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EPA Region 1 RAC2 Contract No. EP-S1-06-03

June 25, 2008
Nobis Project No. 80025
NH-1463-2008-D

Via Electronic Submittal

U.S. Environmental Protection Agency, Region 1
Attention: Mr. Ed Hathaway, Task Order Project Officer
1 Congress Street, Suite 1100
Boston, Massachusetts 02114-2023

Subject: Draft Conceptual Site Model Technical Memorandum
Pike Hill Copper Mine Superfund Site, Corinth, Vermont
Remedial Investigation/Feasibility Study
Task Order No. 0025-RI-CO-017J

Dear Mr. Hathaway:

Attached with this correspondence is the Draft Conceptual Site Model Technical Memorandum for the Remedial Investigation / Feasibility Study at the Pike Hill Copper Mine Superfund Site located in Corinth, Vermont.

Should you have any questions or comments, please contact me at (603) 724-6224 or aboeckeler@nobisengineering.com.

Sincerely,

NOBIS ENGINEERING, INC.

Andrew J. Boeckeler, P.G.
Sr. Project Manager

Attachment

c: File 80025/NH (w/enc.)

SDMS Doc ID 529097

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DRAFT CONCEPTUAL SITE MODEL TECHNICAL MEMORANDUM

Pike Hill Copper Mine Site
Corinth, Vermont

Remedial Investigation/Feasibility Study
EPA Task Order No. 0025-RI-CO-017J

REMEDIAL ACTION CONTRACT
No. EP-S1-06-03

FOR

U.S. Environmental Protection Agency
Region 1

BY

Nobis Engineering, Inc.

Nobis Project No. 80025

June 2008

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Draft Conceptual Site Model Technical Memorandum

Pike Hill Copper Mine Site
Corinth, Vermont
Remedial Investigation / Feasibility Study
EPA Task Order No. 0025-RI-CO-017J

REMEDIAL ACTION CONTRACT

No. EP-S1-06-03

For

U.S. Environmental Protection Agency

Region 1

By

Nobis Engineering, Inc.

Nobis Project No. 80025

June 2008

Andrew J. Boeckeler, P.G.
Project Manager

FOR Vinnie DelloRusso
Senior Geologist, Weston Solutions

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Pike Hill Copper Mine Site
Corinth, Vermont

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1.0 INTRODUCTION

This Section describes the workscope and objectives of the Remedial Investigation/Feasibility Study (RI/FS), the stakeholders and participants, and the primary references and general organization of this Technical Memorandum.

1.1 Work Scope and Objective

This Technical Memorandum was prepared by Nobis Engineering, Inc. (Nobis) for the United States Environmental Protection Agency (EPA) under Contract Number EP-S1-06-03, Task Order Number 0025-RI-CO-017J (Task Order). The work was performed in accordance with the September 27, 2007 EPA Statement of Work (SOW). The Task Order SOW includes the completion of a Remedial Investigation/Feasibility Study (RI/FS) at the Eureka, Union, and Smith Mines, collectively referred to as the Pike Hill Copper Mine Superfund Site (also referred to as the Site) located in Corinth, Vermont. The goal of the RI/FS is to develop the minimum amount of data necessary to support the selection of a remedy that eliminates, reduces, or controls risks to human health and the environment and can be used to prepare a well-supported Record of Decision (ROD).

The objectives of this Technical Memorandum are to:

- Summarize the Site background information including setting and history;
- Present a Preliminary Conceptual Site Model that summarizes the current understanding of Site conditions, and describes fluxes and reservoirs of contaminants at and from the Site, including a conceptual exposure pathway analysis prepared in accordance with EPA Region 1 guidelines;
- Identify existing data gaps that must be addressed to complete the RI/FS; and
- Propose remedial investigation activities that would be performed to complete the RI/FS.

1.2 Stakeholders and Participants

This Technical Memorandum was developed for the EPA under direction provided by EPA, the United States Fish and Wildlife Service (USFWS), and the Vermont Agency of Natural Resources (VTANR). Additional support has been provided by the United States Geological Survey (USGS), United States Army Corps of Engineers (USACE), as well as other contractors to USACE. The municipal agents and residents from the local community are anticipated to be

active participants in expressing their concerns and opinions at public meetings to be held at regular intervals throughout the project.

1.3 Supporting Information

Site specific environmental data summarized herein has been obtained from the following sources:

- *Geochemical Characterization of Mine Waste, Mine Drainage, and Stream Sediments at the Pike Hill Copper Mine Superfund Site, Orange County, Vermont.* Piatak, et. al. (2006).

- *Surface-Water Hydrology and Quality at the Pike Hill Superfund Site, Corinth, Vermont*. October 2004 to December 2005. Kiah, et. al. (2007).

- *Sequential Extraction Results and Mineralogy of Mine Waste and Stream Sediments Associated With Metal Mines in Vermont, Maine, and New Zealand*. Piatak, et. al. (2007).

- *Geochemical Setting of Mine Drainage in the Vermont Copper Belt.* Seal, et. al. (2001).

- *Draft Historic/Archaeological Mapping and Testing, Pike Hill Mines Site (VT-OR-27)*. Public Archaeology Laboratory (PAL, 2007).

- *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States*. Shacklette, et. al. (1984).

- *Geochemistry of Stream Sediments and Heavy-Mineral Concentrates from the Orange County Copper District, East-Central Vermont*. Slack, et. al. (1990).

- *Besshi-Type Massive Sulfide Deposits of the Vermont Copper Belt*. Slack, et. al. (1993).

- *Geology and Geochemistry of Besshi-Type Massive Sulfide Deposits of the Vermont Copper Belt*. Slack, et. al. (1984).

- *Detection of Geobotanical Anomalies Associated with Mineralization in the Glens Falls 1° x 2° Quadrangle*. Power, et. al. (1990).

- *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA (1988).

- *Remedial Investigation/Feasibility Study Work Plan for Pike Hill Mines.* URS (2007a).

- *Draft Field Sampling Plan for Pike Hill Mines.* URS (2007b).

- *Draft Final Report, Remedial Investigation Report, Elizabeth Mine, South Strafford, VT*. URS (2006a).

1.4 Organization of Technical Memorandum

The Technical Memorandum is organized as follows:

- Section 1.0 Introduction provides an overview of Task objectives and SOW.

- Section 2.0 Site Description and Setting provides a general description of the Site, including Site background and history, previous investigations, and general physical/geological information.

- Section 3.0 Site Data Summary includes a summary of existing Site data obtained during previous investigations.

- Section 4.0 Preliminary Conceptual Model presents the current understanding of Site conditions, describes migration pathways, fluxes and reservoirs of contaminants at and from the Site.

- Section 5.0 Human health and ecological risk assessment describes the basis and assumptions for Site risk assessments and presents exposure pathway analyses for human health and ecological risk assessments.

- Section 6.0 Preliminary Response Action Objectives describes the recommended approach to achieve project quality objectives.

- Section 7.0 Potential Remedial Alternatives provides a preliminary overview of remedial options amenable to the Site.

- Section 8.0 Preliminary Data Requirements for RI/FS outlines supplemental data requirements to complete the RI and support the FS.

- Section 9.0 References lists the principal references relied upon to establish the current understanding of the Site.

2.0 SITE DESCRIPTION AND SETTING

This Section provides a brief description of the Site, its general surroundings, pertinent historical facts regarding the mining history, and an overview of the areal geology and hydrology as a context for subsequent sections discussing Site details.

2.1 Site Description and Setting

The Pike Hill Copper Mine Superfund Site includes the Union, Eureka (also known as Corinth), and Smith (also known as Bicknell) mines. The Eureka and Union Mines, each of which is larger than the Smith Mine, are near the top and northeast slope of Pike Hill near the village of Corinth, Vermont (Figure 2-1). The Eureka and Union Mine areas are located approximately 300 meters (m) apart. The mines are generally considered to be a single-impacted landscape within the Pike Hill Brook watershed containing a widespread area of sparsely vegetated waste rock and tailings piles, open mine cuts, trenches, collapsed mine shafts, and three adits. The smaller Smith Mine is located approximately 0.4 miles south of the peak of Pike Hill on the southern flank of the hill and consists of three small mine waste piles and a collapsed adit that lie within the Cookville Brook watershed. The entire Site encompasses about 216 acres (87.5 hectares) and contains approximately 20,000 tons of waste rock and tailings piles that are estimated to contain an average of 1.6% copper (Piatak and others, 2006; URS, 2004; PAL, 2007). The Site landscape is a combination of barren open areas and patches of birch and evergreen trees (Piatak and others, 2006). The locations of remnant foundations of an ore cobbing house, a blacksmith shop, the flotation/magnetic separation mill, and other features associated with historic mining operations have been documented at the Site (PAL, 2007;

Kierstead, 2001). Pike Hill Brook, Cookville Brook and their tributaries are the primary streams draining the Site area, which eventually join the Waits River. Four significant wetland areas exist along Pike Hill Brook downstream of the Site. In addition, a small wetland exists along the tributary to Cookville Brook just upstream of the confluence with Cookville Brook. See Figure 2-3 for Site details.

2.1.1 Topography

Site topography is dominated by the north-south trending ridge of Pike Hill with a peak elevation of approximately 1,965 feet above mean sea level. The Eureka and Union Mines occupy an area extending from the peak northward and eastward along the eastern flank of Pike Hill within an east-trending valley defined by moderate to steep slopes containing one of two tributaries that define the headwaters of Pike Hill Brook. There is approximately 500 feet of relief between the top of Pike Hill and confluence of the tributary with Pike Hill Brook at the eastern margin of the Site at Richardson Road, below which the valley and Pike Hill Brook trend southeasterly. The Smith Mine is located on the east facing, moderate to steep slope at the southern end of the Pike Hill ridge which defines the western portion of a south facing valley drained by a tributary to Cookville Brook.

2.1.2 Population and Land Use

The Pike Hill Mine Site is located in a Town of Corinth, Orange County, Vermont with a population of approximately 1,500 people (URS, 2007a). The Site is located in a rural, sparsely populated area of the town accessed by Copper Mine and Richardson Roads. It is estimated that less than 100 people live within a one mile radius of the Site. The nearest residents are reportedly located on the west side of Richardson Road in a trailer on the adjacent parcel to the southeast of the Site. Another nearby residence is located northeast of Richardson Road. The Site and vicinity is forested with the exception of open areas occupied by mine waste rock piles. The Site is currently privately owned, undeveloped, idle, and generally undisturbed since cessation of mining activities. There are no residents or buildings on the Site. The Site is reportedly also frequented for limited recreational use by off-road vehicles, hikers, and spelunkers.

