US Army Corps of Engineers
New England District

Engineering Evaluation/Cost Analysis (EE/CA)

Elizabeth Mine Strafford and Thetford, Vermont

Draft Report

Draft Report Prepared for

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

25 September 2001

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

Contract No. DACW33-00-D-0002
Task Order 0002

Arthur D. Little Reference 70939

Arthur D Little

Table of Contents

Page

Table of Contents

Page

Table of Contents

Page

Table of Contents

Page

List of Tables

Table of Contents

Page

List of Figures

List of Appendices

List of Acronyms

AIME	American Institute of Mining, Metallurgical and Petroleum Engineers
ALDs	Anoxic Limestone Drains
AMD	Acid Mine Drainage
ANR	Vermont Agency of Natural Resources
APE	Area of Potential Effects
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
AVS/SEM	Acid Volatile Sulfide/Simultaneously Extracted Metals
BERA	Baseline Ecological Risk Assessment
BNA	Base Neutral Acids
BOD	Biological Oxygen Demand
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CLP	Contract Laboratory Program
COCs	Contaminants of Concern
COSOM	Colorado School of Mines
CN	Cyanide
CSFS	Cancer Slope Factors
CWA	Clean Water Act
EBOR	East Branch Ompompanoosuc River
EE/CA	Engineering Evaluation/Cost Analysis
EMCAG	Elizabeth Mine Community Advisory Group
EMSG	Elizabeth Mine Study Group
EPA	United States Environmental Protection Agency
ET	Evapotranspiration
FS	Factor of Safety
HHRA	Human Health Risk Assessment
HIs	Hazard Indices
HNU	Photoionization Detector (Brand Name)
HQs	Hazard Quotients
HRT	Hydraulic Retention Time
IBI	Index of Biotic Integrity
MCL	Maximum Contaminant Level
MOA	Memorandum of Agreement
NCP	National Contingency Plan
NH_3	Ammonia
NHPA	National Historic Preservation Act
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NTCRA	Non-Time Critical Removal Action
O&M	Operation And Maintenance
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyls

PRSC	Post Removal Site Control
PVC	Polyvinyl Chloride
RCC	Roller Compacted Concrete
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation And Feasibility Study
SAPS	Successive Alkalinity Producing Systems
SHPO	State Historic Preservation Officer
SMRCA	The Surface Mining Control and Reclamation Act
SVOCs	Semivolatile Organic Compounds
TBC	To-be-considered
TCLP	Toxic Compound Leach Procedure
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP-1	Tailings Pile 1
TP-2	Tailings Pile 2
TP-3	Tailings Pile 3
TSS	Total Suspended Solids
VHA	Vermont Health Advisory
VLDPE	Very Low-Density Polyethylene
VOCs	Volatile Organic Compounds
VTAEC	Vermont Agency of Environmental Conservation
VTDEC	Vermont Department Environmental Conservation
VTWQS	Vermont Water Quality Standards
WBOR	West Branch Ompompanoosuc River
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Survey
USGS	United States Geological Survey
XRD	X-ray Diffraction

Executive Summary

1.0 Introduction

1.1 Purpose and Scope

This Engineering Evaluation/Cost Analysis (EE/CA) was prepared by Arthur D. Little (ADL) for the U.S. Environmental Protection Agency (EPA) pursuant to an interagency agreement with the U.S Army Corps of Engineers (USACE), New England District to support a Non-Time-Critical Removal Action (NTCRA) at the Elizabeth Mine Site in Strafford and Thetford, Vermont. EPA is the lead federal agency at the Elizabeth Mine Site. Investigations at the Site have identified conditions that correspond to factors in Section 300.415(b)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 C.F.R. 300.415). These conditions indicate that a NTCRA may be necessary to abate, prevent, minimize, stabilize, mitigate, or eliminate threats to human health and the environment.

The EPA has categorized three types of removal actions: emergency, time critical, and non-time-critical. These designations are based on the urgency with which cleanup must be initiated to respond to a threat to human health and the environment posed by a release or potential release of hazardous substances. Emergency and time-critical removal actions are initiated to respond to a release or potential release where less than six months is available for planning the response. In cases where more than six months are available for planning a response to a release or potential release, Section 300.415(b)(4)(I) of the NCP requires the development of an EE/CA along with a public comment period, prior to the signing of the Action Memorandum, to initiate the NTCRA. In February 2000, EPA signed an Approval Memorandum (Appendix A) authorizing the preparation of this EE/CA for the Elizabeth Mine Site. The Approval Memorandum is the first step in the NTCRA process.

The EE/CA for the Elizabeth Mine identifies removal action objectives for protection of human health and the environment, identifies removal action alternatives, and assesses the effectiveness, implementability, and cost of the alternatives that satisfy the removal action objectives. The EE/CA considers the nature of the contamination, any potential risks to human health and the environment, and how the alternatives fit into the overall strategy for site remediation.

The scope of the Elizabeth Mine NTCRA addresses the waste material deposited at the surface of the Site from historic mining and milling operations prior to 1958, including three tailings and mine waste piles (TP-1, TP-2, and TP-3) and the tailings that have eroded off the slope of TP-1. By addressing this source material, the creation and migration of acid mine drainage (AMD) from most of the Site will be eliminated. The NTCRA scope is consistent with the long-term remediation goals of the Site to be addressed during the Remedial Investigation/Feasibility Study (RI/FS) phase.

1.2 Report Organization

This report is organized into six sections:

- Section 1.0: Introduction
- Section 2.0: Identification of Removal Action Scope and Objectives
- Section 3.0: Development of Removal Action Alternatives
- Section 4.0: Analysis of Removal Action Alternatives
- Section 5.0: Comparative Analysis of Removal Action Alternatives
- Section 6.0: References

1.3 Site Description

The Elizabeth Mine is located in the Strafford Quadrangle in east-central Vermont, approximately 1.9 miles southeast of the village of South Strafford, on the eastern flank of Copperas Hill. The mine site is positioned on the Strafford/Thetford town line at Latitude 43.8239 and Longitude 72.3289 (see Figure 1-1).

Historic property boundaries, as determined for the National Register of Historic Places and as accepted by the Vermont State Historic Preservation Officer (SHPO), are inclusive of copperas- and copper-mining landscapes formed during the late-eighteenth to mid-twentieth centuries. Historic and archaeological resources, which include ore extraction and processing sites, support infrastructure, and waste deposits, are distributed over approximately 500 acres, extending from Copperas Hill northeast to the West Branch of the Ompompanoosuc River (WBOR) and southward to Lord Brook.

The boundaries of the Superfund Site (herein referred to as the “Elizabeth Mine Site” or “Site”) include those portions of the historic property that will be directly and indirectly impacted by environmental remediation. Areas of direct impact include mine waste deposits (TP-1, TP-2, and TP-3) and areas favored under some options for the installation of treatment systems. Indirect effects include potential impacts during the NTCRA to all other areas of the historic property. Indirect affects for the historic property, as well as potential direct impacts to an area identified as the “South Mine”, are not included in the scope of this EE/CA, and will be addressed in forthcoming reports.

1.3.1 Historical Summary and Statement of Significance

The Elizabeth Mine massive sulfide ore body was discovered along a ridge located southeast of South Strafford village in 1793. The mine was initially worked for the sulfide mineral pyrrhotite to manufacture copperas, an iron sulfate, used for a variety of purposes, including dye and disinfectant manufacturing. In 1830, Strafford Copper Works was formed to exploit the Site for copper. During the early mining operations, copper was smelted on-site. Underground mining began in the early to mid-1800s. The mine was worked intermittently from 1830 until 1930 when it closed. In 1942, the mine reopened in response to World War II and was operated by Vermont Copper Company.

Most of the underground copper mining occurred between 1942 and the mine's final closure in 1958.

Following the end of mining operations in 1958, the mine property was divided into two parcels and sold. A 400-acre tract, including the 1940s and 1950s-era buildings and TP-1 and TP-2, was purchased by Leonard Cook in the early 1960s and used for storage of construction business equipment. In the 1970s, Mr. Cook auctioned all but 67 acres of the property. Two areas of the Site were used for gravel and soil extraction. The Site is no longer being used for commercial purposes. The town-maintained road that runs through TP-3 is used for logging access, walking, biking, and other forms of recreation.

The tailings material in TP-1 and TP-2 was generated through the milling of sulfide ores between 1942 and 1958. A sulfide flotation mill was constructed during this period, where the ore was refined and the resulting concentrate was shipped to off-site smelters. The flotation mill allowed for efficient recovery of minerals from ore with small percentages of copper. In the flotation circuit, fine-grained particles of the copper-bearing mineral chalcopyrite were extracted. The remaining material was pumped to settling ponds, resulting in the formation of the tailings piles. Today, an orange iron-oxide rich "rind" covers the surface of TP-1 and TP-2 to a depth of one to two feet below the tailings surface. Below this oxidized cap, a uniform layer of black sulfide-rich tailings (anoxic) extends to the base of each pile.

The waste rock and "heap leach" piles situated to the northeast of the North Cut are referred to as TP-3. Colorful piles of variably pyrolyzed sulfide ore are present over an area of approximately 12 acres. These residues are a result of the production of copperas (iron sulfate) throughout the 1800s. Waste sulfides from the late 1800s are situated in the upper-most part of the watershed and cover portions of the copperas wastes. Adjacent to the open North Cut, especially toward the southern end of the cut, low-sulfide content waste rock piles are mixed in with the sulfides used for copperas production. This material appears to have resulted from slope-stabilization cutbacks in the North Cut during the mid to late 1800s.

In-depth and further discussions of the mine history can be found in the following reports prepared by Arthur D. Little, Inc. (ADL) and their subcontractors:

- *Statement of Site Limits, National Register Eligibility, and Potential Resources in the Proposed APE: Elizabeth Mine, South Strafford, Vermont*. Hartgen Archeological Associates, October 2000.
- *Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine.* Public Archeology Laboratory and Arthur D. Little, Inc. May 2001.
- *Elizabeth Mine Site Summary Report.* Arthur D. Little, Inc., October 2000.
- *Elizabeth Mine Site Conditions Report*. Arthur D. Little, Inc., February 2001.
- *Elizabeth Mine Environmental Response Alternatives Analysis Report*. Arthur D. Little, Inc., April 2001.

The Elizabeth Mine is a significant historic resource on local, state, and national scales. The Site embodies the distinctive landscape, engineering, and architectural resources that are characteristic of an early nineteenth- to mid-twentieth-century American metal mining and processing site. The Site constitutes one of the largest and most intact historic mining sites in New England and includes the only intact cluster of hard-rock mining buildings in the region.

Historically, the Elizabeth Mine was the site of a major nineteenth century U.S. copperas manufacturing plant and is associated with successful patents for copperas production. It is also associated with a number of significant commercial, scientific, and political figures, including Isaac Tyson, Jr., a Baltimore, Maryland-based chemical and mining figure who was recently inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers' (AIME) Mining Hall of Fame.

EPA has determined the Elizabeth Mine Site to be eligible for listing on the National Register of Historic Places. EPA will comply with the National Historic Preservation Act (NHPA) as part of any undertaking to address environmental pollution. In accordance with the NHPA, EPA will fully evaluate measures to avoid and/or minimize impacts to historic properties and features of the Site. If impacts are unavoidable and necessary to perform the cleanup, then EPA will enter into a Memorandum of Agreement (MOA) with the appropriate parties to outline actions to avoid, minimize, or mitigate adverse effects to the historic properties.

1.3.2 Surficial and Bedrock Geology

The Elizabeth Mine Site is located approximately 10 miles west of the Connecticut River. The surficial material in the region can largely be attributed to its glacial history, giving rise to the three principal surface overburden units present in the area. The units consist of a dense glacial basal till (resting on bedrock), locally overlain with a sand and gravel outwash deposit. Both deposits are overlain by thin Quaternary alluvium (sand and gravel) in drainage channels. Each unit varies in thickness and distribution. The North Open Cut and three tailing piles (TP-1, TP-2, and TP-3) are situated on the east flank of Copperas Hill, between the elevations of 850 (base of TP-1) and 1,400 feet above sea level (North Mine Cut).

Directly underlying TP-1 and TP-2 is a thin layer of gravel/sand/debris representing the pre-tailings ground surface. This thin, water-bearing horizon appears to be no more than two to three feet in thickness. Directly under this horizon is a glacial basal till sequence, measuring as much as 75 feet in thickness. The basal till rests directly on crystalline bedrock. Core samples of the till indicate that it is highly compact, dry, and comprised of rock fragments in a clay/silt matrix. TP-3 waste rock material and copperas production materials are directly underlain by crystalline bedrock.

The headwaters of the West Branch of the Ompompanoosuc River (WBOR) are underlain in part by the Devonian Waits River Formation, consisting of metamorphosed calcareous shales, and minor quartzite, limestone, and dolostone, as well as the

Devonian Standing Pond Volcanics, comprised of metamorphosed basalts. The West Branch flows through the Devonian Gile Mountain Formation, the host rock of the sulfide deposit, which consists of metamorphosed black shales and graywackes, with lesser metamorphosed sandstones, calcareous shales, and diabase (Slack, 1993). The high hardness values and alkalinity observed in the surface waters of the WBOR can be attributed to the calcareous nature of the rock units upstream of the mine Site.

The massive sulfide deposit at the Elizabeth Mine consists of a series of narrow, tabular ore shoots, dipping steeply to the east, plunging to the north, and extending intermittently over a strike length of more than a mile in a north-south direction. The deposit is characterized as a “Besshi-Type” massive sulfide, comprised largely of pyrrhotite with minor concentrations of chalcopyrite (copper-iron sulfide, 2-5%), and pyrite (iron sulfide). Similar deposits include Ducktown, Tennessee, Fontana, and Hazel Creek mines, North Carolina, and the Windy Craggy deposits in British Columbia, Canada. The sulfide minerals were originally deposited in a deep-sea fumarolic setting, within a mixed sediment and volcanic depositional environment. Mid- to Early Paleozoic metamorphism of the sedimentary sequence resulted in a complex structural setting, where the original units have been tightly folded and overturned, and the sulfide minerals have been remobilized to the hinge zones of the dominant north-south (axis) folds. Within Vermont, massive sulfide deposits similar to those found at Elizabeth Mine also occur at Pike Hill and at the Ely Mine. These three deposits, as well as several smaller deposits/prospects, are referred to as the Vermont Copper Belt.

1.3.3 Climate

The Elizabeth Mine is situated in east-central Vermont, east of the Green Mountains and west of the White Mountains of New Hampshire. The climate in this region is variable, with a large range of diurnal and annual temperatures and significant differences between the same seasons from year to year. Annual precipitation (snow and rain) averages 35 inches, as measured at the nearby Union Village Dam. Average snow accumulation is typically ranges from 3 to 5 feet.

1.4 Previous Removal Actions

1.4.1 Previous EPA Cleanup Actions

There have been no previous EPA cleanup actions at the Site.

1.4.2 Response Actions by the State of Vermont or Federal Agencies

In 1988, the U.S. Army Corp of Engineers (USACE) discovered four large transformers in the TP-2 area that appeared to be leaking. USACE notified the Vermont Department of Environmental Conservation (VTDEC) of the transformers for follow-up investigation. The mine owner claimed that equipment at the mine belonged to the former mine owners and that the transformers had been on the property since 1946. The owner pointed out the presence of 12 smaller transformers in one of the mine buildings. USACE discovered 16 additional smaller transformers in the compressor building. In November 1991, VTDEC sampled the transformers for polychlorinated biphenyls

(PCBs). The analytical results indicated that one transformer contained over one gallon of PCB oils. In February 1992, the owner was requested under Title 10 V.S.A. Section 1283 to remove the oil for proper disposal. In March 1992, the owner notified the VTDEC that he had complied with the removal order.

In July 1989, it was discovered that the mine was being used as an illegal dumpsite for out-of-state construction/demolition debris and possibly for industrial/domestic sewage sludge. The dumpsite was located in the central portion of TP-1. Excavation pits were dug in the dump area to determine if hazardous wastes were present. During excavation, soils were analyzed with a photoionization detector and samples of a sludge-like material were collected by VTDEC for analysis. The only metals detected above the method detection limits were lead (250 ppb) and zinc (8,400 ppb). No semivolatile organic compounds (SVOCs) were identified by Method 8270 analysis. A total of nine VOCs were identified by Method 8240 analysis. Two compounds present in the sample were acetone (17 ppb) and an unknown phthalate ester (40 ppb). The sludge and debris were left in-place and the excavated soil back-filled. No removal actions were undertaken. The owner subsequently covered portions of TP-1 (up to 60%) with a thin soil cover. Indigenous species of grass and acid-tolerant trees and shrubs have established themselves on the soil cover.

1.5 Previous Investigations

The Site Summary Report (ADL, 2000) and Site Conditions Report (ADL, Feb. 2001) both contain a summary of the surface water investigations conducted by EPA and the associated data collected prior to EPA involvement in 2000. An assessment of the quality and usability of the data collected prior to EPA involvement has not been performed; these data therefore must be considered qualitative and of unknown reliability. Data collected by Arthur D. Little, Inc. for EPA are presented in the following reports: *Site Conditions Report (ADL, 2001a)*, *Summary of Preliminary Ecological and Human Health Risk Evaluations (ADL, 2001b)*, and *Alternatives Analysis Report (ADL, 2001c).*

EPA has collected surface water samples at a total of 46 locations throughout the Elizabeth Mine area. Surface water sampling is summarized in the table below.

Sampling Event	Description of Event	Number of Occurrences
Weekly	April – May 2000: Weekly stream sampling at six locations to evaluate spring runoff metals and pH loading	5
Monthly	April, May, Oct. – Dec. 2000: Monthly sampling – subset of locations	6
Synoptic – all stations	June, July, September 2000 - All locations	3
Episodic (Storm Event)	June and July 2000 – Locations 2,6,7,8,13,16	2

The number of locations and analyses varied between sampling events as the program was refined and as data gaps were identified, as described below:

- April 2000: a subset of 17 locations was sampled for total metals, alkalinity, total suspended solids (TSS), total dissolved solids (TDS), and hardness.
- May 2000: 45 locations were sampled for total metals, dissolved metals, alkalinity, TSS, TDS, hardness, total organic carbon (TOC), acidity and cyanide (CN), while a subset of nine locations were sampled for biological oxygen demand (BOD), and ammonia (NH_3).
- June 2000: 32 locations were sampled for total metals, alkalinity, TSS, TDS, hardness, and acidity (lab sample handling errors resulted in a lack of confidence for several June-event samples).
- July 2000: 46 locations were sampled for total and dissolved metals and cyanide, while 41 locations were sampled for alkalinity and anions (negatively charged ions), 42 sampled for hardness, 11 sampled for BOD, Total Kjeldahl Nitrogen (TKN), and NH_3 , and 10 were sampled for volatile organic compounds (VOCs), polychlorinated organic compounds (PCBs), pesticides, and Base Neutral Acids (BNA).
- September 2000: 49 locations were sampled for total and dissolved metals 35 locations for alkalinity, 34 locations for hardness and acidity, 13 locations for CN, and five locations for BOD, TKN, and $NH_{3.}$
- December 2000: 17 locations were sampled for total metals and hardness.

Surface water and sediment sampling continued into 2001, with sampling of surface water during spring 2001 by the United States Geological Survey (USGS) for EPA and additional sampling by ADL in May and September 2001. The September 2001 surface water sampling effort was conducted at the same time as a comprehensive fish sampling program organized by VTDEC and the USACE. Sediment samples were also collected as part of the September 2001 event.

Previous investigations by the State of Vermont, federal agencies, or local organizations include the following:

- The Vermont Agency of Environmental Conservation (1977) sampled 10 locations spaced above, around, and below TP-1, as well as on the Ompompanoosuc River, for analysis of 10 metals.
- Colorado School of Mines (COSOM, 1984) sampled 16 locations around the Site and in the Ompompanoosuc River at the Union Village Dam. Samples were analyzed for metals plus pH.
- USACE generated a report in 1984 entitled, "Union Village Dam Water Quality Evaluation Update," Army Corps of Engineers Hydraulics and Water Quality Section, Water Control Branch, Engineering Division. This report provided surface water sample results from 1971 through 1983 for five stations on the Ompompanoosuc River. The primary metals of concern were copper, aluminum, iron, cadmium, mercury, and zinc.

- In August of 1990, the Vermont Agency of Natural Resources (VTANR, 1990) sampled surface water for a core group of metals plus pH at three locations:
  - SW-1 - Between TP-2 and TP-3
  - SW-2 - Background stream that flows in from east
  - SW-3 - Copperas Brook before confluence with the WBOR
  - GW-3 - Air Vent
- During April and August of 1998, approximately 35 locations were sampled by the USGS around the Elizabeth Mine Site as well as locations upstream and downstream on the Ompompanoosuc River (USGS, 1998). Most of these locations were in and around TP-1. This study included an extensive list of metals (about 60) as well as water quality parameters.
- The Elizabeth Mine Study Group (EMSG, 1999), along with Step by Step, Inc. and Damariscotta, sampled locations for a core group of metals and pH at three locations:
  - H1 - Drainage pipe at eastern corner of TP-1
  - H2 - Western tributary to Copperas Brook below TP-1
  - H3 - Between TP-2 and TP-3

1.6 Source, Nature, and Extent of Contamination

A number of distinct contaminant source areas have been identified at the Elizabeth Mine Site. The three tailing and mine waste piles located in the Copperas Brook watershed are source areas 1 through 3:

- TP-1 – 30 acre area
- TP-2 – 5 acre area
- TP-3 – 12 acre area

A fourth contaminant source area is a continuous discharge of ground water from the underground workings, referred to as the "Air Vent". The Air Vent connects the underground workings (200 feet below the ground surface) with the surface at a location nearly 1 mile north of the main open cuts, adjacent to the WBOR. The fifth and sixth identified source areas are the historic South Cut and the South Mine waste rock pile, each located south of the North Cut and situated along the crest of Copperas Hill ridge. This report addresses contamination associated with TP-1, TP-2, and TP-3. The Air Vent, South Mine, and South Cut sources, as well as any other potential source areas, will be addressed as part of the remedial investigation and feasibility study (RI/FS).

1.6.1 Tailings and Waste Rock

The principal tailings piles located at the Site (TP-1 and TP-2) were generated through sulfide ore milling operations through the 1940s and 1950s. These two waste piles are wedge-shaped, with the thickest sections situated along the down-slope, north-facing sides. TP-1 is approximately 30 acres in area, and has a maximum thickness of approximately 110 feet; TP-2 is approximately five acres in area and has a maximum thickness of approximately 35 feet. Directly underlying TP-1 and TP-2 is the thin layer of gravel and debris from the pre-tailings ground surface.

TP-1 and TP-2 are composed of crushed and processed ore that is a fine sand/silt-sized material. The minerals jarosite and goethite dominate the oxidized surface of the tailings. During July/August 2000, samples of the upper oxidized material were collected and analyzed for metals concentrations and for grain-size distribution by the USGS. Fine-grained sand constitutes more than 50% (by weight) of the surface material in the areas surrounding piezometers #4 and #5 (see Figure 1-2 for the piezometer locations and particle size analysis results). Below this oxidized zone, the tailings consist of a tightly-compacted black anoxic silt/fine sand. There appears to be some (minor) vertical differentiation throughout the pile, with a thin clay-rich accumulation layer in several borings at a depth of several inches to one foot below the tailings surface.

TP-1 and TP-2 are representative of a class of tailings impoundments described by Davies and Martin (2000) as “upstream tailings dams” The tailings impoundments started with an earthen dam constructed at the toe of the impoundment and tailings were deposited from down-slope (downstream) to up-slope (upstream). This approach resulted in wedge-shaped tailings pile, where the down-slope edge is topographically higher than the up-slope edge. By depositing tailings slurry from the down-slope side, coarser sandy material created a dry beach at the down-slope edge and finer materials were transported by gravity and deposited in a settling pond within the upstream interior of the pile. Today, a decant tower for the interior settling pond can be observed on the surface of TP-1. The decant tower and drainage system for TP-2 has collapsed and eroded.

A volume analysis of TP-1 and TP-2 was completed by comparing the 1896 USGS topographic data to the recent (spring 2000) topographic surveys. The 1896 data was calibrated using the borehole information as a guide. From this analysis, the total volume of the combined TP-1 and TP-2 was calculated to be approximately two million cubic yards.

TP-3 has a very irregular surface, with thickness ranging from several feet to more than 40 feet. TP-3 is divided into several subareas on the basis of historic operations and the relative percent of unoxidized sulfide material present. Colorful piles of variably pyrolyzed sulfide ore are present over an area of approximately six acres in the center of TP-3, representing “heap leach” residues from the production of copperas (iron sulfate) throughout the 1800s. Bright orange-red hematite-rich piles represent thoroughly pyrolyzed massive sulfide. Yellow limonite and jarosite-rich rock represents waste material (deposited on top of the copperas heap leach piles) from later phases of copper mining. Adjacent to the North Cut, especially toward the southern end of the cut, low-sulfide content waste rock piles are mixed in with the sulfides used for copperas production. Given the nature of the materials present, TP-3 should not be referred to as “tailings”; however, the TP-3 nomenclature has meaning to most local citizens and site investigators. Therefore, for consistency, this area will be referred to as TP-3 in this report.

The USGS sampled and analyzed portions of TP-3 in 1998 (Hammarstrom, 1999). The USGS divided TP-3 into six subareas (A-F) based on differences in surface color and texture (see Figure 1-3 for the subareas defined by the USGS). Paste pH composite samples were measured in the field, and samples were analyzed for mineralogy and chemistry. Physical characteristics, paste pH and dominant minerals determined by x-ray diffraction (XRD) are listed in Table 1-1. Colors were determined on dry materials by comparison with Munsell soil color charts. These data show that the red piles of the old (copperas) workings (TP-3) are hematite-rich and have slightly higher paste pH values than the adjacent jarosite-rich piles. Weathered ore and waste-rock litters the upper parts of TP-3. After periods of dry weather, white coatings of efflorescent iron sulfate salts cover sulfide-rich cobbles and boulders, creating a “snowball” appearance. The minerals melanterite and rozenite (copper/iron/aluminum salts) wash away with each rainstorm event. The mineralogy and spatial distribution of minerals in TP-3 are important from the standpoint of acid-generation potential. Detailed mapping and analysis of acid-generation potential across TP-3 will be accomplished during the RI/FS.

Selected metal concentrations from chemical analysis of the USGS samples are listed in Table 1-2 along with reference soil values (mean concentrations of elements in eastern U.S. soils). Analytical methods and detection limits are given in Hammarstrom (1999). Hammarstrom (2000) noted that these data lead to several conclusions that should be factored into remedial plans:

- Copper and zinc concentrations in all types of mine waste on the Site are elevated and exceed critical values for acute toxicity for plants; these elevated metal concentrations and the acidity of the surface material probably account for the lack of success of revegetation (planted by volunteers) and the stunted appearance of the vegetation that has established itself on parts of the flat tops of TP-1 and TP-2.
- Metal concentrations in the older waste piles (TP-3) are an order of magnitude (ten times) higher than in TP-1 and TP-2.
- A number of potentially toxic metals, such as mercury, lead, cadmium, and arsenic are present (generally at low concentrations) in waste materials at the Site.

