacceptable risk.

Additional evaluation of potential risks for ecological receptors exposed to sediment included conducting bioassay analyses of upstream and downstream sediment to evaluate adverse effects to survival and growth of freshwater amphipods. The results of this evaluation indicated that organisms in both upstream and downstream samples exhibited below average growth. This is likely due to the low levels of organic carbon (food source) in the sediment combined with the background concentrations of metals in both upstream and downstream sediment. Survival of organisms in upstream and downstream samples was not considered adversely affected. While concentrations of metals in sediment may pose unacceptable risk to ecological receptors, the results of the bioassay sampling indicate that the adverse effects of metals in downstream sediment are equivalent to those of the upstream sediment. Metals in sediment due to releases from the site are therefore not expected to have a negative impact on downstream ecological receptors (including freshwater amphipods, or spawning sensitive fish).

Metals in surface water at the site were below all applicable criteria for the protection of human health and ecological receptors. Surface water is therefore not expected to have a negative impact on human recreational users or on spawning or downstream sensitive fish (including Coho salmon, cutthroat trout, and steelhead trout).

The goal of this EE/CA is to develop and select a removal action alternative that is in accordance with CERCLA criteria to ensure that the selected action is protective of human health and the environment and compliant with Applicable or Relevant and Appropriate Requirements (ARARs).

The following preliminary remedial action objective (PRAO) was developed for the site to ensure that potential human and ecological receptors are protected from elevated metals concentrations in the source materials (mine waste piles) and to eliminate downstream migration of source materials to sediment in Copper Creek:

- **Prevent human or ecological exposure to the waste piles which contain metals at concentrations exceeding the removal action goals.** Direct exposure to metals in the waste piles poses an unacceptable site risk and may impact downstream sediments in Copper Creek.

The preliminary remedial action goals (PRAGs) associated with the site are as follows:

- The threat to potential human or ecological receptors of exposure to metals concentrations in the waste piles shall be eliminated.
- The threat of downstream migration of metals from waste piles to sediments of Copper Creek shall be eliminated.

The following four removal action alternatives were evaluated in the EE/CA to address these PRAGs:

- No Action
- Engineering Controls by In-situ Slope Stabilization with Rip Rap
- Removal of Source Materials followed by On-site Encapsulation and Creek Bank Restoration
- Removal and Off-site Disposal of Source Materials followed by Creek Bank Restoration.

Each alternative was analyzed for effectiveness, implementability, and cost. Following the alternatives analysis, a comparative analysis was conducted for all alternatives and the following alternative was selected as the recommended removal alternative:

Alternative 3, Removal of Source Materials followed by On-site Encapsulation and Creek Bank Restoration.

The primary components of the recommended alternative are as follows:

- An engineering design will be completed for an on-site soil cell, and the excavation and creek bank restoration process. The design will identify an appropriate site for the on-site cell and will outline required geotechnical testing to be accomplished prior to building the cell. The on-site encapsulation design will be submitted to appropriate regulatory agencies.
- An on-site backfill source will be identified and tested for geotechnical and chemical properties to ensure a suitable material for creek bank restoration.
- The current access route to the creek banks will be improved to support the removal activities.
- Temporary sandbags will be placed in the creek on the upstream side of the work areas, creek water will be diverted away from the work area.
- The mine waste piles on the creek banks will be excavated and brought to the on-site stockpile area. The excavated soil will be placed inside the soil cap footprint and stockpiled and compacted by a loader and a dozer.
- After all mine wastes are excavated (estimated 10,000 tons) from the creek banks, minimal amounts of fill will be excavated from an on-site source, and trucked to the excavated area to backfill along the creek banks and restore them to as close to pre-mining conditions as possible. After backfilling is completed, minimal amounts of rip rap may be placed at the toe of the backfill for erosion control.
- The surface of the backfill area will be covered with erosion control mat, and the steep slopes will be hydroseeded and/or live-staked with native plants for slope stabilization.
- The soil cell will be constructed at the designated stockpile area. After all mine wastes are placed inside the soil cell area, a soil cover will be placed on top of the compacted mine waste (specifications for the soil cover will be included in the final design).
- After the removal action and soil cap construction are completed, a focused monitoring and inspection program will be conducted during the first 12 months of the long-term maintenance

program to ensure the planted vegetation is growing and meets expectations, and the erosion controls are functioning as intended.

- After the first year, periodic inspection and maintenance activities will be carried out in subsequent years to maintain the integrity of the soil cap and the restored creek banks.

The estimated cost of the recommended removal action alternative is $678,000. This cost represents an order-of-magnitude estimate, in accordance with guidance for conducting EE/CAs, with an intended accuracy of +50 to -30 percent.

Section 1. Introduction

Engineering/Remediation Resources Group, Inc. (ERRG) has prepared this Engineering Evaluation/Cost Assessment (EE/CA) Report for the U.S. Department of Agriculture Forest Service Region 5 (Forest Service) for the Union-Zaar Mine Site in the Smith River National Recreation Area (NRA) of the Six Rivers National Forest in Del Norte County, California. This work was conducted under the Regional Environmental Response Action Contract (AG-91S8-C06-0056) Activity II, Task 2: EE/CA Support. The EE/CA is preceded by a Preliminary Assessment/Site Investigation (PA/SI) conducted at the site by Tetra Tech, EM Inc. (Tetra Tech) in 2005. The PA/SI recommended that further action should be taken at the site to address and reduce site risks from: (1) impacted sediment at Copper Creek at the probable point of entry (PPE) and downstream from the site and (2) elevated metals in rock piles associated with adits that are in direct contact with the Copper Creek and an unnamed ephemeral creek. This EE/CA is part of the non-time critical removal action to implement these recommendations.

The Union-Zaar Mine is an inactive copper mine located in Section 35, T18N, R1E, within the Smith River NRA in the Six Rivers National Forest, about 25 miles northeast of Crescent City, in Del Norte County, California (Figure 1). The 20-acre site includes roads, adits, and mine waste piles located along the banks of Copper Creek. The mine features consist of one shaft (the Union-Zaar Shaft), two primary adits (the North Adit and the South Adit), several smaller adits and prospect pits, and associated mine waste piles (Figure 2). Copper Creek, a tributary to the Smith River, runs north through the middle of the site. A number of sensitive environments exist at the site and downstream from the site, as summarized in the PA/SI for the site (Tetra Tech, 2005). Sensitive environments include habitat known to be used by the following species listed by the federal government as endangered: McDonald's Rock Cress, Coho salmon, cutthroat and steelhead trout. Sediment in Copper Creek has been impacted by a release of metals (primarily arsenic and copper) from waste rock piles that are in direct contact with the creek.

1.1. REGULATORY FRAMEWORK

Authority for responding to releases from a hazardous waste site is addressed in Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Executive Order 12580 delegates to the U.S. Department of Agriculture (USDA) the authority for removal actions at Forest Service sites whether or not the sites are on the National Priorities List (NPL). The Forest Service, under the delegation of the USDA's authority, is the lead federal agency for the environmental investigation and cleanup of the site, and as such will oversee all project activities. Other federal, state, or

local agency representatives may be consulted, at the discretion of the Forest Service's On-Scene Coordinator (OSC). The Forest Service will ensure that all removal action tasks are in compliance with CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and Division 20, Chapter 6.8, of the State of California Health and Safety Code.

The U.S. Environmental Protection Agency (EPA) has classified removal actions into three types: emergency, time-critical, and non-time critical. The classification is based on the type of situation, the urgency to take action, the threat of release or potential release, and the period of time in which the action must be initiated (EPA, 1993). The removal action at the Union-Zaar Mine site will be non-time critical because a 6-month period is available before a removal action should be taken at the site and the threat to human health and/or ecological receptors is not immediate. Section 300.415(b)(4)(i) of the NCP requires that an EE/CA is produced for all non-time-critical removal actions to evaluate removal alternatives for the site.

1.2. PURPOSE

The purpose of the EE/CA is as follows: (1) meet the environmental review requirements for removal actions; (2) satisfy administrative record requirements for unproved documentation of removal action selection; and (3) identify the objectives of a removal action and analyze the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives.

1.3. REPORT ORGANIZATION

The EE/CA presents background information, analytical results, removal action alternatives, and alternatives analysis. The EE/CA is separated into the following sections:

- **Section 1.0, Introduction -** briefly describes the site location and background, previous findings, and the content of the EE/CA. The section also states the purpose of the EE/CA and the regulatory framework in which the EE/CA resides.
- **Section 2.0, Site Characterization –** states the description and background of the mine site, including previous investigations and the source, nature, and extent of known contamination. This section also makes references to previous analytical data which has characterized the on-site contamination.
- **Section 3.0, Streamlined Risk Evaluation –** provides a screening evaluation of site risks to human health and the environment
- **Section 4.0, Removal Action Objectives and Goals –** states the preliminary removal action objectives and goals that, if met, will result in the protection of human health and the environment, pursuant to CERCLA criteria.

- **Section 5.0, Applicable or Relevant and Appropriate Requirements (ARARs) –** lists and details potential chemical-specific, location-specific, and action-specific ARARs which aid in establishing cleanup criteria for the site.
- **Section 6.0, Identification and Analysis of Removal Action Alternatives –** describes four removal action alternatives and analyzes each for effectiveness, implementability, and cost.
- **Section 7.0, Recommended Removal Action Alternative –** provides a comparative analysis of the four removal action alternatives and analyzes each for effectiveness, implementability, and cost.

Section 2. Site Characterization

This section presents a description of the Union-Zaar Mine site and its historical use as part of the "Low Divide" mining district. It also details the source, nature, and extent of known metal contamination at the site and references analytical data resultant of previous investigations conducted at the site that aided in the assessment of said contamination. This section provides the basis for understanding the contaminants of potential concern (COPCs) and media of potential concern at the mine site, including their derivation, and the setting in which they are currently found.

