Unnamed Bard Creek Mine Engineering Evaluation and Cost Analysis Report

Trout Unlimited, Inc.

Clear Creek County, Colorado

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Contents

Tables

Appendices

Abbreviations and Acronyms

°F	degrees Fahrenheit
4WD	four-wheel drive
amsl	above mean sea level
ARAR	applicable or relevant appropriate requirements
ATV	all-terrain vehicle
BLM	Bureau of Land Management
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CY	cubic yards
DOT	Department of Transportation
Eco-SSL	Ecological Soil Screening Levels
EE/CA	Engineering Evaluation Cost Analysis
EPA	Environmental Protection Agency
ET	evapotranspiration
HAZWOPER	Hazardous Waste Operations and Emergency Response
HDR	HDR Engineering, Inc.
HI	Hazard Index
IC	Institutional Controls
kg	kilogram
LF	linear feet
LOD	level of detection
mg	milligram
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRHP	National Register of Historical Places
NTCRA	Non-Time Critical Removal Action
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCS	Pre-CERCLA Screening
PEL	permissible exposure limit
PPE	personal protective equipment
PRP	Potentially Responsible Party
RAO	removal action objectives
RML	Removal Management Levels
RSL	Regional Screening Level
SF	square feet
Site	Unnamed Bard Creek Mine
SY	square yard
TBD	to be determined
USDA	United States Department of Agriculture

USFS	United States Forest Service
USGS	United States Geological Survey
WGS 84	World Geodetic System 1984
WQS	Water Quality Standards
XRF	X-ray fluorescence

1 Introduction

HDR Engineering Inc. (HDR) has prepared this Engineering Evaluation Cost Analysis (EE/CA) report on behalf of Trout Unlimited, Inc. in partnership with the United States Department of Agriculture (USDA) United States Forest Service (USFS) to develop and evaluate removal action alternatives and identify a preferred remedial approach for the Unnamed Mine at the end of Bard Creek Road. This work is being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Trout Unlimited, Inc. is completing the Non-Time Critical Removal Action (NTCRA) in accordance with Environmental Protection Agency's (EPA) guidance document: EPA 540R-93-057, Guidance on Conducting NTCRAs Under CERCLA, August 1993.

1.1 Purpose

The goal of this EE/CA is to identify the objectives of the removal action, to analyze the various alternatives for effectiveness, implementability, and cost, and to provide a basis of discussion for future public outreach efforts to be conducted by Trout Unlimited, Inc. and USFS.

1.2 Report Organization

This report is arranged in seven sections. Following this Introduction section, the following sections are included:

- Section 2 includes an overview of the Site, a summary of the nature and extent of contamination, and a streamlined risk evaluation.
- Section 3 outlines the removal action scope, removal action objectives, and schedule for the Site.
- Section 4 includes the screening of the removal action technologies and process options and development of removal alternatives.
- Section 4.2.1 presents a detailed analysis of the removal alternatives in accordance with the NCP evaluation criteria.
- Section 6 presents a comparative analysis of the removal alternatives.
- Section 7 presents the recommended alternative.
- Section 8 presents references used for preparing this EE/CA.

2 Site Characterization

2.1 Site Description and Background

2.1.1 Site Location

The Unnamed Bard Creek Mine (Site) is located in the Georgetown–Silver Plume Mining District in Clear Creek County, Colorado. The Site lies wholly within the Arapahoe and Roosevelt National Forest, which is under the jurisdiction, custody, and control of the USFS. The Site is situated at the terminus of Forest Service Road 777.1 (Bard Creek Road), approximately 4.5 miles southwest of the town of Empire, Colorado. The approximate World Geodetic System 1984 (WGS 84) coordinates of the Site are 39.736244° latitude and −105.736574° longitude. The Site encompasses approximately 2 acres at an elevation of about 10,200 feet above mean sea level (amsl) and is located within the Bard Creek drainage, a tributary to the West Fork of Clear Creek, which supports downstream municipal water supplies.

2.1.2 Site History and Operational Status

The Site is located within the Georgetown-Silver Plume Mining District and historically operated as an underground mine, primary producing silver and lead ores during the mid to late-1800s (Applied Intellect 2026). Mining activity occurred for approximately 30 years before regional mining declined and operations ceased. The broader Mining District is no longer active. Although several mining claims have been identified in the surrounding area, no claims have been recorded specifically for the Site.

2.1.3 Site Features

The existing Site features include Bard Creek Road to the south; the Bard Creek Trailhead from Bard Creek Road; a steep, largely unvegetated waste rock pile; an access road leading to the top of the waste rock pile from Bard Creek Road to the east; a former logging road leading to the waste rock pile from Bard Creek Road to the west; and an adit with a collapsed portal and its associated timbers. Additionally, south of Bard Creek Road and out of the immediate waste rock pile area, there is an existing trail or overland access road that appears to be infrequently used.

2.1.4 Surrounding Land Use and Populations

The Site parcel is listed by the Clear Creek County Assessor’s Office as vacant and is under the jurisdiction, custody, and control of the USFS (Applied Intellect 2026). No active residential or commercial development, intact structures, or operational equipment are present on the Site based on recent field surveys. The Site is accessible to the public and exhibits heavy recreational use, including vehicle traffic and camping. Due to the proximity of Bard Creek Road, there is evidence of vehicles driving directly on the pile causing erosion and tracking of contaminated material onto the main road.

Land uses surrounding the Site are predominantly recreational and undeveloped public lands managed by the USFS. A well-used and highly trafficked trailhead is located immediately adjacent to and partially within the Site boundaries, resulting in frequent public access. Recreational activities observed in the vicinity of the Site include hiking, camping, informal social gatherings, and all-terrain vehicle (ATV) use. The Site features, specifically the waste rock pile, are readily accessible from the trail. The broader surrounding area remains largely rural and undeveloped, with the nearest incorporated community being the town of Empire, located approximately 3 miles to the east.

2.1.5 Geology and Hydrogeology

The surface geology at the Site consists of Pleistocene-age glacial drift deposits of Pinedal and Bull Lake Glaciations. Soils on the Site consist of Cryaquolls-Leighcan family silt loam derived from flood plains, drainageways, and depressions, and Leighcan family cobbly silt loam derived from mountain slopes (ERO Resources Corporation 2026).

A small amount of clear water was observed near the collapsed adit. It is undetermined whether this water is draining from the collapsed adit or is surface flow from precipitation. Bard Creek runs approximately 70 feet south of the Site but there is no evidence that surface run-off discharges to the creek.

No site-specific hydrogeologic data has been collected or reviewed to support this EE/CA.

2.1.6 Sensitive Ecosystems

Sensitive ecosystems are typically defined as habitats or ecological resources that are legally protected, support endangered species, or are particularly vulnerable to disturbance. This could include, but is not limited to, wetlands, streams, creeks, riparian areas, designated federal/state wildlife or scenic area, wildlife breeding areas, or threatened or endangered species habitats.

The Site is upstream of a riparian area classified as Crystalline Subalpine Forest. A 3.44-acre freshwater forested/shrub wetland classified as PSS1C is located to the southwest of the Site partially capturing Bard Creek, which flows approximately 70 feet directly south of the Site. While a range of fauna has been observed in the vicinity of the Site, no endangered or threatened species have been identified on or around the Site.

Based on this assessment, no sensitive ecosystems were identified on Site.

2.1.7 Meteorology

The Site meteorology presented in this section is based on Climate Normals for the 1991–2020 period recorded at the Georgetown weather station (USC00053261) located approximately 7 miles away from Site at an elevation of 8,520 feet. Recorded temperature minimum and maximums range from 15 degrees Fahrenheit (°F) to 77°F while monthly temperature averages range from 26°F to 63°F. Winter and spring months show the most snowfall with an average of 13.2 and 15.3 inches/month, respectively. Spring and summer months show the most precipitation with an average of 1.95 and 2.07 inches/month respectively.

2.1.8 Previous Removal Actions and Investigation Activities

No previous removal actions have been conducted at the Site. Previous investigation activities associated with the Site include:

- A Pre-CERCLA screening (PCS) completed in 2022 to determine whether the Site warrants further action under CERCLA based on the presence, nature, and potential risks of contamination (EPA 2022).
- A Cultural Resources Survey completed in 2026 to identify and evaluate archaeological sites, historic structures or other cultural resources that may be affected by the proposed project (ERO Resources Corporation 2026).
- A Potentially Responsible Party (PRP) Search Report completed in 2026 to identify and document parties that may be legally responsible for on-site contamination and may be accountable for investigation and/or cleanup costs under CERCLA (Applied Intellect 2026).

The PCS identified elevated arsenic and lead concentrations in soil exceeding EPA residential and industrial Regional Screening Levels (RSLs) and background with impacts confined to a limited area upgradient of Bard Creek and observed no significant impacts to surface water. The Site was not included in the active Superfund Site inventory and was referred to the USFS for further consideration. The cultural resource evaluations and PRP Search Report indicate there are no National Register of Historical Places (NRHP)-eligible resources and no viable PRPs.

2.2 Nature and Extent of Contamination

The PCS and associated sampling was completed in June 2022 by the Region 8 EPA Site Assessment Program and other federal and state members of the Colorado Mixed Ownership Team (EPA 2022). No other site characterization has been conducted at the Site. During this event, a total of 26 samples were taken to characterize the contamination on this Site and are summarized below:

- One surface water sample was taken from Bard Creek upstream of the Site.
- Three surface water samples were taken from Bard Creek downstream of the Site.
- Two surface water samples were taken from West Fork Clear Creek—one from above and one from below the mouth of Bard Creek.
- One surface water sample was taken from a pooled area of water in an adit/spring seepage area near the collapsed portal.
- Fourteen soil samples were taken over an approximately 2,000 square yard area over the waste rock pile.
- One background soil sample was taken approximately 150 feet west of the waste rock pile.
- Two mine waste soil grab samples.
- One composite background soil sample.
- One composite mine waste rock sample.

Sample locations are documented in the PCS included as **Appendix A**.

2.2.1 Waste Rock and Soil Characterization

The 15 soil samples taken around the collapsed portal were analyzed for metals using X-ray fluorescence (XRF) spectrometry. The four grab and composite samples were analyzed using laboratory analysis methods. The results were compared to EPA's Residential and Industrial RSLs (Arsenic: Carcinogenic SL Target Risk =1E-06; Lead: Noncarcinogenic SL Child Target Hazard Index = 1). Laboratory results for mine waste grab and composite samples, assumed to be taken from ground surface, indicate arsenic and lead levels that exceed both EPA Residential and Industrial RSLs, as well as Bureau of Land Management (BLM) recreational screening levels. These results are summarized below:

<u>Arsenic</u>: Fifteen of nineteen soil samples indicated arsenic concentrations that exceeded the EPA Residential RSL (0.68 milligrams per kilogram [mg/kg]) and Industrial RSL (3.0 mg/kg). Thirteen of nineteen soil samples indicated arsenic concentrations that exceeded BLM recreational screening levels (30.6 mg/kg). The highest arsenic concentration was observed in an XRF sample taken at the southern toe of the waste rock pile with corresponding concentration of 905 mg/kg. Four soil samples taken around the collapsed adit reported concentrations lower than the laboratory level of detection (LOD). The background sample reported an arsenic concentration of 3.35 mg/kg.

<u>Lead</u>: Seventeen of nineteen soil samples indicated lead concentrations that exceeded the EPA Residential RSL (200 mg/kg). Eight of these samples had concentration that exceeded both the Industrial RSL (800 mg/kg) and BLM recreational screening levels (800 mg/kg). The background sample reported a concentration of 32.5 mg/kg. The highest lead concentration was observed in a grab sample taken at the southern toe of the waste rock pile with corresponding concentration of 26,800 mg/kg.

For a complete summary of laboratory results for all sample locations and constituents, refer to the PCS report in **Appendix A.**

2.2.2 Surface Water Characterization

Surface water samples were collected upstream and downstream of the Site and on site from an adit/spring seepage near the collapsed portal. Samples were analyzed for metals (total and dissolved) and water quality parameters using laboratory analysis methods. The results were evaluated against the Colorado Water Quality Standards (WQS) for aquatic life.

Dissolved and total metals concentrations were non-detect in all samples taken upstream and in three downstream locations of the site. Dissolved and total metals concentrations were below the Colorado WQS in the adit pool and remaining sample locations. The pH for all samples was generally neutral (EPA 2022). For a complete summary of laboratory results for all sample locations and constituents, refer to **Appendix A.**

2.2.3 Summary

A PCS conducted in June 2022 by EPA Region 8 characterized contamination at the Site through collection of 26 soil, mine waste, and surface water samples. Elevated arsenic and lead concentrations were identified in on-Site soils and mine waste associated with the waste rock pile, with arsenic and lead exceeding EPA Residential and Industrial RSLs in multiple samples with maximum concentrations of 703 mg/kg and 26,800 mg/kg, respectively. Arsenic and lead concentrations were significantly higher than background, indicating mine waste is the likely source of contamination. Surface water samples from Bard Creek, West Fork Clear Creek, and the adit seep showed metals concentrations below Colorado WQS for aquatic life and near-neutral pH, with no evidence of Site-related impacts to surface water. Overall, contamination is limited to on-site soils and mine waste, with no observed surface water effects. The contaminated area has been defined by USFS as a 2.4-acre polygon surrounding the Site and proposed disturbance areas (Applied Intellect 2026).

2.3 Applicable or Relevant and Appropriate Requirements

There are no Applicable or Relevant and Appropriate Requirements that apply to this project.

2.4 Streamlined Risk Evaluation

A baseline human health or ecological risk assessment has not been performed for the Site. However, consistent with EPA guidance for both Non-Time Critical Removal Actions (EPA 1993) and the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA 1991), information collected during the June 2022 PCS was used to identify potential sources, exposure pathways, and receptors. This streamlined, qualitative risk evaluation relies on screening-level comparisons to applicable criteria, consideration of site-specific land use conditions, and professional judgment to support removal action decision-making.

The primary source of contamination at the Site is exposed mine waste and associated surface soils within the waste rock pile and immediately surrounding areas near the collapsed adit. Arsenic and lead, characteristic of historic silver and lead mining, are assumed to be present largely in inorganic mineral forms associated with mine waste.

The waste rock pile is steep, largely unvegetated, and shows evidence of frequent disturbance from recreational activity, increasing the likelihood of contaminant mobilization through direct contact and dust exposure. No ongoing sources of contamination were identified, and impacts appear confined to on-site soils and mine waste. Surface water sampling indicates that contaminants are not migrating to Bard Creek or downstream waters at levels exceeding Colorado Water Quality Standards.

Based on Site conditions and observed land use, several potential exposure pathways were identified for both human and ecological receptors. These include:

- Incidental ingestion of contaminated soil, such as accidental transfer of soil particles during recreational activities (e.g., camping, cooking, eating, smoking) or future construction or maintenance activities;
- Inhalation of fugitive dust generated from disturbed or exposed mine waste and soils during dry or windy conditions;

- Dermal contact with contaminated soil, which is considered a secondary pathway due to limited dermal absorption of inorganic arsenic and lead; and
- Plant uptake and bioaccumulation, potentially resulting in indirect exposure to wildlife and humans through consumption of vegetation or wildlife.

Among the identified exposure pathways, incidental soil ingestion and inhalation of dust represent the primary human exposure pathways of concern for both arsenic and lead based on recreational uses. Among the identified ecological pathways, direct soil contact, incidental ingestion of soil, plant uptake, and subsequent bioaccumulation by terrestrial receptors (e.g., soil invertebrates, small mammals, and grazing wildlife) represent the primary exposure pathways.

2.4.1 Human Health Risk Evaluation

The human health risk evaluation focuses on potential impacts to recreational site users associated with contaminated surface soils and mine waste at the Site. Among the identified exposure pathways, incidental soil ingestion and inhalation of dusk represent the primary pathways for human receptors.

Initial evaluation of Site conditions (Section 2.2) compared detected soil and mine waste concentrations to EPA Residential RSLs as a conservative screening approach. Residential RSLs are risk-based concentrations developed to protect hypothetical residents under long-term exposure assumptions and represent the most protective generic screening criteria. For arsenic, a carcinogenic constituent, the Residential RSL corresponds to an excess lifetime cancer risk of 1×10^{-6}, while for lead, a non-carcinogenic constituent, the Residential RSL is based on a Hazard Index (HI) of 1. Exceedances of these values indicate the potential for unacceptable risk under highly conservative exposure scenarios and are appropriate for identifying contaminants, media, and areas of concern during site screening.

This EE/CA supports a NTCRA, which is intended to reduce or mitigate near-term exposure risks rather than achieve cleanup levels protective of unrestricted residential use. EPA guidance allows the use of higher, yet still acceptable, risk thresholds for removal action decision-making, with cancer risks up to $\mathbf{1\times10^{-4}}$ and non-carcinogenic risks up to an **HI of 3** considered within the acceptable CERCLA risk range and commonly used to develop Removal Management Levels (RMLs) (EPA 1991).

The Site is located on remote federal land where recreational use is the primary exposure scenario. Given these conditions, to screen for potential human health impacts, measured soil concentrations are compared to arsenic and lead generic EPA Residential RMLs (1×10^{-4} cancer risk and HI = 3), which provides a conservative yet reasonable basis for evaluating potential human health risks. The generic arsenic and lead EPA Residential RMLs (0.68 mg/kg and 200 mg/kg) were compared to PCS data to conduct the risk evaluation. The results of this comparison are presented in Table 1.

Table 1. Human Health Risk Evaluation Summary

Constituent	Residential RML (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	No. of Samples	Exceedance Count
Arsenic	0.68	<LOD[1]	905	19	15
Lead	200	32.5	26,800	19	17

[1] LOD not defined in laboratory analysis provided in PCS

Based on this assessment, the magnitude of observed exceedances, combined with complete exposure pathways and accessibility, indicates that Site conditions may pose a potential threat to human health.

2.4.2 Ecological Risk Evaluation

The ecological risk evaluation focuses on potential impacts to terrestrial receptors associated with contaminated surface soils and mine waste at the Site. Among the identified exposure pathways, direct contact with soil, incidental ingestion of soil, plant uptake, and subsequent bioaccumulation represent the primary pathways for ecological receptors, including soil invertebrates, small mammals, and grazing wildlife.

To screen for potential ecological concerns, measured soil concentrations are compared to arsenic and lead EPA Ecological Soil Screening Levels (Eco-SSLs). The results of this comparison are presented in Table 2.

Table 2. Ecological Risk Evaluation Summary

Constituent	Eco-SSL – avian (mg/kg)	Eco-SSL – mammalian (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	No. of Samples	Exceedance Count[1]
Arsenic	43[2]	46[2]	<LOD[4]	905	19	11
Lead	11[3]	56[3]	32.5	26,800	19	19

[1]Exceedence count based on comparison to lowest Eco-SSL
[2]Reference: EPA 2005a
[3]Reference: EPA 2005b
[4]LOD not defined in laboratory analysis provided in PCS

Based on this assessment, Site conditions may pose a potential threat to ecological receptors.

2.4.3 Summary

The streamlined risk evaluation indicates that arsenic and lead concentrations in exposed mine waste and surface soils exceed EPA human health and ecological screening benchmarks. These exceedances occur in accessible areas with recreational use, resulting in complete exposure pathways for incidental soil ingestion and inhalation of fugitive dust, which is generally understood to be uncontrolled airborne particulate matter resulting from ground disturbing activities. Comparison to EPA Residential RMLs shows potential human health risks under removal-action–appropriate assumptions. In addition, exceedances of EPA Eco SSLs indicate potential risk to terrestrial receptors through soil contact, ingestion, and bioaccumulation.

3 Identification of Removal Objectives

This section presents the statutory limits on removal actions, removal scope, removal action objectives (RAOs), and removal schedule.

3.1 Statutory Limits

Pursuant to CERCLA Section (§) 104(c)(1), the normal statutory limits for CERCLA removal actions of $2 million and 12 months do not apply because the selected action will not be funded by Superfund.

3.2 Removal Action Scope

The scope of the removal action is to reduce potential human health and ecological risks associated with elevated arsenic and lead in exposed mine waste and surface soils at the Site. Removal activities will focus on addressing accessible contaminated materials within the waste rock pile and adjacent disturbed areas to eliminate or reduce direct contact, incidental ingestion, and dust inhalation exposure pathways.

Although not specifically addressed in the risk evaluation, removal activities will also be designed to reduce erosion and minimize the potential for sediment or contaminant transport to nearby Bard Creek and Bard Creek Road, thereby supporting protection of the adjacent surface water body.

3.3 Removal Action Objectives

The RAOs of the removal action are to:

- Minimize human health risks by reducing contact, incidental ingestion, and inhalation of arsenic- and lead-contaminated soils and mine waste in accessible areas.
- Reduce ecological exposure to arsenic- and lead-contaminated soils, mine waste, and plants by stabilizing or removing contaminated soils and mine waste within on-site source areas.
- Prevent erosion and limit migration of contaminants to Bard Creek and Bard Creek Road.

3.4 Removal Actions Schedule

The anticipated removal action schedule is presented in **Table 3** below. This EE/CA presents a recommendation for a removal action which will satisfy the RAOs. The EE/CA will be provided to USFS who will then develop an action memorandum and provide public access to the EE/CA for 30-days to obtain and address community feedback. After community feedback is addressed and the action memorandum is approved, construction of the selected alternative will commence with final removal action completion anticipated in 2026 followed by 1-3 years of post-removal site observation and maintenance as needed based on vegetation establishment.

Table 3. Removal Actions Schedule

Removal Action Milestone	Approximate Completion Date
EE/CA Submission and Design Completion	June 12, 2026
Public Comment Period	June 15 to July 15, 2026
Action Memorandum Submission	August 15, 2026
Construction Kickoff	September 1, 2026
Construction Completion	October 1, 2026

4 Development of Removal Alternatives

4.1 Removal Technology and Process Option Screening

This section describes removal technologies and approaches that may achieve the RAOs identified in Section 3 and discusses whether or not the removal technology or process option is retained for alternative analysis in Section 4.2.1 of this EE/CA.

The process presented in this section follows EPA guidance for NTCRAs (EPA 1993) by first identifying potential removal technologies and process options, screening these options through consideration of practical applications of the technologies to the scope of the removal action.

The purpose of identifying and screening technology types and process options is to eliminate those technologies that are unfeasible or ineffective, while retaining potentially effective options. For this Site, general removal technologies potentially capable of achieving RAOs include no action, institutional controls, access and engineering controls, excavation, and containment.

An overview of the general removal technologies and process options is presented below.

4.1.1 No Action

No Action involves no further response or monitoring. No Action is generally used as a baseline against which other removal options are compared.

No Action would consider no implementation of flow controls, access barriers, contamination excavation, or containment. The No Action alternative would not be effective in achieving the Sites RAOs, but is retained for detailed analysis against other retained removal technologies.

4.1.2 Institutional Controls

Institutional Controls (ICs) are non-engineered measures such as land use restrictions, administrative controls, or public notifications that help manage risk by limiting activities that could result in unacceptable exposure. At this Site, ICs are considered appropriate given the recreational land use and land management by the USFS. ICs may include notifications, such as signage or notification to recreators of the presence of contamination.

This technology is retained for evaluation in combination with other removal technologies. Examples of some of these controls are included in the Design Toolbox in **Appendix C** and discussed in more detail in Section 4.2.1.

4.1.3 Access and Engineering Controls

Access and engineering controls are defined as structures or limited earthwork actions implemented to prevent, minimize, or control the exposure to contaminants. Access and engineering controls generally do not reduce the toxicity of hazardous materials; however, they can generally reduce exposure to contaminants.

Examples of some of these controls are included in the Design Toolbox in **Appendix C** and discussed in more detail below and in Section 4.2.1.

Fences or Barriers

Fencing and Barriers are tools used to prevent human exposure to contamination by establishing physical barriers. They are typically implemented when contamination is discovered during an ongoing cleanup when contamination is present at a level that does not allow for unlimited or unrestricted use (EPA 2025), or when access to an area should be minimized. Fences or barriers are usually employed as a supplementary measure to other removal technologies that address the principal source of contamination.

While the Site is relatively difficult to access, there is still abundant evidence of camping and four-wheeling directly on the waste rock pile. A buck and rail fence, or other physical barricades could be an access control to deter trailhead visitors and campers from entering this area after removal actions have been completed.

Buck and rail fence could be constructed either by importing wood posts or by using fallen trees from the Site with minor on-Site carpentry. Importing wood posts would be easily achievable with current road conditions using off-road capable vehicles.

This process option is retained for evaluation in combination with other removal technologies.

Trailhead Improvements

The existing trailhead southwest of the waste rock pile is currently an open area with little room for parking or vehicle turnaround. This alternative would widen the existing trailhead and grade the surface to facilitate parking and reduce vehicular traffic on or adjacent to the waste rock pile. Limited tree removal may be required for this alternative.

This process option is retained for evaluation in combination with other removal technologies.

Run-On and Run-Off Controls

Run-on and run-off controls are engineered measures designed to prevent or limit contaminant mobilization in surface water by diverting or conveying flow to reduce infiltration into contaminated areas and limiting potential discharge pathways. They are recommended by the USDA as a conservation practice standard for land reclamation and abandoned mined land (USDA 2021). Engineering controls could include run-on, run-off structures and grading and erosion control. Engineering controls generally do not reduce the toxicity of hazardous materials; however, they can significantly reduce the mobility of, and resulting exposure to, contaminants.

These process options are retained for evaluation in combination with other removal technologies.

RUN-ON CONTROLS

Upgradient water diversion, or run-on controls, focus on capturing or redirecting surface water before it comes into contact with contaminated areas, thereby preventing contamination of run-off. Diversion controls may be installed upslope of the collapsed adit, north of the waste rock pile, or at both locations. Controls evaluated for this EE/CA are limited to those that avoid major excavation efforts upslope of the collapsed adit. These controls may include log berms constructed from on-site felled trees and straw or coir erosion control logs (ECLs, or straw wattle). Other diversion structures that may be installed upslope of the waste rock pile include swales and rough grading.

Installation of run-on controls above the collapsed adit would be conducted by a hand crew to minimize disturbance and reduce the potential for additional soil erosion. Although there is no evidence of surface water discharge across the waste rock pile, a small pool of water has been observed near the collapsed adit. Diversion structures may be installed to route drainage and any stormwater or snowmelt flows around the waste rock pile, thereby protecting groundwater and nearby surface waters from potential metals loading from erosion of waste rock.

This process option is retained for evaluation in combination with other removal technologies.

RUN-OFF CONTROLS

The purpose of installing run-off controls is to improve the quality of stormwater leaving the Site and to reduce contaminant mobility. Typical run-off controls include diversion ditches, water bars, rolling dips, and culverts. These controls are intentionally installed downslope of contaminated areas to slow sheet flow and allow suspended sediments to settle, thereby preventing contaminants from migrating off-site. Run-off controls are particularly effective at preventing contaminated discharges when implemented in conjunction with an upgradient system of run-on controls.

This process option is retained for evaluation in combination with other removal technologies.

4.1.4 Excavation

Excavation is a commonly used removal action technology for addressing contaminated surface soils and mine waste that pose direct exposure risks. This technology involves mechanically removing, regrading, or re-contouring contaminated media to eliminate or reduce exposure pathways. For sites with localized contamination and accessible source areas, excavations activities can provide an effective and reliable means of rapidly reducing risk by physically removing contaminated media.

Excavation, Grading, and On-Site Management

Excavation and/or grading of the waste rock pile is done using a hydraulic excavator or comparable equipment. The waste rock materials may be managed at the current waste rock location or relocated to a separate, on-site disposal location. Following excavation, disturbed areas may be backfilled, graded, seeded for revegetation, covered with non-contaminated rock such as talus material, or left in their existing condition, depending on site-specific requirements.

