Basis of Design Report

Phase 2 Remedial Action: Lord Brook Source Areas
Remedial Design
Final Submittal

FOR

ELIZABETH MINE SUPERFUND SITE
SOUTH STRAFFORD, VERMONT

Contract No. W912WJ-11-D-0005
Task Order 0003

Prepared For:

New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Prepared By:

AMEC Environment & Infrastructure, Inc.
511 Congress Street
Portland, Maine 04101

September 2014

AMEC Project Number: 3612112157

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ACRONYMS AND ABBREVIATION

AIME	American Institute of Mining, Metallurgical and Petroleum Engineers
ALD	anoxic limestone drain
AMD	acid mine drainage
ARAR	applicable or relevant and appropriate requirement
ARD	acid rock drainage
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
bmp	best management practice
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
cm	centimeters
COC	Contaminant of Concern
CSM	Conceptual Site Model
CWA	Clean Water Act
cy	cubic yard
EBOR	East Branch of the Ompompanoosuc River
EPA	U.S. Environmental Protection Agency
ET	evapo-transpiration
FS	Feasibility Study
FWS	free water surface
gpm	gallons per minute
HASP	Health and Safety Plan
HSSF	horizontal subsurface flow
LBSA	Lord Brook Source Areas
µg/L	micrograms per liter
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MSL	mean sea level
NaHCO3	sodium bicarbonate
NAVD	North American Vertical Datum
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NTCRA	Non-time Critical Removal Action
OLC	open limestone channel

PRG	preliminary remediation goal
RAO	response action objective
RAPS	reducing and alkalinity producing systems
RI	Remedial Investigation
ROD	Record of Decision
ROM	rough order of magnitude
sf	square feet
SHPO	State Historic Preservation Officer
Site	Elizabeth Mine Superfund Site, South Strafford, Vermont
SOC	South Open Cut
SU	standard units
TCRA	time-critical removal action
TI	Technical Impracticability
TP	Tailing Pile
TR	technical release
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VE	value engineering
VWQS	Vermont Water Quality Standards
WMA	Waste Management Area
WBOR	West Branch of the Ompompanoosuc River
WTS	Water Treatment System
WWII	World War II

1.0 INTRODUCTION

1.1 Purpose

This Basis of Design Report was prepared to document the remedial design approach for the Phase 2 Remedial Action: Lord Brook Source Areas at the Elizabeth Mine Superfund Site in South Strafford, Vermont, as the design reaches the final completion point.

1.2 Background

The Elizabeth Mine Superfund Site (Site) is an abandoned copper mine located on privately owned land in the Towns of Strafford and Thetford, Orange County, in east-central Vermont. It is located approximately two miles southeast of the village of South Strafford, on the eastern flank of Copperas Hill. The Site is approximately 15 miles northwest of White River Junction, Vermont, and 9 miles west of the Connecticut River. Figure 1 shows the Site location.

The Site includes three small watersheds containing Copperas Brook, Lord Brook, and Sargent Brook, which all discharge to the West Branch Ompompanoosuc River (WBOR). All of these surface waters are State-designated as Class B water. The Ompompanoosuc River flows into the Connecticut River about ten miles downstream of the Site. The topography of the area is steep mountainous terrain with elevations ranging from approximately 830 feet above mean sea level (MSL) (North American Vertical Datum [NAVD] 1988) at monitoring well MW-17C adjacent to the WBOR, to 1600 feet above MSL at the top of Copperas Hill.

The Elizabeth Mine was developed in open pits and in extensive underground workings. The mine area is a source of heavy metals and sediments to Lord Brook and Copperas Brook which carry the drainage from the mine and tailings deposits to the WBOR. Mine dumps and tailings from the Elizabeth Mine have been exposed both historically and currently to weathering processes that result in acid mine drainage (AMD) and acid rock drainage (ARD). Major sources of ARD include or have included Tailing Pile 1 (TP-1, 30 acres), Tailing Pile 2 (TP-2, 5 acres), Tailing Pile 3 (TP-3, 6 acres) which consisted of a waste pile adjacent to the North Open Cut, and Tailing Pile 4 (TP-4) which consisted of a waste pile on the east side of Copperas Road adjacent to South Open Cut. A Non-time Critical Removal Action (NTCRA) was performed to consolidate and cap the tailing piles. The OU 1 design, which is the focus of this Basis of Design Report, addresses actions to be taken at the Lord Brook Source Areas, which comprise the South Mine, South Open Cut, and TP-4 to control the discharge of dissolved metals to the Lord Brook drainage area.

1.3 Project Summary

A summary of the history of federal and state investigations and removal and remedial actions is presented below:

The Site was proposed for inclusion on the National Priorities List (NPL) in December 2000. The Site was finalized on the NPL on June 14, 2001. In addition to the upcoming remedial action, The United States Environmental Protection Agency (EPA) has previously implemented

both a time-critical removal action (TCRA), a NTCRA, and the Phase 1 Remedial Action. Figure 2 shows the areas subject to the TCRA, NTCRA, and Remedial Action.

1.3.1 Time Critical Removal Action

Geotechnical investigations and evaluations performed during 2002 identified significant stability concerns associated with the TP-1 tailing dam. The consequence of a failure of the TP-1 dam would have been the release of large quantities of tailing that could threaten up to 11 downstream structures and impact up to 20 miles of river with anoxic tailing. Three mechanisms for the failure or collapse of the TP-1 tailing dam were identified:

- Internal dam erosion (or piping);
- Failure of the decant system resulting in overtopping or elevated levels of tailing saturation within the tailing dam (the decant system was the conveyance system that drained the water from the top of the tailing pile, which included the entire flow of Copperas Brook, through the tailing dam, and into Copperas Brook); and
- Slope failure resulting from surface erosion or from an increase in the water table within TP-1 resulting from other factors (i.e., not decant system related).

Frequent Site inspections of TP-1 were initiated in February 2003. Internal dam erosion was identified to be accelerating during these inspections. Because of these identified conditions and following meetings with local officials and the public, a TCRA was implemented at TP-1 by EPA. The TCRA was implemented to increase the stability of TP-1 and reduce the potential for a dam failure, which posed a public health threat to inhabitants of downstream areas. In conjunction with the TCRA, EPA developed an Emergency Response Plan in coordination with local response officials.

The TCRA began in the spring of 2003 with the installation of graded filters over the areas where the piping of dam material was observed and continued during the fall of 2003 with the installation of a 36-inch diversion pipe and spillway to replace the existing decant drainage system that formerly transmitted Copperas Brook through the lower portion of TP-1. The diversion construction included the installation of a groundwater interception pipe to intercept shallow groundwater entering TP-1 from the east. The inlet/outlet structures and the diversion pipe increased flow capacity for Copperas Brook to pass through TP-1.

The final component of the TCRA was implemented during 2004 and 2005 and included construction of a soil buttress to stabilize the north face of TP-1. The buttress construction involved the placement of approximately 67,000 cubic yards (cy) of soil obtained from both on-site and off-site sources.

The TCRA was completed in fall 2005. The State of Vermont has taken over responsibility for post-removal site control of the TCRA. The post-removal site control activities include maintenance of the toe drains and horizontal drains, inspections of the tailing dam buttress and spillway, and maintenance of the vegetative surface of the buttress and toe drain/horizontal drain area (mowing and weed control).

1.3.2 Non-Time Critical Removal Action

EPA is implementing the NTCRA in three phases. Phase 1 began in 2006 and was completed in 2010. Phase 2 began in 2009 and is expected to be completed in 2016. Phase 3 is the installation of the final passive treatment system for the discharge from the Tailing Impoundment and will be completed when leachate flow from TP-1 is reduced to below 10 gallons per minute (gpm).

The removal action objectives for the NTCRA are:

- Achieve Vermont Water Quality Standards (chemical and biological) as well as other applicable standards for the WBOR by preventing or minimizing the discharge of water with mine-related metals contamination to Copperas Brook and the WBOR;
- Minimize erosion and transport of tailings or contaminated soil into the surface waters of Copperas Brook and the WBOR;
- Evaluate the stability of the waste piles (tailings, waste rock, and leach piles) and modify slope configurations (re-grading, covering, or buttressing) as necessary to provide for an acceptable level of long-term stability;
- Consider measures to minimize and, if possible avoid, an adverse effect on historic resources at the Site, as required by the National Historic Preservation Act (NHPA); and
- Comply with all applicable or relevant and appropriate federal and state regulations (ARARs) while achieving these objectives.

The status of the NTCRA Phase 1 and Phase 2, and a brief description of Phase 3 are presented below:

Phase 1 NTCRA Activities

- **TP-1 Western Side Stabilization and Diversion Channel:** The work generally consisted of flattening the exterior slope of TP-1 and constructing a 1,650 linear foot surface water diversion channel along the west side of TP-1. These activities were completed during 2006.
- **TP-1 East Side Diversion Channel:** The work consisted of constructing a 2,100 linear foot diversion channel to intercept surface water and shallow groundwater before they reached TP-1 and TP-2. The diversion channel also provided conveyance of surface water from upstream of TP-1, including Copperas Brook, around TP-1. These activities were completed during 2007.
- **TP-1 West Side Groundwater Cutoff Trench:** A 1,150 linear foot groundwater interceptor trench was installed in order to account for the depth to the glacial till surface, which did not allow the surface water diversion along the west side of TP-1 to achieve shallow groundwater interception. The cutoff trench was installed in late 2009.

- **TP-2 Diversion Channel:** The work consisted of constructing a 1,300 linear foot diversion channel to intercept surface water and shallow groundwater before it reaches TP-2 and to provide for conveyance of Copperas Brook around TP-2. These activities were initiated in 2007 and completed in 2010.
- **Toe Tailing Waste Removal and Stream Restoration:** The channel restoration included removing tailings from Copperas Brook below TP-1 and constructing about 870 linear feet of new channel. This work was completed in 2010.

Phase 2 NTCRA Activities

- **TP-3 Waste Excavation and Consolidation to TP-1:** The work consisted of the removal of waste rock pile TP-3 and placing this material on TP-1. About 300,000 cy of material were removed from TP-3 and transported to TP-1 and TP-2. This work was completed in 2010.
- **Consolidation of Additional Waste Ore and Other Material:** Waste ore from the waste rock pile TP-4, South Mine, and South Open Cut was excavated and used as fill to establish the final grade on TP-1. Other waste material consolidated onto TP-1 includes lead-contaminated soil from the Copperas Factories closure area, petroleum-impacted soils excavated from the east side of the World War II (WWII) Area, and waste rock surrounding the WWII era buildings. About 100,000 cy of waste rock from these areas was removed and transported to TP-1 and TP-2. Waste rock consolidation was completed in 2012.
- **Copperas Brook channel extension and repair:** A 300-foot extension was added to the northern end of the engineered portion of the Copperas Brook channel at the toe of TP-1 to create an improved transition from the engineered channel to the natural channel. In addition, a 300-foot section of Copperas Channel that was damaged during Tropical Storm Irene in August 2011, at the northeast corner of TP-1, was repaired. The repair included construction of a deeper channel section, placement of a one-foot thick filter stone layer, and approximately 3.7 feet of larger stone to handle a comparable storm in the future. Both of these activities were completed in 2012.
- **TP-1 and TP-2 Cover System:** Waste relocation and final grading activities on TP-1 and TP-2 were initiated in May 2011 and completed in August 2012. The work generally consisted of the relocation and placement of waste rock and tailing from TP-1 and TP-2 to stabilize the tailing piles, creating positive drainage away from TP-1 and TP-2, and establishing a firm and stable (suitable) subgrade surface for the placement of the infiltration barrier cover system. Approximately 195,000 cy of tailing and waste rock was excavated and placed (cut and filled) during waste relocation and final grading activities. A combination of fine tailing, imported sand, and imported sump sand were used to establish a 4-inch thick cushion layer over the 45.1-acre cover system area. The cover system consisted of eight main components: a 60-mil low-permeability geomembrane, a drainage geocomposite, 18 to 24 inches of vegetative support soil, cover system drainage features, toe details, 6 inches of topsoil, seeding and stabilization, and permanent access roads.

Construction of the cover system was performed over two years, with approximately 21.9 acres completed in 2011 and 23.2 acres completed in 2012.

- **Site Restoration:** Site restoration activities were implemented in 2012 and 2013. The activities included removal of temporary access roads, replacement of damaged or removed monitoring wells, restoration of the borrow areas, repair of a slope area that was destabilized, stabilization of remaining soil and stone stockpiles, and completion of permanent access roads. Some punch list restoration items will continue into 2014 and 2015.
- **Water Treatment System:** A Water Treatment System (WTS) was constructed in 2008 to remove iron and reduce AMD impacts from the leachate discharged from the toe drains and horizontal drains of TP-1, prior to discharging to Copperas Brook. The WTS was operated from April through November during 2008 through 2012, and from May through November in 2013. The existing WTS will be operated during 2014. The WTS will need to be operated until construction of the long-term final passive treatment system under the Phase 3 NTCRA.

Phase 3 NTCRA Activities

Phase 3 of the NTCRA is the installation of the final passive treatment system to treat the discharge from the Tailing Impoundment. This activity will not be completed until leachate discharge from TP-1 drops to below 10 gpm. Because of the Phase 1 diversion channels and Phase 2 cover system, the leachate flow rate has been reduced from 55 gpm prior to the NTCRA to 18 gpm as of August 2014.

1.3.3 Remedial Investigation and Feasibility Study

The Remedial Investigation (RI) and Feasibility Study (FS) are described in the RI Report (URS, 2006a), and the key findings are presented in the ROD. Chapter 1 of the FS Report (URS, 2006b) contains an overview of the RI. A reduced summary is provided below.

The existing and former mine features result from the mining and mineral processing of the massive sulfide ore body which is part of the Vermont Copper Belt. The primary physical features associated with the mine include three open rock cuts (the North Open Cut, the South Open Cut, and the South Mine), two pit lakes (located at the South Open Cut and at the South Mine), a series of WWII-era mine support buildings, and approximately 8,000 linear feet of underground mine workings. Two tailing piles (TP-1 and TP-2) and two waste ore and waste rock piles (TP-3 and TP-4) were consolidated under the TP-1/TP-2 cover as part of the NTCRA, The area subject to the RI also included areas of historical ore benification processes (including smelter sites and roast beds) and areas of graded mining wastes used as historical fill.

1.3.3.1 General Characteristics

A. Meteorological Conditions

During over two years of meteorological monitoring at the Site (i.e., 2002 through 2004), a maximum temperature of 95 °F and a minimum temperature of -26 °F were recorded (URS, 2006a).

Area winds consist primarily of the prevailing westerlies (i.e., a northwesterly flow in the winter and a southwesterly flow in the summer). The local wind conditions are influenced by the topography, and, as such, the prevailing winds at the Site blow parallel to the valley (i.e., south). The contrasting air brought into the region by the westerlies interacts to produce localized low-pressure storm systems that cause wide variations in precipitation from one part of the region to another. For this reason, the rainfall at the Site may be significantly different from that measured at the Union Village Dam weather station.

Precipitation is received in fairly uniform amounts throughout the year. During the years of meteorological monitoring at the Site (i.e., 2002 through 2004), rainfall events of up to four inches within 24 hours and several significant snowfall events (i.e., greater than 12 inches within 24 hours) were documented. Average annual precipitation for the region ranges from 36 to 40 inches per year, including an average of 23 inches of snowfall occurring between November and April. Site monitoring has recorded an average annual precipitation of approximately 33 inches per year.

B. Regional Soil Conditions

The Ompompanoosuc River Valley includes glaciofluvial features formed by the melting glaciers (i.e., kames and kame terraces) and glaciolacustrine littoral and lake-bottom deposits. More recently, streams within the drainage basin of the WBOR (including Sargent Brook, Lord Brook, and Copperas Brook) have reworked, transported, and deposited alluvium, consisting predominantly of sand and gravel, along their banks.

C. Regional Bedrock Geology

The Elizabeth Mine is the southernmost mine in the 20-mile-long, Orange County, Vermont, copper belt that includes the Ely Mine in Vershire and the Pike Hill Mines in Corinth. The metallic sulfide mineral deposits of the copper belt are located in the Paleozoic stratigraphic units of the Connecticut Valley Trough that stretches from western Massachusetts to the Gaspe Peninsula of the Province of Quebec, Canada. The bedrock underlying Orange County consists of Silurian and early Devonian metasedimentary rocks with interspersed metavolcanic rocks and igneous intrusives. These rocks were subjected to at least three stages of intense folding and metamorphism during the early Devonian Acadian orogeny. Rock units typically dip steeply to the east and become progressively younger from west to east. Bedrock at the Site (and the host rock of the ore body) is mapped as the Gile Mountain Formation which consists largely of metamorphosed pelitic schist, greywacke (seafloor sediments), and amphibolites. Bedrock to the north and west of the Site consists primarily of the

calcareous Waits River Formation, which contains metamorphosed calcareous pelite, pelite, quartzose limestone, dolostone, and limestone.

The Vermont copper belt ore deposits are examples of Appalachian sulfides. These ore deposits consist of iron sulfide in the form of pyrite or pyrrhotite, commonly mixed with lesser quantities of copper, usually in the form of chalcopyrite, and locally zinc (sphalerite), lead, and trace amounts of other metals, including precious metals. The ore mined at the Elizabeth Mine consisted predominantly of pyrrhotite (iron sulfide) with the copper in chalcopyrite (copper iron sulfide), and traces of zinc and silver. Geologists consider the Elizabeth Mine and other Orange County copper deposits to be examples of a Besshi-type massive sulfide deposit which occurs at rifting (spreading) continental plate margins at oceanic ridge crests or back arc marine basins.

Bedrock topography beneath the Site and RI study area generally slopes north/northeast along the Copperas Brook drainage basin toward the WBOR from an elevation of approximately 1,600 feet above MSL (surface exposed bedrock at the south end of the North Open Cut) to an elevation of approximately 830 feet above MSL at monitoring well location MW-17C. Based upon core samples obtained from beneath and adjacent to TP-1 and TP-2 and adjacent to the South Open Cut, the host bedrock underlying the Site and RI study area is described as schists containing biotite, graphite, and/or garnet, representative of the Gile Mountain Formation. In general, the bedrock within the Site area exhibits a low degree of fracturing with only slight to moderate weathering. As an exception, rock cores obtained just below the bedrock surface were intensely fractured and exhibited a slight to moderate degree of weathering. Many, but not all of the fractures encountered in bedrock at the above-referenced locations were steeply dipping and water-bearing.

D. Regional Surface Water Hydrology

Regionally, the Site is located within the 136 square mile drainage basin of the 23-mile-long Ompompanoosuc River system. The river system consists of the East Branch of the Ompompanoosuc River (EBOR) and the WBOR that flow into and form the Ompompanoosuc River. The EBOR originates in the northwest corner of the town of Vershire and flows east and south to the southern edge of the town of Thetford. The EBOR then flows about 9 miles south to its confluence with the WBOR. The headwater tributaries to the WBOR originate from Hawkins Mountain (elevation 2,363 feet above MSL) in southwest Vershire and Brocklebank Hill (elevation 2,111 feet above MSL) in northeast Tunbridge, Vermont. The WBOR flows southeast through Strafford and the northern portion of the Site near Furnace Flats. The WBOR meets the EBOR to form the Ompompanoosuc River just upstream of the Union Village Dam in Thetford, Vermont. The river then flows southeast for approximately 3.7 miles to its confluence with the Connecticut River in Norwich, Vermont. Three primary watercourses and their associated tributaries provide drainage from the Site to the WBOR. These watercourses include Lord Brook to the southeast, Sargent Brook to the west, and Copperas Brook in the north-central portion of the Site.

E. Site Hydrogeology

There are three principal surface overburden units present in the area: a dense glacial basal till (resting on bedrock); sand and gravel outwash deposits above the basal till; and a thin Quaternary alluvium deposits in the drainage channels. Each unit varies in thickness and distribution.

The boundaries of the groundwater regime at the Site are defined by topography. Recharge to the groundwater system generally occurs in topographically elevated areas, from which groundwater flows downward to areas of lower hydraulic potential. Groundwater discharge occurs primarily in topographically lower areas (e.g., ravines, gullies, and valleys) that are associated with surface water drainage features (e.g., streams or rivers). The direction of groundwater flow in discharge areas is upward, with the water table typically encountered near the ground surface. Recharge areas to the groundwater regimes are interpreted to generally correspond to the drainage divides for the watersheds.