2.1. SITE DESCRIPTION AND BACKGROUND

The Union-Zaar Mine site is an inactive copper mine located in Section 35, T18N, R1E, within the Smith River NRA in the Six Rivers National Forest, about 25 miles northeast of Crescent City, in Del Norte County, California. The site is accessed via an improved gravel road (County Road 308) and then by narrow unimproved roads. Direct access to the site is via old mining roads and is limited to hikers. The 20-acre site includes roads, adits, and mine waste piles located along the banks of Copper Creek. The mine features consist of one shaft (the Union-Zaar Shaft), two primary adits (the North Adit and the South Adit), several smaller adits and prospect pits, and associated mine waste piles. To ensure site safety and limit access to the mine openings, bat gates have been placed over the adits and shaft. Copper Creek, a tributary to Rowdy Creek and the Smith River, runs north through the middle of the site.

The Union-Zaar Mine was originally called the Union Mine and was part of the "Low Divide" mining district, which included the Alta, Union, Crescent, Mammoth, and Star mines. The now-abandoned town of Altaville was also a part of the district. The Low Divide mining district was established in the 1860s as a copper mining district, and in later years chromium mines were also included in the district. As summarized in the PA/SI by Tetra Tech EM Inc. (Tetra Tech, 2005), the bulk of ore production at the Union-Zaar mine occurred in the 1860s, which is when the adits and waste piles that are still present at the site were built.

2.2. GEOLOGY AND SOILS

The Union-Zaar Mine Site is located at the western boundary of the Klamath Mountains geomorphic provinces (Norris and Webb 1990; Harden 1998). The Klamath Mountains province is composed of accreted oceanic terranes divided by roughly north-south trending faults that become younger to the west.

The westernmost of these terranes is separated from the Coast Ranges geomorphic province to the west by the South Fork Mountain Fault. The geologic basement in the region primarily consists of metamorphosed Mesozoic sedimentary and volcanic rocks, including ophiolite suites underlain by older ultramafic rocks, chiefly Mesozoic in age (California Division of Mines and Geology, 1966).

Soils in the vicinity of the site consist of shallow (1-3 foot-thick) soils developed from serpentenite parent rock. According to a study completed in 1985 (Forest Service, 2007) the soils in the vicinity of the site correlate to two main soil series; the Huse Series and the Weitchpec Series. The Huse series soils extend 2 to 3 feet below ground surface (bgs) and consist of A and C horizons. The A Horizon is primarily clay, clay loam, or stony clay loam with the C Horizon composed of clay or loamy clay. The measured pH range is 6.2 in the upper (A) horizon to 6.9 in the lower (C horizon). The surface layer of these soils often exhibits iron-manganese pellets similar to an erosion pavement. The Weitchpec series extend only 1 to 2 feet deep and are also composed of A and C horizons. The A Horizon consists of a dense sod of grass roots and stony loam underlain by clay loam in the C Horizon. The pH range for this soil series was from 6.3 near the surface to 6.8 in lower portions of the C Horizon.

2.3. ENVIRONMENTAL SETTING AND CLIMATE

The Union-Zaar Mine is located in the Six Rivers Forest, approximately 9 miles east of the Pacific Ocean coastline, on the northeastern edge of the Klamath Mountains, at an average elevation of 1,600 feet above mean sea level. The sections below briefly describe the climate, ecological communities, and nearby sensitive environments of the Union-Zaar Mine Site.

The coastal portion of Del Norte County exhibits a temperate coastal climate, with average temperature variations of less than 10 °F throughout the year. The average temperature in the nearby town of Crescent City, approximately 25 miles southwest of the Union-Zaar Mine Site, is 57.7 °F in the summer and 48.0 °F in the winter. Total average annual precipitation is about 66 inches, with about 47 percent of the rainfall in winter, 24 percent rainfall in spring, and 24 percent rainfall in fall. Snow accounts for only about 0.03 percent of the average annual precipitation (Western Regional Climate Center, 2005).

A number of sensitive environments exist at the site and downstream from the site. Specifically, Copper Creek has been identified as spawning habitat for cutthroat and steelhead trout and Chinook and Coho salmon (Tetra Tech, 2005). Surveys conducted by the California Department of Fish and Game (CDFG) in the 1980s identified Copper Creek as “anadromous fish habitat” with a habitat suitability rating of “very high” (Dames and Moore, 1985). In 1972, coho, chinook, and steelhead fingerlings were present in the upper reaches of Copper Creek (Dames and Moore, 1985). In addition, the National Oceanic and Atmospheric Administration (NOAA)’s National Marine Fisheries Service (NMFS) included Copper Creek in their compilation of streams for which historical (pre-1989) or current (1989-2000) records exist

documenting the occurrence of coho salmon (NMFS, 2001). Sensitive species (including threatened and endangered species) in the vicinity of the Union-Zaar Mine site are summarized in Table 1.

Sensitive environments within a 4-mile radius of the Union-Zaar Mine site were identified during the PA/SI (Tetra Tech, 2005). These include habitat known to be used by McDonald's Rock Cress, Coho salmon, cutthroat and steelhead trout (Forest Service, 2007). Copper Creek may serve as habitat for species documented in adjacent areas, including the Mardon Skipper and Oregon Silverspot Butterfly (Tetra Tech, 2005).

Sensitive environments within the 15-mile target distance limit downstream of the Union-Zaar Mine Site include (1) a 3-mile stretch of the Smith River designated as a National Wild and Scenic River and (2) habitats known to be used by the Bald Eagle, Bank Swallow, Tidewater Goby, and the Western Snowy Plover (Tetra Tech, 2005). Other sensitive species that are potentially present within the 15-mile target distance limit include the Marbled Murrelet, Northern Spotted Owl, and Pacific Fisher (Tetra Tech, 2005).

No towns or other human population centers were identified within the 4-mile target distance limit, during the PA/SI (Tetra Tech, 2005).

2.4. HYDROLOGY AND HYDROGEOLOGY

The site is located in the Smith River Plain Groundwater Basin, specifically in the Lower Rowdy Creek Watershed of the North Coast Hydrologic Region. Copper Creek runs north through the site from its headwaters (directly south of the site at the Low Divide) to Rowdy Creek, approximately 3.5 miles downstream. Copper Creek is characterized by a steep gradient in the vicinity of the site (the upper reaches of the creek) which becomes much more gradual before entering Rowdy Creek. Rowdy Creek eventually discharges to the Smith River, approximately 5 miles east of the river's outlet to the sea.

The Smith River Plain is an emerged low-relief marine terrace, the surface of which is characterized by sand dunes, floodplain deposits, unconsolidated river terrace deposits, and marine deposits (California Department of Water Resources [DWR], 2003). Marine deposits of the Battery and St. George formations underlie the floodplain deposits and are in turn underlain by metamorphic basement rock of the Jurassic-Cretaceous Franciscan Complex.

The basin's water-bearing formations are composed of the Quarternary alluvial fan, terrace, flood-plain, and Battery Formation deposits (DWR, 2003). The depth to groundwater varies from 10 to 35 feet over the estimated 31,000-acre basin. Most groundwater in this region is derived from shallow wells (Ranney collectors) installed in the gravel and sand beds of several of the rivers in the region. Local towns, including Smith River and Crescent City receive their water supply from groundwater beneath the Smith River, Rowdy Creek, Klamath River, and Mad River (DWR, 2003).

Two domestic groundwater wells were identified within four miles of the Union-Zaar Mine site with reported static water levels of 29 and 12 feet below ground surface, respectively (Tetra Tech 2005).

2.5. SOURCE, NATURE, AND EXTENT OF CONTAMINATION

The waste rock piles associated with three adits (the North and South Adits and the West Collapsed Adit) are in direct contact with Copper Creek as shown on Figure 3. As summarized in the PA/SI (Tetra Tech, 2005), the Forest Service conducted an investigation in 1991 that included collection of soil and water samples. Results indicated that only one sample, a soil sample containing an elevated concentration of copper collected from the South Adit, posed a potential chemical water quality concern. Additional chemical analyses were performed by the Forest Service in 1998 for preparation of an Abandoned Mine Land Summary Sheet, but none of the samples collected yielded concentrations that would present a chemical water quality concern.

2.5.1. Preliminary Assessment/Site Investigation Results

In 2004 and 2005, soil, surface water, and sediment samples were collected for the PA/SI to assess the level of contamination due to the waste rock piles. Samples taken from the waste rock piles in direct contact with the creek had elevated concentrations (at least three times background levels) of metals, including copper, arsenic, chromium, and nickel. Sediment samples from Copper Creek showed elevated levels of metals, including copper, chromium, and nickel. Surface water analytical results indicated that surface water has not been impacted by the metals in the waste rock piles. No surface water samples collected from Copper Creek showed metals at elevated concentrations with respect to background and water quality criteria. It is assumed that the relatively high pH of the water (pH in Copper Creek is as high as 8.3) inhibits the metals from significantly dissolving from solid media into the water. In addition, leachability testing results from Synthetic Precipitation Leaching Procedure (SPLP) analysis of a sample taken from the waste piles yielded concentrations below EPA Water Quality Criteria and Safe Drinking Water Levels (Maximum Contaminant Levels [MCLs] (Tetra Tech, 2005). Given the SPLP results and the low metals levels in surface water, neither surface water nor groundwater at the site were considered media of potential concern.