1.6.2 Soil Contamination

Surface soil samples were collected from three residences located along Mine Road near the Elizabeth Mine Site in July and November 2000. Each sample was analyzed for metals through the EPA Contract Laboratory Program (CLP). Sample analytical results are provided in Table 1-3, along with risk-based concentrations from several sources and local surface soil background data provided by EPA. The soil data revealed a few instances where levels of iron, lead, and thallium warrant further study as part of the RI/FS for the site, because levels were greater than background. The concentrations of these contaminants were not at levels considered to represent an acute (short-term) hazard. The Agency for Toxic Substances and Disease Registry (ATSDR) confirmed EPA's assessment that the residential soil data do not indicate any current risks that would warrant immediate EPA action. All of the soil data has been transmitted to the residents and the Vermont Department of Public Health. A more detailed evaluation of the soil data will be presented in the Baseline Human Health Risk Assessment, prepared as part of the RI/FS.

1.6.3 Ground Water Contamination

Ground water studies to date are limited to samples from residential wells along Mine Road and water level measurements from piezometers within and adjacent to the tailings piles. Ground water quality information is available from 9 residential wells located along Mine Road, west of TP-1 and TP-2 (EPA 2000 and 2001 sampling program). The concentrations of chemicals detected in drinking water are compared with the health-based primary Maximum Contaminant Levels (MCLs), secondary MCLs (EPA, 1991, 1992), and with the Vermont Health Advisories (VHAs) (VT Department of Health, 1998) in Table 1-4. Figure 1-4 shows the residential locations in relation to the tailings piles.

Drinking water from one former residence, situated at the edge of TP-3, exceeded criteria for copper, cadmium, aluminum, and sulfates. The resident re-located and the well is no longer used. None of the other residential wells sampled, nor the monitoring well installed adjacent to TP-3 indicate an adverse impact to groundwater by the mine.

To evaluate the nature of ground water flow within the tailings, nine piezometers were installed through the tailings in July/August 2000. The piezometers were developed and allowed to equilibrate with local pore pressures. Monthly piezometer monitoring data (piezometric head) were collected for both the tailings and the till (see Figures 1-5 and 1-6). The measurements collected to date reflect summer, fall, and winter conditions. Ground water elevations did not fluctuate significantly between the sampling events, suggesting a hydraulic dampening effect within the tailings that masks the impact of individual storm events. More data is needed to evaluate the seasonal impact on the ground water from precipitation and infiltration, particularly in the spring.

Measurements within and below TP-1 and TP-2 indicate that ground water flow is toward the north-northwest, generally following the pre-tailings surface topography (see Figure 1-7). Nested piezometer couplets indicate that there is a slight downward vertical gradient throughout TP-1 and TP-2. Hydraulic conductivity and porosity have not been determined at this point. The information gathered to date indicates that the basal till underlying TP-1 and TP-2 is a low-yield, nearly impervious geologic material of considerable thickness overlying bedrock. The thin, irregular water-bearing unit between the tailings and till does not appear to be a significant ground water resource, but it may be a preferred hydraulic pathway for minor lateral flow and recharge to the base of the tailings. The downward vertical gradient present during the summer, fall, and winter months suggests, however, that any recharge to the tailings from below is limited.

Recharge of ground water within the tailings material in TP-1 and TP-2 is largely influenced by surface water infiltration. At present, ground water infiltration and transport related to the decant tower and the geologic units below the tailings is not well documented. Further investigation is necessary to evaluate the significance of these features. Several ground water seeps are observed (year-round) at the toe of TP-1, with fewer seeps at the toe of TP-2. Individual seep flow is as much as 15 to 20 gallons per minute. Flow rates for most seeps do not appear to vary significantly on a seasonal basis, suggesting that the tailings pile "dampens" any seasonal or episodic rain or snowmelt event.

A concrete diversion culvert, once situated below TP-2, has completely eroded, resulting in direct discharge of the upper reach of Copperas Brook onto the surface of TP-1. This has resulted in a year-round surface pond, measuring one to two acres, on the top of TP-1. A similar concrete decant tower remains in place below TP-1, to channel Copperas Brook flow from the pond back into the natural drainage channel at the foot of TP-1.

A piezometer situated in TP-3 indicates the presence of a near surface unconfined water-bearing horizon above the bedrock and a second saturated zone within the highly fractured bedrock. Depth to bedrock at TP-3 is approximately 12 feet below ground surface. The piezometer (nested-pair, representing different hydraulic zones) indicates that a significant upward vertical gradient is present between the two water-bearing zones in this area. Recharge to the bedrock aquifer is likely through a combination of precipitation/infiltration and flooded underground workings. The horizontal gradient in the TP-3 area, while not known at this time, is likely significant and follows the natural topography.

1.6.4 Surface Water and Sediment Contamination

To assess the extent of environmental impact from the Elizabeth Mine, EPA collected surface water and sediment samples throughout the Elizabeth Mine area, within the WBOR watershed. Sample locations are broadly divided into the following nine groupings (See Figure 1-8 and Tables 1-5 and 1-6):

- *WBOR upstream of Mixing Zone* includes the WBOR upstream from the Air Vent and Copperas Brook
- *Unaffected tributaries to the WBOR* include Sargent Brook, Abbott Brook, Fulton Brook, Jackson Brook, Bloody Brook, and lower Lord Brook
- *Air Vent Mixing Zone* includes locations within the WBOR between the Air Vent and the confluence with Copperas Brook – approximately 2,500 feet in length
- *Contamination Source Areas* includes location within the Copperas Brook watershed and the Air Vent prior to discharge into the WBOR
- *WBOR Mixing Zone* include the section of the WBOR from Copperas Brook confluence to a point approximately 2500 feet downstream

- *WBOR Below Mixing Zone* includes the stretch of WBOR between the EBOR/WBOR confluence and EPA sample location No. 42
- *Affected tributaries to the WBOR* include upper Lord Brook, two intermittent streams on Mine Road, and an intermittent stream within the Copperas Brook drainage
- *East Branch of the Ompompanoosuc River* (EBOR)
- *Ompompanoosuc River below confluence of EBOR and WBOR*

For surface water, fifteen contaminants were detected at concentrations above Vermont Water Quality Standards (VTWQS) or EPA criteria, including: aluminum, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, selenium, silver, thallium, vanadium, and zinc. VTWQS are available for cadmium, chromium, copper, cyanide, iron, lead, selenium, and zinc. EPA used reference material (EPA, 1996, EPA, 1999, Suter, 1996) to establish the criteria used in this report for aluminum, barium, cobalt, manganese, silver, thallium, and vanadium. Sample data from the 2001 sampling event were not available at the time of report (EE/CA) preparation.

Nine of these 15 contaminants appear to be clearly related to the source material based on their concentration and frequency of occurrence in the Source Area samples: aluminum, cadmium, cobalt, copper, iron, manganese, selenium, silver, and zinc. Six of these metals (aluminum, cobalt, copper, iron, manganese, and zinc) represent the bulk of the risk and have been designated as the primary Contaminants of Concern (COCs). The remaining three from the subset of nine contaminants believed to be Site related (cadmium, selenium, and silver) as well as the other six contaminants detected above reference criteria (barium, chromium, cyanide, lead, thallium, and vanadium) warrant further evaluation as part of the RI/FS to determine if they are Site-related, based on concerns regarding data quality, frequency of occurrence, and/or naturally occurring background levels. Table 1-7 presents the fifteen contaminants of potential concern, and highlights the list of contaminants designated as COCs for the purposes of this report. Detailed findings from the surface water investigation are discussed below (see Section 1.7, Streamlined Risk Evaluation).

Two sediment-sampling events were completed in 2000 and one in 2001. The first was completed in July and the second in September. The 2001 sediment-sampling event was also conducted in September, along with a synoptic surface water-sampling event. In July 2000, 41 locations were sampled for total metals, acid volatile sulfide/simultaneously extracted metals (AVS/SEM), grain size, and Total Organic Carbon. One location was sampled for cyanide, and five locations were sampled for Volatile Organic Compounds (VOCs), Semivolatile Organic Compounds (SVOCs), pesticides, and PCBs. In October 2000, 11 of the 41 locations were sampled for total metals and AVS/SEM. In September 2001, 25 locations were sampled for sediment, including eight samples in the “mudflat” area at the confluence of the Ompompanoosuc and Connecticut Rivers. Findings from the sediment-sampling program are described below (see Section 1.7, Streamlined Risk Evaluation).

1.6.5 Conceptual Site Model

The Elizabeth Mine is located in the Copperas Brook watershed, that drains into the WBOR, approximately six miles upstream from its confluence with the EBOR, near the Union Village dam. The Ompompanoosuc River empties into the Connecticut River approximately three miles downstream of the Union Village Dam. Copperas Brook flows from its headwaters near TP-3 over a distance of nearly one-mile to its confluence with the WBOR. Figure 1-9 provides a summary of the key elements of the Conceptual Site Model, Copperas Brook watershed, including the significant mine features. The Site conceptual model incorporates all of the major source areas and drainage features observed in this figure.

Upper Copperas Brook originates a short distance from the base of TP-3 and flows through a divide in TP-2 onto the surface of TP-1, where it enters a small pond (a former settling pond for tailing fines). A decant tower diverts water from the surface of TP-1 through a concrete pipe, to a discharge point at the northeast corner of the tailings pile. Water from the pipe combines with ground water discharge seeps from the base of TP-1 to form Lower Copperas Brook in the wooded areas and wetlands below the tailings.

The Copperas Brook watershed is approximately 300 acres in size, has an overall vertical drop of approximately 750 feet, and a flow range of approximately 25 gpm to over 2000 gpm at the confluence with the WBOR. The upper portion of the watershed normally experiences low flows in summer months, in the range of less than two gallons per minute (gpm) to 10 gpm at EPA's sample Location Number 2 (below TP-3). Storm event flow of over 300 gpm has been measured at the Location 2 gauging station.

TP-3 sits primarily on bedrock or a thin veneer of overburden material. TP-1 and TP-2 appear to be underlain by a thick glacial till of very low hydraulic conductivity. Although a thin sand unit has been found between the tailings and the till, it is believed that the till layer limits the flow of ground water into the tailings. Surface water/ground water modeling by the USGS (Harte, 2001; *personal communication*) suggests that approximately 80-90% of the water within the tailings results from surface water run-on from upper Copperas Brook; the remaining 10 to 20% is provided mostly by direct precipitation and snowmelt with a small component of flow from ground water.

Acid conditions in surface water are generated by the interaction of waste sulfide minerals (pyrrhotite, pyrite, and chalcopyrite) with water and oxygen. The oxidation of sulfides exposed to natural weathering conditions produces acid, which in turn dissolves metals such as copper, zinc, aluminum, and cadmium. Rain water and ground water discharged within the Copperas Brook watershed transport metals, acidic water, and tailings fines to the WBOR, where impacts to biological communities and water/sediment quality have been observed and recorded by EPA and others.

1.6.6 Site Physical Characteristics That Impact Alternative Evaluation

The following physical characteristics affect the evaluation of cleanup alternatives:

1. The tailings and waste materials are located within a steep drainage in the headwaters of the Copperas Brook watershed. Minimal water storage exists in the upper portion of the basin. Consequently, the watershed displays a wide range in surface water flows due to seasonal conditions and rainstorm events. Because of the lack of significant surface water attenuation (infiltration), cleanup alternatives must be designed to address both the longer-term (minimal) flow rates and the occasional peak storm and snowmelt runoff events.
2. There are stability issues associated with all of the tailing piles and bedrock beneath TP-3. Long-term structural stability is a critical factor. The stability of all tailings piles is reduced when rain, snowmelt, or other conditions result in saturation of the waste material.
3. There is limited space in some areas of the Site to perform the anticipated response actions, due to the presence of historic resources.
4. The flow of ground water within the tailings remains uncertain. Long-term response and remedial actions at the Site must account for discharges of seep water through the base of tailings. Most response actions under consideration will significantly reduce the flow volumes.
5. The natural soils below TP-1 and TP-2 appear to be glacial tills with very low water yielding potential. This limits the ability of the natural system to attenuate peak flows. This layer of glacial till may be used to “key-in” excavated diversion channels to limit flow into the tailings.
6. Most of the tailings material is situated above the natural water table elevation. The bottom of the tailings is currently saturated above the original ground surface. The water level within the tailings appears to be a result of constant infiltration from rain events, discharges from Upper Copperas Brook, and seasonal snowmelt.

1.7 Streamlined Risk Evaluation

Since April 2000, EPA has gathered and analyzed information from the Elizabeth Mine Site to characterize the nature and extent of contamination and associated risks to human health and ecological receptors from waste materials and the mine workings. Surface water and sediment samples have been collected on a regular basis at sampling stations throughout the WBOR. Residential soil, drinking water, and dust samples have been collected from nearby homes to assess potential Site-related risks.

A detailed Human Health Risk Assessment (HHRA) will be performed as part of the RI/FS. Both EPA and ATSDR have completed an evaluation of the data collected to date and have determined that there is no immediate risk to local residents that requires a response action. This determination is based on monthly residential drinking water sampling at a number of residences in the immediate mine area. Initial monthly sampling targeted nine residences; the number of homes sampled on a regular basis was reduced as it became clear that no exceedances of drinking water criteria were found beyond a single home located adjacent to TP-3.

A streamlined ecological risk evaluation was completed to provide an assessment of the likelihood of Site-related effects on certain receptors. This assessment is based on surface water and sediment samples, sediment toxicity tests, benthic community surveys, algae surveys, and fish community surveys. The primary concern at the Site is the AMD resulting from surface water interaction with mine tailings and waste rock piles. For a distance of approximately six miles below the confluence of Copperas Brook with the WBOR, concentrations of metals in surface water exceed applicable Vermont and EPA numerical and biological standards.

1.7.1 Ecological Risk Assessment

The streamlined ecological risk assessment followed a two-step approach to the development of the risk characterization. The first step involved evaluation of chemical data to determine which of the chemicals found in the surface water and sediments are Contaminants of Concern (COCs). The second step involved the use of biological measures of impact, including toxicity testing, fish community surveys, and benthic organism community surveys. The VTWQS consist of both numerical (chemical) and biological criteria to assess compliance with the standards.

The streamlined risk assessment is organized as follows:

- Identification of General Ecological Receptors (Section 1.7.1.1)
- Potential Contaminant Migration Pathways (Section 1.7.1.2)
- Data (Section 1.7.1.3)
- Selection of Contaminants of Concern (COCs) (Section 1.7.1.4)
- Conclusions from Streamlined Ecological Risk Evaluation (Section 1.7.1.5)

1.7.1.1 Identification of General Ecological Receptors

The WBOR, Copperas Brook, and affected tributaries provide habitat for various aquatic receptors, including fish, benthic organisms, macroinvertebrates, plankton, and algae. These receptors in turn likely support piscivorous or omnivorous birds (e.g., kingfishers, herons, ducks) and mammals (e.g., river otter, mink, raccoon). A complete characterization of potential ecological receptors at the Elizabeth Mines Site, based on surveys by professional ecologists or wildlife biologists, will be performed during the process of completing the full Baseline Ecological Risk Assessment (BERA) for the Site.

1.7.1.2 Potential Contaminant Migration Pathways

Surface water and sediment transport contaminants from source areas to receptors. Two recent reports, *Elizabeth Mine Site Conditions Report (ADL, 2001)* and the *Summary of Preliminary Ecological and Human Health Risk Evaluations (ADL, 2001)* provide an overview of the contaminant migration and exposure pathways. As Copperas Brook runs directly through the tailing piles/waste-rock piles, COCs contained in these materials can migrate directly into Copperas Brook. Copperas Brook flows directly into the WBOR. A second contaminated tributary to the WBOR, Lord Brook, is situated in a separate watershed directly south of the Copperas Brook and is contaminated by mine-related waste materials from the South Mine and South Cut. Contaminants may leach from the tailings pile/waste heaps into ground water and discharge into the river. The Air Vent discharges contaminated water directly to the WBOR from the underground mine workings.

Sampling has shown that concentrations of COCs in surface water and sediment of Copperas Brook, the WBOR, and affected tributaries are significantly higher than both appropriate benchmarks and concentrations at nearby (upstream) Reference locations. Therefore, receptors that frequently come in contact with sediment or surface water, or those that reside further up on the food chain and consume aquatic receptors that have taken up COCs, may be impacted. Preliminary investigations have demonstrated impacts on benthic organisms, fish, and algae.

1.7.1.3 Presentation of Data

Surface Water. The surface water data collected since April 2000 indicate that 15 contaminants are detected at concentrations above VTWQS or EPA criteria, including: aluminum, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, selenium, silver, thallium, vanadium, and zinc. Nine of these metals appear to be related to the mine waste source material based on their concentration and frequency of occurrence (aluminum, cadmium, cobalt, copper, iron, manganese, selenium, silver, and zinc). The remaining contaminants (barium, chromium, cyanide, lead, thallium, and vanadium) warrant further evaluation during the RI/FS.

Six of the nine Site related contaminants (aluminum, cobalt, copper, iron, manganese, and zinc) have been designated as COCs in surface water. Table 1-8 summarizes the Hazard Quotients (HQs) and Hazard Indices (HIs) for the relevant samples. A summary of surface water results is provided in Figure 1-10.

The levels of contaminants detected in the surface water of Copperas Brook and the Mixing Zone of the WBOR are many times higher (as indicated by the HQs) than the relevant criteria—one to three orders of magnitude, or tens to thousands of times higher. A decrease in metals concentrations is observed with distance downstream of the Copperas Brook confluence. Copper is the only COC to remain significantly above upstream concentrations beyond the Union Village Dam at EPA Location 44. The following is a summary of key findings from the surface water quality studies conducted by EPA:

- Concentrations of aluminum, cadmium, chromium, cobalt, copper, iron, manganese, silver, and zinc in the Source Area are substantially higher than VTWQS, other EPA accepted criteria for surface water, and the upstream (Reference) areas.

- Six of these contaminants (aluminum, cobalt, copper, iron, manganese, and zinc) are also detected at concentrations above VTWQS and EPA accepted criteria well past the confluence of the WBOR and Copperas Brook.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in surface water within the study area.
- Hazard Quotients (HQs) for copper, iron, aluminum, and zinc are significantly higher (one to three orders of magnitude, or 10 to 1,000 times higher) in the Source Area and Mixing Zone than in upstream (Reference) areas; the corresponding Hazard Indices (HIs) show similar trends.
- Maximum concentrations of metals in the WBOR within the Mixing Zone area exceed applicable criteria (Vermont Water Quality Standards or other EPA criteria) by a factor of 201 for aluminum, nine for cobalt, 63 for copper, 50 for iron, and 17 for manganese.
- Although aluminum is consistently elevated in upstream locations, the levels found in the Source Areas and Mixing Zone are substantially higher than the concentrations detected at upstream locations.
- The point at which the WBOR completely recovers to VTWQS numerical criteria is not known. Elevated metals concentrations have been sporadically detected at the furthest downstream surface water sampling station, below Union Village Dam.

Sediment. Samples of sediment were collected at each surface water sampling location, and several additional locations and submitted for metals analysis during two sampling events (June and September/October 2000). The chemical analysis results for sediment samples are summarized in Table 1-9. A summary of sediment results is provided in Figure 1-11. Concentrations of copper, iron, manganese, and zinc are higher in the Source Areas and the Mixing Zone Area than upstream (Reference) levels. Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in sediment within the study area. Aluminum, iron, and zinc concentrations in sediments do not display the strong Site-related pattern observed for copper. HQs and associated HIs for metals below the confluence of the EBOR and the WBOR are comparable to the Mixing Zone, suggesting that little to modest attenuation of metals contamination in sediment occurs with increasing distance from the Source. The Hazard Index for the Air Vent Mixing Zone was not greater than the upstream areas, suggesting that the Air Vent may not represent a significant metals loading to the sediments or that the Air Vent loading is transported downstream due to scour and re-deposition. The following is a summary of key findings from the sediment studies conducted by EPA:

- Concentrations of copper, iron, manganese, and zinc are higher in the Source Areas and Mixing Zone Area than upstream (Reference) levels.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in sediment within the study area.

- Maximum concentrations of metals in the Mixing Zone Area of the WBOR exceed applicable criteria by a factor of 11 for copper, two for iron, two for manganese, and are slightly above the criteria for zinc.
- HQs for copper and iron are much higher in the Source Area and Mixing Zone than in the Upstream of Mixing Zone Area; the corresponding HIs show similar trends.
- Elevated levels of copper (130 mg/kg), resulting in a Hazard Quotient of six, have been detected below Union Village Dam, as far as the Connecticut River at EPA Location 38.

The surface water and sediment data document severe impact to Copperas Brook and a section of the WBOR as a result of the discharges from the Source Areas. All of Copperas Brook and a section of the WBOR fail to meet numerical VTWQS for several metals on numerous sampling occasions. In addition to the evaluation of the chemical data (described above), several lines of biological evidence were examined to determine the potential for significant impacts. These lines of evidence are summarized below.

Surface Water and Sediment Toxicity Tests. Toxicity tests were conducted to evaluate the effect of exposure to surface water and sediment from the Site on aquatic invertebrates and fish (fathead minnow, amphipod [scud], bloodworm, and water flea). Toxicity tests evaluate cumulative effects of chemicals by introducing healthy organisms to Site surface water and sediment for a specific time period. For comparison, the same types of organisms were exposed to upstream (Reference) area surface water and sediment over the same test period. Two rounds of toxicity testing were performed, corresponding to the June and September 2000 EPA sampling events. The results of the toxicity tests are shown in Figures 1-12 and 1-13. The results of the toxicity testing indicate that Source Area surface water and sediment is toxic to tested organisms. Nearly 100% of the organisms died as a result of exposure to the surface water and sediments from the Source Area. The Copperas Brook surface water was so toxic that even when it was substantially diluted (to levels as low as 10% of the original sample) with clean water, the test organisms died. All test organisms also died from exposure to surface water from sample Location 8 (Air Vent discharge) and Location 12 (within WBOR just downstream of confluence with Copperas Brook). Location 13 (within the WBOR, near the Copperas Brook confluence) showed similar toxic results in the sediment toxicity tests. The following is a summary of key findings from the toxicity tests performed by EPA:

- When exposed to surface water of Copperas Brook, the Air Vent, or the Mixing Zone of the WBOR, nearly all test organisms died (no test organisms survived in three tests and only 10% survived the fourth test).
- When exposed to the sediment of Copperas Brook or the section of the Mixing Zone Area near the confluence at EPA Location 13, nearly all organisms died.
- The sediments Upstream of Mixing Zone, Air Vent Mixing Zone, lower section of Mixing Zone, and Below Mixing Zone Areas did not show toxic effects to test organisms.

- Growth, survival, and reproduction of all organisms tested with water from the Air Vent Mixing Zone were comparable to the Reference Area results.

Benthic Organism Community Assessment. Species diversity and density of benthic organism populations are other key measures of the health of the river environment assessed in this study. Species density and diversity are severely depressed in Copperas Brook, the Mixing Zone, and Affected Tributaries. When compared to the VTWQS, the WBOR does not meet biological standards for three of the criteria (Density, Taxa Richness, EPT Richness) at a location approximately six miles downstream of the confluence with Copperas Brook, near EPA location 44. The WBOR, however, does achieve VTWQS for two or the three measures by EPA Location 19, just upstream of Rice's Mills. Figures 1-14 and 1-15 show the results for the benthic epifauna survey. Statistical projections (plot of abundance and richness over distance from source) confirm that the VTWQS for all criteria should be met on the stretch of the WBOR near Union Village Dam. Figure 1-16 shows the statistical results. The samples of the benthic community in the Air Vent Mixing Zone are similar in most respects to the upstream (Reference) Area and Ompompanoosuc River (below EBOR and WBOR confluence) samples. These results indicate that the Air Vent contribution to the WBOR contamination is not significant in terms of biological impact, even though water chemistry results indicate the potential for impacts to the aquatic organisms in this stretch of the river.

Figures 1-17 and 1-18 show the results of the benthic infauna survey. While there are no VTANR criteria for infauna, a general comparison of abundance and diversity can be made between locations upstream and downstream of Copperas Brook. The infauna results also suggest severe impact in the Source Area and Mixing Zone, with levels returning to normal downstream of the Mixing Zone. The following is a summary of key findings from the benthic community surveys conducted by EPA:

- The density and diversity of benthic water-dwelling species (epifauna) within the Mixing Zone are significantly lower than in the upstream (Reference) area.
- The density of sediment-dwelling organisms (infauna) is impaired within the Mixing Zone; however, infauna diversity within the lower reaches of the Mixing Zone is similar to the upstream (Reference) area.
- Source Area samples show extremely low organism density and little diversity.
- Sediment-dwelling organism (infauna) density in the Source and Mixing Zone locations show little difference when compared with the upstream (Reference) area. This may be due to the limited sediment habitat within the WBOR.

Fish Abundance Surveys. Fish density and diversity are key measures in the evaluation and analysis of impacts to the WBOR and affected tributaries. Studies by the USACE (1990) and VTANR (1987 and 2000) provide a basis for initial assessment of contamination effects on fish communities. A more detailed sampling program was completed in September 2001 to evaluate fish populations throughout the mine area, including the WBOR, the EBOR, Lord Brook, and other tributaries. The fish study results from earlier studies are provided in Figure 1-19. The data from the September 2001 fish surveys will be included in the RI/FS Reports.

USACE (1990) and VTANR (1987 and 2000) provide evidence that the Elizabeth Mine has had a severe impact on the fish communities in the WBOR and affected tributaries. Both studies show that the density of the forage species upstream of the mine was more than three times higher than density at the downstream locations. VTANR calculated an Index of Biotic Integrity (IBI) value for these stations. IBI measures ecological health of the fish community as a whole. Figure 1-19 (top plot) presents IBI as well as fish density for the USACE and VTANR data. The IBI in the upstream areas of WBOR is 39 (as compared to the VT threshold values for Class B waters of 29 to 31), whereas the IBI for the WBOR below Copperas Brook is only nine. A study conducted by the VTANR in the tributaries of WBOR (Langdon, 2001) noted more than a ten-fold reduction of fish density in Lord Brook downstream from the South Cut source area, as compared with a stretch of Lord Brook upstream of the South Cut source. No fish were found in Copperas Brook. Langdon concluded that the impact of toxic levels of metals is likely to be responsible for the low density of fish in these areas. The following is a summary of key findings from the fish surveys conducted by VTANR and USACE:

- The USACE 1990 study of the WBOR found the biomass (total weight of fish within a given area) and density of the forage species (dace, sculpin, and sucker), which are indicative of ecological damages, are severely affected. The biomass and density downstream of the mine were about three times lower than similar characteristics of the upstream reference areas.
- The VTANR studies (1987, 1998, and 2000) found even more severe detrimental effects of contaminants originating from the mines on fish communities in the tributaries of the Ompompanoosuc River. No fish were found in Copperas Brook. The fish density in the affected areas of Lord Brook was almost 10 times lower than fish density in unaffected areas of Lord Brook and Sargent Brook.
- The IBI as a whole was found to be depressed significantly from a value of 39 in the upstream areas of the WBOR (as compared to the VT threshold values for Class B waters of 29 to 31) to a value of nine (well below the WQS threshold) in the downstream areas affected by the mine.
- The degradation of fish community health is supported by both USACE 1990 and VTANR 2000 studies.

1.7.1.4 Selection of Contaminants of Concern (COCs)

Selection of COCs was selected based on the following:

- The geographic extent of contamination as measured by the percent of samples in which chemical concentration was found to exceed applicable regulatory standards, and
- The magnitude of contamination as measured by chemical-specific HQs.