2.1.3 Vermont Copper Belt

The Vermont Copper Belt, also known as the Orange County copper district lies within the Connecticut River watershed in Orange County, Vermont. It is reported to have supplied the

largest historic metal production in New England from the late 1700s to 1958 derived primarily from the Elizabeth, Ely, and Pike Hill Mines within a 20 mile long area from south to north in the belt (Figure 2-2). Other smaller deposits known as the Cookeville, Orange and Gove Deposits also occur within this belt. Early production at the Elizabeth mine was focused on copperas (iron sulfate), followed later by copper production at all three mines. The ore bodies are stratiform massive sulfide deposits similar to those of the Besshi deposits in Japan and are believed to have formed as syngenetic-exhalative processes on the sea floor during the Silurian-Devonian age. The primary ore minerals include pyrrhotite, chalcopyrite with minor sphalerite and pyrite (Slack and others, 2001). The Elizabeth and Ely Mines lie within the Devonian Gile Mountain Formation, and the Pike Hill Mines lie within the Silurian Waits River Formation.

2.1.3.1 Elizabeth Copper Mine

The Elizabeth Mine is the oldest and largest of the three primary mines in the belt, located on Copperas Hill in the towns of South Strafford and Thetford, Vermont and was discovered in 1793 with mineral production beginning in 1809. The deposit was mined until the early 1880s for pyrrhotite to produce copperas. From the 1830s until the mine closed in 1958, copper was mined from chalcopyrite in the deposit. Smelting of copper occurred sporadically at the mine from 1830 to 1919. The mine was revived during World War II until it finally closed in 1958. The total copper output of the mine is estimated at 50,000 tons. The history of the mine spans approximately 160 years and included ore milling and smelting, and includes the only intact historic metal mine process buildings in New England (Kierstead, 2001). Today, the mine encompasses approximately 970 acres in addition to the mine process buildings: the mine area consists of four areas of mine waste rock and tailings piles; three open cuts in bedrock, two of which are water-filled ponds; and approximately 8,000 linear feet of underground workings with limited openings into the mine (URS, 2006a). The Elizabeth Mine Site was listed as a Superfund Site in June 2001 due to environmental impacts from acid rock and acid mine drainage from the Site on the West Branch of the Ompompanoosuc River. The mine is also eligible for the National Register of Historic Places due to its historical aspects (Hathaway and others, 2001). Remedial actions are ongoing at the Elizabeth Mine Site and results of recent studies completed to support evaluation and implementation of remedial alternatives at the mine will form the basis of comparison for future RI/FS at the Ely and Pike Hill Mine Sites.

2.1.3.2 Ely Copper Mine

The Ely Copper Mine lies between the Elizabeth and Pike Hill Mines and is located on the south side of Dwight Hill in the town of Vershire, Vermont. The mine was active between the mid-1850s until 1905. Mineralogy of the ore body was similar to that of the Elizabeth and Pike Hill Mines. Operations at the mine included a large 24-furnace smelter plant, which was among the top ten copper producing operations for a period of its history, with an estimated total copper production of 20,000 tons. It was the only copper mine in Vermont that successfully produced refined ingot copper on a large scale (Kierstead, 2001). The mine encompasses approximately 350 acres, including areas containing waste rock piles and tailings, ore roast beds, a slag pile, over 3,000 linear feet of underground workings, with limited openings into the flooded mine. No buildings remain at the mine. Remnant foundations, pads and stone walls including a 1,400 foot long smoke flue demark the location of former Site structures including a former flotation mill and the smelter plant. In September 2001, the Ely Mine Site was added to the Superfund listing due to environmental impacts from acid rock drainage from the Site on Ely Brook and Schoolhouse Brook. The mine is also eligible for the National Register of Historic Places due to its historical aspects (Hathaway and others, 2001). Remedial investigations are ongoing at the mine (URS, 2004).

2.1.3.3 Pike Hill Copper Mines

The Pike Hill Mines include three separate mine workings located on Pike Hill in the town of Corinth, Vermont discovered in 1845, after the Elizabeth and Ely mine deposits (Figure 2-3). The mines are referred to from north to south as the Union, Eureka (a.k.a. Corinth), and Smith (a.k.a. Bicknell) Mines which operated intermittently between 1846 and 1919 producing approximately 5,000 tons of copper, comprising about 6% of the known production from the Vermont Copper Belt (Kierstead, 2001). The Smith Mine was significantly smaller than the other two mines.

Copper ore was initially discovered in the vicinity of the Smith Mine on Pike Hill in 1845. Due to the low profitability of the Smith Mine, prospecting extended north as evidenced by a series of shallow trenches dug which exist along the south side of the Pike Hill summit. In about 1853, mining of the Eureka deposit began at the peak of Pike Hill. Underground operations at the Eureka and Union Mines began in 1863. The ore mined initially was hand-cobbed and shipped off-site for processing at east coast smelters. In 1879, the ore processing plant was upgraded to enhance ore separation and ore shipment to the Ely Mine smelter until 1905. No smelting

took place at the Pike Hill Mine. In 1881, the ore body at the Union Mine was lost. Between 1882 and 1916 production and activities associated with the mines are poorly documented and appear to be sporadic (PAL, 2007).

From 1904 to 1907, Eureka Mine operations included an on-site processing mill which was used to experiment with separation processes including magnetic separation of pyrrhotite, Wetherill separators, and experimental froth flotation. Unlike the other mines of the Vermont Copper Belt, magnetic ore separation proved successful and continued for a short period (1906-07) until the mine closed temporarily in 1907. The Smith Mine had closed in 1882 due to low copper prices, but renewed exploration in the Smith Mine area occurred briefly in 1907 and 1908 and again in 1913 before being abandoned, leaving a relatively small area of waste rock piles and underground workings. The Eureka Mine ore mill closed in 1907 and activities at the mines are poorly documented between 1907 and 1915, suggesting limited mining activities. Operations at the Eureka and Union Mines resumed under a single company (Pike Hill Mines Company) between 1916 and 1919 during which time approximately 842,000 pounds of copper were produced using flotation processes with pine oil as an additive (PAL, 2007; URS, 2007a).

Operations at the Pike Hill Mines ceased in 1919, but were revisited after 1942 when the Vermont Copper Company, the owner of the nearby Elizabeth Mine, purchased the property. The underground mines were never reopened, but during the late 1940s and early 1950s portions of the ore dumps were trucked to the Elizabeth Mine mill for processing. The United States Bureau of Mines completed several borings, conducted surface mapping, and compiled geological information from the Site in 1944, which documented the known extent of underground workings and provides an interpretation of the nature and extent of the ore body (White and Eric, 1944; PAL, 2007). Remaining Site buildings were destroyed by fire in 1960 (URS, 2007a). Pat Mines, Inc. (a.k.a. North Gate Exploration) purchased the property in 1962 and was the owner through 1983 (PAL, 2007). The property is currently privately owned. Today the Site contains remnant waste rock and tailings piles, open cuts in bedrock, flooded underground workings with limited mine openings.

The Site was placed on the United States (United States) Environmental Protection Agency (EPA) National Priorities List (NPL) in July 2004 due to the impacts of acid rock drainage on Schoolhouse Brook. This Site is also eligible for the National Register of Historic Places due to its historical aspects (PAL, 2007).

2.2 Site Hydrogeology

This section briefly describes the general geology and hydrology of the area encompassing the Site. An additional discussion of the Site geology and hydrogeology is included in Section 4.2.2.

2.2.1 Overburden Geology

The region was glaciated during the most recent, Late-Wisconsinan ice advancement approximately 13,000 years ago (URS, 2006a; PAL, 2007). Outwash, glaciofluvial, and glaciolacustrine deposits were generated in the region as a result of the erosional processes caused by the advance and retreat of the glacier. The dominant overburden unit overlying bedrock in the Site region is glacial till. Significant glaciofluvial and glaciolacustrine deposits as well as recent alluvial deposits are likely to be present at lower elevations, proximal to the major rivers such as the Waits River. Small alluvial deposits derived from reworked natural and manmade soils at the Site are likely along the banks of the tributary streams that are proximal to the Site. The USDA classification of soils in the vicinity of the Site described as Tunbridge-Woodstock-Colrain-Buckland association described as being typical of soils formed in glacial till on upland terrain ranging from stony loam to very stony fine sandy loam (PAL, 2007). In addition to natural soils, the Pike Hill Mine Site includes large areas of manmade soil and disturbed soils as a result of historic mining activities including waste rock and tailings piles. The distribution of these piles are delineated along with historical mining features on Figure 2-3 (PAL, 2007). It is anticipated that surface soils away from these piles over much of the Site have been disturbed due to the expanse of historical activities associated with the Site.

2.2.2 Bedrock Geology

The Vermont Copper Belt lies within a group of Silurian-Devonian rocks comprising the western portion of the Connecticut Valley-Gaspe' Trough extending from Massachusetts to Quebec, Canada. Stratigraphic units in east-central Vermont include from older to younger, the Northfield Formation, Waits River Formation, Standing Pond Volcanics, and the Gile Mountain Formation (Slack and others, 2001). The massive sulfide deposits of the Elizabeth and Ely Mines lie within the Gile Mountain Formation of Devonian age, while the deposit at Pike Hill lies within the Waits River Formation of Silurian age. These rocks have been deformed during three stages of folding and amphibolite-grade metamorphism during the Devonian Acadian Orogeny.

The bedrock at the Site is exposed at many locations in the upper elevations of Pike Hill and is composed primarily of metasedimentary rock (calcareous pelite/schist) representing a

carbonate-rich turbidite protolith, and minor mafic metavolcanic rocks (amphibolite). The main belt of Gile Mountain rocks lies to the east of the Waits River Formation and is comprised primarily of metamorphosed siliciclastic rocks (graphitic pelite and quartzose granofels) representing a quartz-rich turbidite protolith. The Amphibolites of the Standing Pond Volcanics occur typically along the contact between the Waits River and Gile Mountain Formations, and occurs locally within the uppermost Waits River Formation, representing a suite of primarily thin metabasalts. The variations in the stratigraphic position of the Standing Pond Volcanics suggests that the contact between the Waits River and Gile Mountain Formations is time transgressive. It has been suggested that the amphibolites observed in drill cores at Pike Hill represent Standing Pond Volcanic facies (Slack and others, 2001).