2.5.2. Additional Background and Downstream Sediment Sampling

On May 18, 2007 additional sediment sampling was performed by ERRG with the objective of further delineating metals concentrations in the downstream sediments. One upstream sample was collected from approximately the same location as the background sample collected for the PA/SI to evaluate variability in upstream/background metal concentrations in the sediment. Beginning at the West Collapsed adit, four downstream samples were collected at approximately 500 ft. intervals to determine the extent of the metals in the downstream sediments (Figure 4). Samples were collected upstream of the first downstream tributary into Copper Creek, downstream of the Site. All four downstream sediment samples yielded

results for metals that were above background concentrations and screening criteria for the site. Further discussion of the background levels and screening criteria is provided in Section 3.0.

Further downstream sediment sampling was conducted by the Forest Service on July 6, 2007. One sample was collected downstream of the confluence of Copper Creek and the first downstream tributary and one was collected from the unnamed tributary, upstream of its confluence with Copper Creek (Figure 4). Both of these samples contained metals at concentrations above background levels for the site, but did not exceed the screening criteria for the site. Therefore, the extent of metals in sediment is considered delineated by these two samples and does not extend beyond the confluence of Copper Creek and the unnamed tributary.

The complete analytical results for sediment samples collected by ERRG and the Forest Service in 2007 are presented in Appendix A.

2.5.3. Background and Downstream Sediment Bioassay Sampling

On August 23, 2007 two additional sediment samples were collected by the Forest Service, one upstream and one downstream, for bioassay testing, to evaluate whether elevated metals concentrations in sediment in Copper Creek were likely to have adverse effects to the growth or survival of ecological receptors potentially present downstream from the site[1].

Sediment samples were submitted for bioassay testing using *Hyalella azteca*, a freshwater amphipod. This amphipod, a very sensitive ecological receptor, was chosen as a conservative measure to ensure that the test results would be applicable to higher trophic levels (such as sensitive spawning fish in and downstream from Copper Creek). Complete results of the bioassay sampling are presented in Appendix B.

Bioassay testing was conducted using bulk sediment from the site to which filtered water and the amphipods (*Hyalella azteca*) were added. The test was conducted for 10-days and measured both survival and growth endpoints. The test design utilizes eight test chambers for each sediment sample, with each test chamber containing 10 amphipods. The amphipods are added to each test chamber at the start of the test. Following the 10-day exposure period, the amphipods are sieved from the sediment and evaluated for survival. Growth is evaluated by comparing the starting weight of the amphipods to the final weight. A survival rate below 70% was considered indicative of adverse effects on the organism. Measurable growth was compared for upstream and downstream samples to determine whether there

[1] Bioassay data are a more precise evaluation method than a simple comparison of sediment sampling results to ecological screening criteria (see Section 3) since the data are site-specific data reflecting actual toxicity, rather than relying on the assumptions used in development of the ecological screening criteria.

were any adverse effects on the downstream sample. A third (standard or control sediment) test was also run simultaneously to ensure that the starting organism population was healthy and to provide a benchmark for "normal" survival and growth conditions.

The results of the bioassay sampling indicated that both the downstream and upstream sample exhibited more than 80% survival (within the acceptable range) and that survival rate in both samples was reduced when compared to the control sample. The growth testing showed measurable growth in both upstream and downstream samples. When compared to the control sediment, the rate of growth in both upstream and downstream samples was reduced (or below "normal" rates). The reduced growth may be attributed to the fact that the sediment contains little organic carbon[2] and that metals concentrations in both upstream and downstream samples are elevated above those in the control sample.

2.6. CONCEPTUAL SITE MODEL

Investigations conducted at the mine site from 1991 to 2007 indicate that the mine waste piles along Copper Creek are the source of the metals contamination at the site. In addition, results from the PA/SI sampling effort indicate that the elevated metals concentrations are limited to the waste piles and the sediments downstream of the PPE and are not a concern in groundwater or the surface water of Copper Creek. The extent of elevated metals concentrations in sediment is delineated by concentrations below screening criteria. The screening criteria are based on risk assessment data provided in Section 3.0. Sediment concentrations decrease downstream of the confluence of the first tributary and Copper Creek.

The primary pathway for contaminants to migrate from source materials (mine waste piles) to sediment in Copper Creek is via physical erosion of the waste piles where they are in contact with Copper Creek. Materials eroded from the underwater portions of the mine waste piles are transported downstream and re-deposited as sediment in Copper Creek. High creek flow during the winter and spring likely contributes more significantly to erosion of the waste piles than low flow during summer/fall. The concentrations of metals in sediment decrease with distance downstream from the waste piles, indicating that native sediments with lower metals concentrations may be diluting the effects of the metals-impacted sediment.

Surface water quality in Copper Creek in the vicinity of the Union-Zaar Mine Site has not been affected by metals in mine waste piles, likely as a result of a natural buffering effect of the slightly alkaline native subsurface and groundwater. Groundwater and surface water are not considered exposure pathways for contaminants from this site.

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[2] Organic carbon is the primary amphipod food source and was sampled in sediment from Copper Creek during the PA/SI. The maximum detected concentration of total organic carbon in sediment was 0.2 mg/kg (Tetra Tech, 2005).

Section 3. Streamlined Risk Evaluation

The following Streamlined Risk Evaluation (SRE) is intended to evaluate potential risk to human health and ecological receptors from exposure to metals contamination at the Union-Zaar Mine site. Potential risks were evaluated for exposure to soil, sediment and surface water.

Potential risks to human health were evaluated based on consumption of water from Copper Creek and recreational uses at the site (camping, hunting, and fishing). Ecological risk was evaluated based on metals toxicity effect on select sensitive species exposed to contaminated source materials, water and sediment. An additional evaluation of sediment toxicity was conducted following the SRE, to evaluate site-specific effects on ecological receptors.

Prior to conducting the SRE, concentrations of all metals were initially screened against site-specific background concentrations. Concentrations that were deemed elevated with respect to background (ambient) concentrations were further evaluated in the SRE.

The following sections present the background screen for all site data and the Human Health and Ecological SRE results.

3.1. BACKGROUND COMPARISON VALUES

In order to exclude metals concentrations that represent background (ambient) concentrations, all data was screened against background values prior to conducting the SRE. Soil, surface water, and sediment background comparison values were established for a suite of 24 inorganic constituents, including aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc.

3.1.1. Soil

Background concentrations for soil and source sample comparison were based on upgradient soil samples collected in June 2004 as shown on Table 2. Where analytes were not detected, the sample detection limits were used. These background soil concentrations were compared against the regional background concentrations referenced from the U.S. Geological Survey (USGS) and included in the PA/SI (Tetra Tech, 2005). As presented on Table 2, the concentrations in the site-specific background soil

sample (UZBS001) were generally within the range of the regional background concentrations, with the exception of aluminum, barium, calcium, chromium, cobalt, iron, magnesium, nickel, potassium, and selenium. Calcium, iron, magnesium, and potassium are considered essential nutrients that are generally excluded from the risk analysis.

3.1.2. Surface Water

The background values selected for the dry- and wet-season surface water comparisons were measured in upstream water samples collected in June 2004 and February 2005, respectively. Table 2 presents the background concentrations for surface water samples for both seasons.

3.1.3. Sediment

The available data for sediment background concentrations included one sediment sample (UZS007) collected in June 2004 and one (UZS014) collected from the same upstream location in May 2007. Because these samples represent solid matrix and relatively coarse material (fine sand to gravel), the metals concentrations between the two samples were variable. Because no single sediment value was available for comparison, the range of concentrations in the two background samples was used to represent site-specific upstream (background) concentrations (see Table 2).

3.2. CONTAMINANTS OF POTENTIAL CONCERN

Source (waste pile), surface water, and sediment concentrations were compared to background concentrations, as shown in tables 3 through 5. Inorganic constituents detected at concentrations below the background values were removed from the risk evaluation as a contaminant of potential concern (COPC). In addition, several inorganic constituents, including calcium, iron, magnesium, and potassium, are considered essential nutrients and were also not considered COPCs.

As a conservative measure, an inorganic constituent is included as a COPC if the maximum concentration detected exceeds the background comparison value. Tables 3 through 5 compare the data for each media type against the background comparison values.

Concentrations of several metals in source, surface water, and sediment exceeded background concentrations. The following metals and media were considered elevated with respect to background and were retained for further analysis in the SRE:

- Antimony, arsenic, chromium, copper, mercury, nickel, selenium, silver, thallium, vanadium, and zinc in source (mine waste) materials (Table 3)
- Aluminum, antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, molybdenum, selenium, sodium, and zinc in surface water (Table 4)

- Arsenic, beryllium, cadmium, chromium, cobalt, copper, manganese, mercury, vanadium, and zinc in sediment (Table 5)

3.3. EXPOSURE POINT CONCENTRATIONS

The exposure point concentrations (EPC) for each COPC for each affected media have been conservatively estimated to be the maximum concentration detected in the data set. Table 6 summarizes the EPC for each COPC.

3.4. HUMAN HEALTH RISK SCREENING

Potential risks to human health were evaluated by comparing EPCs for each COPC to appropriate screening benchmarks developed for protection of human health. To determine the appropriate benchmarks for the risk screen, exposure pathways were established for affected site media. Three direct exposure media were identified for humans: source material (waste rock), surface water, and sediment. Human receptors can access the site via off road vehicles or on foot and may be exposed to metals contamination in the identified media through ingestion or dermal contact.

Soil, sediment and surface water benchmarks have been developed by the Bureau of Land Management (BLM) for protection of residents, campers, all-terrain vehicle drivers, site workers, and surveyors exposed to metals at BLM mining sites (BLM, 1996). Of these, the camper benchmarks were deemed the most appropriate screening-level benchmarks for protection of human health. For comparison, the BLM soil benchmarks were also evaluated against EPA's Preliminary Remediation Goals (PRGs) for protection of industrial site workers (EPA, 2004) (Table 7). Additional surface water benchmarks include EPA's PRG for tap water (EPA, 2004) and the MCL for drinking water (Marshack, 2003) (Table 7). These secondary benchmarks were used in the absence of BLM criteria as part of the human health risk screen; however, they are deemed conservative given the remoteness of the site, the fact that there are no regular on-site workers, and the absence of drinking water intakes in Copper Creek.