The Hazard Quotient (HQ) is the quotient of the Site contaminant concentration divided by the acceptable ("safe") concentration, or, in other words, the number of times by which the contaminant exceeds the acceptable level. The HQ method was used to identify COCs and calculate potential ecological risks from metal contaminants for each of the nine general Site areas/data groupings (e.g., Source Area, Mixing Zone, etc.). The numerical VTWQS were used as the safe level, when available. Several constituents in surface water did not have a VTWQS. For these instances, EPA identified appropriate criteria from available literature (EPA, 1996, EPA, 1996, Sutter, 1996). There are no Vermont standards for sediment; therefore, all of the safe levels for sediments were from EPA accepted sources. Table 1-10 lists the criteria used as the safe level in calculating the HQs in surface water and sediment.

Table 1-7 presents the fifteen contaminants of potential concern, and highlights those contaminants designated as COCs (aluminum, cobalt, copper, iron, manganese, and zinc) for the purposes of this study.

1.7.1.5 Conclusions from Streamlined Ecological Risk Evaluation

Figure 1-20 provides an overall summary of all chemical and biological lines of evidence, indicating the extent of chemical and biological impact to the WBOR watershed from Elizabeth Mine contaminant sources. Assessments of chemical and biological lines of evidence indicate that Site contaminants adversely affect the fish and benthic communities.

The biological community (benthic organisms and fish) is severely impacted in Copperas Brook, the upper reach of Lord Brook below the South Open Cut, and in the Mixing Zone of the WBOR below Copperas Brook. The biological community appears to recover to conditions similar to upstream (Reference) locations at some point below Union Village Dam, although algae metals concentrations remain high below the dam. Surface water and sediment collected from Copperas Brook, the first section (upstream) of the Mixing Zone, and the Air Vent are highly toxic to aquatic organisms, such that survival of aquatic receptors in this area is not likely. The test results indicate that these toxic effects are not present below the Mixing Zone.

Collectively, the various lines of evidence suggest that EPA Location 44, situated downstream from Union Village Dam, represents the best estimate for the location where the WBOR achieves Vermont Water Quality Criteria for surface water and biological metrics. Chemical evidence from sediment sampling indicates the potential for concentrations above numerical VTWQS further downstream from Location 44. The distance from the Copperas Brook confluence to EPA Location 44 is approximately six miles.

Since all of the lines of evidence show that Copperas Brook and the Mixing Zone are the most severely impacted, it can be inferred that TP-1, TP-2, and TP-3, which are the contaminant sources located within the Copperas Brook drainage, are the cause of the impacts to the WBOR. These impacts firmly support the need for an early cleanup action (NTCRA) to address the principal sources of AMD.

1.7.2 Streamlined Human Health Risk Assessment

The initial risk evaluation focused on whether the Site data strongly suggest the need for an immediate action to prevent exposure to contaminants found at the Site. A more detailed evaluation of the potential long-term threats at the Site will be the subject of the Baseline Human Health Risk Assessment that will be prepared as part of the RI/FS. Drinking water, residential soil, and residential dust sampling results do not suggest a short-term human health exposure above acceptable levels.

EPA has sampled nine residential wells in the immediate vicinity of the Site and one well located within a mile of the site. Several of the water supplies adjacent to the Site were sampled numerous times in 2000. One water supply well did not meet federal drinking water standards for two metals (copper and cadmium). The residents and landowner were promptly notified. The residents have since re-located and the well is no longer in use. All of the other water supply wells were found to meet federal and state primary drinking water standards. Table 1-4 presents the residential water supply data collected to date.

EPA collected residential soil, indoor dust, and air samples from three residences along Mine Road. The soil data revealed several instances where levels of iron, lead, and thallium warrant further study as part of the RI/FS, because the detected levels were higher than background concentrations. The concentrations of these metals were not at levels considered to represent an acute (short-term) hazard (see Table 1-11). Elevated lead levels were found in some of the residential dust samples. The source of the lead is not yet known. All of the water, soil, and dust data have been provided to the residents and the Vermont Department of Public Health. A more detailed evaluation of the soil and dust data will be presented in the Baseline Human Health Risk Assessment. EPA submitted the drinking water, soil, and dust data to the ATSDR. The health consultation from ATSDR confirmed EPA’s assessment that the residential water and soil data do not indicate any current risks that would warrant immediate EPA action. The Baseline Human Health Risk Assessment that will be developed as part of the RI/FS will more fully evaluate the current and future potential threats to human health and the environment, including an assessment of the effects of long-term exposure to windblown dust and the exposed tailings.

1.7.3 Selection of Preliminary Removal Goals

The preliminary risk assessment work completed to date identified clear ecological risks resulting from direct and indirect contact and exposure to contaminated surface water in the WBOR. The overall goal of the NTCRA at the Elizabeth Mine Site is to restore the WBOR to Vermont Water Quality Standards for freshwater rivers. Biological water quality standards (VTDEC, 2000) include eight measures of community structure for benthic invertebrates and fish in freshwater streams. Chemical water quality standards are chemical concentrations in surface water that, if achieved, will reduce or eliminate risks associated with exposure to Site-related contaminants and thus will allow river ecosystems to recover so that biological standards can be met.

The measures of effectiveness of this NTCRA will be the extent to which surface water quality in the WBOR below the confluence with Copperas Brook meets VTWQS for numerical and biological measures. The primary measure of success for this NTCRA will be the quality of the surface water within Copperas Brook and the section of the WBOR just below the confluence with Copperas Brook. Due to the presence of other sources of contamination above and below the confluence of Copperas Brook and the WBOR, the quality of Copperas Brook is the best measure of the actions taken to address the tailings. Secondary goals include addressing community concerns and increasing the stability of the tailings piles.

2.0 Identification of Removal Action Scope and Objectives

This section presents the statutory limitations on removal actions, identifies the conditions that justify the performance of a NTCRA at the Elizabeth Mine Site, presents the overall goals and objectives of the proposed NTCRA, and identifies potential federal and state requirements with which the selected removal action must comply. A proposed NTCRA schedule is also provided.

The general objectives of the Elizabeth Mine NTCRA include the following:

- Prevent or minimize discharges of water with mine-related metals contamination to Copperas Brook and the WBOR, so as to achieve Vermont Water Quality Standards (chemical and biological) and other applicable standards in the WBOR.
- Increase safety of slopes to prevent landslides in the tailing piles; minimize erosion and transport of tailings into the surface waters of Copperas Brook and the West Branch of the Ompompanoosuc River.
- Comply with requirements of the National Historic Preservation Act with respect to any historical and cultural features that could be impacted through EPA actions.
- Comply with all applicable federal and state regulations while achieving these objectives.

2.1 Statutory Limits on Non-Time-Critical Removal Actions (NTCRA)

40 CFR Part 300.415(b)(5) and Section 104(c)(1) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) set limits of 12 months and $2 million for fund-financed removal actions. An exemption from the time and dollar limitations in the statutes can be granted in situations where EPA determines that the proposed removal action is appropriate and consistent with the anticipated long-term remedial action. Implementation of any of the alternatives in this EE/CA will result in costs exceeding the NTCRA $2 million and 12-month statutory limits. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

2.2 Conditions That Justify a Removal Action

Section 300.415(b)(2) of the NCP lists a number of factors for EPA to consider in determining whether Site conditions indicate performance of a NTCRA is appropriate, including the following:

i) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants;
ii) Actual or potential contamination of drinking water supplies or sensitive ecosystems;
iii) Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers, that may pose a threat of release;
iv) High concentrations of hazardous substances, pollutants, or contaminants in soils largely at or near the surface, that may migrate;
v) Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released;
vi) Threat of fire or explosion;
vii) The availability of other appropriate federal or state response mechanisms to respond to the release, and
viii) Other situations or factors that may pose threats to public health or welfare or the environment.

An evaluation of the conditions at the Elizabeth Mine Site indicates that several of these factors are applicable, as described below.

(i) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants. There is current actual exposure of animals to hazardous substances, pollutants, and contaminants such that the benthic organism and fish communities have been severely impacted. A six-mile stretch of the WBOR violates VTWQS for both numerical and biological water quality measures. In addition, there is a potential exposure to hazardous substances, pollutants, or contaminants from ingestion of groundwater within close proximity to TP-3. A water supply was recently removed from use, due to contamination above federal and state drinking water standards.

(ii) Actual or potential contamination of drinking water supplies or sensitive ecosystems. Prior to the termination of the use of one water supply well, there was actual contamination of a drinking water supply by the mine waste. The potential for future contamination of water supplies remains for any future wells installed in close proximity to the tailings. The aquatic ecosystem of Copperas Brook and the WBOR have been substantially impacted by the tailings. Surface water data documents actual contamination of the entire one-mile length of Copperas Brook and an additional six miles of the WBOR, extending to below the Union Village Dam. Sediment data suggests that contamination may extend to the confluence of the Connecticut River, which is another three miles downstream. Site-related contamination has clearly resulted in significant impairment to ecosystems in the mine area.

(iv) High concentrations of hazardous substances, pollutants, or contaminants in soils at or near the surface that may migrate. High concentrations of metals (including aluminum, cadmium, chromium, cobalt, copper, iron, manganese, and zinc) have been detected in tailings materials exposed at the surface in the Elizabeth Mine area.

Currently, a large portion of TP-1 and TP-2 (seven to 10 acres) has little to no vegetated cover. TP-3 is largely not vegetated. Contamination is being continually released through erosion and acid mobilization of the metals. Local residents report that migration of dry oxidized tailings through wind-blown dust has been a problem in the past. It could continue to be a problem if actions are not taken to stabilize (cover) the TP-1 and TP-2 tailings.

(v) Weather conditions that may cause hazardous substances, pollutants or contaminants to migrate or be released. The principal contaminant transport pathway at the Elizabeth Mine Site is storm water runoff. The mine is situated in a mountain valley in east central Vermont, where storm conditions through much of the year produce short-term rainfall events. Annual precipitation averages approximately 35 inches in the South Strafford area. Erosion of exposed tailings results in acid drainage with high dissolved and suspended metals runoff, which flows into the headwaters of Copperas Brook and ultimately to the WBOR. Spring snowmelt conditions contribute the greatest metal and acid loads to the surface water environment over a four-week period from early April to early May. Snow pack at the beginning of the spring melt is typically in the three to four-foot range throughout the Copperas Brook watershed. Catastrophic failure of TP-1 resulting from extreme weather events or small earthquakes could have a significant long-term adverse effect the quality of the WBOR.

(vii) The availability of other appropriate federal or state response mechanisms to respond to the release. There are no other known federal or state funds or response mechanisms available to finance this action.

Combined, these factors indicate that the tailings at the Elizabeth Mine Site constitute a threat to public health or the environment (principally to sensitive ecological receptors) through the release, or potential release, of hazardous substances, pollutants, and contaminants into the environment. A NTCRA is therefore appropriate to abate, prevent, minimize, stabilize, mitigate, or eliminate such threats. In particular, a NTCRA is necessary to provide source control measures to remove, control, or contain the risk to the sensitive ecological receptors within Copperas Brook and the WBOR as well as potential future users of the groundwater.

This Removal Action is designated as non-time-critical, because more than six months planning time is available before on-site activities must be initiated. Prior to the actual performance of a NTCRA at this Site, Section 300.415(b)(4) of the NCP requires that an EE/CA be performed to evaluate response options.

2.3 Applicable or Relevant and Appropriate Requirements

Section 300.415(i) of the National Contingency Plan (NCP) requires that "Fund-financed removal actions under CERCLA Section 104 and removal actions pursuant to CERCLA Section 106, shall, to <u>the extent practicable</u>, considering the exigencies of the situation, attain Applicable or Relevant and Appropriate Requirements (ARARs) under federal or state environmental or facility siting laws".

In determining whether compliance with ARARs is practical or practicable, EPA may consider appropriate factors, including the urgency of the situation and the scope of the removal action to be performed. An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances (40 CFR 300.430[f][1][ii][C]):

1. The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;
3. Compliance with the requirement is technically impracticable from an engineering perspective;
4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirements, or limitation through use of another method or approach;
5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other remedial actions within the state; or
6. For fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the Site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured.

2.3.1 Terms and Definitions

The following are explanations of the terms and definitions used throughout this ARARs discussion:

Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" *(52 FR32496,* August 27, 1987). An example of an applicable requirement is compliance with the NHPA for a site that has been determined eligible for listing in the National Register of Historic Places.

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" *(52 FR 32496).* For example, while the federal maximum contaminant levels (MCLs) established under the Safe Drinking Water Act are applicable standards for public water supplies, MCLs are considered relevant and appropriate for use as groundwater cleanup levels when the groundwater is considered an actual or potential drinking water source.

Requirements under federal or state law may be either applicable or relevant and appropriate to CERCLA cleanup actions, but not both. Requirements must be both relevant and appropriate for compliance to be necessary. In the case where both a federal and a state ARAR are available, or where two potential ARARs address the same issue, the more stringent regulation must be selected. The final NCP states that a state standard must be legally enforceable and more stringent than a corresponding federal standard to be relevant and appropriate (*55 FR 8756,* March 8, 1990).

CERCLA on-site response actions must only comply with the substantive requirements of an ARAR and not the administrative requirements. “No Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely onsite, where such remedial action is selected and carried out in compliance with this section” [CERCLA § 121(e) (1)]. As noted in the ARARs guidance (EPA, 1988):

> *The CERCLA program has its own set of administrative procedures which assure proper implementation of CERCLA. The application of additional or conflicting administrative requirements could result in delay or confusion.*

Substantive requirements pertain directly to the actions or conditions at a site, while administrative requirements facilitate their implementation. The NCP defines on-site as "the area extent of contamination and all areas in very close proximity to the contamination necessary for implementation of the response action". EPA recognizes that certain administrative requirements, such as consultation with state agencies and reporting, are accomplished through the state involvement and public participation requirements of the NCP. Off-site response actions must comply with both the substantive and administrative requirements of an applicable (but not a relevant and appropriate) regulation.

In the absence of federal- or state-promulgated regulations, there are many criteria, advisories, and guidance values that are not legally binding, but that may serve as useful guidance for response actions. These are not potential ARARs, but are "to-be-considered" (TBC) guidance. These guidelines or advisory criteria should be identified if used to develop cleanup goals or if they provide important information needed to properly design or perform a response action. Three categories of TBC information are as follows:

(1) Health effects information with a high degree of certainty (e.g., reference doses),
(2) Technical information on how to perform or evaluate site investigations or response actions, and
(3) Regulatory policy or proposed regulations. For example, EPA Region III Residential Risk Based Concentrations and Region IX Preliminary Remediation Goals (Residential) provide guidance to be considered to assess the health implications during site activities.

ARARs are divided into the three categories listed below.

- **Location-specific ARARs** "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (*53 FR 51394*). In determining the use of location-specific ARARs for selected remedial actions at CERCLA sites, the jurisdictional prerequisites of each of the regulations must be investigated. In addition, basic definitions and exemptions must be analyzed on a site-specific basis to confirm the correct application of the requirements. For example, federal and state regulations concerning wetlands apply at a site where remedial activities may impact an existing wetland.
- **Chemical-specific ARARs** are usually health- or risk-based standards that limit the concentration of a chemical found in or discharged to the environment. They govern the extent of site remediation by providing either actual cleanup levels, or the basis for calculating such levels. Chemical-specific ARARs may also be used to indicate acceptable levels of discharge in determining treatment and disposal requirements, and to assess the effectiveness of future remedial alternatives. For example, state water quality standards apply at a site where treatment effluent is discharged to a surface water.
- **Action-specific ARARs** set controls or restrictions on particular kinds of activities related to the management of hazardous waste (*53 FR 51437*). Selection of a particular response action at a site will invoke the appropriate action-specific ARARs that may specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. For example, the federal noise regulations apply at a site where construction and heavy equipment activities are expected.

Many regulations can fall into more than one category. For example, many location-specific ARARs are also action-specific because they are triggered if response activities affect site features. Likewise, many chemical-specific ARARs are also location-specific.

The Occupational Safety and Health Administration (OSHA) has promulgated standards for protection of workers who may be exposed to hazardous substances at Resource Conservation and Recovery Act (RCRA) or CERCLA sites (29 CFR Part 1910.120 and 1926.65). EPA requires compliance with the OSHA standards in the NCP (40 CFR 300.150), not through the ARAR process. Therefore, the OSHA standards are not considered ARARs. Although the requirements, standards, and regulations of OSHA are not ARARs, they will be complied with during response activities.

Identification and evaluation of ARARs is an iterative process, which continues throughout the response process as a better understanding is gained of site conditions, contaminants, and response alternatives. Therefore, preliminary lists of ARARs and their relevance may change through time as more information is obtained and as the preferred alternative is chosen.

2.3.2 Location-Specific ARARs

Location-specific ARARs are related to the presence of specific natural or manmade features or potentially affected resources at the Site. ARARs relating to wetlands, floodplains, wildlife, archaeological, and historical resources have been identified. Table 2-1 contains a list of the location-specific ARARs that may apply to the removal alternative evaluated in this EE/CA. The ARARs for each cleanup alternative are discussed in Section 4.

The text below includes a discussion of several key location specific ARARs that apply to the NTCRA. EPA is seeking comment from the public regarding the following:

(1) Impacts to wetlands and floodplains
(2) A variance to the VT Solid Waste Management Regulations
(3) Adverse effects to historic properties

Floodplain Impacts: The Floodplain Management (Executive Order 11988, 40 CFR 6.302(b) and 40 CFR 6, App. A (Policy on Implementing E.O. 11988) and Vermont Watershed Protection and Flood Prevention, Title 10, V.S.A. Chapter 39 establish guidelines for any federal activities that may impact floodplains. Some of the construction activities anticipated under the NTCRA will be performed within the floodplain areas of the upper portion of the Copperas Brook watershed. The activities described in the EE/CA are not expected to impact floodplain areas of the WBOR. The cleanup alternative must be design to ensure no net loss of floodplain storage (with respect to surface water drainage from snowmelt or precipitation). If necessary, temporary storage/holding areas may need to be constructed in the Copperas Brook watershed for excess storm water runoff to prevent flooding.

Wetland Impacts: Vermont Water Resources Management, Title 10, V.S.A. Chapter 37, establishes guidelines for the protection of water, ground water, and wetland resources. EPA must evaluate potential effects of any new construction in wetlands and identify, evaluate, and as appropriate, implement alternative actions that may avoid or mitigate adverse impacts to wetlands and other water bodies. Vermont Wetlands Rules (Vermont Agency of Natural Resources, Water Resources Board, 12-004-056) establishes criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed and conditional uses for these wetlands. The uses must not have undue adverse impacts on the significant functions of the wetland. The Protection of Wetlands (Executive Order 11990), 40 CFR 6.302(a) and 40 CFR 6, App. A (Policy on Implementing E.O. 11990) requires federal agencies to avoid undertaking or providing assistance for new construction located in wetlands unless there is no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use.

The State of Vermont has identified portions of the surface of TP-1 as a designated Class 2 Wetland (Quackenbush, August 2001, personal communication). This area is the receiving point for surface water flow from upper Copperas Brook. Typical wetland vegetation (cattails and phragmites) occupies an area measuring less than one acre to the south of the "permanent" pond on the east-side of TP-1. A small stand of cattails (measuring 30'x 75') has been established (naturally) at the toe of TP-1 in an area receiving seep water from the base of the tailings. A small stand of cattails is also present at the mouth of the main mine adit, used most recently during the WWII-era mining campaign. Each alternative considered in this EE/CA will have a significant negative impact on the wetlands on the surface of and immediately below TP-1. These two wetland areas (less than one acre in total area) must be completely eliminated to achieve the goals of each alternative. The extent of the mitigation for impacting wetlands will be determined during design. The wetlands to be constructed as part of the passive treatment systems cannot be considered mitigation, but will host similar vegetation and provide more quality habitat and ecological diversity than the wetlands that will be destroyed by the NTCRA project. The combination of holding ponds and Successive Alkalinity Producing System (SAPS) will provide open water habitat that will complement the wetland ecosystems. Once constructed, the treatment system wetlands must be preserved and reconstituted (mitigated with replanting) following periodic cleanout.

Impacts to Historic Mine Features: Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effect of all of its actions on historic properties. For purposes of EPA compliance with the NHPA, the term "historic property" will be applied to the Elizabeth Mine as defined in 36 CFR § 800.16(l)(1), "*Historic property means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places …*" In order to be considered eligible, the site must meet at least one of four Criteria for Evaluation, 36 CFR §60.6, and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, the EPA has determined the Elizabeth Mine Site eligible for the National Register.

The EPA has determined the Site's significance to be best reflected by Criterion A: *Those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *Those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Throughout its history, the Elizabeth Mine has made significant contributions at the local, state, and national levels in the areas of commerce, economics, engineering, industry, and invention. The

Elizabeth Mine was the site of a major U.S. copperas manufacturing plant that dominated production of this important industrial chemical during the mid-nineteenth century. It was the scene of several important firsts in American copper metallurgy, including successful mine-side smelting, large-scale smelting of sulfide ores, and smelting with hot blast and anthracite, and successful use of chromite refractories. After its World War II revival, it became one of the 20 most productive copper mines in the U.S. and was the largest and most productive copper mine in New England.

The Elizabeth Mine landscape has the potential to yield information on industrial activities spanning almost 160 years. Standing structures, mine-related features, and archaeological sites pertain to various phases of copper and copperas extraction, including ore processing, beneficiation and smelting activities, transportation, and worker accommodation. In keeping with Criteria D, such information could contribute significantly to knowledge about industrial processes, mining lifestyles, and the dynamics of mining systems.

The integrity of the location, setting, feelings and association of the Elizabeth Mine help to define what makes the historic property important to the local communities. The mining landscape is complex with multiple overlapping layers. There remains visible landscape evidence of the nineteenth-century copperas production and mid-twentieth century copper production in the forms of waste rock, roast beds, heap leach piles, and flotation tailings. Tailings and waste rock piles are the most obvious, massive, and powerful evidence of the significant contributions to copper mining history that the Elizabeth Mine has had throughout its history. It is Tailing Piles 1, 2, and 3 that are most readily identified as the contributing and defining features of the historic property. Other important features include standing structures, the open mine cuts, Furnace Flat, stone foundations, brick and clustered remnants of cut timber, and associated mine artifacts.

EPA has been working with the SHPO and local communities to fully define the historic properties and potential construction-related impacts. From these meetings with a diverse group of interested parties, the EPA has identified historic features of the site that are valued by the surrounding communities. These include the copperas works of TP-3, features related to the Tyson-era of mining and smelting, all of the remaining standing structures, Furnace Flat, the North and South Mine Cuts, and mining landscape itself.

Construction activities and associated actions considered in this EE/CA will have an effect on features of the historic property at the Elizabeth Mine Site. The Area of Potential Effects (APE) means, "…the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties…" 36 CFR §800.16(d). The preliminary APE for direct effects is shown in Figures 3-2 through 3-6. The APE will be further defined to address indirect effects, cumulative effects, and other effects when the remediation option is selected and the construction design is completed.

EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

2.3.3 Chemical-Specific ARARs

Table 2-2 contains a summary of the chemical-specific ARARs for the removal alternatives evaluated in this EE/CA. The ARARs for each alternative for the Site are identified and discussed in greater detail in Section 4.

2.3.4 Action-Specific ARARs

Table 2-3 contains a summary of the action-specific ARARs for the removal alternatives evaluated in this EE/CA. The ARARs for each alternative for the Site are identified and discussed in greater detail in Section 4. Key action-specific ARARs are described below.

Vermont Land Use and Development Law; Title 10, Chapter 151 of Vermont Statutes Annotated (Act 250): CERCLA response actions are exempted from obtaining Act 250 permits, but must meet the substantive requirements of Act 250. The following issues to be addressed in assessing compliance with Act 250:

- impact on wetlands (criterion 1[G])
- erosion control (criterion 4)
- construction-related noise and dust (criteria 1 and 8)
- impact on historic sites (criterion 8)

The response action contractor will be responsible for ensuring that any off-site material source areas located in Vermont comply with Act 250.

Solid and Hazardous Wastes: The tailings and solid wastes present at the Site are not “hazardous waste” as defined by RCRA 40 C.F.R. 261. Under 40CFR 261.4(b)(7) (Bevill Exclusion), solid wastes from the extraction, beneficiation, and processing of ores and minerals (including coal) are excluded from the definition of hazardous waste, and therefore not subject to RCRA Subtitle C requirements. These wastes are excluded because implementation of Subtitle C requirements would be unnecessary, technically infeasible, or economically impracticable, due to the types of waste and conditions commonly found at mining sites. These conditions commonly include high volumes of waste with low toxicity and highly mobile constituents and large areas of contamination.

EPA has performed Toxic Compound Leach Procedure (TCLP) analyses of the tailings to determine if the tailings would be considered hazardous. Results indicate that the tailings do not exceed the numerical criteria that would result in the tailings being considered “hazardous waste”. As a result, the RCRA 40 C.F.R. 264 and 265 closure and post-closure standards are not ARARs.

EPA has also evaluated whether the tailings are subject to the requirements that apply to ‘solid waste”. The Vermont Solid Waste Management Rules (10 VSA Chapter 159) provide an exemption for “earth materials resulting from mining, extraction, or processing operations except where the Secretary determines that these materials may pose a threat to public health and safety, the environment, or cause a nuisance”.

The Solid Waste Management Rules apply to the cleanup actions at the Elizabeth Mine Site. The Vermont Solid Waste Management Rules stipulate design specifications for aspects of cap/cover construction and performance including cover material, cover design, and grading requirements. However, the State of Vermont does allow for a variance to be granted from the Solid Waste Requirements by “(a) A person who owns or is in control of any plant, building, structure, process or equipment may apply to the board (solid waste and air quality variance board) for a variance from the rules of the secretary. The board may grant a variance if it finds that:

1) The variance proposed does not endanger or tend to endanger human health or safety; and
(2) Compliance with the rules from which variance is sought would produce serious hardship without equal or greater benefits to the public.
(3) The variance granted does not enable the applicant to generate, transport, treat, store, or dispose of hazardous waste in a manner which is less stringent than that required by the provisions of Subtitle C of the Resource Conservation and Recovery Act of 1976, and amendments thereto, codified in 42 U.S.C. Chapter 82, subchapter 3, and regulations promulgated under such subtitle.
(b) No variance shall be granted pursuant to this section except after public hearing on due notice and until the board has considered the relative interests of the applicant, other owners of property likely to be affected, and the general public.
(c) Any variance or renewal thereof shall be granted within the requirements of subsection (a) of this section and for time periods and under conditions consistent with the reasons therefor, and within the following limitations:
(1) If the variance is granted on the ground that there is no practicable means known or available for the adequate prevention, abatement or control of the air and water pollution involved, it shall be only until the necessary practicable means for prevention, abatement or control become known and available, and subject to the taking of any substitute or alternate measures that the board may prescribe.
(2) If the variance is granted on the ground that compliance with the particular requirement or requirements from which variance is sought will necessitate the taking of measures which, because of their extent or cost, must be spread over a considerable period of time, it shall be for a period not to exceed such reasonable time as, in the view of the board, is requisite for the taking of the necessary measures. A variance granted on the ground specified herein shall contain a time schedule for the taking of action in an expeditious manner and shall be conditioned on adherence to the time schedule.
(3) If the variance is granted on the ground that it is justified to relieve or prevent hardship of a kind other than that provided for in subdivisions (1) and (2) of this

subsection, it shall be for not more than one year, except that in the case of a variance from the siting requirements for a sanitary landfill, the variance may be for as long as the board determines necessary, including a permanent variance.
(d) Any variance granted pursuant to this section may be renewed on terms and conditions and for periods which would be appropriate on initial granting of a variance. If complaint is made to the board on account of the variance, no renewal thereof shall be granted, unless following public hearing on the complaint on due notice, the board finds that renewal is justified. No renewal shall be granted except on application. The application shall be made at least 60 days prior to the expiration of the variance. Immediately upon receipt of an application for renewal, the board shall give public notice of the application in accordance with rules of the board.
(e) A variance or renewal shall not be a right of the applicant or holder thereof but shall be in the discretion of the board. However, any person adversely affected by a variance or renewal granted or denied by the board may obtain judicial review thereof in the supreme court.
(f) This section does not limit the authority of the secretary under section 6610 of this title concerning imminent hazards from solid waste, nor under section 6610a of this title concerning hazards from hazardous waste and violations of statutes, rules or orders relating to hazardous waste. Added 1979, No. 197 (Adj. Sess.), §§ 4, eff. May 6, 1980; amended 1983, No. 148 (Adj. Sess.), §§§§ 9, 10; 1987, No. 76, §§ 18; 1997, No. 161 (Adj. Sess.), §§ 10, eff. Jan. 1, 1998; 1999, No. 148 (Adj. Sess.), §§ 84, eff. May 24, 2000."