2.2.3 Surficial Hydrology

The northeast slope of Pike Hill, which contains most of the waste rock associated with the Union and Eureka Mines, is drained by a single small stream, which is one of two unnamed tributaries at the headwater to Pike Hill Brook. Pike Hill Brook flows southeast from the Site, through a series of four wetlands encompassing some 60 acres, approximately 3.5 kilometers (km) downstream from the Site, and continues eastward another 3 km to its confluence with the Waits River. The Smith Mine area drains into a small unnamed tributary that flows south for approximately 1.6 km before it enters Cookville Brook. A small wetland exists just upstream of the tributary's confluence with Cookville Brook. Cookville Brook flows southeastward approximately 4.5 km from this tributary to its confluence with the South Branch of the Waits River. The South Branch then joins the main branch of the Waits River approximately 8 km downstream. The Waits River eventually flows into the Connecticut River. Both of these rivers are used for recreational purposes and contain fisheries (Piatak and others, 2006).

Shallow groundwater and surface water flow at the Site is controlled by the relatively steep, upland topography of the Site as well as the Site geology. The locations of the Union, Eureka and Smith Mines and their associated waste rock piles span the crest of Pike Hill. As a result, two adjacent watershed areas exist within the boundaries of the Site, one draining to Pike Hill Brook and the other to Cookville Brook. The boundary between these areas extends eastward from the peak of Pike Hill such that essentially all of the mine features and waste rock piles associated with the Eureka and Union Mines lie within the Pike Hill Brook watershed, and the Smith Mine lies within the Cookville Brook watershed. A small volume of Eureka waste rock

located along the crest of Pike Hill along the watershed divide lies within the Cookville Brook watershed area.

The Eureka and Union Mine areas of the Site are located in a broad but well-defined, moderately sloping valley drained by a single tributary which forms a major portion of the headwaters to Pike Hill Brook. A second headwater tributary to Pike Hill Brook drains an area immediately to the north of the Union Mine area which is apparently not impacted by the mine waste areas. These two tributaries merge at the eastern margin of the Site along Richardson Road to form Pike Hill Brook. At least four ephemeral seeps have been identified on-site within this tributary valley that emerge from within and around waste rock and tailings piles located in the lower portion of the valley below the elevation of the former flotation mill.

The Smith Mine and associated waste rock piles are located within 500 feet of a perennial tributary stream to Cookville Brook on the southeastern flank of Pike Hill, approximately 0.4 miles south of the hill top. This tributary originates approximately 1,000 feet upstream from the Smith Mine location in an area of historic prospect trenches but no mine waste piles. The tributary extends southward approximately 1.6 km to its confluence with Cookville Brook. Cookville Brook flows southeastward approximately 4.5 km from this tributary to its confluence with the South Branch of the Waits River. The South Branch then joins the main branch of the Waits River approximately 8 km downstream. The Waits River eventually flows into the Connecticut River.

2.2.4 Bedrock Hydrology

Due to the lack of subsurface investigations, information regarding the nature of bedrock groundwater in the vicinity of the Site is limited and based on general knowledge of subsurface conditions for the area. Groundwater in the bedrock is largely stored in open fractures which where interconnected form an important groundwater flow pathway. In general, the shallow portion of bedrock typically contains a higher frequency of open fractures depending on the rock type, rock fabric and extent of weathering of the rock. The frequency of open fractures typically decreases with depth in bedrock, however, the presence of large, isolated, throughgoing fractures can provide significant flow through the bedrock at depth. The flooded underground workings form unique reservoirs of groundwater which likely play an important role in the subsurface hydrology of the Site.

3.0 SITE DATA SUMMARY

Section 3.0 includes a summary of the existing Site data obtained during previous investigations conducted at the Site by EPA, the USACE, the USGS, the State of Vermont, and others.

These previous studies provide important background information, but analytical data from some of these studies is not anticipated to be incorporated into the Site RI/F database due to data validation issues. Regardless of whether analytical data will be directly incorporated into the RI/FS database, available information will be considered and used where appropriate to support the RI/FS. A brief overview of some of these studies follows.

In 1997, VTDEC completed a study of macroinvertebrate and fish populations in surface waters downstream of the Site indicating significant impairment presumably the result of acidic mine drainage from the Site (EPA, 2004a). Data from this study was not available for review. The USGS completed studies of metals in stream sediment in the watersheds of the area surrounding the mine and reported anomalous concentrations of cobalt, copper, and zinc in stream sediments from drainages near the Site (Slack and others, 1984 and 1990). Slack and others (2001) provided a compilation of the geology and geochemistry of the massive sulfide ores in the Vermont Copper Belt including results from a variety of geochemical studies of select samples of ore and host rocks used as a basis to evaluate the origin of the deposits and identify comparable analogues. The leaves of several birch species were analyzed to assess the use of airborne spectroradiometric data and were found to contain anomalous concentrations of several metals including Cu and Zn, which were correlated to anomalous spectral signatures for forest canopy surrounding the Eureka and Union Mines (Power and Milton, 1990). Two Middlebury College thesis projects included the geochemical and mineralogical analysis of waste-rock material (Wiercinski, 1999) and iron-oxide precipitates (Totten, 1999).

Since 2004, the USGS has completed two studies at the Site under an Interagency Agreement with EPA focused on the characterization of the sources of acid drainage from the Site and their potential impact of the downstream aquatic environment (Piatak and others, 2006; Kiah and others, 2007). Additional studies of wetlands and aquatic habitats downstream of the Site by USGS in conjunction with EPA are currently in progress. It is anticipated that results from these studies will be used where appropriate for future RI/FS work. A brief outline of the analytical data generated to date during these studies is provided as a basis to evaluate additional data

needs to support an RI/FS at the Site. Tables 3-1 through 3-4 list data available by media and source. Sample locations listed in these tables are shown on Figures 3-1 through 3-5.

Investigations by USGS have primarily focused on the Site waste materials and their effects on Site and downgradient surface waters (Piatak and others, 2006). Waste rock characterization performed by USGS has included the following: bulk geochemistry, mineralogy, acid base accounting, paste pH, and a modified field-leach test. Eleven composite soil samples (<2mm size material) were collected using a 30 aliquot sample grid over separate areas of waste rock and tailings piles encompassing all waste source areas of the Site (Table 3-1; Figure 3-1). Numerous additional discrete samples of efflorescent salts, precipitates and ferricrete were analyzed from mine waste piles, seeps, mine pool and adit areas. Forty-five surface water and twelve sediment samples were collected from the mine pools, seeps, and tributaries at the Site, and at select off-site locations along Pike Hill Brook including four background samples for comparison (Table 3-2; Figure 3-2). Water analyses included a wide range of major and trace elements, inorganic parameters, and standard field parameters. Sediment samples (<2mm fraction) were collected as 30-aliquot sample composites and analyzed for mineralogy and bulk metal geochemistry (Table 3-3; Figure 3-2). Water and sediment sample results from this USGS work are also incorporated into the surface water study by Kiah and others (2007). Based on its results, USGS concluded that the mine waste rock and tailings at the Site are similar to the Elizabeth and Ely mine wastes, and are acid generating with the potential to release metals to surface water (Piatak and others, 2006). However, USGS also concluded that due to the fact that the Waits River Formation contains significant amounts of calcite, the impacts to surface waters may be less severe than those observed at the other mine sites due to the buffering capacity of the host rock (Piatak and others, 2006).

The USGS recently completed hydrologic and water quality monitoring of Pike Hill Brook and tributaries, Cookville Brook tributary, and the Waits River between 2004 and 2005 (Kiah and others, 2007). Monitoring data included physical, chemical, and biological data from 14 locations with primary focus on Pike Hill Brook (Figure 3-3). Continuous stream flow and water quality information included the use of three gauging stations with analysis of surface water samples during four synoptic sampling events. Continuous monitoring parameters included stream flow, specific conductance, temperature, and pH. Surface water samples were analyzed for major ions and trace elements including sulfate. Surface water analytical data indicates that some concentrations of aluminum, cadmium, copper, iron and zinc are above the National

Recommended Water Quality Criteria. Benthic macroinvertebrate samples were analyzed from 11 sites (Table 3-4; Figure 3-3). Biological data showed a trend of gradually improving conditions downstream of the Site, with an increase in abundance and richness of taxa with decreasing concentrations of acid-rock drainage. Data from the USGS work documents seasonal variations in stream conditions including during snow melt, spring rain events, and summer/fall low-flow periods and describes preliminary interpretations of the interaction of downstream wetlands along Pike Hill Brook with surface waters from the Site.

In 2007, field sampling for the Site aquatic risk assessment was conducted by EPA (ESAT), USGS, FWS, and USACOE which included detailed characterization of water and sediment quality and the existing biota in Pike Hill Brook and the tributary to Cookville Brook downstream of Site sources (unpublished). In addition, sampling to support a preliminary evaluation of potential impacts from the Site on wetland soil, surface water and pore water was conducted in the series of four wetlands that form a wetland complex (hereinafter referred to as the "Wetland Complex") along Pike Hill Brook (see Figures 2-1 and 3-5). Results from these assessments are currently being compiled and due to be published in Fall 2008. An overview of the data collected is provided below. Results from these studies will be used as a basis to determine supplemental RI/FS investigation work.

The aquatic assessment examined trace element concentrations in surface water, pore water and sediment, relating these to the macroinvertebrate and fish communities and evaluating the toxicity of these media. A summary of samples collected, and parameters analyzed is included in Table 3-5. Sample locations are shown on Figure 3-4. The assessment included eight locations along Pike Hill Brook, six locations along the tributary to Cookville Brook, and one reference location upstream of the Site along Cookville Brook. These locations, in part, overlapped with locations analyzed in previous USGS studies (Kiah and others, 2007). Preliminary results of surface water analyses confirmed the prior USGS results of copper concentrations above Ambient Water Quality Criteria (AWQC) in Pike Hill Brook in the reach above the Wetland Complex, and below AWQC at all six locations in the tributary to Cookville Brook. Pore water evaluations included samples collected using a push point and "peepers", and analysis of in situ, centrifuged, and 28-day settled samples for comparison of collection and analysis methods. Preliminary results showed dissolved copper concentrations above AWQC at all the Pike Hill Brook locations and the five Cookville Brook locations above the wetland near the Cookville Brook confluence. Preliminary results of sediment chemistry showed copper

concentrations above the Probable Effect Concentration (PEC) except for an anomalously low result at Location 4 upstream of the Wetland Complex, and locations downstream of Wetland 2 (Locations 5 and 6). Along the tributary to Cookville Brook, preliminary sediment chemistry results show copper concentrations above the copper PEC at locations downstream of a seep between locations 10A and 10B, and below the PEC above the seep and within the wetland near the Cookville Brook confluence. Preliminary macroinvertebrate abundance and richness data show trends similar to those documented by USGS indicating impairment along the reach from the Site to a point within Wetland 2 of the Wetland Complex. Along the tributary to Cookville Brook, preliminary macroinvertebrate results suggest impairment along the reach between the seep and the wetland near the confluence with Cookville Brook.