Table 8 presents the results of the human health SRE for COPCs in source materials, surface water, and sediment. Arsenic, chromium, and nickel concentrations in source materials exceeded the human health benchmarks in source materials. No other human health benchmarks were exceeded for source, surface water, or sediment.

The SRE for human health indicates that humans who use Copper Creek for recreational activities or work at the site will not be exposed to metals in surface water or sediment at concentrations that pose an unacceptable health risk. Humans who are exposed to the mine waste piles at the Union-Zaar mine site (through extended recreational activities such as camping) may be exposed to arsenic, chromium, and nickel at concentrations that may pose a significant health risk. Elevated chromium concentrations were present in all of the waste piles at the site; elevated arsenic concentrations were present at the waste piles

associated with the South, West Collapsed, and Midslope adits; and elevated nickel concentrations were present at the West Collapsed Adit waste pile only.

Exposure to source materials in the waste piles that are located along the creek (North Adit, South Adit, and West Collapsed Adit waste piles) is considered more likely than exposure to source materials at the Midslope Adit, due to the remote location of the Midslope Adit and the steepness of the slope to access it. It is reasonable to conclude that human visitors will have limited to no exposure to arsenic from the Midslope Adit.

3.5. ECOLOGICAL RISK SCREENING

Potential risks to ecological receptors were evaluated by comparing the EPC for each COPC to appropriate ecological screening benchmarks developed for protection of environmental receptors. As discussed in subsection 2.3, sensitive environments within a four mile radius of the site include suitable habitat for the McDonald's Rock Cress, Coho salmon, cutthroat trout, and steelhead trout. Coho, Chinook, and steelhead have been observed to be present in Copper Creek in the past (Dames and Moore, 1985; NMFS, 2001). To determine the appropriate benchmarks, exposure pathways were established for affected site media and key receptors.

Three direct exposure media were identified: source material (waste rock), surface water, and sediment. Mammals were identified as the key receptors that may be exposed to metals in source materials by ingestion or dermal contact. The key receptors that may be exposed to surface water include mammals, birds, fish, fish eggs from spawning fish, and fish fry. These receptors may be exposed to metals in surface water through ingestion or dermal contact. Invertebrates were identified as the key receptors for sediment.

3.5.1. Ecological Benchmarks

Soil, sediment and surface water benchmarks have been developed by the BLM for protection of birds, wildlife, and livestock exposed to metals at BLM mining sites (BLM, 1996). The benchmarks for each media type were developed from several resources:

- **Surface Water Ecological Benchmarks.** Ecological benchmarks presented in "*A Compilation of Water Quality Goals*" (Marshack, 2003), including the California Toxics Rule Criteria for Freshwater Aquatic Life Protection and EPA's National Ambient Water Quality Criteria for Freshwater Aquatic Life Protection, were developed to protect fish and lower trophic levels in fresh waters. The EPA's National Ambient Water Quality Criteria were deemed most appropriate.

- **Sediment Ecological Benchmarks.** Ecological criteria developed to evaluate sediment quality in freshwater ecosystems, including the threshold effect concentrations (TEC), the probable effects

concentrations (PEC) (EPA, 2002), as well as the threshold effects level (TEL) and probable effects level (PEL) developed specifically for invertebrates living in freshwater sediment (FDEP, 1994). Of these benchmarks, the PECs were deemed most appropriate and protective for sediment comparisons.

- **Soil Ecological Benchmarks.** EPA's Environmental Screening Levels (ESLs) (EPA 2003a, 2003b, 2003c, 2003d, 2003e), ecological PRGs for soil (Efroymson and others, 1997) and BLM wildlife and livestock criteria for soil were evaluated and selected as screening criteria. Of these, the soil Environmental Screening Levels (ESL) were deemed most appropriate for comparison to source materials. In the absence of an ESL, the other criteria listed were evaluated and the most appropriate was selected.

All criteria evaluated are presented in Table 9. Table 10 presents the results of the ecological SRE for COPCs in source materials, surface water, and sediment.

3.5.2. Ecological Benchmark Comparison Results

The EPCs for each COPC were compared against the selected ecological benchmarks for soil, surface water, and sediment. Based on this comparison, mammals and other receptors exposed to the mine waste piles may be exposed to metals at concentrations that may pose unacceptable risks. Invertebrates or other ecological receptors exposed to sediment in Copper Creek may be exposed to chromium, nickel and copper in sediment at levels that may pose unacceptable risk. The ecological SRE indicates that fish and other ecological receptors exposed to surface water in Copper Creek will not be exposed to metals at concentrations that pose unacceptable risk. A discussion of each media and the corresponding evaluation results is provided in the following subsections.

3.5.2.1. Source Material Results

Concentrations of antimony, arsenic, chromium, cobalt, copper, mercury, nickel, selenium, thallium, and vanadium in source (waste rock) materials exceeded ecological benchmarks (Table 10). Based on the EPC value and toxicity characteristics, arsenic, chromium, copper, nickel, and mercury are considered the primary risk drivers with a high risk of adverse effects to wildlife receptors exposed to the waste piles.

3.5.2.2. Surface Water Results

In surface water, none of the COPCs exceeded their respective benchmarks with the exception of selenium and lead, which are discussed below.

- **Selenium in Surface Water.** The EPC for selenium in surface water (5.6 micrograms per liter [µg/L]) exceeded the ecological benchmark of 5 µg/L. The range of detected concentrations for selenium in surface water at the site is 3.1 µg/L to 5.6 µg/L with a background (upstream)

concentration of 4.3 µg/L. The selenium EPC is not significantly elevated with respect to the background concentration.

- **Lead in Surface Water.** The EPC for lead in water (7.4 µg/L) exceeded the hardness-corrected ecological benchmark (6.7 µg/L) but was within the range of lead benchmarks for the hardness range of all samples at the site (2.0 to 11.5 µg/L). The range of detected concentrations for lead in surface water at the site is less than 2.3 to 7.4 µg/L. The EPC selected for lead represents a sample collected from the drainage of the South Adit during the wet season (UZW010). The second-highest lead concentration in surface water (5.8 µg/L), collected from the North Adit drainage during the dry season (UZW002), was well below the hardness-corrected benchmark (11 µg/L). In addition, the lead EPC is not significantly elevated with respect to the background (upstream) concentrations for lead (4.8 µg/L).

To further evaluate the potential adverse effects of selenium and lead in surface water, a comparison was made to acute criteria for aquatic life protection (Marshack, 2003). The hardness-corrected acute exposure concentration (1-hour average) for lead in surface water is 280 µg/L. The EPC for lead is nearly 38-times lower than the acute exposure value. The acute exposure concentration for selenium is 20 µg/L, 3.6-times the EPC for selenium.

The fact that the maximum concentrations (EPCs) for selenium and lead concentrations are not significantly elevated with respect to the background and that both metals are well below any acute effects levels indicates that they represent acceptable incremental risk above background and are not likely to significantly contribute to adverse effects to ecological receptors in contact with surface water at the site. Receptors exposed to surface water in Copper Creek (including fish, birds, and mammals) are not likely to be adversely affected by these concentrations.

3.5.2.3. Sediment Results

Concentrations of chromium, copper, and nickel in sediment exceeded screening-level benchmarks for protection of invertebrates in sediment. The maximum chromium concentration (1,120 mg/kg) was just over 10-times the PEC; the maximum nickel concentration (2,910 mg/kg) was 60-times the PEC and the maximum copper concentration (1,040 mg/kg) was approximately 7-times the PEC. These levels of chromium, nickel and copper indicate a moderate to high risk of adverse effects to receptors exposed to sediment in Copper Creek.

To further evaluate site-specific effects of metals in sediment, bioassay data for freshwater amphipod testing were used. A discussion of bioassay sampling and results is presented in subsection 2.5.3 with the complete bioassay test results in Appendix B. Sediment bioassay data indicated that survival and growth of the freshwater amphipod *Hyalella azteca* were not adversely effected when downstream sediment test was compared to the upstream sediment test.

3.6. STREAMLINED RISK EVALUATION CONCLUSIONS

The results of the SRE indicate that surface water at the Union Zaar Mine site does not pose unacceptable risk to human health or the environment, but that source materials (mine waste piles) may pose unacceptable risk to human health and the environment.

Humans who come in contact with the mine waste piles at the Union-Zaar mine site (through extended recreational activities such as camping) may be exposed to arsenic at concentrations that pose a significant health risk. Elevated arsenic concentrations were present in all of the waste piles at the site, but humans are expected to have extremely limited exposure to the Midslope Adit, given its remote location. Ecological receptors may also be exposed to arsenic, copper, and mercury in the mine waste piles at concentrations that pose unacceptable risk.

Metals in surface water at the site were below applicable criteria for the protection of human health and ecological receptors. Surface water is therefore not expected to have a negative impact on human recreational users or on spawning or downstream sensitive fish (including Coho salmon, cutthroat trout, and steelhead trout).

Concentrations of chromium, copper, and nickel in sediment were greater than screening criteria protective of invertebrates. Further sediment toxicity evaluation (bioassay testing) indicated no increase in toxicity in downstream sediment when compared to upstream sediment. Thus, although metals concentrations in downstream sediment samples were greater than background and screening levels, the effect of these concentrations on survival and growth of invertebrates was no greater in the downstream sediment when compared to background effects. Based on the SRE, sediment is not expected to pose unacceptable risk to human recreational users of Copper Creek or to invertebrates or higher trophic levels (fish, birds, or mammals).