EPA is seeking public comment regarding a proposed variance from certain components of the Vermont Solid Waste Management Rules in this EE/CA.

Surface Mining Control and Reclamation Act: The Surface Mining Control and Reclamation Act of 1977 (SMRCA) governs activities associated with coal exploration and mining. Because the standards promulgated under SMRCA are intended for active coal mines, they will not be applicable to actions at Superfund mining sites. However, the standards found in 30 CFR Parts 816 and 817, which govern surface mining activities and underground mining activities, respectively, may be relevant and appropriate at inactive CERCLA mining sites where activities similar to SMCRA-regulated activities occur. This is because SMCRA regulations often address circumstances that are similar and establish performance objectives that are consistent with the objectives of a CERCLA investigation.

Clean Water Act: The discharge from the passive treatment systems will be required to meet federal Clean Water Act requirements under the National Pollution Discharge Elimination System (NPDES) or the VTWQS. Each passive treatment system must be designed to meet these requirements along with federal water quality criteria at the point at which the discharge enters Copperas Brook.

2.4 Non-Time Critical Removal Action Schedule

The schedule in Figure 2-1 shows key administrative steps in the NTCRA process. The NCP requires a public comment period of 30 days following submittal of the Final EE/CA. An additional 30 days are given for EPA to respond to significant comments received during the public comment period. The Action Memorandum is generally signed within 60 days following the response to comments. The schedule for completion of the removal actions is dependent upon approved funding.

3.0 Development of Removal Action Alternatives

3.1 Overview

The guidance for completion of Non-Time-Critical Removal Actions requires that the goals and objectives of the NTCRA are consistent with and supportive of the Remedial Program goals and objectives. EPA is committed through the CERCLA process to addressing all known and/or suspected sources of contamination at the Elizabeth Mine Site through either the NTCRA or Remedial programs. The NTCRA is the first step in the process of defining cleanup goals and objectives and is geared toward addressing the most obvious and significant sources of ongoing contaminant releases to the environment. The NTCRA addresses contamination associated with TP-1, TP-2, and TP-3. Source areas that will be addressed in the Remedial Program include the Air Vent, the South Cut and South Mine, and the underground flooded mine workings (mine pool).

3.2 Statutory and Policy Considerations

Relevant statutes and policies were identified and reviewed to help formulate the range of removal alternatives. These are summarized in the following subsections.

3.2.1 Statutory Considerations

General response actions describe categories of removal actions that may be used to satisfy removal action objectives by eliminating, reducing, or controlling risks and provide a basis for identifying specific removal technologies. Potentially applicable general response actions for a source control NTCRA include implementing administrative measures to prevent, reduce, or control exposure; removing contaminants to prevent, reduce, or control exposure or prevent a release; and, providing treatment to reduce the toxicity, mobility, or volume of contaminants.

The NCP (40 CFR 300.415 (e)) identifies appropriate removal actions that address risks to the public health or welfare, or the environment including, but not limited to, the following:

1. Fences, warning signs, or other security or site control precautions - where humans or animals have access to the release
2. Drainage controls, (e.g. run-off or run-on diversion), where needed, to reduce migration of hazardous substances or pollutants or contaminants off-site or to prevent precipitation or run-off from other sources (e.g. flooding), from entering the release area from other areas
3. Stabilization of berms, dikes, or impoundments or drainage/closing of lagoons, where needed, to maintain the integrity of the structures

4. Capping of contaminated soils or sludges, where needed, to reduce migration of hazardous substances or pollutants or contaminants into soil, ground, or surface water, or air
5. Using chemicals and other materials to retard the spread of the release or to mitigate its effects, where the use of such chemicals will reduce the spread of the release
6. Excavation, consolidation, or removal of highly contaminated soils from drainage or other areas, where such actions will reduce the spread of or direct contact with the contamination
7. Removal of drums, barrels, tanks, or other bulk containers that contain or may contain hazardous substances or pollutants or contaminants, where it will reduce the likelihood of spillage, leakage, exposure to humans, animals, or the food chain; or fire or explosion
8. Containment, treatment, disposal, or incineration of hazardous materials, where needed, to reduce the likelihood of human, animal, or food chain exposure
9. Provision of alternative water supply, where necessary, to immediately reduce exposure to contaminated household water, and continuing the supply until such time as local authorities can satisfy the need for a permanent remedy

CERCLA §9604(a)(2) and the NCP (40 CFR 300.415(c)) provide that removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release of concern. In addition, Section 121(b) of CERCLA expresses the preference for treatment over conventional containment or land disposal to address a principal threat at a site. This preference for treatment applies explicitly to remedial actions, but the overall strategy is also appropriate for removal actions.

3.2.2 Policy and Guidance Considerations

The principal guidance used for development of this EE/CA was the EPA guidance for NTCRAs: "Guidance for Conducting Non-Time-Critical Removal Actions Under CERCLA" (EPA, 1993). The guidance document provides information and procedures/activities for performing NTCRAs.

3.3 Assessment of General Response Actions and Response Technologies

To meet the Removal Action Objectives and ARARs, an evaluation of General Response Actions and Response Technologies was performed. Complete removal and off-site disposal of contaminants (to prevent, reduce or control exposure or mitigate/prevent a release) is not a practical solution for the main tailings piles (TP-1 and TP-2). Together, these tailings piles represent approximately two million cubic yards of material. Removal of all, or a portion of TP-3, with subsequent incorporation into TP-1, has been considered as a viable approach to address ongoing contaminant releases from that portion of the Site. However, the baseline assumption for this EE/CA is that TP-3 will remain in place and measures will be taken to capture and treat contaminated water resulting from storm water runoff and ground water seeps from this area. Covering or capping the waste materials in TP-1 and TP-2 represents the most practical and cost-effective response measure to reduce the mobility of contaminants by eliminating, or greatly reducing, the generation of AMD. Covering or capping does not address the toxicity of the contaminants, nor does it reduce the volume of the contamination source material.

3.3.1 Overview and Summary of Alternatives

Section 300.415(e) of the NCP provides examples of removal actions appropriate for a range of situations, but sets forth no specific requirements for identifying and evaluating removal alternatives. EPA guidance on preparing an EE/CA recommends identifying and assessing a limited number of alternatives appropriate for addressing the removal action objectives, while considering the CERCLA preference for treatment. The guidance also suggests the use of "presumptive remedies" (such as capping) to limit the wide spectrum of potential alternatives for the NTCRA.

The development of Removal Action Alternatives for the Elizabeth Mine involved an initial screening step that was summarized in the Alternatives Analysis Report (ADL April 2001). That report described the evaluation of a wide array of technologies available to mitigate and/or control the production of AMD. Many of these approaches are well established with proven track records of success. Others are emerging technologies without a long track record. This EE/CA includes a thorough review of a subset of the alternatives described in the Alternatives Analysis Report (AAR). A brief summary of the AAR follows.

Technologies for addressing AMD can be categorized under the following general approaches:

Treatment Technologies. These technologies treat AMD after formation through biological or chemical reactions which reduce acidity and/or metals concentrations in AMD-contaminated waters.

Containment Technologies. These technologies prevent or reduce the formation of AMD by isolating the AMD generating wastes from oxygen and/or water infiltration, or by using chemical and biological methods that prevent or retard the formation of AMD.

Combined Containment and Treatment*.* These technologies both limit AMD formation and treat any residual contamination that exists after control mechanisms are in place. Response approaches for mine sites often incorporate both containment and treatment techniques in order to achieve water quality and land use objectives.

Table 3-1 presents a summary of potential response technologies considered in the initial screening.

Table 3-1: Technologies Considered in the Initial Screening

Technology Reviewed		Retained for Preliminary Evaluation	April 2001 Alternative That Contained These Components
Control			
Caps	Multi-barrier	Yes	2A, 2B, 2C
	Soil Cover	Yes	3
	Organic Waste Cover	No	——
	Chemical Hardpan Cap	Yes	3
Groundwater Control		Yes	1, 2, 3, 4
Inundation/Wet Covers		Yes	4
Slurry Walls and Grout Curtains		No	——
SurfaceWater Diversion Channels		Yes	1, 2, 3, 4
Treatment			
Active Treatment Plant		Yes	1
Biocides		No	——
Buffering Systems		Yes	2, 3, 4
Contructed Wetlands	Aerobic Wetlands	Yes	2, 3, 4
	Anaerobic Wetlands	Yes	2, 3, 4
Limestone Drains/Channels		Yes	2, 3, 4
Limestone Ponds		Yes	2, 3, 4
Settling Ponds	SAPS	Yes	2, 3, 4
	Oxidation	Yes	2, 3, 4
Vertical Flow Systems		No	——
Reaction Walls		No	——
Sulfate Reducing Bacteria (SRB)		Yes	2, 3, 4

A single remedial technology seldom proves sufficient for addressing the complex and multi-faceted environmental issues at former mining and milling sites. Four response scenarios (alternatives) were developed and presented in the AAR, representing the technologies that hold the most promise for success.

Each alternative from the AAR is briefly described in Table 3-2.

Table 3-2: Response Alternatives

Alt. #	Description	Technology Components	EE/CA Status
1	Collect and treat surface runoff with active treatment	• Surface water diversion • Runoff retention pond(s) • Chemical treatment plant • Sludge management systems • Erosion control and stabilization of tailings using a retention structure, most likely Roller Compacted Concrete (RCC)	Alternative not retained for analysis in EE/CA. Community and State were opposed to large long-term costs associated with total capture and treatment of the run-off.
2A	Hydraulic Containment	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 • Excavate and move TP-2 and TP-3 onto surface of TP-1 • Regrade TP-1 to eliminate steep slope • Hydraulic isolation of combined tailings pile	Alternative not retained for analysis in EE/CA. Community and NHPA concerns eliminated this option.
2B	Hydraulic Containment: 2A, but leave portion of TP-3 in place	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Excavate and move TP-2 and Subarea A of TP-3 onto TP-1 • Regrade TP-1 to eliminate steep slopes • Hydraulic isolation of combined tailings pile	Alternative evaluated in EE/CA.
2C	Hydraulic Containment: 2B, but retain current surface profile of TP-1 and TP-2	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Excavate and move (portion of) TP-3 onto TP-1 and TP-2 surfaces • Retain profiles of TP-1 and TP-2 with minimal regrading necessary to ensure positive surface drainage • Construct retention structures (RCC) to stabilize slopes • Hydraulic isolation of combined tailings piles (TP-1 and 2)	Alternative evaluated in EE/CA with some modifications regarding TP-3.
3	Soil cover	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Regrade all three tailing piles (possibly retain portion of TP3) • Soil layer underlain by crushed limestone • Vegetate surface	Alternative evaluated in EE/CA. Alternative was evaluated as three separate soil cover approaches in EE/CA.
4	Wet Cover	• Surface water diversion onto surface of TP-1 and TP-2 • Re-grading of TP-1 and TP-2 to achieve terrace profile • Construct fens/wetlands on surface of TP-1 and TP-2 • Construct toe drain at base of TP-1 • Passive treatment of seeps at base of TP-1 • (possibly include passive treatment of portion of TP-3) • Soil cover over TP-1 and TP-2 • Re-vegetate soil cover and fens/wetlands	Alternative not retained for analysis in EE/CA. EPA and state eliminated this alternative due to technical concerns regarding this approach.

The results of the AAR evaluation and subsequent comments are summarized below:

- Alternatives 1 and 4 from the AAR were eliminated from further consideration in the EE/CA due to cost and technical considerations**.**
- Alternative 2A was eliminated from further consideration due largely to the proposed impacts to features of historic significance (complete excavation of TP-2 and TP-3).
- Alternatives 2B and 2C were retained for evaluation in the EE/CA.
- Alternative 3A was eliminated due largely to the impact to historic features.

Based on the results of the AAR and the subsequent comments from the public and state, EPA developed a focused list of five alternatives for consideration in the EE/CA. Alternatives 3B, 3C, and 3D evolved from further consideration of the original Alternative 3(A). Alternatives 3B, 3C, and 3D are evaluated in this EE/CA along with Alternatives 2B and 2C.

3.3.2 Common Elements/Technologies in Each Alternative

A number of treatment technologies are common to each alternative under consideration. This section provides a description of these technologies to minimize redundancy in the detailed description of alternatives. The common elements consist of the following:

- Passive treament systems for runoff/seeps
- Slope stabilization measures
- Covers/caps

3.3.2.1 Passive Treayment Systems

Preliminary design concepts for addressing mine wastes at the Elizabeth Mine incorporate “passive” treatment approaches into the long-term remedy to provide a low-cost sustainable solution to acid mine drainage. Passive treatment involves natural physical, biochemical and geochemical reactions and processes within a series of engineered treatment facilities (that require very little maintenance once constructed and operational) to achieve treatment goals. Passive approaches to treating acid mine drainage are increasingly accepted by regulators throughout North America and around the world.

All of the cleanup options under consideration by EPA, and evaluated in this EE/CA, seek to minimize the infiltration of surface water into tailings and other waste materials through the construction of caps or covers over TP-1 and TP-2. Infiltration rates vary depending on the surface cover/cap construction approach. Ultimately, all water that infiltrates into TP-1 and TP-2 must be treated at the toe of TP-1. Similarly, all runoff and seep water from TP-3 must be treated by passive systems, since the current approach involves retaining TP-3 in its current condition.

Passive water treatment systems involve a variety of chemical and biochemical reactions, including (but not limited to) calcium carbonate dissolution, sulfate reduction, bicarbonate alkalinity generation, metals oxidation, and metals precipitation. Further, plant species in constructed wetlands stabilize mobile metals through uptake and incorporation into plant tissue. The passive treatment systems proposed at Elizabeth Mine are designed for contaminated water to flow naturally from one component to another by gravitational forces. The passive systems will be designed to achieve Vermont water quality standards for the water flowing out of the treatment systems at the point of discharge. As the standards must be adjusted for hardness in the effluent, setting the final treatment goals will be determined during the Design process.

AMD at both treatment areas will be collected in holding ponds and discharged to the treatment components. Preliminary engineering analysis indicates that a SAPS is most appropriate for treatment of the runoff from TP-3. High metals concentrations observed at EPA Location 2 dictate that two SAPS (in-series) will likely be necessary to achieve the desired treatment. SAPS will be followed by a final polishing step in an aerobic wetland. SAPS are considered in this EE/CA for the TP-1/TP-2 passive system as well.

The following is a description of the passive treatment system elements that are envisioned in this EE/CA for long-term AMD remediation at the Elizabeth Mine. Construction and Post Removal Site Control (PRSC) costs presented in this report are based on the assumptions and design elements provided. Bench and pilot-scale tests will be proposed for the pre-design phase, followed by a more definitive proposed approach during the design stage.

Anoxic Limestone Drain

Anoxic Limestone Drains (ALDs) are buried trenches of limestone used to passively treat acid mine drainage. As contaminated water flows through the ALD, limestone is dissolved to add alkalinity to the acidic water (Gazea, *et al.,* 1996). Thus, pH is raised such that precipitation of dissolved metals occurs after the water exits the drain (Watzlaf and Hyman, 1994). An ALD is proposed at the base of the TP-1/TP-2 toe drain to provide initial treatment of AMD from this source. Dissolved oxygen and aluminum concentrations are too high in the TP-3 AMD to make construction of an ALD feasible for this area.

Design

AMD is piped into the ALD directly from the source, before it has been exposed to the atmosphere. AMD passes through a limestone layer, typically three feet thick. The limestone layer is overlain by 10 to 20-mil plastic sheeting, followed by a geosynthetic fabric to prevent puncturing of the plastic. The fabric is then covered with compacted clay. The plastic and clay are emplaced to inhibit the infiltration of atmospheric oxygen. Clay is then covered by native soil. The clay should be three feet thick. The surface of the ALD should be mounded to inhibit surface water infiltration and to accommodate long-term subsidence as the limestone dissolves. The outflow pipe is installed at the top of the limestone trench and is equipped with an air trap to prevent oxygen migration into the drain. Ideally, the limestone layer should be fully saturated at all times. ALD effluent will be discharged to the holding pond.

Sizing Considerations

At the TP-1 treatment area, an Anoxic Limestone Drain (ALD) is planned prior to the holding pond to increase alkalinity. The USGS has demonstrated relatively high alkalinity in the near neutral seep waters from TP-1. Hammarstrom (2001) has postulated that the till underlying the tailings piles may be the source of the alkalinity. Additional alkalinity is desired to neutralize the high acid potential of the TP-1 seep water. Water chemistry and space restrictions do not make construction of an ALD at the TP-3 treatment area feasible. For costing purposes, the preliminary design assumes an ADL length of 400 feet. To achieve this size in the TP-1 area, the trench must be constructed in an east-west fashion, parallel to the toe of the tailings north slope.

Holding Ponds

Holding ponds provide hydraulic retention of contaminated water prior to discharging to SAPS or aerobic wetlands. Hydraulic retention stabilizes flow rates to the treatment systems so that acid-shocks to bacteria do not occur. A secondary purpose of the holding pond is to allow settling of particulate matter prior to discharge to the treatment systems. The planned treatment system requires holding ponds at the toe of TP-1 and below TP-3 at the headwaters of Copperas Brook.

Design

The holding ponds will be of earthen construction and lined with very low-density polyethylene (VLDPE). Pond depth is designed to be six feet deep. A perimeter fence may be constructed around the ponds. The earthen structure will be constructed in a manner that conforms to the local topography to the greatest extent possible, both to minimize construction costs and improve the visual appearance.

Sizing Considerations

The holding pond at the toe of TP-1 will receive water captured in a toe drain and treated through the ALD at the bottom of the TP-1 north slope. Discharges from TP-2 seeps and the 1940s/50s adit will be conveyed to the holding pond via the toe drain system. Discharge from the holding pond will be at the same rate as inflow into the passive treatment systems. The assumptions used to size the TP-1/TP-2 holding pond are the following:

- *Ground Water Contributions*: The “clean” stormwater diversion channel, which is proposed around the perimeter of TP-1 and TP-2, will be “keyed” into the underlying till layer and will intercept shallow ground water flowing from upgradient locations around the tailings piles. These perimeter drains will likely have a substantial impact on the amount of water passing through the tailings over time by removing the run-on and lateral contribution components to the overall hydrologic conceptual model. Future contribution of ground water to the total effluent toe-drain discharge is expected to be small, due to the low permeability of the glacial till which underlies the tailing piles. We assumed a nominal future ground water contribution of 5 gpm.

- *Hydrologic Buffering Capacity*: The impact of storm events on the discharge rate of contaminated water from the toe of TP-1/TP-2 will be buffered by infiltration through the tailing piles; short-term increases as a result of individual storm events are unlikely. We expect that the effects of precipitation during storm events or spring melting will be attenuated over a long period of time, so that pond sizing becomes a function of average precipitation rates rather than storm precipitation rates.
- *Hydraulic Storage Depletion:* The reduction of inflow due to the cover/cap and the perimeter diversion channel will lower the steady state groundwater levels within TP-1, which in turn will reduce the seepage at the toe of TP-1 as the tailing pile drains. The reduced toe seepage will reduce the future required holding pond capacity. The holding pond sizing calculations consider the initial, (i.e. maximum), inflows.
- *Contingency Factor*: All holding pond sizing calculations are increased by 50% to account for uncertainty related to long term discharge rates.

The following equation is used to determine the average effluent flow rate along the toe drain:

$E = (IA/T)7.48\text{gal/ft}^3 + G$, where

E = Effluent flow rate (gpm)

I = Infiltration (ft): Average precipitation at Union Village Dam is 35 inches (2.92 ft). Depending of the remediation alternative, various infiltration amounts are used. For example, infiltration of zero-inches is used for Alternatives 2B/2C because a RCRA cap proposed as the cover for the tailings pile.

A = TP-1/TP-2 Area (ft^2)

T = Detention Time (min): The detention time is assumed is assumed to be 182.5 days (½ year [263,000 min]). There are periods of time during the year, particular spring and late fall, where the highest discharge rates are expected. Assigning a detention time of ½ year has the net effect of increasing the calculated discharge rate by 100 % over the annualized discharge rate, thus providing a measure of conservatism in final sizing determination.

G = Ground Water Contribution: A nominal ground water contribution is expected even after the surface water diversion channels are installed around the perimeter of TP-1/TP-2. This contribution is estimated at 5 gpm.

The holding pond below TP-3 will receive mostly storm water runoff from the TP-3 area. The amount of runoff will vary depending on how much of TP-3 is removed (if any). Discharge from the holding pond is estimated to range as high as 40 gpm. The TP-3 holding pond was sized using the 100-year 24-hour storm event (5.65 inches). Details of the system will be addressed during the Design stage. Three analytical methods were evaluated:

- *Correlation with USGS-Gauged Watersheds*: Damariscotta (1999) used the Sleepers River Experimental Watershed (W-9) in Danville, Vermont, where extensive flow data have been collected, as a calibration standard for expected flow from the Copperas Brook basin.
- *USDA Storm Water Flow Model – TR55*
- *Runoff Calculations Assuming Minimal Infiltration and Retention*

The results that were calculated by each of these methods were averaged to provide the runoff volume used in this analysis. As a contingency, the total volume of the holding pond was then increased by 50% to account for uncertainty in the estimate. The sizing table below assumes a six-foot deep pond in all cases. Various options for TP-3 are considered in the following table to provide a sensitivity analysis.

Remediation Alternative	**Holding Pond Size (Acres)**	
	TP-1/TP-2	**TP-3**
Alternative 2B – RCRA Cap on TP-1/TP-2		
Scenario 1: TP-3 Left In-Place	0.04	1.01
Scenario 2: Excavate TP-3A_2 and TP-3A_3	0.04	0.55
Scenario 3: Excavate TP-3A	0.04	0.24
Alternative 2C– RCRA Cap on TP-1/TP-2		
Scenario 1: TP-3 Left In-Place	0.04	1.01
Scenario 2: Excavate TP-3A_2 and TP-3A_3	0.04	0.55
Scenario 3: Excavate TP-3A	0.04	0.24
Alternative 3B – 42-inch Soil Cover; TP-1/2		
Scenario 1: TP-3 Left In-Place	0.07	1.01
Scenario 2: Excavate TP-3A_2 and TP-3A_3	0.07	0.55
Scenario 3: Excavate TP-3A	0.07	0.24
Alternative 3C – 6-inch Soil Cover, TP-1/TP-2		
Scenario 1: TP-3 Left In-Place	0.10	1.01
Scenario 2: Excavate TP-3A_2 and TP-3A_3	0.10	0.55
Scenario 3: Excavate TP-3A	0.10	0.24
Alternative 3D –Hardpan Cover, TP-1/TP-2		
Scenario 1: TP-3 Left In-Place	0.04	1.01
Scenario 2: Excavate TP-3A_2 and TP-3A_3	0.04	0.55
Scenario 3: Excavate TP-3A	0.04	0.24

Successive Alkalinity Producing Systems (SAPS)

Successive Alkalinity Producing Systems (SAPS) are proposed as the principal passive treatment technology for AMD at the Elizabeth Mine. The SAPS design utilizes the sulfate reduction processes and alkalinity generation of anaerobic wetlands and ALDs to remove metals from mine water, while greatly increasing the alkalinity production beyond the capabilities of either of the two systems working alone. SAP systems are considered for treatment of TP-1/TP-2 and TP-3 effluent streams.

Design Considerations

SAPS treat AMD through a combination of an organic substrate layer and a crushed limestone layer. A typical SAP is constructed within a lined earthen pit. Typical components of the SAP are a three-foot column of water, underlain by two-feet of organic substrate, and three-feet of gravel-size limestone. Metal removal is principally achieved through reduction reactions in the organic substrate layer, resulting in the removal of dissolved oxygen and biologically-mediated precipitation of metal sulfides through the reduction of sulfate. While iron is the principal metal removed, the anaerobic conditions present in the organic layer are also conducive to the removal of aluminum, cadmium, copper, and zinc (Gusek and Wildeman, 1995). The water flows downward through the organic layer to the underlying limestone where additional alkalinity is generated.

Aluminum hydroxide precipitation can result in clogging of the limestone substrate, particularly where aluminum concentrations exceed 40 mg/L (Hyman, 2000, Personal Communication). For this reason, PVC piping will be installed within and at the base of the limestone layer to facilitate the periodic flushing of the substrate. A design limitation is the effective life of the organic layer and the limestone substrate. The ability of the organic mat to function as a reducing medium will eventually diminish to the point where metal precipitation on limestone will occur, thus reducing the treatment capability of the SAP. When this occurs, the limestone and organic layers will need replacement. Using data from existing SAPS (e.g. Howe Bridge) we anticipate a design life of 12 to 15 years. The effective life can be increased if treatment criteria are achieved through a single SAP (assuming two are constructed in series or in parallel) in either location. This may be possible for TP-1, but it is unlikely for TP-3.

Sizing and Performance Considerations

Guidance for the sizing of SAPS is provided by the Pennsylvania Department of Environmental Protection, Bureau of Mining and Reclamation (PADEP, 2000). Sizing begins with determining the mass of limestone that will be required to meet certain design criteria. The following equation was developed by Hedin and Watzlaf for ALDs (1994), but is also recommended for SAPS:

$$M = Q_{Pbtd}/V_v + QCT/x$$

where,

M = mass of limestone (t)
Q = is the volumetric flow rate (gallons per minute)
pb = bulk density of limestone (t/m^3)
td = detention time (hrs)
Vv = bulk void volume fraction

C = predicted effluent alkalinity concentration (mg/L)
T = design life (years)
x = $CaCO_3$ fraction of limestone

Volumetric Flow Rate (Q)
The flow entering proposed SAPS is controlled in order to minimize acid shock to sulfate reducing bacteria and maintain a constant head on the organic mat. The principal means of controlling flow into the SAPS is the holding pond. A constant flow rate allows greater predictability for overall performance and O&M (PRSC) costs. Flow rates for the SAPS receiving seep discharge from TP-1 and TP-2 are calculated using the estimated infiltration rate through these tailings piles. A safety factor equal to 100% of the seepage flow rate is added to the design flow to account for ground water flow that may not be completely cut-off by the surface water diversion channels around the TP-1 and TP-2. Because the cover design for TP-1 and TP-2 varies under each remediation alternative, the flow rate to the SAPS will be different, ranging between 5 to 10 gpm for Alternatives 2B/2C to 40 gpm for Alternative 3C.

The flow rate for SAPS receiving storm water runoff from TP-3 is estimated to be 20 to 40 gpm for alternatives under consideration. The holding pond is designed to handle runoff from a hypothetical 100-year, 24-hour storm event.

Bulk Density of Limestone (pb)
The bulk density of limestone is estimated to be 1.2 tons per cubic yard, based on information provided by a possible vendor located near Burlington, Vermont (Shelburne Limestone Corporation, Essex Junction).