F. Acid Rock Drainage

The major issue at the Elizabeth Mine is ARD. Impacts to environmental media at the Site result primarily from acid rock drainage, which occurs when sulfide mineral-bearing rock and ore are exposed to oxidizing conditions through natural weathering processes. At the Site, ARD occurs in response to the oxidation of waste sulfidic rock, waste ore, tailing, and exposed sulfidic bedrock in open cuts or underground workings.

Acid rock drainage produces a low-pH solution (typically less than 4.0 standard units [SU]) containing elevated concentrations of iron, sulfate, and base metals present within the ore body. The geochemical reactions responsible for the oxidation of sulfide minerals, such as pyrrhotite, are driven by the availability of atmospheric oxygen and water. These geochemical reactions produce sulfuric acid, which enhances mineral weathering and promotes the mobility of certain metals native to the ore body and associated host rock, including aluminum, cadmium, cobalt, copper, iron, manganese, nickel, and zinc. In addition to the oxidation of the sulfide-bearing minerals, the cyclic formation and subsequent dissolution of evaporative metal salts on exposed waste ore and tailing also contributes ARD to site waters. Metal salts form on the surfaces of the weathered rock as metal-containing acidic moisture evaporates. The metals stored in these salts are dissolved and remobilized during subsequent rainfall events. This run-off eventually is conveyed to receiving streams resulting in an increase in the metals loading above the base loading from the ongoing ARD.

Metals associated with ARD at the Site have been detected at elevated concentrations in groundwater, surface water, soil, and sediment. ARD directly affects both groundwater and surface water quality at the Site by lowering the pH and contributing elevated concentrations of metals to these media. This has been observed at the Artesian Vent (underground workings discharge point) and at discharges from the pit lakes, where mining impacted waters discharge directly to the ground surface as AMD. In addition, analytical data and empirical observations indicate that toxic tailing, weathered waste ore, processed ore, and byproducts generated from the smelting

process (i.e., slag) have been transported from the original areas of deposition by erosion and re-distributed, causing elevated concentrations of metals in the soil adjacent to the disposal areas. Transport of some of these materials by overland flow has resulted in elevated concentrations of metals in sediment along the following drainage ways: Copperas Brook; the WBOR; unnamed Lord Brook tributaries leading from the South Mine, the South Open Cut, and TP-4; and Lord Brook.

G. Remedial Investigation Findings

A summary of the RI findings pertaining to the Lord Brook Watershed and associated source areas are presented below. For more detailed information on the Lord Brook watershed, the Sargent Brook Watershed, WBOR, and underground workings, refer to the RI and the ROD.

The only threat relating to soil that is not acid generating and contributing to the ARD was identified for lead contaminated soil associated with the Copperas Factories. This threat was address as part of the Phase 1 Remedial Action.

Surface water is the primary exposure medium of concern in the Lord Brook watershed. Surface water analytical data collected as part of the RI indicated the following:

- Drainage from the South Mine contained total and dissolved aluminum, cadmium, copper, zinc, and occasionally dissolved iron, lead, and nickel at concentrations that exceeded surface water quality criteria. The sources of these metals were identified as discharges from the South Mine pit lake during periods of high flow along with runoff and groundwater seepage through the waste ore materials located along the east and north sides of the South Mine.
- Drainage from the South Open Cut and TP-4 contained concentrations of total and/or dissolved aluminum, cadmium, copper, zinc, and occasionally iron, mercury, nickel and/or lead at concentrations exceeding surface water quality criteria.
- The combined drainage from the South Mine, the South Open Cut, and TP-4 contained concentrations of total and dissolved aluminum, cadmium, copper, and zinc above surface water quality criteria.
- Total and/or dissolved aluminum, copper, and zinc periodically exceeded surface water quality criteria in Lord Brook near the confluence with the mine drainage tributary.
- The benthic and fish communities sampled in the mine drainage tributary and from Lord Brook immediately downstream of the mine drainage tributary confluence failed to meet Vermont Water Quality Standards (VWQS) Class B aquatic life use criteria.

1.3.3.2 Historic Resources

The Elizabeth Mine is an historic resource that 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. It 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. 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 inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers' (AIME) Mining Hall of Fame in 1996. EPA has determined the Elizabeth Mine Site to be eligible for listing on the National Register of Historic Places. As part of the RI, EPA documented the historic resources at the Site in several reports that are contained in the Administrative Record for the Site. The South Open Cut, South Mine, and South Mine shaft are considered historical features.

1.3.3.3 Conceptual Site Model

As described in the ROD, surface water presently within and discharging from the three source areas within the Lord Brook Watershed (South Open Cut, South Mine, and TP-4) was found to be causing adverse effects to the periphyton, benthic macroinvertebrate, fish, and amphibian communities. The impairment is most severe in the unnamed tributaries that drain the Lord Brook source areas and in the initial portion of Lord Brook below the confluence with these tributaries. Surface water ecological contaminants of concern identified in the ROD consist of cadmium, copper, iron, lead, nickel, selenium, and zinc. Adverse human health effects were not associated with the Lord Brook source areas.

The source of these contaminants at Elizabeth Mine and the Lord Brook source areas is ARD. ARD occurs when sulfide mineral-bearing rock and ore are exposed to oxidizing conditions through natural weathering processes. At the Lord Brook Source areas, ARD occurs in response to the oxidation of waste rock and exposed bedrock both in open cuts and underground workings.

ARD produces a low-pH solution (typically less than 4.0 SU) containing elevated concentrations of iron, sulfate, and base metals present within the ore body. The geochemical reactions responsible for the oxidation of sulfide minerals, such as pyrrhotite, are driven by the availability of atmospheric oxygen and water. These geochemical reactions produce sulfuric acid, which enhances mineral weathering and promotes the mobility of certain metals native to the ore body and associated host rock, including aluminum, cadmium, cobalt copper, iron, manganese, nickel, and zinc. In addition to the oxidation of the sulfide-bearing minerals, the cyclic formation and subsequent dissolution of evaporative metal salts on exposed waste ore and tailing also contributes ARD to site waters. Metal salts form on rock surfaces as metal-containing acidic moisture evaporates. The metals stored in these salts are dissolved and remobilized during subsequent rainfall events. This run-off eventually is conveyed to receiving streams resulting in an increase in the metals loading above the base loading from the ongoing ARD.

Metals associated with ARD at the Site have been detected at elevated concentrations in groundwater, surface water, soil, and sediment. ARD directly affects both groundwater and surface water quality by lowering the pH and contributing elevated concentrations of metals to environmental media. This occurs at discharges from the pit lakes, where mine impacted waters discharge directly to the ground surface as AMD. In addition, weathered waste rock can

be transported from the original areas of deposition by erosion and re-distributed, causing elevated concentrations of metals in the soil adjacent to the disposal.

ARD and erosion of material from waste piles are the primary mechanisms by which contaminants are being transported from the source areas and causing degradation of surface water, sediment, and groundwater.

ARD can be controlled by preventing sulfide mineral contact with oxygen and/or water. Limestone will neutralize ARD and raise the pH of ARD, but does not stop the reaction.

Additional detail about the Conceptual Site Model (CSM) is provided in the ROD.

1.4 Remedial Action Summary

1.4.1 Description of the Selected Remedy

The September 2006 ROD set forth the selected remedy for the Elizabeth Mine Site. Two additional response actions, a NTCRA and TCRA, were selected for the Site by EPA prior to the September 2006 ROD. The remedy selected in the 2006 ROD identified five areas of the Site, not addressed by the TCRA or NTCRA, that pose an unacceptable threats to human health and the environment. The remedy for these five areas is being implemented in three phases (Figure 2):

Phase 1 Remedial Action: Upper and Lower Copperas Factories

The Phase 1 Remedial Action: Copperas Factories involved the placement of a two-foot layer of soil/stone over lead contaminated soil within and surrounding the Upper and Lower Copperas Factories to eliminate the human contact risk. In September 2008, EPA signed an Explanation of Significant Differences for the September 2006 ROD to document that some portion of the lead contaminated soil excavated at the Copperas Factories would be consolidated under the cover system to be installed for TP-1 or TP-2.

Phase 2 Remedial Action: Lord Brook Source Areas

The Phase 2 Remedial Action: Lord Brook Source Areas was selected to minimize the discharge of ARD from the three Lord Brook Source Areas (South Open Cut, South Mine, and TP-4) to achieve federal and state water quality standards at the point of compliance. The major components of the Phase 2 Remedial Action are: diversion of surface water around the pit lakes; mitigation of the ARD created by the pit lakes and surrounding waste rock through consolidation and covering of the waste; filling and covering portions of the pit lakes; and site restoration. The Phase 2 Remedial Action is the subject of this remedial design and is described in more detail in the following paragraphs.

Phase 3 Remedial Action: Impacted Sediment, WWII Infrastructure Area, and Site-Wide Alternatives

There are three components to the Phase 3 Remedial Action.

Component 1 - Impacted Sediment (SED) Monitored Natural Recovery

This component of the Phase 3 Remedial Action relies upon natural processes, such as long-term burial and dispersion to change the distribution of contaminated sediments. The long-term result will be that the sediments are no longer toxic to aquatic organisms and will not cause the surface water to fail Vermont Class B Water Quality Standards. The NTCRA and Lord Brook Source Areas cleanup actions will eliminate the contaminant loading to Copperas Brook, WBOR, and the unnamed tributaries of Lord Brook, also reducing the acidity of the water and the leaching of contaminants into the waters. There will be no construction activities associated with this alternative. EPA will perform an initial baseline surface water, sediment, and biological monitoring program. Long-term monitoring of surface water, sediment, and the biological community will be performed.

Component 2 - World War II-Era Infrastructure Area (IA) Limited Action (Institutional Controls and Monitoring)

This component of the Phase 3 Remedial Action relies upon the successful implementation of the NTCRA to achieve Vermont Water Quality Standards at the point of compliance in Copperas Brook, downstream of TP-1. As a result, the only necessary activities to prevent an increase in ARD will be monitoring of the water quality at the compliance point, along with implementation and monitoring of a land use restriction that restricts any alteration of the WWII-Era Mine Infrastructure Area in a manner that would expose waste rock and create additional ARD.

Component 3 - Site-wide Groundwater (SW) Monitoring and Institutional Controls

This component of the Phase 3 Remedial Action includes land use restrictions to prevent future consumption of contaminated groundwater in limited areas of the Site. The contaminated groundwater is found within the Underground Workings of the Elizabeth Mine and within and adjacent to TP-1, TP-2, and TP-3. The TP-1 groundwater restriction may also extend into some of the WWII Infrastructure Area, depending on the extent of the final cover for TP-1. Some combination of local ordinances, deed notices, restrictive covenants, and/or other institutional controls, coupled with periodic compliance monitoring of the restrictions, would be used to provide awareness that the Underground Workings contain water that is unsuitable for ingestion and to prevent installation of a water supply well into the Underground Workings. No residential wells are currently installed in the Underground Workings.

In addition, institutional controls in the form of land use restrictions would also be used to prevent future use of the groundwater beneath and adjacent to TP-1, TP-2, and TP-3. One residential well is located within the Waste Management Area (WMA) for TP-1, TP-2, and TP-3; however, the property is no longer occupied, and the well is not currently in use. The groundwater contamination associated with TP-1, TP-2, and TP-3 is restricted to the area under the WMA. The institutional controls, in the form of land use restrictions or other land use controls, will protect the integrity and long-term effectiveness of the response actions implemented as part of the TCRA and NTCRA. There will be a review of the remedy, at a minimum, every five years to determine whether the cleanup action remains protective of human health and the environment.

EPA has invoked a statutory Technical Impracticability (TI) Waiver in the ROD, as permitted by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), for the groundwater within the Underground Workings. EPA has determined that it is technically impracticable, from an engineering perspective, to achieve Federal Safe Drinking Water Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) (40 C.F.R. Parts 141.11-.16 and 141.50-.53, and the State of Vermont Primary Groundwater Quality Standards, VT Env. Prot. R. Ch. 12-702 and 703) for the water within the Underground Workings (mine pool). Therefore, EPA has waived these standards as ARARs for the groundwater within the Underground Workings. This waiver applies to all of the inorganic constituents that are present in the naturally occurring material at the Site and specifically to cadmium, copper, manganese, mercury, and nickel, which have been detected in the groundwater of the Underground Workings at concentrations above MCLs, MCLGs, or the Vermont Primary Groundwater Quality Standards.

1.4.2 Phase 2 Remedial Action: Lord Brook Source Areas

The following description of the remedy for the Phase 2 Remedial Action: Lord Brook Source Areas is taken from the 2006 ROD.

> "Lord Brook Source Area (LBSA), Partial consolidation of surficial mine waste and surface water diversion with discharge of water to tributary of Lord Brook or groundwater. This alternative minimizes the discharge of ARD from the three Lord Brook Source Areas (South Open Cut, South Mine, and TP-4). To accomplish this, exposed waste rock from TP-4 and a portion of the waste rock from the South Mine will be consolidated into the dry portion of the South Open Cut and placed under a cover that will promote surface run-off. The majority of the buried waste rock surrounding the South Open Cut or South Mine will remain in place to minimize disturbance to the forest and the historic features. The amount of material removed from the South Mine area will be determined during design. It is possible that the pit lake within the South Mine may be drained to allow for the removal of waste rock that may be located beneath the pit lake. The South Mine pit lake would be allowed to re-establish itself. The South Open Cut pit lake would also remain and would have an increased water level because of the installation of a dam at the outlet. The design would determine the optimal location for a dam to prevent the uncontrolled release of water from the South Open Cut pit lake. EPA has determined that LSBA 4 is the least damaging practicable alternative to achieve the protection of downstream wetlands and aquatic resources from acid rock drainage. To the extent federally regulated wetlands are identified outside the limits of the waste management area, the altered resources will be restored. The design and construction activities will include measures to minimize the impacts on wetlands through the use of best management practices. EPA has also determined that there will be unavoidable impacts to historic resources. Mitigation measures, if required under applicable historic preservation standards, will be undertaken."

The ROD lists the following the primary elements of the selected remedy:

- Construction of surface water diversions around the South Mine and the South Open Cut/TP-4.
- Excavation of waste ore from the South Mine, with consolidation into the South Open Cut. The amount of material to be re-located will be determined during the design. The objective will be to minimize the extent of disturbance to areas that are not contributing to the ARD release and to also minimize the impact to historic features. The South Mine pit lake would be allowed to restore itself and serve as a detention basin.
- Excavation of TP-4 waste rock and waste ore with consolidation into the dry portion of the South Open Cut.
- Installation of a dam in the vicinity of the haul road from the South Open Cut to contain the South Open Cut pit lake and allow for a controlled release of water from the pit lake. The dammed pit lake also will inundate additional areas of exposed rock and create conditions that will reduce the production of acid rock drainage.
- Discharge of water from the South Open Cut and South Mine pit lakes via either direct discharge to surface water into the tributary to Lord Brook or infiltration into the ground. Discharge of the water from the South Open Cut to the underground workings will also be evaluated. An estimated flow of 2 gpm for the South Open Cut and 5 gpm from the South Mine are estimated as the long-term discharge rates.
- Covering of areas of consolidated mine wastes in the cuts with a vegetative soil cover to act as a contact barrier and to promote vegetative growth and possible addition of lime or other buffering agents.
- Covering areas from which waste rock has been excavated (e.g., TP-4) to promote vegetative growth and possible addition of lime or other buffering agents.
- Performing maintenance and inspections of the covers.
- Performing monitoring of the unnamed tributaries of Lord Brook and Lord Brook to determine if the actions have restored these waters to federal Clean Water Act and Vermont Class B Water Quality Standards at compliance points downgradient from the area. Monitoring of groundwater if discharges are infiltrated into the ground.
- Institutional controls, such as restrictive covenants, to protect the cleanup action from damage and to ensure that buried waste rock is not exposed in the future. Periodic inspections would be performed to ensure compliance with the institutional controls.
- A review of the remedy at a minimum of every 5 years to determine whether the cleanup action remains protective of human health and the environment.

1.4.3 Changes to the Phase 2 Remedial Action: Lord Brook Source Areas

The remedial design includes revisions to the cleanup plan that was described in the ROD. The two major revisions involve the South Open Cut and South Mine pit lakes and the extent of the waste rock excavation at the South Mine and South Open Cut. Figure 3 shows the Phase 2 Remedial Action as shown in the 2006 ROD cleanup plan, and Figure 4 shows the updated Phase 2 Remedial Action.

The first revision is that the South Open Cut and South Mine pit lakes will need to be filled and eliminated in order to meet the cleanup objectives. The 2006 ROD had assumed these features could be incorporated into the cleanup design as storage basins and passive treatment technologies would be used to treat the discharge from these sources. As a result of the design evaluations, a reliable and low maintenance passive treatment that could meet this objective was not identified. A critical issue was the open nature of the pits which required management and treatment of storm flows. This required the design of a dam to use the pit lakes as storage and regulate the discharge of flow. Because of the remoteness of the Site and winter weather conditions, the design did not identify a low maintenance, practical, method for achieving the flow regulation. Alternative approaches to meet the cleanup levels were evaluated with the outcome that source control measures to eliminate the pit lakes would be the most cost effective way to achieve the cleanup levels. As a result, the final design for the Phase 2 Remedial Action: Lord Brook Source Areas cleanup includes the filling of the South Mine and South Open Cut pit lakes. Mine waste and other fill will be placed in the pits and a soil cover will installed over the fill. There may be some residual leachate from the South Open Cut or South Mine. The flow rate of this leachate is expected to be minimal and passive treatment approaches, if necessary, should be able to treat this flow. This approach is very similar to alternative LBSA 3, which was presented in the 2006 Feasibility Study and Proposed Plan.

The 2006 ROD also identified that the remedial design would determine the extent of the mine waste requiring removal from the South Mine area. The remedial design has identified the need for more substantial waste rock removal to achieve the cleanup objectives. All of the exposed mine waste at the South Mine will be excavated and placed under a soil cover at the South Mine or South Open Cut. The mine waste along the west rim of the South Open Cut and along the Haulage-Way will also be excavated and consolidated beneath a soil cover. The removal and covering of the exposed waste will further reduce the acid mine drainage from the South Mine and South Open Cut.

1.4.4 Remedial Action Objectives for Phase 2 Remedial Action: Lord Brook Source Areas

Based on preliminary information relating to the types of contaminants, environmental media of concern and potential exposure pathways, the ROD identifies the following response action objective (RAO) for the Lord Brook Source Areas:

- Achieve federal Clean Water Act and Vermont Water Quality Standards for a Class B surface water in Lord Brook and the tributaries of the Lord Brook that drain the South Mine, South Open Cut, and TP-4, by reducing or preventing the release of ARD containing metal concentrations above surface water cleanup levels from these areas.

1.4.5 Cleanup Levels for Phase 2 Remedial Action: Lord Brook Source Areas

The cleanup levels for surface water are the federal Clean Water Act and Vermont Water Quality Standards for Class B surface water. The ROD identifies the cleanup levels listed in the following table.

Surface Water Cleanup Levels		
Contaminant of Concern	**Surface Water Cleanup Level (µg/L)**	**Basis**
Cadmium	1.13*	VWQS
Copper	11.8*	VWQS
Iron	1,000	VWQS
Lead	3.18*	VWQS
Nickel	158*	VWQS
Selenium	5	VWQS
Zinc	106*	VWQS

* Denotes contaminant of concern (COC) whose cleanup level is based on the hardness of the receiving water. The cleanup levels are based on a hardness of 100 mg/L. Actual hardness values will be used, as appropriate, to adjust cleanup levels. Concentrations are based on Vermont average allowable (chronic) concentrations for dissolved contaminant. Vermont Water Quality Standards, Appendix C (Vermont Nat. Res. Brd, 2011)

Much of the historical data available for assessing the concentrations of COCs in surface water at the Elizabeth Mine Site has been reported as less than the reporting limit; however, the reporting limit has exceeded the cleanup level.

1.4.6 Points of Compliance

Figure 5 shows the surface water points of compliance (SC04 and SM01, respectively) for the discharges from South Open Cut and South Mine.