Section 4. Removal Action Objectives and Goals

The goal of this EE/CA is to develop and analyze removal action alternatives in accordance with CERCLA criteria, and to recommend a removal action alternative which is protective of human health and the environment and compliant with ARARs. The removal action alternative will be selected in an Action Memorandum, which is to be prepared by the lead federal agency (Forest Service). The preliminary removal action objective (PRAO) and preliminary removal action goals (PRAGs) that have been selected for the site are in compliance with these criteria and are detailed in the following subsections. These preliminary goals for the site may be altered following the submittal of this EE/CA, if additional information that requires re-evaluation of the PRAO becomes available from stakeholders or other interested parties. As such, the final removal action objectives and goals will reflect these alterations and refinements, if any, and will be defined in the action memorandum.

4.1. PRELIMINARY REMOVAL ACTION OBJECTIVE

The PRAO for the Union-Zaar Mine site ensures that potential human and ecological receptors are protected from elevated metals concentrations in the source materials (mine waste piles) and potential downstream erosion to Copper Creek sediments at the site. The objective is as follows:

- **Prevent human or ecological exposure to the waste piles which contain metals at concentrations exceeding the removal action goals.** Direct exposure to metals in the waste piles poses an unacceptable site risk and may impact downstream sediments in Copper Creek.

The attainment of the PRAO is expected to result in achieving compliance with CERCLA criteria.

4.2. PRELIMINARY REMOVAL ACTION GOALS

Due to the inherent high levels of metals found at mine sites, generic cleanup goals such as PRGs are not applicable. As such, the higher value of background concentrations (see Table 5) and soil benchmarks for the protection of human health (see Table 6) and ecological receptors (see Table 10) will be used for the waste piles to determine if the metals contamination has been reduced to acceptable levels. Although the cleanup criteria shall act as alternative-specific PRAGs, general goals for all alternatives are as follows:

- The threat to potential human or ecological receptors of exposure to metals concentrations in the waste piles shall be eliminated.

- The threat of erosion of contamination to sediments of Copper Creek by the waste piles shall be eliminated.

By achieving the PRAGs, the PRAO will be met and the potential risks to human health and the environment will be eliminated.

Section 5. Applicable or Relevant and Appropriate Requirements (ARARs)

Section 300.415(i) of the NCP provides that removal action must attain Applicable or Relevant and Appropriate Requirements (ARARs) to the extent practical, considering the exigencies of the situation.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. The requirement is applicable if the jurisdictional prerequisites of the law or regulation directly address the circumstances at the site. An applicable federal requirement is considered an ARAR. An applicable state requirement is an ARAR only if it is more stringent than federal ARARs.

If the requirement is not legally applicable, then the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations similar to the circumstances of the proposed removal action and are well suited to the conditions of the site (EPA, 1988a). A requirement must be determined to be both relevant and appropriate to be considered an ARAR.

To qualify as a state ARAR under CERCLA and the NCP, a state requirement must be a promulgated law, substantive, consistently applied, and more stringent than a federal requirement. Provisions of generally relevant federal and state statutes and regulations that were determined to be procedural or nonenvironmental, including permit requirements, are not considered to be ARARs. Nonpromulgated advisories or guidance issued by federal or state governments are not legally binding and do not have the status of ARARs. However, such requirements may be useful and are “to be considered” (TBC) for guiding decisions regarding cleanup levels or methodologies when regulatory standards are not available.

The EPA has developed three categories of ARARs to assist in the identification of Site requirements. The three categories are (1) chemical-specific, (2) location-specific, (3) and action-specific ARARs. EPA guidance recognizes that some requirements do not fall neatly into this classification; however, the following definitions provide a general guideline for each of these categories:

- Chemical-Specific ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numeric values (cleanup levels). These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to the ambient environment.
- Location-Specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations. Location-specific ARARs relate to the geographical or physical position of the site (e.g., presence of wetlands, sensitive species, flood plains, etc.).
- Action-Specific ARARs are activity- based requirements or limitations on actions taken with respect to hazardous substances.

The Forest Service has primary responsibility for identifying federal ARARs. On November 28, the Forest Service requested ARARs from NOAA's NMFS, the CDFG and the North Coast Regional Water Quality Control Board (RWQCB). The federal and state ARARs that are presented in this document represent a preliminary analysis of potential ARARs. In addition, standards and statutes developed and compiled from the Six Rivers Land and Resource Management Plan and the Smith River NRA were included as "to be considered" in the ARARs evaluation. The complete text of these statutes is presented in Appendix C. Other federal and state advisories, criteria or guidance may, as appropriate, be considered in formulating the removal action. Table 11 summarizes the potential ARARs for this project.

Section 6. Development, Identification and Analysis of Removal Action Alternatives

The development of removal action alternatives for the Union-Zaar Mine site began with a determination of potential response actions based on the PRAO, ARARs, and EPA guidance. Appropriate response actions were then identified. The retained technologies and process options were assembled into removal action alternatives, which are identified and analyzed in this section and evaluated in Section 7.0.

As described in subsection 4.1, the PRAO for the Union-Zaar Mine Site is:

- **Prevent human or ecological exposure to the waste piles which contain metals at concentrations exceeding the removal action goals.** Direct exposure to metals in the waste piles poses an unacceptable site risk and may impact downstream sediments in Copper Creek.

This section evaluated remedial alternatives for meeting the PRAO.

6.1. GUIDANCE DOCUMENTS

Response actions for CERCLA chemicals were identified based on regulatory agency guidance documents for feasibility studies (EPA, 1988b) and guidance on evaluating non-time critical removal actions (EPA, 1993).

6.2. RESPONSE ACTIONS CONSIDERED

Three general response action categories were considered for this EE/CA:

1. No action
2. Engineering/institutional controls
3. Removal by excavation of source materials (mine waste piles) at three stretches of the creek bank to eliminate erosion of the source materials into Copper Creek and to reduce human and ecological exposure to source materials

The no-action category is required for consideration in CERCLA and EPA guidance for conducting EE/CAs. Table 12 summarizes the screening of technologies and processes associated with these response actions.

6.3. RESPONSE ACTION EVALUATION CRITERIA

Response actions were evaluated in accordance with EPA guidance on conducting feasibility studies (EPA, 1988b), Guidance On Conducting Non-Time Critical Removal Actions Under CERCLA", OSWER 9360.0-32 and "Outline of EE/CA Guidance", EPA, March 30, 1988. The criteria that were used in the evaluation are effectiveness, implementability, and cost, as discussed in the following subsections.

6.3.1. Effectiveness

In accordance with EPA guidance, the effectiveness screening criterion included the following elements:

- Ability to achieve PRAO
- Permanent removal and reduction of site-specific COPCs
- Long-term effectiveness (with technologies that have significantly lower long-term risks being preferred)
- Short-term effectiveness (with technologies that minimize safety risks in planning, conducting, and implementing removal actions being preferred)

6.3.2. Implementability

The screening criterion of implementability included the following elements:

- Ability to implement the removal action alternative under existing site conditions
- Ability to remove COPCs from the Union-Zaar Mine Site
- Availability of necessary materials and equipment (with the preferred technologies being those that are commercially developed and readily available, or innovative technologies that have been field-tested with documented results)
- Regulatory and community acceptance

6.3.3. Cost

Technologies were evaluated based on qualitative costs. Alternatives with lower costs were preferred if the effectiveness and implementability criteria were judged to be similar.

The cost estimates were prepared to aid in the evaluation of alternatives using information that is currently available. These costs are order-of-magnitude estimates with an intended accuracy of +50 to -30 percent (EPA, 2000). These costs are not construction bid costs, nor are they final project costs. Final project costs will depend on actual labor and material costs, actual engineering design costs, actual site conditions (including the actual quantities of mine waste excavated and the amount of material that

may be classified as hazardous waste), competitive market conditions, the final project scope, the final project schedule, and other variables. As a result, the final project costs will vary from these estimates.

6.4. REMOVAL ACTION ALTERNATIVES

The following removal action alternatives were developed for the Union-Zaar Mine Site based on the three response action categories described in subsection 6.2:

1. No Action
2. Engineering Controls by In-situ Slope Stabilization with Rip Rap
3. Removal of Source Materials followed by On-site Encapsulation and Creek Bank Restoration
4. Removal and Off-site Disposal of Source Materials followed by Creek Bank Restoration

Each alternative was analyzed for its capability to reduce the risks detailed in Section 3. Specifically, the alternatives are analyzed for effectiveness, implementability, and cost. Following the alternatives analysis, a comparison will be made, and one alternative will be selected as the recommended removal action (Section 7).

6.4.1. Alternative 1: No Action

Under the No Action alternative, no remedial or removal action would be taken at the site. As such, the human and ecological risks relating to the site would remain unchanged. The No Action alternative is used as a baseline for all other alternatives and will be retained for the alternative analysis.

6.4.1.1. Effectiveness

The No Action alternative is expected to have low effectiveness for achieving the PRAO at the site. The alternative would not remove the source (i.e. mine waste piles). As such, the COPCs will remain in place and would likely continue to pose potential unacceptable risk to human health and the environment. In addition, no action would be taken to reduce or eliminate the erosion of materials from the waste piles to the sediment in the creek and the waste piles will continue to contribute to the downstream sediment impacts. This alternative would not reduce or eliminate the risk to ecological and human receptors.

As no action would be taken to reduce or eliminate the COPCs at the site this alternative would not meet potential ARARs.

6.4.1.2. Implementability

The No Action alternative would be readily implementable and administratively feasible. No federal agency authorization would be required to implement this alternative. No services or materials would be needed for the implementation of this alternative.

6.4.1.3. Cost

There are no foreseen costs associated with the implementation of the No Action alternative, other than nominal long-term administrative costs.