Detention Time (td)
Detention times of 15 hours are typically used (Hedin and Watzlaf, 1994), as additional detention time in a SAP does not significantly increase alkalinity.

Bulk Void Volume Fraction (Vv)
The bulk void volume is estimated to be 0.3.

Predicted Effluent Alkalinity (C)
The predicted effluent alkalinity is estimated to be 200mg/L of $CaCO_3$ equivalent. Seeps at the base of TP-1 range in alkalinity as $CaCO_3$ from 2.45 to 120.1, with an average of 52 mg/L (USGS, 1998). The alkalinity as $CaCO_3$ at the base of TP-3 is 0 mg/L (USGS, 1998). The acidity of these waters is about 1,300 mg/L as $CaCO_3$ (Darmariscotta, 1999). An increase in alkalinity to 200 mg/L from similarly acidic waters has been documented (Skousen, et al., undated).

Design Life (T)
A design life of 12 to 15 years is used for all SAPS. This represents the estimated effective lifespan of the limestone and organic mat. Examples of sustained SAP

performance of 10 to 15+ years include Howe Bridge and Oven Run, both located in Pennsylvania.

$CaCO_3$ fraction of limestone (X)
The $CaCO_3$ fraction of the limestone is estimated to be 95%.

The table below summarizes the size of the SAP-systems proposed for the TP-1/TP-2 and TP-3 areas. Each SAP system is designed as two SAPS in series. This design offers a certain degree of redundancy to ensure that effluent attainment goals, including reducing acidity, increasing alkalinity, Fe^{+3} precipitation, and sulfate reduction, are achieved. In the event of extremely high flow conditions (flow exceeding holding pond limits), the SAPS can be modified to act in parallel. Further, the dual SAP system allows for periodic maintenance without shutting-off the treatment process.

Remediation Alternative	**SAP Size (Acres)**	
	TP-1/TP-2	**TP-3**
Alternative 2B – RCRA Cap on TP-1/TP-2	0.482	0.661
Alternative 2C– RCRA Cap on TP-1/TP-2	0.482	0.661
Alternative 3B – 42-inch Soil Cover; TP-1/TP-2	0.773	0.661
Alternative 3C – 6-inch Soil Cover, TP-1/TP-2	0.966	0.661
Alternative 3D –Soil/Hardpan Cover, TP-1/TP-2	0.488	0.661

Aerobic Wetlands
The final component of the proposed passive treatment system is an aerobic wetland. Aerobic wetlands are used to collect water and provide residence time and aeration so metals can precipitate. Wetland ecosystems have the ability to further raise the pH of acidic waters and to remove metals from AMD through a variety of mechanisms. Wetlands may be created or constructed to treat contaminated water, allowing the treatment potential of wetland ecosystems to be utilized without endangering natural, existing systems. Constructed wetlands typically consist of one or more wetland cells; each cell is a shallow basin or channel through which the contaminated water flows to be treated. An impermeable liner along the bottom and sides of the cell provides a barrier to seepage of contaminated water into the surrounding environment. Inlet and outlet structures at opposing ends of the wetland cell are designed to optimize distribution of the wastewater throughout the cell. Wetland cells are generally designed to be plug-flow systems, where the wastewater entering at a certain point can be assumed to spend a certain amount of time within the wetland for treatment before exiting as treated effluent. The amount of time that a given quantity of water spends in the wetland is the hydraulic retention time (HRT) of the wetland cell. This parameter is important for design and for determining the effectiveness of the wetland system in removing contaminants. (Reed *et al*, 1995)

Metal removal occurs in wetland systems through various mechanisms. Gusek and Wildeman (1995) describe the following major processes:

- Filtering of suspended material
- Ammonia-generated neutralization and precipitation
- Adsorption and exchange with plant, soil and other biological materials
- Metal uptake into live roots and leaves
- Hydroxide precipitation catalyzed by bacteria in aerobic zones
- Sulfide and carbonate precipitation catalyzed by bacteria in anaerobic zones

The wetlands included in the Elizabeth Mine preliminary design concepts serve as a polishing step following treatment in the SAPS.

The primary means of removal for many metals is through chemical fixation through sulfide precipitation and chemical precipitation as pH is raised. Adsorption onto substrates used in wetland cells is another prominent metal removal mechanism in wetlands. Plant roots may serve as a local site for both adsorption and/or metal precipitation. As the wetland plants mature, portions of the root material are discarded causing adsorbed metals to become part of the organic sedimentation and bottom sludge of the wetland (Reed *et al*, 1995). Uptake of metals by plants (or absorption) is a less significant means of removal, as has been presented by a number of studies over the past decade, including a relatively recent study by Mitsch and Wise, 1998. Thus, above water plant biomass tends to retain fairly low concentrations of heavy metals, while the sediment material of the wetland tends to accumulate metals. This is significant because it may lead to the need for dredging wetlands that have been exposed to relatively high metals loading as a part of maintaining operations.

There are two types of constructed wetlands used for the treatment of AMD: aerobic and anaerobic wetlands. Aerobic wetlands are designed with large surface area to volume ratios to promote contact of water with the atmosphere. Treatment is provided through oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) which then forms ferric hydroxides and oxyhydroxides through hydrolysis. The reaction rate is partially pH-dependent, with the rate decreasing with lower pH (Robinson, 1997). A shallow soil layer (<30 cm) is placed on the bottom of the wetland to provide a growth substrate for macrophyte vegetation. (Gusek and Wildeman, 1995, Hedin, 1996)

In contrast, anaerobic wetlands are designed to promote reducing conditions. In anaerobic wetland cells, AMD water flow is directed through an organic substrate which fills the wetland cell. This subsurface flow through a permeable organic substrate reduces exposure of water to air, providing the anaerobic conditions and the organic material necessary for the functioning of sulfate-reducing bacteria. Common organic substrates used in anaerobic wetland cells include spent mushroom compost. Vegetation is planted on the surface of the organic substrate, and as the plants mature the root systems extend into the substrate. The root systems of the plants help to prevent channeling (or preferential flow) of the water flow through the substrate. Channeling reduces the effectiveness of the wetland system by reducing HRT, and therefore reduces exposure time of the AMD to the primary treatment mechanisms. Designs of inlet and outlet systems are also important for reducing channeling, and providing an even distribution of contaminated water through the wetland cell. (Williams and Stark, 1996).

A simple comparison of the aerobic and anaerobic wetland systems provides a basic context for contrasting their potential effectiveness for a given application. The following is provided by Gusek and Wildeman, 1995:

Aerobic Wetland Systems	Anaerobic Wetland Systems
Emphasize oxidation reactions	Emphasize reduction reactions
Surface flow of water	Subsurface water flow
Metal-oxide precipitates	Metal-sulfide precipitates
Processes can lower pH	Processes can raise pH
Operate best at pH > 5.5	Can work at pH ≥ 2.5
Might freeze in winter temp)	Operate in winter (below freezing
Removes Fe, Mn, Se, As	Remove other heavy metals quite well

Site specific factors such as the climate, flow rates, and the specific chemistry of the AMD, including pH and contaminant concentrations are important in choosing a wetland type and in developing design criteria. As a polishing step, the aerobic system is preferred for the passive treatment system at the Elizabeth Mine. Sulfate reduction in the SAPS is the primary metals removal step. The aerobic wetland is designed to reintroduce oxygen to the treated water, enhance overall biodiversity, and remove any remaining metals that may be above discharge criteria.

Sizing and Performance Considerations

Guidance for the sizing of aerobic wetlands is provided by the (former) U.S. Bureau of Mines. The size of the wetland, measured in acres of surface area, is estimated by the following equation:

[Fe loading (lb/day)/180(lb/ac/day)]+[Mn loading (lb/day)/9(lb/ac/day)]+[acidity(lb/day)/60(lb/day/acre)]

Iron Loading: The SAP systems are very effective at retaining iron in organic substrate. As a result, the iron species in the effluent will be significantly reduced before discharge to the wetland. For example, the Howe Bridge SAP in Pennsylvania has reduced iron by 50%, and even higher removal rates have been documented (Skousen, et al. undated). For conservative estimation purposes, we assumed that only 50% of the iron would be retained in the SAPS, with the remainder discharging to the wetlands. Seeps at the toe of TP-1 have iron concentrations ranging from 101 mg/L to 747mg/L in recent sampling events. We assumed an average seep concentration of 462 mg/L. Iron concentrations at the TP-3 area range from 70.7 mg/L to 106 mg/L, with an average concentration of 88 mg/L.

Manganese Loading: Manganese concentrations have been measured between 2 mg/L and 6 mg/L. We assumed that 50% of the manganese load would pass thought the SAPS into the wetland.

Acidity Loading: The acidity of the seeps at TP-1 and stormwater runoff at TP-3 is approximately 1300 mg/L as $CaCO_3$. Existing SAPS, such as Howe Bridge in Pennsylvania, have successfully decreased acidity by 40% or more. Assuming the same level of reduction at the Elizabeth Mine SAPS, we estimate that the acidity loading will be approximately 780 mg/L. A safety factor of 50% was applied to the calculated size of the wetland in order to account for uncertainties associated with the loading assumptions. The sizing equation described above was developed for Abandoned Mine Lands (AML) compliance. According to the Pennsylvania DEP, National Pollution Discharge Elimination System (NPDES) effluent limits are generally more conservative than AML criteria. Therefore, as a “rule-of-thumb”, standard practice is to create a wetland twice as large as suggested by the AML sizing calculation to meet NPDES criteria.

Remediation Alternative	**Wetland Size (Acres)**	
	TP-1/TP-2	**TP-3**
Alternative 2B – RCRA Cap on TP-1/TP-2	1.6	1.4
Alternative 2C – RCRA Cap on TP-1/TP-2	1.6	1.4
Alternative 3B – 42“ Soil Cover, TP-1/TP-2	2.5	1.4
Alternative 3C – 6” Soil Cover, TP-1/TP-2	3.2	1.4
Alternative 3D – Hardpan Cover, TP-1/TP-2	1.6	1.4

3.3.2.2 Slope Stabilization Technologies

A geotechnical engineering evaluation was performed to assess the stability of the existing tailings. The critical areas for all of the tailings are the steep side slopes. TP-1 has the most extensive area of steep slopes. These slopes could fail at high groundwater levels or under earthquake loading. Thus, preserving these slopes requires stabilization techniques. There are two basic approaches to slope stabilization. The most common method is to re-shape the slope to a less steep and more stable configuration. Alternative 2B takes this approach to slope stabilization. When space or other factors (associated impacts with exposure of unoxidized tailings and historic preservation) dictate that re-shaping is not desirable, then other more sophisticated engineering options may be applied. Alternatives 2C, 3B, 3C, and 3D preserve the tailing slopes for TP-1 and TP-2 at their existing slope angles using engineered measures. The *Guidelines on Ground Improvement for Structures and Facilities* by the U.S. Army Corps of Engineers (USACE, 1999) lists a number of methods for improving the stability of slopes, including admixture stabilization, roller compacted concrete, grouting, and soil nailing. Methods that may be applicable to the Elizabeth Mine are described below.

Roller Compacted Concrete: Roller compacted concrete (RCC) is essentially a “no-slump” concrete material composed of a blend of coarse aggregate, fine aggregate, cement, and water. It can be used to construct earth dams with steep slopes, to provide overtopping protection for existing earth dams, and to buttress existing slopes. It is placed and spread using conventional earth moving equipment, compacted with vibratory rollers and allowed to cure. During curing, the RCC hydrates and hardens into weak concrete. In recent years, many dams have been constructed or rehabilitated using RCC.

Selection of Materials for RCC - It is important to assess the availability and suitability of the materials needed to manufacture RCC with qualities that meet the structural and durability requirements.

a. Cementitious Materials. Type II Portland cement is recommended because of its low heat generation characteristics at early ages and its longer set times. The slower rate of strength development of some cements generally results in greater ultimate strength for a given cement content. The use of a pozzolan or ground slag may be especially beneficial in RCC as a mineral filler and for its cementitious properties, as well as providing a degree of lubrication during compaction. RCC mixtures containing Class F fly-ash benefit from increased placement time and increased workability. Reuse of this fly-ash waste material achieves further environmental benefits. Laboratory testing should be conducted to verify and evaluate the benefits of using pozzolan and fly-ash.

b. Aggregates. Aggregate for RCC should meet the standards for quality and grading as required by the desired properties for the design structure. Changes from the grading or quality requirements must be supported by laboratory or field test results included in a design memorandum.

c. Water. Experience has shown that the source of water (groundwater vs. surface water) can have a significant effect on RCC performance. Times of setting and strength development can vary significantly.

d. Chemical Admixtures. Chemical admixtures can be used to improve workability, delay time of setting, and improve durability of such mixtures. Dye can be added to RCC to change its color to match the current color (tan-orange) of the tailings piles.

Design and Construction Considerations - Factors in selecting the features of an RCC structure for the Elizabeth Mine are discussed below.

a. Foundation. Building the RCC buttress requires construction of a proper foundation, or improvement of the foundation soils that are in place. Preliminary investigations show that weak soils exist at the surface near the toe of the TP-1 and TP-2 slopes. However, a dense glacial till with excellent construction properties is present at the toe of TP-1 at a depth averaging three feet below current ground surface. The foundation design requires careful consideration of subsurface drainage.

b. Drainage System. The RCC structure must include provisions for the cap drainage system and underground water seepage. Ground water discharge through the toe of the tailings must be controlled, as described in Alternative 2B.

c. Reinforcement. It may be necessary to embed reinforcing steel in the RCC. This will be analyzed in detail during the design stage.

Admixture Stabilization: Admixture stabilization consists of mixing or injecting admixtures such as cement, lime, fly-ash, or bentonite into a soil to improve its properties. Admixtures can be used to increase the strength, decrease the permeability, or improve the workability of a soil. Admixtures can fill voids, bind particles, or break down soil particles and form cement. The general process of admixture stabilization consists of (1) excavating and breaking up the soil, (2) adding the stabilizer and water, if necessary, (3) mixing thoroughly, and (4) compacting the soil and allowing it to cure. Soil-cement admixtures have been successfully employed to protect and stabilize steep slopes.

Soil Nailing: The basic concept of soil nailing is to reinforce and strengthen the existing ground by installing closely-spaced steel bars, called "nails", into a slope. This process creates a reinforced section that is internally stable and able to retain the ground mass. The nails used in soil-nailing retaining structures are generally steel bars that can resist tensile stresses, shear stresses, and bending moments. They are generally either placed in drilled boreholes and grouted along their total length or driven into the ground. By spacing the “nails” closely, a composite structural entity can be formed. The nails are typically steel bars 20 to 35 mm in diameter, with a yield strength in the range of 420 to 500 N/mm^2, and are typically installed at a spacing between 1 and 2 meters. Drainage from the soil is provided with strip drains and the face of the slope is protected with a shotcrete layer.

The purpose of soil nailing is to improve the stability of slopes or to support slopes by intersecting potential failure planes. There are two mechanisms involved in the stability of nailed soil structures (Mitchell and Christopher, 1990). Resisting tensile forces are generated in the nails in the active zone. These tensile forces must be transferred into the soil in the resisting zone through friction or adhesion mobilized at the soil-nail interface. The second mechanism is the development of passive resistance against the face of the nail.

The nails need to be epoxy-coated for corrosion protection. The shotcrete can be dyed for aesthetic purposes.

Cost considerations will likely eliminate soil nailing as the preferred slope stabilization option, unless other options are not feasible.

Mini-Piles: Mini-piles, also known as micro-piles or root piles, are “small-diameter, bored, grouted-in-place piles incorporating steel reinforcement” (ASCE, 1997). Mini-piles can be used to withstand axial loads and/or lateral loads, either for the support of structures or the stabilization of soil masses. Diameters are usually in the range of 100 to 250 mm with lengths up to 20 to 30 m and capacities from about 100 to 300 kN (67 to 225 kips).

Conventional concrete cast-in-place piles generally rely on the concrete to resist the majority of the applied load. In contrast, mini-piles often contain high strength steel elements that occupy up to 50 % of the borehole volume. Therefore, the steel element is the primary load-bearing component, and can develop high load carrying capacities, while the grout serves to transfer the load from the steel to the soil.

Due to the acid-generating conditions in the tailings piles, the mini-piles stabilization system is not recommended.

3.3.2.3 Caps/Covers

Hydraulic isolation of tailings will prevent water from entering the tailings from the top and sides, thus reducing erosion and leachate generation. A surface water diversion channel is included in all Alternatives. This diversion channel will intercept all run-on and shallow groundwater that is currently entering TP-1 and TP-2.

To complete the isolation of TP-1 and TP-2 from water (and subsequent AMD formation) a cover is need to limit the amount of direct infiltration (rain/snowmelt) from entering the tailings. Capping system will support vegetation, improve aesthetics, provide a stable surface over the tailings, and prevent human exposure from direct contact with the tailings.

A multi-layer cap is a components of Alternatives 2B and 2C. A soil cover is a component of Alternatives 3B, 3C, and 3D. All cover systems (multi-layer caps and soil covers) will be installed with surface grades that promote run-off (assumed to be 2-3%).

Multi-layer Caps:

In accordance with USACE (1994), Rast (1997), and EPA (Gagne and Choi, 1997, 2001), the multi-layer cap system should include the following layers:

Top Cover – The top cover layer (usually vegetation) protects the underlying layers from water and wind erosion and dehydration. Typical design options for the top cover include vegetative cover, rock or gravel, and polymeric liner. Vegetative cover is the most common top cover used to protect the underlying layers and is recommended at the Elizabeth Mine. The design of the vegetative cover involves: (a) selection of suitable plant species, (b) seedbed preparation, (c) seeding /planting, (d) mulching and/or chemical stabilization, and (e) fertilization and maintenance. The type of top cover can be integrated with the final Site use plan.

Soil Cover – The soil cover provides root support for the vegetative cover. It must have sufficient thickness to protect the underlying liners from vegetative root disturbance and frost (if necessary). The minimum top layer (top soil and additional soil) suggested by the EPA is 24 inches for caps with a drainage geocomposite layer. (EPA, Choi, 2001). The topsoil layer is typically at least six inches in thickness and is composed of soil and other material suitable to support organic growth. The remaining soil is often common borrow with a gradation determined by the design. Alternative materials, (compost, wood chips, etc.) will be evaluated for use in the topsoil layer. More detailed evaluation will be performed during Design if a reduced thickness of this layer would be acceptable in order to reduce truck traffic.

Filter Layer – The filter layer separates the soil cover layer from the drainage layer, thus preventing soil layer fines from clogging the drainage layer. Typically, the filter layer is made up of sand, gravel, and/or geotextiles. This layer would only be necessary if a soil/gravel drainage layer was selected as a component of the cap.

Drainage Layer – The drainage layer provides a controlled outlet for the water that flows through the soil and would otherwise pond above the barrier layer. The drainage layer plays a critical function in minimizing the saturated thickness of the soil which improves the stability of the soil and reduces the potential for water to enter any holes or cracks in the barrier layer. Material options for the drainage layer includes drainage geocomposites, sand, and gravel. A drainage geocomposite is recommended for use at the site.

Low Permeability Layer – The low-permeability layer sits below the drainage layer and prevents the flow of water into the tailings. A two component low permeability layer is often installed to provide a backup in the event the primary layer is punctured. The primary low permeability layer is expected to consist of a geomembrane (at least 40 mil) with a 12-inch low-permeability soil or a bentonite geocomposite secondary layer as the backup layer. PVC, HDPE, or LDPE can all be used as the synthetic material in the primary barrier layer. The geomembrane is usually smooth, however, texture can be added to improve the friction angle (stability) on slopes. Geomembrane sheets are heat welded together to form a continuous barrier layer. The secondary barrier layer can be a thin panel of bentonite sandwiched between two fabric layers or 12 inches of soil with a permeability of no greater than 1×10^{-5} cm/sec.

3.3.2.4 Alternative Cover Layers

Two alternative cover designs were evaluated as part of the EE/CA.

Evapotranspiration Covers (Alternative 3B)

Evapotranspiration (ET) Covers are soil covers with an engineered vegetative covering that encourages water storage and enhances evapotranspiration. The evaporative depth of an ET cover mainly depends on the soil type of the bottom compacted soil layer. For a soil type between silt and clay, the average evaporative depth is 19 to 42 inches (assuming a six-inch top vegetative soil cover). For the Elizabeth Mine ET cover, a 36-inch soil thickness was used, with a six-inch topsoil layer. For ET covers:

- The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration.
- Where surface vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration. The influence of plant roots usually extends somewhat below the depth of root penetration because of capillary suction to the roots.
- The depth of capillary draw to the surface without vegetation or to the root zone may be only several inches in gravels; in sands, the depth may be about four to eight inches; in silts, about eight to 18 inches; and, in clays, about 12 to 60 inches.

For an ET cover with a six-inch top vegetation layer, we can assume that the root zone (root penetration depth) is greater than six inches. The evaporative depth will mainly depend on the capillary depth of the bottom compacted soil layer:

Compacted Soil Layer	Capillary Depth (inch)	Evaporative Depth (inch)
Silt	8 to 18	> 14 to 24 (average 19)
Clay	12 to 60	> 18 to 66 (average 42)

The 36-inch ET thickness was determined through case studies that demonstrated effectiveness at 36 to 42 inch thicknesses, but limited ET effectiveness at 24 inches or less. These studies, coupled with modeling using EPA's *HELP* model, provide a preliminary ET thickness estimate of 36 inches to achieve effectiveness in Vermont. The ET thickness will be optimized during Design if selected by EPA.

Induced Chemical Hardpan (Alternative 3D)

Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailings pile's surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is "self-healing," (i.e., when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction) (Chermak and Runnells, 1996).

This form of chemical capping requires direct contact between tailings and limestone (or crushed lime), to cause the formation of a "low-permeability" gypsum and iron oxyhydroxide hardpan layer. The following reactions, as presented by Chermak and Runnels (1996), show the general behavior of the system:

Pyrite/pyrrhotite dissolution:

$$FeS_2 + 7/2O_2 + H_2O \rightarrow 2SO_4^{2-} + 2H^+ + Fe^{2+}$$

calcite dissolution and gypsum precipitation:

$$SO_4^{2-} + CaCO_3 + 2H^+ + H_2O \rightarrow CaSO_4 \bullet 2\,H_2O + CO_2$$

iron oxyhydroxide precipitation:

$$Fe^{3+} + 2\ H_2O \rightarrow FeO(OH) + 3H^+$$

Laboratory testing of hardpan formation performed by Chermak and Runnels showed that when lime is applied, hardpan formation improves with increased fresh (unoxidized) sulfide content. Ettner and Braastad (1999) demonstrated the use of hardpan cap construction for a tailings impoundment in Roros, Norway. After one year, an induced hardpan layer was found to significantly reduce the hydraulic conductivity of the tailings. Their field tests demonstrated that hardpan formation is possible at shallow depths in deeply oxidized tailings and under extreme climatic conditions. Concerns remain, however, regarding the limitations of hardpan effectiveness. Demonstrations to date have not reported on the uniformity of the hardpan layer; however, they have reported decreases in vertical hydraulic conductivity approaching two orders of magnitude. The stability of the hardpan also remains in question in a dynamic geochemical environment, where precipitation and dissolution of secondary minerals is an ongoing issue.

Induced Hardpan References:

Chermack, J.A., D.D. Runnells. "Development of Chemical Caps in Acid Rock Drainage Environments". *Mining Engineering*. June 1997, p. 93-97.

Chermak, J.A. and D.D. Runnells. "Self-Sealing hardpan barriers to minimize infiltration of water into sulfide-bearing overburden, ore, and tailings piles." *Tailings and Mine Waste '96: Proceedings of the Third International Conference on Tailings and Mine Waste '96/Fort Collins/Colorado/USA.* Rotterdam: A. A. Balkema, 1996.

Ettner, D.C. and Braastad, G. , "Induced hardpan formation in a historic tailings impoundment, Roros, Norway". Tailings and Mine Waste, 1999; *Proceedings of the Third International Conference on Tailings and Mine Waste '99/Fort Collins/Colorado/USA;* Balkema, Rotterdam, Netherlands

3.3.2.5 Tailings Pile 3 (TP-3)

The historical significance of TP-3 has been the subject of ongoing discussions and concerns by local citizens from the outset of EPA's involvement at the Elizabeth Mine. Discussions between EPA, the VTANR, and the State Historic Preservation Officer, led to the design of EE/CA cleanup alternatives that minimize the impact of the cleanup on this valuable historic resource.

All cleanup options considered in this EE/CA presume complete preservation of TP-3. This assumption will only be revisited if further studies completed during Design or RI/FS indicate it is not possible to leave material in place because of human health exposure concerns, stability of the waste piles, or VTANR's unwillingness to accept the long-term maintenance costs associated with the preservation of TP-3. Figure 3-1 contains a plan view of TP-3.

Appendix B contains supporting material for the EE/CA which includes stability and analysis of tailings slopes, abandonment of subtailings drainage pipes, environmental concerns during response activities, and access and egress to the Site.

3.3.3 Alternative 2B – Multi-barrier Cap with re-graded side slopes

3.3.3.1 Objectives

The objectives of Alternative 2B are to isolate the tailings material from interaction with water and oxygen, thereby eliminating (or significantly reducing) the generation of acid mine drainage. This Alternative is designed to minimize the long-term operations and maintenance costs.

3.3.3.2 Detailed Description of Alternative

To accomplish this primary objective, Alternative 2B relies on regrading the existing tailings piles (TP-1 and TP-2) and constructing an impervious cap. This alternative consists of the following components (see Figure 3-2 for Alternative 2B conceptual drawing):

- Pre-design investigations
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Move tailings from TP-2 and
- Regrade combined tailings to 3:1 slope
- Construct cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Each of these components is described further below.

Combine Tailings Piles

All of TP-2 would be excavated and hauled to TP-1. Tailings materials from TP-2 would be used to fill low-lying portions of TP-1 and help achieve the design grade requirements for the final cap.

Regrade and Cap Tailings

The final top surface of the consolidated tailings would be regraded to approximately 2 to 3% grade (this balances the need to promote lateral drainage for reducing infiltration to the waste material, and to reduce the potential for erosion). The Design will specify the final surface grade for the cover.

Regrading the tailings can achieve the following, according to the Department of the Army, U.S. Army Corps of Engineers (*Engineering and Design – Technical Guidelines for Hazardous and Toxic Waste Treatment and Cleanup Activities*, EM 1110-1-502, 30 April 1994):

(a) Reduce ponding on the Site and consequently minimize infiltration of water into the tailings.
(b) Reduce the rate of contaminant leaching from the groundwater.
(c) Reduce erosion of cover soils of the capping system.

Final side slope angles will be optimized during the design phase to promote slope stability, minimize earthmoving, and minimize exposure of unoxidized tailings during construction. It is currently assumed that for Alternative 2B the side slopes will have a slope of 3(H) to 1(V).

Mutli-layer Cap

A multi-layer cap will be installed over TP-1 to minimize infiltration into the tailings. The major components of the multi-layer cap are described in Section 3.3.2.3. A 24-inch soil component (including six inches of topsoil) with a geocomposite drainage layer, geomembrane, and bentonite blanket are the layers of the multi-layer cap. Figure 3-2 provides a side view of the proposed multi-layer cap.

Stability

A Factor of Safety in stability assessments predicts whether the slopes will fail under specific conditions. A Factor of Safety (FS) less than one reflects an unstable slope, and an FS greater than one means the slopes are stable.