1.4.7 Wetland Impacts

1.4.7.1 Regulated Wetlands in Lord Brook Source Areas

The substantive requirements of the Clean Water Act (CWA) Section 404 are relevant and appropriate to the Elizabeth Mine site. The CWA requires that adverse impacts to wetlands and aquatic resources be avoided, or minimized, or for unavoidable impacts, compensatory mitigation be performed to replace the loss of wetland and aquatic resource functions in the watershed. Wetland construction and ecological restoration are proposed at Elizabeth Mine to meet the CWA compensatory mitigation requirements as part of site restoration following completion of major site remedial activities.

Local hydrology around the site, including wetland boundaries, has evolved as a result of mining operations, forest harvesting, and remedial activities. A wetland presence/absence survey was conducted by URS in 2003 as part of the Baseline Ecological Risk Assessment (BERA) (URS, 2006c). The survey identified 58 potential wetland areas within the Elizabeth Mine Site and proximal areas. Wetland investigations were also conducted in 2011 at the South Mine to determine the status of wetlands in that area prior to waste rock removal. A total of 30 regulated wetlands and water bodies are located within and near the site. Of these, ten are located in or near the South Open Cut and South Mine and warrant mitigation for impacts anticipated to be caused by remedial activities.

1.4.7.2 Wetland Functional Assessment

Construction of wetlands at the site is proposed to compensate for functions and values lost, rather than type and area of wetlands lost (although these are the more readily quantifiable measures). Many of the wetlands that have been or will be impacted by remedial actions were previously impacted by historical mining activities or other human activities, and have decreased function and value compared to undisturbed wetlands. (Restoration is not intended to compensate for wetlands impacted solely by historical mining activities.)

Most wetlands described in the BERA conducted in 2003 (URS, 2006c) were identified as palustrine emergent wetlands, many with an emergent marsh component. Other wetland types identified were scrub-shrub and open water; with the three types often existing together. Many wetlands likely include a palustrine forested component because of adjacent canopy cover, or existed beneath a variably closed tree canopy. The 2011 investigation of wetlands near South Mine identified two wetlands as forested.

AMEC performed a wetland functions and values assessment in accordance with the U. S. Army Corps of Engineers New England District (Highway Methodology Workbook Supplement – Wetland Functions and Values, a Descriptive Approach) based on field inspection and data from the site Baseline Ecological Risk Assessment (URS, 2006). The following table shows the significant functions and values exhibited by regulated wetlands and aquatic resources within the site and proximal areas. These wetlands and aquatic resources are shown in Figure 6. The most significant functions determined to be present in the affected wetlands are floodflow alteration (storage & desynchronization) and wildlife habitat. Several affected wetlands also manifest the functions groundwater recharge/discharge, sediment/ toxicant/ pathogen retention, and nutrient transformation. Those wetlands exhibiting additional functions are not anticipated to be impacted. The principal function expected to be lost is floodflow alteration. Secondary impacts or indirect loss of pre-existing wetland functions and values were not explicitly included in the tabulation of wetland loss.

Wetlands in Lord Brook Watershed - With Functions and Values				
ID	**Type**	**Significant Functions**	**Area (sf)**	**Loss (sf)**
Wetland F	Emergent marsh	None	838	838
South Open Cut Pit Lake	Open water	None	39,000	39,000
PW-15	Emergent marsh	Floodflow alteration, wildlife habitat	340	0
Haulage Way	Stream	None	0	0
South Mine Pit Lake	Open water	None	11,322	11,322
Wetland A	Emergent marsh, open water	Groundwater discharge, floodflow alteration	8,672	8,672
Wetland B	Palustrine forested	Floodflow alteration, sediment retention, nutrient transformation, wildlife habitat	2,758	0
Wetland C	Palustrine forested	Floodflow alteration, sediment retention, nutrient transformation, wildlife habitat	16,592	0
Wetland D	Emergent marsh	Groundwater discharge	1,138	0
Wetland E	Emergent marsh	Floodflow alteration	2,310	2,310
		Totals:	82,970	62,142

Note:

sf = square feet

1.4.7.3 Wetland Restoration

This wetland and ecological restoration design has been prepared to restore wetland functions and values that have been or will be lost due to remedial actions, increase the ecological value of disturbed areas of the site, and improve the ability of disturbed areas to retard and filter surface water as these areas return by self-design over time to a naturally vegetated condition. The design described herein applies to areas south of Mine Road. Ecological restoration north of and adjacent to Mine Road was completed in 2013.

The term replacement wetland is used here to describe wetlands proposed for construction to compensate for functions and values lost due to remedial actions. Replacement includes both wetland restoration (return of a wetland from a disturbed or altered condition) and wetland creation (conversion of a previous upland or transitional area to a persistent wetland). In

addition, recommendations are presented for plantings in the TP-3 area to improve the upland ecology and accelerate the return of the mine-impacted landscape to a natural state.

The design is intended to provide primarily the functions of floodflow alteration and wildlife habitat. Other functions are anticipated to develop over time, including aesthetic value. The objective at all four wetland restoration sites is a watershed/ landscape approach to increase the value of ecological services provided by each area, with a minimum of additional grading or hydrologic alteration beyond that required for remedial activities. Wetland construction areas were selected based on position in the landscape with respect to surface water, ground water, and geological characteristics that control hydrology (surface relief and slope, properties of soil and underlying unconsolidated materials). An attempt has been made to work as effectively as possible with the available hydrogeology, rather than seek to construct replacement wetlands in the same areas and with the exact same characteristics as those that may have been lost. Grading and soil placement has been determined appropriate in some areas, either for stabilization, soil enhancement to encourage plant growth, or to isolate potentially sulfidic materials. Diverse seed mixes have been proposed, with combinations of upland, facultative, and wetland species. Seeding will be performed by hydroseeding with mulch and tackifier to ensure surface stability and seed establishment. Plant materials have been selected for their wildlife habitat value, and because they have been documented in undisturbed areas of the site. A balance is sought between construction and self-design to enhance the return to a natural landscape while minimizing restoration cost. Proximal wetlands that have not been impacted by remedial activities may serve as references for construction and monitoring of the replacement wetlands. No future maintenance is planned unless determined necessary due to failure warranting re-construction, re-planting, or for removal of non-native nuisance species.

The table below shows the areas (square feet) of wetlands proposed for construction near the South Open Cut and South Mine.

Wetlands Construction by Area	
Work Area	**Wetlands Construction (sf)**
TP-4	16,875
South Open Cut	51,000
Haulage Way	17,770
South Mine	18,000
Total:	103,645

A total of 103,645 sf is proposed for construction. The estimated area of wetland loss is 62,142 sf. Wetland construction is described in the Technical Memo in Appendix N.

2.0 SOUTH OPEN CUT

2.1 Design Objectives

Objectives for the South Open Cut design include

- Minimizing the concentration of COCs at the point of compliance in order to achieve cleanup criteria.
- Maintaining evidence of the pit lake as an historic feature.
- Ensuring that the walls of the cut are stable and do not pose a safety hazard during or after remediation.
- Minimizing the quantity of water that may require treatment.
- Decreasing reliance on treatment.
- Minimizing the complexity and cost of long term monitoring and maintenance.

2.2 Data Summary

2.2.1 Historical Data and Information

The South Open Cut is a WWII-era mine feature developed in the early 1950s and located north of the South Mine. The cut is approximately 1,600 feet long with a maximum depth of 90 feet near the north end. The cut is oriented approximately south to north along the strike of the ore body and was excavated into the ore body from ground surface. A haulage way was cut through the east wall of South Open Cut to facilitate rock and ore removal during the period of mine operation. The portion of the South Open Cut located north of the Haulage Way consists of a pit lake containing approximately 3.6 million gallons of water. The pit lake discharges seasonally through the Haulage Way. Drainage through the Haulage Way flows eastward beneath Copperas Road, along the southern flank of the former location of TP-4, and eventually into Lord Brook. The approximate 500 foot portion of South Open Cut south of the Haulage Way is known as the Dry Crevasse. Its depth varies from the ground surface at its south end to approximately 25 feet at the Haulage Way. As its name implies, the Dry Crevasse is above the surface elevation of the pit lake.

The majority of the waste rock between Copperas Road and the South Open Cut Haulage Way was removed between December 29, 2011, and February 24, 2012, to provide fill material necessary to achieve final grade for the NTCRA cover system on TP-1 and TP-2. The NTCRA work consisted of excavating waste rock and soil from an approximate 1.3 acre, 300 by 125 foot, area between Copperas Road and the Haulage Way down to native till. The excavation left exposed bedrock over much of this area. Areas where the excavation did not extend to bedrock were sloped back and covered with 7-inch minus riprap. Agricultural limestone was broadcast at a minimum rate of 3 tons per acre over excavated areas to help neutralize acidic conditions, and the area was seeded with a Vermont conservation seed mix.

Surface water has been monitored for contaminants of concern identified in the ROD at four locations between the outlet of the South Open Cut pit lake and the discharge's confluence with Lord Brook since 2007. Sample location SC01, located at the east end of the Haulage Way rock cut is the most upstream location. Sample location SC03 is the outlet of the culvert that conveys the South Open Cut drainage beneath Copperas Road. The water quality compliance point for the South Open Cut discharge, SC04, is located approximately 400 feet downstream of SC03. A fourth location, SC02, is located approximately one-half mile downstream of SC03, just before the confluence of this tributary with Lord Brook (Figure 5). Location SC02 also receives the discharge from the South Mine pit lake.

2.2.1.1 Chemistry Data Prior to Haulage Way Cleanup

Table 1 and Table 2 in Appendix A summarize available monitoring data for South Open Cut surface water monitoring points for contaminants of concern identified in the ROD and pH data, respectively. Table 3 in the same appendix provides summary statistics for copper, iron, and zinc in samples from South Open Cut monitoring points. Review of Table 1 shows that samples from SC01 and SC03 consistently exceeded cleanup levels for copper and zinc prior to the removal action, and that samples from SC01 frequently exceeded the cleanup level for iron. Samples from compliance location SC04 showed consistent exceedances for copper and exceedance for zinc in one of three samples. The far downgradient location SC02 showed frequent exceedances for copper, exceedance for zinc in one of 11 samples, and no exceedances for iron. There were no exceedances for cadmium, lead, nickel, or selenium at any of these locations. It should be noted, however, that the reporting limit for cadmium, copper, iron, lead, selenium, and zinc exceeded the respective cleanup levels for most samples. Average concentrations for copper, iron, and zinc for the period prior to January 2012 (i.e., before the removal action) along with pH are shown in the following table.

Average COC Concentrations in South Open Cut Discharge Prior to January 1, 2012					
Parameter	**Cleanup Level (µg/L)**	**SC01**	**SC02**	**SC03**	**SC04**
Copper, Dissolved	11.8	790	<36*	810	87
Copper, Total	11.8	830	149	1040	147
Iron, Dissolved	1000	1700	<56*	480	<45*
Iron, Total	1000	3300	<63*	350	<40*

Average COC Concentrations in South Open Cut Discharge Prior to January 1, 2012					
Parameter	**Cleanup Level (µg/L)**	**SC01**	**SC02**	**SC03**	**SC04**
Zinc, Dissolved	106	230	74	210	94
Zinc, Total	106	250	<84*	270	113
pH		4.3	7.4	No data	6.1
All concentrations in micrograms per liter (µg/L). pH in SU. * = Includes non-detect values at the reporting limit.					

2.2.1.2 Chemistry Data Following Haulage Way Cleanup

Review of Table 1 (Appendix A) shows that samples from SC01 and SC03 continue to consistently exceed cleanup levels for copper and zinc and sporadically exceed the cleanup level for iron after the removal action. Samples from compliance location SC04 consistently exceed the cleanup level for copper, exceed the cleanup level for zinc in two of six samples, and do not exceed the cleanup level for iron. The only cleanup level exceedance at far downgradient SC02 after the removal action is a single exceedance for copper. There are no exceedances for cadmium, lead, nickel, or selenium at any of these locations. It should be noted, however, that the reporting limit for cadmium, copper, iron, lead, selenium, and zinc exceeded the respective cleanup levels for most samples. Average concentrations for copper, iron, and zinc for the period beginning January 1, 2012, (i.e., after initiation of the removal; action) along with pH are shown in the following table.

Average COC Concentrations in South Open Cut Discharge Beginning January 1, 2012					
Parameter	**Cleanup Level (µg/L)**	**SC01**	**SC02**	**SC03**	**SC04**
Copper, Dissolved	11.8	380	<22*	360	75
Copper, Total	11.8	420	<20*	470	83
Iron, Dissolved	1000	800	<45*	<210*	<110*
Iron, Total	1000	2100	<40*	820	160

Average COC Concentrations in South Open Cut Discharge Beginning January 1, 2012					
Parameter	**Cleanup Level (µg/L)**	**SC01**	**SC02**	**SC03**	**SC04**
Zinc, Dissolved	106	140	<37*	170	88
Zinc, Total	106	140	39	180	87
pH		5.8	6.7	6.4	6.3
All concentrations in µg/L. pH in SU. * = Includes non-detect values at the reporting limit. Based on data through April 30, 2014.					

2.2.1.3 Pit Lake Study by USGS

The United States Geological Survey (USGS) performed a study of the South Open Cut pit lake in 2003 and 2004. The purpose of the study was to identify the physical and geochemical characteristics of the pit lake through a combination of a bathymetric survey, continuous monitoring of temperature at various depths within the lake for a year, and quarterly water-quality sampling for an annual cycle. The results of the study, included in Appendix B, were used to evaluate remediation options for the pit lake.

2.2.2 Hydrology

2.2.2.1 Existing Condition Surface Water Drainage from the South Open Cut

Under existing conditions, water flowing from the South Open Cut pit lake and Dry Crevasse combines and flows out of the cut via the Haulage Way under Copperas Road through a 24-inch culvert and eventually to Lord Brook. Currently, the majority of stormwater runoff originating in the wooded area located upgradient and to the west of the South Open Cut is blocked by the existing jeep trail (gravel road) and collected in various depressions or intercepted by a minimal roadside ditch of variable size and shape. The road and roadside ditch or depressions were created, either purposefully or coincidentally, during mining operations by stockpiling waste rock spoils. Some stormwater runoff is conveyed to a low point on the west side of the road across from the Haulage Way. This water then flows through a small culvert to the South Open Cut.

Much of the stormwater runoff approaching the South Open Cut from the west infiltrates the waste rock/soil that forms the road and minimal roadside ditch and/or depressions, and expresses itself on the western wall for the South Open Cut. Rock units at South Open Cut exhibit a south to north strike and dip steeply to the east. Dip angles of the features typically range between E40° and E80° off the horizontal plane, with occasional flatter features dipping E30° off horizontal. Water infiltrating the roadside ditch from the west flows along the till/bedrock surface or enters rock fractures. Seeps can be observed on the west wall of the

South Open Cut. Water infiltrating bedrock on the eastern side of the South Open Cut would flow away from the South Open Cut, and no seeps have been observed on the eastern face of the South Open Cut. A limited amount of stormwater runoff reaches the South Open Cut from other directions (i.e., north, east, and south).

2.2.2.2 Proposed Condition Surface Water Drainage from the South Open Cut

Under proposed conditions, the South Open Cut pit lake will be partially filled eliminating the open water of the lake. In addition, a road side ditch will be constructed on the upgradient side of the gravel road along the west side of South Open Cut to protect the road and to create a more uniform positive surface water flow. The road side ditch has been sized to convey the 100-year event and will divert stormwater runoff around the pit lake and Dry Crevasse to an improved discharge point located across from the Haulage Way. The proposed remediation at the South Open Cut also includes constructing soil covers within the partially fill pit lake, the Dry Crevasse, and the Haulage Way.

Post-remediation, water flowing from the covered pit lake and Dry Crevasse, as well as the road side diversion ditch will combine and flow out of the cut via the Haulage Way under Copperas Road through the existing 24-inch culvert and eventually to Lord Brook, as it does currently. No change in the overall watershed size to Lord Brook will occur as a result of South Open Cut remediation activities.

2.2.2.3 Lord Brook Stormwater Impact

To evaluate the potential hydrologic impact to the Lord Brook watershed from the proposed South Open Cut remediation, a hydrologic analysis was conducted comparing the proposed or post-remediation conditions to existing or pre-remediation conditions. The analysis points for this evaluation include the SC04 and SC02 monitoring points for Lord Brook. For both compliance points, the impact on pre- and post-remediation peak flows from the 2-, 10-, 25-, and 100-year, 24-hour storm events was generally less than 3%. The drainage areas for these evaluations are shown in Figure 7. The results of this pre- and post-remediation watershed analysis are provided in Appendix F. The following tables provide a summary of the stormwater runoff impacts to SC04 and SC02.

Lord Brook Watershed Stormwater Impact @ SC04

STORM EVENT (24 HR)	EXISTING CONDITIONS		PROPOSED CONDITIONS (Pit Lake Partially Filled)		IMPACT	
	Area (Ac)	Peak Discharge (cfs)	Area (Ac)	Peak Discharge (cfs)	Δ Peak Discharge (cfs)	Δ Peak Discharge (%)
2-Year	29.18	5.98	29.18	5.91	-0.07	-1.18%
10-Year		24.20		23.52	-0.68	--2.81%
25-Year		30.99		30.14	-0.85	-2.74%
100-Year		48.72		47.01	-1.71	-3.51%

cfs = cubic feet per second

Lord Brook Watershed Stormwater Impact @ SC02

STORM EVENT (24 HR)	EXISTING CONDITIONS		PROPOSED CONDITIONS (Pit Lake Partially Filled)		IMPACT	
	Area (Ac)	Peak Discharge (cfs)	Area (Ac)	Peak Discharge (cfs)	Δ Peak Discharge (cfs)	Δ Peak Discharge (%)
2-Year	165.37	29.68	165.37	29.14	-0.54	-1.82%
10-Year		124.36		121.64	-2.72	-2.19%
25-Year		160.31		157.14	-3.17	-1.98%
100-Year		253.75		250.20	-3.55	-1.40%

2.2.2.4 SOC Pit Lake Subsurface Base Flow

The USGS Water-Resources Investigations Report 02-4238, entitled "Flow-Frequency Characteristics of Vermont Streams" by Scott Olson, dated 2002, provides empirical methods for estimating base flow in Vermont streams. The variables in the flow equations include drainage basin area, yearly precipitation, and the percentage of basin at or above elevation 1200 feet. The empirical equations do not differentiate between water and land surface area in the drainage basin. A reduction from existing base flow out of the pit lake would be expected because of the diversion ditch which will reduce the overall surface water drainage area to the pit lake as well as a reduction due to the loss of transpiration added to the water balance for the filled and vegetated pit lake. If it assumed some subsurface seepage within and/or along the bedrock still occurs into the pit lake from the west side of the SOC upgradient of the diversion channel, but would be approximately offset by the transpiration losses, then the base flow reduction would be approximately 7.2 gpm to 2.4 gpm from existing conditions to proposed conditions. The results of this pre- and post-remediation SOC Pit Lake base flow impact analysis, including estimated impacts to SC04 and SC02 compliance points, as well as Lord Brook, using the empirical equations is provided in Appendix F. Estimated base flow impacts to compliance points SC04 and SC02 are summarized in the following tables.