Grading the remaining soils from the waste rock pile to tie-in to the surrounding grade would improve slope stability and reduce erosion caused by precipitation, wind, or animal activity. Grading to a slope less than 3 horizontal to 1 vertical (3H:1V) is typically considered stable and supportive of establishing vegetative cover. This removal technology would require the use of heavy construction equipment such as a bulldozer and an excavator. Natural debris like fallen trees and large rocks would need to be removed prior to grading to prevent differential settlement, depressions, or voids from developing over time.

The top 1-2 inches of the graded surface shall be roughened using heavy equipment or hand tools to create pockets perpendicular to sheet runoff to dissipate energy across the surface and reduce the migration of sediments. The grading of the pile will promote stormwater runoff and prevent migration of sediments off site. This rough grading should be followed with revegetation for further erosion control.

This process option is retained for further evaluation.

Excavation and Off-Site Disposal

Excavation and off-site disposal is intended to minimize the volume of contaminated material remaining on-Site by using a hydraulic excavator or comparable equipment to excavate the waste pile. Following excavation, disturbed areas will be graded, and seeded for revegetation, or left in their existing condition, depending on site-specific requirements.

Exporting contaminated material off-site is an effective and permanent removal action due to removal of the contaminant source and resulting exposure. This approach can be implemented rapidly and requires limited or no long-term monitoring and maintenance. However, off-site disposal can be costly due to the remote location of the Site and transportation and disposal costs. Contaminated materials would need to be transported in containers or by other U.S. Department of Transportation (DOT)–approved methods. In addition, hauling activities introduce potential risks associated with off-site transportation, such as traffic incidents and accidental releases.

This process option is retained for further evaluation.

4.1.5 Containment

Containment actions include physical measures that prevent or minimize exposure to contaminants or reduce the mobility or migration of contaminants. Examples include soil caps and engineered barriers, such as impermeable caps, to address direct contact and minimize infiltration, a key mechanism for contaminant transport to other media at the Site.

Revegetation is a best management practice that should be considered alongside any containment action. Revegetation typically involves placement of a soil or growth medium capable of supporting root development and plant establishment, followed by seeding with a Site-appropriate mix composed of species native or adapted to the surrounding area.

SOIL CAP

Soil capping involves placing a layer of clean material over contaminated soils or mine waste to isolate contaminants and prevent exposure. Soil caps at mine sites typically consist of compacted soil, limestone, or a combination of materials designed to address pH issues, limit direct contact, reduce dust generation, and minimize infiltration and erosion. This technology does not remove contamination but instead manages risk by preventing exposure pathways for human and ecological receptors. Soil caps are most effective where contamination is shallow, stable, and localized, and they can be combined with ICs, grading, and run-on and run-off controls to ensure protection of human health and the environment.

Soil capping has been retained for further evaluation.

ON-SITE ENGINEERED REPOSITORY

The creation of an on-site repository for waste rock and soil containment can be an effective removal action technology that isolates contaminated materials from the environment. This process option does not remove contamination but instead manages risk by preventing exposure pathways for human and ecological receptors and reducing infiltration, thus reducing the potential for contaminant migration. On-site repositories involve excavating and potentially lining an intentionally selected area similar to a landfill; excavating, hauling, placing lifts, and compacting waste rock; installing a cap over the waste; and revegetating the area. Considerations for an on-site repository should include local climate, hydrogeology, and terrain; space at the Site for equipment and material staging; and contamination characteristics. This technology can be cost effective in comparison with off-site disposal options.

This process option has been retained for further evaluation due to the anticipated level of disturbance and limited on-site location for an engineered repository.

Table 4. Removal Technology Screening Summary

Removal Technology	Process Option	Description	Screening Comment
No Action	Not applicable	No action.	**Retained**. To be utilized as a baseline comparison against other retained alternatives.
Institutional Controls	Signage	Regulatory signage to notify public of area access.	**Retained**. Can be effective to modify recreator behaviors that may minimize contact with and exposure to contamination. To be combined with other process options. Not sufficient to address the issue on its own.
Engineering Controls	Fences and barriers	Buck and rail fence or other physical barriers that prevent access to the waste rock pile and adit feature.	**Retained**. Can be effective to modify recreator behaviors that may minimize contact with and exposure to contamination. To be combined with other process options. Not sufficient to address the issue on its own.
	Trailhead Improvements	Construct a turnaround area and informal parking for vehicles at existing trailhead.	**Retained**. Can be effective to modify recreator behaviors that may minimize contact with and exposure to contamination. To be combined with other process options. Not sufficient to address the issue on its own.
	Run-on and run-off controls	Implement stormwater best management practices (BMPs) such as log or earthen diversion berms, drainage pathways, etc.	**Retained**. Can be effective in preventing stormwater contact with waste rock and soil contamination, reducing potential for contaminant mobilization and erosion.
Excavation	Excavation, grading, and on-site management	Excavate and grade waste rock pile; haul on-site for or recontour for consolidation/disposal at waste rock pile location; regrade; revegetate.	**Retained.** Can be effective in reducing erosion and grading site to manage run-on and run-off. May be most effective when combined with other process options.
	Excavation and off-site disposal	Excavate waste rock pile and adjacent contaminated soil; haul off-site for disposal at an approved landfill facility; restore grade to pre-existing/pre-mining grade; revegetate.	**Retained**. Can be effective in permanently removing source contaminants and minimizing potential exposure to contaminants.
Containment	Soil cap	Place soil cover material on waste rock pile; place topsoil and amendments (e.g., adding compost, lime); and revegetate.	**Retained**. Can be effective for minimizing direct exposure of recreators and wildlife to contaminants; erosion; and fugitive dust emissions.
	On-site engineered repository	Excavate and construct an engineered repository where waste rock and contaminated soil would be placed, compacted and capped for long-term containment.	**Retained**. Can be effective in minimizing direct exposure of recreators and wildlife to contaminants; erosion; and fugitive dust emissions. May be most effective when combined with other process options.

4.2 Proposed Alternatives

Based on the analysis, Table 4 presents the alternatives that will undergo analysis in Section 4.2.1.

Table 5. Removal Alternatives

Alternative Name	Alternative Summary
B-1 No Action	No removal actions or post removal site controls. Used as a basis for comparison
B-2 Run-on and Run-off Controls	• Institutional controls which may include signage or other public information tools • Access and engineering controls including trailhead improvements, fencing and barriers, and run-on and run-off controls • O&M for three years after removal action is complete
B-3 Waste Rock Pile Grading, Soil Cap, and Run-on/Run-off Controls	• Institutional controls which may include signage or other public information tools • Access and engineering controls, including trailhead improvements and run-on and run-off controls • Waste rock pile excavation, grading, and recontouring to facilitate soil cap • Placement of a soil cap and revegetation to reduce infiltration, erosion, and direct exposure to contaminants • O&M for three years after removal action is complete
B-4 Waste Rock Pile Excavation and Off-site Disposal	• Waste Rock Pile excavation, site restoration including revegetation • Off-site disposal at approved location • O&M for three years after removal action is complete

4.2.1 Topographic Surface Development

The grading design presented in this report is projected in the NAD83 Colorado State Plane North Zone, US Survey Feet state plane coordinate system. Existing topography features and contours were sourced from publicly available United States Geological Survey (USGS) Light Detection and Ranging (LiDAR) data. USGS LiDAR data provide high-resolution topographic information but are limited in densely vegetated environments. Although USGS Quality Level 2 LiDAR data are generally accurate to approximately ±10 centimeters in open terrain, forest canopy cover and terrain complexity can reduce accuracy due to limited laser penetration and increased uncertainty in ground surface classification.

As a result, all contours and earthwork quantities shown should be considered preliminary estimates for planning purposes only. The contractor is solely responsible for conducting a detailed, site-specific topographic survey to confirm actual field conditions prior to commencing construction. Verification should include, at a minimum, existing grades, breaklines, proposed tie ins, and quantities necessary to execute the work. No guarantee is made regarding the precision of the LiDAR-derived surface for construction staking or final grading.

5 Analysis of Removal Alternatives

5.1 Evaluation Criteria

EPA guidance on NTCRAs (EPA 1993) lists the following considerations for effectiveness, implementability, and cost.

- **Effectiveness**: An alternative's effectiveness is its ability to meet the objective within the scope of the removal action. This criterion focuses on how well each alternative protects public health and the environment. This discussion draws on assessment conducted under the following evaluation criteria:
  - Compliance with applicable or relevant and appropriate requirements (ARARs): This criterion evaluated whether each alternative would meet the identified ARARs.
  - Long-term Effectiveness and Permanence: This criterion evaluates the extent and effectiveness of controls that may be required to manage the risk posed by contaminated material residuals and/or materials left in place.
  - Reduction of contaminant toxicity, mobility, or volume: This criterion addresses the statutory preference for remedies that employ treatment or removal as a principal element by assessing the relative performances of technologies for reducing toxicity, mobility, or volume of the contaminated media. Specifically, the analysis should examine the magnitude, significance, and irreversibility of each estimated reduction.
  - Short-term effectiveness: This criterion addresses the effects of the alternative during implementation before the RAOs have been met considering protection of the community, protection of workers, environmental impacts, and time until RAOs are achieved.
- **Implementability**: An alternative's implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. This evaluation considers the following three elements.
  - Technical Feasibility: This criterion takes into account construction and operational considerations, demonstrated technology performance, adaptability to environmental conditions, and timing.
  - Administrative Feasibility: This criterion considers coordination with other offices and agencies, including off-site permits, adherence to applicable non-environmental laws, concerns of other regulatory agencies, and state and community acceptance.
  - Availability of Services and Materials: This criterion considers the availability of personnel, services, materials, and technology.
- **Cost**: An AACE Class 5 estimate has been prepared for each alternative's cost evaluation. Each estimate worksheet considers direct and indirect capital costs, annual O&M costs, periodic costs, and net present value. Cost worksheets are presented in **Appendix B** and were developed using a combination of vendor costs

from quotations and RSMeans Data from GORDIAN, using cost data for the DENVER (800-802) location, release year 2026 Quarter 1. RSMeans Line Numbers are presented for each line item in which they were used.

5.2 No Action – Alternative B-1

Under this alternative, no removal actions would take place to modify the Site. Contaminated materials in the waste rock and adjacent soils containing elevated levels of arsenic and lead would be left in place with no measures to minimize human or wildlife exposure.

5.2.1 Effectiveness

Long-term Effectiveness and Permanence: Alternative B-1 does not offer any long-term effectiveness and permanence to reduce risks to human health or the environment. By leaving the Site as-is, the risk associated with the waste rock pile would persist and likely mobilize off-site.

Reduction of Toxicity, Mobility, or Volume: Alternative B-1 would not satisfy RAOs or reduce the principal threats posed by the waste rock pile. Hazardous material would not be destroyed or treated, and toxicity, mobility, and volume of the waste would not be reduced.

Short-Term Effectiveness: Alternative B-1 requires no action; therefore, there are no impacts to the public, the environment, or construction workers during implementation. Additionally, this alternative would not achieve RAOs in the short term.

5.2.2 Implementability

Alternative B-1 is both technically and administratively feasible, and the availability of resources would not be an issue. However, agency and public acceptance is not likely.

5.2.3 Cost

[Redacted]

5.3 Run-on and Run-off Controls – Alternative B-2

Under this alternative the Site will be controlled utilizing upgradient run-on controls, downgradient run-off controls, access controls, trailhead improvements, and ICs. The former logging road will be ripped and restored; ECLs or anchored logs will be installed upgradient of the collapsed adit; drainage ditches will be added upgradient and downgradient of the waste rock pile; fencing will be placed blocking entry to the Site; and regulatory signage would be installed instructing people to stay off the Site area.

Access to the Site is currently limited to a rough, two-track road requiring four-wheel drive (4WD) and high clearance. While the majority of construction activities could be completed with hand tools and manual labor, tracked equipment such as a bulldozer with rippers, loader, excavator, and skid steer may be used to haul materials to site, complete channel excavation and V-ditch grading, and rip on-site roads. Tracked equipment can likely utilize the two-track road without issue, minimizing the need for access road improvements to facilitate construction.

Run-on controls will be installed north of the erosion feature associated with the collapsed adit in the form of ECLs or logs from fallen or local trees within the project area of effect if locally available. These run-on controls will be approximately 100 linear feet (LF) in length and will require minor excavation (i.e., hand-digging) consisting of digging a shallow trench in which to place the logs. If local fallen trees are selected for use, chainsaws or other similar hand tools may be used to remove branches or reduce logs to a manageable size. Once the logs are placed in the shallow trench, wood stakes or t-posts will be installed as anchors on the upgradient and downgradient sides with stainless steel wire or other similar fastener used to secure the logs to the anchors. Excavated soil will be placed on the upgradient side of the logs and hand-tamped to prevent erosion during storm events or snowmelt. These logs should be installed along a contour (e.g., at zero grade) to promote even, distributed flow and prevent channelized flow from discharging at either end of the run-on control structure. If ECLs are used, the netting will be made of biodegradable material.

A V-ditch type diversion ditch will be added both north (upgradient) and south (downgradient) of the waste rock pile. To the north, the V-ditch will be sized to convey the precipitation of a 25-year, 24-hour storm at an approximate 0.5% minimum slope. This ditch will be installed directly downgradient of the collapsed adit and will be designed to convey water around the contaminated footprint of the waste rock pile as delineated in the PCS report (**Appendix A**). A riprap apron will be installed at either end of the ditches to reduce erosion potential of the stormwater discharge.

To the south of the waste rock pile, a V-ditch will be installed between the toe of the pile and the northern, uphill side of Bard Creek Road. This ditch would be installed as a typical V-ditch with a minimum 0.5% slope designed to convey water along Bard Creek Road. V-ditches designed to convey water should be lined with either riprap or vegetation to provide a roughness factor, slowing conveyed water and preventing further channelization of the V-ditch. While riprap will slow the water more effectively than a vegetated ditch, it will also increase the rate of sedimentation and will require more frequent cleanouts or removal and replacement of rip rap to maintain functionality.

The run-off control to the south of the waste rock pile will convey flows along the north side of Bard Creek Road to the east, following the natural topography of the area until a low spot in the road is reached, at which point a water bar road crossing would be constructed in accordance with the USFS *Water/Road Interaction: Introduction to Surface Cross Drains* design guidance (included in **Appendix C**). A check dam consisting of compacted local earth will be constructed within the ditch to force water into the water bar. The water bar will be sized to convey the 25-year 24-hour design storm while also taking into consideration soil type of the road, road grade, and anticipated traffic use. Flows entering the water bar will discharge to a riprap apron on the south side of Bard Creek Road dispersing run-off for uptake or infiltration.

In addition to run-on and run-off controls, improvements to the existing trailhead (southwest of the waste rock pile, at the west end of Bard Creek Road) will be made by expanding the parking area to accommodate overnight parking and/or a turnaround area for vehicles. A bulldozer or skid steer may be used to grade the trailhead to a flat surface designed to drain stormwater and snowmelt into the run-off controls described above. No additional fill will be required; it is assumed that any material excavated during trailhead grading activities could be utilized, or a local area could be utilized as a small borrow source if needed.

The former logging road (currently a non-motor vehicle use road) will be ripped using a bulldozer, and an excavator or hand-digging will be used to create hummocks over the surface of the waste rock pile to discourage recreators from camping on exposed contaminated materials.

Buck and rail fence (also called jack leg fencing) will be installed to limit access to the Site. This fencing, included in **Appendix C**, generally consists of jack leg braces constructed of 8-inch minimum diameter treated or untreated wood posts and horizontal treated or untreated wood poles that are a minimum of 6-inch-diameter. This type of fencing does not require digging or excavation to install but does require a relatively high number of materials and labor for assembly. It is known to be a durable fence type that is wildlife-friendly and can withstand heavy snowfall.

Signage and a monument will also be installed as part of this alternative. Signage will be designed in accordance with Chapter 6A of the USFS *Signage and Poster Guidelines*, included in **Appendix C**. Signage will notify foot and vehicle traffic that the area is protected and closed to the public and may be installed using a manual post driver or a skid steer attachment if location allows.

Barriers and signage will be installed along the perimeter of the trailhead, at the southern toe of the waste rock pile that currently comes into contact with Bard Creek Road, and at the entrance to the former logging road.

Operations and Maintenance

General operations and maintenance would commence for the first three years after construction. The current USFS Operating Plan will apply to the area once this period has ended.

5.3.2 Effectiveness

Long-term Effectiveness and Permanence: Alternative B-2 is not effective in the long-term and is not a permanent solution to meet Site RAOs. While access, engineering, and institutional controls are put into place to discourage recreational use of the Site, the risk associated with exposure to the uncovered waste rock pile remains largely undiminished.

With proper implementation and maintenance, ICs and engineering and access controls are effective for controlling flow. While the ditches and anchored logs have been carefully designed for the project environment, run-on and run-off controls can be vulnerable to heavy storm events. ECLs or tree logs could be damaged or displaced by significant stormwater flow. Diversion ditches may become damaged, eroded, or blocked by debris or sediment, requiring hand tools to repair and clean out or, in more extreme cases, heavy equipment to reshape and clean out the ditches.

In summary, without the incorporation of additional removal actions, Alternative B-2 does not offer long-term effectiveness in addressing the Site's RAOs to minimize migration of contaminants out of the area of potential effects, and it does not reduce exposure of humans and wildlife to the greatest extent possible.

Reduction of Toxicity, Mobility, or Volume: While engineering and ICs may reduce contact between run-off and waste rock, this action does not reduce the toxicity or volume of waste. The waste rock pile would remain in place and exposed to the environment, wildlife, and any traffic that continued to visit the Site despite signage and barriers. In summary, Alternative B-2 does not reduce the toxicity or volume of contaminants but may reduce the volume of contaminants that might mobilize off-site in stormwater run-off.

Short-Term Effectiveness: No impacts to the community are expected during removal activity implementation due to the remote location of the Site.

There is a risk of worker exposure to contaminants in the waste rock and soil that may be mitigated by requiring thorough handwashing before eating, prohibiting cigarette smoking on-site, requiring either respirators or air monitoring that ensures arsenic and lead levels are below the permissible exposure limit (PEL), and any other safeguards required by the Occupational Safety and Health Administration (OSHA) standards for arsenic and lead. Direct worker exposure to contaminated material through airborne dust and debris or contact with the water draining the mine cannot be eliminated but can be minimized with appropriate construction practices such as dust suppression and donning appropriate personal protective equipment (PPE). For all aspects of construction, contractor employees working at the Site should have completed the 40-hour OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) training, and standard work practices should be used as designated to ensure worker safety.

Engineering controls would be effective for controlling run-on and run-off as soon as they are implemented. These controls would be effective in reducing contaminant mobilization in the short term. Alternative B-2 would not address Site RAOs to prevent exposure of humans and wildlife to contaminants as the waste rock pile will remain undisturbed, leaving it exposed to wildlife, climate conditions, and trespassers.

5.3.3 Implementability

Technical Feasibility: Alternative B-2 is technically feasible with minimal challenges that may be presented to the construction contractor. Construction access should not be an issue if the contractor has off-road capable vehicles and tracked equipment, although traveling to and from Site may take more time than normal depending on the condition of Bard Creek Road. Similarly, mobilizing construction equipment will require tracking equipment from just outside of the town of Empire to the Site, and multiple trips will be required to mobilize other materials, such as wood poles for fencing. Access to Site will likely be unavailable from October through May, depending on snowfall.

Trailhead expansion may be limited by the bounds of acceptable tree removal in this area.

Issues that may delay the scheduled completion include weather delays, issues with trucks and equipment, and unforeseen environmental impacts to travel routes. The Site is at 10,000 feet amsl, and, as a result, has a short construction season between snowmelt around May and snowfall in October. During construction season, the area is subject to monsoon season between July and September, which consists of afternoon storms that may present lightning and flash flooding hazards. Unforeseen environmental impacts include rockfall, landslides, or treefalls across Bard Creek Road, which may block access to the Site and delay the work schedule.

Administrative Feasibility: Alternative B-2 is administratively feasible. This removal action will be performed under CERCLA and on USFS land, eliminating the need to apply for excavation permits with Clear Creek County or right-of-way permitting for the work along Bard Creek Road (which is a USFS road).

Availability of Services and Materials: Personnel, including equipment operators and laborers, as well as heavy equipment and materials such as ECLs and wood posts are readily available in the area.

Run-on and run-off controls in the form of ECLs and diversion ditches are common BMPs on abandoned mine land and land reclamation sites and are common stormwater management practices in general. As such, ECLs are readily available in stores for immediate pick-up. The staff required to perform this work is available. Alternatively, fallen trees are readily available in the area and can be readily moved using heavy equipment.

Signage can be ordered from several different companies and shipped, and wood posts for buck and rail fencing (treated or untreated) is available from local lumber mills or ranch and hardware stores in the area.

Heavy equipment and staff required to construct V-ditches and make the discussed improvements to the trailhead are also available.

5.3.4 Cost

[Redacted]

5.4 Waste Rock Pile Grading, Soil Cap, and Run-on/Run-off Controls – Alternative B-3

Alternative B-3 consists of the work activities described in Alternative B-2 and includes the additional waste rock pile excavation, re-contouring, and placement of a soil cap to further control erosion and limit exposure to contaminated waste rock and soils. Under this alternative, exposure to the waste rock pile and contaminated soils will be managed by access, engineering controls, and a soil cap. Access to the Site is currently limited to a rough, two-track road requiring 4WD and high clearance. Improvements made to the existing access road may be necessary to make it suitable for material imports, which may involve clearing and grubbing of large trees and shrubs and byproduct management along somewhat steep slopes. Any improvements would be minor and made strictly where necessary.

Run-on controls would be installed upgradient of the collapsed adit in the form of ECLs or tree logs, and run-off controls would be constructed above and below the capped waste rock pile in the form of V-ditches as discussed in Alternative B-2. These controls would be implemented during the construction phase and would be kept as permanent Site features to protect the integrity of the cover system.

Additional data collection activities for Alternative B-3 may include borrow area characterization to identify any areas on or near the Site that may be utilized as a source for soil cover. This includes geotechnical sampling to confirm potential fill meets gradation requirements, laboratory analysis to confirm fill is not contaminated, and confirmation that there is enough borrow material to meet the volume requirements of the soil cap. If a borrow source area is identified, access improvements will be completed (including clearing and grubbing of the borrow area) and a truck loadout area will be graded near the borrow source. Potential borrow areas at the Site include the area directly east of the waste rock pile and the former roads to the east and west of the waste rock pile. If all potential borrow areas identified at the Site are deemed unsuitable for the soil cap, soil will be sourced from a local aggregate supplier. For the purpose of costing, this EE/CA assumes an on-site borrow area is available.

As part of contractor mobilization and site preparation activities, improvements to Bard Creek Road may be required to facilitate borrow source deliveries via dump truck, as needed. Temporary construction fencing or high visibility barriers will be installed on Bard Creek Road east of the Site to prevent recreators from entering the work area and potentially causing a safety hazard.

Construction of the cap requires grading of the waste rock pile to prepare the surface for the cap, which is made up of the addition of lime and a soil cover. The slopes should not exceed a slope of 3:1 (or 33%) – any steeper, and the waste rock pile will be subject to greater risk of erosion and revegetation failure. To achieve this slope, the waste rock pile elevation will decrease, and the footprint will expand to accommodate the excess material. Material will not be placed within the collapsed adit area due to uncertainties associated with geotechnical stability.

The soil cover will be placed and compacted in 12-inch lifts. The contractor shall sufficiently compact placed fill and disturbed areas using means and methods appropriate to the remote setting. Such methods would include but not be limited to excavator mounted vibratory compactors or sheepsfoot-style roller wheels. Final compaction to be approved by owner & engineer in the field. Soil cover thickness will be equal to twice the thickness of the largest diameter waste rock. For the purpose of this EE/CA, it is assumed that the largest diameter rock will be 6-inches, so the cap is assumed to be 12 inches thick. Prior to construction implementation, rock size should be verified within the waste rock pile to determine actual cover thickness. The material utilized for the cover will be a viable medium for plant growth, and amended topsoil (i.e. bio-sol + humate or approved equivalent) will be applied directly to the cap surface. An initial lift of limestone will be placed on or blended into the waste rock to stabilize pH in the event percolated stormwater reaches the waste rock and may create a cementitious layer when mixed with infiltrated water. Limestone should be applied to the surface as directed by the manufacturer.

The area would be revegetated with a shallow-rooting upland seed mix native to Clear Creek County specified to 7,000 feet of elevation or higher as approved by USFS. Seed will be applied by broadcast methods and covered with wood straw or seed tackifier. Seeding should occur in late September or early October to allow snowpack to cover the seed before germinating the following spring.

During construction, any waste materials such as felled trees or large non-contaminated rock will be staged at the trailhead and evaluated for potential on-site reuse for run-on and run-off controls. If not suitable for reuse as part of the construction activities, USFS may deem the materials suitable to stay at the trailhead.

Operations and Maintenance

Vegetation should be monitored periodically to determine if the area is on track to reach 70 percent coverage within 2 years. If patchy, bare areas are identified, supplemental seeding may be required. General operations and maintenance would commence for the first three years after construction. The current USFS Operating Plan will apply to the area once this period has ended.

5.4.2 Effectiveness

Long-term Effectiveness and Permanence: Alternative B-3 is effective in the long-term. While the contaminated material would remain on-site, installing a soil cover and revegetation would provide long-term and effective protection that would limit direct exposure of the environment, humans, and wildlife to contamination and would prevent migration of contaminants off-site by preventing erosion of the waste pile, fugitive dust, and infiltration of stormwater that would cause leaching or mobilization of covered contaminants. The cover may be vulnerable to significant storm events, burrowing animal species, deep-rooting vegetation, and significant or destructive human activity over the cap. Run-on controls are suggested to facilitate sheet flow over the cap and protect it from soil erosion. To maintain long-term effectiveness, this alternative may require periodic maintenance.

Reduction of Toxicity, Mobility, or Volume: Installing a soil cap over the mine waste does not address the contaminant toxicity or volume remaining on-site. However, this alternative would reduce the mobility of contaminants by placing a soil cap designed to prevent exposure to or leaching from the waste rock.

Short-Term Effectiveness: Minimal impacts to the community may occur during removal activities, depending if borrow materials would need to be imported to Site, which would require truck traffic through the town of Empire and Bard Creek Road, increasing vehicle emissions and noise levels during work hours.

Impacts to the environment anticipated during construction activities include tree removal to facilitate grading the waste rock pile to an acceptable slope. Fugitive dust and water contamination from runoff before finishing the soil cover, which can be mitigated by employing appropriate BMPs such as water trucks for dust suppression and temporary silt fence or other erosion control measures to prevent off-site run-off.

There is a risk of worker exposure to contaminants in the soil, which may be mitigated by requiring thorough handwashing before eating, prohibiting cigarette smoking on-site, requiring either respirators or air monitoring that ensures arsenic and lead levels are below the PEL, and any other safeguards required by OSHA standards for arsenic and lead. Direct worker exposure to contaminated material through airborne dust and debris or contact with the water draining the mine cannot be eliminated but can be minimized with appropriate construction practices such as dust suppression and donning appropriate PPE. For all aspects of construction, contractor employees working at the

Site should have completed the 40-hour OSHA HAZWOPER training, and standard work practices should be used as designated to ensure worker safety.

Alternative B-3 would achieve RAOs upon construction completion.

5.4.3 Implementability

Technical Feasibility: Alternative B-3 is technically feasible with minimal challenges that may be presented to the construction contractor. Heavy equipment and trucks will need to access the Site. While tracked equipment can easily navigate off-road conditions, construction access routes may need to be improved, which may require grading portions of Bard Creek Road to facilitate dump truck access where absolutely necessary. Byproduct management along somewhat steep slopes and in forested areas may also pose a challenge during construction activities.