A preliminary evaluation of the FS for the slopes of TP-1 indicate that regrading the slope to a surface with a 1:3 vertical to horizontal ratio (after regrading), results in an acceptable Factor of Safety. The estimated FS against shear slide for this alternative are estimated as 2.8, 1.3, and 2.3 respectively for the existing (“low”) groundwater level, the “high” groundwater level (a 100-year storm), and the existing (“low”) groundwater level plus earthquake loading.

Surface Water Diversion

A single diversion channel would be constructed on each side of the combined tailings pile to collect the surface water from the capping system and from the rest of the watershed. Since surface water runoff would never contact tailings material under this scenario, all runoff (except that associated with ground water seeps at the TP-1 toe drain) can be diverted around the base of the capped tailings into the Copperas Brook stream channel. The diversion channels would be constructed to a sufficient depth to collect shallow ground water. The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material so the channels do not act as ground water recharge galleries at the base of the tailings. Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Collect and Treat Seepage with Passive System

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the capping and containment strategy in Alternative 2B, a toe-drain system would be constructed to collect all discharges of ground water from the base of the combined tailings pile. Once the cap and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Ground water influx into the base of the tailings would continue at a significantly reduced rate. The design would include studies to determine the groundwater contribution to flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. Further reductions in seasonal variability are likely, following completion of the Alternative 2B capping and diversion scenario, since the primary contributions to seep flow (surface and shallow lateral ground water infiltration) would be eliminated. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps following cap construction is on the order of 5 gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm.

The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components considered for possible application at TP-1 include a water holding/retention basin(s), a Successive Alkalinity Production system(s) (SAPS), and an aerobic wetland. Ground water from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of one or two SAPS ponds in series would increase the alkalinity of the influent water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic/anaerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook.

Detailed analysis of potential passive treatment systems will be performed as part of the design process. A modular system is envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with sufficient conservatism to allow for substantially greater flows.

Since storm events under this alternative would largely discharge clean runoff water around the tailings, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, catchment basin(s), buffering system, and SAPS would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent. Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. Such innovative passive/natural treatment system would promote sustainable operations, biological diversity, and minimize operational and maintenance costs.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The preliminary design concepts include a holding pond, two SAPS in series, and an aerobic wetland.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of VT will be responsible for the PRSC at the Site.

For Alternative 2B, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in SAPs or equivalent passive system for treatment of seeps (assumed 12 to15 year cycle) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (12 to 15 year cycle)

Cost

The major costs for Alternative 2B are associated with regrading, capping, building diversion channels, seepage collection system (toe drain), holding pond, passive/natural treatment system, and PRSC. The critical factors associated with the cost of Alternative 2B include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Volumes of earth to be moved and regraded

- Management and control of exposed fresh oxides during construction
- Cost of low permeability liner and drainage geocomposite
- Frequency of passive system cleanout

The total capital cost (direct and indirect) for Alternative 2B is estimated to be **$9,424,755.**

Annual PRSC for routine maintenance activities is approximately $26,544. The 30-year present value for the routine maintenance and periodic replacement of the passive treatment systems is $491,758 for TP-1 and $406,389 for TP-3. See Table 3-3 for a more detailed presentation of the costs.

PRSC includes periodic maintenance of the passive treatment system. PRSC will decrease substantially following cap construction, due to the reduced flow seeping from the source material. Flow reductions of greater than 90% are typical approximately two years after cap construction. During these two years, the seepage could bypass passive treatment to allow the flow to stabilize and to minimize the size required for the passive treatment system.

3.3.4 Alternative 2C: Multi-barrier cap with retaining wall (2B, But Retain Current Surface Profile of TP-1, TP-2)

3.3.4.1 Objectives

Alternative 2C seeks to further reduce the impacts of response actions on the historic industrial landscape by preserving the profile and current locations of TP-1 and TP-2. Under this Alternative, innovative geotechnical solutions are proposed (described above) that would allow the high angle slopes on TP-1 and TP-2 to remain largely in place, while at the same time achieving the necessary protection through hydraulic isolation. TP-3 will be preserved in place unless design investigations demonstrate a need to remove a portion of TP-3.

3.3.4.2 Detailed Description of Alternative 2C

Treatment Components

Alternative 2C has the same objectives as Alternative 2B, while seeking to further reduce the impacts of response actions on the historic industrial landscape by preserving the profile and current locations of TP-1 and TP-2 (see Figure 3-3 for a conceptual drawing of Alternative 2C). This alternative consists of the following components:

- Pre-design investigations
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Excavate and move a small portion of TP-2 and combine onto surface of TP-1

- Stabilize TP-1 and TP-2 slopes with RCC or equivalent at their present slope angles
- Re-grade (2% backslope) and isolate TP-1 and TP-2
- Construct cap system
- Construct passive treatment system
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Each of these components is further described below. The current steep and highly eroded slopes of TP-1 and TP-2 will be stabilized, but the profiles should remain largely intact. Surface drainage would follow the original surface flow patterns across the tailings and clean storm-water would be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. Passive/natural treatment approaches described under Alternative 2B would be implemented.

Combine Tailings Piles

A large portion of TP-2 would be retained and capped in-place without significant regrading. Failure of the concrete drainage culvert below TP-2 resulted in a substantial erosion channel that isolated a portion (approximately 20 %) of TP-2. The isolated portion and all erosion channel-fill material would be excavated and combined onto the surface of TP-1. This additional material is insignificant in terms of overall volume of TP-1. Removal of this portion of TP-2 would allow greater freedom of movement in the construction of diversion channels around TP-1 under Alternative 2C.

Regrade and Isolate Tailings

The top surfaces of TP-1 and TP-2 would be regraded to a (minimum) 2% slope. The current slope angle is approximately 1%, from west to east and from north to south. The proposed hydraulic isolation approach is described above in Alternative 2B. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 and TP-2 would be retained as much as possible.

The high-angle slopes on TP-1 and TP-2 would be stabilized through innovative geotechnical means, as described above. Slight regrading to smooth the erosion surfaces and create a uniform slope angle would be necessary for both TP-1 and TP-2.

Mutli-layer Cap

A multi-layer cap will be installed over TP-1 to minimize infiltration into the tailings. The major components of the multi-layer cap are described in Section 3.3.2.3. A 24-inch soil component (including six inches of topsoil) with a geocomposite drainage layer, geomembrane, and bentonite blanket are the layers of the multi-layer cap. Figure 3-3 provides a side view of the proposed multi-layer cap.

Surface Water Diversion

Surface water diversion under Alternative 2C is largely the same as that proposed for 2B. A key difference is that TP-2 would remain largely in place, therefore the diversion channel origin point must be positioned further up-gradient in the drainage channel. A surface water diversion to allow for the flow of Copperas Brook from just below TP-3, where it originates, to a point past the TP-3 passive treatment systems will also be necessary.

Collect and Treat Seepage

The collection and treatment systems described in Alternative 2B are duplicated in Alternative 2C. Although TP-2 remains largely in place, the ground water collection and treatment system designed for the toe of TP-1 would be adequate for handling any additional seepage resulting from this area.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 2C, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in SAPs or equivalent passive system for treatment of seeps (assumed 12 to15 year cycle) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (12 to 15 year cycle)

Cost

The major costs for Alternative 2C are associated with regrading, capping, building diversion channels, seepage collection system, water holding ponds, passive treatment systems, slope stabilization (including RCC), and PRSC.

The construction and capital cost for this alternative is estimated to be **$11,690,690.**

While the regrading costs are considerably less than in Alternative 2B, the cost of the RCC slopes will have an offsetting effect. Factors affecting the cost of Alternative 2C include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Volumes of earth to be moved and regraded – significantly less than Alternative 2B

- Management and control of exposed fresh sulfides during construction – significantly less than Alternative 2B
- Cost of low permeability liner and drainage geocomposite
- Source of RCC – whether onsite plant or trucked-in from offsite plant
- Frequency of passive treatment system cleanout

Annual PRSC costs for routine maintenance activities are on the order of $28,236.

The 30-year present value of routine maintenance and periodic replacement of the passive treatment system is $517,200 for TP-1 and $406,389 for TP-3.

PRSC includes periodic maintenance of the passive treatment system. Minor additional costs are likely for the inspection and repair of the high-angle stabilized slopes on TP-1 and TP-2. PRSC will decrease substantially following cap construction, due to the reduced flow seeping from the source material. Flow reductions of greater than 90% are typical approximately two years after cap construction. During these two years, the seepage could bypass passive treatment to allow the flow to stabilize and to minimize the size required for the passive treatment system. Two passive treatment systems are proposed: one for TP-3 and one for TP-1. See Table 3-4 for a more detailed presentation of the costs.

3.3.5 Alternative 3B

3.3.5.1 Objectives

Alternative 3B is designed to stabilize tailings piles, limit erosion and transport of tailings material, and reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD. This would be accomplished through minimal regrading of tailings and construction of an evapotranspiration (ET) soil cover over TP-1 and TP-2, as described above.

3.3.5.2 Detailed Description of Alternative

Treatment Components

Alternative 3B has the same objectives as Alternative 2C but uses an evapotranspiration (ET) cover of sufficient thickness for evaporation and plant transpiration to reduce rain water infiltration, instead of a multi-layer cap system. Analyses indicate that a minimum cover thickness of approximately 42 inches is needed to achieve the ET performance requirements for Vermont. This consists of 36 inches of common borrow material with a six-inch topsoil cover, capable of supporting a diverse plant population, including trees. See Figure 3-4 for a plan view of this Alternative. This alternative consists of the following components:

- Pre-design investigations
- Engineering design
- Mobilization and site preparation

- Construct holding ponds
- Construct surface water diversion system
- Excavate and move a small portion of TP-2 and combine onto surface of TP-1
- Stabilize TP-1 and TP-2 with RCC (or equivalent) slopes at their present slope angles
- Re-grade (2% backslope) and isolate TP-1 and TP-2
- Construct ET cover
- Construct passive treatment system
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Each of these components is further described below. Alternative 3B is designed to allow TP-1, TP-2, and TP-3 to remain largely in place and minimize impacts to key historic features of the Site. This alternative takes advantage of soil cover technologies that have been demonstrated to be effective under certain conditions. Soil covers are very effective, low-cost alternatives for situations that allow water and oxygen infiltration to the materials below the cover. They are especially effective in arid and semi-arid climates where evapotranspiration removes much of the water that falls on the surface of the covered materials.

To achieve the desired outcome with soil covers alone, the current tailings pile profiles would be slightly impacted to achieve the necessary slope angles to ensure proper drainage. The final surface expression of TP-1 and TP-2 is likely to be similar to that envisioned under Alternative 2C.

Rainwater and snowmelt infiltration would result in ongoing seepage from all tailings piles. Passive treatment approaches would be constructed to treat the resulting AMD. These systems would require operation in-perpetuity. The associated PRSC costs to handle the assumed flow rate would be higher than the options presented for Alternative 2B and 2C. Surface water diversion channels would eliminate clean surface water flow onto the surface of TP-1 and TP-2. Passive treatment systems for TP-3 could be several acres in surface area to handle the storm water runoff and seep flow. The footprint of a treatment system in the area between TP-2 and TP-3 is likely to have some impact on features of historic interest and importance.

Regrade and Cover Tailings

To install the soil cover, the existing tailings piles need to be regraded. For TP-1 and TP-2, a 2% to 3% grade for the top surface is recommended. The front and side slopes of TP-1 and TP-2 would be stabilized by RCC or an equivalent approach. For TP-3, regrading is not necessary.

Stability

The front and side slopes of TP-1 and TP-2 would be stabilized by RCC or equivalent approach, as described above.

Surface Water Diversion

Surface water diversion systems under Alternative 3B must accommodate clean runoff water from TP-1 and TP-2, as well the remainder of the watershed that drains toward the tailings. A single channel would be constructed on either side of the tailings piles to divert the surface water and shallow ground water around the tailings to lower Copperas Brook below TP-1. The toe drain will be designed to collect contaminated seepage from the tailings and divert it to the passive treatment system situated below TP-1, as described in Alternative 2B. Open, lined rip-rap channels are assumed to be satisfactory for these purposes.

For TP-3, the water generated at the seepage collection points will combine with runoff water. A toe drain will be constructed at the base of TP-3 to collect contaminated seepage water for treatment by passive means.

Collect and Treat Seepage

Alternative 3B would allow water and oxygen infiltration through the soil cover into the underlying tailings. Modeling of infiltration indicates that Alternative 3B will have an infiltration rate of approximately four inches of water per year and evapotranspiration of approximately 24 inches per year. Runoff accounts for the remaining annual precipitation (total of approximately 34.5 inches of rain and snowfall). Processes such as barometric pumping (i.e., changes in barometric pressure causing the piles to breathe) can readily facilitate the process of oxygen infiltration; the soil cover approach would not completely eliminate the access of oxygen to the waste piles. Storm events would result in both runoff and infiltration. The runoff should remain clean and would be diverted to channels around the tailings and into the lower part of Copperas Brook.

Under Alternative 3B, the rate of seep discharge at the toe of TP-1 is likely to be in the range of 30 gpm. The passive treatment components described under Alternative 2B would be capable of handling the resulting flow, however, all system components would be “sized” to handle significantly greater volumes of seep water. Detailed hydrologic modeling would be necessary during Design to predict the resulting flows and properly size a passive treatment system.

Infiltration into TP-3 would be significant and the resulting seeps must be collected and treated in a passive approach, similar to that described under Alternative 2B. Seeps can be expected to have low pH and high metals concentrations. Further assessment during Design will determine the specific needs of passive systems to treat seep water from the different locations.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 3B, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in SAPS or equivalent passive system for treatment of seeps (assumed 12 to 15 year cycle) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (12 to 15 year cycle)

Cost

The costs for Alternative 3B are associated with regrading, soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The construction and capital cost (direct and indirect) for this alternative is estimated to be **$10,400,229.**

The critical factors associated with the cost of Alternative 3B include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance)
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout

Annual PRSC costs for routine maintenance activities are likely to be in the range of $28,236.

The 30-year present value for routine maintenance activities and the periodic replacement of the passive treatment systems is $693,792 for TP-1 and $406,389 for TP-3. PRSC includes periodic maintenance of the passive treatment system. PRSC for Alternative 3B will be slightly higher than the options presented under Alternative 2C, due to the need to operate passive treatment systems at a higher flow rate. See Table 3-5 for additional detail regarding cost.

3.3.6 Alternative 3C

3.3.6.1 Objectives

Alternative 3C is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD. This would be accomplished through minimal regrading of tailings and construction of a minimal (six-inch) soil cover over TP-1 and TP-2.

3.3.6.2 Detailed Description of Alternative

Treatment Components

Alternative 3C has the same objectives as Alternative 3B but seeks to minimize the soil cover to achieve the necessary level of protection. A six-inch topsoil cover over all of TP-1 and TP-2 is considered for this alternative. See Figure 3-5 for a plan view of this Alternative. This alternative consists of the following components:

- Pre-design investigations
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Excavate and move a small portion of TP-2 and combine onto surface of TP-1
- Stabilize TP-1 and TP-2 slopes at their present slope angles
- Re-grade (2% backslope) and isolate TP-1 and TP-2
- Construct six-inch soil cover
- Construct passive treatment system
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Each of these components is further described below. Alternative 3C is designed to allow TP-1, TP-2, and TP-3 to remain largely in place and minimize impacts to key historic features of the Site. This alternative takes advantage of soil cover technologies that have been demonstrated to be effective under certain conditions. Soil covers are very effective, low-cost alternatives for situations that allow water and oxygen infiltration to the materials below the cover. They are especially effective in arid and semi-arid climates where evapotranspiration removes much of the water that falls on the surface of the covered materials.

To achieve the desired outcome with soil covers alone, the current tailings pile profiles would be slightly impacted to achieve the necessary slope angles to ensure proper drainage. The final surface expression of TP-1 and TP-2 is likely to be similar to that envisioned under Alternative 2C.

Rainwater and snowmelt infiltration would result in ongoing seepage from all tailings piles. Passive treatment approaches would be constructed to treat the resulting AMD. These systems would require operation in-perpetuity. The associated PRSC costs to handle the assumed flow rate would be higher than the options presented for Alternative 2B, 2C, and 3B. Surface water diversion channels would eliminate clean surface water flow onto the surface of TP-1 and TP-2.

Regrade and Cover Tailings

A six-inch soil cover (assumed to be topsoil) would be placed over the entire top of TP-1 and TP-2 and seeded. To install the soil cover, the existing tailings piles need to be regraded. For TP-1 and TP-2, a 2% to 3% grade for the top surface is recommended. The front and side slopes of TP-1 and TP-2 would be stabilized by RCC or an equivalent approach, as described above.

Stability

The front and side slopes of TP-1 and TP-2 would be stabilized by RCC or equivalent approach, as described above.

Surface Water Diversion

Surface water diversion systems under Alternative 3C must accommodate clean runoff water from TP-1 and TP-2, as well as the remainder of the watershed that drains toward the tailings. A single channel would be constructed on either side of the tailings piles to divert the surface water and shallow ground water around the tailings to lower Copperas Brook below TP-1. The toe drain will be designed to collect contaminated seepage from the tailings and divert it to the passive treatment system situated below TP-1, as described in Alternative 2B. Open, lined rip-rap channels are assumed to be satisfactory for these purposes. For TP-3, the water generated at the seepage collection points will combine with runoff water. A toe drain will be constructed at the base of TP-3 to collect contaminated seepage water for treatment by passive means.

Collect and Treat Seepage

Alternative 3C would allow significant water and oxygen infiltration through the soil cover into the underlying tailings. Modeling of infiltration indicates that Alternative 3C will have an infiltration rate of approximately 10 inches of water per year. Processes such as barometric pumping (i.e., changes in barometric pressure causing the piles to breathe) can readily facilitate the process of oxygen infiltration; the soil cover approach would not completely eliminate the access of oxygen to the waste piles. Storm events would result in both runoff and infiltration. The runoff should remain clean and would be diverted to channels around the tailings and into the lower part of Copperas Brook. Under Alternative 3C, the rate of seep discharge at the toe of TP-1 is likely to be in the range of 60 gpm. The passive treatment components described under Alternative 2B would be capable of handling the resulting flow, however, all system components would be “sized” to handle significantly greater volumes of seep water. Detailed hydrologic modeling would be necessary during Design to predict the resulting flows and properly size a passive treatment system.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of VT will be responsible for the PRSC at the Site.

For Alternative 3C, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in SAPS or equivalent passive system for treatment of seeps (assumed 12 to 15 year cycle) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (12 to 15 year cycle)

Cost

The costs for Alternative 3C are associated with regrading, soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The construction and capital cost for this alternative is estimated to be **$8,153,965**.

The critical factors associated with the cost of Alternative 3C include the following:

- Location of a borrow source for the soil/cover layer (Increased costs with increased haul distance
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout
- Frequency of repair of the minimal soil cover to prevent exposure of tailings

Annual PRSC costs for routine maintenance activities are likely to be in the range of $28,236.

The 30-year present value for routine maintenance and periodic replacement of the passive treatment systems is $870,603 for TP-1 and $406,389 for TP-3. PRSC includes periodic maintenance of the passive treatment system. PRSC for Alternative 3C will be higher than the options presented under Alternative 2C and 3B, due to the need to operate passive treatment systems at a higher flow rate. See Table 3-6 for a more detail regarding cost.

3.3.7 Alternative 3D

3.3.7.1 Objectives

Alternative 3D is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD. This would be accomplished through minimal regrading of tailings and construction of a hardpan cover with a soil cover over TP-1 and TP-2.

3.3.7.2 Detailed Description of Alternative

Treatment Components

Alternative 3D has the same objectives as Alternatives 3B and 3C but incorporates an induced chemical hardpan formation with a soil cover and drainage layer to minimize potential infiltration and support a grass covered surface. See Figure 3-6 for a plan view of this alternative. This alternative consists of the following components:

- Pre-design investigations
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Excavate and move a small portion of TP-2 and combine onto surface of TP-1
- Stabilize TP-1 and TP-2 slopes at their present slope angles
- Re-grade (2% backslope) and isolate TP-1 and TP-2
- Construct limestone layer, drainage layer, and soil cover
- Construct passive treatment systems
- Collect and treat runoff from portions of TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Each of these components is further described below. Alternative 3D is designed to allow TP-1, TP-2, and TP-3 to remain largely in place and minimize impacts to key historic features of the Site. This alternative takes advantage of innovative induced hardpan construction techniques as well as soil cover technologies that have been demonstrated to be effective under certain conditions.

To achieve the desired outcome with the induced hardpan and soil cover, the current tailings pile profiles would be slightly impacted to achieve the necessary slope angles to ensure proper drainage. The final surface expression of TP-1 and TP-2 is likely to be similar to that envisioned under Alternative 2C.

Rainwater and snowmelt infiltration would result in ongoing seepage from all tailings piles. Passive treatment approaches would be constructed to treat the resulting AMD. These systems would require operation in-perpetuity. The associated PRSC costs to handle the assumed flow rate would be slightly higher than the options presented for Alternative 2B and 2C. Surface water diversion channels would eliminate clean surface water flow onto the surface of TP-1 and TP-2. Passive treatment systems for TP-3 could be several acres in surface area to handle the storm water runoff and seep flow. The footprint of a treatment system in the area between TP-2 and TP-3 is likely to have some impact on features of historic interest and importance.

Regrade and Cover Tailings

To install the crushed limestone for hardpan formation, as well as the soil cover, the existing tailings piles need to be regraded. For TP-1 and TP-2, a 2% to 3% grade for the top surface is recommended. Six inches of crushed limestone, coupled with eighteen inches of common borrow, overlain by six inches of topsoil would be placed over the areas to be reseeded. A drainage layer would be placed over the crushed limestone. The limestone will be tilled-in to the upper six inches of tailings material.

Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailings pile's surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is “self-healing,” (i.e. when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction)(Chermak and Runnells, 1996).

Stability

The front and side slopes of TP-1 and TP-2 would be stabilized by RCC or equivalent approach.

Surface Water Diversion

Surface water diversion systems under Alternative 3D must accommodate clean runoff water from TP-1 and TP-2, as well the remainder of the watershed that drains toward the tailings. A single channel would be constructed on either side of the tailings piles to divert the surface water and shallow ground water around the tailings to lower Copperas Brook below TP-1. The toe drain will be designed to collect contaminated seepage, as described above.

For TP-3, the water generated at the seepage collection points will combine with runoff water. A toe drain will be constructed at the base of TP-3 to collect contaminated seepage water for treatment by passive means.

Collect and Treat Seepage

Alternative 3D would allow water and oxygen infiltration through the soil cover into the underlying tailings. Modeling of infiltration indicates that Alternative 3D will have an infiltration rate of approximately 1.5 inches of water per year and evapotranspiration of approximately 24 inches per year. Runoff accounts for the remaining annual precipitation (total of approximately 34.5 inches of rain and snowfall). Processes such as barometric pumping (i.e., changes in barometric pressure causing the piles to breathe) can readily facilitate the process of oxygen infiltration; the soil cover approach would not completely eliminate the access of oxygen to the waste piles. Storm events would result in both runoff and infiltration. The runoff should remain clean and would be diverted to channels around the tailings and into the lower part of Copperas Brook. Under Alternative 3D, the rate of seep discharge at the toe of TP-1 is likely to be in the range of 8 gpm. The passive treatment components described under Alternative 2B would be capable of handling the resulting flow, however, all system components would be "sized" to handle significantly greater volumes of seep water. Detailed hydrologic modeling would be necessary during Design to predict the resulting flows and properly size a passive treatment system.

Infiltration into TP-3 would be significant and the resulting seeps must be collected and treated in a passive approach, similar to that described under Alternative 2B. Seeps can be expected to have low pH and high metals concentrations. Further assessment during design will determine the specific needs of passive systems to treat seep water from the different locations.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of VT will be responsible for the PRSC at the Site.

For Alternative 3D, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in SAPS or equivalent passive system for treatment of seeps (assumed 12 to 15 year cycle) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (12 to 15 year cycle)

Cost

The costs for Alternative 3D are associated with regrading, limestone and soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The construction and capital cost (direct and indirect) for this alternative is estimated to be **$10,881,365.**

The critical factors associated with the cost of Alternative 3D include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Volumes of earth to be moved and regraded

- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout
- Effectiveness of the induced hardpan

Annual PRSC costs for routine maintenance activities are likely to be in the range of $28,236.

The 30-year present value for routine maintenance and periodic replacement of the passive treatment system is $520,183 for TP-1 and $406,389 for TP-3. PRSC includes periodic maintenance of the passive treatment system. PRSC for Alternative 3D will be slightly higher than the options presented under Alternative 2C, due to the need to operate passive treatment systems at a slightly higher flow rate. See Table 3-7 for more details regarding cost.

4.0 Analysis of Removal Action Alternatives

Section 4.0 presents an analysis of the Removal Action Alternatives. The alternatives (see Table 4-1) are evaluated on the basis of effectiveness, implementability, and cost, pursuant to EPA guidance on development of an EE/CA. Each alternative considered in this EE/CA exceeds the $2 million statutory limit; therefore, alternatives are further evaluated to determine the consistency with future remedial actions to be taken at the Site.

The Removal Action Alternatives described in this section are designed to address the tailings and mine waste piles (TP-1, TP-2, and TP-3) located in the Copperas Brook watershed.

While several additional known and potential contaminant source areas are present at the mine Site, the NTCRA phase is focused on addressing contamination associated with the tailings alone. Other source areas will be addressed under the future Remedial Program, following completion of the RI/FS. Planning for the RI/FS will take place over the coming months and implementation will begin in late 2001 or in early 2002.

4.1 Approach

Each alternative is evaluated on the basis of effectiveness, implementability, and cost, as set forth in the NCP and EPA guidance on conducting EE/CAs.

4.1.1 Effectiveness

Effectiveness refers to the ability of an alternative to meet the removal action objectives. The effectiveness of each alternative is evaluated in accordance with the following criteria:

- Overall protection of human health and the environment
- Compliance with ARARs and other criteria, advisories, and guidance
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness

4.1.2 Implementability

Implementability addresses the technical and administrative feasibility of implementing an alternative and availability of various required services and materials. Implementability is evaluated in accordance with the following criteria:

- Technical feasibility
- Administrative feasibility

- Availability of services and materials
- State acceptance
- Community acceptance

4.1.3 Cost

A cost estimate is prepared for each alternative to help EPA and the State in the selection of a removal action. Each estimate contains the capital cost, (consisting of direct and indirect costs), and the Post-Removal Site Control (PRSC or operations and maintenance) costs.

Capital costs include those expenditures initially incurred to develop, design, and implement the removal alternative. Direct costs include expenditures for the equipment, labor, and materials necessary to prepare the site, regrade the tailings, stabilize the slopes, and construct the passive treatment systems. Indirect costs include additional costs for services that are not actually components of the alternatives, but that are required to complete the project implementation.

The PRSC costs include sampling and analysis of the effluent from the passive treatment systems, inspection and maintenance of cap/cover (including mowing) and passive systems, and periodic cleanout/repair of diversion channels and passive treatment systems.

4.2 Alternative 2B

4.2.1 Description (2B)

The objectives of Alternative 2B are to isolate the tailings material from interaction with water and oxygen, thereby eliminating (or significantly reducing) the generation of AMD (see Figure 3-2 for Alternative 2B conceptual drawing and Section 3.0 for a detailed description of Alternative 2B). To accomplish this primary objective, Alternative 2B relies on regrading the existing tailings piles (TP-1 and TP-2) and constructing an impervious cap.