SC04 DAILY BASE FLOWS

% Time Daily Base Flow	EXISTING CONDITIONS			PIT LAKE CONTRIBUTION			PIT LAKE IMPACT			
	Area (Ac)	A = Basin Area in sq miles	Daily Base Flow (cfs)	Area (Ac)	A = Basin Area in sq miles	Daily Base Flow (cfs)	Δ Area (Ac)	Δ Area (%)	Δ Base Discharge (cfs)	Δ Base Discharge (%)
D_{75}	29.18	0.0456	0.012	5.70	0.0089	0.002	23.48	19.5%	0.010	17.14%
D_{50}			0.030			0.0054			0.024	18.30%
D_{25}			0.077			0.015			0.06	19.22%

SC02 DAILY BASE FLOWS

% Time Daily Base Flow	EXISTING CONDITIONS			PIT LAKE CONTRIBUTION			PIT LAKE IMPACT			
	Area (Ac)	A = Basin Area in sq miles	Daily Base Flow (cfs)	Area (Ac)	A = Basin Area in sq miles	Daily Base Flow (cfs)	Δ Area (Ac)	Δ Area (%)	Δ Base Discharge (cfs)	Δ Base Discharge (%)
D_{75}			0.076			0.002			0.010	2.63%
D_{50}	165.4	0.2584	0.180	5.70	0.0089	0.0054	159.7	3.4%	0.024	3.01%
D_{25}			0.440			0.015			0.06	3.33%

Another method for estimating the subsurface base flow from the SOC Pit Lake following the construction of the pit lake cover system was conducted using the HELP (Hydraulic Evaluation of Landfill Performance) Model. The HELP Model provides an estimate of the water balance through layers of soil, waste, and/or geosynthetics. For the HELP Model, the following layers from the bottom to top were used for the pit lake filling:

- Impervious bottom (assumed water table at current lake elevation).
- Blasted rock layer, average thickness of 10 feet (above water table elevation) and hydraulic conductivity of 3 cm/sec.
- Consolidated waste soil and rock from SM and diversion channel, etc. with an average thickness of 4 feet and hydraulic conductivity of $1x10^{-2}$ cm/sec.
- 12 inches of low-permeability soil, hydraulic conductivity of $1.7x10^{-5}$ cm/sec.
- 18 inches of common borrow, hydraulic conductivity of $5.2x10^{-4}$ cm/sec.
- Final 12 inch topsoil layer, hydraulic conductivity of $3.7x10^{-4}$ cm/sec.

The HELP Model results indicate the average yearly seepage out of the pit lake would be approximately 16% of the yearly precipitation. The pit lake cover system is approximately 1.6 acres. Another approximate 4.1 acres around the pit lake would discharge runoff onto the cover system with an assumed 80% runoff efficiency (due to shallow or exposed bedrock); or 3.3 acres draining 100% of the yearly runoff onto the cover system. The diversion channel has an approximate drainage area of 10.2 acres with an assumed 25% seeping to and/or below the cover system (30% directed away as runoff and 45% lost as evapo-transpiration [ET]); or 2.6 acres draining 100% of the yearly runoff onto the cover system. Therefore an assumed 7.5 acres (1.6 + 3.3 + 2.6) is assumed to provide direct precipitation to cover system with approximately 16% of the yearly precipitation contributing to the subsurface seepage out of the pit lake. Using an average yearly precipitation of 42 inches over 7.5 acres, the average seepage out of the pit lake is estimated to be 2.6 gpm. The results of this Help Model water balance analysis are provided in Appendix F.

2.2.3 Dimensions, Storage Volumes, and Capacities

The South Open Cut is approximately 1,600 feet in length, but it only reaches approximately 85 feet maximum in width, and for most of its length, the width is less than 50 feet. The Dry Crevasse consists of an approximately 500 foot portion of the South Open Cut south of the Haulage Way. The pit lake, which occupies the northern portion of the cut, is approximately 1,100 feet in length and is divided into two parts by a historical rockslide near the north end that filled approximately 300 feet of the length of the lake. The rockslide consists of primarily of boulder-sized material with individual boulders up to several meters across. Overburden soil and waste rock from the edge of the South Open Cut are also present on top and within the voids of the talus material and have allowed vegetation to become established. As best as can be determined, the two portions have similar water surface elevations; however, it is not known how freely water can flow between the two portions. The water depth in the southern portion reaches a maximum depth of 21.7 feet. The northern water depth reaches a maximum depth of 14.1 feet. The USGS Pit Lake Study reports that the northern portion continues in a tunnel-like excavation sheltered by overhanging rock. On the basis of the USGS bathymetric survey, the southern portion of the lake has an current estimated volume of 440,000 ft^3 (from the water surface elevation at approximately 1418.8 to pit lake bottom) and the northern portion has an current estimated volume of 9,810 ft^3 (approximately same surface water elevation of 1418.8) for a combined volume of 449,810 ft^3.

Design volume calculations developed in AutoCAD Civil3D indicate that there is currently sufficient fill volume within the proposed South Open Cut pit lake and Dry Crevasse grading plans to accommodate blasted rock from the west rim as well as to reconsolidate waste rock and soil removed from the South Mine, gravel road and diversion channel construction, and Haulage Way. This is based upon the design contours presented on the design drawings provided in Appendix C. Although an accurate volume of waste rock and soil to be excavated and placed in the SOC is not possible, the grading plan for the pit lake filling allows for field adjustment of final grades based on actual volumes encountered. The proposed cover system for both the pit lake and Dry Crevasse is proposed to be the 3.5-foot soil cover as shown on the design drawings and described in Sections 2.3.1 and 2.3.2.

2.3 Design

The design for South Open Cut includes the following elements:

- Partial filling of the South Open Cut pit lake will be conducted by blasting bedrock and collapsing the blasted rock from the South Open Cut west face into the lake, as well as using existing waste soil/rock excavated from other locations as part of source removal activities, including: South Mine, jeep trail/gravel road removal, diversion ditches, and Haulage Way. A vegetated low-permeability soil cover will be constructed over the reconsolidated rock fill and waste rock/soil.
- Filling of the Dry Crevasse will also be conducted using existing waste soil/rock excavated from other locations as part of source removal activities, including: South Mine, gravel road removal, diversion ditches, and Haulage Way. A vegetated low-

permeability soil cover will be constructed over the reconsolidated waste rock/soil. Slumped and unstable bedrock within the Dry Crevasse will require removal and sizing by blasting or other mechanical means prior to soil cover construction.

- Lime and/or limestone will be incorporated into the rock fill and waste rock/soil prior to soil cover construction over the pit lake and Dry Crevasse.
- Prior to filling the South Open Cut pit lake, water in the lake will be pre-treated to raise pH to protect Copperas Brook and facilitate precipitation/settling of metals. Following treatment, the lake will be partially drained by pumping to TP-3 and into the Copperas Brook watershed or into the underground working via the North Open Cut.
- The existing gravel road and adjacent waste rock/soil spoils will be removed and placed within the drained South Open Cut pit lake or Dry Crevasse.
- The gravel road to the west of the South Open Cut pit lake and Dry Crevasse will be reconstructed including a roadside ditch (diversion channel) upgradient of the west side of the cut. The ditch will redirect stormwater runoff around the pit lake and Dry Crevasse. The diversion ditch will be lined with low-permeability soil to minimize infiltration and seepage of runoff into the South Open Cut pit lake and Dry Crevasse.
- Installation of an anoxic limestone drain below cover soils within the Haulage Way at the south end of the pit lake for passive treatment of subsurface seepage from the pit lake.
- An open limestone channel will be constructed that will receive surface water flow from the roadside diversion channel, partially filled South Open Cut pit lake, and Dry Crevasse.
- Waste soil/rock remaining in the lower 2/3 (eastern 2/3) of the Haulage Way will be removed by ripping and/or blasting and placed within the South Open Cut pit lake or Dry Crevasse. A clean soil cover will be constructed over completed areas and re-vegetated.
- The side slopes in the upper 1/3 (western 1/3) of the Haulage Way will be flattened and stabilized to a slope of 3H:1V (horizontal to vertical). Completed slopes will be covered with a vegetated soil cover. Removed rock and soil will be placed within the South Open Cut pit lake or Dry Crevasse.
- The Project involves significant earthwork activities requiring appropriate erosion and sediment control best management practices (BMPs) to be installed and maintained throughout the construction activities to prevent exceedances of turbidity regulatory requirements. The remedial action contractor shall prepare and implement an Erosion Prevention and Sediment Control Plan providing BMPs to be provided and maintained throughout the construction activities in accordance with Vermont Standards and Specifications for Erosion Prevention and Sediment Control and the Vermont General Permit for Stormwater Runoff from Construction Sites. The requirements include providing and maintaining erosion and sediment control best management practices to prevent sediment laden runoff from being transported from work areas with turbidity greater than 25 NTUs to surface waters. BMPs shall include as required, sediment

basins, sediment traps, filter bags, sediment barriers, check dams, diversions, and mulching in accordance with the Vermont Standards and Specifications.

Design drawing and specifications are included in Appendix C and Appendix D, respectively.

The remedial design for the SOC is expected to meet the remedial action objective by providing the following benefits:

- Removal or waste rock and soil source areas currently exposed to precipitation and stormwater runoff.
- The minimum 3.5-foot low-permeable soil cover systems for the pit lake and Dry Crevasse will restrict vertical infiltration and oxygen diffusion and acid generation and metals release should be minimized.
- The majority of the cover system for the South Open Cut pit lake will be created as wetland which will consume oxygen and reduce the generation of AMD, and add dissolved organic carbon to the water which can complex with certain metals to reduce toxicity.
- The residual subsurface flow out of the pit lake and Dry Crevasse will be reduced because of the diversion channel and additional ET losses from the vegetated cover systems.
- As an additional protection measure, a passive subsurface anoxic limestone drain (ALD) will be installed below the cover soils within the Haulage Way which will intercept groundwater seepage from the pit lake and the Dry Crevasse.

If future post-remediation surface water quality results do not meet standards, additional future measures that could be implemented to reduce impacted residual flow from the SOC could include: a horizontal drain out of the bottom of the cut to Copperas Brook; a series of horizontal drains into the west wall of the SOC perpendicular to the long axis of the cut to intercept flow prior to the pit lake; a bioreactor located at the downgradient end of the Haulage Way, or lined french drains along the cover system - rock interface in the cut to intercept flow prior to the pit lake.

2.3.1 Pit Lake

The South Open Cut pit lake presents an environmental hazard because of the low pH and high metals content of the water. The remedial design for the South Open Cut includes filling the pit lake and eliminating surface water discharge from the open water of the lake. The filling of the pit lake includes the construction of a low-permeability cover system which will be seeded and planted and permitted to vegetate naturally over time. Although the South Open Cut pit lake will be filled, a surface depression and a significant portion of the east wall will remain visible. These physical features will provide reminders of historical mining activities.

2.3.1.1 Construction Sequencing

The filling of the South Open Cut pit lake requires consideration of the stability of the west rim and wall as it pertains to health and safety during construction activities. The selected RA Contractor will be required to prepare for review and approval, a site specific Work Plan and Health and Safety Plan outlining in detail the planned approach and sequence for work activities and safety procedures. This construction sequence is expected to generally consist of the following:

- Prior to construction activities, establish safety zones and procedures. See Subsection 2.3.1.3 for additional detail.
- Prior to pumping activities to dewater the lake, pre-treatment to raise the pH, protect Copperas Brook from pH excursions, and to facilitate precipitation/settling of metals. Following pH adjustment, the pit lake will be dewatered by pumping to TP-3 and the Copperas Brook watershed or to the underground workings through the North Open Cut. See Subsection 2.3.1.3 for additional detail.
- Conduct clearing of vegetation along the gravel road and between the gravel road and the South Open Cut.
- Flatten and stabilize the side slopes in the upper 1/3 of the Haulage Way. Removed rock and soil will be placed within the South Open Cut pit lake or Dry Crevasse, but may require temporary staging until the South Open Cut pit lake and Dry Crevasse are ready for filling.
- Conduct controlled blasting of the bedrock constituting the west rim of the South Open Cut pit lake to achieve a final 30º rock slope (30º from horizontal) and to control the size of blast rock. See Section 2.3.1.3 for additional detail.
- Following rock removal to a final 30º rock slope, construct access to the pit lake.
- Grading, crushing, and consolidation of the blasted rock with a large bulldozer to achieve approximate desired grade and to fill voids. Supplemental blasting of large boulder-sized rock within the pit lake may be required.
- Removal of slumped and unstable bedrock within the Dry Crevasse and sizing by blasting or other mechanical means.
- Scaling of portions of the east cut face (west facing cut face) of the South Open Cut pit lake and Dry Crevasse to remove loose rock.
- Slaked lime slurry will be spread and injected into rock voids for pH treatment.
- Existing waste soil/rock excavated from other locations as part of source removal will be spread, vibrated, and worked to fill the rock voids for the cover system subgrade. During waste soil/rock placement, Ground agricultural lime/limestone will be incorporated/mixed into the waste rock/soil prior to soil cover construction.

- If rock voids are still evident in the completed waste soil/rock graded surface, shotcrete may be applied to fill remaining voids to provide a working surface for the soil cover construction and to mitigate migration of smaller sized waste soil.
- Construct a cover system on the completed subgrade with positive drainage toward the Haulage Way. See Section 2.3.1.4 for additional detail.

Additional detail on construction approach is provided in the following sections for pumping the pit lake, filling the pit lake, and the cover system and grading.

2.3.1.2 Pit Lake Pumping

The South Open Cut pit lake contains approximately 3 to 4 million gallons of water, and before blasting rock fill into the pit lake, most of the water will be pumped out. The pumping approach and sequence is expected to consist of the following:

- Prior to dewatering of the pit lake, pH adjustment will be performed to raise the pH to levels that will maintain desirable pH levels in Copperas Brook and facilitate precipitation/settling of metals, especially copper, in the pit lake. Vermont general surface water quality standards are based on a pH range of 6.5 to 8.5 SU. The pH adjustment may be accomplished with sodium bicarbonate (NaHCO3) or slaked lime; however, better control may be possible with NaHCO3. An acidity titration curve will be developed from pit lake water samples to estimate/predetermine the required dosage and simple jar tests performed to confirm dosage requirements. Copper hydroxide solubility decreases with increasing pH up to approximately a pH of 9, so the upper end of the 6.5 to 8.5 range is recommended. It is expected that the pH will drop after discharge to upper Copperas Brook and prior to the CB16 compliance point. It may be necessary to repeat the treatment, depending on the buffering nature of the minerals at the lake-bed, in suspension, and in solution, to meet the pH target. A responsible person on site in coordination with the EPA and Vermont Department of Environmental Conservation will decide when the pH treatment is deemed adequate in the event that there is excessive buffering in the lake water.
- Initial acidity titration data for both pit lakes is provided in the Specifications (Appendix D, Section 02 52 13 – Surface water pH Adjustment). The remedial action contractor will be required to take several addition samples for acidity titration testing prior to preparing a pH adjustment Work Plan.
- For treatment, water from the lake would be pumped using a diesel/gas power pump located in the Haulage Way to a treatment mixing tank located along the east rim of the pit lake. The treated water would be pumped back into the pit lake near the south end of the talus deposit/scree near located near the north end of the South Open Cut pit lake. Periodic water sampling will occur to monitor the pH in the lake.
- North of the talus deposit/scree, the treatment of the water would likely require direct dosing of the NaHCO3 or slaked lime based on the estimated water volume and the results from the treatment of the larger south end of the lake.

- The intake hose for the pump would be extended and floated a sufficient distance (~110 feet) into the lake to so it its positioned in the deeper part of the lake. The intake would be submerged just below the water surface.
- Following pH treatment, the pit lake will be drained by pumping to the Copperas Brook watershed via TP-3 or pumped to the underground working via the North Open Cut. A pumping rate of approximately 100 gpm would allow the lake to be lowered sufficiently in a time frame of approximately 3 weeks. The pumping of the lake will cease when there is still approximately 4 to 5 feet of water remaining in the bottom of the lake to avoid pumping sediment or precipitated sludge.
- During dewatering operation of the pit lake following pH adjustment, provide for the monitoring of the pit lake pH to verify pH of lake water is within required range. During pit lake dewatering operation, it may be necessary to repeat the treatment. Provide pH monitoring with data loggers or other approved methods during dewatering pumping operations.
- A pumping rate of 100 gpm or 0.22 cfs would approximately double the estimated base flow at the existing 48-inch culvert crossing under Mine/New Boston Road, but would only be 1% of the estimated peak flow from a 1-year storm event. The dewatering would not overwhelm Copperas Brook. It is also not expected to overwhelm the underground workings if pumped to the North Open Cut. Safety considerations in the remedial action contractor's safety plan will need to address possibilities for leaks in pumps and hoses, and anchoring the equipment to avoid danger to personnel (as well as the environment).
- Once the pumping operation is completed, filling the lake with blasted rock from the west rim will begin. Assuming a pit lake recharge rate of 5 gpm and an approximate volume of 760,000 gallons (reduced from 3.5 million gallons for the 4 to 5 feet of water remaining in the lake and an approximate 30% void space in the fill), over 100 days would be required to refill the lake to its current elevation. Depending on precipitation events, additional pumping could be required during the rock filling activities, but once the rock blasting is completed, the rock fill elevation will be above the current water elevation and would not impact the subsequent grading operations.

2.3.1.3 Pit Lake Filling

The west face of the South Open Cut pit lake has experienced historical movement of bedrock and rock slides. A rock stability evaluation performed at the site (Appendix H) indicates the projection of a hypothetical 40° failure plane (from horizontal) from the bottom of the pit lake, which is believed to be representative of reasonable maximum structural features and jointing in the bedrock, shows that the existing access road and diversion ditch will lie outside and to the west of the 40° impact zone. The projection of a hypothetical 30° failure plane, which is representative of the worst-case low-risk limit of structural features and jointing in the bedrock, shows that the existing access road and diversion ditch lie within the 30° to 40° failure zone. The filling of the pit lake will be conducted in a manner that 1) avoids risk to construction personnel and equipment, and 2) minimizes the risk of a non-construction-related rock slide at

some future date that could compromise completed work and/or pose a risk to site visitors. The pit lake filling approach and sequence is expected to consist of the following:

- Safety zones will be established and clearly delineated in the field. Safety zones are expected to include: an Exclusion Zone, Hazard Zone, Low Hazard Zone, and Safe Zone on based potential rock failure planes of 50º or steeper, 40º to 50º, 30º to 40º, and flatter than 30º respectively.
    1. The Exclusion Zone is represented as the area between the pit lake rim and the current 50º rock failure plane where no personnel or equipment would be allowed.
    2. The Hazard Zone is represented as the area between the current 40º to 50º rock failure planes where access is restricted to approved active equipment and workers. Workers, in particular the wood cutters and the drilling/blasting crew, would be required to tether off to anchorage within the Safe Zone and will not work down slope of equipment. Approved equipment would be limited to smaller equipment (less than 4 tons). No equipment or material staging will be permitted in this zone.
    3. The Low Hazard Zone is represented as the area between the current 30º to 40º rock failure planes where access is restricted to approved active equipment and workers. Workers would not be required to be tethered and approved equipment would be limited to medium equipment (less than 12 tons). No equipment or material staging will be permitted in this zone.
    4. The Safe Zone is represented as the area beyond the current 30º rock failure planes where access is not restricted. Equipment or material staging will be permitted in this zone.
- Clearing of vegetation along the gravel road and between the gravel road and the South Open Cut will be conducted following establishment and marking of safety zones and approval of work and safety procedures. Some trees and vegetation closer to the west rim may not be able to be removed and will drop into the lake with the blasted rock.
- Clearing vegetation from the west rim will require wood cutting equipment and workers to enter the Hazard Zone. Safety procedures will require workers to be harnessed and tethered back within the Safe Zone. Workers will be prohibited from positioning themselves between clearing equipment and the pit lake. In addition, clearing activities will follow all other required safety procedures established for each safety zone.
- Conduct controlled blasting of the west rim to achieve a final 30º rock slope at or below the rock fill height and to control the size of blast rock. To help control blasted rock sizes, it is expected the blasting would occur in a series of relatively thin layers. It expected that a large crane operating from outside the 30º failure plane or smaller equipment in Low Hazard or Hazard Zones would be used to lay mats over each blast. The remedial action contractor shall be required to develop a safe blasting approach outlined in a remedial action contractor prepared blasting and monitoring plan. Technical requirements for the blasting activity are provided in the specifications included in Appendix D.