Soil cover systems are a proven technology which are commonly used in mine waste closure as discussed in **Appendix C**, and have been selected for use at other CERCLA sites across the country.

Issues that may delay the scheduled completion include weather delays, issues with trucks and equipment, and unforeseen environmental impacts to travel routes. The Site is at 10,000 feet amsl, and, as a result, has a short construction season between snowmelt around May and snowfall in October. During construction season, the area is subject to monsoon season between July and September, which consists of afternoon storms that may present lightning and flash flooding hazards. Unforeseen environmental impacts include rockfall, landslides, or treefalls across Bard Creek Road, which may block access to the Site and delay the work schedule.

Access controls (such as temporary exclusion fencing) that limit access to the revegetated area and engineering run-on controls are suggested to protect the integrity of the soil cover.

Administrative Feasibility: Alternative B-3 is administratively feasible. This removal action will be performed under CERCLA and on USFS land, eliminating the need to apply for excavation permits with Clear Creek County or right-of-way permitting for the work along Bard Creek Road (which is a USFS road). It is likely that the community would accept this alternative.

Availability of Materials: Personnel, including equipment operators and laborers, as well as heavy equipment and materials are readily available and can mobilize to the Site.

Suitability of the borrow area and quantities available will be confirmed as part of the data collection activities during construction planning. Should the borrow area not be suitable for capping material, appropriate materials would be available for procurement and delivery within an agreeable timeframe. Seed mix, fertilizer, and mulch are all available for procurement and delivery within an agreeable timeframe.

5.4.4 Cost

[Redacted]

5.5 Waste Rock Pile Excavation and Off-Site Disposal – Alternative B-4

Under this alternative, the waste rock pile will be removed to underlying native materials and revegetated. Access to the Site is currently limited to a rough, two-track road requiring 4WD and high clearance. Improvements made to the existing access road may be necessary to make it suitable for material imports, which may involve clearing and grubbing of large trees and shrubs and byproduct management along somewhat steep slopes.

As part of contractor mobilization and site preparation activities, improvements to Bard Creek Road will be required to facilitate aggregate deliveries via dump truck and frequent dump truck loadout with waste rock. Exclusion fencing or a gate will be installed on Bard Creek Road east of the Site to prevent recreators from entering the work area and potentially causing a safety hazard.

Approximately 3,500 CY would be excavated from the waste rock pile. The collapsed adit will be left alone due to safety concerns associated with the stability of the area. Excavated waste would be directly loaded into DOT-compliant containers and hauled off-site to be disposed of at an approved landfill facility that accepts contaminated soil. Excavated waste may not be staged or stockpiled outside of the project boundaries defined in the drawings attached to this EE/CA.

The area would be revegetated with a shallow-rooting seed mix native to Clear Creek County specified to 7,000 feet of elevation or higher as approved by USFS. Seed will be applied by broadcast methods and covered with wood straw or seed tackifier. Seeding should occur in late September or early October to allow snowpack to cover the seed before germinating the following spring.

During construction, any waste materials such as felled trees or large non-contaminated rock will be staged at the trailhead and evaluated for potential Site reuse. If not suitable for reuse as part of the construction activities, USFS may deem the materials suitable to stay at the trailhead.

Operations and Maintenance

Vegetation should be monitored periodically to determine if the area is on track to reach 70 percent coverage within 2 years. If patchy, bare areas are identified, supplemental seeding may be required. The current USFS Operating Plan will apply to the area once this period has ended.

5.5.2 Effectiveness

Long-term Effectiveness and Permanence: This alternative is an effective and permanent technology to remove contaminants from the Site. No long-term monitoring or maintenance is associated with this alternative.

Reduction of Toxicity, Mobility, or Volume: This alternative directly addresses the source of contamination. The volume of contaminated material at the Site is diminished to minimal levels. Remaining contamination in residual soils is covered with clean, revegetated material. Mobility of contaminants off-site would no longer be a concern.

Short-Term Effectiveness: This removal action alternative presents risk of impacts to the community and/or environment by accidental spill or traffic incident during transit of the contaminated soil. These risks increase as transport distances increase. Additional community impacts include trucking through the town of Empire and Bard Creek Road, increasing vehicle emissions and noise levels during work hours.

Impacts to the environment anticipated during construction activities include tree removal to facilitate excavation of the waste rock pile. Fugitive dust and water contamination from runoff before finishing the excavation can be mitigated by employing appropriate BMPs, such as water trucks for dust suppression and temporary silt fence or other erosion control measures to prevent Site run-off.

There is a risk of worker exposure to contaminants in the soil that may be mitigated by requiring thorough handwashing before eating, prohibiting cigarette smoking on-site, requiring either respirators or air monitoring that ensures arsenic and lead levels are below the PEL, and any other safeguards required by OSHA standards for arsenic and lead. Direct worker exposure to contaminated material through airborne dust and debris or contact with the water draining the mine cannot be eliminated but can be minimized with appropriate construction practices such as dust suppression and donning appropriate PPE. For all aspects of construction, contractor employees working at the Site should have completed the 40-hour OSHA HAZWOPER training, and standard work practices should be used as designated to ensure worker safety.

Alternative B-4 would achieve RAOs upon construction completion. Removal of the waste rock would remove the principal threats associated with the Site, and any residual waste rock or soil impacts would be covered by 36 inches of material to limit further exposure.

5.5.3 Implementability

Technical Feasibility: Alternative B-4 is technically feasible with some challenges that may be presented to the construction contractor. Heavy equipment and trucks will need to access the Site. While tracked equipment can easily navigate off-road conditions, construction access routes will need to be improved, which may require clearing and grubbing of large trees and shrubs on-site, grading portions of Bard Creek Road to facilitate dump truck access. Byproduct management along somewhat steep slopes and in forested areas may also pose a challenge during construction activities.

Waste removal and disposal is a proven and reliable technology that will meet Site RAOs upon construction completion. Issues that may delay the scheduled completion include weather delays, issues with trucks and equipment, and unforeseen environmental impacts to travel routes. The Site is at 10,000 feet amsl and has a short construction season between snowmelt around May and snowfall in October. During construction season, the area is subject to monsoon season between July and September, which consists of afternoon storms that may present lightning and flash flooding hazards. Unforeseen environmental impacts include rockfall, landslides, or treefalls across Bard Creek Road, which may block access to the Site and delay the work schedule.

Contaminated waste rock and soil requires loading into containers or DOT-approved transportation mechanisms for off-site transport, which is typically associated with high costs. In addition, the potential for spills or off-site transportation incidents can pose significant impacts on the community and should be considered.

Issues that may delay the scheduled completion include weather delays, issues with trucks and equipment, and unforeseen environmental impacts to travel routes. The Site is at 10,000 feet amsl, and, as a result, has a short construction season between snowmelt around May and snowfall in October. During construction season, the area is subject to monsoon season between July and September, which consists of afternoon storms that may present lightning and flash flooding hazards. Unforeseen environmental impacts include rockfall, landslides, or treefalls across Bard Creek Road, which may block access to the Site and delay the work schedule.

Administrative Feasibility: Alternative B-4 is administratively feasible. This removal action will be performed under CERCLA and on USFS land, eliminating the need to apply for excavation permits with Clear Creek County or right-of-way permitting for the work along Bard Creek Road (which is a USFS road). However, since the alternative involves moving contaminated material off-site, RCRA permitting and EPA tracking of the chain of custody of the material will be required. Transporting excavated material would require waste sampling and characterization prior to removal, approval from the disposal facility, and disposal manifest management, as deemed necessary. It is likely that the community would accept this alternative.

Availability of Services and Materials: Personnel, including equipment operators and laborers, as well as heavy equipment and materials are readily available and can mobilize to the Site.

Availability of trucking companies may be dependent upon the condition of Bard Creek Road and truck turnaround area on-site and would be costly due to the relatively remote location of the Site.

Suitability of the borrow area and quantities available will be confirmed as part of the data collection during remedial action planning. Should the borrow area not be suitable for backfill, appropriate materials would be available for procurement and delivery within an agreeable timeframe. Seed mix, fertilizer, and mulch are all available for procurement and delivery within an agreeable timeframe.

5.5.4 Cost

[Redacted]

Table 6. Summary of Alternatives Analysis

Alternative Name	Description/Scope	Objective	Effectiveness	Implementability
B-1 No Action	No action	No objectives since this is a no action alternative	**Long-term effectiveness:** Not effective at protecting public health and the environment or minimizing the migration of contaminants from the Site. The waste rock pile would still be accessible to the public for camping and other recreational activity and would continue to potentially impact wildlife and human health. Contaminated run-off would remain uncontrolled and would remain a source of potential contamination for areas downgradient of the Site. **Reduction of toxicity, mobility, and volume:** Not effective. **Short-term effectiveness:** Not effective at protecting public health and the environment or minimizing the migration of contaminants from the area of potential effects for reasons listed above.	**Technical feasibility:** No actions, no considerations. No long-term maintenance. **Administrative feasibility:** No permits required to completed this removal action under CERCLA. There will be a public comment period and action memorandum. **Availability of services/materials:** No materials required.
B-2 Run-on and Run-off Controls	Pre-construction submittals & site preparation Install run-on controls north of collapsed adit (e.g., wattles or trees taken down during clearing/grubbing) Install run-off controls north of the waste rock pile and between southern toe of waste rock pile and uphill of Forest Service road Rip & restore existing access roads Trailhead improvements Install access controls and ICs (buck and rail fence & signage)	Reduce erosion and sediment transport (e.g. contaminant migration), control surface water and run-off (e.g. contaminant migration through run-off), reduce human exposure (e.g. access controls and ICs).	**Long-term effectiveness**: Effective to control stormwater flow and interaction with the waste rock pile; as-needed maintenance (e.g., clearing of V-ditch obstructions). Alternative B-2 would not be effective at protecting public health and the environment in the long term as mine wastes are still exposed and accessible to recreators and wildlife. **Reduction of toxicity, mobility, and volume:** Would reduce the mobility of contamination through the use of run-on and run-off controls. Does not reduce the toxicity or volume of contamination. **Short-term effectiveness**: Effective to control run-on and run-off off flow. Alternative B-2 would be effective at protecting public health and the environment in the short term through the use of access controls. Minimizing the migration of contaminants from the area would be reduced by the use of flow controls.	**Technical feasibility:** Heavy equipment will need to be able to access Site which may require minor access road improvements. May require periodic maintenance of run-on and run-off features. **Administrative feasibility:** No permits are required to complete this removal action under CERCLA. There will be a public comment period and action memorandum. **Availability of services/materials:** Laborers, equipment, and supplies are available for procurement in an agreeable timeframe.
B-3 Waste Rock Pile Grading, Soil Cap, and Run-on/Run-off Controls	Data collection (define borrow area, topographic survey of trees and vegetation, etc.) Pre-construction survey (topography, trees, vegetation); sampling to confirm borrow area; etc. Pre-construction submittals & site preparation Install water bar on FS access road; clearing & grubbing; etc. Trailhead improvements (e.g., turnaround area for vehicles, overnight parking) Install run-off controls (V-ditches) north of the waste rock pile and between southern toe of waste rock pile and uphill of Forest Service road Grade the waste rock pile and prepare surface for soil cap Cap graded waste rock pile & adit with soil cover consisting of limestone and on-site borrow materials if available Install access and institutional controls (buck and rail fence & signage) Revegetate, rip & restore former access roads, and demobilize	Minimize erosion and sediment transport (e.g., contaminant migration), control surface water and run-off (e.g., contaminant migration through run-off), reduce human and ecological exposure (e.g., soil cap, access controls, and ICs).	**Long-term effectiveness**: Effective for eliminating direct exposure, erosion, dust exposure, and infiltration of water; as-needed maintenance (e.g., clearing of V-ditch obstructions). **Reduction of toxicity, mobility, and volume:** Would reduce the mobility of contamination through the use of capping and run-on and run-off controls. Does not reduce the toxicity or volume of contamination. **Short-term effectiveness:** Capping and engineering controls address exposure pathways in the short-term, after constructed.	**Technical feasibility:** Heavy equipment will need to be able to access Site which may require minor access road improvements. May require periodic maintenance of soil cap, and run-on and run-off features. **Administrative feasibility:** No permits are required to complete this removal action under CERCLA. There will be a public comment period and action memorandum. **Availability of services/materials:** Verify borrow quantities available on-site as part of data collection activities. Laborers, equipment, and supplies are available for procurement in an agreeable timeframe.

Alternative Name	Description/Scope	Objective	Effectiveness	Implementability
B-4 Waste Rock Pile Excavation and Off-site Disposal	Pre-design investigation Site survey (topography, trees, vegetation); sampling to confirm borrow area; etc. Pre-construction & site preparation Install water bar on FS access road; clearing & grubbing; etc. Excavate waste rock pile Dispose of waste rock at approved landfill Rip & restore access roads, revegetate, demobilize	Reduce erosion and sediment transport, and human exposure and ecological exposure through waste rock pile removal	**Long-term effectiveness:** This is an effective and permanent technology by removing the waste rock pile from the Site. **Reduction of toxicity, mobility, and volume:** Would permanently reduce the toxicity, mobility, and volume of contamination by removing the waste rock pile from the Site. **Short-term effectiveness:** Excavation and off-site disposal immediately removes the contaminant source. Risk of exposure to the public during loading and transportation.	**Technical feasibility:** Heavy equipment and trucks will need to be able to access Site which will require access road improvements. Will require suitable backfill material. Hydrogeology at the Site will need to be evaluated to confirm water management is not necessary during excavation activities. Erosion and soil migration may be a concern during excavation. Possibility of off-site incidents (spills, etc.) should be considered. Soil must be loaded into containers or DOT-approved transportation mechanism (typically high cost). Run-on and run-off controls will need to be implemented during excavation but will not be required in the long-term. No long-term monitoring or engineering controls are required. **Administrative feasibility:** Due to off-site transportation, necessary RCRA permitting and EPA tracking of change of material custody may apply. There will be a public comment period and action memorandum. **Availability of services/materials:** Verify borrow quantities available on-site as part of data collection activities. Consider verification of the depth/volume of contaminated soils as part of data collection activities. Laborers, equipment, and supplies are available for procurement in an agreeable timeframe.

6 Comparative Analysis

Alternative B-1 (No Action) was evaluated as a baseline for comparison and does not provide protection of human health or the environment. Under this alternative, contaminated waste rock would remain exposed, and no controls would be implemented to limit erosion, stormwater contact, or direct access. As a result, contaminant mobility and exposure pathways would remain unchanged, and the Site RAOs would not be met. While Alternative B-1 is readily implementable and does not incur cost, it is not effective in either the short or long term and would not be consistent with CERCLA removal action objectives.

Alternative B-2 incorporates run-on and run-off controls, access controls and ICs to manage potential exposure and limit contaminant migration. Relative to Alternative B-1, this alternative provides an improvement by reducing stormwater interaction with contaminated materials and discouraging recreational access. These measures are technically feasible, rely on commonly used BMPs, and would provide immediate reduction in migration potential once installed. However, when compared to Alternatives B-3 and B-4, Alternative B-2 does not isolate or remove contaminated materials. The waste rock pile remains exposed, and long-term effectiveness is dependent on sustained inspection, repair, and maintenance. Consequently, Alternative B-2 provides limited long-term effectiveness and does not fully meet the Site RAOs when implemented as a standalone action.

Alternatives B-3 and B-4 provide substantially greater effectiveness by addressing exposure pathways at their source. Alternative B-4, which includes excavation and off-site disposal of contaminated waste rock, provides the greatest degree of permanence and fully eliminates the principal threat at the Site. However, this alternative presents higher short-term risks associated with excavation and transport of contaminated materials, increased disruption to the surrounding area, greater implementation complexity, and significantly higher cost. Alternative B-3, which consists of grading, installation of a soil cap, revegetation, and supporting run-on/run-off, access, and ICs, effectively isolates contaminated materials, reduces erosion and infiltration, and minimizes exposure and migration. While contaminated materials remain at the Site, the soil cover provides long-term protection when properly maintained and represents a proven and reliable remedial approach.

Table 7. Comparative Analysis Summary

Alternative Name	Effectiveness		Implementability		
	Protectiveness	Ability to Achieve RAOs	Technical Feasibility	Availability	Administrative Feasibility
B-1 No Action	**Public health & community:** Not protective of public health. No community effects. **Workers during implementation:** N/A - no construction activities performed. **Environment:** Not protective of the environment. **Complies with RAOs:** Does not comply with RAOs.	**Level of containment:** None. **Residual effect concerns:** Waste remains in place; exposure risk persists.	**Construction & O&M:** No construction or O&M required. **Useful life:** N/A - no technology constructed or applied. **Environmental adaptability:** N/A - no technology constructed or applied. **Can be implemented in 1 year:** Yes - no technology constructed or applied.	**Equipment:** N/A - no technology constructed or applied. **Personnel & services:** N/A - no technology constructed or applied. **Post-removal O&M:** N/A - no technology constructed or applied.	**Permit requirements:** No permits are required to complete this removal action under CERCLA. **Impacts on adjoining property:** No short-term impacts. Potential future impacts due to potential of contaminants to mobilize into waterways. **Ability to impose institutional controls:** No ability. **Likelihood of acceptance:** Lowest likelihood - principal threat persists on-site.
B-2 Run-On and Run-Off Controls	**Public health & community:** Not protective of public health. No community effects. **Workers during implementation:** Moderate risk of worker exposure; risk increases if hand tools are used on waste rock pile. **Environment:** Somewhat protective. Waste rock pile remains exposed, but institutional controls may reduce human exposure and contaminant mobility. **Complies with RAOs:** Does not comply with RAOs.	**Level of containment:** Minimal. **Residual effect concerns:** Waste remains in place; exposure risk persists, but is reduced compared to B-1.	**Construction & O&M:** Relatively low construction requirements. O&M required for upgradient run-on features, fencing, and ditch maintenance. **Useful life:** Multiple years. **Environmental adaptability:** High adaptability. **Can be implemented in 1 year:** Yes.	**Equipment:** Highest likelihood of availability and can mobilize to Site. **Personnel & services:** Highest likelihood of availability. **Post-removal O&M:** Will likely require continued periodic maintenance of run-on and run-off controls to maintain functionality and lifespan.	**Permit requirements:** No permits are required to complete this removal action under CERCLA. **Impacts on adjoining property:** No short-term impacts. Potential future impacts due to potential of contaminants to mobilize into waterways. **Ability to impose institutional controls:** High ability during and after construction. **Likelihood of acceptance:** Low likelihood due to low effectiveness of remedy.
B-3 Waste Rock Pile Grading, Soil Cap, & Run-On and Run-Off Controls	**Public health & community:** Second most protective of public health. Low community impacts if material imports are required. **Workers during implementation:** Moderate risk of worker exposure during grading activities. **Environment:** Protective of the environment upon construction completion. **Complies with RAOs:** Complies with RAOs.	**Level of containment:** High. Cap isolates waste, limiting exposure to contaminants. **Residual effect concerns:** Low. Waste remains on-site. Cover reduces contaminate exposure as long as it is maintained.	**Construction & O&M:** Higher construction level of effort than B-2 but lower than B-1. Highest O&M requirements due to monitoring requirements of cap and vegetation in addition to requirements for upgradient run-on features, fencing, and ditch maintenance **Useful life:** Likely longer lifespan than B-2. **Environmental adaptability:** High adaptability. **Can be implemented in 1 year:** Yes.	**Equipment:** Likely available and can mobilize to Site. **Personnel & services:** Higher availability than B-4. **Post-removal O&M:** O&M of B-2 required.	**Permit requirements:** No permits are required to complete this removal action under CERCLA. **Impacts on adjoining property:** No effects to adjoining property expected. **Ability to impose institutional controls:** High ability during and after construction. **Likelihood of acceptance:** Highest likelihood due to balance of cost, effectiveness, and implementability.
B-4 Waste Rock Pile Excavation and Off-Site Disposal	**Public health & community:** Most protective of public health. High potential for community exposure impacts during waste disposal hauling. **Workers during implementation:** Moderate risk of worker exposure during excavation activities. **Environment:** Most protective of the environment upon construction completion. **Complies with RAOs:** Complies with RAOs.	**Level of containment:** Highest. Waste would be disposed of off-site. **Residual effect concerns:** No concerns with residual effects. Waste would be disposed of off-site.	**Construction & O&M:** Highest level of effort for construction. O&M requirements slightly higher than B-2 to continue monitoring vegetation in addition to upgradient run-on features, fencing, and ditch maintenance. **Useful life:** Longer lifespan than B-2 or B-3. **Environmental adaptability:** High adaptability. **Can be implemented in 1 year:** Yes, assuming no issues cause a schedule delay over the winter months.	**Equipment:** Disposal trucking may not be available or able to traverse Bard Creek Road without major grading and may not be able to loadout on-Site without construction of a truck turnaround. Other heavy equipment is available and can mobilize to site. **Personnel & services:** Personnel and lab services available. **Post-removal O&M:** O&M of B-2 required.	**Permit requirements:** Due to off-site transportation, necessary RCRA permitting may apply (e.g. waste manifests). **Impacts on adjoining property:** No effects to adjoining property expected. **Ability to impose institutional controls:** Moderate ability during construction. Potential difficulty preventing recreators from accessing Site if Bard Creek Road remains open to allow truck traffic. Similar ability to B-2 and B-3 after construction. **Likelihood of acceptance:** Moderate likelihood due to community impacts and capital expenditure cost.

7 Recommended Alternative

Based on comparative evaluation of effectiveness, implementability, and cost, Alternative B-3 is identified as the preferred alternative for the Site. It offers substantially greater protectiveness and long-term effectiveness than Alternatives B-1 and B-2, while avoiding the elevated short-term risks, logistical challenges, and high costs associated with Alternative B-4. Alternative B-3 achieves the Site RAOs upon construction completion by eliminating direct exposure pathways and controlling contaminant migration, uses established technologies suitable for the Site conditions, and is anticipated to be acceptable to the community and resource agencies.

8 References

Applied Intellect. 2026. Potentially Responsible Party Search Report Unknown Mine at the end of Bard Creek Road. January 2026.

Bureau of Land Management. 2017. Screening Assessment Approaches for Metals in Soil at BLM HazMat/AML Sites. September 2017.

EPA (Environmental Protection Agency),

1991 Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30. April 22, 1991.

1993 Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA. August 1993.

2005a OSWER Directive 9285.7-62, Ecological Soil Screening Levels for Arsenic Interim Final, March 2005

2005b OSWER Directive 9285.7-70, Ecological Soil Screening Levels for Lead Interim Final, March 2005

2022 Pre-CERCLA Screening Checklist/Decision Document. June 29, 2022.

2025 Superfund: Institutional Controls. November 21, 2025

ERO Resources Corporation, 2026. Cultural Resources Survey Bard Creek Abandoned Mine Hazard Treatment Project Clear Creek County, Colorado. January 16, 2026.

USDA (U.S. Department of Agriculture). 2021. Natural Resources Conservation Service Conservation. Practice Standard: Land Reclamation, Abandoned Mined Land. Code 543 (ac). July 2021.

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Appendix A. PCS Report

Bard Creek Mine
Clear Creek County, Colorado

Attachment A:

Pre-CERCLA Screening Checklist Decision Form

Pre-CERCLA Screening

Checklist/Decision Form

This form is used in conjunction with a site map and any additional information required by the EPA Region to document completion of a Pre-CERCLA Screening (PCS). The form includes a decision on whether a site should be added to the Superfund program's active site inventory for further investigation.

EPA Region: 8 **State:** Colorado

EPA ID No. (If Available): Not Applicable

Site Category: Tronox Mines	**Select a Site Name (Primary):** Bard Creek Mine - Reliance Mine
Site Number: Not Applicable	
Date of Site Visit: June 29, 2022	**Time of Site Visit:** 11:27

Checklist Preparer

Title: USFWS Liaison to EPA

Name: Robyn Blackburn

Organization: USFWS

Street Address: 1595 Wynkoop St

City: Denver

State: Colorado **Zip Code:** 80202

Phone: (303) 312-6666

Email: Blackburn.Robyn@epa.gov

Site Contact

Title: N/A

Name: N/A

Organization: N/A

Street Address: N/A

City: N/A

State: N/A **Zip Code:** N/A

Phone: N/A

Email: N/A

Site Information - Preliminary

Site Name (Alternate 1): N/A

Site Name (Alternate 2): N/A

Region: 8

State: Colorado **County:** Clear Creek

Congressional District: 2

Township & Range:

Section:

Section (1/4):

Section (1/16):

Spatial Location

Latitude: 39.736244

Longitude: -105.736574

Collection Method: GPS (handheld, Smartphone, other device with < 25m accuracy)

Horizontal Accuracy in Meters: 2.3963015252676363

Site Description (of this Spatial Location):

Approximate Center of Site

Preliminary Assessment - Historical Data

CERCLA 105d Petition for Preliminary Assessment: No

Petition Date: Not Applicable

RCRA Subtitle C Site Status: **Is site in RCRA Info?:** No

RCRAInfo Handler ID #: Not Applicable

Additional RCRAInfo ID #: Not Applicable

State ID: None **Other ID:**

Ownership Type: Mixed Ownership

Site Type: Abandoned Mine Site

Site Sub-Type: Hard Rock Mining

Federal Facility: No

Federal Facility Owner: Not Applicable

Federal Facility Operator: Not Applicable

Formerly Used Defense Site (FUDS): No

Federal Facility Docket: No

Federal Facility Docket Listing Date: Not Applicable

Federal Facility Docket Reporting Mechanism: Not Applicable

Native American Interest: Unknown

Tribe: Not Applicable **Additional Tribe:** Not Applicable

Site Description - Physical Setting

Abandoned Mine Site: Yes

Buildings: Buildings Not Present

Mill or Milling Equipment or Tailing Present: No

Steep Waste Piles: Yes

Safety Hazards Present: Yes

Safety Hazards Dangerous slide potential or steep vertical face/wall/cliff (caused by mining operations), Steep Vertical Inclines

Accessibility (provide details with regard to ability to access the site) Remote - NonDangerous/NonDifficult Access

Time it takes to reach this site (Hours: Minutes): 30:00

Detailed description of how the site was accessed: Empire to Bard Creek Road. Use high clearance 4-wheel drive on rough 2-track for approximately 3 miles.

Adjacent to Resident(s): No

Adjacent Residential Features: Not Applicable

Mountainous Steep Terrain: Yes

Vegetation Present: Yes

Vegetation Density: Heavy

Surface Water Body on or Adjacent to the Site: Yes

Open Fields: No

Waste Pile Erosion Observed: Yes

Describe Waste Pile Run Off: Waste observed in forested upland

Tailings Erosion Observed: No

Describe Tailings Run Off: Not Applicable

Draining Adits or Seeps Discharge from the Site: Yes

Adits Flow Rate from Site: Minor

Describe Adit Flow from Site: Very small puddle at base of collapsed adit

Draining Adits or Seeps Discharge Across Waste Piles: No evidence of discharge across pile

Draining Adits or Seeps Discharge to Adjacent Habitat: Upland forested area

Adit Flows into what habitat: No Applicable

Habitat Name: Arapaho National Forest

Physical Setting and Access Features: Accessible and unique recreational area (e.g., tourist/natural attractions, hiking/biking trails, etc.)

Physical Setting (Field Notes - provide a brief summary of physical setting including notable safety concerns, waste types, human uses/exposures to wastes, runoff/drainage, and notable habitat/ecological use): Trail to Pile and surrounded by forest with Evidence of camping and recreational use. Camp fires, broken glass, ATV tracks. Waste appears to be ore/rock from fine to cobble. Highly variable lead concentration. Bard creek downgradient likely fishing.