4.2.1.1 Overall Protection of Human Health and the Environment (2B)

Alternative 2B achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The vegetated soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. Regrading the tailings to a 3:1 slope will stabilize the current TP-1 slopes and eliminate the risk of slope failure. The filling of the decant pipes will further improve the stability of TP-1. The multi-barrier cap and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The estimated long-term ground water influx into the combined tailings will be on the order of five gallons per minute (gpm); so the seepage at the toe of the combined tailings pile will be on the order of 5 gpm (possibly less). The seepage will be collected with a toe-drain system and treated using the passive treatment system. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.2.1.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (2B)

Table 4-2 identifies the ARARs that apply to Alternative 2B. Alternative 2B would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. There are several ARARs for which additional discussion is warranted. EPA is specifically seeking public comment on the following:

Unavoidable impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities that will cause these impacts. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the 2 million cubic yards of tailings is considered impracticable.

Variance to the VT Solid Waste Management Regulations:

This EE/CA documents the basis for granting a variance to the VT Solid Waste Regulations. Section §§ 6613 of describes the process for a variance. EPA is proposing a variance from all design and closure provisions of The VT Solid Waste Management Act for TP-3. EPA has determined that this variance would be necessary and appropriate to achieve compliance with NHPA and Act 250. Collection and treatment of the run-off from TP-3 will achieve an equivalent level of protection to the surface water. In addition compliance with the rule would result in a hardship in that the historic resources of TP-3 would be permanently and irreparably damaged. In addition, the tailings and waste material are not hazardous waste as defined by Subtitle C of RCRA.

This EE/CA also documents the basis for granting a variance from the final grade requirements with respect to TP-1 and TP-2. The Solid Waste Management Regulations state that the minimum grade be at least 5% and the maximum grade by 33%. A variance from these requirement is considered necessary and appropriate to achieve compliance with NHPA and Act 250. An equivalent level of protection will be achieved with a lesser grade on the top surface and allowing a steeper grade on the slopes. The tailings will not be subject to the substantial settlement that is encountered at solid waste landfill and the engineered slope stabilization (through regrading or other reinforcing measures) will also achieve the same standard of performance. Compliance with the rule would result in a hardship in that substantial quantities of soil and the associated truck traffic would be required to meet the surface grade of 5% over the tailings.

Adverse Effect to a Historic Resource

Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site’s significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be*

> *likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary Area of Potential Effect (APE) for direct effects is shown in Figure 3-2. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.2.2 Effectiveness (2B)

4.2.2.1 Long-term Effectiveness and Permanence (2B)

Alternative 2B achieves long-term effectiveness and permanence by the following:

TP-3

The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2

The long-term effectiveness and permanence of surface water diversion, multi-barrier cap, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and multi-barrier cap can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the cap system will essentially eliminate surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about 5 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The cap will also effectively prevent exposure to the tailings.

4.2.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment (2B)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. SAPS are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of acid mine drainage and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.2.2.2 Short-Term Effectiveness (2B)

Alternative 2B achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a substantial decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 2B does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly-ash and cement kiln dust. The Design stage will fully evaluate options for construction safety needs. The exposure of large quantities of unoxidized tailings also creates the potential for major impacts to Copperas Brook and the WBOR if a storm event were to overwhelm the sediment and erosion control measures at the Site. Careful implementation and substantial erosion control measures will be necessary during construction to minimize the potential for this situation to occur.

Alternative 2B requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed cap, diversion channels and passive treatment systems will require approximately 11,131 trucks over a six-month period to deliver the necessary materials. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.2.3 Implementability (2B)

4.2.3.1 Technical Feasibility (2B)

Alternative 2B is technically feasible. Design and construction of the cap system (cap, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cap system that will meet the response objectives and EPA's technical guidance on final covers. The technical activities associated with moving and regrading large quantities of the tailings are more complicated but can be implemented with careful planning.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, personal communication, and ICARD 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months. Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. Successful examples include a SAPS system at the Howe Bridge, Pennsylvania mine site that was constructed to handle flows of approximately 20 gpm, and a SAPS system at the Oven Run, Pennsylvania site that was designed to handle flows of approximately 100 gpm. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and SAPS sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.2.3.2 Administrative Feasibility (2B)

Alternative 2B is administratively feasible. Implementation of Alternative 2B will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.2.3.3 Availability of Services and Materials (2B)

Services and materials to implement alternative 2B are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 156,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.2.3.4 State and Community Acceptance (2B)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the Elizabeth Mine Community Advisory Group (EMCAG) to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices
- Each alternative was designed to minimize impact to the historical resources of the Site
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible

State and Community acceptance will be evaluated upon closure of the public comment period.

4.2.4 Cost (2B)

The capital costs and PRSC are summarized under Alternative 2B in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Alternative 2B	Cost ($)
Capital Costs	
Total – Direct [Present Value]	7,334,440
Total – Indirect [Present Value]	2,090,315
Total – Capital [Present Value]	9,424,755
PRSC	
Annual [Nominal]	26,544
PRSC TP-1 (30 yr NPV)	491,758
PRSC TP-3 (30 yr NPV)	406,389

4.3 Alternative 2C

4.3.1 Description (2C)

Alternative 2C has the same objectives as Alternative 2B, while seeking to further minimize the impacts of response actions on the historic industrial landscape by preserving the profile and current locations of TP-1 and TP-2. Innovative geotechnical solutions will be implemented to allow the high angle slopes on TP-1 and TP-2 to remain largely in place, while at the same time achieving the necessary protection through hydraulic isolation.

The current steep and eroded slopes of TP-1 and TP-2 will be stabilized, but the profiles should remain largely intact. The use of innovative geotechnical materials and strategies would allow a permanent steep-slope face that is structurally stable and capable of preventing water and oxygen infiltration, while retaining the overall shape of the original tailings (as described in Section 3.0). Roller Compacted Concrete (RCC) provides the most attractive option for stabilizing the existing slopes. Other alternatives considered include gabion boxes, articulated concrete blocks, and rip-rap. Further analysis of stabilization options will be addressed during Design. Use of the RCC option in the cost estimation provides a conservative value.

Surface drainage will follow the original surface flow patterns across the tailings and clean storm-water will be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. A toe drain will be installed to collect the seepage at the toe of TP-1. The collected water will be treated with the passive/natural treatment system.

4.3.2 Effectiveness (2C)

The following section provides a detailed analysis of the effectiveness of Alternative 2C.

4.3.2.1 Overall Protection of Human Health and the Environment (2C)

Alternative 2C achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3 are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of acid mine drainage. The vegetated soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. The stabilization of the slopes by installing a reinforced wall of RCC or other material will stabilize the current TP-1 slopes and eliminate the risk of slope failure. The filling of the decant pipes will further improve the stability of TP-1. The multi-barrier cap and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in acid mine drainage from TP-1. The estimated long-term ground water influx into the combined tailings will be on the order of 5 gpm; so the seepage at the toe of the combined tailings pile will be on the order of 5 gpm (possibly less). The seepage will be collected with a toe-drain system and treated using the passive treatment system. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.3.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (2C)

Table 4-2 identifies the ARARs that apply to Alternative 2C. Alternative 2C would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. There are several ARARs for which additional discussion is warranted. EPA is specifically seeking public comment on the following:

Unavoidable impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (see Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable

alternatives to the cleanup activities that will cause these impacts. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the 2 million cubic yards of tailings is considered impracticable.

Variance to the VT Solid Waste Management Regulations:

This EE/CA documents the basis for granting a variance to the VT Solid Waste Regulations. Section §§ 6613 of describes the process for a variance. EPA is proposing a variance from all design and closure provisions of The VT Solid Waste Management Act for TP-3. EPA has determined that this variance would be necessary and appropriate to achieve compliance with NHPA and Act 250. Collection and treatment of the run-off from TP-3 will achieve an equivalent level of protection to the surface water. In addition compliance with the rule would result in a hardship in that the historic resources of TP-3 would be permanently and irreparably damaged. In addition, the tailings and waste material are not hazardous waste as defined by Subtitle C of RCRA.

This EE/CA also documents the basis for granting a variance from the final grade requirements with respect to TP-1 and TP-2. The Solid Waste Management Regulations state that the minimum grade be at least 5% and the maximum grade by 33%. A variance from these requirement is considered necessary and appropriate to achieve compliance with NHPA and Act 250. An equivalent level of protection will be achieved with a lesser grade on the top surface and allowing a steeper grade on the slopes. The tailings will not be subject to the substantial settlement that is encountered at solid waste landfill and the engineered slope stabilization (through regrading or other reinforcing measures) will also achieve the same standard of performance. Compliance with the rule would result in a hardship in that substantial quantities of soil and the associated truck traffic would be required to meet the surface grade of 5% over the tailings.

Adverse Effect to a Historic Resource

Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary Area of Potential Effect (APE) for direct effects is shown in Figure 3-3. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc (40 CFR 202, 203, 205), however, they are not considered ARARs for the purposes of this EE/CA.

4.3.2.3 Long-term Effectiveness and Permanence (2C)
Alternative 2C achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2
The long-term effectiveness and permanence of surface water diversion, multi-barrier cap, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and multi-barrier cap can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the cap system will essentially eliminate surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be

about 5 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The cap will also effectively prevent exposure to the tailings.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (2C)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. SAPS are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at circum-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of acid mine drainage and reduce the mobility of contaminants with the tailings; however, this benefit is achieved through containment, not treatment.

4.3.2.5 Short-Term Effectiveness (2C)

Alternative 2C achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a substantial decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 2C does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The Design stage will fully evaluate options for construction safety needs.

Alternative 2C requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed cap, diversion channels and passive treatment systems will require approximately 12,942 trucks over a six-month period to deliver the necessary materials for the cover system and an additional 6,544 for the RCC. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.3.3 Implementability (2C)

4.3.3.1 Technical Feasibility (2C)

Design and construction of the cap system for Alternative 2C (cap, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cap system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, personal communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. Successful examples include a SAPS system at the Howe Bridge, Pennsylvania mine site that was constructed to handle flows of approximately 20 gpm, and a SAPS system at the Oven Run, Pennsylvania site that was designed to handle flows of approximately 100 gpm. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and SAPS sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.3.3.2 Administrative Feasibility (2C)

Alternative 2C is administratively feasible. Implementation of Alternative 2C will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.3.3.3 Availability of Services and Materials (2C)

Services and materials to implement alternative 2C are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 234,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.3.3.4 State and Community Acceptance (2C)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the Elizabeth Mine Community Advisory Group (EMCAG) to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices
- Each alternative was designed to minimize impact to the historical resources of the Site
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible

State and Community acceptance will be evaluated upon closure of the public comment period.

4.3.4 Cost (2C)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Alternative 2C	Cost ($)
Capital Costs	
Total – Direct [Present Value]	9,097,813
Total – Indirect [Present Value]	2,592,877
Total – Capital [Present Value]	11,690,690
PRSC	
Annual [Nominal]	28,236
PRSC TP-1 (30 yr NPV)	517,200
PRSC TP-3 (30 yr NPV)	406,389

4.4 Alternative 3B

4.4.1 Description (3B)

Alternative 3B has the same objectives as Alternative 2C but uses an evapotranspiration (ET) cover of sufficient thickness for evaporation and plant transpiration to reduce rain water infiltration, instead of a multi-layer cap system. Analyses indicate that a minimum cover thickness of approximately 42 inches is needed to achieve the ET performance requirements for Vermont. This consists of 36 inches of common borrow material with a six-inch topsoil cover, capable of supporting a diverse plant population, including trees.

As in Alternative 2C, the current steep and highly eroded slopes of TP-1 and TP-2 will be stabilized, but the profiles should remain largely intact. The use of innovative geotechnical materials and strategies would allow a permanent steep-slope face that is structurally stable and capable of preventing water and oxygen infiltration, while retaining the overall shape of the original tailings; however final assessment of slope stabilization will be done during Design. The details on RCC, one of the options for slope stabilization, are provided in Section 3.0.

Surface drainage will follow the original surface flow patterns across the tailings and clean storm-water will be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. A toe drain will be installed to collect the seepage at the toe of TP-1. The collected water will be treated with the passive/natural treatment system.

Construction of an ET cover of 42 inches would significantly increase the trucks required for delivering soils and other construction materials to approximately 17,997 trucks over the period of construction. This will significantly increase the direct and indirect adverse effect on the surrounding towns and residents, including noise, dust, and road degradation. Delivery of the RCC material alone requires 6,544 trucks.

4.4.2 Effectiveness (3B)

The following section provides an analysis of the effectiveness of Alternative 3B.

4.4.2.1 Overall Protection of Human Health and the Environment (3B)

Alternative 3B achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. Since TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3 are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The vegetated soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. The stabilization of the slopes by installing a reinforced wall of RCC or other material will stabilize the current TP-1 slopes and eliminate the risk of slope failure. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in acid mine drainage from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 15 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.4.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3B)

Table 4-2 identifies the ARARs that apply to Alternative 3B. Alternative 3B would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. There are several ARARs for which additional discussion is warranted. EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action.

These impacts are unavoidable as there are no practicable alternatives to the cleanup activities that will cause these impacts. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the 2 million cubic yards of tailings is considered impracticable.

Variance to the VT Solid Waste Management Regulations:

This EE/CA documents the basis for granting a variance to the VT Solid Waste Regulations. Section §§ 6613 of describes the process for a variance. EPA is proposing a variance from all design and closure provisions of The VT Solid Waste Management Act for TP-3. EPA has determined that this variance would be necessary and appropriate to achieve compliance with NHPA and Act 250. Collection and treatment of the run-off from TP-3 will achieve an equivalent level of protection to the surface water. In addition compliance with the rule would result in a hardship in that the historic resources of TP-3 would be permanently and irreparably damaged. In addition, the tailings and waste material are not hazardous waste as defined by Subtitle C of RCRA.

This EE/CA also documents the basis for granting a variance from the final grade requirements with respect to TP-1 and TP-2. The Solid Waste Management Regulations state that the minimum grade be at least 5% and the maximum grade by 33%. A variance from these requirement is considered necessary and appropriate to achieve compliance with NHPA and Act 250. An equivalent level of protection will be achieved with a lesser grade on the top surface and allowing a steeper grade on the slopes. The tailings will not be subject to the substantial settlement that is encountered at solid waste landfill and the engineered slope stabilization (through regrading or other reinforcing measures) will also achieve the same standard of performance. Compliance with the rule would result in a hardship in that substantial quantities of soil and the associated truck traffic would be required to meet the surface grade of 5% over the tailings.

Adverse Effect to a Historic Resource

Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary Area of Potential Effect (APE) for direct effects is shown in Figure 3-4. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc (40 CFR 202, 203, 205), however, they are not considered ARARs for the purposes of this EE/CA.

4.4.2.3 Long-term Effectiveness and Permanence (3B)
Alternative 3B achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2
The long-term effectiveness and permanence of surface water diversion, soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and soil cover can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the cap system will greatly reduce surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage

quantity at the toe of the combined tailings pile is estimated to be about 15 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The soil cover will also effectively prevent exposure to the tailings.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (3B)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. SAPS are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of acid mine drainage and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.4.2.5 Short-Term Effectiveness (3B)

Alternative 3B achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 3B does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The Design stage will fully evaluate options for construction safety needs.

Alternative 3B requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 17,987 trucks over a six-month period to deliver the necessary materials for the cover system and an additional 6,544 for the RCC. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.4.3 Implementability (3B)

4.4.3.1 Technical Feasibility (3B)

Alternative 3B is technically feasible. Design and construction of the cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, personal communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. Successful examples include a SAPS system at the Howe Bridge, Pennsylvania mine site that was constructed to handle flows of approximately 20 gpm, and a SAPS system at the Oven Run, Pennsylvania site that was designed to handle flows of approximately 100 gpm. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and SAPS sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.4.3.2 Administrative Feasibility (3B)
Alternative 3B is administratively feasible. Implementation of Alternative 3B will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.4.3.3 Availability of Services and Materials (3B)
Services and materials to implement alternative 3B are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 294,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.4.3.4 State and Community Acceptance (3B)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the Elizabeth Mine Community Advisory Group (EMCAG) to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices
- Each alternative was designed to minimize impact to the historical resources of the Site
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible

State and Community acceptance will be evaluated upon closure of the public comment period.

4.4.4 Cost (3B)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Alternative 3B	**Cost ($)**
Capital Costs	
Total – Direct [Present Value]	8,093,564
Total – Indirect [Present Value]	2,306,666
Total – Capital [Present Value]	10,400,229
PRSC	
Annual [Nominal]	28,236
PRSC TP-1 (30 yr NPV)	693,792
PRSC TP-3 (30 yr NPV)	406,389

4.5 Alternative 3C

4.5.1 Description (3C)

Alternative 3C has the same objectives as Alternative 3B but seeks to minimize the soil cover to achieve the necessary level of protection. A six-inch topsoil cover over all of TP-1 and TP-2 is considered for this alternative.

The current steep and highly eroded slopes of TP-1 and TP-2 will be stabilized, but the profiles should remain largely intact. The use of innovative geotechnical materials and strategies would allow a permanent steep-slope face that is structurally stable and capable of preventing water and oxygen infiltration, while retaining the overall shape of the original tailings. RCC provides the most attractive option for stabilizing the existing slopes. The details on RCC and alternative approaches to slope stabilization are provided above.

Surface drainage would follow the original surface flow patterns across the tailings. Clean storm-water would be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. A toe drain will be installed to collect the seepage at the toe of TP-1. The collected water will be treated with the passive/natural treatment system.

Reducing the soil cover thickness to six inches would significantly decrease the trucks required for delivering the soil and other construction materials – from approximately 17,997 trucks for the 42-inch ET cover to approximately 3,851 trucks for the six-inch soil cover. This would significantly reduce the direct and indirect adverse effect on the surrounding towns and residents, including noise, dust, and road degradation. Delivery of the RCC material requires 6,544 trucks.

4.5.2 Effectiveness (3C)

The following sections provide the analysis of effectiveness for Alternative 3C.

4.5.2.1 Overall Protection of Human Health and the Environment (3C)

Alternative 3C achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. Since TP -3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The vegetated soil cover over the tailings will stabilize the tailings surface to minimize windblown transport of dust and minimize erosion. The stabilization of the slopes by installing a reinforced wall of RCC or other material will stabilize the current TP-1 slopes and eliminate the risk of slope failure. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will reduce the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 22 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.5.2.1 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3C)

Table 4-2 identifies the ARARs that apply to Alternative 3C. Alternative 3C would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. There are several ARARs for which additional discussion is warranted. EPA is specifically seeking public comment on the following:

Unavoidable impacts to Wetlands and Floodplain:

The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities that will cause these impacts. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the 2 million cubic yards of tailings is considered impracticable.

Variance to the VT Solid Waste Management Regulations:

This EE/CA documents the basis for granting a variance to the VT Solid Waste Regulations. Section §§ 6613 of describes the process for a variance. EPA is proposing a variance from all design and closure provisions of The VT Solid Waste Management Act for TP-3. EPA has determined that this variance would be necessary and appropriate to achieve compliance with NHPA and Act 250. Collection and treatment of the run-off from TP-3 will achieve an equivalent level of protection to the surface water. In addition compliance with the rule would result in a hardship in that the historic resources of TP-3 would be permanently and irreparably damaged. In addition, the tailings and waste material are not hazardous waste as defined by Subtitle C of RCRA.

This EE/CA also documents the basis for granting a variance from the final grade requirements with respect to TP-1 and TP-2. The Solid Waste Management Regulations state that the minimum grade be at least 5% and the maximum grade by 33%. A variance from these requirement is considered necessary and appropriate to achieve compliance with NHPA and Act 250. An equivalent level of protection will be achieved with a lesser grade on the top surface and allowing a steeper grade on the slopes. The tailings will not be subject to the substantial settlement that is encountered at solid waste landfill and the engineered slope stabilization (through regrading or other reinforcing measures) will also achieve the same standard of performance. Compliance with the rule would result in a hardship in that substantial quantities of soil and the associated truck traffic would be required to meet the surface grade of 5% over the tailings.

Adverse Effect to a Historic Resource

> Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary Area of Potential Effect (APE) for direct effects is shown in Figure 3-5. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc (40 CFR 202, 203, 205), however, they are not considered ARARs for the purposes of this EE/CA.

4.5.2.2 Long-term Effectiveness and Permanence (3C)

Alternative 3C achieves long-term effectiveness and permanence by the following:

TP-3

The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2

The long-term effectiveness and permanence of surface water diversion, soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and soil cover can function effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the soil cover will greatly reduce surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The shallow soil cover will be susceptible to erosion and would require more rigorous inspection and maintenance activities than a cover of more substantial thickness. In addition, it is uncertain if vegetation can survive long-term with only six inches of soil as a buffer. Acid creep into the soil cover could have an impact on the vegetation. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about 22 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The soil cover will also effectively prevent exposure to the tailings.

4.5.2.3 Reduction of Toxicity, Mobility, or Volume Through Treatment (3C)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. SAPS are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and soil cover do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.5.2.4 Short-Term Effectiveness (3C)

Alternative 3C achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur as a result of the soil cover. Alternative 3C does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly-ash and cement kiln dust. The Design stage will fully evaluate options for construction safety needs.

Alternative 3C requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 3,851 trucks over a six-month period to deliver the necessary materials for the cover system and an additional 6,544 for the RCC. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.5.3 Implementability (3C)

4.5.3.1 Technical Feasibility (3C)

Alternative 3C is technically feasible. Design and construction of the cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, personal communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. Successful examples include a SAPS system at the Howe Bridge, Pennsylvania mine site that was constructed to handle flows of approximately 20 gpm, and a SAPS system at the Oven Run, Pennsylvania site that was designed to handle flows of approximately 100 gpm. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and SAPS sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.5.3.2 Administrative Feasibility (3C)

Alternative 3B is administratively feasible. Implementation of Alternative 3C will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.5.3.3 Availability of Services and Materials (3C)

Services and materials to implement alternative 3C are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 125,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.5.3.4 State and Community Acceptance (3C)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the Elizabeth Mine Community Advisory Group (EMCAG) to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices
- Each alternative was designed to minimize impact to the historical resources of the Site

- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible

State and Community acceptance will be evaluated upon closure of the public comment period.

4.5.4 Cost (3C)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Alternative 3C	**Cost ($)**
Capital Costs	
Total – Direct [Present Value]	6,345,498
Total – Indirect [Present Value]	1,808,467
Total – Capital [Present Value]	8,153,965
PRSC	
Annual [Nominal]	28,236
PRSC TP-1 (30 yr NPV)	870,603
PRSC TP-3 (30 yr NPV)	406,389

4.6 Alternative 3D

4.6.1 Description (3D)

Alternative 3D has the same objectives as Alternatives 3B and 3C, but incorporates an induced chemical hardpan formation with a soil cover and drainage layer to minimize potential infiltration and support a grass covered surface.

Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailings pile's surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is “self-healing,” (i.e., when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction)(Chermak and Runnells, 1996).

Induced chemical hardpans have certain drawbacks that must be fully evaluated prior to selection and implementation. Since this technology is relatively new to mine site remediation, there is little supporting literature to demonstrate the effectiveness of this approach. Although the concept involves a self-healing gypsum precipitation approach, it will be difficult to determine if the hardpan layer is uniformly reducing ground water infiltration. Studies to date have demonstrated a one-order-of-magnitude (10x) reduction in vertical permeability in one year in Norway using lime and limestone. Greater reductions would be necessary to be a cost-effective long-term approach for the

Elizabeth Mine. The behavior of the hardpan in a climate similar to Vermont is in question, given the annual freeze-thaw cycles.

Given that this technology is in the development stage, there is a need for pilot scale testing to determine the effectiveness at the Elizabeth Mine. For Alternative 3D, the hardpan layer is covered by a drainage fabric, which is, in turn, covered by soil. Combined, this alternative offers two lines of defense against infiltration of water (ET cover with drainage layer, followed by the hardpan cap).

In Alternative 3D, the current steep and highly eroded slopes of TP-1 and TP-2 will be stabilized, but the profiles should remain largely intact. The use of innovative geotechnical materials and strategies would allow a permanent steep-slope face that is structurally stable and capable of preventing water and oxygen infiltration, while retaining the overall shape of the original tailings. RCC provides the most attractive option for stabilizing the existing slopes.

Surface drainage would follow the original surface flow patterns across the tailings and clean storm-water would be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. TP-3 contaminated surface water and seepage will be treated as in Alternative 3C. A toe drain will be installed to collect the seepage at the toe of TP-1. The collected water will be treated with the passive/natural treatment system.

4.6.2 Effectiveness (3D)
The following sections provide an analysis of the effectiveness of Alternative 3D.

4.6.2.1 Overall Protection of Human Health and the Environment (3D)
Alternative 3D achieves overall protection of human health and the environment by the following:

TP-3
For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP -3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The hardpan cap/soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. The stabilization of the slopes by installing a reinforced wall of RCC or other material will stabilize the current TP-1 slopes and eliminate the risk of slope failure. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 8 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.6.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3D)

Table 4-2 identifies the ARARs that apply to Alternative 3D. Alternative 3D would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. There are several ARARs for which additional discussion is warranted. EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities that will cause these impacts. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the 2 million cubic yards of tailings is considered impracticable.

Variance to the VT Solid Waste Management Regulations:

This EE/CA documents the basis for granting a variance to the VT Solid Waste Regulations. Section §§ 6613 of describes the process for a variance. EPA is proposing a variance from all design and closure provisions of The VT Solid Waste Management Act for TP-3. EPA has determined that this variance would be necessary and appropriate to achieve compliance with NHPA and Act 250. Collection and treatment of the run-off from TP-3 will achieve an equivalent level of protection to the surface water. In addition compliance with the rule would result in a hardship in that the historic resources of TP-3 would be permanently and irreparably damaged. In addition, the tailings and waste material are not hazardous waste as defined by Subtitle C of RCRA.

This EE/CA also documents the basis for granting a variance from the final grade requirements with respect to TP-1 and TP-2. The Solid Waste Management Regulations state that the minimum grade be at least 5% and the maximum grade by 33%. A variance from these requirement is considered necessary and appropriate to achieve compliance with NHPA and Act 250. An equivalent level of protection will be achieved with a lesser grade on the top surface and allowing a steeper grade on the slopes. The tailings will not be subject to the substantial settlement that is encountered at solid waste landfill and the engineered slope stabilization (through regrading or other reinforcing measures) will also achieve the same standard of performance. Compliance with the rule would result in a hardship in that substantial quantities of soil and the associated truck traffic would be required to meet the surface grade of 5% over the tailings.

Adverse Effect to a Historic Resource

Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary Area of Potential Effect (APE) for direct effects is shown in Figure 3-6. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a Memorandum of

Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc (40 CFR 202, 203, 205), however, they are not considered ARARs for the purposes of this EE/CA.

4.6.2.3 Long-term Effectiveness and Permanence (3D)
Alternative 3D achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2
The long-term effectiveness and permanence of surface water diversion, hardpan cap/soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and hardpan cap/soil cover can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the hardpan cap system will greatly reduce surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about 8 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The soil cover will also effectively prevent exposure to the tailings. The long-term effectiveness of the hardpan cap has not been proven, due to limited use of this technology.

4.6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (3D)
The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1/TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. SAPS are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and hardpan cap do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.6.2.5 Short-Term Effectiveness (3D)

Alternative 3D achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and hardpan cap/soil cover installation being complete. Alternative 3D does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The Design stage will fully evaluate options for construction safety needs.