During Summer 2007, the preliminary evaluation of the Pike Hill Brook Wetland Complex included sampling and analysis of surface water, pore water, and wetland soil from four wetlands that occur in a series along the lower reach of Pike Hill Brook as shown on Figure 3-5. The wetlands are labeled 1 to 4 from downstream to most upstream, respectively. The approximate area of Wetlands 1 through 4 are 15, 11, 34, and 0.6 acres, respectively. Over 250 soil samples were analyzed from the top 1 foot of wetlands 3 and 4 at over 100 locations using XRF analysis for Cu, Fe, Pb, and Zn (Table 3-5). Surface and pore water samples were collected from five locations in Wetland 3. Soil cores up to 2 feet deep were collected from 10 locations distributed across the 4 wetlands as shown on Figure 3-5. Preliminary results indicate elevated copper and iron concentrations with the highest concentrations in the range of 1-2% copper in soil being found in portions of Wetland 3. Based on the USGS results to date from Wetland 3, the wetland is behaving as a natural geochemical sink for metals as surface water infiltrates the wetland precipitating as metal sulfides in soil in the upper portion of the wetland, and remobilizing metals to surface water in the lower portion of the wetland. As a result of the high metals concentrations in the Wetland Complex, this area may be considered a potential source area and will require additional characterization to assess the potential impact of the wetland soils.

4.0 PRELIMINARY CONCEPTUAL SITE MODEL

The current understanding of Site sources, release mechanisms, migration pathways, and conceptual model of groundwater flow at the Site are summarized based on existing data.

4.1 Site Contaminant Sources

Historical mining operations at the Site have resulted in the deposition of piles of waste rock and tailings that are the source of acid rock drainage from the Site. The following sections describe the current understanding of Site sources and a Preliminary Conceptual Site Model of the relationship between these sources and Site media.

The Site consists of three separate mine areas known as the Union Mine, Eureka Mine, and Smith Mine areas (Figure 4-1). The Union and Eureka Mines are located along the crest of Pike Hill extending along the northeast flank of the hill within the Pike Hill Brook watershed. The Smith Mine is located on the southeastern flank of Pike Hill within the Cookville Brook watershed. Each of these areas is overlain by a series of surface waste rock piles. Around the mine openings and waste rock piles are remnant historical archaeological features such as former building and equipment foundations and walls relating directly to the mine processes that were conducted at the Site. Variations in the ore processing resulted in some variation in characteristics of wastes that are currently found on-site. The use of flotation separation techniques produced tailings piles which are generally distinguished from ore and waste rock due to their finer and more homogenous sand-sized grain size. Hand processing of ore resulted in generally cobble to boulder sized materials mixed with finer waste rock which comprises the majority of waste rock piles at the Site. A magnetic separation process was employed for a short timeframe near the end of the mining history which produced distinctly fine and concentrated mineral wastes which are identified in limited areas near the former Eureka mill location.

Previous work by USGS and the VTANR have characterized significant impacts to Pike Hill Brook and biological impairments related to acid rock drainage emanating from the Eureka and Union mining areas. In comparison, a lesser impact to the tributary to Cookville Brook has been documented relating to activities at the Smith Mine. Groundwater comprising the mine pool of the flooded underground workings may also impact groundwater in the vicinity of the mines in addition to acid mine drainage at the surface, although direct surface discharge from the mines appears to be limited.

Results from prior sampling of the waste rock and tailings piles by USGS indicates that the majority of the waste rock piles are similar in character to waste rock at the Elizabeth and Ely Mines having been derived from ore deposits of very similar composition. Based on composite

sample results from waste piles at the Site, the waste rock piles appear to have similar composition and acid-generating potential with the exception of the flotation and magnetic separation tailings. Flotation tailings tend to contain a higher concentration of pyrrhotite as a result of the removal of the chalcopyrite ore and are somewhat more susceptible to weathering and combustion as evidenced by reported smoldering of portions of these piles in the early 1980s (PAL, 2007). Magnetic separation tailings tend to contain high concentrations of quartz and feldspar and low sulfide concentrations as a result of the removal of the metal-bearing minerals.

For the purpose of describing the distribution of Site sources and evaluating what additional data is needed to support the RI/FS, the waste source areas surrounding the mines have been subdivided into smaller subareas of mine wastes based solely on their relative position with respect to mine openings and the locations of processing areas. The mine waste pile locations and locations of the pertinent mine features and remnant historical features have been mapped in detail by PAL as shown on Figure 2-3 and Figure 4-1. This map base was used to establish sample and well locations proposed.

4.1.1 Union Mine Waste Piles

Waste rock piles associated with the Union Mine consist of approximately 11 separate or overlapping piles of waste rock located in the north-central and lowermost portion of the valley. Tailings are not identified among the Union Mine waste piles and appear to be limited to the Eureka Mine mill area. Due to the apparent compositional similarity and their spatial distribution along a line extending down the center of the valley, these piles are grouped together and proposed as a single human health risk exposure area for risk characterization as discussed in Section 5.1.2. These piles are located generally downslope from the Union Mine openings and underground workings. Because they occupy the lower elevations and are centrally located in the valley, they have a greater potential for interaction with surface runoff from Pike Hill and discharging groundwater and mine drainage than waste piles further upslope. Two seeps drain from this area and the main stem of the stream draining the valley runs along the southern margin of these piles. Available information does not provide any significant distinguishing features between individual piles other than their size and location. The largest waste pile area consists of three overlapping piles filling a portion of the center of the valley. Two composite soil samples were analyzed by USGS from the larger piles in this area with copper concentrations between 3,670 and 8,410 ppm (Piatak and others, 2006).

4.1.2 Eureka Mine Waste Piles

Waste rock and tailings piles relating to the Eureka Mine extend from the peak of Pike Hill to the north and northeast along the northeast facing slope of Pike Hill. These piles are grouped into four subareas based on type of waste and location relative to the mine workings and from north to south. These subareas are: the Flotation/Magnetic Separation Mill Area; Piles Northeast of the Main Adit; Between the Upper and Main Adits; and the Peak of Pike Hill (Cuprum Shaft/Open Cut Area). Of these four subareas, only the Flotation/Magnetic Separations Mill Area piles are compositionally distinct based on results from USGS analyses. Due to the apparent compositional similarity and the spatial distribution along the length of the contiguous underground workings, the three waste rock pile subareas described in the Eureka Mine area are proposed as a single human health risk exposure area for risk characterization as discussed in Section 5.1.2 (Figure 4-1). The Flotation Mill area discussed in Section 4.1.3 and associated tailings are also preliminarily proposed as a separate human health risk exposure area as shown on Figure 4-1 and discussed in Section 5.1.2, due to the distinct character of the tailings.

4.1.2.1 Northeast of the Main Adit

There are approximately twelve closely clustered and overlapping waste rock piles covering the steep slope extending downslope between the Eureka Mine main adit and the former mill foundation. These piles appear to fill the area at the head of the main tributary stem that drains the valley. These piles may interact with mine drainage from the main adit. USGS analyzed one composite soil sample from one of the larger piles in this group with a copper concentration of 8,060 ppm (Piatak and others, 2006).

4.1.2.2 Between the Upper and Main Adits

This is an area of six relatively small, tightly clustered waste rock piles on the steep slope between the Upper Adit/Eureka Shaft and the main Eureka Mine Adit. There is a separation of over 200 feet (ft) between these piles and the piles below the main adit and no seeps have been identified in this area. These piles appear to lie above the elevation of the mine pool and are not likely to interact with mine drainage. However, drainage from this area may, in part, contribute to the mine pool. One composite sample and one grab sample was analyzed by USGS from these piles with a copper concentration of 3,240 ppm (Piatak and others, 2006).

4.1.2.3 Peak of Pike Hill

There are approximately 14 waste rock piles of varying sizes distributed along the crest of Pike Hill along the west and northwest side of the open cut near the Cuprum Shaft location and immediately west of the Upper Adit. Half of these piles are overlapping or tightly clustered near the Upper Adit. Others are distributed uphill of the open cut and a cluster of three small piles are located west and downslope of an old access road along the western flank of Pike Hill. Unlike the areas previously described above, several of the individual piles in this area appear to be beyond the Pike Hill Brook watershed, in areas likely draining to the west and south (Cookville Brook). No seeps are identified in this area. Waste piles in this area appear to lie above the elevation of the mine pool and are not likely to interact with mine drainage. However, drainage from this area may contribute, in part, to the mine pool. USGS analyzed two composite soil samples and one ore rock grab sample from the waste rock piles in this area. Copper concentrations ranged from 3,000 to 4,410 ppm (Piatak and others, 2006).

4.1.3 Eureka Mine Flotation/Magnetic Separation Mill Area

This subarea includes the area underlying and immediately surrounding the former ore processing mill and four overlapping piles of flotation tailings, partially burnt tailings, and magnetic separation tailings located immediately north of the former mill foundation. A separate and smaller pile of magnetic separation tailings is located immediately northwest of the former mill foundation. The main tributary stem that drains the valley is located on the northwest margin of these piles. A seep emanates from the downslope/northeast margin of these piles. USGS analyzed one composite soil sample from burnt tailings; one composite sample from magnetic separation tailings; and grab samples from each of the red, gray, and yellow-colored waste layers within the piles for characterization. Copper concentrations from the tailings ranged from 7,200 to 9,200 ppm (Piatak and others, 2006).

4.1.4 Smith Mine Waste Piles

The Smith Mine is located approximately 0.4 miles south of the Peak of Pike Hill within the Cookville Brook watershed on the southeastern flank of Pike Hill. The mine area consists of the collapsed main adit with three nearby waste rock piles, the largest of which is immediately downslope of the collapsed adit location. A series of historical exploratory trenches dissect the intervening hillside between the Smith and Eureka Mine areas, but no mining of ore occurred in this area, and no waste rock containing ore is known to exist in this area (PAL, 2007). No seeps are identified in the immediate vicinity of the Smith Mine waste piles; however, the unnamed

tributary to Cookville Brook is located approximately 500 ft downslope of the waste rock piles and a bedrock seep has been identified along the bank of the brook (Piatak and others, 2006). Three composite soil samples (one from each waste rock pile), four grab samples, and a soil composite sample from a downslope area were analyzed by USGS from this area. Copper concentrations from the waste rock piles ranged from 1,380 to 1,800 ppm (Piatak and others, 2006).