Site Description - Land Use

Roads/Trails: Yes

Road/Trail Type: 4-Wheel Track/Trail

Human Activity: Yes

Human Activity Type: Moderate

Residential: No

Residential Density: Not Applicable

Recreational Use: Yes

Recreational Density: Moderate

Camping: Yes

Camping Frequency: Moderate

Fishing: Yes

Fishing Frequency: Minimal

Hiking: Yes

Hiking Frequency: Moderate

Biking: Yes

Biking Frequency: Moderate

Picnicking: Yes

Picnicking Frequency: Minimal

Ecological Activity: Yes

Ecological Activity: Heavy

Observed/likely fishing/consumption of fish/aquatic organisms at the mine site or within ¼ miles downstream: Yes

Are there other observed sensitive environments on-site or downstream of the waste area(s) within ¼ mile? Yes

Sensitive Environment (wetland, stream, creek, river, known to be in the vicinity of a National Park, designated federal/state wildlife or scenic area, fish hatchery/spawning area, designated for wildlife or game management, known to be used by or designated critical habitat for Threatened or Endangered Species, or any other sensitive environment critical to supporting wildlife): Other

Other Sensitive Environments: Riparian area with possible wetlands and fish populations downstream

Land Use (Field Notes – provide a brief summary of human/ecological type of use and use level (e.g., heavily used for biking and camping; observed camp fire rings and picnic tables at the site immediately adjacent to the waste runoff; narrow foot trail with difficult steep access to the waste areas and minimal use of the area, etc.): Trails, steep denuded pile used for ATV and camping and partying. People be having some fun on this pile.

Site Surface Description

Draining Adit: Yes

Draining Adit Type: Collapsed portal/small pool

Waste Piles: Yes

Number of Waste Piles: 1

Airborne Release of Fine Material/Dust: Yes

Surface Water on or Immediately Adjacent: Yes

Water Body Name: Bard Creek

Wetlands on or Adjacent to Site: Yes

Riparian on or Adjacent to the Site: Yes

Forested on or Adjacent to the Site: Yes

Site Surface (Field Notes): Steep waste pile, no vegetation on pile, with active use by recreational use. Waste area was dry with a small seep near a collapsed adit. The waste pile area is surrounded by a dense forested area. No evidence of run off from the portal onto the waste pile. Bard Creek is across the adjacent to the US Forest Service road and there is no evidence that any surface run off makes it to the creek.

Site Description - Other

Groundwater Seeps Observed: Maybe, small, clear seep found at collapsed portal

Primary Drainage Name: Bard Creek/West Fork Clear Creek

Groundwater Seeps (Field Notes): See above

Previous Investigations: Unknown

Investigation Type: Unknown

Who Completed Investigations at this Site: Not Applicable

Cleanup Activities: Not Applicable **Cleanup Type**: Not Applicable

Site Description Cleanup Field Notes: Not Applicable

Who Completed Cleanup Activities at this Site: Not Applicable

Previous Regulatory Actions (Permitting and Enforcement): Unknown

Previous Regulatory Type: Unknown

Site Feature Name(s): Not Applicable

Field Note(s): Not Applicable

Who Completed Regulatory Actions at this Site: Not Applicable

Institutional Controls: None observed **Institutional Control Type**: Not Applicable

Institutional Controls (indicate name/entity on signs/controls): Not Applicable

Community Interest: Unknown **Community Interest Type**: Unknown

Community Interest (Indicate watershed group or other interest group): Unknown

Survey Form

1. An initial search for the site in EPA's Superfund active, archive and non-site inventories should be performed prior to starting a PCS. Is this a new site that does not already exist in these site inventories?	Yes
2. Is there evidence of an actual release or a potential to release? **Evidence of Potential Release** Waste pile material observed in water body or other surrounding environment	Yes
3. Are there possible targets that could be impacted by a release of contamination at the site?	Yes
4. Is there documentation indicating that a target has been exposed to a hazardous substance released from the site?	No
5. Is the release of a naturally occurring substance in its unaltered form, or is it altered solely through naturally occurring processes or phenomena, from a location where it is naturally found?	No
6. Is the release from products which are part of the structure of, and result in exposure within, residential buildings or business or community structures?	No
7. If there has been a release into a public or private drinking water supply, is it due to deterioration of the system through ordinary use?	No
8. Are the hazardous substances possibly released at the site, or is the release itself, excluded from being addressed under CERCLA?	No
9. Is the site being addressed under RCRA corrective action or by the Nuclear Regulatory Commission?	No
10. Is another federal, state, tribe or local government environmental cleanup program other than site assessment actively involved with the site (e.g., state voluntary cleanup program)?	No
11. Is there sufficient documentation or evidence that demonstrates there is no likelihood of a significant release that could cause adverse environmental or human health impacts?	No
12. Are there OTHER site-specific situations or factors that warrant further CERCLA remedial/integrated assessment or response?	No

US EPA Pre-CERCLA Checklist/Decision Form OLEM 9355.1-119, February 2018.

Current version of the PCS checklist and additional information is available at: https://www.epa.gov/superfund/pre-cercla-screening.

Preparer's Recommendation

Preparer's Recommendation: Do not add site to the Superfund active site inventory

Please explain recommendation below: The mine/waste pile area is remotely located approximately 3 miles from Empire via USFS Road 778, which is a relatively rough 4-wheel/high clearance 2-track dirt road. The steep mine pile has evidence of regular use by recreational ATVs with incised tracks on the steep waste pile, and hiking/biking trails are directly on and adjacent to the mine waste area. The waste area is unfenced and accessible, obvious signs of recent use including a fire camp ring, camping/picnicking recreational trash were present on the top of the pile.

Laboratory results for a waste/soil grab sample from the pile was significantly elevated indicating arsenic at 703 mg/kg and lead at 26,800 mg/kg. A composite sample from the pile was also elevated indicating arsenic at 78.2 mg/kg and lead at 2,660 mg/kg. Both the grab and composite sample results for arsenic in soil are greater than the corresponding EPA Regional Soil Level (RSL) for both residential (0.68 mg/kg) and industrial (3.0 mg/kg). Lead concentrations in both samples are also above both residential (400 mg/kg) and industrial (800 mg/kg). Arsenic and lead are detected at over 3 times their corresponding background concentrations measured from an unimpacted natural area near the site.

A surface water sample from an adit/spring seepage pooled area near the collapsed portal indicates relatively low detections of dissolved arsenic, cadmium, and lead, strontium, uranium, and zinc with a pH of 6.7. All levels are below the Colorado Water Quality Standards for aquatic life. All surface water samples from Bard Creek in upstream and three downstream locations were all reported with near neutral pH and all non-detect to the mouth with the West Fork of Clear Creek (in Empire). West Fork Clear Creek was sampled above and below the mouth of Bard Creek and only copper was detected in West Fork Clear Creek in both the upstream (3.4 ug/L) and downstream (1.6 ug/L) of the confluence with Bard Creek. The upstream concentration of copper was approximately double the concentration reported for downstream of confluence of Bard Creek suggestion the source of copper is in West Fork Clear Creek upstream and not related to contributions from Bard Creek. Copper concentrations in West Fork Clear Creek are below Colorado Water Quality Standards for aquatic life.

No further action by EPA is recommended at this time due to the remote location, relatively limited area of contamination, no residential properties, and no impacts to surface water.

Site Assessor's Name: Jean Wyatt

Site Assessor's Signature:

Jean Wyatt

Date: June 29, 2022

EPA Regional Review and Pre-CERCLA Screening Decision

EPAs Recommendation:

Add site to the Superfund active site inventory for completion of a:

☐ Standard/full preliminary assessment (PA)

☐ Abbreviated preliminary assessment (APA)

☐ Combined Preliminary Assessment/Site Inspection (PA/SI)

☐ Integrated Removal Assessment and Preliminary Assessment

☐ Integrated Removal Assessment and Combined PA/SI

☐ Other Description

Do not add site to the Superfund active site inventory. Site is:

☐ Not a valid site or incident

☐ Refer to/being addressed by EPA's Removal Program

☐ Refer to/being addressed by a State cleanup program

☐ Refer to/being addressed by Tribal cleanup program

☐ Refer to/being addressed under Resource Conservation and Recovery Act (RCRA)

☐ Refer to/being addressed by the Nuclear Regulatory Commission (NRC)

☑ Other Description – Not high enough priority for further consideration at this time. However, due to elevated arsenic and lead concentrations in soil/waste and the observed recreational use, the site is referred to the US Forest Service for additional consideration.

EPA Region 8 Reviewer's Name: Jean Wyatt

EPA Region 8 Reviewer's Signature: Jean Wyatt

Site Location

Photographs

Bard Creek Mine - Reliance Mine: Top of pile from trail entrance

Bard Creek Mine (6/29/2022)

2022 Pre-CERCLA Screening Tronox Mines

USFS-TRNX-BCM-SO-Comp-01
Mine Waste Composite Location

Bard Creek Mine (6/29/2022)

2022 Pre-CERCLA Screening Tronox Mines


USFS-TRNX-BCM-SO-Grb-02
Mine Waste Grab Location

Bard Creek Mine - Reliance Mine: Camp fire ring on top of pile /ATV Tracks on top of pile

Bard Creek Mine - Reliance Mine: Collapsed adit next to pile

Small pool at base of collapsed adit

Bard Creek Mine

Clear Creek County, Colorado

Attachment B:

Pre-CERCLA Sampling and Analysis Summary

Table A.2. 2022 Pre-CERCLA Screening Tronox Mines, Bard Creek Mine Sampling Analytical and Field Data Results

Surface Water Total Recoverable Metals Analytical Chemistry Results

Location ID	Analysis	Matrix	Sample Date	Sample Time	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silica	Silver	Sodium	Strontium	Thallium	Uranium	Vanadium	Zinc
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
USFS-TRNX-BCM-SW-A01-01	Total Recoverable Metals	Surface Water	6/29/2022	12:58	<50.0	<2.50	6.40 J	<25.0	<2.00	<0.500	56800	<5.00	<0.500	<2.50	<100	0.651 JD	12200	<7.50	<0.0380	<5.00	5.29	1910	<7.50	13100	<2.50	5840	6300	<5.00	12.6	<10.0	174
USFS-TRNX-BCM-SW-BC-UPS-01	Total Recoverable Metals	Surface Water	6/29/2022	12:28	<50.0	<2.50	3.60 J	<25.0	<2.00	<0.500	3190	<5.00	<0.500	<2.50	<100	<0.500	1190	<7.50	<0.0380	<5.00	<2.50	391 J	<7.50	6650	<2.50	1340	18.0	<5.00	1.03	<10.0	<15.0
USFS-TRNX-BCM-SW-BC-DNS-01	Total Recoverable Metals	Surface Water	6/29/2022	11:39	<50.0	<2.50	4.13 J	<25.0	<2.00	<0.500	3250	<5.00	<0.500	<2.50	<100	<0.500	1230	<7.50	<0.0380	<5.00	<2.50	398 J	<7.50	6790	<2.50	1380	18.6	<5.00	0.912 J	<10.0	<15.0
USFS-TRNX-BCM-SW-DNS-02	Total Recoverable Metals	Surface Water	6/29/2022	10:45	<50.0	<2.50	6.00 J	<25.0	<2.00	<0.500	3480	<5.00	<0.500	<2.50	<100	<0.500	1290	<7.50	<0.0380	<5.00	<2.50	401 J	<7.50	7610	<2.50	1440	22.8	<5.00	0.724 J	<10.0	<15.0
USFS-TRNX-BCM-SW-MTH-01	Total Recoverable Metals	Surface Water	6/29/2022	11:25	<50.0	<2.50	6.51 J	<25.0	<2.00	<0.500	4070	<5.00	<0.500	<2.50	157 J	<0.500	1500	23.8	<0.0380	<5.00	<2.50	429 J	<7.50	7970	<2.50	1630	28.0	<5.00	0.559 J	<10.0	15.6 J
USFS-TRNX-BCM-SW-WFCC-UPS-01	Total Recoverable Metals	Surface Water	6/29/2022	10:45	147	<2.50	4.28 J	<25.0	<2.00	<0.500	18500	<5.00	0.860 J	5.43	109 J	<0.500	2010	144	<0.0380	5.25	<2.50	1650	<7.50	5960	<2.50	9560	90.8	<5.00	0.862 J	<10.0	22.4 J
USFS-TRNX-BCM-SW-WFCC-DNS-01	Total Recoverable Metals	Surface Water	6/29/2022	10:15	90.4 J	<2.50	4.52 J	<25.0	<2.00	<0.500	16000	<5.00	<0.500	<2.50	<100	<0.500	1850	75.1	<0.0380	<5.00	<2.50	1430	<7.50	6180	<2.50	8270	80.7	<5.00	0.741 J	<10.0	19.6 J

J = Laboratory quality control review indicates that this result is considered estimated

Surface Water Dissolved Metals Analytical Chemistry Results

Location ID	Analysis	Matrix	Sample Date	Sample Time	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silica	Silver	Sodium	Strontium	Thallium	Uranium	Vanadium	Zinc	Hardness[1]
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
USFS-TRNX-BCM-SW-A01-01	Dissolved Metals	Surface Water	6/29/2022	12:58	<50.0	<0.500	1.05 J	20.6	<2.00	0.250	57000	<1.00	0.166 J	1.26	<100	0.123 J	12300	<7.50	N/A	1.06	4.93	1980	<1.50	12500	<0.500	5890	6330	<1.00	12.7	<2.00	171	193
USFS-TRNX-BCM-SW-BC-UPS-01	Dissolved Metals	Surface Water	6/29/2022	12:28	<50.0	<0.500	<0.600	14.7	<2.00	<0.100	3110	<1.00	<0.100	<0.500	<100	<0.100	1150	<7.50	N/A	<1.00	<0.500	333 J	<1.50	6680	<0.500	1280	16.8	<1.00	0.780	<2.00	<15.0	13
USFS-TRNX-BCM-SW-BC-DNS-01	Dissolved Metals	Surface Water	6/29/2022	11:39	<50.0	<0.500	<0.600	14.9	<2.00	<0.100	3140	<1.00	<0.100	<0.500	<100	<0.100	1160	<7.50	N/A	<1.00	0.642 J	372 J	<1.50	6850	<0.500	1330	17.5	<1.00	0.793	<2.00	<15.0	13
USFS-TRNX-BCM-SW-DNS-02	Dissolved Metals	Surface Water	6/29/2022	10:45	<50.0	<0.500	<0.600	16.0	<2.00	<0.100	3320	<1.00	<0.100	<0.500	<100	<0.100	1210	<7.50	N/A	<1.00	<0.500	360 J	<1.50	6940	<0.500	1340	20.9	<1.00	0.672	<2.00	<15.0	13
USFS-TRNX-BCM-SW-MTH-01	Dissolved Metals	Surface Water	6/29/2022	11:25	<50.0	<0.500	<0.600	17.2	<2.00	<0.100	3790	<1.00	<0.100	<0.500	<100	<0.100	1380	16.8	N/A	<1.00	<0.500	394 J	<1.50	7160	<0.500	1480	24.8	<1.00	0.513	<2.00	<15.0	15
USFS-TRNX-BCM-SW-WFCC-UPS-01	Dissolved Metals	Surface Water	6/29/2022	10:45	76.6 J	<0.500	<0.600	16.0	<2.00	<0.100	16800	<1.00	0.566	3.42	<100	<0.100	1780	86.6	N/A	5.49	1.78	1500	<1.50	4980	<0.500	8760	80.9	<1.00	0.852	<2.00	<15.0	49
USFS-TRNX-BCM-SW-WFCC-DNS-01	Dissolved Metals	Surface Water	6/29/2022	10:15	<50.0	<0.500	<0.600	16.0	<2.00	<0.100	15100	<1.00	0.220	1.63	<100	<0.100	1760	50.9	N/A	4.54	1.35	1350	<1.50	5450	<0.500	7900	74.9	<1.00	0.708	<2.00	<15.0	45

[1] Sample-specific hardness calculated using dissolved calcium and magnesium concentrations for use in assessing hardness-based in accordance with Colorado Water Quality Control Commission, Regulation 31 (https://www.colorado.gov/pacific/sites/default/files/31_2018%2801%29.pdf)
N/A = not analyzed
J = Laboratory quality control review indicates that this result is considered estimated

Field-Measured Water Quality Parameters

Location ID	Analysis	Matrix	Sample Date	Sample Time	pH	Temp.	Dissolved Oxygen	Conductivity	Flow	Flow Measurement Equipment
					Stand. Unit	°C	mg/L	µS/cm	cfs	
USFS-TRNX-BCM-SW-A01-01	In Situ Measure	Surface Water	6/29/2022	12:58	6.74	10.1	5.8	434.5	N/C[a]	N/A
USFS-TRNX-BCM-SW-BC-UPS-01	In Situ Measure	Surface Water	6/29/2022	12:28	6.89	6.4	10.06	45.9	N/C[b]	N/A
USFS-TRNX-BCM-SW-BC-DNS-01	In Situ Measure	Surface Water	6/29/2022	11:39	6.99	6	9.78	55.5	15.0083	FlowTracker2
USFS-TRNX-BCM-SW-DNS-02	In Situ Measure	Surface Water	6/29/2022	10:45	6.49	5.6	10.45	50.8	N/C[b]	N/A
USFS-TRNX-BCM-SW-MTH-01	In Situ Measure	Surface Water	6/29/2022	11:25	7.42	8.7	9.67	44.9	20.3505	FlowTracker2
USFS-TRNX-BCM-SW-WFCC-UPS-01	In Situ Measure	Surface Water	6/29/2022	10:45	7.28	10	9.05	188.1	N/C[c]	N/A
USFS-TRNX-BCM-SW-WFCC-DNS-01	In Situ Measure	Surface Water	6/29/2022	10:15	7.53	9.4	9.35	164.7	125	USGS gauge

N/C = not collected; N/A = not applicable; USGS = U.S. Geological Survey
a = Pooled water was not flowing
b = Stream channel too complex to measure flow
c = Stream conditions too dangerous to measure flow

Surface Water Wet Chemistry Analytical Results

Location ID	Analysis	Matrix	Sample Date	Sample Time	Bromide	Chloride	Fluoride	Nitrate/Nitrite as N	Sulfate as SO_4	Total Alkalinity
					mg/L	mg/L	mg/L	mg/L	mg/L	mg($CaCO_3$)/L
USFS-TRNX-BCM-SW-A01-01	Wet Chemistry	Surface Water	6/29/2022	12:58	<0.2	<1.0	0.4	<0.5	113	107
USFS-TRNX-BCM-SW-BC-UPS-01	Wet Chemistry	Surface Water	6/29/2022	12:28	<0.2	<1.0	<0.1	<0.5	<2.5	15.6
USFS-TRNX-BCM-SW-BC-DNS-01	Wet Chemistry	Surface Water	6/29/2022	11:39	<0.2	<1.0	<0.1	<0.5	<2.5	19.3
USFS-TRNX-BCM-SW-DNS-02	Wet Chemistry	Surface Water	6/29/2022	10:45	<0.2	<1.0	<0.1	<0.5	<2.5	16.5
USFS-TRNX-BCM-SW-MTH-01	Wet Chemistry	Surface Water	6/29/2022	11:25	<0.2	1.0 J	<0.1	<0.5	2.9 J	19.4
USFS-TRNX-BCM-SW-WFCC-UPS-01	Wet Chemistry	Surface Water	6/29/2022	10:45	<0.2	8.6	0.6	<0.5	46.9	16.9
USFS-TRNX-BCM-SW-WFCC-DNS-01	Wet Chemistry	Surface Water	6/29/2022	10:15	<0.2	7.5	0.6	<0.5	39	17.7

J = Laboratory quality control review indicates that this result is considered estimated

Table A.2. 2022 Pre-CERCLA Screening Tronox Mines, Bard Creek Mine Sampling Analytical and Field Data Results (continued)

Mine Waste and Surface Soil

Location ID	Analysis	Matrix	Sample Date	Sample Time	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silica (SiO2)	Silver	Sodium	Strontium	Thallium	Uranium	Vanadium	Zinc
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
USFS-TRNX-BCM-SO-Comp-01	Total Recoverable Metals	Mine waste	6/29/2022	12:40	1150	0.699 J	78.2	39.1	<0.993	0.884	375 J	4.24	1.52	58.5	22900 J	2660	423	346 J	1.084	2.11	3.34	1780	<1.49	1910	24.7	<124	46.8	<0.993	0.796	5.42	168
USFS-TRNX-BCM-SO-Grb-01	Total Recoverable Metals	Mine waste	6/29/2022	12:45	530	6.43	703	40.9 J	<1.01	3.76	<88.2	<5.04	<0.504	218	33100 J	26800	159 J	13	0.548	8.98	<2.52	2790	<7.56	1380	50.7	<126	63.6	<5.04	<0.504	<10.1	745
USFS-TRNX-BCM-SO-Grb-02	Total Recoverable Metals	Mine waste	6/29/2022	12:55	352	<0.946	101	24.6	<0.946	0.941	<82.8	<1.89	0.272 J	59	20000 J	4990	<118	21.9	0.297	<1.89	<0.946	2260	<2.84	760	55.1	<118	53.5	<1.89	<0.189	<3.78	127
USFS-TRNX-BCM-SO-BKG-01	Total Recoverable Metals	Soil	6/29/2022	13:06	6500	<0.507	3.35	166	<1.01	0.897	2320 J	11.1	4.22	5.74	11600 J	32.5	2220	783	0.056	<1.01	8.16	2090	<1.52	6500	<0.507	<127	20	<1.01	1.34	12.7	120

J = Laboratory quality control review indicates that this result is considered estimated

Soil Synthetic Precipitation Leaching Procedure (SPLP) Leachate

Location ID	Analysis	Matrix	Sample Date	Sample Time	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
USFS-TRNX-BCM-SO-Comp-01	SPLP	Leachate	6/29/2022	12:40	73 J	<6.8	<4.2	79 J	0.34 J	4.2 J	3600 J	<0.81	<11	16 J	<31 J	5200	700 J	800	0.85	<7.6	3800 J	<15	<1.5	<520	<7.0	<3.2	410

J = Laboratory quality control review indicates that this result is considered estimated

Soil Toxicity Characteristic Leaching Procedure (TCLP) Leachate

Location ID	Analysis	Matrix	Sample Date	Sample Time	Arsenic	Barium	Cadmium	Chromium	Lead	Manganese	Selenium	Silver
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
USFS-TRNX-BCM-SO-Comp-01	TCLP	Leachate	6/29/2022	12:40	<4.2	170 J	7.7	<0.81	20000	<0.097	<15	<1.5

X-Ray Fluorescence (XRF) Spectrometry Soil Survey Results

Mine Name	XRF Sample ID	Latitude	Longitude	Date	Time	Units	Ti	Ti +/-	Cr	Cr +/-	Mn	Mn +/-	Fe	Fe +/-	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Se	Se +/-	Rb	Rb +/-
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X001	39.736262	-105.736531	6/29/2022	11:40	PPM	2478	375	<LOD	120	169	50	22188	281	<LOD	163	<LOD	47	<LOD	25	83	7	<LOD	28	<LOD	4	131	3
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X002	39.736310	-105.736496	6/29/2022	11:47	PPM	2760	434	<LOD	131	<LOD	158	24651	326	<LOD	182	<LOD	51	58	11	44	6	212	23	<LOD	8	186	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X003	39.704312	-105.703533	6/29/2022	11:50	PPM	2764	548	<LOD	190	<LOD	233	43017	606	<LOD	279	<LOD	75	265	19	863	25	905	56	<LOD	17	173	5
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X004	39.736318	-105.736596	6/29/2022	11:53	PPM	3354	405	<LOD	131	706	66	24681	315	<LOD	175	<LOD	48	<LOD	27	197	10	28	6	<LOD	4	146	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X005	39.736231	-105.736481	6/29/2022	11:56	PPM	3458	382	<LOD	109	<LOD	130	15740	208	<LOD	132	<LOD	43	27	9	56	6	103	13	<LOD	5	124	3
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X006	39.736178	-105.736478	6/29/2022	11:59	PPM	2693	370	<LOD	115	<LOD	130	21639	273	<LOD	156	<LOD	45	<LOD	24	30	5	32	8	<LOD	4	153	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X007	39.736124	-105.736499	6/29/2022	12:01	PPM	4174	430	<LOD	131	1882	90	33328	399	<LOD	197	55	18	37	10	628	17	61	8	<LOD	4	158	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X008	39.736127	-105.736536	6/29/2022	12:04	PPM	1522	324	<LOD	110	<LOD	113	11666	168	<LOD	116	<LOD	40	<LOD	26	15	4	<LOD	17	5	1	113	3
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X009	39.736146	-105.736581	6/29/2022	12:07	PPM	4731	491	<LOD	166	<LOD	209	58185	685	<LOD	275	<LOD	62	73	11	85	7	<LOD	42	<LOD	6	179	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X010	39.736204	-105.736553	6/29/2022	12:10	PPM	3868	405	<LOD	116	288	52	20843	268	<LOD	157	<LOD	47	<LOD	27	54	6	<LOD	33	<LOD	5	157	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X011	39.736076	-105.736588	6/29/2022	12:16	PPM	2273	356	144	42	<LOD	142	22117	275	<LOD	159	<LOD	47	60	10	29	5	46	7	<LOD	4	130	3
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X012	39.736028	-105.736555	6/29/2022	12:19	PPM	2699	380	<LOD	126	161	52	26663	323	<LOD	175	<LOD	50	63	10	54	6	31	8	<LOD	5	149	4
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X013	39.736023	-105.736504	6/29/2022	12:22	PPM	2035	394	<LOD	128	265	57	28849	355	<LOD	186	<LOD	48	67	10	85	7	54	8	<LOD	4	125	3
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X014	39.736120	-105.736422	6/29/2022	12:26	PPM	4530	864	<LOD	245	<LOD	305	23859	597	<LOD	327	<LOD	97	<LOD	57	<LOD	29	75	19	<LOD	10	150	7
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X015	39.736187	-105.736392	6/29/2022	12:30	PPM	2932	372	<LOD	125	5486	139	20670	265	<LOD	152	<LOD	46	<LOD	26	206	9	49	7	<LOD	4	149	4