- The blasting of east face of the pit lake will not occur since the rock failure planes project into the rock face and away from the lake. Although blasting of the east face is not anticipated, scaling of the face to remove loose rock may be required.
- Rock removal from the west face for filling the lake will require drilling equipment and workers to enter the Hazard Zone. Safety procedures will require workers to be harnessed and tethered back beyond the Safe Zone. Workers will be prohibited from positioning themselves between drilling equipment and the pit lake. In addition, blasting activities will follow all other required safety procedures established for each safety zone.
- Once a final 30º rock slope and the blasted rock below this line buttresses the lower portion (and ultimately buried portion) of the west face, establishing construction access to the pit lake will be required. Access may be provided through either or both the Haulage Way and the south end of the Dry Crevasse. Access through the Haulage Way and Dry Crevasse will require additional rock removal to provide a safe, stable corridor.
- Extensive rework, grading, crushing, and consolidation of the blasted rock with a large bulldozer will be conducted to achieve approximate desired grade and to fill voids. Supplemental blasting of large boulders within the pit lake and Dry Crevasse may be required, and the grading effort will be conducted to work smaller rock in and around larger material to eliminate large voids. Technical requirements for the rock grading and consolidation activity are provided in the specifications included in Appendix D.
- At the north end of the pit lake, the entrance to the horizontal tunnel/adit will be filled and covered with the blasted rock. Rock will be pushed via bulldozer several feet into the opening with the inside fill slope corresponding to the angle of repose (likely between 45º and 50º). Based on input from Scott Darling at Vermont Fish & Wildlife, the tunnel at the north end of the South Open Cut is not suitable for bats, and an opening will not be left for bats to enter the tunnel.
- As stated previously, once the rock blasting is completed, the rock fill elevation will be above the current pit lake water elevation and remaining pit lake water will not affect subsequent grading operations. Additional pumping or special upgradient surface water management should not be required.
- Following rock consolidation and grading, an application of slaked lime slurry will be spread and injected into rock voids for pH treatment. An estimated volume of (estimate TBD based on titration results) of slurry would be applied over the entire rock fill area.
- Based on the current grading plan, approximately 24,000 cy of rock will be removed from the west face. An additional estimated volume of 10,000 cy of waste soil and rock excavated from other locations will be placed in the pit lake over the rock fill. The total in-place fill volume, assuming a minimum 30% void space in the rock fill, is approximately 41,000 cy.
- Existing waste soil/rock excavated from other locations as part of source removal activities will be spread, vibrated, and worked to fill the rock voids and to construct the cover system subgrade. The waste soil and rock will be spread in thin lifts (~12 inches) to maximize migration into the rock voids during spreading and consolidating.

- During the placement of waste soil and rock, agricultural lime will be applied to the graded waste at an approximate mix ratio of 150 pounds of lime per 30 cy of waste soil/rock. This rate is based upon a reference from Colorado State University Extension which recommends an application rate of 50 to 70 pounds of agricultural lime per 1000 sf (6 inch to 7 inch deep) to raise soil from a pH of 3.5 to a pH of 7.0 for sandy to loamy soil respectively. Using an application rate of 60 pounds per 1000 sf for a six inch waste rock/soil layer provides approximately 3.25 pounds per cy of soil or 97 pounds per 30 cy with a 1.5 safety factor providing approximately 150 pounds per cy.
- If rock voids are still evident in the graded surface, shotcrete may be required to fill remaining voids to provide a working surface for the soil cover construction and to mitigate migration of soil sized material at the direction of the USACE Construction Onsite Representative. If shotcrete is required, long-term integrity of the shotcrete is not expected or required. Voids that may develop in the fill are expected to be isolated and would be spanned by the heavy duty stabilization and separation geotextile and geogrid support layer included as part of the cover system.
- A cover system described in the next section will be constructed following suitable subgrade and working surface preparation construction.
- Additional technical requirements for the pit lake filling are provided in the specifications provided in Appendix D.

2.3.1.4 Cover System and Final Grading

The final grading plan for the South Open Cut pit lake only partially fills the pit lake leaving a significant reminder of the pit lake as a historic feature. At the north end, the final grade in the South Open Cut will be approximately 1457 feet above MSL, with the west rim above elevation 1480 feet and the east rim above elevation 1495 feet. At the mid length of the pit lake, the final grade in the South Open Cut will be approximately 1437 feet with the west and east rim elevations both above elevation 1480 feet. The final grade in the South Open Cut at the south end near the Haulage Way will be approximately 1434.5 feet, with the west rim elevation above elevation 1450 feet and east rim above elevation 1445 feet.

The final grading plan of the pit lake will range from a high elevation of approximately 1457 feet at the north end of the pit lake (the top of the tunnel opening is at an approximate elevation of 1448 feet) to a low elevation of 1434.5 feet at the south end near the Haulage Way. The northern-most approximately 380 feet will be graded at an approximate 5% slope from the elevation 1457 feet high point to elevation 1438 feet. The remaining approximate 700 feet will be graded at a minimal slope of 0.5%.

The South Open Cut pit lake soil cover system will consist of a heavy duty stabilization and separation geotextile and geogrid support layer (to mitigate subsidence that might be induce by migration of soil sized waste material into voids in the reworked rock fill) over the consolidated waste soil and rock, 12 inches of low-permeability soil, a root or biotic barrier material (e.g., geotextile), 18 inches of common borrow, and a final 12 inch topsoil layer seeded and planted with a native wetland species for the lower flatly graded 700 feet portion of the South Open Cut

and with native seed mix (Vermont Conservation Mix) for the upper more steeply graded 380-foot section. The geotextile and geogrid will be anchored along the sides of the South Open Cut faces by extending each material 3 feet upward along the contact of the cover and the cut face. The cover will be graded to convey stormwater runoff to the Haulage Way. The cover system will be permitted to vegetate naturally over time. The total South Open Cut cover system will cover approximately 70,000 sf. Over 70% or approximately 50,000 sf of the cover system will be created as vegetated wetland.

Design drawings showing the South Open Cut final grading and cover system details are included in Appendix C and technical requirements are provided in the specifications provided in Appendix D.

2.3.1.5 Subsurface Seepage from Pit Lake and Dry Crevasse

It is expected that the pit lake basin water elevation within the rock fill and below the cover system will recover to the current water elevation of approximately 1419 feet above MSL. Subsurface seepage along the bedrock surface out of the pit lake is likely to occur. Some minor subsurface seepage out of the Dry Crevasse is also likely. The low-permeable soil layer within the cover systems for the pit lake and Dry Crevasse will restrict vertical infiltration and oxygen diffusion. In addition, the majority of the cover system for the South Open Cut pit lake will be created as wetland which would consume oxygen which reduces the generation of AMD and adds dissolved organic carbon to the water which can complex with certain metals to reduce toxicity. With the minimum 3.5-foot soil covers, acid generation and metals release should be minimized. As an additional protection measure, a passive subsurface ALDolc will be installed below the cover soils within the Haulage Way which would intercept groundwater seepage from the pit lake and the Dry Crevasse. The ALD would consist of underdrain trench filled with a 1:1 mix of hard rock and limestone followed by a polishing filter of bedding stone and coarse sand. A filter analysis for the stone and sand materials is provided in Appendix P. Beyond the passive treatment, the groundwater seepage would continue along bedrock down to an existing bedrock depression near the east end of the Haulage Way where a mitigation wetland will be constructed.

Design drawings showing the subsurface seepage passive treatment details are included in Appendix C.

2.3.2 Dry Crevasse

Existing soil and waste rock remaining in the Dry Crevasse as well as excess waste rock and soil excavated from the gravel road and diversion channel, Haulage Way, and South Mine will be consolidated within the Dry Crevasse and covered with a soil cover system. Prior to waste rock and soil filling operations in the Dry Crevasse, after establishing a safe construction access, ground limestone will be applied to the Dry Crevasse at an approximate rate of 3 tons per acre (same application rate used for the NTCRA waste rock/soil removal conducted at the South Mine and Haulage Way in late 2011 and early 2012). Also, prior to installing the cover, ground limestone will be mixed with the waste rock and mining impacted soil during placement (approximate mix ratio of 150 pounds of lime per 30 cy of waste soil/rock – see 2.3.1.3 for basis

for application rate) as a neutralizing agent. The Dry Crevasse soil cover system will consist of a heavy duty stabilization and separation geotextile over the consolidated waste soil and rock, 12 inches of low-permeability soil, a root or biotic barrier material (e.g., geotextile), 24 inches of common borrow, and a final 6 inch topsoil layer seeded with a native seed mix (Vermont Conservation Mix). The cover will be graded to convey stormwater runoff to the Haulage Way. The cover system will be permitted to vegetate naturally over time.

The side walls of the Dry Crevasse currently rise at a slope ranging from approximately 0.5H:1V to 2H:1V and have experienced rock slides/falls in the past. The surface of the side walls is currently comprised of weathered, “rotten” rock that may fall off the side walls and pose a hazard to persons below. Filling and covering the Dry Crevasse will address this as a permanent issue, but the potential hazard will need to be managed during the construction activities. Establishing a safe construction access through the Dry Crevasse will be required. Access may be provided by advancing through either or both the east side of Haulage Way and the south end of the Dry Crevasse. Access through the Haulage Way and Dry Crevasse will require additional rock removal to advance and establish a safe stable corridor.

Approximately 12,300 cy of waste rock and soil will be consolidated within the crevasse under the soil cover. The cover system will have a stable maximum 3H:1V side slopes with an overall mounded shape to provide sufficient volume for the consolidated waste rock and soil and cover system. With geotextiles incorporated into the cover system, a slope interface friction analysis was conducted for the maximum 3H:1V side slopes (Appendix I).

Mine waste was historically placed and has been observed to the east between the crevasse and Copperas Road. The remedy includes placing an eighteen inch soil cover (6 inches of topsoil and 12 inches of common borrow) and seeding with a native seed mix over this waste material. Exact limits of this waste material have not been determined, but based on topographic evidence, this waste area covers approximately 37,000 sf. Prior to cover system construction, following clearing activities, lime will be applied to subgrade at a rate of approximately 3 tons per acre. As with other cover systems, it will be permitted to vegetate naturally over time.

The soil covers will minimize negative effects to human health and the environment by preventing direct contact with mining impacted soil and waste rock as well as minimizing stormwater contact with those materials and the resulting generation of ARD. Allowing the cover to vegetate naturally will minimize maintenance requirements.

Design drawings showing the Dry Crevasse final grading and cover system details are included in Appendix C and technical requirements are provided in the specifications provided in Appendix D.

2.3.3 Haulage Way

The side walls of the Haulage Way currently rise at a slope ranging from approximately 0.5H:1V to 2H:1V. The surface of the side walls is currently comprised of weathered, “rotten” rock with the potential for loose rock to dislodge and pose a hazard to persons below. The remedy will

provide a safer, more stable surface through removal of exposed rock to flatten the side walls of the Haulage Way to a stable slope of approximately 3H:1V. Eighteen inches of soil cover (6 inches of topsoil and 12 inches of common borrow) and a native seed mix will be placed on the cut back slopes. The vegetated cover will reduce the availability of oxygen for generation of ARD and will prevent transport of ARD by runoff. Like the Dry Crevasse and South Open Cut pit lake cover systems, the Haulage Way will be permitted to vegetate naturally over time, thereby minimizing maintenance and blending in with the surrounding natural environment. Establishing a safe construction access through the Haulage Way will be required. Access may be provided by advancing through either or both the east side of Haulage Way and the south end of the Dry Crevasse. Access through the Haulage Way and Dry Crevasse will require additional rock removal to advance and establish a safe stable corridor.

One sample of rock and two samples weathered waste rock were collected at the Haulage Way and South Open Cut in November 2012 and sent to an off-site laboratory for acid base accounting analysis; analytical results and a figure showing sample locations are provided in Appendix J. Sample EMRKSC001 was collected from several locations on the north face of the Haulage Way near its intersection with South Open Cut, sample EMSOSC002 was collected from the loose, saturated waste rock at the intersection of the Haulage Way with South Open Cut, and sample EMSOSC003 was collected from the weathered waste rock on the east rim of the Dry Crevasse. EMRKSC001 had a net neutralization potential of 180 which predicts that the rock it represents will produce alkaline drainage. Samples EMSOSC002 and EMSOSC003 had net neutralization potentials of -54 and -52 which predicts the production of acid drainage.

Additional data on rock characteristics and acid generating potential was gathered in October and December 2013 through the completion of 8 borings to collect rock core for logging and collection of samples for two samples from each borehole for acid base accounting analysis. Boring logs, analytical results, cross-sections, and a figure showing sample locations are provided in Appendix K. Several of these samples showed no acid potential, and the majority of the remaining showed a positive net neutralizing potential predicts that the rock it represents will produce alkaline drainage. Two samples, HW001 at 3 ft below ground surface (bgs) and HW007 at 16 feet bgs, showed negative net neutralizing potential which predicts that the rock they represent will produce acid drainage. Removed sulfide waste rock will be placed in the South Open Cut pit lake or Dry Crevasse to minimize weathering and acid generation.

Drainage from the Haulage Way will be directed via an open limestone channel (OLC) to a constructed wetland (considered a replacement wetland, not a treatment wetland) before discharge to the east beneath Copperas Road. An OLC is provided in the Haulage Way to provide pH buffering if required, although the South Open Cut remedy includes source removal and cover systems to eliminate ARD. This same OLC will also provide pH buffering for water flowing from the roadside diversion channel, Dry Crevasse cover system, and South Open Cut pit lake cover system.

Design drawings showing the Haulage Way final grading and cover system details are included in Appendix C.

2.3.4 West South Open Cut Waste Rock/Soil Removal and Roadside Ditch

The SOC remedial design includes improving the existing minimal roadside ditch and depressions to create a more uniform positive surface flow, less permeable diversion channel to divert stormwater runoff around the pit lake and Dry Crevasse to an improved discharge point located across from the Haulage Way. Test pit records conducted along the existing gravel road (Appendix E) for evaluating potential bedrock concerns during ditch construction, indicate that waste soil/rock is approximately 3 to 4 feet thick on average and currently includes the material used for the road construction and likely extends to the east to the west rim of the pit lake. An extensive test pitting program to delineate the extent and volume of waste soil and rock was not conducted, but based on interpretation from the test pits, the waste volume is estimated to be approximately 10,000 cy to 12,000 cy.

The waste soil and rock along the west side of the South Open Cut will be removed and placed within the pit lake and/or Dry Crevasse prior to construction of the cover systems (see Section 2.3.1 and 2.3.2). The gravel road will be reconstructed following removal of the mine waste and a roadside diversion channel will be constructed on the upgradient side of the road to protect the road and to create a more uniform positive surface water flow. The road replacement will consist of a minimal road width of only ten feet with 6 inches of gravel as shown on the drawings to match current conditions, and not an extra wide improved road. Once the ditch subgrade is contoured, the channel will be constructed by backfilling with low-permeability soil material (e.g., native till) to reduce stormwater runoff from infiltrating through/under the channel and reaching the South Open Cut pit lake. Stormwater runoff within the channel will be conveyed to twin 24" culverts located (approximately) across from the Haulage Way, discharging south of the pit lake and continuing down the Haulage Way. However, it is important to note that some stormwater runoff originating west of the channel may still infiltrate into the pit lake fill or on the cover system prior to reaching discharge point at the Haulage Way. The roadside diversion channel will reduce the South Open Cut drainage area, but, as with the final cover systems of the pit lake and Dry Crevasse, runoff will remain within the Lord Brook watershed. No change in the size of the Lord Brook watershed will occur as a result of the roadside diversion ditch (see Section 2.2.2). In addition to the gravel road reconstruction and roadside construction, a vegetated eighteen inch soil cover (6 inches of topsoil and 12 inches of common borrow) will be installed between the road and the final 30° rock slope. The soil cover will be seeded with a native seed mix and will be permitted to vegetate naturally over time.

The roadside diversion channel and discharge (twin culverts) were sized using the 100-year, 24-hour storm event with a stormwater model developed for the Site using HydroCAD software, which is based upon the United States Department of Agriculture Technical Release 20 (TR-20) methods. TR-20 is a standard engineering method used to evaluate runoff conditions and develop stormwater controls. The results of the channel design analysis are provided in Appendix G. The stability of the channel (i.e., lining) was evaluated using several methods: HEC-11 and USACE Engineer Manual No. 1110-2-1601. For the road protection, the roadside ditch only requires a depth of 1.5 feet and a bottom width of 2 feet, even for the 100-year design event. As indicated on the drawings, portions of the diversion channel have velocities less than 3 feet per second allowing for a vegetated lining to be used. Also, the drawings indicate where

appropriate, field changes to the diversion channel profiles provide steps (small waterfalls) and pools/wetlands shall be provided as approved/directed by the Contracting Officer and regulatory agencies. Riprap lined channels sections will include geotextile filter material below the stone; refer the Appendix P for filter analysis.

Bedrock does not appear to pose an issue to construction of the roadside diversion channel as bedrock observed during test pit activities indicated it is located deeper than the channel subgrade (refer to test pit records in Appendix E).

As stated in Section 2.3.3.1, the west face of the South Open Cut pit lake has experienced historical movement of bedrock and rock slides and presents safety concerns during construction. The waste soil and rock removal, road reconstruction, and roadside ditch construction will occur after the pit lake filling is completed and a final 30° rock slope and buttress effect is achieved. Approximately 160 feet of the gravel road will be relocated at the north end of the South Open Cut because it is currently located within the final 30° rock slope. Following removal and replacement of the existing gravel road, the remedial action contractor shall conduct a property line survey along the road to re-establish the property line along the road.

Samples to characterize surface water quality in the ditch west of the South Open Cut were collected in December 2013 and April 2014 at location SCWest. The data indicate no significant mining-related impacts. Copper, lead, and zinc concentrations were less than reporting limits. pH was 6.06 SU. Based on these data, no treatment of the discharge from the diversion channel is required; however, the current design includes an OLC from the discharge of the diversion channel through the Haulage Way to Copperas Road as a precaution to prevent the discharge of low pH water to this Lord Brook tributary.

Design drawings showing the gravel and roadside diversion ditch final grading and details are included in Appendix C.

3.0 SOUTH MINE

3.1 Design Objectives

Objectives for the South Mine design include

- Minimizing the concentration of COCs at the point of compliance in order to achieve cleanup criteria.
- Maintaining some indication of the pit lake as an historic feature, if possible.
- Ensuring that rock overhangs and walls of the cut are stable and do not pose a safety hazard during or after remediation.
- Minimizing the quantity of water that may require treatment.
- Decreasing reliance on treatment.
- Minimizing the complexity and cost of long term monitoring and maintenance.
- Preventing contamination of restored areas.

3.2 Data Summary

The South Mine consists of an approximate 250-foot-long rock cut forming a pit lake and underground cavern with an approximate maximum depth of 20 feet. Sources of contamination and ARD at the South Mine include the exposed hanging and foot walls of the cut, residual waste rock remaining after a 2012 removal action, and exposed sulfidic bedrock. During periods of high flow (e.g., spring snow melt) water in the pit lake discharges to a drainage channel that eventually flows into Lord Brook.

USACE's remedial action contractor removed waste rock soil from an approximate 4.2 acre, 300 by 600 foot, area adjacent to the South Mine between December 27, 2011, and February 24, 2012, with the objective of excavating waste rock and soil down to native till with a pH greater than 4. The excavation left exposed bedrock over much of this area. Areas where soil remained were seeded and now support sparse vegetation. A drainage swale lined with 7-inch minus rip rap extends approximately 350 feet from the outlet of the pit lake to where the natural stream channel begins at the edge of the removal area. Excavated material was placed beneath the cover at TP-1/TP-2. Agricultural limestone was broadcast at a minimum rate of 3 tons per acre over excavated areas to help neutralize acidic conditions, and the area was seeded with a Vermont conservation seed mix.

Surface water has been monitored for contaminants of concern identified in the ROD at three locations between the outlet of the South Mine pit lake and the discharge's confluence with Lord Brook since 2007 (Figure 5). Sample location SMD is located at the outlet weir at the South Mine pit lake, and SM01, the South Mine water quality compliance point, is located approximately 350 downstream where the natural stream channel begins at the edge of the 2012 removal area. Sample location SC02 is located approximately 3,300 feet downstream of

SM01, just before the confluence with Lord Brook. Location SC02 also receives the discharge from the South Open Cut.

In October 2013, the pit lake was pumped down, exposing the bottom of the pit lake as well as an adjacent cavern (refer to Section 3.2.3).

3.2.1 Chemistry Data Prior to Waste Rock Removal

Table 2 and Table 4 in Appendix A summarize available monitoring data for South Mine surface water monitoring points for pH and contaminants of concern identified in the ROD, respectively. Table 5 in the same appendix provides summary statistics for copper, iron, and zinc in samples from South Mine monitoring points. Data are available for only one sampling event at location SMD prior to the removal action, and those data show exceedances of the copper, iron, and zinc cleanup levels. Review of Table 4 shows that samples from SM01 consistently exceeded cleanup levels for copper and zinc, but exceeded the cleanup level for iron in only one of 14 samples before the removal action. The far downgradient location SC02 showed frequent exceedances for copper, exceedance for zinc in one of 11 samples, and no exceedances for iron. Cadmium exceeded its cleanup level in one of 10 samples from location SM01. There were no exceedances for lead, nickel, or selenium. It should be noted, however, that the reporting limit for cadmium, copper, iron, lead, selenium, and zinc exceeded the respective cleanup levels for most samples. Average concentrations for copper, iron, and zinc for the period prior to January 2012 (i.e., before the removal action) along with pH are shown in the following table.