4.1.5 Underground Workings

The extent of the underground working in Eureka and Union Mine areas has been estimated by White and Eric (1944) based on historical records. The locations of the mine openings and related surface features have been mapped by PAL as shown on Figure 4-1 (PAL, 2007). The surface projections of the mine workings are estimated on Figure 4-1 based on a structural contour map of the ore zone compiled by White and Eric (1944).

4.1.5.1 Union Mine

The Union Mine underground workings underlie an area approximately 250 feet wide by approximately 750 feet long, sloping 25 to 30 degrees downward along the dip of the ore body to the northeast of the upper adit (White and Eric, 1944). There are two shaft openings to this mine at the most upslope point of the mine. A third opening exists is the main adit located near the central portion of the mine workings. The Union Mine underground workings appear to be nearly completely flooded up to the level of the main adit. Water samples were analyzed by USGS from the mine pool at the main adit and the uppermost mine opening and showed copper concentrations of 1,800 ppb and 4,950 ppb, respectively. The extent to which water from the mine pool is actively seeping from the mine via overland flow appears to be minimal but is not well-documented.

4.1.5.2 Eureka Mine

The Eureka Mine workings are located south of the Union Mine and extend northward from the Cuprum Shaft near the peak of Pike Hill to the main adit. The ore body and related workings are described as following the same northeasterly dipping trend as the Union Mine. The Eureka Mine underground workings underlie an area of approximately 200 feet wide by approximately 600 feet long sloping downward to the northeast from the open cut at the peak of Pike Hill along the 25 to 30 degree dip of the ore body. Four mine openings exist located from south to north: the Cuprum Shaft, Upper Adit, Eureka Shaft, and Eureka Adit. A water sample from the mine

pool was analyzed by USGS at the Eureka Adit and had a copper concentration of 1,980 ppb. The mine appears to be flooded up to this level which suggests the uppermost portion of the mine is not flooded. The extent to which water from the mine pool is actively seeping from the mine via overland flow appears to be minimal but is not well-documented.

4.1.5.3 Smith Mine

Information on the extent of the Smith Mine underground workings was limited to a projection provided in the URS Draft RI/FS Work Plan showing an area approximately 75 feet wide by 100 feet long extending westward from the shaft location, which is the only existing opening to the mine (URS, 2007a). Information on the inclination and depth of the mine was not available. The collapsed adit to the mine extends eastward from the shaft location. The underground workings appear to be completely flooded to a level just below the main shaft. No surface seepage of the mine pool has been observed. The Smith Mine pool is shallow enough to allow sampling from the surface, below the main shaft/adit opening, although the elevation has not been recorded. USGS analyzed a water sample from the mine pool at the main shaft location with a copper concentration of 992 ppb.

4.1.6 Pike Hill Brook Wetland Complex

As shown on Figure 3-5, the Pike Hill Brook Wetland Complex includes four separate wetlands that are designated from downstream to upstream as Wetland 1 through Wetland 4. Preliminary results from ongoing studies being conducted by EPA, USGS, and others indicate elevated copper and iron concentrations are present in shallow wetland soil within four wetlands located along Pike Hill Brook downstream from the Site. To date, the studies have been focused on Wetland 3 which appears to contain the highest concentrations of metals in wetland soil, in the range of 1-2% copper in localized areas, comparable to concentrations in waste rock at the Site. Elevated copper and iron concentrations were detected throughout the sampled areas of Wetlands 3 and 4 with copper concentrations typically in the range of 100 to 3,000 ppm over wide areas. The preliminary conceptual Site model proposed by the USGS based on results to date from Wetland 3 suggests the wetland is behaving as a natural geochemical sink where surface water containing dissolved metals from the Site enters the wetland, infiltrates the wetland soil, and precipitates metal sulfides in soil under the reducing conditions in the upper reaches of the wetland. Metals appear to be remobilized to surface water in the lower reach of the wetland, as the groundwater encounters oxidizing conditions as it enters the stream. As a result of the high metals concentrations in the Wetland Complex, this area may represent a

potential source area and will require additional characterization to assess the potential impact to the wetland soils. Results to date, from the tributary to Cookville Brook at the location of the small wetland, do not indicate a significant impact to this wetland and as a result additional characterization may not be warranted.

4.2 Contaminant Migration

The mechanisms of contaminant migration, transport pathways, and media potentially affected by the Site contamination are discussed in the following Sections.

4.2.1 Release Mechanisms

There are four primary mechanisms that can release and transport contaminants at the Site: surface water runoff, leaching into groundwater, seeps, and wind erosion. Surface water runoff occurs during precipitation events or snow melts when contaminants in the soil and waste piles are released and transported to other areas on-site and off-site via Site drainage features. Precipitation, snow melt, surface water, and groundwater which comes into contact with iron sulfide ore minerals, dominantly pyrrhotite, in the waste rock/tailings and bedrock results in weathering (oxidation) and leaching of the ore and host rock through a series of chemical reactions that define the primary mechanism by which acid drainage is generated at the Site (Seal and others, 2001; Hammarstrom and others, 2001). The resultant low pH of drainage from these sources carries significant concentrations of elements and base metals that along with high acidity and high sulfate concentrations impact the surface waters downstream from the Site. In addition, groundwater from the underground mine pools may contribute to the release of contaminants through the discharge of acid mine drainage via surface flow from mine openings and through fractures in the bedrock. In addition, erosion of surface waste rock/tailings may result in mass transport of potentially acid- and metal-generating materials into the stream sediment downgradient of the Site. Due to the barren to poorly-vegetated nature of the surface waste rock and tailings piles, wind transport of fines also has the potential to spread these materials beyond the footprint of the piles. As a result, surface soil, subsurface soil, sediment, surface water and groundwater at the Site and proximal to the Site are potentially impacted by Site sources. In addition, surface water and sediment distal from the Site along streams downgradient are potentially affected. Trophic transfer of contamination in the aquatic and terrestrial food chains as a result of surface water and sediment contamination is also a potentially important migration pathway. The potential significance of exposures to human populations, the food chain, and environmental receptors is described in Section 5.0.

4.2.2 Receiving Media and Transport Pathways

As a result of the various release and transport mechanisms, a number of media both on-site and off-site can be potentially affected. The on-site media include: soil (surface and subsurface), sediment and surface water in the on-site drainage features, and groundwater. The potentially affected off-site media include: soil (surface and subsurface, and wetland soil), groundwater, fish tissue, sediment, and surface water associated with the surface water pathway including Pike Hill Brook, the Pike Hill Brook wetlands, the unnamed tributary to and Cookville Brook itself, the South Branch of the Waits River, the Waits River, and the Connecticut River.

4.2.2.1 Soil

Existing data from Site soils is limited to shallow depth characterization of waste source areas which focused on the mineralogical and chemical characterization of the mine wastes (Piatak and others, 2006). As a result, the characteristics of natural subsurface soils at the Site are not known. The overburden at the Site is likely comprised of glacial till, typically a gray to olive gray to brown, variably dense, poorly sorted, nonstratified deposit comprised of clay to cobble-sized material and of variable thickness. Based on the relatively steep topography at the Site and the extent of bedrock exposure, it is anticipated that glacial till at the Site is relatively thin (less than 10 ft). The thickest deposits would be anticipated in the central part of the valley along the tributary to Pike Hill Brook. This area is also overlain in part by waste rock and tailings piles which are estimated up to 20 to 30 feet in thickness locally and likely represent the largest volume of the overburden at the Site. The waste rock pile materials are derived from processing of the ore and host rock by hand-cobbing and typically consist of a broad range of grain size from silt to boulder-size material, while tailings tend to be finer, better sorted and more distinct mineralogically due to the more efficient separation technology (flotation, magnetic separation) used to generate them. In comparison to natural soils, waste rock and tailings exhibit a wide range of colors from brownish yellow to red when oxidized to black where anoxic. Based on the Site history, shallow soils are likely to be widely disturbed. Although the lateral extent of waste rock piles have been preliminarily identified by PAL during the Site survey of archaeological features, the potential impact of these waste areas on surrounding soils will require additional characterization.

4.2.2.2 Bedrock

The bedrock at the Site, exposed at many locations in the upper elevations of Pike Hill, is primarily composed of the Waits River Formation, a calcareous pelite/schist with minor amounts of mafic metavolcanic rock (amphibolite). These rocks have been deformed during three stages of folding and amphibolite-grade metamorphism during the Acadian Orogeny. The ore zones within the mines are described as being stratiform and stratabound, meaning they follow the same orientation as the layering within the country rock. The ore zones consist of pyrrhotite and chalcopyrite, with minor sphalerite and pyrite and strike approximately north-south with a dip of about 30 degrees to the east (Slack and others, 2001). The ore was found to occur in overlapping sheet-like lenses. The location of the ore zone was projected on a structural contour map such that the top of the zone lies between 50 and 250 ft below the ground surface in most locations in the Union and Eureka Mine areas (White and Eric, 1944). Information on the extent of the ore zone at the Smith Mine was not available. As a result of the deformational history of these rocks, the orientation of layering within the bedrock is anticipated to be locally variable. Bedrock mapping in the Pike Hill area by USGS documented the orientation of cleavage in the bedrock at the Site which is largely parallel to compositional layering (White and Eric, 1944). Additional data documenting the occurrence and orientations of fractures within bedrock at the Site were not available, but will be important in interpreting contaminant migration and groundwater flow in the bedrock. Although bedrock is not typically viewed as a source of contamination, the fact that the Site impacts are directly related to minerals extracted from the bedrock at the Site requires that consideration be given to remnant or unmined ore, which remains in the bedrock underlying the Site and vicinity. To the extent that the presence of massive sulfide ore at the Site is a naturally occurring condition, the evaluation of the influence of mining at the Site must take this into account; in particular with regard to the potential impact to bedrock groundwater.