6.4.2. Alternative 2: In-Situ Slope Stabilization of Mine Waste Piles using Rip Rap

Alternative 2 employs an engineering control approach, which requires the placement of filter-fabric on the existing mine waste piles, followed by the placement of a layer of large rocks (as rip rap) on top of the filter fabric to physically stabilize the existing mine waste piles. The filter fabric will prevent the release of fine sediment (silts) into the creek, while the rip rap will prevent future creek bank erosion. This alternative would not remove COPCs from the site.

Based on the size of the creek, one-man rock[3] should provide adequate protection from erosion along the slopes of the waste piles even during wet seasons. Larger, two- and three-man rock[4] would be necessary at the toe of the rip rap embankment to keep the rip rap on the upper slope from sliding along the steep slope of the embankment. A final engineering study and design is required as part of this alternative to ensure its implementability and to appropriately size the rocks to be used as rip rap for effective erosion control. An evaluation of the availability and suitability of local quarry sources to supply the rip rap must also be conducted as part of the design.

Under this alternative, the existing mine waste piles will be left in place, therefore, no mine waste pile removal or off-site disposal are required. If this work is to be conducted during the dry season, no creek diversion would be required. The toe and portions of the slope of the mine waste piles may need to be cut when larger rip rap is placed at the toe area. A detailed engineering study would be required prior to cutting back the toe, to ensure the feasibility of this alternative, including evaluation of overall slope stability, determination of space requirements for the final modified slope, and determining the appropriate size and volume of rip rap to be placed for slope stabilization. Placement of large (two- and three-man) rock at the toe of the slopes may alter the course of the creek and (depending on the volume of

[3] A one-man rock is typically up to300 pounds.

[4] A two-man rock is typically 300 to 800 pounds; a three-man rock is typically 800 to 1,500 pounds.

rock required) may some rock may be placed on top of portions of the existing natural creek bed. Mine waste removed from the toe or slope will likely need to be put on the top of the mine waste piles (where the current bench/road is) before the piles could be lined with filter fabric and armored by the rip rap. The limited distance (i.e. width) between the current edge of the top of the waste piles (bench) and the bedrock of the hillslope (especially in the area of the North and South adits) will limit the amount of excavated waste materials that can be placed on top of the piles, and therefore may render this alternative less implementable. If there is insufficient space for stockpiling excavated material on the bench, some material may need to be hauled off site (see Alternative 4). This evaluation would be determined in the engineering study. For the purposes of this analysis, it is assumed that there will be sufficient space to place any excavated materials on top of the bench above the current waste piles and that adequate drainage from and access to the North and South adits will be able to be maintained.

Long-term maintenance associated with this alternative would include periodic inspection and repair of the rip rap embankment. No creek bank restoration or revegetation is included in this alternative.

Based on the results of the risk evaluation (Section 3), it is anticipated that by effectively preventing erosion of the source material (mine waste piles), the influx of additional sediment into the creek will be significantly reduced. Periodic monitoring of metals levels in the sediments at and downstream of the impacted creek sections will be conducted to evaluate long term protection of downstream sediment.

Future institutional controls may be required to accompany the engineering control design, such as placing signs along the rip rap banks to warn people not to dig through or disturb the rip rap or filter fabric, thus compromising the integrity of the capping materials.

6.4.2.1. Effectiveness

The filter fabric and rip rap would physically prevent the continued erosion of sediment from the mine waste piles into Copper Creek, therefore reducing the volume of contaminated sediments in the creek. This will in turn eliminate the direct contact of the in-stream invertebrates with hazardous substances. This alternative would leave waste materials in place on site and would not permanently reduce or remove the COPCs from the site. This alternative is effective in the short-term at achieving the PRAO by reducing exposure to wastes for humans and ecological receptors. This alternative is effective in short-term protection of human health because the site workers will have minimal exposure to contaminated mine waste piles as no removal of the mine waste is required.

If the rip rap along the creek banks are adequately inspected and maintained, this alternative is moderately effective in providing long-term protection to human health and ecological receptors. It is expected that long-term maintenance of the rip rap slopes and the filter fabric would be required to minimize further erosion of the waste piles. The effectiveness of the filter fabric and rip rap in preventing erosion of the

waste piles is highly dependent on the ability of the cover to withstand erosion of Copper Creek at the site. Long-term monitoring would be required to fully evaluate the effectiveness of this alternative.

While this alternative will meet some potential ARARs, several potential federal and State ARARs may not be attainable without significant additional study, including:

- Federal regulations pertaining to the protection of floodplains requiring that actions within floodplains should avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values and must be designed, constructed, and operated to avoid washout.
- Federal regulations for protection of endangered species, including requirements that actions may not jeopardize the continued existence of any Federally listed species or cause the destruction or adverse modification of critical habitat or negatively effect survival or reproduction of any state threatened or endangered species.
- Federal regulations specific to the Smith River and its tributaries that require improving the anadromous fishery and water quality, including improving fish spawning and rearing habitat, and placing appropriate restrictions or limitations on soil disturbing activities and providing for the restoration of landscapes damaged by past human activity consistent with the purposes of the act.

This alternative would not comply with the stated objectives in the standards and guides for the Smith River NRA which include maintaining and restoring the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations; and maintaining and restoring the sediment regime under which aquatic ecosystems evolved (see Appendix C). Potential negative impacts to the stretch of creek in the vicinity of the mine site would need to be thoroughly evaluated as part of the engineering study prior to implementing this alternative. There is a possibility that placing large rocks in the creek bed will have negative effects on the sensitive creek habitat and would restrict access to spawning fish.

This alternative has short-term effectiveness, except that may not meet certain potential ARARs. This alternative is relatively effective in the long-term, but its effectiveness in achieving the PRAO and PRAGs would need to be weighed against possible long-term degradation of creek habitat due to the addition of large rip rap to the creek bed. Regulatory and community acceptance of this alternative is assumed to be low, because COPCs would be left in place and the creek bank would be un-vegetated and exposed (possible aesthetic impact).

6.4.2.2. Implementability

This alternative is readily implementable using existing construction technology. Some improvement of the site access road would be required in order to transport large rocks to the site and place the rip rap along the creek bank using an excavator. Portions of the waste piles would need to be disturbed, excavated, and placed on the upper bench (where the old access road to the site currently exists). The

volume of material required for excavation may exceed the available space on the narrow bench. In addition, placing the material on this bench may obstruct access to the North and South adits and may block the perennial drainage of water from these adits. Otherwise, the implementation of this alternative is relatively straightforward.

The procurement of the rip rap rock for this alternative is dependent on the availability and suitability of rip rap materials from a local quarry source. If a local source cannot be identified, the implementabiliy of this alternative will be less favorable, because rip rap rock will have to be trucked to the site.

Long-term inspection and maintenance would be required to ensure the integrity of the filter fabric and rip rap embankment over time and its usage as a detaining device against contaminant mobility and toxicity.

6.4.2.3. Cost

The estimated cost for implementing this alternative is $495,000. Detailed cost estimate is included in Appendix D. The following are major assumptions for this alternative:

- The site management personnel would consist of a site superintendent, three operators, two laborers, and a site quality control (QC) representative/health and safety/site engineer.
- A long-arm large excavator will be used to place the rocks, and a mid-size front-end loader will be used for transporting rocks to the site from haul trucks.
- The estimated duration of field activities is 15 days.
- Estimated quantities of filter fabric to be used is 10,000 square feet.
- Estimated tonnage of rip rap for this project is 700 tons (including both two- and three-man rock).
- A local quarry source for rip rap is assumed to be available. If a local source is not available, the costs may be increased by a significant factor.
- Minimal excavation and relocation of mine waste piles are assumed.
- Road improvement ($10,000) costs are included in the total costs.
- Level D personal protection equipment is assumed for aspects of this project that include handling waste materials.
- Long-term inspection and maintenance for the rip rap embankment will be required for the next 10 years ($9,000 per year).
- The category of “Field, Planning, Reporting, and Regulatory Support” includes costs for home office support; project management; health, safety, and regulatory compliance review; meetings and client support; and preparation of the Removal Action Summary Report.

6.4.3. Alternative 3: Removal of Source Materials followed by On-Site Encapsulation and Creek Bank Restoration

Alternative 3 requires the removal of source materials (mine waste piles) currently lining the creek banks (a total of approximately 250 linear feet in three locations) and the transportation of removed source materials to a designated on-site upland impoundment area. The creek will be temporary dammed and diverted to lower the water level at the creek while the toe of the mine waste piles are being excavated and backfilled from above. Creek water upstream of the construction area will be dammed using sandbags, diverted from the creek bed, and released at a location downstream of the active construction area. A tracked excavator with a long-arm will be used to remove the mine waste piles on the creek bank, and a dump truck will be used to transport the excavated materials to the on-site impoundment area. A front-end loader and a dozer will be used to build the stockpile and the soil cap.

The removed and stockpiled mine waste will be capped and graded for drainage, and topped with approximately 6-inches of top soil as a vegetative layer. This soil cap would essentially encapsulate the removed mine waste and eliminate any future exposure to human or ecological receptors. Clean, on-site material free of mine waste and constituents of concern and with similar gradation to the natural creek bank would be used to backfill the excavated areas along the creek bank. If suitable materials are not found at the site, backfill that meets the gradation requirement will be trucked in from the nearest source. For the purposes of this evaluation, an appropriate on-site source of backfill material is assumed. Minimal backfilling will be done to restore, to the degree practicable, the natural, pre-mining contours and morphology of the creek bank. The backfilled creek bank material will be compacted and the creek bank will be restored using a biodegradable erosion control mat. The erosion control mat would be used as a creek bank liner and would be temporary stabilized by staking and with sandbags. Rip rap (rock) may be placed at the bottom of the restored creek bank to prevent scouring of the newly placed bank materials and to better simulate the natural (bedrock) creek bed substrate. Live staking of native plants may be completed on the restored creek bank for long-term stabilization.