Alternative 3D requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 10,622 trucks over a six-month period to deliver the necessary materials for the cover system and an additional 6,544 for the RCC. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.6.3 Implementability (3D)

4.6.3.1 Technical Feasibility (3D)

Alternative 3D is technically feasible. Design and construction of the hardpan cap/soil cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a hardpan cap/soil cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, personal communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months. Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. Successful examples include a SAPS system at the Howe Bridge, Pennsylvania mine site that was constructed to handle flows of approximately 20 gpm, and a SAPS system at the Oven Run, Pennsylvania site that was designed to handle flows of approximately 100 gpm. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and SAPS sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.6.3.2 Administrative Feasibility (3D)

Alternative 3D is administratively feasible. Implementation of Alternative 3D will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.6.3.3 Availability of Services and Materials (3D)
Services and materials to implement alternative 3D are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 294,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson’s Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.6.3.4 State and Community Acceptance (3D)
EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of “Concerns Expressed to Date”: In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the Elizabeth Mine Community Advisory Group (EMCAG) to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices
- Each alternative was designed to minimize impact to the historical resources of the Site
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possibles

State and Community acceptance will be evaluated upon closure of the public comment period.

4.6.4 Cost (3D)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Alternative 3D	**Cost ($)**
Capital Costs	
Total – Direct [Present Value]	8,467,988
Total – Indirect [Present Value]	2,413,377
Total – Capital [Present Value]	10,881,365
PRSC	
Annual [Nominal]	28,236
PRSC TP-1 (30 yr NPV)	520,183
PRSC TP-3 (30 yr NPV)	406,389

5.0 Comparative Analysis of Removal Action Alternatives

This section of the EE/CA provides a comparison of the five removal action alternatives described in Section 4.0. Figure 5-1 is a comparative analysis of the response action alternatives. The relative advantages and disadvantages of each alternative are discussed with respect to the following criteria:

1. Effectiveness
   - -Overall protection of human health and the environment
   - -Compliance with ARARs and other criteria, advisories, and guidance
   - -Long-term effectiveness and permanence
   - -Reduction in toxicity, mobility, or volume through treatment
   - -Short-term effectiveness

2. Implementability
   - -Technical feasibility
   - -Administrative feasibility
   - -Availability of services and materials
   - -State and community acceptance

3. Cost

The Cost criterion includes both direct and indirect capital costs. The State and Community Acceptance criteria will be modified following the public comment period to reflect issues and concerns that arise through discussions with the Elizabeth Mine Community Advisory Group (EMCAG) and the public.

5.1 Effectiveness

5.1.1 Overall Protection of Human Health and the Environment

The five alternatives all offer similar levels of protection of human health and the environment. For TP-3, each alternative has identical performance. For TP-1 and TP-2, the major differences are as follows:

- The thin soil cover component of Alternative 3C could allow exposure of the tailings after erosion.
- The thin soil cover component of Alternative 3C may not be able to sustain vegetation due to acid creep.
- The long-term effectiveness of the Alternative 3D hardpan cap is not known.
- The quantity of water that is expected to infiltrate the cap/cover due to the cover system components. Alternatives 2B and 2C would result in the least amount of infiltration into the tailings of TP-1 and TP-2.

The multi-barrier cap that is a component of Alternatives 2B and 2C has a proven record of performance. The multi-barrier cap has a tiered system that limits the infiltration of water into the tailings. First, the surface grade promotes run-off as opposed to infiltration. Second, the vegetative cover stores and uses water through the process of evaporation and transpiration. Third, the drainage layer within the cover provides a high capacity system for removing water that remains after the first two components. Fourth, a geomembrane prevents further water migration by acting as seal or barrier to water flow. Finally, the second barrier layer seals any holes in the geomembrane to further prevent the inflow of water into the tailings. The system of natural and engineering components should eliminate all infiltration into the tailings from the surface.

The soil cover components of Alternatives 3B, 3C, and 3D also perform the first two functions (drainage and evapotranspiration) described above. Alternative 3C does not have any additional measures to reduce surface infiltration, whereas, Alternative 3D includes the drainage layer component and a single barrier layer (hardpan). Alternative 3B attempts to maximize the use of water and storage properties of soil by increasing the thickness of the soil layer, as opposed to installing a barrier layer. Most other aspects of these alternatives, relative to overall protection of human health and the environment, are the same.

5.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Each alternative evaluated in this EE/CA will be designed and implemented to comply with the identified ARARs. The approach to compliance with ARARs is largely the same for each alternative. All alternatives will have the same level of impact to wetlands, stream channels, and floodplains. These impacts are unavoidable and will be subject to mitigation. In addition, each alternative requires a variance from the VT Solid Waste Management Regulations.

The extent to which historic and culturally significant features are preserved is an important distinguishing factor between the alternatives. All alternatives under consideration in this EE/CA involve impacts to historic resources that are eligible for the National Register of Historic Places.

From a historic preservation standpoint, the best response alternatives for resources of archaeological value are those that avoid disturbance to archaeologically sensitive areas, or that combine site avoidance with an archaeological data recovery component for those areas that cannot be avoided. The best response action alternatives for resources of visual landscape value are those that retain and/or recreate the basic formal elements of the historic resource, including size, mass, shape, geometry, color, and texture. Retention of these areas and qualities also offers a highly advantageous result in terms of future uses for the mine.

The adverse effects of the cleanup on the historic resource include covering or capping TP-1 and TP-2. Alternatives 2C, 3B, 3C, and 3D will result in a final tailings profile that looks similar to that observed today; however, the color, texture, and ability to directly observe the tailings will be lost. The top surface TP-1 and TP-2 will be grass-covered and the steep, eroded slopes observed today will become a sloped grass cover or a relatively smooth wall of concrete or rock. Alternative 2B will result in irreversible impacts to TP-1 and TP-2 in the form of re-grading to an acceptable slope for engineering control. The use of the retaining wall in Alternatives 2C, 3B, 3C, and 3D is seeks to minimize the impacts to the tailings profiles in TP-1 and TP-2.

EPA intends to preserve as much of TP-3 as possible and minimize direct impacts to the copperas works and Tyson-era features. As stated earlier, it is not possible to anticipate the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution to the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA.

Each of the alternatives considered in this report seeks to preserve areas of the mine that have been identified as especially significant from the standpoints of their historic value. All three tailings piles possess value as historic landscapes. The most immediate and visible historic resources at the Elizabeth Mine are the major landscape elements left from the copperas and copper production activities in the form of tailings or waste rock piles.

Many of the historic components, such as TP-3, are known or potential archaeological resources that have the potential to yield information about industrial and technological activities spanning almost 160 years. TP-3 has been identified as the location of the nineteenth-century copperas production and, therefore, possesses high historic value as an archaeological site for its potential to contain information about this poorly understood early industrial process.

Although there is potential for archaeological remains of late nineteenth and early twentieth-century industrial activity under TP-1 and TP-2, those resources have already been impacted by burial under tailings materials that are not slated for removal. There may be some archaeological testing required in areas slated for associated response activity, such as transportation routes or grading activities, particularly at the west edges of TP-1 and TP-2. The major impact to historic resources associated with TP-1 and TP-2 will be impacts to their appearance and value as major historic landscape elements.

5.1.3 Long-Term Effectiveness and Permanence

The five alternatives all provide the same level of long-term effectiveness and permanence with respect to TP-3.

- The tailings moved from TP-2 are regraded on the surface of TP-1 and covered with a cap (Alternatives 2B and 2C), soil cover (Alternatives 3B and 3C), or soil/hardpan cover (Alternative 3D). The cover system will reduce the surface water infiltration into the tailings of TP-1 and TP-2. The surface water diversion channels around TP-1 and TP-2 will intercept outside surface water flow and shallow groundwater flow into the tailings. Combined, these actions will reduce the seepage at the toe of TP-1 (surface water flow and seepage). Seep water will be collected and treated with spassive/natural treatment at the toe of TP-1 and at the toe of TP-3. The effluent of passive/natural systems will meet the EPA and VT water criteria. Regrading to 3:1 (Alternative 2B) and RCC (Alternatives 2C, 3B, 3C, and 3D) will stabilize the tailings slopes of TP-1 and TP-2.

For each alternative, the collection and treatment of the contaminated water and the stabilization of tailings slopes will be permanent and irreversible. However, Post-Removal Site Controls (PRSC) will be required in order for the cleanup activities to be effective over the long term. Alternative 3C is likely to continue to allow significant surface water infiltration into the tailings, for the following reasons:

- Considering construction accuracy, the soil cover may be less than six inches in some places and more than six inches in others.
- Cyclic wet/dry conditions and frost/melt events will result in non-uniform infiltration.
- Six inches of soil is insufficient to maintain a healthy, sustainable vegetative cover.

Alternatives 2B and 2C have the highest level of long-term effectiveness and permanence. Alternative 3D may approach the long-term effectiveness and permanence of 2B and 2C if the hardpan is truly uniform, self-healing, and of low permeability. Alternative 3B has a somewhat lower level of effectiveness, because it allows greater infiltration into the tailings. Alternative 3C has the lowest level of effectiveness and permanence, given the thin cover and potential for disturbance and erosion.

5.1.4 Reduction in Toxicity, Mobility, or Volume through Treatment

Caps and covers are not considered treatment. Treatment under the Alternatives currently considered for the Elizabeth Mine is restricted to the passive systems that will handle long-term seepage and runoff water. Treatment is largely the same for all five alternatives. Each has the same performance requirements from the two passive treatment systems. Sizing of the treatment systems for the alternatives varies according to the anticipated amount of water infiltration through the cap/cover. Therefore, reduction in toxicity, mobility, or volume through treatment is not a distinguishing factor between alternatives, except that the amount of water treated will vary.

5.1.5 Short-term Effectiveness

Short-term effectiveness includes an assessment of the time period until the removal action goals are met. All alternatives should be able to meet these goals shortly after construction is complete.

Short-term effectiveness also considers the magnitude of potential threats to the community, Site workers, and the environment during implementation of a response action. This includes threats that result from implementing the remedy itself as well as existing threats that persist until mitigated by the cleanup action.

Alternative 2B will have a greater potential for exposure of fresh sulfide material to storm events, due to the exceptionally large amount of unoxidized tailings material that must be regraded to achieve the desired slope angle. Exposure of fresh unoxidized tailings remains largely the same for the other four alternatives.

Each alternative involves substantial construction-related activity and truck traffic. Tailings movement from TP-2 to TP-1 will occur over a several month period and require continuous truck traffic during working hours along a small portion of Mine Road unless an alternate route is identified. This activity should not result in a direct impact to the village of South Strafford; however local residents in the Mine Road area would be directly impacted. Regrading of the tailings does not involve truck traffic along town roads, but does involve considerable on-site truck and heavy machinery traffic over several months. The estimated trucks required for delivering construction materials for each alternative are shown in the table below:

Alternative	***Estimated Truck Count For Cap/Cover[1,2] (Round Trips)***	***Estimated Truck Count For RCC[1,2] (Round Trips)***
Alternative 2B	11,131	0
Alternative 2C	12,942	6,544
Alternative 3B	17,997	6,544
Alternative 3C	3,851	6,544
Alternative 3D	10,622	6,544

1. A two season construction period has been estimated,
2. Estimations based on 12 cubic yard truck volume.

The surrounding towns, including Norwich, Sharon, Strafford, and Thetford, will be affected by increased truck traffic, noise, dust, and road surface degradation. On-site heavy equipment operations will be necessary throughout construction. Road weight limits, soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect truck traffic volume. If a soil borrow pit is identified near the Site, traffic impacts may be reduced to a small area especially if roads can be constructed through the woods from the Site to the soil borrow pit.

Potential risks to Site workers arise from performing construction activities and from exposure to contaminants in tailings, soil, groundwater, and air. Potential risks will be controlled by development and adherence to a site-specific Health and Safety Plan. Alternative 2B will expose the largest volume of unoxidized tailings and thus will have the greatest potential risks.

5.2 Implementability

5.2.1 Technical Feasibility

It is technically feasible to implement each of the five alternatives. Design and construction of the cap/soil cover system and the surface water diversion channels use proven and easily implemented technologies. For Alternative 2B, it is technically feasible to regrade the tailings to 3:1 to stabilize the tailings slopes. For all other alternatives, the tailings slopes will be stabilized using RCC or an equivalent method which has been used in construction and slope rehabilitation of many dams.

It is technically feasible to build the passive/natural treatment system for all alternatives. The technology associated with the passive treatment system has been successfully implemented at a large number of sites around the world. Technical feasibility is not a strong distinguishing factor among alternatives.

5.2.2 Administrative Feasibility

Implementation of any of the alternatives in this EE/CA will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate state and local agencies will be required to implement any of the alternatives. Construction involves direct and indirect impacts to both the town and the local residents through truck traffic, noise, and dust. EPA will coordinate with the Vermont Agency of Transportation, town Select Boards and the local community regarding traffic impacts and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Norwich, Strafford, Sharon, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the town Select Boards.

Administrative feasibility is not, therefore, a strong distinguishing factor among alternatives.

5.2.3 Availability of Services and Materials

The differences between alternatives are largely related to cap and cover construction materials and the necessary service expertise for installation/construction. Common borrow material and topsoil are needed for each of the alternatives. Crushed limestone is needed for passive treatment systems in each alternative. Availability of services and materials should not be a constraint for any of the alternatives under consideration. On the basis of this criterion, none of the five alternatives are more or less desirable.

5.2.4 State and Community Acceptance

State and community acceptance will be addressed through the public comment process.

EPA has worked closely with the State of Vermont and local communities to develop the short list of alternative response actions represented in this EE/CA.

Throughout this process, the community has clearly articulated their concerns and desires. The state has been involved in all aspects of the planning and community outreach process.

Community concerns include the following:

- Effectiveness of the cleanup
- Preservation (to the extent practicable) of Site elements with historic/cultural value
- Limiting truck traffic and construction impacts to the community
- Scale and cost of the cleanup
- Innovation, re-use, and education

Effectiveness of the Cleanup. The alternatives can be distinguished on the basis of Effectiveness of the Cleanup. Alternatives 2B and 2C will be most effective at reducing acid mine drainage over the long-term, while Alternative 3C will be the least effective. Uncertainties remain concerning the effectiveness of an induced hardpan layer in Alternative 3D.

Preservation of Historic Site Elements. The response alternatives described in this EE/CA all have the potential to impact the physical integrity of the historic landscape and resources at the Elizabeth Mine. The impacts from Alternatives 2C, 3B, 3C, and 3D will be largely indistinguishable. Alternative 2B will have a profound impact on the physical appearance of TP-1 and TP-2.

The SHPO and the community have a strong preference for alternatives that will minimize the impact on features of historic significance, including the mining landscape itself. As a result, the EE/CA has developed cleanup alternatives that minimize or eliminate construction activities near most features of historic significance, including the WW II-era buildings and the remains of buildings from early copperas and copper production.

During scoping meetings, discussions identified the attributes of the site that are most valued by the community. They include the copperas works, the Tyson-era associated features, standing structures, Furnace Flat, the North and South open cuts, and the overall industrial landscape reflected by the tailings and waste rock piles.

Alternatives 2C, 3B, 3C, and 3D were developed jointly by EPA, the State, and the community in an effort to minimize the impact of NTCRA actions on the mining landscape. None of the alternatives will have a substantial direct impact on standing structures, Furnace Flat, or the open cuts. The adverse effect for the five alternatives will be defined by the impact on the mining landscape that will alter the integrity of the setting, location of features, associations and relationships of the different mining periods and the feelings associated with the historic landscape.

EPA intends to preserve as much of TP-3 as possible and avoid direct impacts to the copperas works and Tyson-era features. As stated earlier, it is not possible to anticipate of the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the Design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution of the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA.

Limiting Truck Traffic. While each of the alternatives will require a large number of trucks to transport cover/cap material and other construction materials to the Site, the alternatives presented in this EE/CA vary considerably in terms of the amount of truck traffic that is likely to occur. Alternative 3B will require the largest number of trucks (approximately 24,541), while Alternative 3C will require the fewest (approximately 10,395 trucks). Each alternative that incorporates RCC slope stabilization (2C, 3B, 3C, and 3D) will require approximately 6,544 trucks for concrete transportation. The remaining trucks are largely for soil and other construction material transportation. Truck traffic over town roads may be significantly reduced if local sources of common borrow material can be located and acquired. Alternative nearby sources will be evaluated in the Design phase. EPA would attempt to reduce the thickness of the covers described for Alternatives 2B, 2C, and 3D during the design process.

Scale and Cost of the Cleanups. From the beginning of EPA's involvement, the local community has expressed concerns about the scale and cost of the cleanup. Variations in scale and cost between alternatives are largely a function of the cap/cover construction specifications. Multi-barrier caps require more engineering control and construction care, whereas soil covers are generally less complex, but also potentially less effective. The current range of alternatives represent a set of options that are comparable in scale and costs and represent reasonable approaches to the environmental problems at the Site.

More detailed information regarding the estimated cost of the various alternatives is included in Section 5.3. State and community acceptance and concerns regarding the scale and cost of the cleanup will be further considered following receipt of comments during the public comment period.

Innovation, Re-use, and Education: EPA believes that most of the cleanup alternatives (2B, 2C, 3B, and 3D) would include the use of innovative technologies regarding slope stabilization and infiltration reduction. The passive treatment systems are an emerging innovative technology and are included in all alternatives. EPA agrees that re-use and education are valuable components of any cleanup. EPA has provided the community with a re-development grant to facilitate a community dialogue regarding Site re-use. EPA has been meeting with the landowners to address liability issues that could be a barrier to re-use. EPA provided a Technical Assistance Grant to the community to provide additional technical support to the community. Finally, EPA will continue to support outreach and education activities with respect to the Site.

5.3 Costs of Response Alternatives

The estimated cost to complete each of the response alternatives is provided in Table 5-1. Alternative 3C is the least expensive approach, with a capital cost of $8.15 million and a 30-year Net Present Value (NPV) for PRSC of $1,276,993, while Alternative 2C is the most expensive with a capital cost of $11.69 million and a 30-year NPV for PRSC of $923,590. The cost difference between Alternatives 2B, 2C, 3B, and 3D is within the margin of error (for cost estimation); therefore, these alternatives are essentially equal in cost.

5.4 Differentiators Among Alternatives

In summary, the alternatives that have been described and evaluated in this EE/CA are very similar when evaluated against most of the evaluation criteria. There remain significant concerns as to whether Alternative 3C has sufficient thickness of soil to provide long-term protection against erosion and whether the thin cover would support vegetation. The major difference between the alternatives is the approach to reducing the generation of AMD from TP-1 and TP-2. Alternatives 2C and 2B offer the greatest reduction in infiltration and subsequent AMD formation followed by 3D, 3B, and 3C.

The relative effectiveness of each alternative was also evaluated using a set of detailed engineering criteria. The evaluation is summarized in Table 5-2. The detailed evaluation tables are found in Appendix D. The Performance Aspects and Performance Criteria used in this EE/CA include many subjective aspects of overall performance, as well as aspects of performance that are recommended or mandated by guidance documents and regulations. While many of the criteria used in the engineering analysis are not specified by EPA or USACE guidance documents, they are instructive and helpful in the overall evaluation of alternatives, where many of the conventional comparison criteria may not point to a clear and obvious choice. For example, the local community has a strong preference for minimizing the amount of truck traffic through the affected towns. When applied, this criterion would favor alternatives with thinner surface covers/caps to reduce the amount of offsite material trucked to the Site. The Performance Evaluation reveals that Alternative 2C has the highest score in this evaluation.

EPA will use the information contained in this EE/CA to develop a Proposed Plan (fact sheet) that will present the alternative that EPA believes is the best approach to address the contamination at the Site. This EE/CA and Proposed Plan will be subject to a public comment period. EPA will consider the public comments and issue a decision document (Action Memorandum) along with a response to comments to formally select the cleanup alternative.

6.0 References

Arthur D. Little, Inc., 2001a. *Draft Site Conditions Report.* February.

Arthur D. Little, Inc., 2001b. *Summary of Preliminary Ecological and Human Health Risk Evaluations.* July.

Arthur D. Little, Inc., 2001c. *Elizabeth Mine Environmental Response Alternatives Analysis Report*. April.

Arthur D. Little, Inc., 2000. *Elizabeth Mine Site Summary Report*. October.

ASCE Soil Improvement and Geosynthetics Committee, Ground Improvement Subcomittee. 1997. “Soil Improvement and Geosynthetics Committee Report”, *Ground Improvement Ground Reinforcement and Ground Treatment, Developments 1987-1997*, Geotechnical Special Publication No. 69, Proceedings of the sessions sponsored by the Committee on Soil Improvement and Geosynthetics of the Geo-Institute of ASCE in conjunction with Geo-Logan 97’, Logan, Utah, July 1997, V.R. Schaefer, ed., ASCE. pp 1-371.

Colorado School of Mines, 1984. *Water Quality Implications and Control Techniques Associated with the Proposed Union Village Hydroelectric Project.* January.

Davis, S.N. 1969. *Porosity and Permeability of Natural Materials.* Flow Through Porous Media, ed. R.J.M. De Wiest. Academic Press, New York, pp.54-89

Department of the Navy. 1982. *Soil Mechanics, Design Manual 7.1,* NAVFAC DM-7.1.

Elizabeth Mine Study Group (EMSG), Step by Step, Inc., and Damariscotta, Inc (EMSG). 1999. *Hydrologic Characterization and Remediation Options for the Elizabeth Mine, South Strafford, VT.* February.

Elizabeth Mine Study Group (EMSG). 2000. *Ompompanoosuc River Benthic Macroinvertebrate Monitoring Program, 1998-99 Results.* Prepared for the Elizabeth Mine Study Group by Geoff Dates, River Watch Program Director, River Network, April 15, 2000.

Gagne, D. P., and Choi, Y.J. “Alternative cap design guidance proposed for unlined, hazardous waste landfills in the EPA region 1.” 1997. Revised in 2001.

Gazea, B., K. Adam, A. Kontopoulos. 1996. “A Review of Passive Systems for the Treatment of Acid Mine Drainage.” *Minerals Engineering*. 9(1): 23-42.

Goodman, R. E., and Kieffer, D. S. 2000. “Behavior of rock slopes”. *Journal of Geotechnical and Geoenvironmental Engineering,* ASCE, 126(8), 675–684.

Gusek, J.J. and Wildeman, T. 1995. "New Developments in Passive Treatment of Acid Rock Drainage," *Presented at the Technical Solutions for Pollution Prevention in the Mining & Mineral Processing Industries*, Engineering Foundation, Palm Coast, FL. January 23.

Hammarstrom et al., USGS. 1999. *Characterization of Mine Waste at the Elizabeth Copper Mine.*

Hartgen Archeological Associates, 2000. *Statement of Site Limits, National Register Eligibility, and Potential Resources in the Proposed APE: Elizabeth Mine, South Strafford, Vermont*. October.

Hedin, Robert S. 1999. "Environmental Engineering Forum: Long-Term Effects of Acid Mine Drainage with Limestone." *Applied Geochemistry*. July. 1338-1345.

International Society for Rock Mechanics (ISRM). 1978."Suggested methods for quantitative description of discontinuities in rock masses," *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts*, 15, 319–368.

Mitchell, J.K. and Christopher, B.R. 1990. "North American Practice in Reinforced Soil Systems". *Proceedings of a Conference, Design and Performance of Earth Retaining Structures*. June. ASCE Geotechnical Special Publication No. 25, pp. 246-322.

Public Archeology Laboratory and Arthur D. Little, Inc. 2001. *Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine*. May.

Quackenbush, A. 2001. Personal communication with Jeremy Picard.

Rast, R. R. "Environmental remediation estimating methods." R.S. Means Company, Inc., 1997.

Reed, Sherwood C., Crites, Ronald W., and Middlebrooks, E. Joe. 1995. *Natural Systems for Waste Management and Treatment*, New York: McGraw Hill, Inc.

Robinson, James D. F. 1997. "Wetland Treatment of Polluted Waters," *Phytoremediation*, April 28–May 1. p. 339–344.

Skousen, Jeff. 1991. "Anoxic Limestone Drains for Acid Mine Drainage Treatment" *Green Lands*., 21 p. 30-35.

Slack, JF, Offield, TW, Shanks, WC, III, and Woodruff, LG, 1993, Besshi-type Massive Sulfide Deposits of the Vermont Copper Belt, in JF Slack and TW Offield, eds., Selected mineral deposits of Vermont and the Adirondack Mountains, New York, II. Besshi-type Massive Sulfide Deposits of the Vermont Copper Belt: Society of Economic Geologist Guidebook Series, v. 17, p. 32-73.

U.S. Army Corps of Engineers Hydraulics and Water Quality Section, Water Control Branch, Engineering Division (USACE). 1984. *Union Village Dam Water Quality Evaluation Update.* August.

U.S. Army Corps of Engineers (USACE). 1990. *Effects of the Abandoned Elizabeth Copper Mine on Fisheries Resources of the West Branch of the Ompompanoosuc River.* January.

U.S. Army Corps of Engineers (USACE). 1994. *Engineering and Design—Technical Guidelines for Hazardous and Toxic Waste Treatment and Cleanup Activities,* EM 1110-1-502, April 30.

U.S. Army Corps of Engineers (USAGE). 1999. *Engineering and Design—Guidelines on Ground Improvement for Structures and Facilities,* ETL 1110-1-185, February 1.

U.S. Environmental Protection Agency. 1989. “Final Covers on Hazardous Waste Landfills and Surface Impoundments,” (EPA-530-SW-89-047), July.

U.S. Environmental Protection Agency (EPA). 1991. "National Primary Drinking Water Regulations: Proposed Rule (40 CFR Parts 141 & 142)." National Primary Drinking Water Regulations: Final Rule (40 CFR Parts 141, 142 & 143). *Fed. Reg.* 56 (20):3526(89). January 30.

U.S. Environmental Protection Agency (EPA). 1992. "National Primary Drinking Water Regulations – Synthetic Organic Chemicals and Inorganic Chemicals; National Primary Drinking Water Regulations Implementation (Final rule)." *Fed. Reg.* 57 (138) :31776(74). July 17.

U.S. Environmental Protection Agency (EPA). 1996. *ECO Update: Ecotox Thresholds. Intermittent Bulletin* Volume 3, No. 2.

U.S. Environmental Protection Agency (EPA). 1999. “Preliminary Ecological Risk Evaluation for the Elizabeth Copper Mine in Strafford, Vermont.” Memo from Patti Lynne Tyler to Wing Chau, September 29, 1999. EPA New England, Office of Environmental Measurement and Evaluation, Lexington, MA.

U.S. Geological Survey (USGS). 1998. *USGS Spring and Summer Sample Data and Maps.* August.

Vermont Agency of Environmental Conservation (VTAEC). 1977. *Elizabeth Mine, South Strafford, VT, reporting on sampling of mine drainage and area waterways*. December.

Vermont Department of Health. 1998. Memorandum From William C. Bress, PhD, State Toxicologist, Re: Vermont Department of Health Drinking Water Guidance. Division of Health Protection, Environmental Health. December 1998.

Watzlaf, George R. and Hyman, David M. 1995. “Limitations of Passive Systems for the Treatment of Mine Drainage,” 17th Annual Conference of the National Abandoned Mine Land Program, October 15–19.

Williams, Frederick M. and Lloyd R. Stark. 1996 “Environmental Engineering Forum: Long-Term Effects of Wetland Treatment of Acid Mine Drainage, Discussion by Frederick M. Williams and Lloyd R. Stark.” *Journal of Environmental Engineering*. January.

Appendix A: Approval Memorandum to Perform EE/CA for NTCRA

Appendix B: Engineering Evaluation Supporting Material

Appendix C: Engineering Evaluation Cost Breakdown

Appendix D: Engineering Evaluation Performance Criteria Tables