Average COC Concentrations in South Mine Discharge Prior to January 1, 2012				
Parameter	**Cleanup Level (µg/L)**	**SMD**	**SM01**	**SC02**
Copper, Dissolved	11.8	820	850	<36*
Copper, Total	11.8	1000	<850*	149
Iron, Dissolved	1000	910	<180*	<56*
Iron, Total	1000	1100	300	<63*
Zinc, Dissolved	106	600	770	<74*
Zinc, Total	106	640	710	84*
pH		No data	5.7	7.4
All concentrations in µg/L. pH in SU. * = Includes non-detect values at the reporting limit.				

3.2.2 Chemistry Data Following Waste Rock Removal

Review of Table 4 (Appendix A) shows that samples from locations SMD and SM01 continue to consistently exceed cleanup levels for copper and zinc after the removal action. Total and dissolved iron at SMD continues to exceed the iron cleanup level, as does total iron at SM01. Copper exceeded its cleanup level in one of 16 samples from far downgradient SC02 after the removal action. Cadmium exceeded its cleanup level in three of 13 samples from SMD and two of 19 samples from SM01 after the removal action. There are no exceedances for lead, nickel, or selenium. It should be noted, however, that the reporting limit for cadmium, copper, iron, lead, selenium, and zinc exceeded the respective cleanup levels for most samples. Average concentrations for copper, iron, and zinc for the period beginning January 1, 2012 (i.e., after initiation of the removal action) along with pH are shown in the following table.

Average COC Concentrations in South Mine Discharge Beginning January 1, 2012				
Parameter	**Cleanup Level (µg/L)**	**SMD**	**SM01**	**SC02**
Copper, Dissolved	11.8	<1200*	260	<22*
Copper, Total	11.8	1300	390	<20*
Iron, Dissolved	1000	5600	<370*	<45*
Iron, Total	1000	6800	980	<40*
Zinc, Dissolved	106	1800	820	<37*
Zinc, Total	106	1800	830	39
pH		5.3	6.1	6.7
All concentrations in µg/L. pH in SU. * = Includes non-detect values at the reporting limit Based on data through April 30, 2014.				

3.2.3 Hydrology

3.2.3.1 Existing Condition Surface Water Drainage from the South Mine

The South Mine pit lake receives surface water runoff from the upgradient areas to the south and west. The first of these areas is the approximate 100 by 300 foot strip of land between the pit lake and Copperas Road. The second of these areas is the wooded area on the west side of the road located west of the pit lake. Stormwater runoff flows down the wooded hillside and either flows over Copperas Road or is conveyed in shallow, irregular channels to one of two

existing culverts passing under Copperas Road. Runoff from these two areas comingles and flows overland to either the pit lake or the surrounding South Mine area.

The immediate South Mine area including the pit lake is approximately 6.4 acres in size with an existing surface cover that includes vegetated areas (e.g., grass, brush, and woods), exposed to nearly exposed bedrock, and gravel roads. Approximately 6% of the ground surface consists of impervious cover. The South Mine topography is best described as undulating, with slopes ranging from gradual to steep, sometimes with nearly vertical rock faces.

The wooded area on the west side of the road is approximately 22.5 acres in size. The topography of this area is best described as moderately steep slopes.

3.2.3.2 Proposed Condition Surface Water Drainage from the South Mine

Under proposed conditions, the South Mine pit lake will be partially filled eliminating the open water of the lake. In addition, a road side ditch will be constructed on the upgradient side of the gravel road along the west side of South Mine area to protect the road and to create a more uniform positive surface water flow. The road side ditch will divert stormwater runoff around the pit lake to a new culvert near the south end of South Mine area. The proposed remediation at the South Mine also includes constructing a soil cover over the former waste rock/soil disposal areas which will be allowed to naturally re-vegetate over time.

Post-remediation, water flowing from the covered pit lake and surrounding South Mine area, as well as the road side diversion ditch will combine and flow out of the South Mine area into an existing drainage channel where the SM01 compliance point is located and eventually to Lord Brook, as it does currently. No change in the overall watershed size to Lord Brook will occur because of the South Mine remediation activities.

3.2.3.3 Lord Brook Impact

To evaluate the potential hydrologic impact to the Lord Brook watershed from the proposed South Mine remediation, a hydrologic analysis was performed comparing the proposed or post-remediation conditions to existing or pre-remediation conditions. The analysis points for this evaluation include SM01 and SC02 monitoring points for Lord Brook. For impact to compliance point SC02, refer to Section 2.2.2.3. The drainage areas for these evaluations are shown in Figure 7. For the SM01 compliance point, the impact on pre- and post-remediation peak flows from the 2-, 10-, 25-, and 100-year, 24-hour storm events is generally around 1 cfs or less. The results of this pre- and post-remediation watershed analysis are provided in Appendix F. The following table provides a summary of the impacts to SM01.

Lord Brook Watershed Impact @ SM01

STORM EVENT (24 HR)	EXISTING CONDITIONS		PROPOSED CONDITIONS (Pit Lake Partially Filled)		IMPACT	
	Area (Ac)	Peak Discharge (cfs)	Area (Ac)	Peak Discharge (cfs)	Δ Peak Discharge (cfs)	Δ Peak Discharge (%)
2-Year	28.67	5.38	28.67	4.93	-0.45	-8.36%
10-Year		22.41		21.46	-0.95	-4.24%
25-Year		28.86		27.77	-1.09	-3.78%
100-Year		45.55		44.26	-1.29	-2.83%

The USGS Water-Resources Investigations Report 02-4238, entitled "Flow-Frequency Characteristics of Vermont Streams" by Scott Olson, dated 2002, provides empirical methods for estimating base flow in Vermont streams. The variables in the flow equations include drainage basin area, yearly precipitation, and the percentage of basin at or above elevation 1200 feet. Since these variables are unchanged from the pre- to post-remediation conditions, minimal to no change in base flow to SM01 is expected.

3.2.3.4 Groundwater

There is little to no overburden over most of the South Mine area, and the groundwater potentiometric surface typically resides in bedrock, and approximately 3 to 8 feet bgs, at bedrock well MW-02 adjacent to Copperas Road. Groundwater is typically 1 to 3 feet bgs in bedrock well IC-03 approximately 250 feet east of IC-02. Artesian conditions exist at bedrock well IC-04 approximately 360 feet northeast of IC-02. The interpreted groundwater flow direction is to the east and northeast.

3.2.3.5 Mine Shaft

A vertical mine shaft that poses a fall hazard exists next to Copperas Road north of the South Mine pit lake. During a pumping operation conducted in October 2013, the shaft was determined to have an approximately 6- by 9-foot opening. Three to four feet of water was pumped from the shaft prior to reaching a very soft muck. In May, 2014, a man-portable Geoprobe was setup on the plank cover placed over the shaft opening in December 2013. The muck in the shaft provided only limited resistance to the drill rods, and they advanced under their own weight to 27 feet below the top of the cover. The Geoprobe was then used to hammer/drive the rods to refusal at 41 feet below the top of the cover. During attempts to collect soil samples, refusal, interpreted to be a rock/boulder, was encountered at 27 feet below the top of the cover. The depth to competent bottom was interpreted to be 27 feet below the top of the cover.

During periods of relatively high groundwater, the shaft has historically overflowed to its east through a shallow channel. During placement of a wooden cover over the shaft in November 2013, the historical overflow channel was deepened 2 to 3 feet to lower the water level in the

shaft opening such that the cover would not float. The shaft has an historical overflow elevation of approximately 1418 feet above MSL.

The surface elevation of the pool at the mine shaft is typically several feet higher than the surface of the South Mine pit lake, and the pool and pit lake do not appear to be connected,

3.2.3.6 Other Sources

Two small pools with a maximum depth of 1 to 2 feet have formed in the area between the South Mine and Copperas Road following the 2012 soil removal action. A white precipitate which analysis has shown it to be aluminum has been observed on the bottom of the more northerly pool. The presence of aluminum is attributed to ARD which released this element from host rock. The dissolved aluminum then precipitates as an amorphous hydroxide when exposed to the pH (approximately 6.8) and dissolved oxygen in the pool. Aluminum precipitate has not been observed in the other pool.

3.2.4 Dimensions, Storage Volumes, and Capacities

The South Mine pit lake was once assumed to be about 10 feet deep on average. In October 2013, the pit lake was pumped nearly dry, leaving only approximately 2 to 3 feet of water remaining within an adjacent lower cavern that was exposed during the pumping operation. Refer to photographs #16 to #20 in Appendix L. The rock overlying the cavern is supported by rock piers along the open west side of the cavern. The pit lake as seen from the surface was approximately 10 feet deep, but sloped down another ±10 feet to the lower cavern floor. The cavern is approximately 120 feet long with an average width of approximately 30 feet and approximately 15 feet high from floor to ceiling. At the time of the pumping, the pit lake and cavern were documented by a mine historian. The volume of the South Mine pit lake and cavern is estimated to be approximately 22,000 cubic feet. Some of this capacity will be taken up by rock removal efforts to knock down a potentially unstable overhanging ledge. Per details developed for the final design, the remaining volume will be filled with flowable fill to avoid the need for access into the cavern and a final layer of limestone.

3.3 Design

The design for South Mine includes the following elements:

- Construct a diversion channel upgradient of the cut on the west side of the existing gravel road to redirect stormwater runoff around the pit lake.
- Fill the pit lake and associated underground cavern beginning with dewatering the lake and breaking and knocking overhanging rock shelves into the pit lake. Fill the lower portions of the pit lake and underground cavern with flowable fill so that no equipment or personnel are required to enter the cavern. Finish filling with wetland topsoil and seed with wetland mix.

- Fill the existing vertical mine shaft with rock and stone. Stone/rock size will be incrementally reduced in size as the fill approaches the surface and finish with wetland topsoil and seed with wetland mix.
- Install an open limestone channel down gradient from the pit lake.
- At designated areas shown on the drawings, remove existing waste soil/rock remaining in the South Mine area. Apply ground limestone over the completed waste soil/rock removal area to treat any existing soil remaining prior to soil cover placement. Provide a clean soil cover over completed areas and re-vegetate.
- Construct several mitigation wetlands in low areas and depressions within the South Mine site.
- Place all excess waste rock/soil materials excavated during construction activities at the South Mine in the South Open Cut pit lake or Dry Crevasse.
- The Project involves significant earthwork activities requiring appropriate erosion and sediment control BMPs to be installed and maintained throughout the construction activities to prevent exceedances of turbidity regulatory requirements. The remedial action contractor shall prepare and implement an Erosion Prevention and Sediment Control Plan providing BMPs to be provided and maintained throughout the construction activities in accordance with Vermont Standards and Specifications for Erosion Prevention and Sediment Control and the Vermont General Permit for Stormwater Runoff from Construction Sites. The requirements include providing and maintaining erosion and sediment control best management practices to prevent sediment laden runoff from being transported from work areas with turbidity greater than 25 NTUs to surface waters. BMPs shall include as required, sediment basins, sediment traps, filter bags, sediment barriers, check dams, diversions, and mulching in accordance with the Vermont Standards and Specifications.

Design drawing and specifications are included in Appendix C and Appendix D, respectively.

The remedial design for the SM is expected to meet the remedial action objective by providing the following benefits:

- Removal or waste rock and soil source areas currently exposed to precipitation and stormwater runoff.
- The minimum 1.5-foot soil cover placed over residual waste rock / soil reducing oxygen diffusion and acid generation and metals release should be minimized.
- Filling of the pit lake and creation of a treatment wetland which would consume oxygen, reduces the generation of AMD, and adds dissolved organic carbon to the water which can complex with certain metals to reduce toxicity.

If future post-remediation surface water quality results do not meet standards, a bioreactor (treatment wetland) located at the downgradient from the pit lake before SM01 as described in section 3.3.5, could be constructed.

3.3.1 Diversion Channel

The proposed design includes improvements to the existing roadside ditch on the west side of Copperas Road to create a more uniform diversion channel to convey stormwater runoff to the existing culverts as well as a new culvert at the north end of the South Mine site. The roadside diversion channel will be constructed by excavating soil along the west side of the road to reach subgrade elevations. Once the subgrade is contoured the channel will be constructed with suitable stable lining material. Stormwater runoff will be conveyed to several existing culverts and one new culvert (replacing a 6-inch existing culvert) crossing under Copperas Road. Culvert outlet protection will include riprap aprons; refer to Appendix R for sizing calculations.

The roadside diversion channel and discharge were sized using the 100-year, 24-hour storm event with a stormwater model developed for the Site using HydroCAD software, which is based upon the United States Department of Agriculture Technical Release 20 (TR-20) methods. TR-20 is a standard engineering method used to evaluate runoff conditions and develop stormwater controls. For the South Mine area, proposed roadside diversion channel segments include C-9 to C-12 in the South Mine area. The west upgradient drainage areas for the roadside diversion channels range from a low of 0.26 acres for C-12, to a maximum of 16.05 acres for C-11, with peak estimated peak design (100-year storm event) discharges of 1.06 cfs and 29.6 cfs, respectively. In addition, an OLC (OLC-13A and B) is provided across the South Mine area (approximately 6.4 acres) to provide pH buffering if required, although the South Mine remedy includes source removal and cover systems to eliminate ARD. Channel C-12 will discharge to a level spreader to dissipate flow into an existing stable vegetated area prior to reaching channel C-11 and the new culvert under Copperas Road. Refer to Appendix Q for the level spreader calculation.

The results of the channel analysis are provided in Appendix G. The stability of the channel (i.e., lining) was evaluated using several methods: HEC-11 and USACE Engineer Manual No. 1110-2-1601. For the road protection, the roadside ditch only requires a depth of 1.5 feet and a bottom width of 2 feet, even for the 100-year design event. Riprap lined channels will include geotextile filter material below the stone; refer the Appendix P for filter analysis.

3.3.2 Soil Removal

Remaining waste impacted soil at the South Mine will be excavated to remove an ongoing source of ARD. An approximate volume of 7,500 cy of waste soil is expected to be excavated and placed in the South Open Cut pit lake or Dry Crevasse and covered. The excavated area will be backfilled with clean, imported soil and graded generally to mirror existing contours, keeping depressions that may serve as vernal pools/pocket wetlands. The covered area will be seeded and mulched and will be allowed to re-vegetate naturally over time.

3.3.3 Mine Shaft

The mine shaft will be addressed by filling the dewatered portion of the shaft with stone to about 2 feet below existing surrounding grade. The top portion will receive soil and wetland plantings, as the mine shaft is within an existing wetland area. The depth to competent bottom was interpreted to be 27 feet below the top of the cover. The drainage channel constructed in 2013 will be filled to restore the pool elevation to historical levels.

3.3.4 Pit Lake

As stated previously, the South Mine pit lake opens to a cavernous void beneath the water's surface and extends below the adjacent rock outcrop. The exposed rock face on the east side of the South Mine pit lake is essentially a large, overhanging, unstable outcrop that poses a risk because of the potential for the rock outcrop to break away. Remedial construction activities will mitigate this risk by dewatering the pit lake, then demolishing a portion of the outcrop to a stable face with the rock falling to the pit lake floor. Similar to the approach for the South Open Cut pit lake, the water within the pit lake will be treated to increase pH and precipitate the dissolved metals. Once treated, the water would likely be pumped to the South Open Cut pit lake or a detention basis to settle any suspended material prior to discharge into the unnamed tributary of Lord Brook. The implementation plan will evaluate whether discharge of the treated water to Copperas Brook would be appropriate.

Controlled low strength material (i.e., flowable fill) will be used to fill the remainder of the bottom portion of the cavern and pit lake so that construction personnel or equipment will not need to enter the cavern. The flowable fill will stabilize the void beneath the remaining exposed rock at the surface. The upper portion will receive a final vegetated (wetland) soil cover. To the observer, the end result will be a topographically depressed area where the pit lake once existed with the exposed rock outcrop with a stable rock face. From an environmental standpoint, filling of the pit lake will eliminate an environmental hazard by removing a source of water with low pH and high metals.

3.3.5 Treatment Wetlands

Treatment wetlands were incorporated into the 30% and 60% designs, but are currently being considered as a supplemental remediation activity, to be constructed only if primary remediation measures fail to satisfy the water quality criteria at the South Mine monitoring point. The location and grading of the treatment wetland at South Mine was provided in the 60% design and is also shown in gray scale on the final design drawings. The treatment wetlands were sized during the 30% design. The basis for the wetland sizing is provided as an attachment to this document (Appendix M). The estimated area (upper limit) of the wetland for the South Mine was 200 square meters.

Copper removal efficiencies vary from wetland to wetland. Efficiencies for copper removal for wetlands treating mine water reported by Kadlec and Wallace (2009) range from -100% to 99%. The median copper reduction for free water surface (FWS) wetlands was reported to 66%. Removal efficiencies reported for horizontal subsurface flow (HSSF) wetlands were generally

higher at 81 to 84%. Specific copper removal efficiencies for reducing and alkalinity producing systems (RAPS) were not identified in the literature, but are expected to be similar to or greater than the HSSF wetlands. Under sulfate reducing conditions, copper has been shown to be removed efficiently and is generally the first divalent metal to precipitate because of its very low solubility product of CuS ($K_{sp} = 4.0 \times 10^{-38}$).

A bench or field test to verify the design is recommended. The 60% design would be the basis for the field test. The test wetland should be constructed in time to allow performance to be assessed during the two most critical seasons: hot, dry conditions in the summer and cold, freezing conditions in winter. Therefore, the test would need to run for at least 5 to 6 months.

There is considerable information in the literature regarding operation of treatment wetlands in cold (subfreezing) environments. The treatment system designed for the Elizabeth mine is essentially a reducing and alkalinity producing system (RAPS), but many of the principles for energy budget calculations should be transferable. During periods below freezing, the water temperature can no longer be approximated by air temperature once an ice layer forms on a wetland. One of the challenges in estimating energy budgets and ice thickness is the variability from year to year in temperatures and snowfall, which is a principal factor in the insulation of the wetland system. Because of the complexities attributable to spatial variability within wetlands and year-to-year variations in winter conditions, simplifying assumptions are typically used to estimate ice formation.

To evaluate whether the wetland designed for the Elizabeth Mine is of sufficient thickness for winter protection, example detailed calculations for ice formation for a FWS wetland presented by Kadlec and Wallace (2009) was examined. The example presented is for a FWS wetland in Duluth Minnesota, where the annual swing in mean daily temperature is -11 to 19 ^{o}C. This leads to 150 days of freezing temperatures, with a mean of -7 ^{o}C from November 8 to April 7 (Kadlec and Wallace, 2009). Initial calculations assuming worst case with no snow cover for these extreme conditions predicted an ice layer of 41 centimeters (cm). However, snow commonly collects on top of the ice layer, a situation enhanced by the presence of emergent vegetation. If snow is entered into the equation, the modeled ice thickness is 16 cm. The authors note that the early winter phenomenon of snow in the canopy and unfrozen below is common in cold temperature wetlands.

Review of climate data from Montpelier Airport, Vermont published by the National Oceanic and Atmospheric Administration (NOAA) suggests that winter conditions at the Elizabeth Mine are not expected to be as extreme as those presented in the above example and snow cover on the wetland is likely. If a one foot (30.5 cm) water depth in the winter above organic material for the Elizabeth Mine wetland is assumed, then a 16 cm ice layer would be easily accommodated.

Passive treatment systems, such as constructed wetland and RAPS have been employed at numerous coal and hard rock mines throughout North America over the past couple of decades. These systems have been able to provide effective treatment throughout the year, even in cold climates. Formation of an ice layer generally will reduce the depth of the open water and thereby reduce detention times. This can be compensated for by increasing the depth of the water (e.g. decreasing freeboard) prior to the onset of freezing conditions. Ice thickness can

vary considerably from year to year dependent on temperature and snowpack available for insulation. Wetlands with emergent vegetation are much more effective at trapping and retaining snow than un-vegetated areas, and, therefore, the ice thickness over wetlands will generally be much less than in adjacent lakes or ponds. In addition, the constant influx of warmer, high TDS and low pH ARD beneath the ice layer also tends to limit the thickness of the ice layer. A bench or field test run through several cold months will be necessary to evaluate the proposed wetland construction at Elizabeth Mine. Based on a period of surface water sample results at SM01 following completion of the primary remedial construction activities outlined in this design (Phase 1), the need for a treatment wetland (Phase 2) would be determined. If it is determined a treatment wetland at the South Mine is required, the bench or field test would be conducted at that time.