X-Ray Fluorescence (XRF) Spectrometry Soil Survey Results Continued

Mine Name	XRF Sample ID	Latitude	Longitude	Date	Time	Units	Sr	Sr +/-	Zr	Zr +/-	Mo	Mo +/-	Ag	Ag +/-	Cd	Cd +/-	Sn	Sn +/-	Sb	Sb +/-	Ba	Ba +/-	Hg	Hg +/-	Pb	Pb +/-
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X001	39.736262	-105.736531	6/29/2022	11:40	PPM	77	3	253	5	11	3	<LOD	36	<LOD	42	<LOD	68	<LOD	74	<LOD	508	<LOD	12	583	13
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X002	39.736310	-105.736496	6/29/2022	11:47	PPM	79	3	220	5	<LOD	9	120	13	<LOD	45	<LOD	73	<LOD	80	678	198	<LOD	19	3074	43
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X003	39.704312	-105.703533	6/29/2022	11:50	PPM	86	4	244	6	17	4	56	15	<LOD	51	<LOD	83	<LOD	90	<LOD	743	<LOD	39	13705	183
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X004	39.736318	-105.736596	6/29/2022	11:53	PPM	138	4	236	5	<LOD	9	<LOD	37	<LOD	43	<LOD	70	<LOD	76	<LOD	530	<LOD	13	168	7
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X005	39.736231	-105.736481	6/29/2022	11:56	PPM	109	3	190	4	17	3	56	12	<LOD	41	<LOD	67	<LOD	73	<LOD	499	<LOD	13	1090	19
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X006	39.736178	-105.736478	6/29/2022	11:59	PPM	189	4	181	4	<LOD	9	<LOD	35	<LOD	42	<LOD	67	<LOD	73	<LOD	492	<LOD	13	451	11
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X007	39.736124	-105.736499	6/29/2022	12:01	PPM	55	2	178	4	<LOD	9	<LOD	36	<LOD	43	<LOD	69	<LOD	75	<LOD	553	<LOD	12	415	11
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X008	39.736127	-105.736536	6/29/2022	12:04	PPM	106	3	109	3	<LOD	8	249	13	<LOD	41	91	23	<LOD	74	<LOD	452	<LOD	12	206	8
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X009	39.736146	-105.736581	6/29/2022	12:07	PPM	79	3	169	4	<LOD	9	<LOD	38	<LOD	45	<LOD	72	<LOD	80	<LOD	627	19	6	1216	22
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X010	39.736204	-105.736553	6/29/2022	12:10	PPM	68	3	198	4	11	3	<LOD	36	<LOD	42	<LOD	69	<LOD	75	<LOD	520	<LOD	14	856	17
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X011	39.736076	-105.736588	6/29/2022	12:16	PPM	80	3	176	4	<LOD	9	<LOD	35	<LOD	42	<LOD	67	<LOD	73	<LOD	483	<LOD	12	331	10
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X012	39.736028	-105.736555	6/29/2022	12:19	PPM	126	3	208	4	<LOD	9	<LOD	35	<LOD	42	<LOD	68	<LOD	75	<LOD	509	<LOD	12	402	11
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X013	39.736023	-105.736504	6/29/2022	12:22	PPM	63	2	166	4	<LOD	9	<LOD	36	<LOD	43	<LOD	69	<LOD	74	709	185	<LOD	12	315	10
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X014	39.736120	-105.736422	6/29/2022	12:26	PPM	76	5	193	8	<LOD	18	<LOD	72	<LOD	85	143	46	<LOD	148	<LOD	1108	<LOD	28	558	26
Bard Creek Mine	USFS-TRNX-BCM-SO-Comp-01-X015	39.736187	-105.736392	6/29/2022	12:30	PPM	47	2	128	3	13	3	<LOD	35	<LOD	42	<LOD	67	<LOD	73	<LOD	488	<LOD	12	300	9

LOD = level of detection

Ti = titanium; Cr = chromium; Mn = manganese; Fe = iron; Co = cobalt; Ni = nickel; Cu = copper; Zn = zinc; As = arsenic; Se = selenium; Rb = rubidium; Sr = strontium; Zr = zirconium; Mo = molybdemum; Ag = silver; Cd = cadmium; Sn = tin; Sb = antimony; Ba = barium; Hg = mercury; Pb = lead

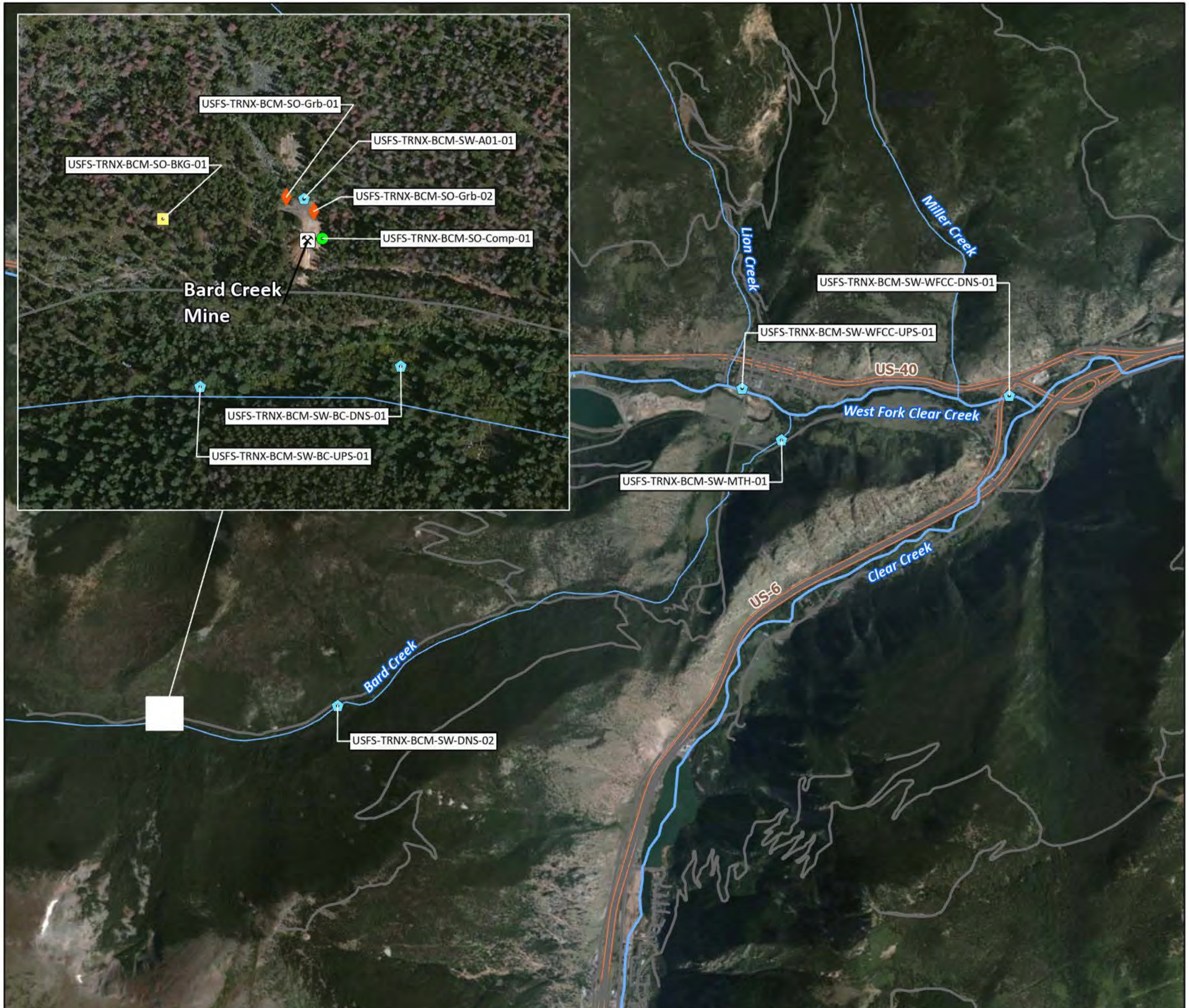

Figure A.3

Bard Creek Mine

Clear Creek Watershed

Clear Creek County, Colorado

2022 Pre-CERCLA Screening

Tronox Mines

Surface Water, Mine Waste, Soil Sample Locations

June 29,2022

- Bard Creek Mine
- Surface Water Grab Sample Location
- Mine Waste Grab Sample Location
- Background Soil Composite Sample Location
- Mine Waste Composite Sample Location
- Stream
- Road
- Highway

Date: September 28, 2022

Map Projection: UTM Zone 13N, WGS84, Meters

Data Sources:

Mine Locations: *U.S. EPA* (2022);

Sample Locations: *U.S. EPA* (2022);

RSL: *https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables;*

Streams: *NDHPlus V2* (2013).

Roads/Highways: *HERE* (2016).

Base Map: *Esri World Imagery (Clarity) Web Service* (2022).

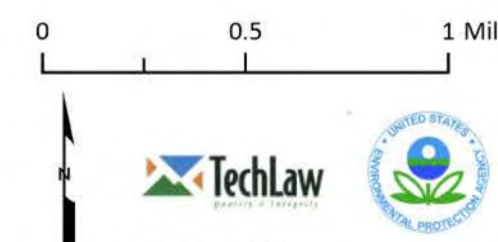

Figure A.4

Bard Creek Mine

Clear Creek Watershed
Clear Creek County, Colorado

2022 Pre-CERCLA Screening
Tronox Mines
XRF Survey - Arsenic Results (mg/kg)
Survey Date: June 29, 2022

- Bard Creek Mine
- < Instrument Level of Detection (LOD)
- > Detected Above Residential and Industrial Regional Screening Level (RSL)*
- > 10x Industrial Regional Screening Level
- > 50x Industrial Regional Screening Level
- > 100x Industrial Regional Screening Level

Arsenic Residential Screening Level = 0.68 mg/kg
Arsenic Industrial Screening Level = 3.00 mg/kg

***Note that the analytical sensitivity of the XRF meter is not fine enough to detect arsenic near the RSLs; consult the total recoverable metals mine waste/soil analytical results in Table 4.4 for more representative arsenic concentrations.**

Date: September 28, 2022
Map Projection: UTM Zone 13N, WGS84, Meters
Data Sources:
Mine Locations: *U.S. EPA* (2022);
Sample Locations: *U.S. EPA* (2022);
RSL: *https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables;*
Base Map: *Esri World Imagery (Clarity) Web Service* (2022).

TechLaw

Figure A.5
Bard Creek Mine
Clear Creek Watershed
Clear Creek County, Colorado

2022 Pre-CERCLA Screening
Tronox Mines
XRF Survey - Lead Results (mg/kg)
Survey Date: June 29, 2022

- Bark Creek Mine
- < Instrument Level of Detection (LOD)
- < Residential Regional Screening Level (RSL)
- > Residential Regional Screening Level
- > Industrial Regional Screening Level
- > 2x Industrial Regional Screening Level
- > 4x Industrial Regional Screening Level

Lead Residential RSL = 400 mg/kg
Lead Industrial RSL = 800 mg/kg

Date: February 16, 2023
Map Projection: UTM Zone 13N, WGS84, Meters
Data Sources:
Mine Locations: *U.S. EPA* (2022);
Sample Locations: *U.S. EPA* (2022);
RSL: *https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables*;
Base Map: *Esri World Imagery (Clarity) Web Service* (2022).

0 75 150 Feet

N

Area Enlarged

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Appendix B. Cost Estimate Worksheets [Redacted]

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Appendix C. Design Toolbox

Natural Resources Conservation Service

Log Erosion Barriers (LEBs)

Denver Federal Center
Building 56, Room 2604
PO Box 25426
Denver, Co 80225-0426

720-544-2810 - office
www.co.nrcs.usda.gov

What are log erosion barriers?

Log Erosion Barriers (LEBs) are logs placed in a shallow trench on the contour to intercept water running down a slope and trap sediment. This treatment may also be known as contour log felling, log terraces or terracettes.

When are log erosion barriers used?

Log erosion barriers are used on moderate or severely burned slopes ranging between 20% to 60%, with erosive soils. LEBs are used where erosion rates have increased significantly because of the fire and there are high values at risk downstream. The site must have enough trees of adequate size to meet treatment objectives (at least 60 trees per acre). Soils can be shallow, but not less than about 8 inches. LEBs increase infiltration, adds roughness, reduce erosion, and help retain small amounts of eroded soil on site. LEBs should be effective for a period of one to two years, providing short term protection on slopes where permanent vegetation will re-establish and provides long term erosion control.

What materials are needed?

- 6-12 inch diameter logs, 10-30 feet long
- An expert sawyer and labor crew with hand tools
- Machines may be used for moving logs or trenching them in on 30% or flatter slopes

How are log erosion barriers installed?

A contour line is marked on the slope to identify the approximate cross slope alignment. Trees along this line are felled on the upstream side of the contour line as much as possible. Stumps are left about 12” high to brace the tree. The logs are cut to a length that permits safe handling and placement for the crew, generally 10 to 30 feet. Tree limbs are removed to the extent necessary for the log to lie flat on the ground. A shallow trench (about 4 to 6 inches deep) is dug along the contour. The log is placed in the trench and seated with tamped backfill such that water flowing down the slope will not run under it. For this practice to be effective, enough trees must be felled along the contour line to create a semi continuous barrier to the movement of water down the slope, as shown in Figure 1 & 2.

How many log erosion barriers are required?

Depending on characteristics of the slope, somewhere between 60 and 152 trees per acre are needed for use of LEBs to be effective. Figure 1 depicts the pattern of LEBs on the slope, and Table 1 shows recommended spacing.

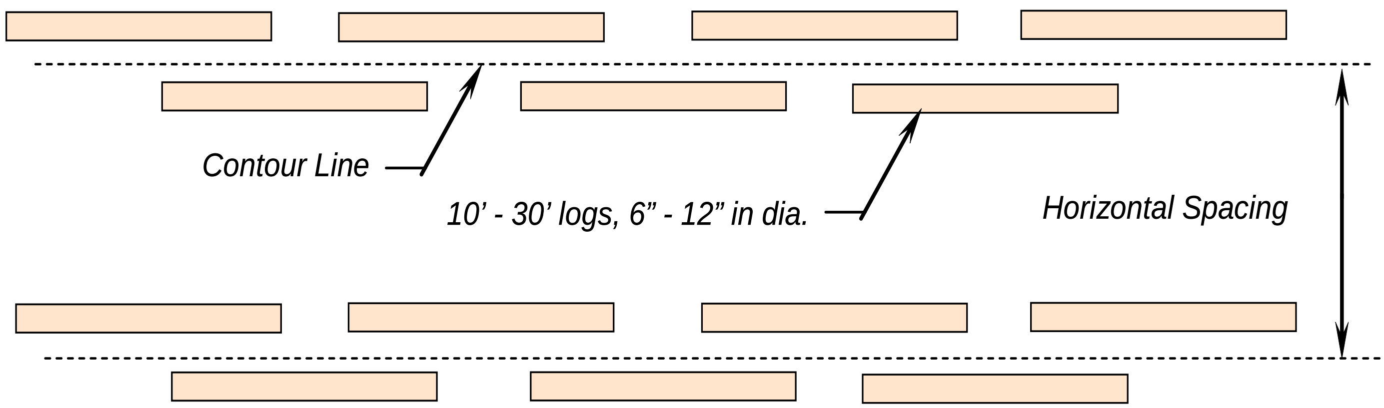


FIGURE 1 - Theoretical log terracing pattern

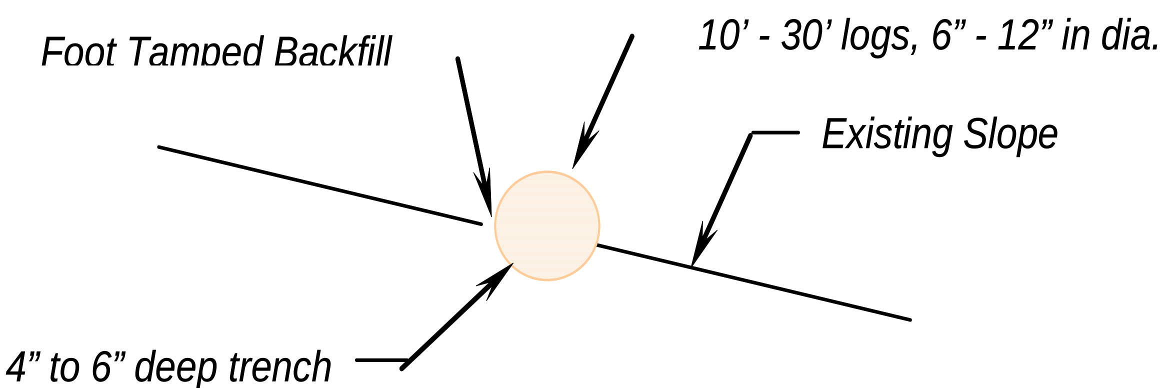


FIGURE 1 - Typical log & bedding detail

Slope steepness (percent)	Burn Intensity	
	Moderate	Severe
	Spacing (feet)	
10 - 20%	60	40
20 - 50 %	30	20
> 50%	15	10

TABLE - Recommended spacing for contour slope treatments

NOTE: After a fire many trees are weakened from burning around the base of the trunk. The trees can fall over or blow down without warning. Shallow rooted trees can also fall. Therefore be extremely alert when around burned trees.

Pre-CERCLA Screening Checklist/Decision Document

Bard Creek Mine

Clear Creek County, Colorado

June 29, 2022

EPA Region 8

Site Assessment Program
1595 Wynkoop Street
Denver, CO 80202

Pre-CERCLA Screening–Bard Creek Mine

Pre-CERCLA[1] Screening (PCS) and sampling was conducted at the Bard Creek Mine on June 29, 2022, by Region 8 Environmental Protection Agency (EPA) Site Assessment Program and other federal and state members of the Colorado Mixed-Ownership Team. Sampling and analysis were completed in accordance with the EPA-approved Sampling and Analysis Plan/Quality Assurance Project Plan: Pre-CERCLA Screening of Tronox Mines on Forest Service-Managed Lands, Sampling and Analysis Plan/Quality Assurance Project Plan, prepared by the US Forest Service, May 2022.

The PCS Checklist/Decision Document, as required by EPA Pre-CERCLA Guidance (Office of Land and Emergency Management (OLEMJ) Directive# 9200.3-107, is included as Attachment A. A sample location figure and summary of soil and water analytical results as reported by the EPA Contract Laboratory is included in Attachment B.

1 Comprehensive Environmental Response, Compensation, and Liability Act

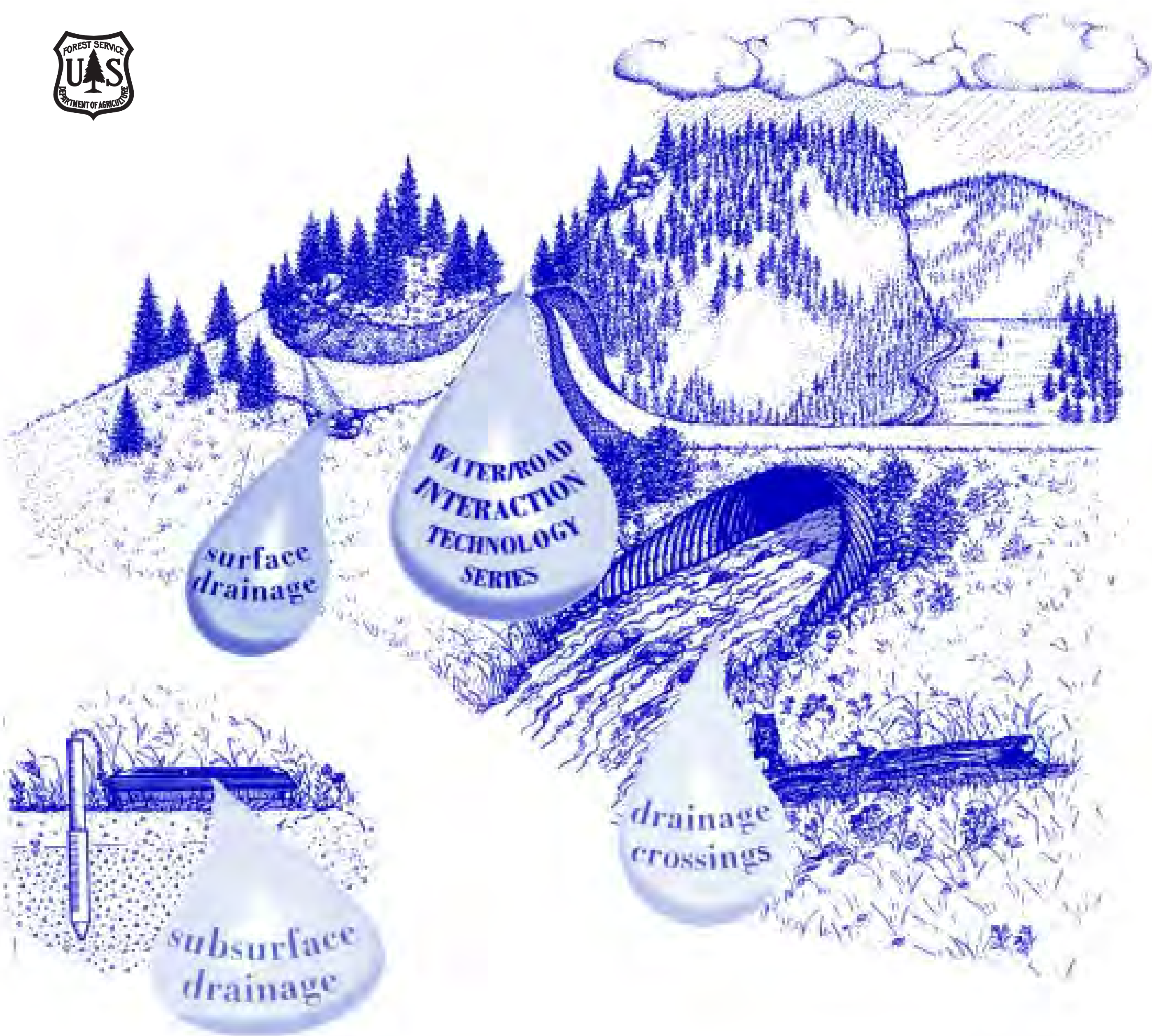
United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

7700—Transportation Systems
2500—Watershed and Air Management
September 1998
9877 1806—SDTDC

Water/Road Interaction: Introduction to Surface Cross Drains



Water/Road Interaction: Introduction to Surface Cross Drains

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September 1998

ABSTRACT

Copstead, Ronald L.; Johansen, David Kim; Moll, Jeffry. 1998. Water/Road Interaction: Introduction to surface cross drains. Report 9877 1806ÑSDTDC. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology and Development Program. 15 p.

A variety of surface cross drains that are used on forest roads are described, including cross‑drain dips, waterbars, and open top culverts. The applicability of different designs is given. Factors to consider when designing surface cross drains for forest roads are discussed, including location, geometry of dips, orientation, and erosion control. Some of the work that has been done to develop guides for cross drain spacing is discussed, and suggestions are made as to how to apply this work.

Keywords: Forest roads, drainage, cross drains, road erosion

ACKNOWLEDGMENTS

Information for and technical review of this manuscript were provided by the Water/Road Interaction core team including Larry Cronenwett, Bill Elliot, Tom Moore, Richard Sowa, Bill Hartsog, and Dave Gibbons. Many of their comments and suggestions have been incorporated into this report.

CONTENTS

INTRODUCTION

One element of the interaction between water and roads in forested areas is concentration and flow of water on native or aggregate surfaced roads. Roads with sustained grades have the potential to concentrate runoff to the point where erosion, sedimentation, and unstable slopes cause large changes in stream habitat quality, stream channel development, surface and groundwater distribution, and consequently plant and animal health, and population composition and distribution. A brief introduction is presented to devices and surface shaping techniques designed to direct runoff to the surrounding area in a way that minimizes effects to the watershed. Existing technology, design criteria, and guides on use for surface cross drainage are also presented.

WHAT ARE SURFACE CROSS DRAINS

Surface cross drains consist of surface shaping and devices designed to capture water that collects on and drains down the road and release it in a manner that minimizes effects to adjacent areas and the watershed. Surface shaping includes broad-based (driveable) dips (Figure 1), waterbars, and rolls in profile (twist of crown or inslope templates to outslope and back again). Devices include open top or slotted culverts (Figure 2)(Kochenderfer 1995), metal waterbars (Figure 3), and rubber water diverters (Figure 4)(Gonzales 1998).

WHEN AND WHERE TO USE

For low-volume roads, surface cross drains provide an economical alternative to using ditches and culverts (Cook and Hewlett 1979). Surface cross drains can be designed into any shape road surface template to divert water collecting on and running down the traveled surface. They may also be used to relieve ditches and the inside edge of insloped roadways without ditches. Ditch dams are used to direct ditch water into the cross drain (Figure 5).

Surface cross drains should be planned as part of an overall drainage strategy that may include ditch relief culverts. Broad-based dips are used primarily for draining the road surface, and are not usually relied on for draining ditches, although this can be done for small-flow quantities. Rolls in profile can often be used on grades too steep for broad-based dips. Waterbars are usually installed as simple erosion-control measures on roads, skid trails, and fire linesÑespecially on roads that have been closed to traffic. Open top culverts provide road surface drainage for traveled way surfaces without requiring large-profile shape changes, and also allow minimal localized grade increases on steeper road sections (Kochenderfer 1995).

One study of the number and type of distresses associated with broad-based dips relative to drainage using inside ditches with culverts for cross drainage concluded by proposing a decision-making guide as to which type of cross drainage to install (Eck and Morgan 1987). The applicability of the proposed guide was limited to the Appalachian region of the United States, but probably could be adapted to other locations.

In areas of cut slope instability, frost heave slough, or erodible ditches, properly located and constructed surface cross drainage can result in less erosion and disturbance to the surrounding watershed than relying completely on insloped roadways with ditches and culverts. In these locations, the surface cross drains can also reduce the need for maintaining the roadway surface accompanied by its associated sediment pulseÐby reducing ponding and erosion caused by concentrated surface flow. In summary, surface cross drains can provide effective cross drainage, while reducing the risk associated with plugged ditch relief culvert inlets, which can divert water over the road in unplanned or undesirable locations.

WHAT TO CONSIDER

Road surfacing material properties, local climate, road grade, road service level (amount and type of traffic) and road service life are the primary factors affecting the applicability and location of surface cross drain types. **Surfacing material characteristics** affect the ability of dips to retain their shape, and the rate of in-filling for any type of cross drain. For example, a rock surfaced road will result in much less sediment than a soil surfaced road. A decomposed, granitic soil surface of poorly graded sand and fine gravel will produce more sediment than a cohesive, silty sand surface. **Climates** with intense rainfall and rain-on-snow events result in higher runoff volumes and thus create the potential for more erosion and sedimentation than do milder climates. If all else is equal, steeper road **grades** exhibit greater surface flows and erosion than milder grades.

Road service level (higher-service-level roads are designed for more traffic and for larger or special purpose vehicles) should be considered when determining surfacing material and dip geometry. High levels of traffic, or heavy vehicles, require dips that are deeper, longer, and surfaced with higher quality materials. For these situations, the design

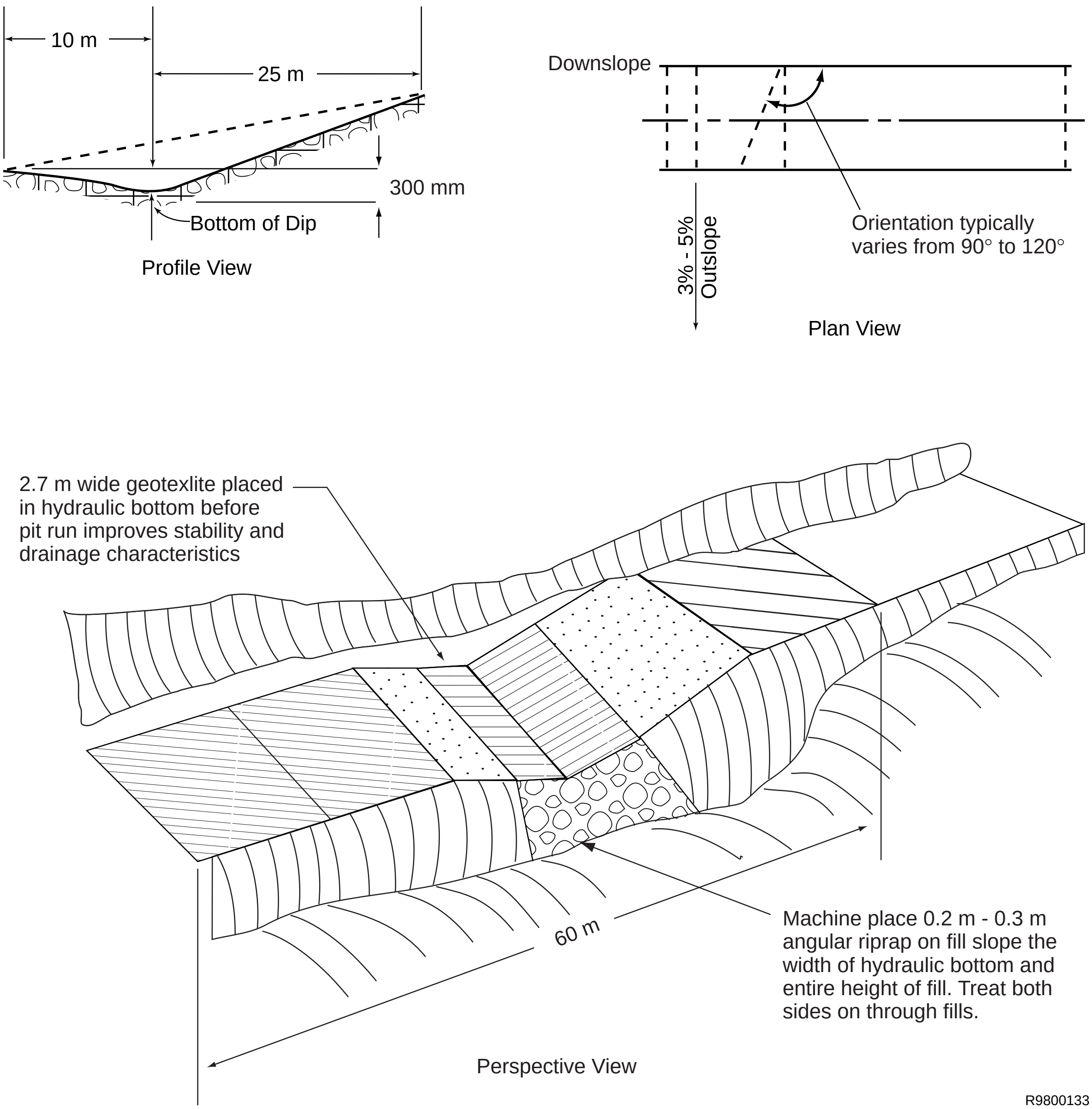

Figure 1ÑBroad based dip typically used on forest roads. Dimensions are shown only for example. Actual designs should be planned after considering local site conditions.