4.2.2.3 Sediment and Surface Water

The Eureka and Union Mine areas are located in a broad but well-defined, moderately sloping valley which forms a major portion of the headwaters to Pike Hill Brook. As a result, the contribution of flow to Pike Hill Brook from this area is considerable and the quality of water in the brook downstream is highly dependent on the composition of the runoff from these areas. A schematic interpretation of groundwater flow at the Site is illustrated in Figure 4-2 showing the inferred relationship between groundwater and surface water at the Site. The headwaters of the Pike Hill Brook tributary are located at an elevation between the former ore mill and lower Union

Mine waste rock piles based on the location of multiple groundwater seeps observed in this area, which coalesce into a perennial stream below the lowermost waste rock piles, with a range of flow between 0.01 and 2.5 cfs prior to entering Pike Hill Brook (Piles 1, 2, 3 and 7 of PAL, 2007; Kiah and others, 2007). Considering the steep topography in the upper elevations of the Site, it is anticipated that precipitation will infiltrate downward, recharging groundwater in the overburden and bedrock and move laterally and downward toward the discharge areas defined by the tributary streams in the lower portions of these valleys. In general, the natural till soils, where thin, will have limited storage capacity and low hydraulic conductivity. Therefore, the overburden may be unsaturated and the primary flow path of shallow groundwater may be along the bedrock surface or within the shallow portion of the bedrock depending on fracture porosity of the rock. In addition, waste rock piles in the upper elevations are likely to drain precipitation readily downward into the natural overburden and shallow bedrock. The USGS observed rapid fluctuations in the flow of the tributary to Pike Hill Brook during significant rain events. This suggests a generally low permeability and/or low storage capacity of the overburden and shallow bedrock resulting in considerable overland flow and rapid discharge of shallow groundwater to the seeps and tributaries (Kiah and others, 2007). The ephemeral nature of the seeps at the Site also suggests that the base flow observed year round in the lower portions of these tributary valleys is derived largely from bedrock groundwater discharging upward through the overburden in these areas. The volume of mine pool discharge directly from Eureka and Union Mine openings to the surface appears to be minor as no streams have been identified from these locations.

Results from sediment and surface water samples collected to date by USGS from seeps and tributary streams indicate that these Pike Hill Brook waters are impacted by acidification and elevated concentrations of metals. It is assumed these metals are derived from the previously described mine rock and tailings piles resulting in exceedances of regulatory criteria along the entire length of Pike Hill Brook (Piatak and others, 2006; Kiah and others, 2007). Copper concentrations in surface water entering Pike Hill Brook from the Site range from 1,940 to 30,800 ppb. The range of pH measured in the tributary to Pike Hill Brook was between 2.7 and 4.4 standard units (Kiah and others, 2007). The sediment in the tributary to Pike Hill Brook downgradient of the waste rock piles has a copper concentration of 8,070 ppm that is comparable to the waste rock (Piatak and others, 2006).

The Smith Mine area is located along the western flank of a narrow south-facing valley drained by a 1.6 km long tributary to Cookville Brook. The headwater to this tributary is located upgradient of the mine area and does not appear to have any significant branches in the vicinity of the mine. This tributary passes within 500 ft of the mine waste rock piles and at least one significant seep was identified by USGS along the bank of this tributary downslope of the mine. No surface drainage has been observed directly from the Smith Mine pool. Stream flow of this tributary was estimated between 0.19 and 0.63 cfs during two observations by USGS (Kiah and others, 2007). Copper concentrations in surface water downstream from the Site ranged from 3.6 to 11 ppb with a pH of 7.9 su. Only one of three samples collected exceeded a chronic toxicity standard. However, a seep water sample collected from the bank of the tributary downgradient of the Site had a copper concentration of 5,030 ppb and a pH of 4.4 su. A copper concentration of 539 ppm was detected in a sediment sample from this tributary (Piatak and others, 2006). As a result, the magnitude of the potential impact to the tributary and to Cookville Brook from the Smith Mine area appears to be low, and is significantly less than that posed by the Eureka and Union Mine areas on Pike Hill Brook.

Based on studies by USGS, the primary source of impact to surface water is derived from the interaction of water from snow melt, rain, and groundwater percolating through the piles of waste rock and tailings which subsequently transports low pH, metal-laden water and sediment downgradient into Pike Hill Brook and the tributary to Cookville Brook. Pike Hill Brook extends approximately 7 km from the Site to the confluence with the Waits River. Copper concentrations in Pike Hill Brook immediately upstream of the confluence range from 4.3 to 30 ppb, with 2 of 4 samples exceeding a chronic toxicity standard (Kiah and others, 2007).

The Pike Hill Brook Wetland Complex is located approximately 3.5 km downstream of the Site and intercepts surface water flow impacted from the Site. Preliminary characterization studies of these wetlands and the potential impact of runoff from the Site to these wetlands is currently being studied by EPA, USGS and others (unpublished) as previously discussed in Section 4.1. Preliminary results suggest that these wetlands have been widely impacted by runoff from the Site and may act as a significant sink and potential source of metals. Based on USGS data, impacts to surface water quality from the Site beyond the confluence with the Waits River are within regulatory criteria.

4.2.2.4 Groundwater

Groundwater at the Site is present in overburden and bedrock. Due to the lack of subsurface investigations at the Site, the thickness of waste rock piles, and the character and thickness of the natural overburden soils at the Site is not known. Due to the moderately steep slopes at the Site, natural soil overlying bedrock is likely to be thin (less than 10 ft) and as such will have a limited capacity to store groundwater. Groundwater in the bedrock is largely stored in open fractures. Where interconnected, fractures can form a considerable reservoir of groundwater. In addition, the flooded underground workings form unique reservoirs of groundwater which may play an important role in the subsurface hydrology of the Site. There are currently no monitoring wells at the Site and as a result, the groundwater conditions at the Site can only be interpreted from surface observations. Based on information from previous studies at the Site, a schematic interpretation of groundwater flow at the Site is illustrated in Figure 4-2.

The upper elevations of Pike Hill above the levels of the mine pools will tend to be an area of recharge such that precipitation will tend to infiltrate downward through unsaturated mine waste and overburden and into the bedrock. In areas overlying the underground workings, groundwater may be intercepted and flow through the open areas of the mine until it reaches the level of the mine pool. In the case of the Eureka Mine pool, there is likely some flow at or very near the surface which is regulating the mine pool at the elevation of the lower adit, such that the hydraulic head of groundwater in bedrock in the vicinity of the mine is maintained at this level. As a result, bedrock groundwater in the vicinity of the mine may migrate toward the mine pool during periods of significant recharge. If the mine pool is perched, such that the elevation of the mine pool is above the head levels in surrounding bedrock then water from the mine pool will tend to recharge the surrounding bedrock. Figure 4-2 illustrates the case where the hydrostatic head levels in the vicinity of the mine are depressed due to the unrestricted flow from the mine opening. Based on the water levels observed at adits to the three mines, flow directly from the uppermost part of the mine pool may be influencing shallow groundwater in these areas (Paitak and other, 2006).

In general, shallow groundwater will tend to flow northeastward and eastward toward the discharge area in the lower portions of the tributary valley and Pike Hill Brook. Deeper groundwater may be directed in a more easterly or southeasterly direction in response to regional scale discharge areas or local pumping stresses. The lower portion of the Pike Hill Brook tributary valley, below the elevation of the former ore mill, where slope gradients are

somewhat gentler and multiple groundwater seeps have been observed in and around waste rock piles, defines an area of local discharge extending downslope to Richardson Road. In this area, the base flow of the seeps and tributary stream are likely being fed by the discharge of groundwater from the shallow overburden, and bedrock groundwater moving through the overburden. In addition, the moderately steep terrain, low groundwater infiltration rates, and limited storage capacity of the thin overburden and shallow bedrock results in the rapid discharge of spring snow melt and significant rain events to surface waters via overland flow, resulting in extreme fluctuations in stream flows over short duration (Kiah and others, 2007). Infiltration of snow melt and rainfall during the Spring and periods of intense rainfall may also result in local mounding of groundwater in areas overlain by the waste piles due to their likely higher permeability and storage capacity.

During periods of the year when the magnitude of precipitation is low, it is likely that the saturated thickness in waste rock piles is limited, due to their presumed coarse grained and poorly consolidated nature as evidenced by the lack of seeps above the base of the piles. Figure 4-2 shows an inset illustration of how groundwater may interact with waste rock and tailings in the lower portions of the valley where groundwater is likely to discharge into overlying materials with greater hydraulic conductivity. During periods of increased rainfall and snow melt, rapid fluctuations of the water table may result in periods during which the lower portions of waste rock/tailings piles may be intermittently saturated.

In the vicinity of the Smith Mine, shallow overburden and bedrock groundwater is anticipated to flow southeastward toward the Cookville Brook tributary. Deeper bedrock groundwater may flow in a more southerly direction influenced by more regional scale discharge areas. The limited volume of waste rock and reportedly small scale of the underground workings at the Smith Mine may limit the potential impact on groundwater at the Site.

Based on limited Site information, and the preliminary interpretation of groundwater conditions previously described, waste rock piles may potentially impact groundwater and overland flow in the upper elevations of Pike Hill, while the discharge of shallow groundwater in the lower portions of the valley may prevent the potential impact to deeper groundwater in those areas. The potential impact from the mine pools is dependent of the flow characteristics of the bedrock. In addition, naturally occurring, unmined massive sulfide ore that may occur within bedrock in the vicinity of the Site may also impact groundwater quality and complicate interpretation of the

affects of mining on groundwater quality. Groundwater use in the vicinity of the Site is very limited with a low density of private drinking water wells in the immediate vicinity and downgradient of the Site. Information was not available on the quality of groundwater from nearby drinking water wells. Data documenting the orientations of fractures within bedrock at the Site were not available, but will be important in interpreting groundwater flow in the bedrock. Bedrock outcrops identified in the Cookville Brook tributary streambed near the Smith Mine suggests that the quality of bedrock groundwater in this area will have a strong influence on surface water quality (White and Eric, 1944).

5.0 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

The purpose of this section is to present a proposed approach to performing the human health risk assessment (HHRA) and the baseline ecological risk assessment (BERA) for the Site.

5.1 Human Health Risk Assessment Approach

The proposed approach for the HHRA is based on what is currently known about the existing contamination on the Site, the likely potential receptors and exposure pathways based on the current and future uses of the Site, and to a lesser degree, the HHRA performed for the Elizabeth Mine Site.

5.1.1 Preliminary HHRA Exposure Pathway Analysis

The HHRA will focus on those human populations likely to be exposed to each of the potentially contaminated Site media currently and/or in the future. This approach ensures that the range of risks over various population subgroups are characterized for potential activities and land/water uses.

5.1.1.1 Exposure Media and Routes of Exposure

The potentially contaminated media include soil, surface water, sediment, groundwater, mine pool water, and fish tissue. The list below presents these media along with the likely routes of exposure:

- Soil – contaminants in the soil may be incidentally ingested and absorbed through the skin by exposed humans. In addition, contaminants adsorbed onto particulate released from the soil into the air would be available for inhalation.