4.0 OTHER CONSIDERATIONS

4.1 Monitoring

Following the construction at the South Open Cut and South Mine, monitoring will be performed to assess environmental conditions and the effectiveness of the remedy.

- Performing monitoring of the unnamed tributaries of Lord Brook and Lord Brook itself to determine if remedial actions have restored these waters to federal Clean Water Act and Vermont Class B Water Quality Standards at compliance points downgradient from the area. If primary remediation measures fail to satisfy the water quality criteria at the South Mine monitoring point, treatment wetlands would be considered as a supplemental remedy. A bench or field test to verify the treatment wetland design is recommended.
- Performing maintenance and inspections of the vegetation and for erosion of soil covers and channel linings.
- Wetland restoration areas will be monitored for: erosion or sediment accretion, readily observable surface water level fluctuations, establishment of wetland indicator species, density of vegetation by cover type, and ecosysem maturation (temporal variation of species assemblages). Site-wide monitoring will also be performed for invasive species, as knotweed and phragmites are known to occur on site.
- Implementing institutional controls, such as restrictive covenants, to protect the cleanup action from damage and to ensure that buried waste rock is not exposed in the future. Periodic inspections would be performed to ensure compliance with the institutional controls.
- Reviewing the remedy at a minimum of every 5 years to determine whether the cleanup action remains protective of human health and the environment.

4.2 Green Construction

The proposed design includes the following green construction elements:

- Native vegetation is specified for both upland areas and wetland mitigation/replacement seed mixes and plantings.
- Soil covers constructed as part of this remedial construction will be permitted to vegetate naturally over time, thereby minimizing maintenance and blending in with the surrounding natural environment. This includes both the South Open Cut pit lake and Dry Crevasse cover systems which will include a root barrier over the lower low-permeability soil layer with 30-inches of overlying soil so that trees can be allowed to become established.
- The use of constructed slopes at 3:1 (horizontal to vertical) that allows the use of vegetated cover instead of riprap. Also, as indicated on the drawings, portions of the

diversion channels have velocities less than 3 feet per second allowing for a vegetated lining to be used. Also, the drawings indicate where appropriate, field changes to the diversion channel profiles provide steps (small waterfalls) and pools/wetlands shall be provided as approved/directed by the Contracting Officer and regulatory agencies.

- Onsite borrow or available rock materials will be utilized to extent practical for required fill materials.

4.3 National Historic Preservation Act

The South Mine pit lake and the nearby vertical shaft were pumped down in mid October 2013, and the structures were photo-documented by M. Kierstead of Milestone Heritage Consulting in Beacon, New York, pursuant to NHPA requirements. In addition, Specification 01 11 00 Section 3.02.D includes requirements for photographic documentation prior to construction, as well during and post construction; refer to the specifications provided in Appendix D. This documentation is required for all phases of the work at the South Open Cut and South Mine.

As stated in Section 2.3.1, the proposed grading plan for the South Open Cut pit lake will not fill the South Open Cut to its top and leaves the east wall above the pit lake intact. Similarly, as stated in Section 3.3.4, portions of the hanging wall and a surface depression will remain at South Mine where that pit lake currently exists. This will maintain a significant reminder of both pit lakes as historic features.

The Phase 2 Remedial Design was reviewed by a qualified individual to address potential impacts to historic properties as a result of the cleanup (Milestone Heritage Consulting, 2014) (Appendix S). The review suggested that the cleanup approach should perform the least amount of work to safely meet project engineering and environmental goals in order to minimize impacts to the historic landscape. Specific comments were also provided regarding the South Mine, South Open Cut, the South Mine shaft, and TP-3. For the South Open Cut, pre- and post-construction photo documentation were suggested. The final restoration for South Mine, South Open Cut, and South Mine shaft should consider approaches that balance maintaining the view of the open cut while achieving vegetative restoration. For the South Mine, the implementation plans will evaluate whether evidence of the former mining practices (drill holes) can be maintained as visible features consistent with the vegetation restoration. Although stone highlighting of key features (pit lakes) was suggested, it may not be possible to use stone to highlight the former pit lakes and achieve clean water act wetland mitigation requirements. It is also unlikely that sulfide rock will be left exposed which would allow generation of acid mine drainage. Outcrops of the ore can be found at the top of TP-3 for geologic inspection. The request to identify the location of South Mine Shaft location so it would be visible at the ground surface will be included in the implementation plans.

4.4 Site Hazards

Several safety hazards to workers, authorized visitors, and trespassers exist at the Elizabeth Mine Site. In addition, several environmental hazards exist because of the presence of waste soil/rock and mining impacted water within the pit lakes. The bullets below describe safety and

environmental hazards at the South Open Cut and South Mine areas of the Site that will be improved by remedial construction activities.

- The side walls of the Dry Crevasse and Haulage Way currently rise at a slope ranging from approximately 0.5H:1V to 2H:1V and have experienced rock slide/falls in the past. The surface of the side walls is currently comprised of weathered, “rotten” rock that fro0m time to time breaks off the side walls posing a hazard to persons in the Dry Crevasse or Haulage Way below. Large rock segments are located within the bottom of the Dry Crevasse.
- The west face of the South Open Cut pit lake has experienced historical movement of bedrock and rock slides. A rock stability evaluation (Appendix H) indicates the projection of a hypothetical 40° failure plane from the bottom of the pit lake, which is representative of worst case maximum structural features and jointing in the bedrock, shows that the existing access road and diversion ditch will lay outside and to the west of the 40° impact zone. The projection of a hypothetical 30° failure plane, which is representative of the extreme low-risk limit of structural features and jointing in the bedrock, shows that the existing access road and diversion ditch lie within 30° to 40° failure zone. The filling of the pit lake will be conducted in a manner that 1) avoids risk to construction personnel and equipment, and 2) prevents a non-construction-related rock slide at some future date that could compromise completed work and/or pose a risk to site visitors. The remedy will provide a final 30° rock slope as well as a buttress effect from the rock fill.
- Rock removal operations conducted as part of the remedial construction, including drilling and blasting, will be conducted in accordance all applicable federal and state regulations as well as the remedial action contractor’s approved Health and Safety Plan and Blasting Plan.
- During pre-treatment for pH and dewatering of the pit lakes, safety considerations in the remedial action contractor’s safety plan will need to address possibilities for leaks in pumps and hoses, and anchoring the equipment to avoid danger to personnel (as well as the environment). Decontamination of the pumps and hosing would also be required.
- Following the west face rock removal and pit lake filling, establishing a safe construction access to the pit lake will be required. Access may be provided by advancing through either or both the Haulage Way and the south end of the Dry Crevasse. Access through the Haulage Way and Dry Crevasse will require additional rock removal to advance and establish a safe, stable corridor.
- The South Mine pit lake opens to a cavernous void beneath the water’s surface. The exposed rock face on the east side of the South Mine pit lake is essentially a large overhanging unstable outcrop that poses a risk because of the potential for the rock outcrop to break away. Remedial construction activities will mitigate this risk by dewatering the pit lake, then demolishing a portion of the outcrop to a stable face with the rock falling to the pit lake floor. Controlled low strength material (i.e., flowable fill) will be used to fill the remainder of the bottom portion of the cavern and pit lake so that construction personnel or equipment will not need to enter the cavern. The flowable fill will stabilize the void beneath the remaining exposed rock at the surface. The upper

portion will receive a final vegetated wetland cover system. To the observer, the end result will be a topographically depressed area where the pit lake once existed with the exposed rock outcrop with a stable surface.

- To the north of the South Mine pit lake is a vertical mine shaft that poses a fall hazard. During a pumping operation conducted in October 2013, the shaft was determined to have an approximately 6- by 9-foot opening. Three to four feet of water was pumped from the shaft prior to reaching a very soft muck. In May, 2014, a man-portable Geoprobe was setup on the plank cover placed over the shaft opening in December 2013. The muck in the shaft provided only limited resistance to the drill rods, and they advanced under their own weight to 27 feet below the top of the cover. The Geoprobe was then used to hammer/drive the rods to refusal at 41 feet below the top of the cover. During attempts to collect soil samples, refusal, interpreted to be a rock/boulder, was encountered at 27 feet below the top of the cover. The depth to competent bottom was interpreted to be 27 feet below the top of the cover. According to Matt Kierstead of Milestone Heritage Consulting in Beacon, NY, the South Mine shaft was an exploratory shaft that was not developed for ore production. Following the removal of accumulated muck, the majority of the shaft will be filled with stone and a final vegetative wetland cover will be installed.
- Exposed waste rock and soil at the South Open Cut and South Mine areas pose an environmental concern because of acid generating potential. Soil from the South Mine, waste rock/soil excavated from the Haulage Way, and waste rock/soil excavated from the west side of the South Open Cut will be consolidated in the South Open Cut pit lake and Dry Crevasse. The South Open Cut pit lake and Dry Crevasse will receive a soil cover systems over the waste rock and soil. Excavated areas in the Haulage Way and South Mine will be restored with a soil cover and seed and the diversion channels will receive linings. Erosion and sediment control best management practices must be used throughout remedial construction.
- The pit lakes at the South Open Cut and South Mine present an environmental hazard because of the low pH and high metals content of the water. Both the South Open Cut pit lake and the South Mine pit lake will be filled in and cover systems installed during remedial activities, eliminating these sources.

The selected remedial action Contractor will be required to develop a Site Specific Health and Safety Plan (HASP) for its operations. The Contractor shall implement this plan taking precautions as necessary to protect the public and work force personnel from potential hazards.

4.5 Wetland Restoration

In addition to remedial activities, wetland mitigation and restoration will take place as part of construction. Refer to Appendix N for additional information.

4.6 Cost Estimate

Contract Statement of Work states that the deliverable should include a rough order of magnitude (ROM) cost estimate. Although a ROM cost is required, a detailed estimate was developed primarily by utilizing bottoms up estimating methods consistent with a project at this design stage. The complete estimate, including the detailed backup is provided along with an estimate summary (roll-up line items) for this current design deliverable. The costing was based on quantity take-offs from the current design drawings. The total estimated cost for the South Mine/South Open Cut remedial construction is $10 million. Refer to Appendix O for the cost estimate.

4.7 Value Engineering

A Value Engineering (VE) screening was performed for the Phase 2 Remedial Action Remedial Design as required by the EPA directive: Value Engineering Program Plan for Superfund Fund-lead Remedial Design and Remedial Action Activities, April 14, 2006, OSWER 9335.5-24; Federal Acquisition Regulations 48.101(b)(2); and OMB Circular No. A-131, May 31, 1993. The VE screen did not identify any potentially high cost design elements or subsystems that would be appropriate candidates for a former VE study. The cleanup subject to the Phase 2 Remedial Action design is an earthwork project with few physical components that could be evaluated for substitution or replacement. A formal VE study was not recommended.

The Phase 2 Remedial Action design focused on cost effectively achieving the cleanup goals and objectives while complying with the identified ARARs. Several VE type assessments were performed by the design team to assess the need for horizontal drains, whether to include a low-permeability geomembrane in the cover system, and whether storm flows could be managed and treated successfully by a passive treatment system. As a result of these evaluations, the design was changed to address performance concerns with the passive treatment component.

The preliminary design did include a value engineering assessment regarding the nature of the soil cover for the South Open Cut Dry Crevasse and the value of the South Open Cut surface water diversion channel. A summary of the analysis is below:

VE Item 1: South Open Cut Low-Permeability Soil Cover

Two options were identified for the low-permeability soil cover at the Dry Crevasse:

A. Partial Filling: Flatten side slopes of dry crevasse, partially fill in, and provide a concave soil cover. This would require less material, but is only applicable if the fill volume is less than the capacity of the Dry Crevasse.

B. Complete Filling: Do not flatten side slopes of Dry Crevasse, fill the crevasse to height, and provide a slightly concave or convex soil cover. Cut/fill volumes calculated during the 30% design revealed that the excess materials from construction activities at the South Mine and South Open Cut plus the 2.5-foot low-permeability soil cover will fill the Dry Crevasse to height without the additional fill required by flattening the crevasse

side slopes. Therefore, the first option (A) is not viable and no cost comparison was performed. The 30% design incorporates a slightly concave low-permeability soil cover with swale.

Conclusion: Because of the anticipated volume of material, the dry crevasse slopes do not require adjustment because the dry crevasse will be filled and there will not be steep sideslopes remaining above the cover system

VE Item 2: South Open Cut Stormwater Diversion

Two options were considered for managing stormwater flowing to the pit lake at the South Open Cut:

A. With Stormwater Diversion: This option entails constructing a stormwater diversion channel along the road on the upgradient (west) side of the cut to divert runoff around the pit lake and Dry Crevasse. The diversion channel would greatly reduce the pit lake drainage area, effectively reducing the amount of water to be discharged to and treated by the wetland. Appendix T contains a VE cost estimate for this option that incorporates work elements that varied between the two options. The total cost for Option A is $207,138.71.

B. Without Stormwater Diversion: Option B does not include stormwater diversion; rather, stormwater runoff from west of the road will continue to flow into the pit lake. Thus, in comparison to Option A, a larger area would be contributing stormwater runoff to the pit lake. A larger wetland would be required to treat the flow. Appendix T contains a VE cost estimate for this option that incorporates work elements that varied between the two options. The total cost for Option B is $314,418.98.

Conclusion: Constructing an upgradient stormwater diversion channel is cost effective

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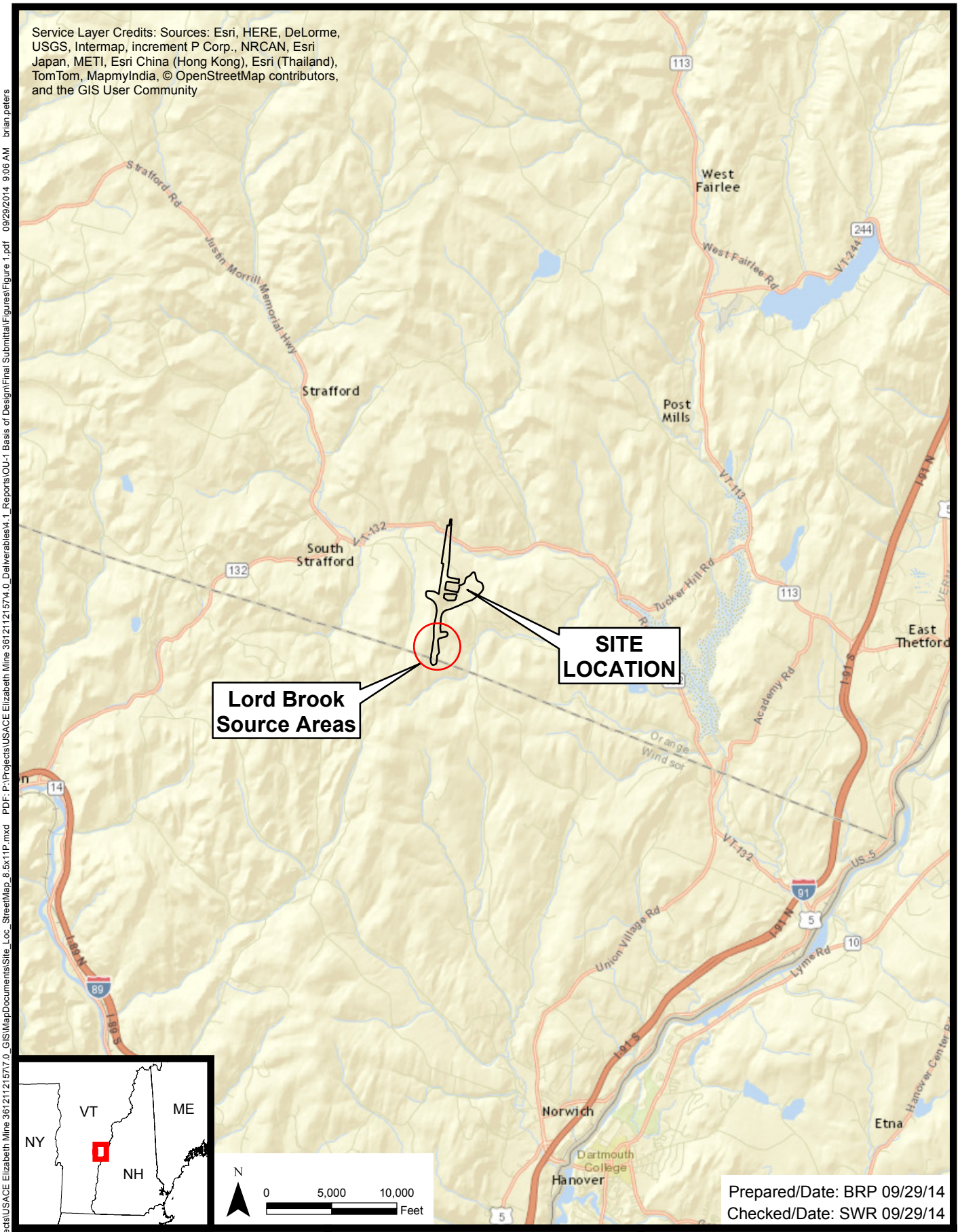
FIGURES



USACE
Elizabeth Mine Superfund Site
South Strafford, Vermont

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Site Location Map

Project 3612112157 Figure 1

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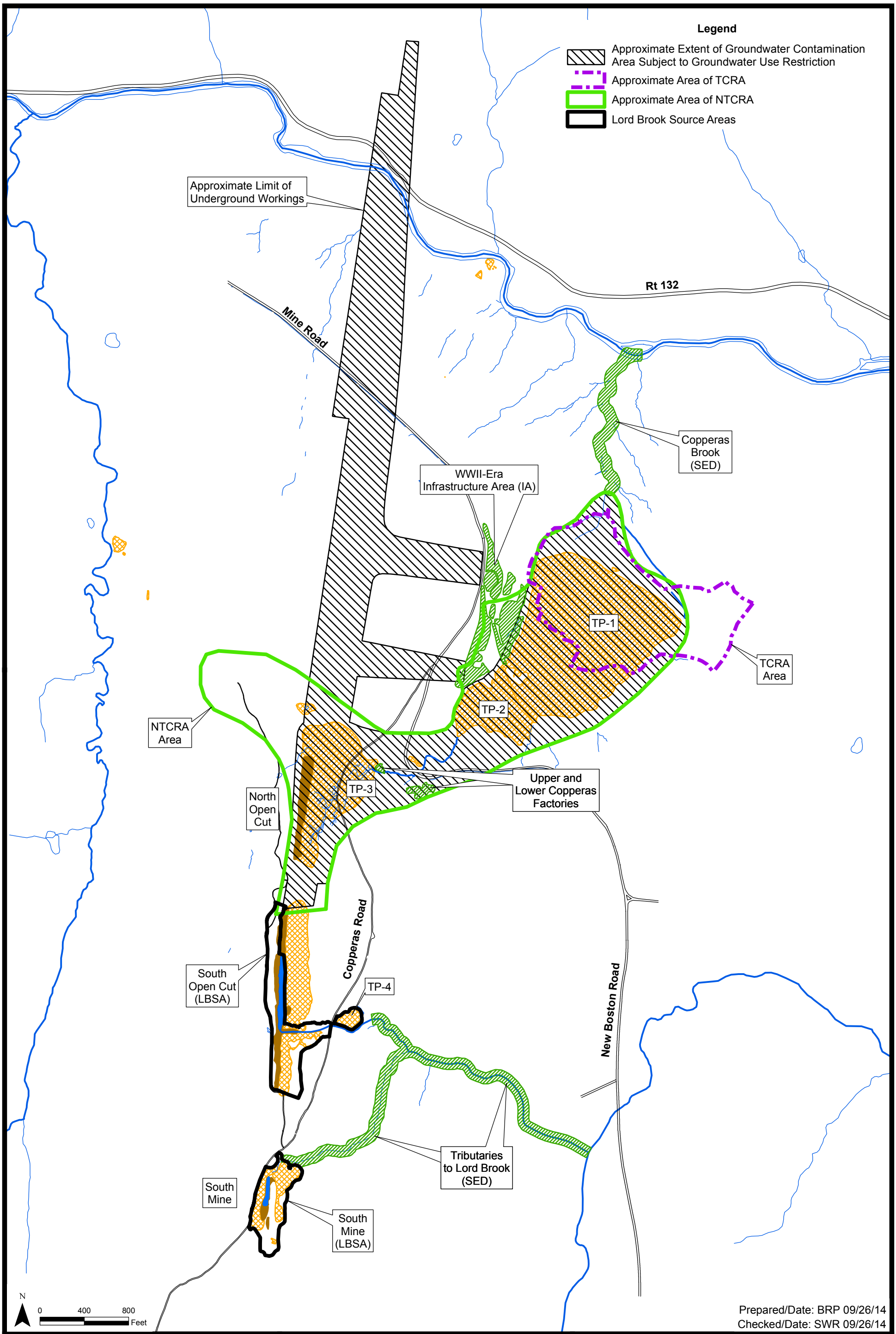