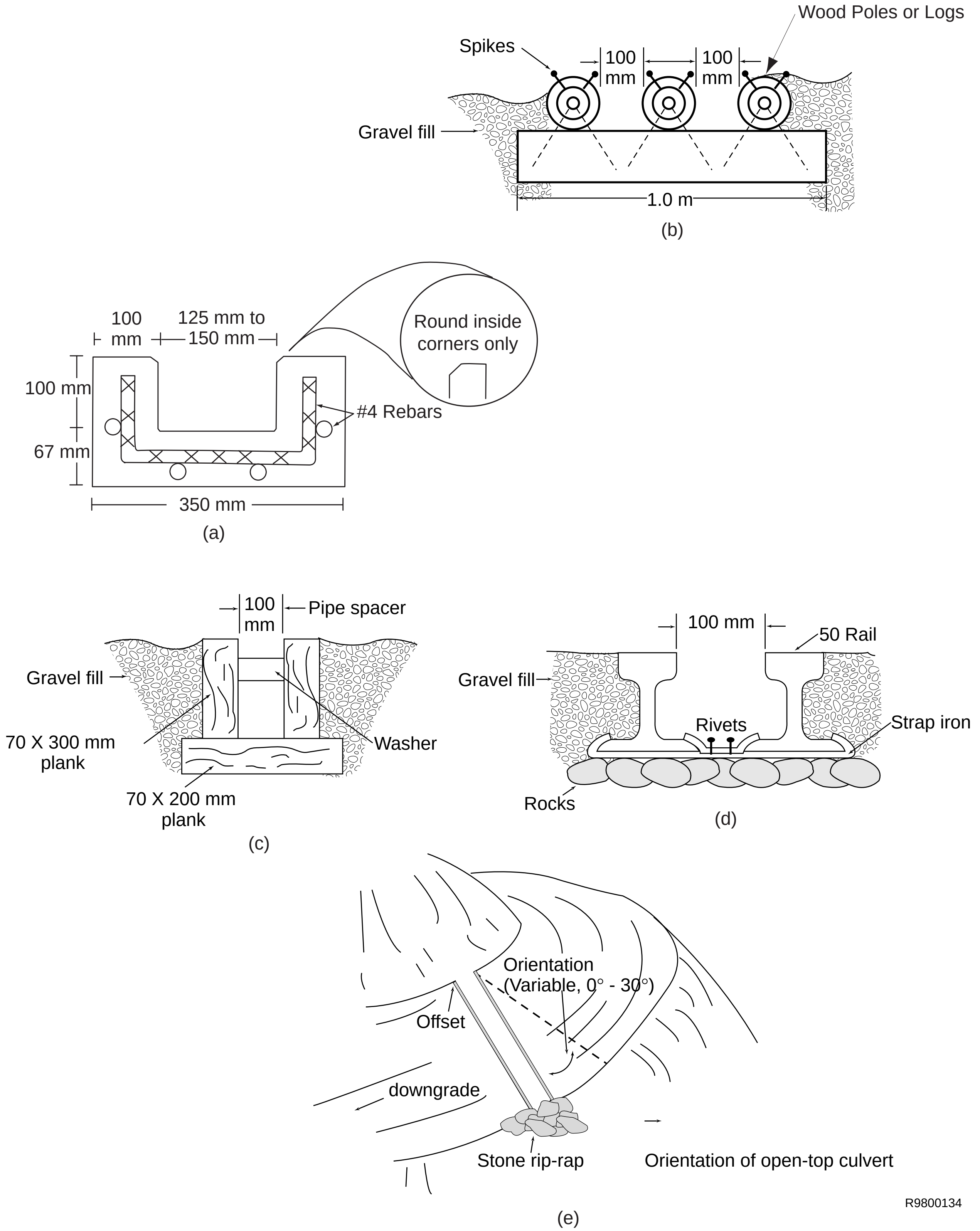

Figure 2ÑV arious open top culvert surface cross drain designs: (a) concrete, (b) pole, (c) wood box; (d) rail culvert, (e) orientation is typically up to 30 degrees from perpendicular to the direction of travel.

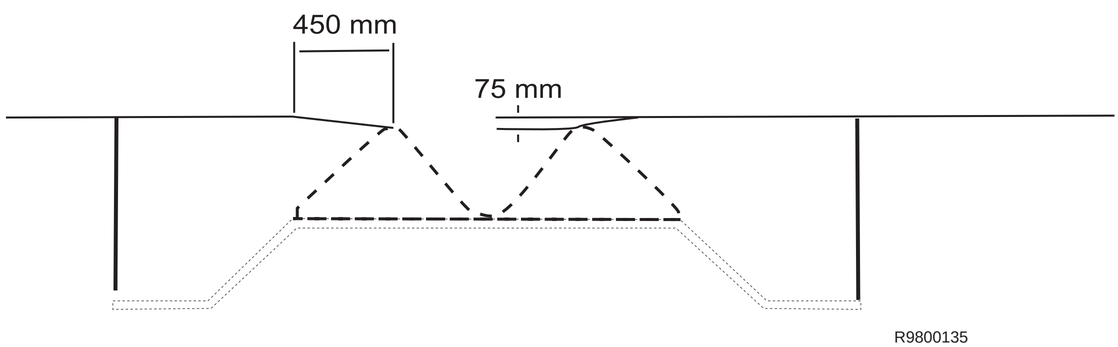

Figure 3ÑMetal waterbar cross drain design.


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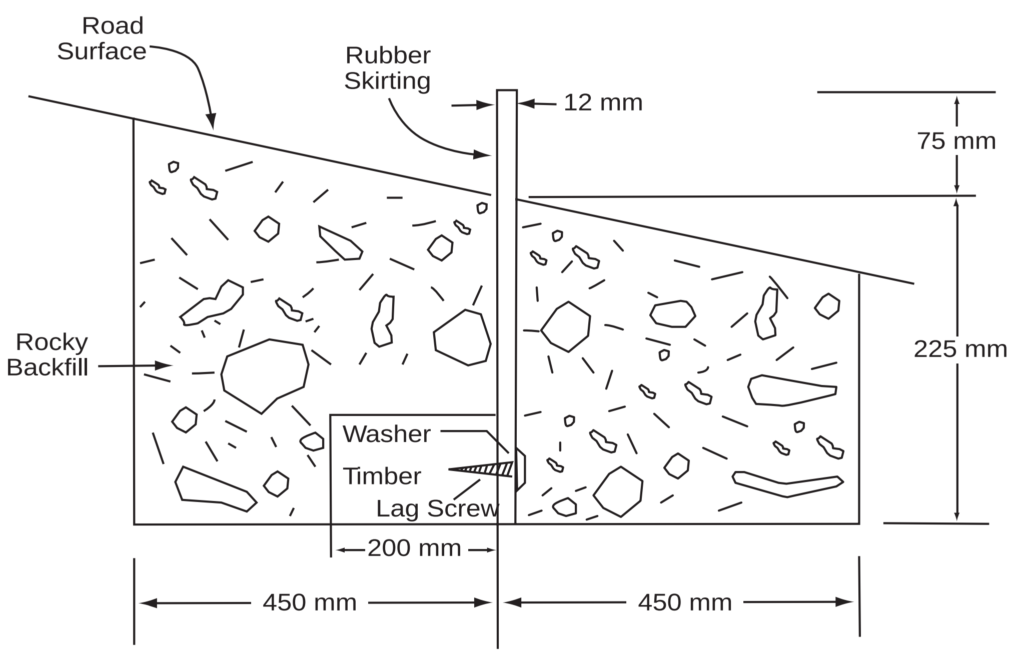
(a)



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(b)

Figure 4ÑRubber water diverter cross drain design: (a) installation on a crowned road surface, (b) typical design details.

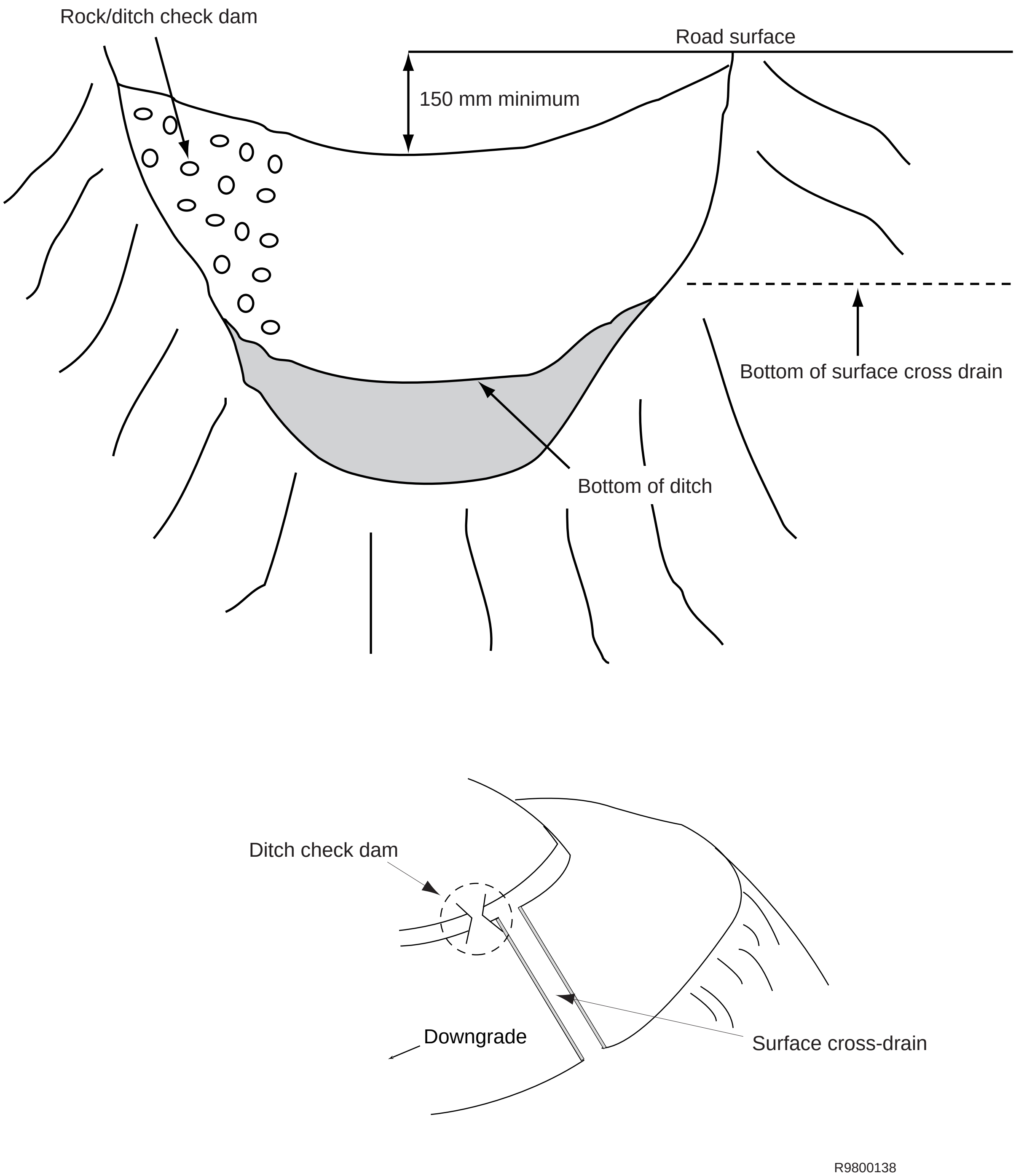

Figure 5ÑDitch dams are used for directing runof f toward surface cross drains.

freeboard (hydraulic depth) of a dip should be about 300 millimeters (Figure 1)(Hafterson 1973). Depths less than this will render the dip ineffective after a short time because ruts will cut through the top of the dip, especially if lower quality materials are used. On the other hand, passage of vehicles such as log trucks, lowboys, and recreational vehicles that are large or that include trailers should also be considered. Vehicle frames can be twisted or ÒrackedÓ if the orientation angle is not 90 degrees (Figure 1). If the dip geometry cannot be designed to satisfy hydraulic requirements and still meet requirements for vehicle passage and safety, then other types of drainage should be planned.

Dips are less susceptible than open top drains to being filled with sediment because they have a larger **holding capacity**. Most surface cross drains reduce the ability of a road to carry traffic (reduced travel speed and user comfort) relative to insloped roads constructed with ditches and culverts. Dips can result in localized increases in the effective road grade by one and one-half to two times (Figure 6).

DESIGN CRITERIA

Proper design and location of surface cross drainage are required in order to prevent water concentration, erosion of traveled way surfaces, erosion of fill slopes, instability of fill slopes, longitudinal rutting, siltation, and ponding (Eck and Morgan 1987). Factors affecting performance of surface cross drains are shown in Table 1. Design criteria for successful road surface cross drainage follow from the basic principles of erosion caused by rainfall and the need to meet transportation objectives. The factors controlling this type of erosion are amount and form of precipitation, soil type, topography, and the type and extent of any vegetative cover. For road surfaces, these factors correspond to local climate, road-surface material properties, road grade, distance between drains, position on the slope, the location of road cuts and fills, and any vegetative cover on the road surface that may be present. Transportation objectives may include the need to support a variety of traffic types without compromising erosion control and slope stability objectives. Table 2 relates the advantages and disadvantages of different types of surface cross drains.

Cross Drain Locations

A road design variable that has received substantial attention is the distance between cross drains on continuous, monotonic grades (Table 3). Water must be drained before it concentrates to volumes that will cause erosion or unstable hillslopes, but transportation needs may not allow the undulating or outsloped roadway that would meet these hydraulic requirements. Figures 6 and 7 graph several surface cross drain spacing guidelines. Figure 6 shows relationships between dip spacing, overall road grade, and approach grade resulting in dip geometry that would allow reasonable driving conditions (Hafterson 1973). These relationships define a lower bound on dip spacing based on geometric and traffic considerations. Other published guidelines (Figure 7) define upper bounds on the distance between contiguous surface cross drains in terms of soil characteristics and road grade. Many guides used in the USDA Forest Service are based on a study, completed between 1958 and 1962, of roads on the Boise National Forest (Packer 1967).

Table 1ÑFactors af fecting performance and erosion of surface cross drains.

Performance (ability to provide adequate drainage and support expected traffic)	¥ Spacing (i.e., properly locating sufficient cross drains for the expected runoff volume) ¥ Storm intensity (peak runoff) ¥ Erodibility of surfacing material (affects sediment conveyed and ability to keep drain functional) ¥ Traffic volume, type, and weight (consider hardening to increase strength) ¥ Strength of cross drain surfacing material ¥ Drain geometry (freeboard, runout distance, approach grade)
Erodibility (consider lining to reduce erodibility)	¥ Soil and surfacing type ¥ Grade and location on slope ¥ Fill height ¥ Frequency of maintenance (affects ponding and drain function)

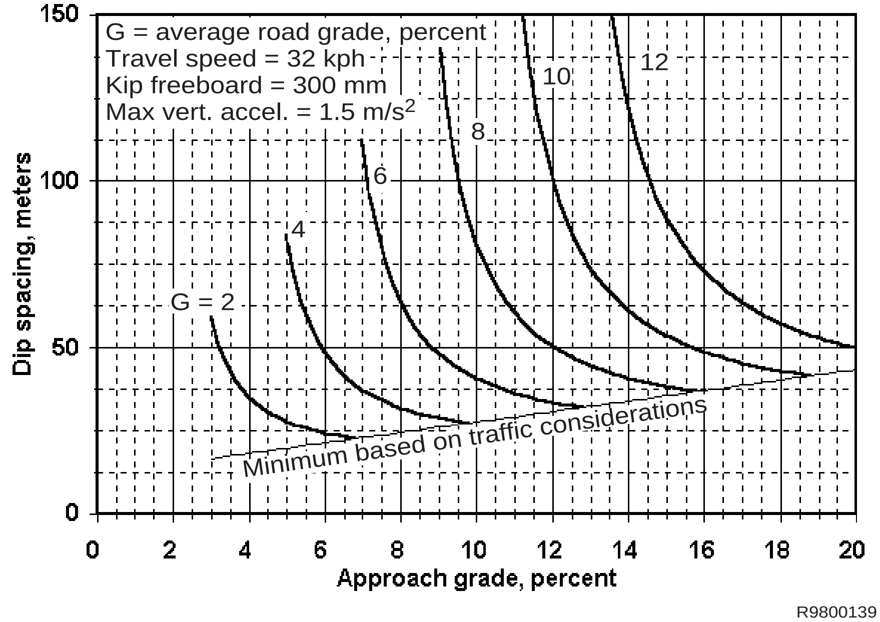

Figure 6ÑConstraints on broad based dip geometry and location as a result of the need to accomodate traf fic (Hafterson 1973). Approach grade is the local slope on the uphill side of the bottom of the dip.

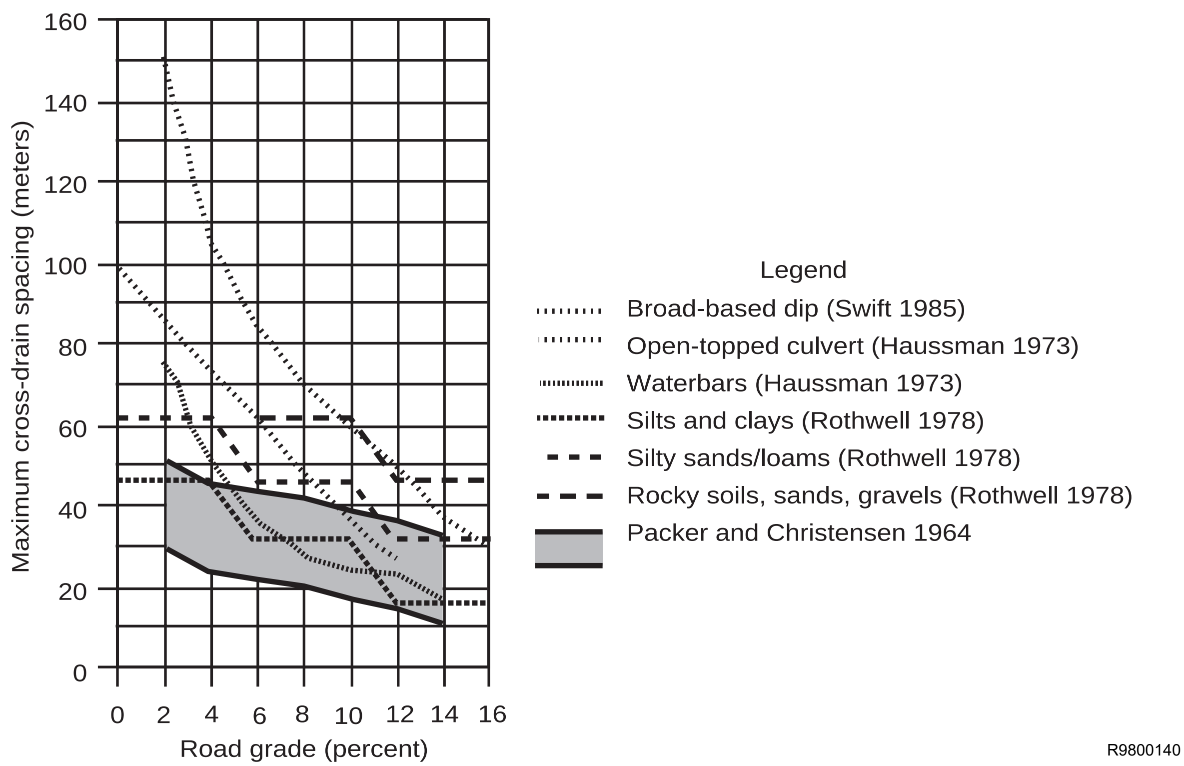

Figure 7ÑT ypical maximum distances specified in various published guidelines for locating surface cross drains. These maximum distances are often used for guidance on the location of ditch-relief culverts.

Table 2ÑAdvantages and disadvantages of dif ferent types of surface cross drains.

Type	Advantages	Disadvantages
Broad based dips	¥ Lower cost[a] than ditches and culverts ¥ Can disperse water	¥ Can impede some traffic ¥ Erodes and ruts unless armored
Drain dips and waterbars	¥ Lowest cost[a] surface cross drain ¥ Easy to construct	¥ Difficult for some traffic (worse than broad based dips) ¥ Erodes and ruts unless armored with rock
Open top culverts	¥ Stays in place ¥ Okay for traffic	¥ Higher cost[a] ¥ Lower durability ¥ Requires hand maintenance ¥ Potential for approach problems
Slotted metal pipe	¥ Stays in place ¥ Does not impede traffic	¥ Vulnerable to plugging or filling with sediment, debris, or loose surface rock ¥ Requires hand maintenance (flushing)
Flexible rubber strip	¥ Stays in place ¥ Does not impede traffic	¥ Low capacity ¥ Erodible unless armored ¥ Low durability, limited life

[a] Guidance on cost estimates is included in some published material (Kochenderfer 1995) (Gonzales 1998). Site-specific cost estimates are best prepared, however, in accordance with regional Cost Estimating Guides by experienced estimators familiar with local conditions and construction practices, equipment, material, and labor rates.

Table 3ÑRange of published surface cross drain spacing recommendations for native soil surfaced roads. [a]

	Maximum surface cross drain recommendation (meters)			
Road grade (percent)	2 - 5	5 - 10	10 - 15	15 - 20
Haupt 1959	41 - 76	24 - 41	18 - 24	14 - 18
Haussman 1973	95 - 150	60 -95	35-60	
Packer 1967	23 - 51	17 - 44	11 - 39	
Rothwell 1978	46	31 - 61	15 - 46	
Swift 1985	67 - 85	37 - 67	6 - 37	

[a]These guides generally do not specify climate or location, but caution the practitioner to consider the variety of conditions that may be encountered.
[b]Includes additional reductions for slope location, side-slope angle, and aspect that typically would need to be applied according to this guide. (See Table 4, note a.)

Criteria were proposed for the longitudinal flow distance that would limit 83 percent of road surface erosion rills to 25 millimeters or less. This work was based on measurement of 25 topographic and road characteristics for 720 road segment sites over a two-year period and indicated that the most important factors influencing erosion of road surfaces were the percent of water-stable soil aggregates in the road surface that were larger than 2 mm in diameter, and road grade (Packer 1967).

A guide that is widely used and that has become the basis for most of the regional and local guides used in the USDA Forest Service was written by Packer and Christensen and is based on these measurements (Packer and Christensen 1964). The cross drain spacing guidance in this pocket-sized publication is presented as a table of minimum distances between cross drains on a continuous grade for each of six soil groups, which are derived from bedrock lithology. Road grade covered by the table ranges from 2 to 14 percent. The user enters the table with known road grade and soil group. After obtaining the minimum distance from the table, adjustments are made based on the location of the road on the slope, directional aspect, and steepness of the sidehill slope. As an example, if a road is on the lower one-third of a 20 percent hill slope with a south aspect, the guide recommends reducing the distance between cross drains by 25 meters from the tabled value. This would result in a cross drain spacing ranging from 0 to 25 meters.

Although this guide and the guides based on it were written with practical field application in mind, they may not be appropriate in locations outside the northern Rocky Mountain region where the supporting data were obtained. Factors that were not included in this work were the infiltration and water-holding capacity of the soil and surfacing materials, the shape and surface angularity of the road surfacing materials, and climatic factors such as total precipitation amounts or snowmelt characteristics. Neither were allowances made for vegetative cover if it existed. Of the factors omitted, the properties of surfacing materials and climatic factors are probably most important because designers usually make the conservative assumption that vegetative cover does not exist on roadway surfaces.

The soil group classification used for the Packer and Christensen guide, which apparently considers only parent material bedrock lithology, may not adequately consider local soil erodibility that is dependent on local climatic, physical, chemical, and biological factors. In general, erosion of exposed soil surfaces (including native surfaced roads) decreases with increasing organic content and cover and clay size fraction. Erosion also depends on soil texture, moisture content, compaction, pH, and composition or ionic strength of eroding water. Based on our field observations of cross drain spacing applications in seven regions of the USDA Forest Service, no single existing guide encompasses the range of road surface soils found across all locations. It is common for cross drain spacings to exceed the maximum recommended in Packer and Christensen's guide (50 meters) (Packer and Christensen 1964) and in other guides based on this guide, without experiencing appreciable erosion. This may be because road surfacing material (which is applied in part to protect against surface erosion) may not have been taken into account, or it could be a result of differences in climate, topography, or traffic.

In many cases, geometric and physical constraints (e.g., suitability for vehicular traffic and ease of maintenance) require cross drain spacing greater than the 25 meters calculated for the example above (Figure 6). Therefore, Packer and Christensen's guide would preclude the use of road designs employing surface shaping for large percentages (80 to 90 percent) of the combinations of road grades and soil groups listed. Other guides give maximum spacings, which seem to correlate better with what has been used successfully on native surface roads in areas having erosion resistant soils, or on aggregate surfaced roads (Swift 1985).

Another modification that has typically been made to guides derived from the Packer and Christensen guide is to redefine the spectrum of soil erodibility in terms of the Unified Soil Classification System (USCS), which more easily relates to information that may be available to the practicing engineer (for example, see Baeder and Christner 1981). This is based on the idea that soils can be grouped into approximate erodibility classes based on grain size, distribution and cohesiveness (Gray and Leiser 1982). We have converted Packer and Christensen's soil categories to this grouping based on soil erodibility and use this grouping to recommend maximum surface cross drain spacing based on the USCS soil types and road gradient (Table 4).

New cross drain spacing guidelines using the Water Erosion Prediction Program (WEPP) to model surface erosion from roads have been derived (Morfin et al. 1996). Approximately 50,000 iterations of the WEPP were made for input ranges of local climatic conditions, surfacing material characteristics, maintenance frequency, distance between cross

Table 4ÑGuidelines for maximum distance[a] between contiguous surface cross drains based on USCS soil erodibility groups[b].