- Surface Water – contaminants in the surface water may be incidentally ingested and absorbed through the skin by exposed humans.

- Sediment – contaminants in the sediment may be incidentally ingested and absorbed through the skin by exposed humans.

- Groundwater – contaminants in the groundwater may be ingested and absorbed through the skin by exposed humans while showering and bathing.

- Mine Pool Water – contaminants in the surficial expressions mine pool water may be incidentally ingested and absorbed through the skin by exposed humans. Any contact with mine pool water is expected to be of short duration.

- Fish – contaminants in edible fish tissue may be consumed by anglers and their families.

There are several pathways of exposure that could possibly exist in the areas surrounding the Site, either currently or in the future, which are proposed to be eliminated from consideration in the HHRA. These include the consumption of game obtained while hunting (deer, waterfowl, etc.) in the area and the consumption of meat and possibly milk from cattle that might graze in areas contaminated with metals from the Site. The reasons for eliminating these pathways from evaluation in the HHRA include:

- Minimal potential for the metals of concern (e.g. copper and iron) to bioaccumulate in the edible tissues of these animals. These pathways are typically of concern from potential exposure to lipophilic organic compounds like PCBs and dioxin/furans. The likely contaminants at the Site are not lipophilic and are likely to be regulated by a number of mechanisms, such as metabolism and elimination that preclude the accumulation of significant concentrations in edible tissue or milk.

- Cattle (beef or dairy) would need a large area to graze and are typically fed a diet that consists of a significant portion of grain that would be expected to be grown outside of the area of concern. Potential grazing activities in areas with contaminated soils would likely be minimal.

- Deer generally range across hundreds of acres and would be exposed to a wide range of habitats, most of which would likely be completely uncontaminated by the Site. In addition, the most critical exposure to deer at this Site would be incidentally ingested soil (and possibly sediment to a lesser degree) and given the nature of the typical diet - browse (leaves and shoots of woody plants), forbs (broad-leafed weeds and flowering plants), and mast (fruits and nuts) - a deer would be unlikely to consume a significant amount of incidentally ingested soil. Also, given the number of sources of surface water available, it is unlikely that this would be a significant exposure route.

- Ducks typically feed on invertebrates and aquatic vegetation, and have a limited rate of sediment consumption. As noted above, the metals of concern, while potentially high in the sediment, are not likely to bioaccumulate to a significant degree in the edible tissue of ducks or other waterfowl.

In addition, given the nature of metals in general and the potential exposure pathways at this Site, other pathways such as inhalation, incidental soil/sediment ingestion, and dermal absorption are likely to result in significantly higher exposures to both child and adult receptors than any of the above pathways. It is recommended that these exposures be discussed qualitatively in the HHRA unless the Site investigation process provides evidence that one or more of these pathways could become critical in the evaluation of human health risks.

5.1.1.2 Potentially Exposed Populations

The HHRA will focus on those human populations likely to be exposed to the potentially contaminated Site media currently and/or in the future. There are a number of activities that may lead to contact with Site media including: riding ATVs, hunting, birding, horseback riding, spelunking, hiking, and adolescent gatherings. Of these activities, riding ATVs appears to be a common activity as indicated by the trails and tracks in and around the Site. In addition, there is a trailer located close to the Site which indicates potential current residential use. It will be assumed that the Site will be used for residential purposes in the future. Based on the CSM (see Section 4.2 and Figure 5-1) and the current and potential future land and water uses, five potentially exposed populations are proposed to be evaluated in the HHRA. These five potentially exposed populations include:

- Current/future recreational visitors (adolescent and adult) – the soil exposure to the recreational visitors will be based on riding ATVs since this is a common recreational activity at the Site that could result in an intensive level of soil contact. The ATV riding exposure will be based on conservative assumptions that will cover the potential exposure associated with other, less-intensive soil contact activities. It will be assumed that the recreational visitors contact the on-site piles and the surface soil surrounding the Site. Therefore, the incidental soil ingestion, the dermal contact and absorption, and the inhalation pathways are proposed to be evaluated for these receptors. In addition to contacting the Site soil, the recreational visitors will also be assumed to contact the mine pool water while exploring the mines shafts, adits, and any accessible underground complexes. The duration and magnitude of contact with the mine pool water is expected to be low.

- Current/future swimmers/waders (adolescent and adult) – the swimmers/waders will be assumed to contact the surface water and sediment while engaging in recreational activities in downstream waterbodies. The incidental ingestion and the dermal contact and absorption pathways are proposed to be evaluated for these receptors.

- Current/future fish consumers – these receptors represent anglers who catch and consume fish from the impacted downstream waterbodies. It will be assumed that the anglers share their catch with other household members (i.e. young children). For the purposes of this document, recreational level fish consumption will be assumed. However, the degree of potential fish consumption (subsistence or recreational) will be determined for each potentially impacted downstream waterbody as the HHRA process evolves. Subsistence level consumption will be evaluated if it is determined that a waterbody has both the ability to produce enough fish of edible size to support subsistence level ingestion and the presence of any local subpopulations that are likely to ingest a large amount of fish. Based on preliminary information, subsistence level consumption of fish obtained from Pike Hill Brook and Cookville Brook is not likely. It may be possible that Waits River can support subsistence level consumption. However, this has not been confirmed.

- Current/future residents (young child and adult) – it is possible that the nearby residents use the Site on a regular basis. This type of exposure is assumed to continue into the

future. Therefore, residential exposure will be evaluated for the current and future uses of the Site. The current residents will be assumed to contact the surface soil and the future residents will be assumed to contact the surface and subsurface soil as a result of soil mixing during future excavation and construction activities. The incidental soil ingestion, the dermal contact and absorption, and the inhalation pathways are proposed to be evaluated for residential receptors. Local area residents currently use groundwater as their source of potable water. This is expected to continue in the future. It is not known if the local residents' groundwater is impacted by the Site. Exposure to groundwater assuming the local residents ingest the groundwater underlying the Site through the ingestion and showering/bathing exposure routes will be evaluated for both current and future use scenarios.

- Future construction workers – the Site may undergo some type of construction activities at some point in the future, which may result in contact with surface and subsurface soil (top 10 feet assumed). Therefore, the incidental soil ingestion, the dermal contact and absorption, and the inhalation pathways are proposed to be evaluated for these future receptors. The duration of intensive contact with the Site soil during construction activities such as excavation is expected to be short.

The generation of dust containing contaminants as a result of wind erosion, riding ATVs, and construction activities and the subsequent inhalation by exposed populations is an important route of potential exposure for the Pike Hill Copper Mine Site. EPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (SSG) (EPA, 2002a) will be used to estimate emissions. Dust emissions as a result of wind erosion will be modeled to evaluate residential inhalation exposure. Emissions as a result of heavy truck traffic on unpaved roads will be used to estimate inhalation exposure to recreational visitors while riding ATVs and to workers during construction activities.

5.1.2 HHRA Exposure Areas

The first step in developing the HHRA approach is to determine the manner in which the Site will be divided into exposure areas (EAs). The Pike Hill Copper Mines Site will be evaluated based on the existing array of waste and tailings piles, the current and potential future land and water uses, the on-site drainage features, and downstream waterbodies. The EAs will be determined to enable the HHRA to focus on specific areas and exposure media and estimate

risks for those areas and media alone. Table 5-1 presents the proposed EAs, by media, for the Site. The proposed EAs are discussed in the following subsections.

5.1.2.1 Soil Exposure Areas

Appendix B of the PAL report (PAL, 2007) was reviewed to determine a suitable manner in which to identify the soil EAs. A total of four soil EAs are proposed (see list below). Figure 4-1 provides the extent of the proposed EAs.

- Various Union Mine waste piles.
- Eureka Mine Tailing Piles (magnetic and flotation).
- Various Eureka Mine waste piles.
- Smith Mine waste piles.

As presented on Figure 4-1, the proposed soil EAs are large. The EAs were delineated based on the assumption that the contaminant levels and Site use are relatively similar within each area. If the analytical results from the collected samples or observations recorded indicate any specific areas of elevated contamination or obvious use, the extent of the soil EAs may be modified. Exposure doses and risks (cancer and noncancer) will be calculated for each soil EA in the HHRA. In addition, doses and risks will be calculated for the Union and Eureka Mines piles combined.

5.1.2.2 Surface Water, Sediment, and Fish Exposure Areas

The surface water and sediment EAs were identified based on the waterbody and considered the length of the EA and waterbody characteristics such as morphology and flow regimes. A total of three surface water and sediment EAs are proposed for the Union and Eureka Mines. They include:

- Pike Hill Brook downstream to the wetlands complex- this EA does not include the on-site tributary to Pike Hill Brook.
- Pike Hill Brook wetlands complex.
- Pike Hill Brook wetlands complex discharge downstream to the Waits River.

Two surface water and sediment EAs are proposed for Smith Mine including:

- Unnamed tributary to Cookville Brook - the unnamed tributary is not on site. It potentially receives runoff from the Smith Mine area and it is approximately 1.6 km in length.
- Cookville Brook downstream to the South Branch of the Waits River.

The need to evaluate the potential exposure with the surface water and sediment in the Waits River will be determined after sampling results are known. It is possible that the Site contamination is not adversely affecting surface water and sediment in the Waits River. It is assumed that the streams and seeps (perennial and ephemeral) located on Site will not be frequently contacted by any individual and that the amount of water does not provide a significant exposure potential. Therefore, on-site exposure to surface water (with the exception of mine pool surface water) and sediment will not be evaluated.

Each surface water and sediment EA will be investigated to determine if the waterbody supports edible fish communities. Impacted areas generally do not have fish that people would consume (e.g. trout) and, therefore, dace will be used as a proxy for trout. The available dace data will be compared to the Region 3 fish risk-based concentrations (RBCs). If the dace concentrations are less than the RBCs, it is likely that the concentrations in edible fish will not be of concern. If the datasets allow, trout concentrations will be predicted using the dace data and the available trout data.

5.1.2.3 Groundwater

A number of monitoring wells are proposed to be drilled and sampled. These wells will be associated with the Union Mine Area, the Eureka Mine Area, and the Smith Mine Area. The data associated with these wells will be evaluated in the HHRA.