As with Alternative 2, this alternative would require a final engineering study and design to establish siting requirements for the mine waste encapsulation area, to locate and conduct geotechnical and chemical testing for an on-site source for backfilling the excavated creek banks, and to ensure appropriate requirements are met in terms of waste placement and capping.

Future institutional controls may be required to accompany the engineering control design, such as placing signs or fencing around the encapsulation area to reduce the potential for erosion of the cap by site visitors.

6.4.3.1. Effectiveness

This alternative is effective in removing the source materials from the creek, thereby eliminating future release of contaminated materials into the creek. It is anticipated that by removing the source material (mine waste piles) from the creek banks, there will be no future influx of additional material from the waste piles into the creek. Periodic monitoring of metals concentrations in sediments at and downstream of the restored creek sections will be conducted to evaluate long term health of the creek. As such, it is expected that chemical-specific ARARs will be met over the long term.

The on-site capping of the excavated materials should eliminate human and ecological exposure to metals at the site, although long-term periodic inspection and maintenance of the soil cap may be required to ensure the long-term integrity of the cap will not be compromised by natural erosion or human activities.

It is assumed that removal activities associated with this alternative would not have severe and lasting effects on the sensitive species at and downstream of the site. The PRAO would be met under Alternative 3.

This alternative would meet the potential ARARs specified in Table 11 and would comply with the stated objectives in the standards and guides for the Smith River NRA which include maintaining and restoring the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations; and maintaining and restoring the sediment regime under which aquatic ecosystems evolved (see Appendix C).

Regulatory and community acceptance of this alternative is assumed to be high, given the overall benefits of restoring the creek to its natural condition and improving/restoring the habitat for spawning fish. This alternative meets both short- and long-term effectiveness.

6.4.3.2. Implementability

This alternative is readily implementable using existing construction technologies. The site access road will likely require some modification to allow heavy equipment and import materials to be transported to the site after improvement work to the road is done. Encapsulation of contaminated materials is a proven technology that has been used extensively for mine waste treatment. Because of the short duration of draining of the affected creek section for source material removal and creek bank restoration, no long-term effect is expected on the ecological health of the affected creek section.

Because mine waste is exempt from RCRA waste disposal criteria while it is located within a mining area (40 Code of Federal Regulations [CFR] §261.4(b)(7)), on-site encapsulation of mine waste will not be regulated under hazardous waste disposal and landfill regulations. However, other federal or state requirements regarding appropriate siting, construction, and long-term inspection and maintenance may

apply (e.g., Corrective Action Management Units [CAMU] regulations at 40 CFR 264 Subpart S, and 40 CFR Part 264.552(c) and mining waste regulations pursuant to California Water Code Section 13172 [at 27 CCR § 22470-22510]).

Because the waste piles would be consolidated and encapsulated on-site, the Forest Service would ensure that substantive requirements for siting and construction of mine waste impoundments to ensure protection of groundwater and surface water downgradient from the consolidation unit were met (27 CCR §22510). Existing leaching test data indicated that the encapsulated mine waste should not pose future threat to water quality if the integrity of the cap is maintained.

This alternative is implementable if a suitable on-site repository can be identified. Several potential sites for the repository have been identified. One is a relative flat area of approximately 1.5 acres at the southern part of the site, north of the Site's historic ore loading platform that is suitable for stockpiling purposes. This flat area is near the site boundary and is immediately adjacent to a privately owned (patented) mine claim. Appropriate notifications and collaboration with the adjacent property owner would be required in order to transport materials to this location (because portions of the access road cross the private claim). A second potential site for the repository is located upslope from and east of the site, east and north of the area where prospect pits 1 and 2 are shown on the map (see Figure 3). This area is slightly further from the site than the first (by approximately 1,000 feet), and may require some additional road improvement work, but would not require transportation across any private roads or collaboration with the adjacent property owner, because it is entirely on Forest Service land. A third potential site for the repository is along the flat portion of the roadway leading to the upper portion of the site. This location may be the most preferable, given its proximity to the site (shorter travel distance) and the fact that it would not require transportation across private roads or property.

The final decision regarding the location for the repository would be made during the design phase of the project.

6.4.3.3. Cost

The estimated cost for implementing this alternative is $678,000. Detailed cost estimate is included in Appendix D. The following are major assumptions for this alternative:

- The site management personnel would consist of a site superintendent, three operators, two laborers, and a site QC representative/health and safety/site engineer.
- A long-arm large excavator will be used to excavate the mine waste piles, and for backfilling. A mid- to large-size front-end loader will be used for transporting excavated materials and for placing materials in the stockpile area
- One solo dump truck will be used for transporting excavated materials to the stockpile area.
- A dozer will also be needed for constructing the soil cell and cover.

- The estimated duration of field activities is 30 days.
- Estimated quantity of mine waste to be excavated is 10,000 tons.
- For estimating purposes, 5,000 tons of backfill be used for restoring the creek banks. Less backfill is required because it is expected that the creek banks will be restored to natural contour instead of the present shape which are intruding into the creek. It is assumed that this material will be available from an on-site source, such as the area to be graded/excavated for the repository. The potential on-site source will needed to be tested prior to use to ensure it is suitable (geotechnically) for stream bank use, and also that the concentrations of metals in the native material are within background concentrations for site sediment. If an appropriate on-site backfill source is not located, the cost of implementation would increase to account for importing backfill from off site.
- $10,000 is allowed for live-staking of native plants as part of the bank restoration effort.
- 1,500 tons of top soil are estimated for the construction of the soil cap (assumes no impermeable cap layer).
- Road improvement ($10,000) costs are included in the total costs.
- An estimated $9,500 per year is assumed for long-term inspection and maintenance for the soil capped cell and restore banks for the next 10 years.
- The category of "Field, Planning, Reporting, and Regulatory Support" includes costs for home office support; project management; health, safety, and regulatory compliance review; meetings and client support; and preparation of the Removal Action Summary Report.

6.4.4. Alternative 4: Removal and Off-Site Disposal of Source Materials Followed by Creek Bank Restoration

Alternative 4 is similar to Alternative 3 in terms of source materials removal and creek bank restoration. However, rather than on-site consolidation, the removed source materials (mine waste piles) will be loaded into dump trucks for off-site disposal at the nearest permitted disposal facility. A front end loader will be used for loading the mine waste into dump trucks for off-site disposal.

Creek restoration will be achieved with the approach described in Alternative 3.

6.4.4.1. Effectiveness

This alternative is very effective in removing the source materials, thereby eliminating future releases of contaminated sediment into the creek. It is anticipated that by effectively removing the source material (mine waste piles) from the creek banks, there will be no future influx of additional sediment from the waste piles into the creek.

Because the waste piles will be transported off-site, there will be no future threat to on-site water quality, and 27 CCR §22510 does not apply to this alternative. Furthermore, no long-term monitoring of the soil cap for onsite mine waste is required.

It is assumed that removal activities associated with this alternative would not have severe or lasting effects on the sensitive species at and downstream of the site. The PRAO and action-specific ARARs would be met under this alternative.

6.4.4.2. Implementability

This alternative may be implemented using existing construction technology. Significant improvements to the site access road would be required to allow access to heavy equipment and dump trucks for off-site transportation and disposal. Because of the short duration of the removal activities, no long-term effect is expected on the ecological health of the affected creek section. Because the contaminated material will be transported off-site for disposal, no on-site soil cell will be constructed, thus eliminating the long-term inspection and maintenance requirements of an on-site soil cell

Off-site waste disposal is a proven remedial alternative for contaminated site, and there are numerous RCRA- and State-permitted landfills that could accept the mine waste piles, albeit a relatively long distance from the site. There are numerous licensed trucking companies in the State of California that could be subcontracted to provide transportation of the mine waste.

This alternative would meet the potential ARARs specified in Table 11.

Regulatory and community acceptance of this alternative is assumed to be high, given the overall benefits of restoring the creek to its natural condition and improving/restoring the habitat for spawning fish. This alternative meets both short- and long-term effectiveness.

6.4.4.3. Cost

The estimated cost for implementing this alternative is $2,585,000. Detailed cost estimate is included in Appendix D. The following are major assumptions for this alternative:

- The site management personnel would consist of a site superintendent, three operators, a laborer, and a site QC representative/health and safety/site engineer.
- A long-arm large excavator will be used to excavate the mine waste piles, and for backfilling. A mid- to large-size front-end loader will be used for transporting excavated materials and for loading haul trucks for off-site disposal.
- One solo dump truck will be used for transporting excavated materials to the staging area for truck loading.

- The estimated duration of field activities is 25 days.
- Estimated quantity of mine waste to be excavated and disposed of is 10,000 tons.
- For estimating purposes, 5,000 tons of backfill be used for restoring the creek banks. Less backfill is required because it is expected that the creek banks will be restored to natural contour instead of the present shape which are intruding into the creek. It is assumed that this material will be available from an on-site source, such as the area to be graded/excavated for the repository. The potential on-site source will needed to be tested prior to use to ensure it is suitable (geotechnically) for stream bank use, and also that the concentrations of metals in the native material are within background concentrations for site sediment. If an appropriate on-site backfill source is not located, the cost of implementation would increase to account for importing backfill from off site.
- $10,000 is allowed for live-staking of native plants as part of the bank restoration effort.
- An estimated $3,000 is assumed for long-term inspection and maintenance for the restored creek banks for the next 10 years.
- Costs for significant road improvement ($13,000) are included in the total costs.
- Mine waste is assumed to be non-hazardous waste for off-site disposal. It is assumed that the mine waste will be trucked to the Central Valley for disposal purposes, because there is no suitable landfill in Del Norte and adjacent counties. As a result, the transportation costs will be $105/ton, and the disposal costs will be $40/ton.
- The category of "Field, Planning, Reporting, and Regulatory Support" includes costs for home office support; project management; health, safety, and regulatory compliance review; meetings and client support; and preparation of the Removal Action Summary Report.