Road Grade	Group 1 GW, GP, Aggregate Surfacing	Group 2 GM, GC	Group 3 CH, CL	Group 4 MH, SC, SM	Group 5 & 6 SW, SP, ML
percent	------------------	------------------	*meters*	------------------	------------------
2	120	97	75	52	29
4	103	84	65	45	26
6	88	71	55	39	23
8	74	60	47	33	20
10	61	50	39	28	17
12	50	41	32	23[c]	14[c]
14	42[c]	34[c]	26[c]	19[c]	11[c]

[a]Distance between cross drains should be reduced according to the following (based on Packer and Christensen 1964):

Reduce the distance by:	If the road is located:
5 meters	in the middle one-third of a slope
11 meters	in the bottom one-third of a slope
3 meters	on an east or west exposure
6 meters	on a south slope.

If, after applying the above, the resulting distance is less than 20 meters, set the distance between cross drains at 20 meters and apply aggregate surfacing and erosion protection measures, such as vegetative seeding of road, fills, shoulders, ditches, and embankments.

[b]Adapted from the distance recommendations summarized in Table 3, and soil erodibility hierarchy suggested by Gray and Leiser.

[c]Not recommended for dips because they may require approach grades steeper than 15 percent.

drains, and road grade typical for U.S. National Forests. The output of these analyses is the distance that the sediment plume travels from the road. One way that this effort was made usable by field personnel is through a computer based lookup table (Elliot et al. 1998). It is hoped that this product will serve the dual purposes of facilitating the determination of proper cross drain spacing and helping to predict probable sediment yields based on local values for the above factors. The advantage of this computer based tool is that it is specifically applicable as a cross drain spacing guide for a wider range of conditions than paper based guides can be. In all cases, however, suitability of a particular location for broad based dip design should be reviewed by a soil scientist or geotechnical specialist to evaluate the stability of fill slopes. Preliminary results based on 7,000 of the runs from the above-described WEPP modeling effort show recommended distances between cross drains generally less than the figures shown in Table 4, indicating that the table may be conservative (Morfin et al. 1996).

Some guides point out that there is no set spacing that should be followed in any specific setting (Schwab 1994). It is pointed out that Òfrequent cross-ditches are optimal,Óbut that the spacing of cross-drains should fit the natural drainage requirements of the terrain. Certainly, it should be recognized that cross drain spacing guides apply only to the surface erosion aspect of the location of surface cross drains. Where roads are located in areas of highly dissected and variable terrain, cross drain locations may be required more frequently, and located more carefully, than would be the case in areas where surface erosion is the predominant concern.

Location, geometry, orientation, and erosion-protection considerations for surface cross drains are given in Figures 8 through 11.

Because of the cost involved in planning, constructing, and maintaining surface cross drains, it is important to determine their location so that

Checklist for Surface Cross Drain Locations

- ❒ Surface cross drains should be located at intervals close enough to prevent volume concentration that causes surface erosion or unstable slopes.
- ❒ Locate cross drains far enough above stream crossings to avoid releasing drainage water directly into live streams. Surface and ditch water should be diverted and dispersed before it enters streams using lead-out ditches, settlement ponds, ditch dams, surface shaping, or other measures.
- ❒ Where overtopping of the road could occur, a dip or grade roll should be designed to ensure that the overtopping flow crosses the road at a point that minimizes erosion (erodible-resistant surfacing is often added), and so that flow is not diverted along the road or away from its natural flow path.
- ❒ Cross drains should be located above breaks in vertical profile from shallow to steep grades to prevent the shallow grade surface drainage from gaining velocity and erosive power on the steep grade.
- ❒ Whenever possible cross drains should be located to release water on convex slopes or other stable areas that will disperse water rather than channeling it.
- ❒ Dips should not be used within the confines of curves with a radius of less than 30 meters on roads open to traffic because they may create unsafe conditions for vehicle travel.
- ❒ Surface dips are not recommended for grades over ten percent because of the steepness of the dip approach grade that would be required (see Figure 6).

R9800141

Figure 8ÑChecklist for location of surface cross drains.

Checklist for Surface Dip Geometry

- ❒ Cross drains should be constructed with an outslope grade of 3 to 5 percent or equal to the existing out-slope grade. In colder climates where snow and ice create driving hazards, the outslope grade should be reduced.
- ❒ For drivable dips, the minimum freeboard should be 150 millimeters with a roll-out length of at least 6 meters. If the dip is unarmored, freeboard should be increased to allow for the tendency of the dip to lose its shape due to traffic (Figure 1).
- ❒ Drain dips and drivable water bars negotiable by high-clearance vehicles have steeper rollout grades. The recommended minimum depth is 150 millimeters with a rollout distance of at least 1 m.
- ❒ The above values are minimums to be maintained. If maintenance cannot be performed to maintain this minimum geometry, freeboard and roll-out length should be increased so that ruts that cut through the top of the dip do not reduce freeboard below these minimums.
- ❒ The above values should be adjusted according to local climate. Freeboard and run-out distance should be increased for surface dips and waterbars where run-off volumes could be higher.

R9800142

Figure 9ÑChecklist for surface dip geometry .

Checklist for Orientation of Surface Cross Drains

- ❒ Dip orientation (skewed or perpendicular to the road centerline, Figure 1) depends on the type of traffic expected, length of the dip, and road grade. If dips are shorter and the traffic will include larger trucks with longer frames, then the dips should be oriented perpendicular to the direction of traffic. Dips skewed from perpendicular to centerline more effectively drain steep road grades, are more comfortable for vehicle occupants, and, if long enough, will not cause severe twisting of truck frames.
- ❒ Open-topped culverts, and slotted culvert pipes may be oriented from 60 to 90 degrees to the direction of travel.
- ❒ Waterbars are typically used in closed-off areas with little traffic, and should be oriented to lead the flow from the surface. One rule of thumb is to add five to the percent road grade and orient the waterbar at that many degrees off perpendicular.

R9800143

Figure 10ÑChecklist for orientation of surface cross drains.

Checklist for Control of Erosion in Surface Cross Drains

- ❒ Cross drains should be armored where soils are highly erodible or provide poor traffic support during wet weather use. (USCS groups CH, CL, MH, SC, SM, SW, SP, ML).
- ❒ Permanent erosion control measures (armoring, flow spreaders, vegetation) should be used at all cross drain outlets in USCS soil groups CH, CL, MH, SC, SM, SW, SP, ML).

R9800144

Figure 11ÑChecklist for control of erosion in surface cross drains.

economic and resource objectives will be met, while minimizing the cost of maintaining and repairing forest roads. Further studies are being planned to compare cross drain locations to the various recommendations and to what may be needed to adequately protect resources and transportation facilities.

Typical Materials, Construction, and Maintenance

Specifications for surface cross drains are usually described by drawings or by written specifications developed by an engineer (USDA FS 1996).

Waterbars, broad based dips, and drain dips are excavated into road surface materials. Rock aggregate and grass are often used to stabilize the crest and trough areas (Kochenderfer and Helvey 1987). Adding geotextile material to the construction of dips (Figure 1) can substantially improve the stability and drainage characteristics of these installations.

Open topped culverts have been made from a variety of materials, including dimension lumber, small logs, half metal culverts, railroad rails, concrete, or shaped soil-cement mixtures (Gonzales 1998) (Figure 2). Slotted metal pipes can be either steel or aluminum (Kochenderfer 1995).

Surface cross drains can be built and maintained with standard construction equipment such as a dozer or grader.

A road grader or dozing blade is needed to shape cross-drain dips. Open topped culverts, slotted metal pipes, and other suface drain devices require hand labor to replace backfill against the structures, or to excavate deposited sediment. Occasionally pipes need to be replaced, which requires a backhoe to excavate the damaged structure. Care must be taken to avoid building up a soil berm at the outlet of surface cross drainage structures during maintenance operations.

Regular maintenance of surface cross drains is required. The capacity of surface cross drains is quickly reduced as sediment and debris in storm runoff settle in these drains. Surface cross drains should be inspected, cleaned out, or reshaped to original capacity after each storm.

Routine surface maintenance (primarily blading) can be more time consuming, and thus costly, where reshaping of dips is necessary. This is also true for other types of cross drains where care must be taken not to push surface material into the drain, leave it piled in front of or at the outlet of the drain, or dislodge installed cross drain structures such as sheet metal waterbars.

UNIT CONVERSIONS

Multipy	by	To get
mm (millimeters)	0.0394	in. (inches)
cm (centimeters)	0.394	in. (inches)
m (meters)	39.4	in. (inches)
m (meters)	3.28	ft (feet)
hectares	2.47	ac (acres)
m^3 (cubic meters)	1.31	yd^3 (cubic yards)

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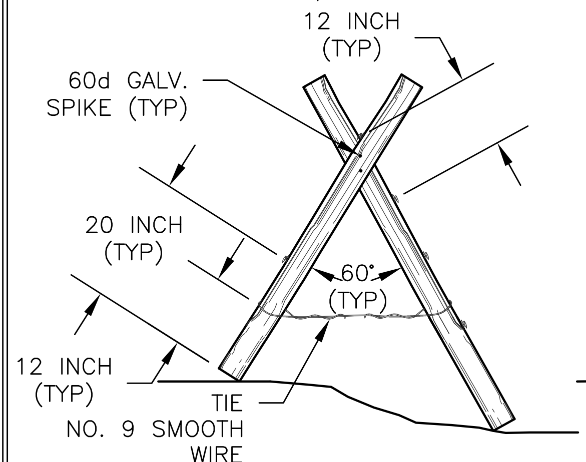
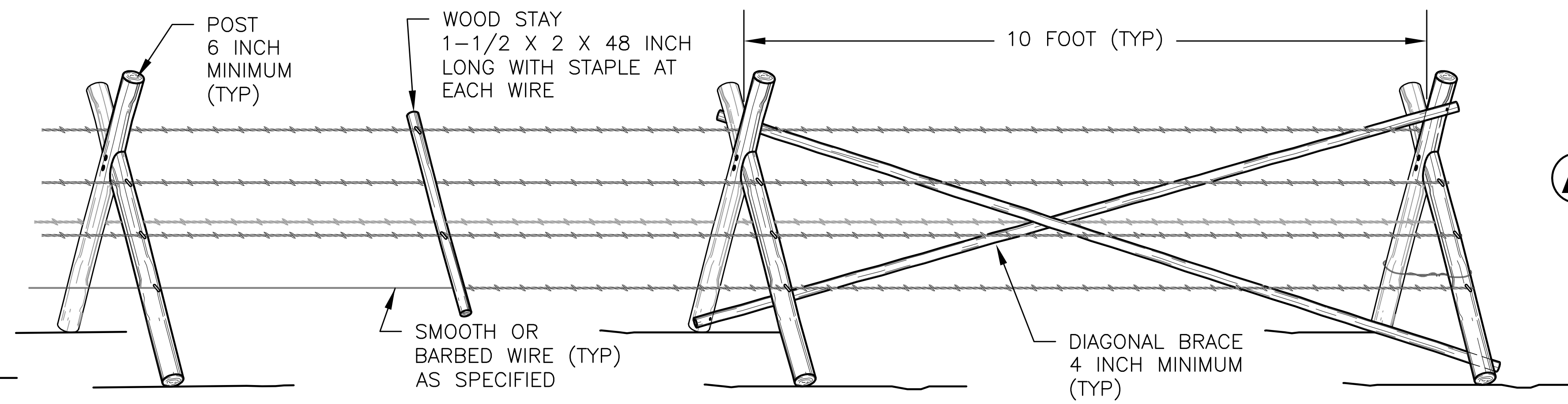
JACK LEG FENCE

TYPICAL ID	FENCE: WIRE TYPE	FENCE: HEIGHT (INCHES)	POST: TYPE	POST: SIZE	POST: LENGTH (FEET)	POST: SPACING (FEET)	POST: PRESERV. TYPE	STAYS: TYPE	HORIZONTAL BRACING: SIZE	HORIZONTAL BRACING: 3-POST SPACING (FEET)	HORIZONTAL BRACING: EMBEDMENT DEPTH	HORIZONTAL BRACING: POST CONNECTION DETAIL	COMMENTS
JLF-1							P						

N/A WHEN NOT APPLICABLE



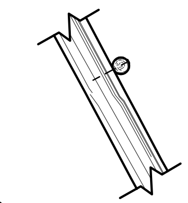
TYPICAL JACK LEG ON UNEVEN GROUND



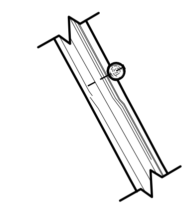
F1 JACK LEG WITH WIRE AND DOUBLE BRACE

(LIVESTOCK)

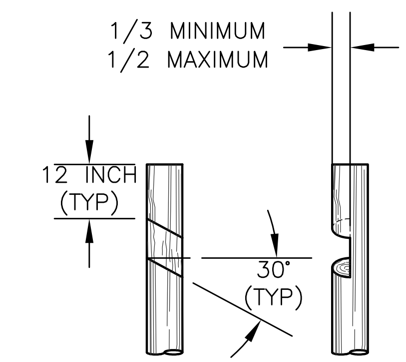
SEE STD_942 FOR GATE DETAILS



A SPIKE DETAIL



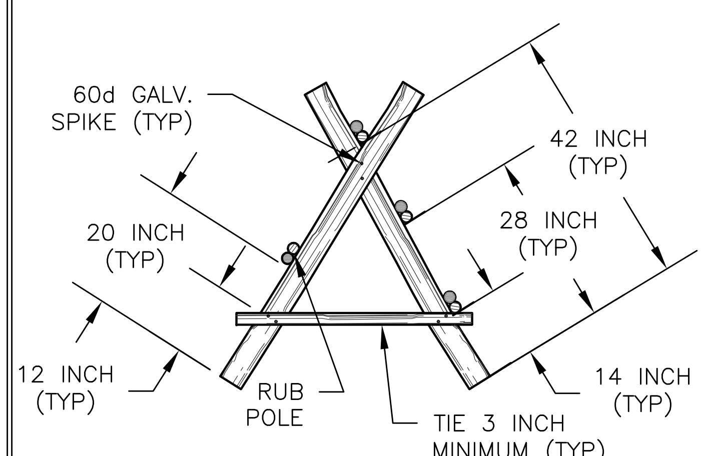
B NOTCH DETAIL



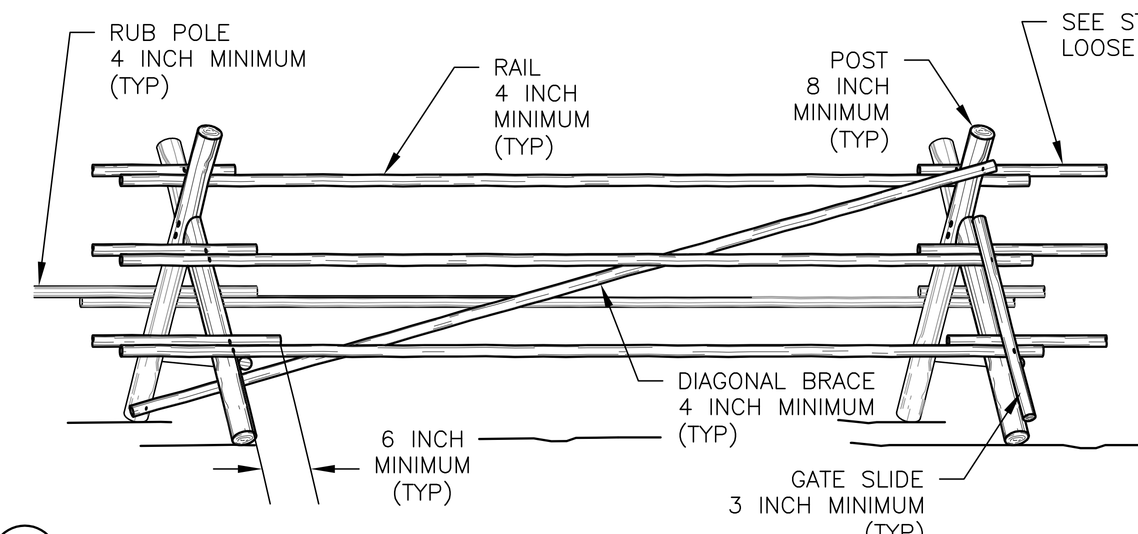
TYPICAL CUT SECTION

NOTES:

1. REFER TO THE PUBLICATION "FENCES" PREPARED BY THE MISSOULA TECHNOLOGY AND DEVELOPMENT CENTER FOR ADDITIONAL CONSTRUCTION DETAILS AND INSTALLATION PROCEDURES.
2. FENCE AND GATE LOCATIONS AS STAKED IN THE FIELD.
3. PRE-DRILL HOLES FOR FASTENERS TO PREVENT SPLITTING OF BRACING OR POSTS.
4. COMPACT AND BACKFILL POST HOLES IN 6 INCH LIFTS UNTIL NO VISUAL DISPLACEMENT.



TYPICAL JACK LEG ON EVEN GROUND



F2 JACK LEG WITH RAILS AND SINGLE BRACE

(WILDLIFE)

PRESERVATIVE TREATMENT – (REFER TO AWPA USE CATEGORY SYSTEM)			
PRESERVATIVE TYPE	TREATMENT TYPE	USE CATEGORY	COMMENTS
P1	WB	UC4A	
P2	WB	UC3B	
P3			

TREATMENT TYPE

WB = WATERBORNE
OT = OIL-BORNE

USE CATEGORY

UC3B = ABOVE GROUND – EXPOSED
UC4A = GROUND CONTACT – GENERAL USE
UC4B = GROUND CONTACT – HEAVY DUTY

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE **STANDARD TRAIL PLAN**	PROJECT NAME & LOCATION	DRAWING NAME **JACK LEG FENCE**	REVISION DATE **XX/XX/XX**	DRAWING NO. **STD_941-40-01**
		SECTION **941 - FENCES** TYPICAL ID **JLF**	**NOT TO SCALE**	SHEET OF

6A.1 Travel Management Sign (TM)

Text layout—Travel Management sign (TM)

TM1 and TM2

TM3 and TM4

Text and symbol dimensions (inches)

			A	B Restrictions			C	D	E
			Title	B1 Word Messages (Prefered)	B2 Symbols (Optional)		Dates or Conditions	Reasons, Contacts and Optional Messages	Shield and Logos
Sign number	**L**	**H**	**Minimum text size (upper case)**	**Minimum text size (upper case)**	**Minimum symbol size**	**Maximum number of symbols**	**Minimum text size (upper case)**	**Minimum text size (sentence case)**	**Minimum size**
TM-1	12	18	1	1	3	3	⅝	⅝	I ½
TM-2	18	24	1 ½	1 ½	3	5	1	⅝	2
TM-3	18	12	1	1	3	4	⅝	⅝	I ½
TM-4	24	18	2	2	3	6	1	1	2

Notes

Letter height may be larger depending on importance and length of message.

Word messages are preferred over symbols for the restriction message.

Restricted word messages should reflect the appropriate travel management decision.

For examples of message inserts, see section 6A-3.

Text layout for Area Boundary signs is similar to text layout for Area Closed signs. Refer to chapter 6, section 6.4.2a.

Colors

Black lettering, symbols, and borders on white background.

Red slash on symbols—from upper left to lower right.

Red letters may be used to highlight safety messages or other important messages, see chapter 6, section 6.4.2e, example 3.

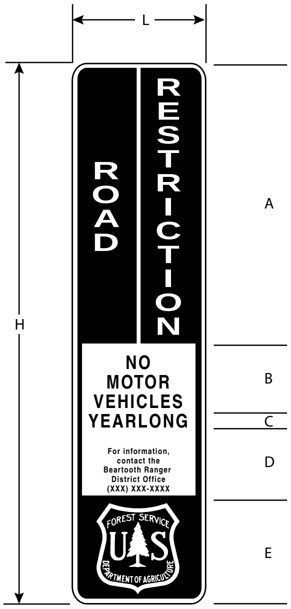
References

For sign guidelines, see chapter 6

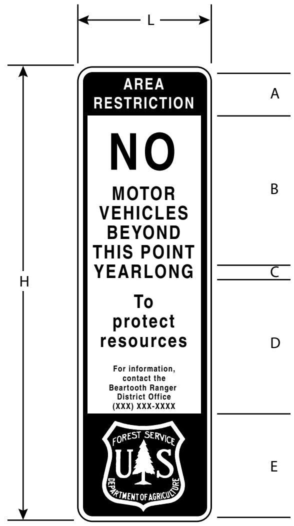
For Forest Service shield, see chapter 8C, section 8C.7.

6A.2 Travel Management Decal (TM-D)

Text layout—Travel Management decal (TM-D)



TM-D1



TM-D2

Text and symbol dimensions (inches)

			A	B			C	D	E
				Restrictions					
			Title	B1 Word Messages (Prefered)	B2 Symbols (Optional)		Dates or Conditions	Reasons, Contacts and Optional Messages	Shield and Logos
Sign number	L	H	Minimum text size (upper case)	Minimum text size (upper case)	Minimum symbol size	Maximum number of symbols	Minimum text size (upper case)	Minimum text size (sentence case)	Minimum size
TM-D1	3	V*	1	⅝	2	4	½	½	2
TM-D2	3	V*	½	⅝	2	4	½	½	2

**V = variable*

Notes

Letter height may be larger depending on importance and length of message.

Word messages are preferred over symbols for the restriction message.

Restricted word messages should reflect the appropriate travel management decision.

For examples of message inserts, see section 6A.3.

Text layout for Area Boundary signs is similar to text layout for Area Closed signs. Refer to chapter 6, section 6.4.2a.

Colors

Black lettering, symbols, and borders on white background.

Red slash on symbols—from upper left to lower right.

Red letters may be used to highlight safety messages or other important messages (see section 6.4.2e, example 3).

References

For sign guidelines, see chapter 6.

6A.3 Travel Management Sign Messages

A—Title (upper case)

- ROAD RESTRICTION or ROAD CLOSED
- TRAIL RESTRICTION or TRAIL CLOSED
- AREA RESTRICTION or AREA CLOSED
- Combination (ROAD and TRAIL, ROAD and AREA)

The following lists are examples of possible messages that may be needed on Travel Management signs. The lists are not all inclusive and other messages may be used as appropriate.

B(1)—Restricted Traffic Word Message (upper case)

Use word messages instead of recreational and cultural interest area symbols for clearer understanding or if the symbol is not representative of the specific vehicle designation.

- NO MOTOR VEHICLES
- NO MOTOR VEHICLES AND SNOWMOBILES or NO MOTORIZED VEHICLES
- NO PUBLIC MOTOR VEHICLES
- NO MOTORIZED AND MECHANIZED VEHICLES
- NO MOTOR VEHICLES GREATER THAN XX INCHES WIDE
- CLOSED TO ALL TRAFFIC, INCLUDING FOOT TRAFFIC

B(2)—Restricted Traffic Symbols

For a complete list of recreational and cultural interest area symbols, refer to chapter 3E, section 3E.11 and the MUTCD, chapter 2M. When used, symbols should be placed in the following order from left to right for consistency.

- RG-010R—Automobiles
- RS-067—Off-Road Vehicle Trail (4-wheel drive)
- RS-095—All-Terrain Trail (ATV)
- RL-150R—Motorcycle
- RS-052—Snowmobiling
- RL-090R—Bicycle
- RS-064—Horse Trail
- RS-068—Hiker Trail
- RS-046—Cross Country Skiing

C—Dates or Conditions (upper case)

- The FROM and THRU dates of the restriction
- YEARLONG
- WHEN SNOW IS xx INCHES OR DEEPER
- UNTIL SURFACE DRIES

D—Optional Explanations for the Restriction/Closure (sentence case or upper case)

A brief explanation of why the restriction or closure is in effect often helps the public understand why the restriction is in effect.

- To protect wildlife habitat
- To protect calving habitat
- To protect nesting habitat
- To protect winter range
- To protect summer range
- To protect migration corridors
- To provide wildlife security
- To protect threatened or endangered wildlife habitat
- To protect grizzly bear habitat
- To protect caribou habitat
- To protect eagle habitat area
- To protect aquatic habitat
- To prevent sedimentation
- To prevent temperature increase
- To provide aquatic security
- To protect water quality
- To protect municipal water supply
- To reduce invasive species
- To reduce maintenance costs
- To reduce user conflicts
- To reduce sound levels
- To protect facilities

- To prevent damage to vegetation
- To prevent damage to (road/trail) surfaces
- To return (road/trail) to its original condition
- Due to unsafe conditions
- To protect special areas
- To protect special interest area
- To protect wild and scenic river area
- To protect the wilderness environment/values
- To protect research natural area
- To protect roadless areas
- To protect a natural meadow
- To provide a nonmotorized recreation experience
- To protect __________ habitat
- To protect __________ quality
- To protect __________ area
- For public safety

D—Optional Messages (sentence case or upper case)

- Open to all other uses
- Foot travel allowed yearlong
- Non-motorized use allowed yearlong
- Above uses allowed outside these dates
- Administrative use by permit
- Timber harvest activities allowed
- Please do not block gate
- Motor vehicles restricted to designated routes

E—MVUM and/or Contact Message for the responsible office (sentence case)

- For further information, refer to the XXX Motor Vehicle Use Map or call ____ Ranger District at (phone number).
- For further information, call ____ Ranger District at (phone number).
- For further information, contact the nearest Forest Service office.

F—Shields and Logos

The Forest Service shield shall be at the bottom of the sign. Insert logos from other cooperating agencies, organizations or programs as appropriate.

All cooperative agencies should be shown. The Forest Service shield and logos shall be the same size.