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South Strafford, Vermont

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TCRA, NTCRA and
Remedial Action Areas
Project 3612-11-2157 Figure 2

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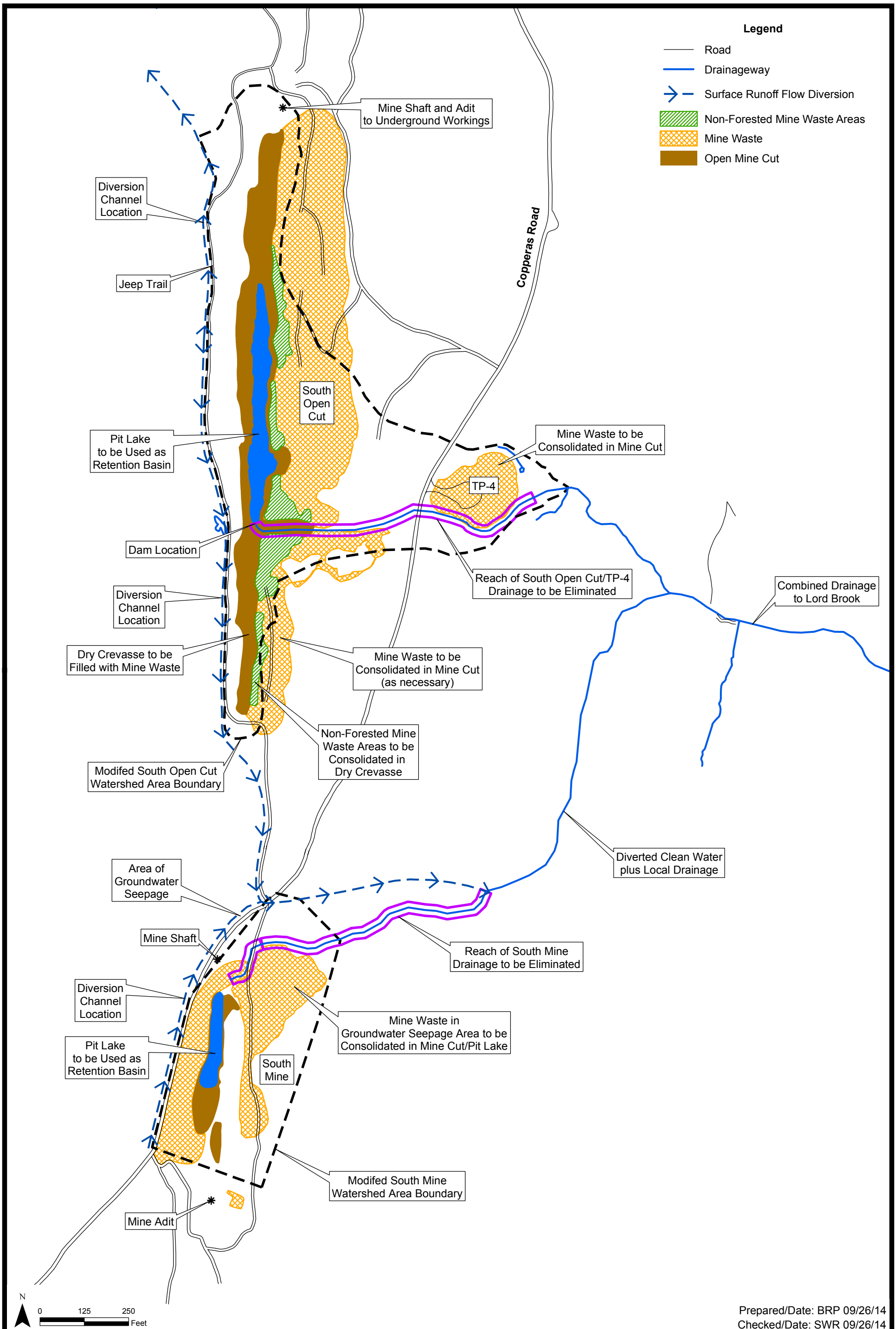

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South Strafford, Vermont

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Lord Brook Source Areas
ROD Alternative LBSA-4
Project 3612-11-2157
Figure 3

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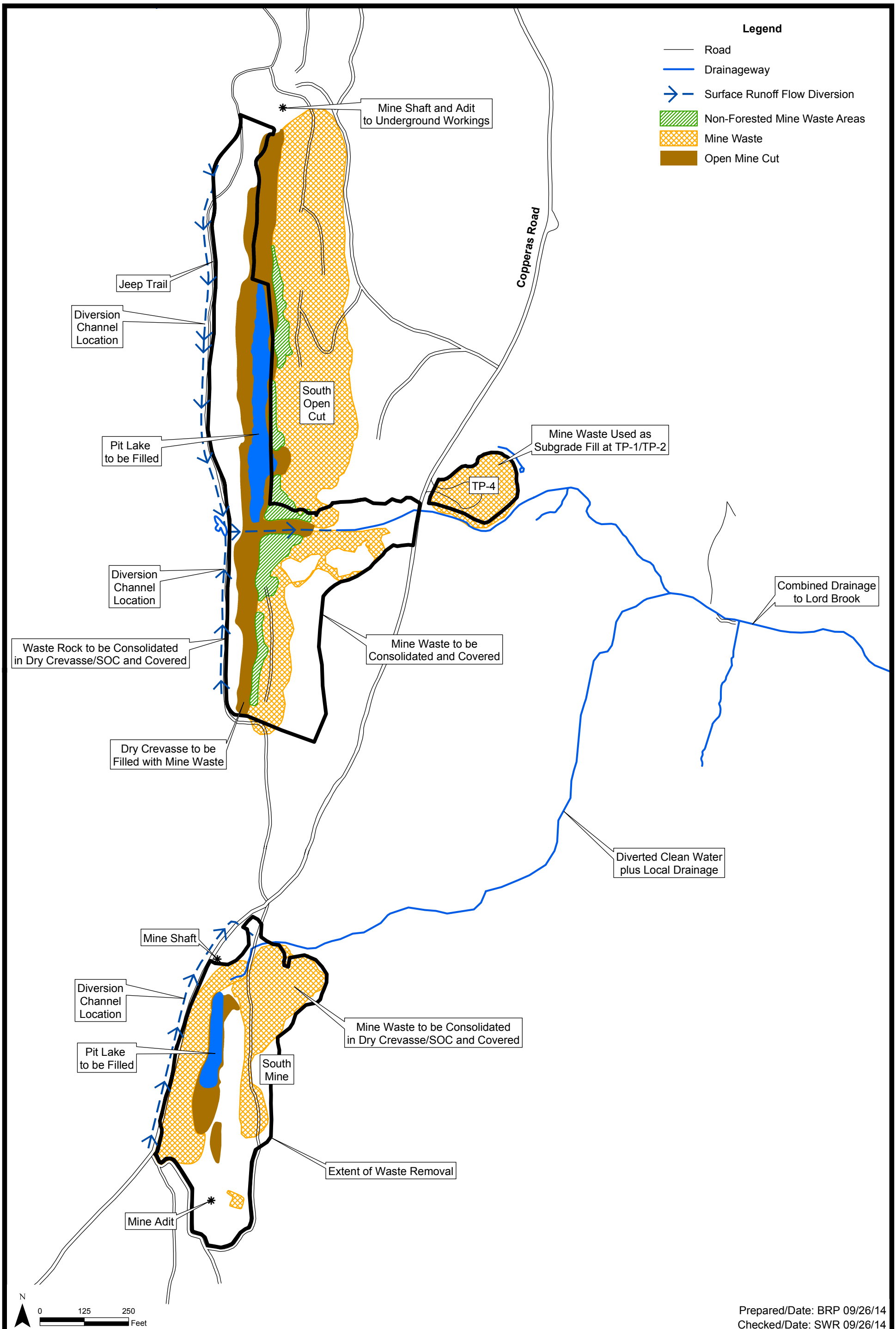

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Elizabeth Mine Superfund Site
South Strafford, Vermont

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Modified Lord Brook Source Areas
Alternative LBSA-4
Project 3612-11-2157 Figure 4

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Legend

Sample Location

USACE
Elizabeth Mine Superfund Site
South Strafford, Vermont

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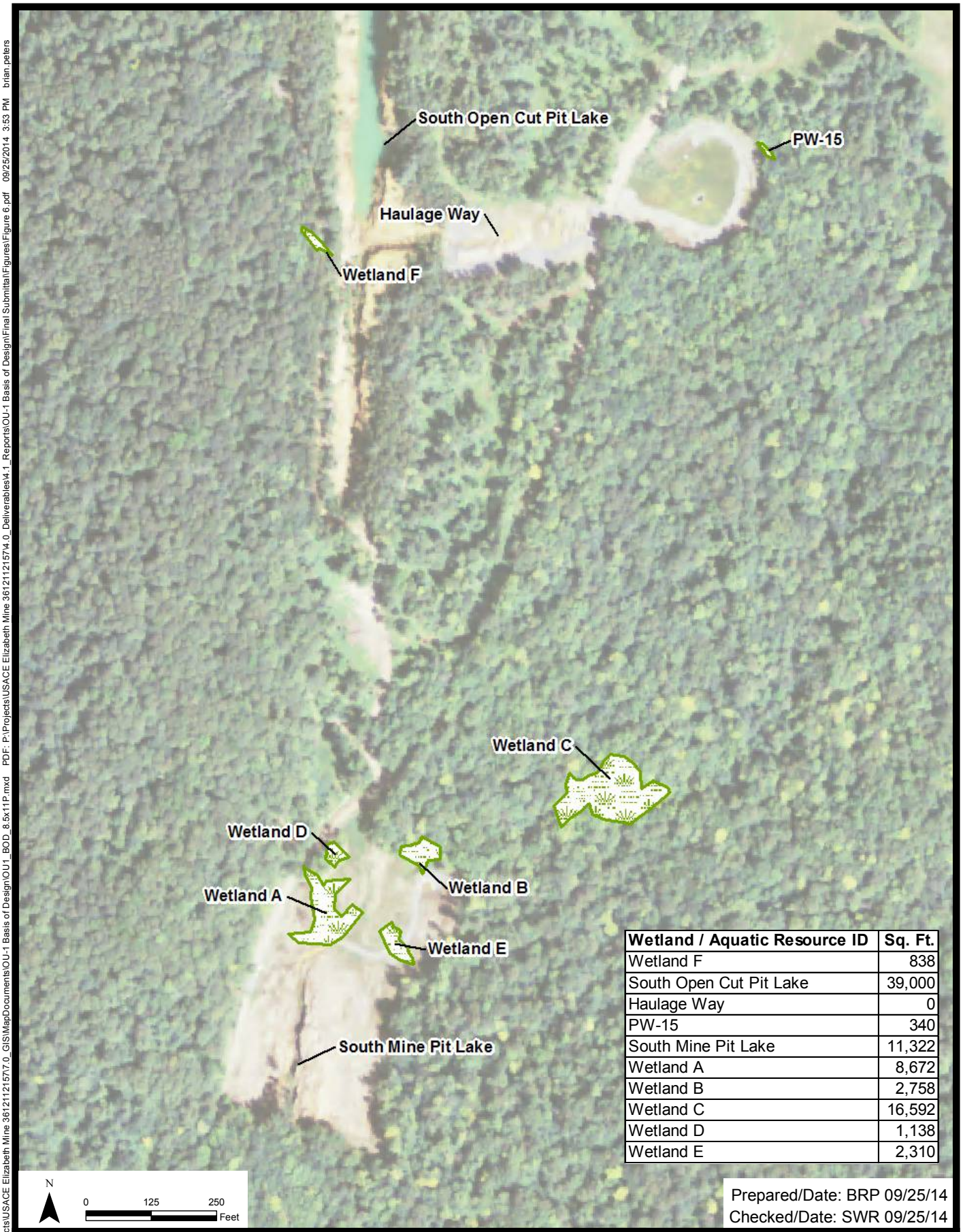
South Mine and South Open Cut
Surface Water Sample Locations
Project 3612-11-2157 Figure 5



Wetland / Aquatic Resource ID	Sq. Ft.
Wetland F	838
South Open Cut Pit Lake	39,000
Haulage Way	0
PW-15	340
South Mine Pit Lake	11,322
Wetland A	8,672
Wetland B	2,758
Wetland C	16,592
Wetland D	1,138
Wetland E	2,310

Prepared/Date: BRP 09/25/14
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South Strafford, Vermont

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Wetlands and Aquatic Resources
at Lord Brook Source Areas
Project 3612-11-2157 Figure 6

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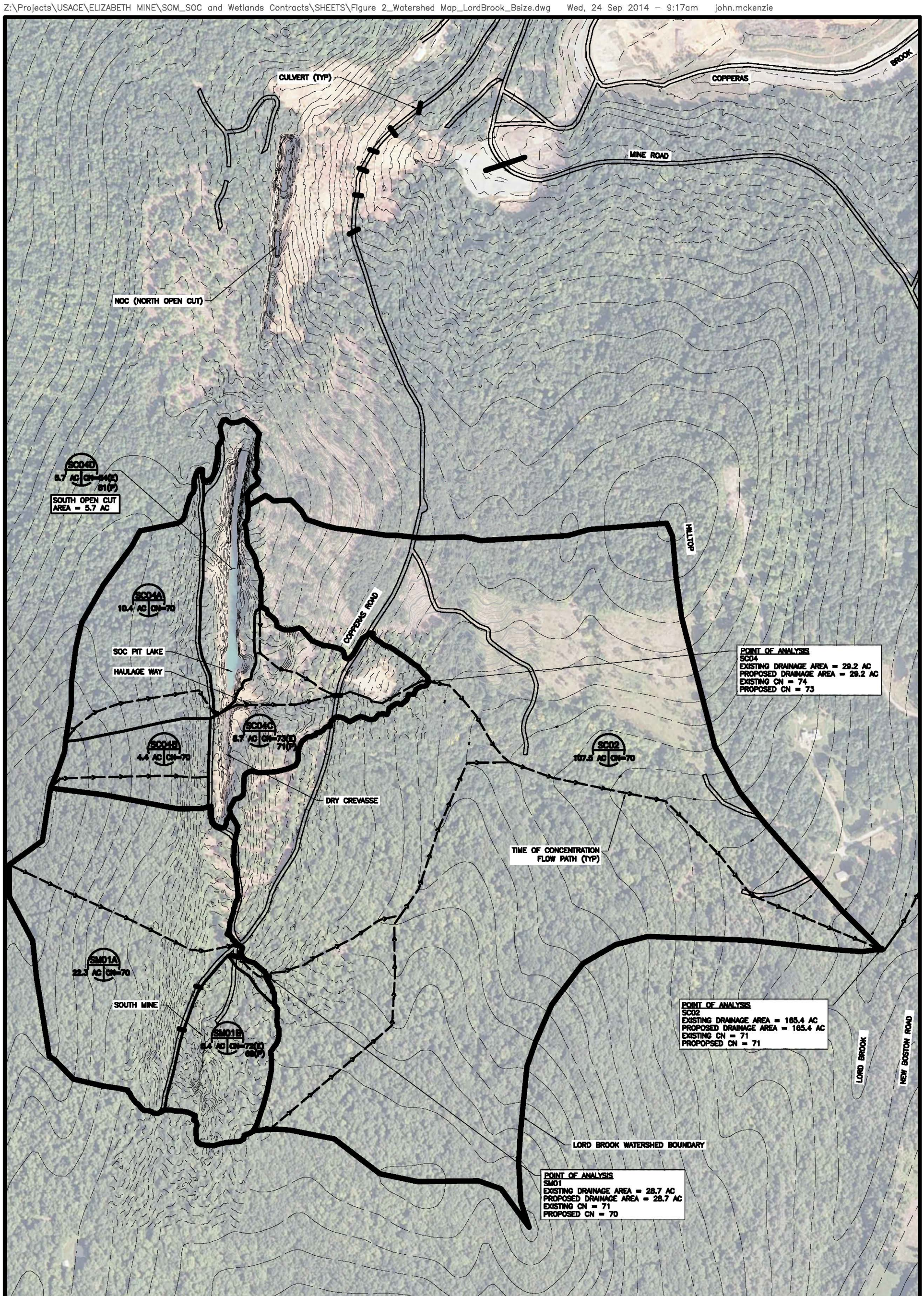

MAPPING DATA:

CONTOURS IN THE VICINITY OF NORTH OPEN CUT AREA ARE REPRESENTED BY 10 FOOT INTERVAL AERIAL TOPOGRAPHY FROM PREVIOUS PROJECTS AND VARIOUS AS BUILT SURVEYS AS PROVIDED BY NOBIS.

CONTOURS WITHIN THE VICINITY OF SOUTH MINE AND SOUTH OPEN CUT ARE 5 FOOT INTERVAL AERIAL PHOTOTGRAPHY OBTAINED DURING REMEDIAL DESIGN PROCESS.

OVERALL CONTOUR COVERAGE IS 20 FOOT INTERVAL PUBLICLY AVAILABLE GIS CONTOUR DATA.

IMAGES ARE PUBLICLY AVAILABLE, GEOSPACIALLY CORRECTED, PHOTOGRAPHY DATED JULY AND AUGUST 2009.

SC04A — WATERSHED IDENTIFIER
1,044 AC CN=70 — CURVE NUMBER; DRAINAGE AREA

SEE APPENDIX F FOR ADDITIONAL EXPLAINATION

0 200 400 800
SCALE IN FEET

Prepared/Date: JVM 9/24/14
Checked/Date: SWR 9/24/14

USACE Elizabeth Mine Superfund Site South Strafford, Vermont	amec	LORD BROOK SOURCE AREAS WATERSHED MAP Project 3612-11-2157 Figure 7

APPENDIX A

WATER QUALITY DATA

APPENDIX B

USGS SOUTH OPEN CUT PIT LAKE CHEMISTRY

APPENDIX C

DESIGN DRAWINGS

APPENDIX D

SPECIFICATIONS

APPENDIX E

DIVERSION CHANNEL TEST PIT RECORDS

APPENDIX F

TECHNICAL MEMORANDUM

LORD BROOK DISCHARGE EVALUATION

APPENDIX G

TECHNICAL MEMORANDUM – CHANNEL DESIGN

APPENDIX H

TECHNICAL MEMORANDUM – ROCK STABILITY

APPENDIX I

TECHNICAL MEMORANDUM – SLOPE INTERFACE FRICTION

APPENDIX J

WASTE ROCK ACID POTENTIAL

APPENDIX K

HAULAGE WAY BORINGS

APPENDIX L

PHOTOGRAPHS

APPENDIX M

WETLAND SIZING CALCULATIONS

APPENDIX N

TECHNICAL MEMORANDUM – WETLAND RESTORATION

APPENDIX O

COST ESTIMATE

APPENDIX P

GEOTEXTILE AND SOIL FILTER CALCULATIONS

APPENDIX Q

LEVEL SPREADER CALCULATIONS

APPENDIX R

OUTLET PROTECTION CALCULATIONS

APPENDIX S

NHPA SOUTH MINE/SOUTH OPEN CUT

NINETY PERCENT RD REVIEW

APPENDIX T

SOUTH OPEN CUT STORMWATER DIVERSION VE COST ESTIMATES