Section 7. Comparative Analysis and Recommended Removal Action Alternative

The removal action alternatives identified in Section 6.4 were compared with one another by using the evaluation criteria described in Section 6.3. This section describes the results of the comparative evaluation and one alternative will be selected as the recommended removal action.

7.1. COMPARISON OF ALTERNATIVES

7.1.1. Alternative 1: No Action

Alternative 1 does not meet the effectiveness criterion because it does not meet the PRAO and PRAGs of the proposed removal action. Although it is easily implementable and the alternative with the lowest cost, it is not likely to be acceptable to the community or the regulatory agencies. Alternative 1 was retained as required by regulatory guidance and for comparative purposes.

7.1.2. Alternative 2: In-Situ Slope Stabilization of Mine Waste Piles with Rip Rap

Alternative 2 partially meets the effectiveness criterion but does not meet the requirement for permanent removal of mine waste piles from the creek banks. It is implementable, provided that an engineering study is conducted to confirm the engineering and institutional controls and appropriate land use restrictions are acceptable to federal, state, and local authorities. Alternative 2 meets the PRAO for reduction of human health and ecological risks, although it does not eliminate future risk of erosion and sedimentation of the mine waste piles. Waste material may potentially migrate downstream if the filter fabric and rip rap degrade. Alternative 2 is relatively low in cost, but would require long-term inspection and maintenance of the rip rap embankment. This alternative does not meet all potential ARARs. Potential negative impacts to the stretch of creek in the vicinity of the mine site would need to be thoroughly evaluated as part of the engineering study prior to implementing this alternative. This alternative has a likelihood of degrading the overall creek habitat because of the need to place large rip-rap rock within the creek bed and along the flood plain of the creek, which would likely negate any benefits to the habitat that could be gained by controlling waste rock erosion. This alternative would not comply with the stated objectives in the standards and guides for the Smith River NRA regarding maintaining and restoring aquatic shorelines, banks, and bottom configurations; and maintaining and restoring the sediment regime under which aquatic ecosystems evolved (see Appendix C).

The long-term maintenance requirements of the rip rap embankment will be somewhat less than the long-term maintenance of the on-site encapsulation of the excavated source materials required under Alternative 3, but more than those under Alternative 4. In the short term, it would pose slightly less risk to construction workers than Alternatives 3 and 4 because there would be minimal intrusive activities that would potentially expose the workers to metal-contaminated mine waste piles.

7.1.3. Alternative 3: Removal of Source Materials followed by On-site Encapsulation and Creek Bank Restoration

Alternative 3 gives additional protection beyond what is offered in Alternative 2, providing for the removal and on-site encapsulation of the source materials (mine waste piles). As opposed to Alternative 2, no mine waste would be left in the vicinity of the creek bed under this alternative. The removal of the mine waste piles will eliminate future erosion of source materials into Copper Creek, would meet the potential ARARs and would comply with the stated objectives in the standards and guides for the Smith River NRA regarding maintaining and restoring aquatic shorelines, banks, and bottom configurations; and maintaining and restoring the sediment regime under which aquatic ecosystems evolved (see Appendix C).

Because the excavated mine waste piles will be relocated, stockpiled, and encapsulated in an upland area with a vegetated low-permeability soil cap, the PRAO and PRAG for mine waste will be achieved, provided that the integrity of the soil cap for the mine waste cell is maintained by a long-term inspection and maintenance program. It is implementable using existing construction technology. It is more costly than Alternatives 1 and 2, and would pose somewhat more risk to site workers during implementation of the removal action.

This alternative has similar long-term maintenance costs to those of Alternative 2. An engineering study would need to be conducted prior to implementation of this alternative to determine an appropriate site for the construction of the on-site permanent cell.

7.1.4. Alternative 4: Removal and off-site disposal of Source Materials followed by Creek Bank Restoration

Alternative 4 is effective in eliminating future human health and ecological risks from exposure to source materials (mine waste piles) at the Site, by removing mine waste piles that are in contact with the creek and transporting them off-site for disposal. Like Alternative 3,,no mine waste will be left in the vicinity of the creek bed. However, since waste would be disposed of off site, no long-term maintenance and inspection would be required with this alternative. The PRAO and PRAG will be met at the site with this alternative.

This alternative is implementable, provided the required modifications to Site access roads are able to be made to accommodate haul trucks. The removal of the mine waste piles will eliminate future erosion of source materials into Copper Creek, would meet the potential ARARs and would comply with the stated objectives in the standards and guides for the Smith River NRA regarding maintaining and restoring aquatic shorelines, banks, and bottom configurations; and maintaining and restoring the sediment regime under which aquatic ecosystems evolved (see Appendix C).

Because of the remoteness of the site, off-site disposal of the contaminated mine waste would result in significant costs when compared to Alternatives 1 through 3. In addition, the excavated mine waste might need to be staged on site prior to load-out, because the site dirt roads can not support truck and trailer operation, thereby adding material handling costs. As a result, the cost for this off-site disposal alternative would be prohibitively high.

This alternative would pose some short-term risk during implementation of the removal action, similar to that posed by Alternative 3.

7.2. RECOMMENDED REMOVAL ACTION ALTERNATIVES

The removal action alternative recommended for the Union-Zaar Mine site is **Alternative 3, Removal of Source Materials followed by On-site Encapsulation and Creek Bank Restoration.** Alternative 3 will meet the PRAO and PRAGs at the site, eliminate future introduction of mine waste to Copper Creek, and exposure pathway human and ecological receptors to the encapsulated mine waste will be minimal if the integrity of the soil cap is maintained. This alternative is preferable to Alternative 2, because the removal of the mine waste piles will eliminate future erosion of source materials into Copper Creek, would restore the creek banks to their pre-mining conditions, and would meet the potential ARARs and standards and guides of the Smith River NRA. Overall it affords the same level of protection of human health and ecological receptors as in Alternative 4, at less than one-third of the estimated cost of Alternative 4.

The primary components of the recommended alternative are as follows:

- An engineering design will be completed for an on-site soil cell, and the excavation and creek bank restoration process. The design will identify an appropriate site for the on-site cell and will outline required testing to be accomplished prior to building the cell. The on-site encapsulation design will be submitted to appropriate regulatory agencies for review prior to mobilization to the site.
- An on-site backfill source will be identified and tested for geotechnical and chemical properties to ensure a suitable material for creek bank restoration.
- The current access route to the creek banks will be improved to support the removal activities.
- Temporary sandbags will be placed in the creek on the upstream side of the work areas, and water will be temporarily diverted away from the work area.

- The mine waste piles on the creek banks will be excavated and brought to the on-site stockpile area. The excavated soil will be placed inside the soil cap footprint and stockpiled and compacted by a loader and a dozer.
- After all mine wastes are excavated (estimated 10,000 tons) from the creek banks, minimal amounts of fill will be excavated from an on-site source, and trucked to the excavated area to backfill along the creek banks and restore them to as close to pre-mining conditions as possible. After backfilling is completed, minimal amounts of rip rap may be placed at the toe of the backfill for erosion control.
- The surface of the backfill area will be covered with erosion control mat, and the steep slopes will be hydroseeded and/or live-staked with native plants for slope stabilization.
- The soil cell will be constructed at the designated stockpile area. After all mine wastes are placed inside the soil cell area, a soil cover will be placed on top of the compacted mine waste (specifications for the soil cover will be included in the final design).
- After the removal action and soil cap construction are completed, a focused monitoring and inspection program will be conducted during the first 12 months of the long-term maintenance program to ensure the planted vegetation is growing and meets expectations, and the erosion controls are functioning as intended.
- After the first year, periodic inspection and maintenance activities will be carried out in subsequent years to maintain the integrity of the soil cap and the restored creek banks.

The estimated cost of the recommended removal action alternative is $678,000. As discussed in subsection 6.3.3, this cost represents an order-of-magnitude estimate with an intended accuracy of +50 to -30 percent (EPA, 2000). Final project costs will depend on actual labor and material costs, actual engineering design costs, actual site conditions (including the actual quantities of mine waste excavated and the amount of material that may be classified as hazardous waste), competitive market conditions, the final project scope, the final project schedule, and other variables.

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Figures

Figure 1. Union-Zaar Mine Site Vicinity Map

Figure 2. Site Location Map

Figure 3. Site Layout

Figure 4. Sample Location Map

Figure 5. Pre-Removal Conditions

Figure 6. Post-Removal Conditions

Tables

Table 1. Sensitive Species Potentially Present in the Vicinity of the Union-Zaar Mine Site

Table 2. Table 2. Summary of Background Values

Table 3. Summary of Source Sample Analytical Results Compared to Background

Table 4. Summary of Surface Water Sample Analytical Results Compared to Background

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Table 6. Exposure Point Concentrations for Each Contaminant of Potential Concern for All Media

Table 7. Summary of Human Health Risk Screening Benchmarks

Table 8. Exposure Point Concentrations Compared to Applicable Human Health Benchmarks

Table 9. Summary of Ecological Risk Screening Benchmarks

Table 10. Exposure Point Concentrations Compared to Applicable Ecological Benchmarks

Table 11. Applicable or Relevant and Appropriate Requirements

Table 12. Summary of Response Action Screening

Appendix A. Analytical Results for 2007 Sediment Sampling

Appendix B. Results of Bioassay Sampling

Appendix C. Riparian Management Standards and Statutes for Copper Creek CERCLA Mine Tailing Abatement

Appendix D. Detailed Cost Estimate