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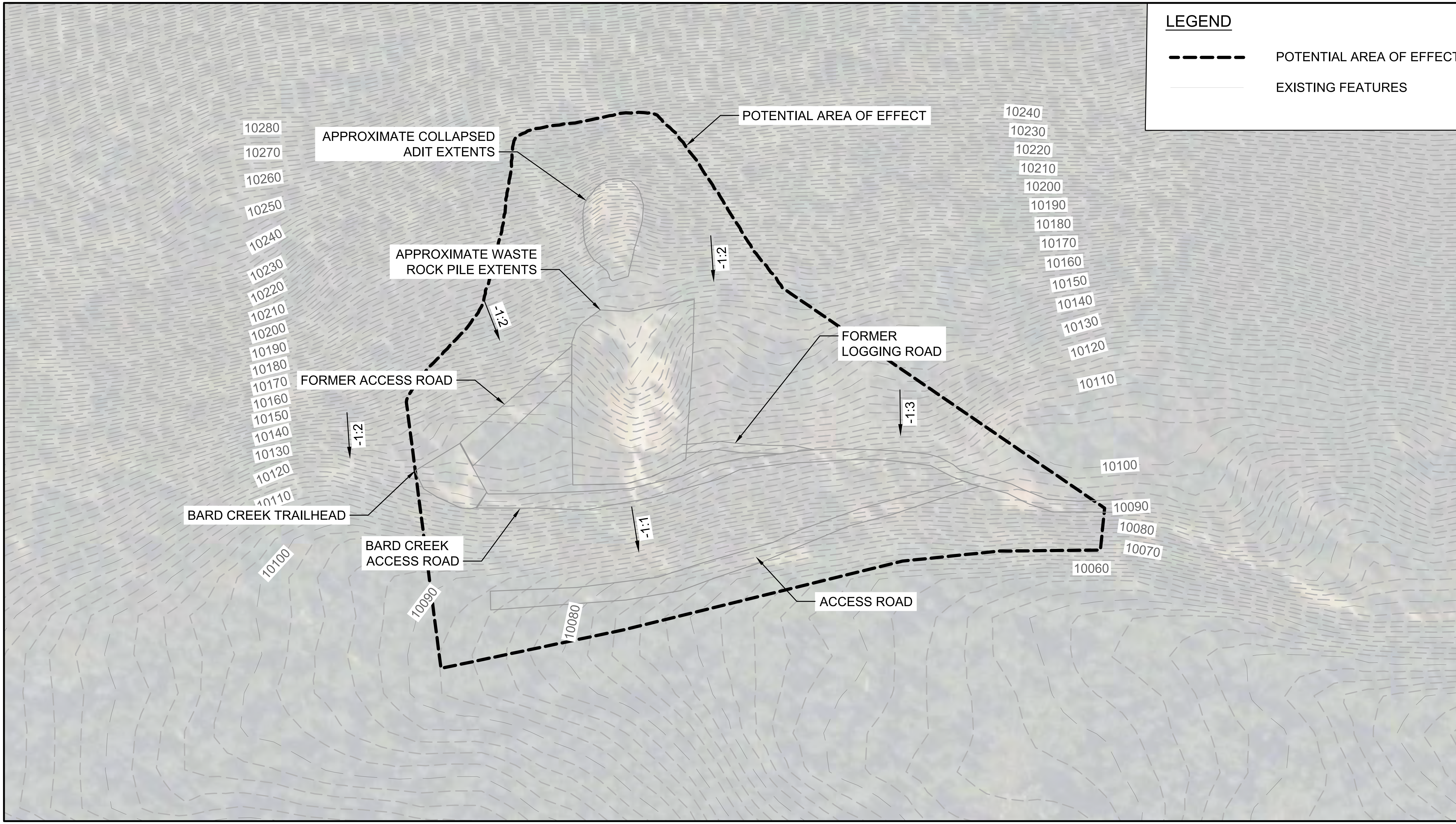
Appendix D. Conceptual Alternative Drawings



N

80 0 80 160

SCALE IN FEET

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

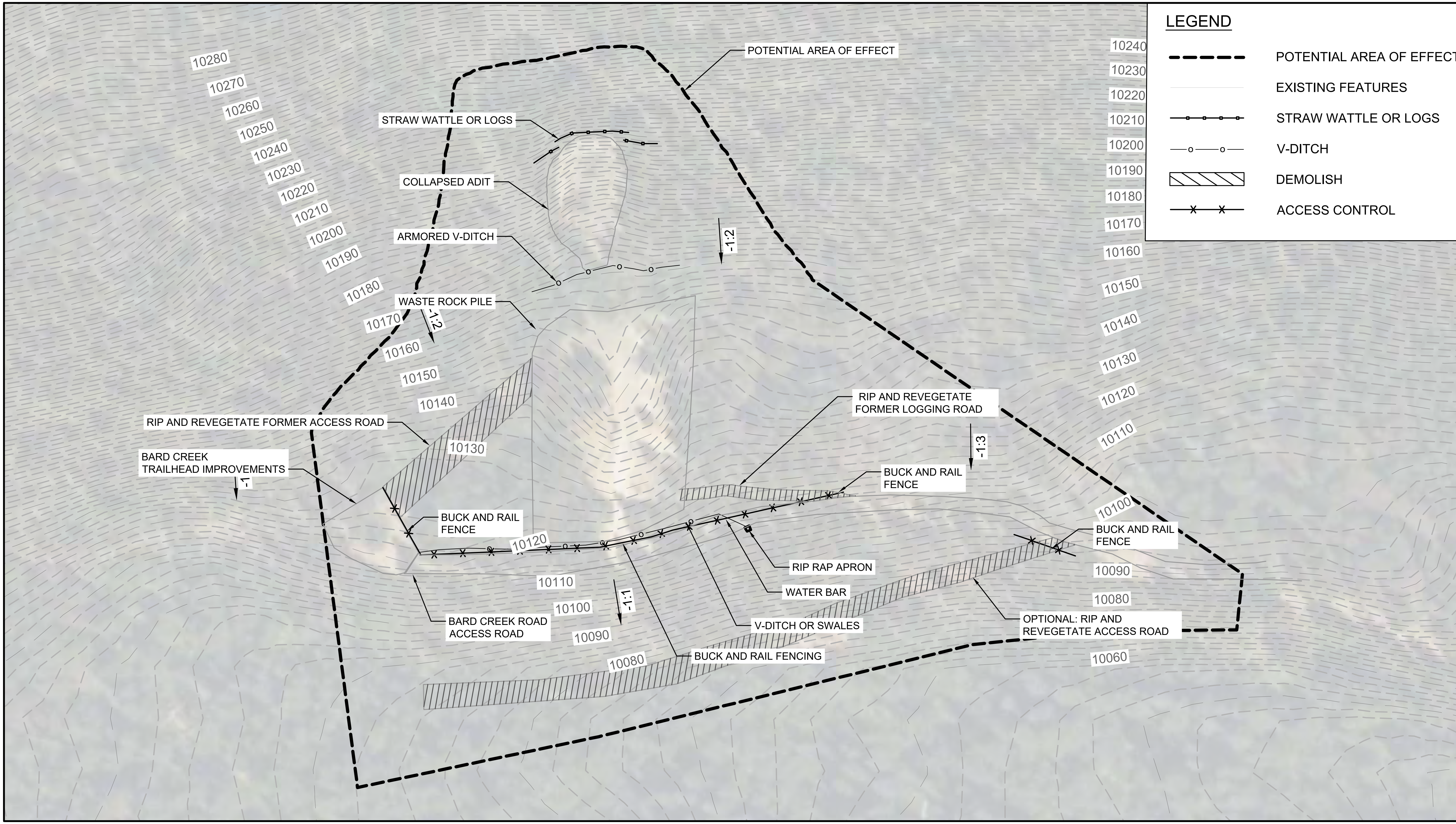
SHEET TITLE: EXISTING CONDITIONS

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 1



N

60 0 60 120

SCALE IN FEET

HDR

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

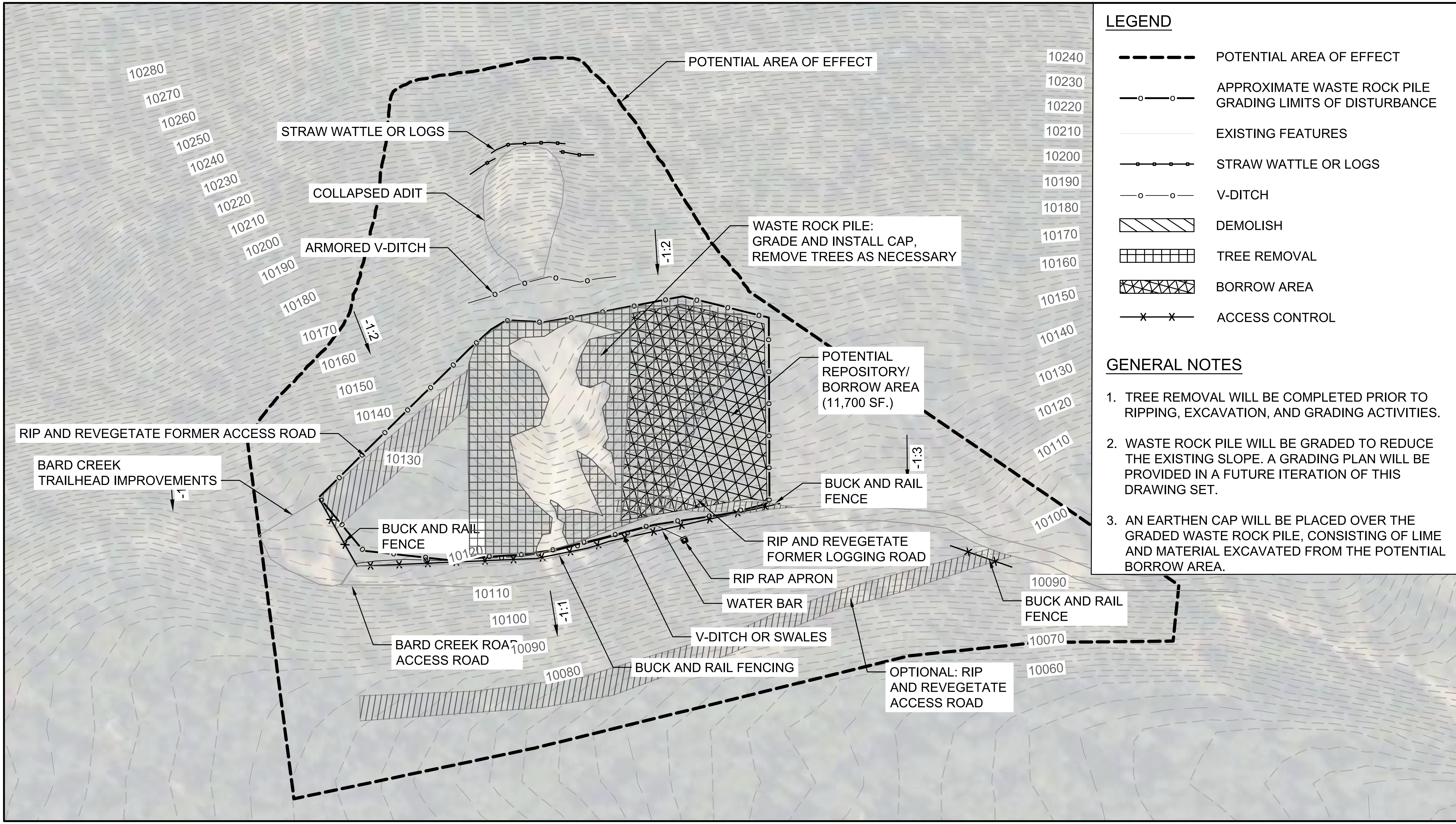
SHEET TITLE: ALTERNATIVE B-2 ENGINEERING AND INSTITUTIONAL CONROLS

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 2



LEGEND

- POTENTIAL AREA OF EFFECT
- APPROXIMATE WASTE ROCK PILE GRADING LIMITS OF DISTURBANCE
- EXISTING FEATURES
- STRAW WATTLE OR LOGS
- V-DITCH
- DEMOLISH
- TREE REMOVAL
- BORROW AREA
- ACCESS CONTROL

GENERAL NOTES

1. TREE REMOVAL WILL BE COMPLETED PRIOR TO RIPPING, EXCAVATION, AND GRADING ACTIVITIES.
2. WASTE ROCK PILE WILL BE GRADED TO REDUCE THE EXISTING SLOPE. A GRADING PLAN WILL BE PROVIDED IN A FUTURE ITERATION OF THIS DRAWING SET.
3. AN EARTHEN CAP WILL BE PLACED OVER THE GRADED WASTE ROCK PILE, CONSISTING OF LIME AND MATERIAL EXCAVATED FROM THE POTENTIAL BORROW AREA.

N

60 0 60 120
SCALE IN FEET

HDR

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

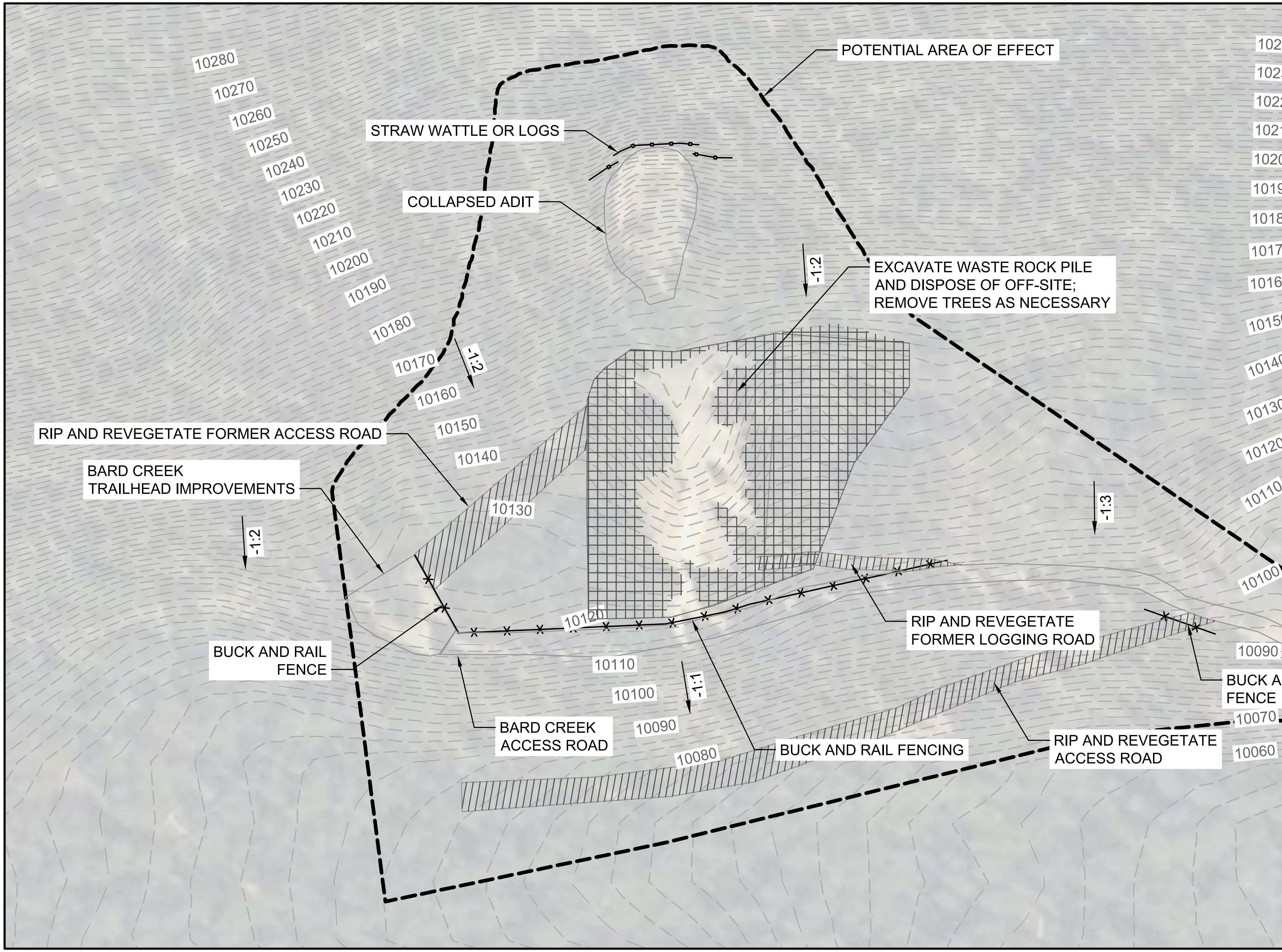
SHEET TITLE: ALTERNATIVE B-3 CAP, SOIL AMENDMENTS, AND REVEGETATION

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 3



LEGEND

- POTENTIAL AREA OF EFFECT
- EXISTING FEATURES
- STRAW WATTLE OR LOGS
- DEMOLISH
- TREE REMOVAL
- ACCESS CONTROL

GENERAL NOTES

1. TREE REMOVAL WILL BE COMPLETED PRIOR TO RIPPING, EXCAVATION, AND GRADING ACTIVITIES.
2. WASTE ROCK PILE WILL BE EXCAVATED TO TIE-IN TO SURROUNDING GRADE, AND EXCAVATED MATERIAL WILL BE DISPOSED OF OFF-SITE.

N

60 0 60 120

SCALE IN FEET

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

SHEET TITLE: ALTERNATIVE B-4 SOIL DISPOSAL WITH CAPPING, SOIL AMENDMENTS, AND REVEGETATION

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 4

LEGEND

EXISTING CONTOURS

PROPOSED CONTOURS

EXCAVATION CUT/FILL		
CUT (CU.YD.)	FILL (CU.YD.)	TOTAL (CU.YD.)
2235	653	1582 (CUT)

N

40 0 40 80

SCALE IN FEET

HDR

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

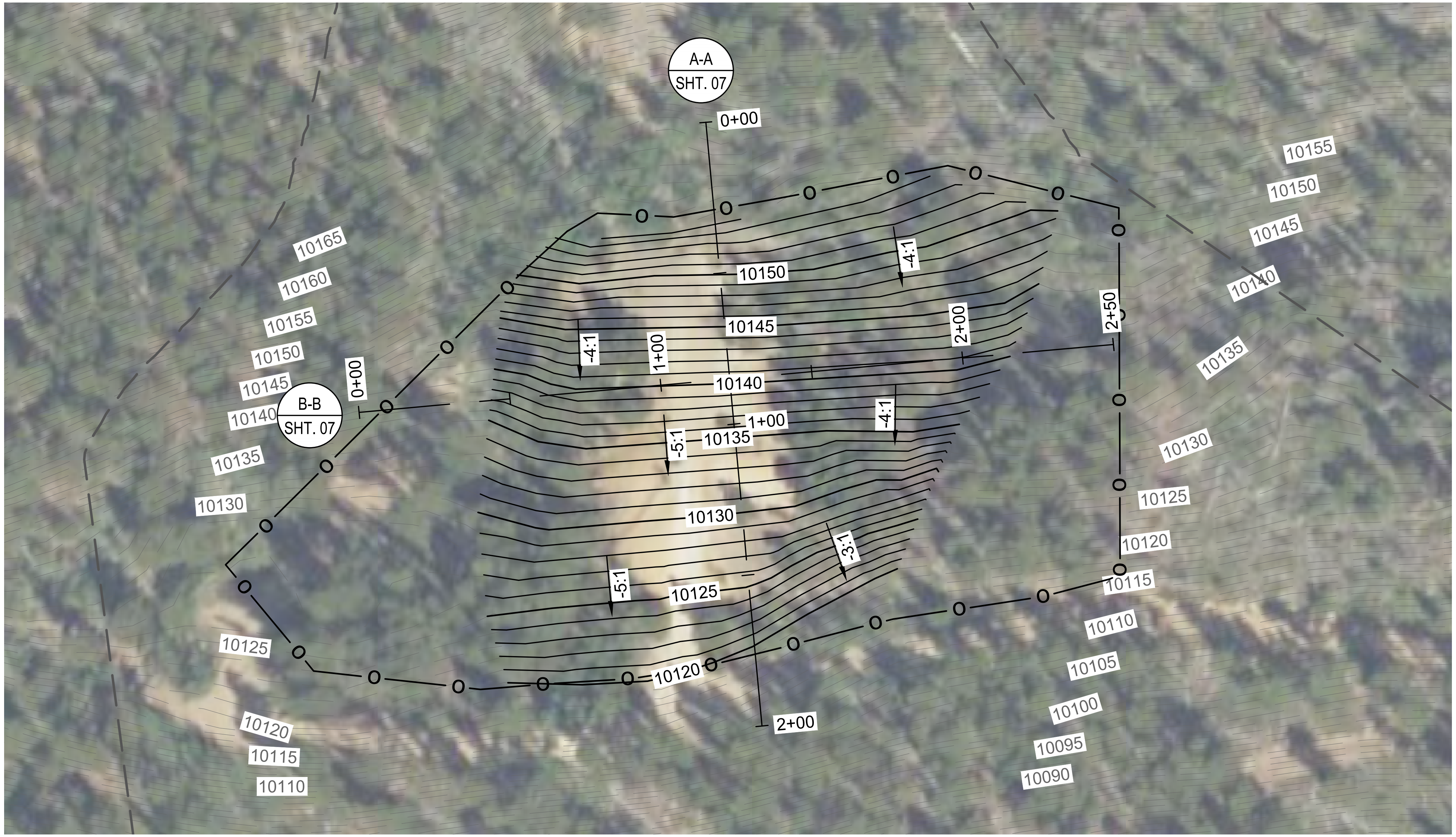
SHEET TITLE: ALTERNATIVE B-3 EXCAVATION PLAN

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 5



LEGEND

EXISTING CONTOURS

PROPOSED CONTOURS

STABILIZATION CUT/FILL			
	CUT (CU.YD.)	FILL (CU.YD.)	TOTAL (CU.YD.)
STABILIZATION	-	692	692 (FILL)

40 0 40 80
SCALE IN FEET

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

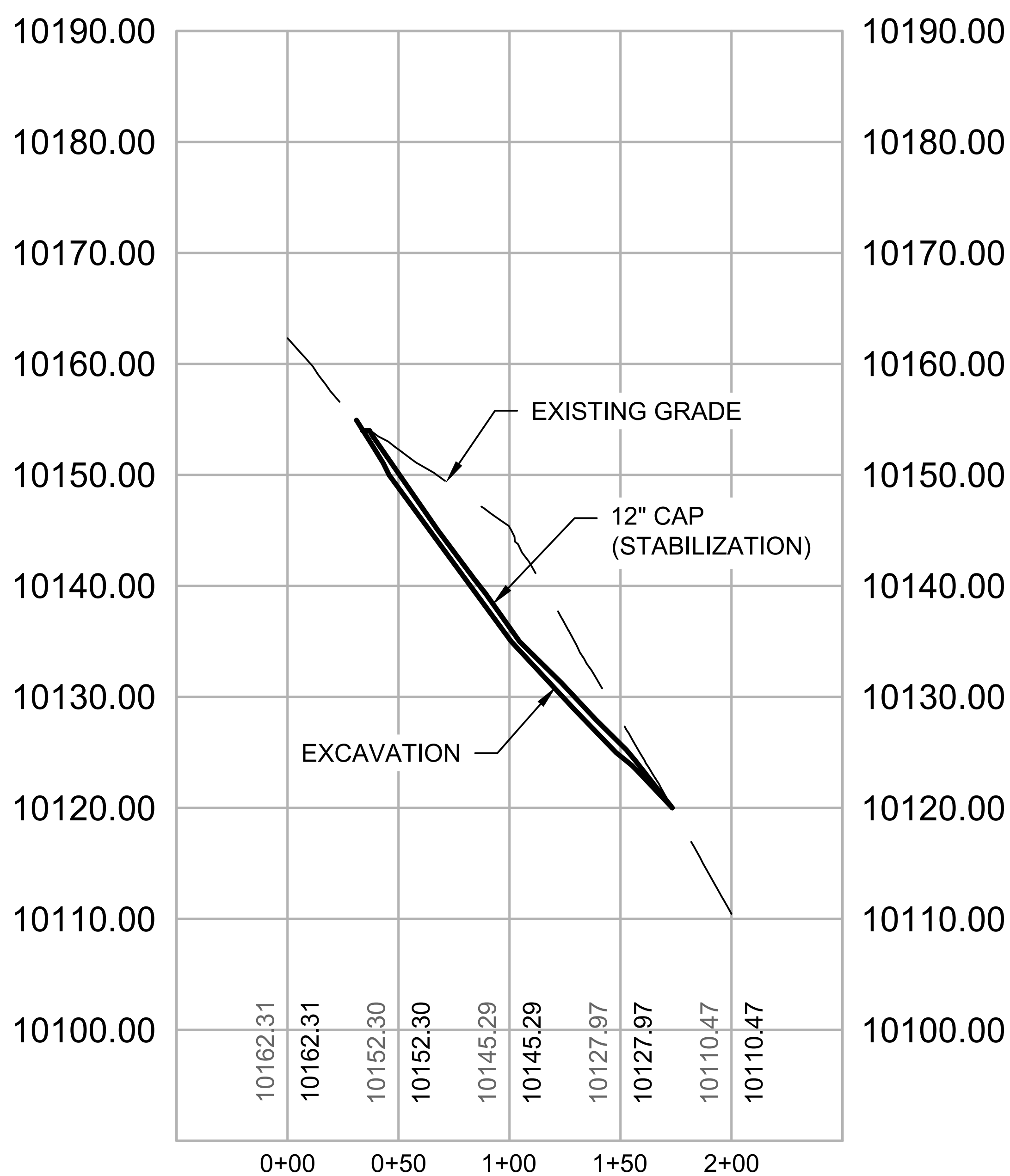
SHEET TITLE: ALTERNATIVE B-3 FILL PLAN

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

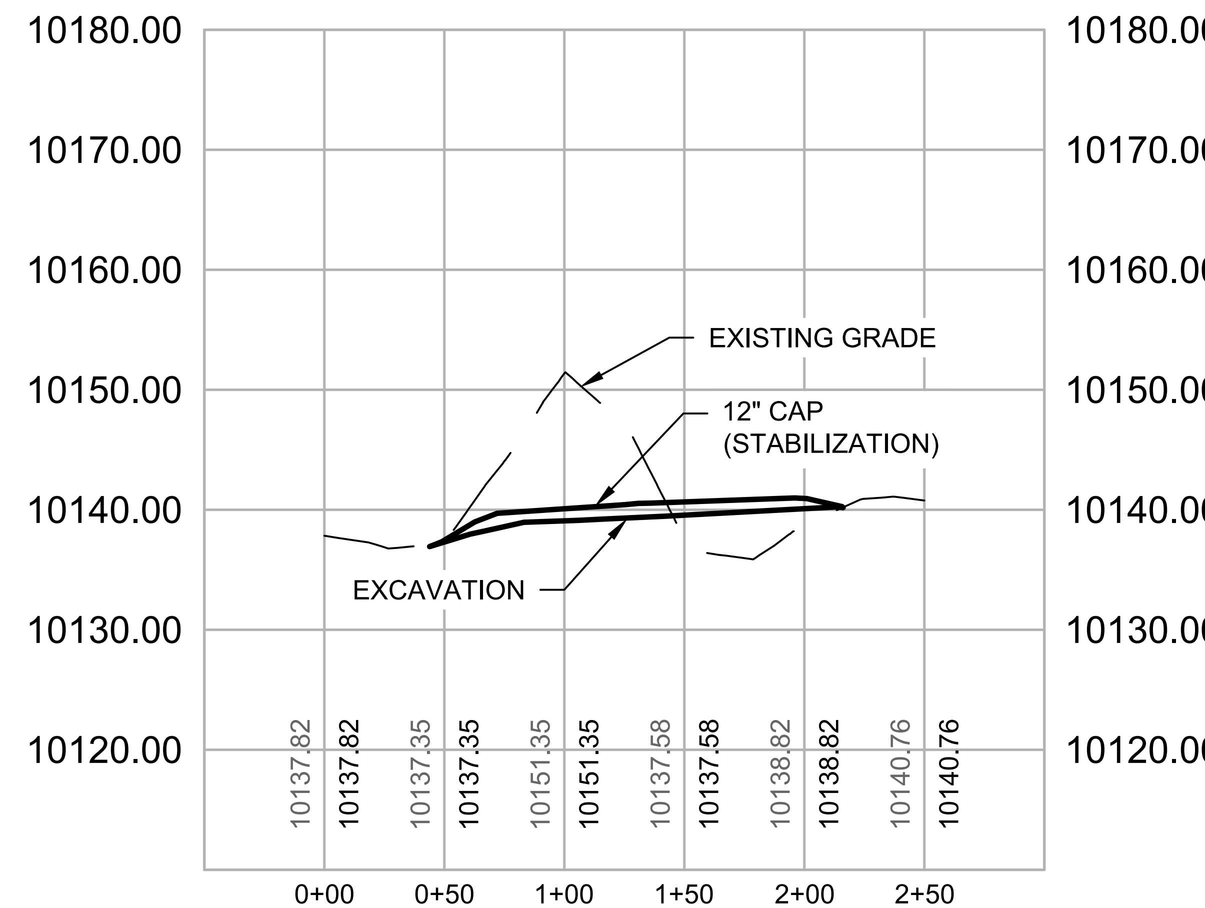
SHEET NO. 6



A-A
SHT. 5-6

SECTION A-A

VERTICAL: 1" = 80'
HORIZONTAL: 1" = 16'



B-B
SHT. 5-6

SECTION B-B

VERTICAL: 1" = 80'
HORIZONTAL: 1" = 16'

N

80 0 80 160
SCALE IN FEET

PROJECT TITLE: UNNAMED BARD CREEK MINE EE/CA

SHEET TITLE: ALTERNATIVE B-3 STABILIZATION PROFILES

PROJECT NUMBER: 10456964

PROJECT MANAGER: BRAD WOODARD

DATE: 06/2026

SHEET NO. 7

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