5.1.3 HHRA Exposure Parameters

The exposure parameters that will be used to calculate the exposure doses (chronic daily intakes or CDIs) for each receptor population through the applicable exposure routes are presented in Tables 5-2 through 5-6. Two types of exposure doses will be calculated depending on whether the contaminant is considered to be carcinogenic. In the first model, the doses will be averaged over the assumed exposure duration and will be used to evaluate the potential for noncancer health effects (i.e. the average daily dose [ADD]). The second model, in which the

doses will be averaged over a 70 year lifetime, will be used to evaluate potential carcinogenic risk (i.e. the lifetime average daily dose [LADD]). The exposure doses will be expressed as either administered (oral, inhalation) or absorbed (dermal) doses, in milligrams of contaminant per kilogram body weight per day (mg/kg-day).

To ensure that the risk estimates will be conservative and protective of human health, the intakes will be based on a combination of average and upper-end, typically the upper 90th or 95th percentile, exposure parameters. Many of the proposed exposure parameters are default values recommended by EPA in various current risk assessment guidance documents. In some cases, professional judgment was used to develop the proposed parameters. In other cases, additional work still needs to be performed to determine the exposure parameters.

5.1.3.1 Current/Future Recreational Visitors

Table 5-2 presents the proposed exposure factors for the recreational visitors. The adolescent will be assumed to be exposed from 10 to 18 years of age. Thus, the exposure duration (ED) for the adolescent will be 8 years. For the adult, an ED of 24 years will be used based on the assumption that the adult visitor is a nearby resident. The adolescent body weight (BW) will be 52 kg. This value is the average body weight for males and females ages 10 to 18 (see Tables 7-6 and 7-7 of EPA, 1997a). The adult body weight will be 70 kg (EPA, 2002a).

- The recreational visitors will be assumed to be exposed to Site soil for 8 months of the year (April through November) for 3 days/week (assumes 4.33 weeks per month). This equates to an exposure frequency (EF) of approximately 104 days/year. The visitors are not expected to contact the soil during January, February, March, and December.

- The incidental soil ingestion rate (IRS) will be assumed to be 100 mg/day. This value represents the adult IRS conventionally used for residential exposure (EPA, 2002a). The fraction ingested (FI) will be 1.0 indicating that 100% of the amount of ingested soil will be come from the Site.

- The exposed skin surface area (SA) for soil exposure will be assumed to consist of the head, hands, forearms, lower legs, and feet. Using the data provided in Exhibit C-1 in RAGS Part E (EPA, 2004b), the SAs for the adolescent and adult will be 5,900 cm^2 and 6,900 cm^2, respectively. The soil-to-skin adherence factor (AF) will be based on the

geometric mean value for the heavy equipment operators activity (0.2 mg/ cm^2) (EPA, 2004b). The AF from this activity was selected for the recreational visitors because it is assumed to represent an upper-end activity for individuals riding ATVs. The dermal absorption factors (ABS) will be obtained from RAGS Part E.

- Inhalation of dusts generated while riding ATVs will be evaluated by using the moderate short-term inhalation rates for outdoor workers (EPA, 1997a; see Table 5-23). The air inhalation rate (IRA) will be 1.5 m^3/hr. It will be assumed that the recreational visitors will be at the Site for a total of two hours. Therefore, the daily IRA will be 3 m^3/day. As previously mentioned, the particulate emission factor (PEF) will be calculated based on heavy truck traffic on unpaved roads according to the SSG (EPA, 2002a).

- The recreational visitors will be assumed to be exposed to the mine pool water once a month for 5 months of the year (May through September) when the weather is conducive to water contact activities. Each exposure event will be assumed to last for one hour. The incidental surface water ingestion rate will be assumed to be 0.05 L/hour (EPA, 1989). Dermal contact with the mine pool water will be assumed to occur to the face, hands, and forearms. Contact with the legs and feet is likely to be avoided. Thus, the SAs for the adolescent and adult will be 2,100 cm^2 and 2,500 cm^2, respectively. The dermal permeability coefficient (Kp) will be obtained from RAGS Part E.

5.1.3.2 Current/Future Swimmers/waders

Table 5-3 presents the proposed exposure factors for the swimmer/waders. The ED and BW values described in Section 5.1.3.1 for the recreational visitors will also be used for the swimmers/waders. However, the swimmers/waders will be assumed to be exposed to sediment and surface water for 5 months of the year (May through September) when the weather is warmer and conducive to water contact activities for 1 day/week (assumes 4.33 weeks per month). This equates to an EF of approximately 22 days/year. The swimmers/waders are not expected to contact the surface water and sediment during January through April and October through December.

- The IRS will be assumed to be 100 mg/day. The FI will be 1.0.

- The SA for sediment exposure will be assumed to consist of the head, hands, forearms, lower legs, and feet. Therefore, the SAs for the adolescent and adult will be 5,900 cm^2 and 6,900 cm^2, respectively. The AF will be based on the geometric mean value for the reed gatherers (0.32 mg/ cm^2) (EPA, 2004b). The AF from this activity was selected for the swimmers/waders because it is assumed to represent an upper-end activity for individuals wading and contacting sediment.

- Each surface water exposure event will be assumed to last for 2 hours. The incidental surface water ingestion rate will be assumed to be 0.05 L/hour. While swimming, it will be assumed that the individual is fully immersed. Thus, the SAs for the adolescent and adult will be 14,900 cm^2 and 18,000 cm^2, respectively.

5.1.3.3 Current/Future Fishermen

Table 5-4 presents the proposed exposure factors for the fishermen. The total ED will be assumed to be 30 years (6 years for young child and 24 years for adult). The residential EF of 350 days/year will be used. The child BW will be 15 kg (EPA, 2002b). The fish ingestion rate (IRF) has not yet been determined. Further evaluation is needed to determine the degree of consumption (i.e. subsistence level versus recreational level). After this is determined, a regional-specific IRF will be proposed.

5.1.3.4 Current/Future Resident

Table 5-5 presents the proposed exposure factors for the residents. The total ED will be assumed to be 30 years (6 years for young child and 24 years for adult). The EFs will be 150 days/year for soil contact and 350 days/year for groundwater contact. The soil contact EF is based on the likelihood that the residents will not contact the soil when the ground is frozen or snow-covered. The same EF values were used for the GE-Housatonic River Site HHRA and the Elizabeth Mine Site HHRA.

- The IRS values will be assumed to be 100 mg/day and 200 mg/day for the adult and child, respectively (EPA, 2002a; 2002b). The FI soil will be assumed to be 1.

- The SA will be assumed to be 2,800 cm^2 for the child (head, hands, forearms, lower legs and feet) and 5,700 cm^2 for the adult (head, hands, forearms and lower legs) (EPA, 2004b). The AF for the child will be the geometric mean value for the daycare child (0.2

mg/ cm^2). The adult AF will be the geometric mean value for the resident gardener (0.07 mg/ cm^2). The SA and AF values proposed to be used are default values for residential exposure as recommended by EPA.

- Inhalation of dusts generated as a result of wind erosion will be determined by conventional techniques presented in the SSG assuming the child inhales 10 m^3/day and the adult inhales 20 m^3/day (EPA, 2002a).

- The groundwater ingestion rate (IRW) values will be assumed to be 2 L/day and 1 L/day for the adult and child, respectively (EPA, 2002a; 2002b).

- The SA for exposure while bathing/showering will be 6,600 cm^2 and 18,000 cm^2 for the child and adult, respectively. The child bathing time will be 1 hour/event and the adult showering time will be 0.58 hour/event (35 minutes) (EPA, 2004b).

5.1.3.5 Future Construction Worker

Table 5-6 presents the proposed exposure factors for the construction worker. The adult construction worker will be assumed to be exposed for 60 days/year (i.e. 5 days/week for 12 weeks). The IRS will be assumed to be 330 mg/day (EPA, 2002a). The FI is assumed to be 1. The SA will be assumed to consist of the 50th percentile values for head, hands and forearms of the male and female (i.e. 3,300 cm^2). The AF will be 0.24 mg/ cm^2, which represents the geometric mean value for the utility workers activity. The IRA will be 20 m^3/day. As previously mentioned, the PEF will be calculated based on heavy truck traffic on unpaved roads according to the SSG (EPA, 2002a).

5.1.4 HHRA Bioavailability Considerations

Based on EPA's Framework for Metals Risk Assessment (EPA, 2007a), there may be a need to adjust the potential exposure to account for the differences in absorption between the form of the metal assumed in the derivation of the toxicity factor (slope factor or reference dose) and the form of the metal assumed to be present at the Site. Currently, established toxicity factors are not available for key metals. Copper, for example, has a drinking water standard presented in EPA's Health Effects Assessment Summary Tables (HEAST) (EPA, 1997b) that has been used as the basis of the reference dose used by a number of EPA Regional offices. However, it has been concluded that the available data is inadequate for the calculation of a copper reference

dose (EPA, 1997b). Based on previous communications, EPA Region 1 has requested that the EPA Center for Exposure Assessment develop toxicity factors specifically for this Site for copper, iron, and possibly other metals. When this information is received, it is proposed that the team evaluate the bioavailability issue and determine the most reasonable path forward. To assist in this, it is proposed that the *Recommended Decision Framework for Assessing Oral Bioavailability of Metals at Contaminated Sites* (EPA, 2007b) be consulted. For the purposes of this Technical Memorandum, a default bioavailability factor of 100% will be assumed given the nature of the metals on the Site (highly soluble for the most part). It is not expected at the present time that more detailed studies on bioavailability, such as an animal feeding study with juvenile swine, would be considered for this Site.

5.2 Baseline Ecological Risk Assessment (BERA) Approach

Based on the SOW and additional guidance from EPA, there will be two BERAs developed for the Site: a terrestrial BERA (which includes a wetland component) and the aquatic BERA that focuses on impacts to Pike Hill and Cookville Brooks, their tributaries and the Waits River (EPA, 2007c). The aquatic BERA, which will be produced by EPA in the summer of 2008, is focused on the water channels and the aquatic ecosystems present therein. Included in this assessment are semi-aquatic receptors that forage on prey items living in the water channels, exclusive of the wetland complex. However, it should be noted that some data collected for the aquatic BERA (e.g. surface water) also will be used to assess risk to selected receptors evaluated in the terrestrial BERA. Where possible, receptors and exposure pathways for each of the risk assessments will remain distinct; the only exposure overlap currently identified is the surface water ingestion pathway which will be common to many of the receptors proposed. Consideration of the use of adjustment factors to evaluate metal bioavailability, as discussed in Section 5.1.4, will also be explored when assessing exposures to ecological receptors.

The remainder of this discussion focuses on exposure pathways, areas and receptors for the terrestrial and wetland portions of the BERA. It is anticipated that as more baseline information is collected for the wetlands complex (see Section 8.2), the ecological risk assessment will be adjusted to reflect a better understanding of contaminant fate and transport mechanisms within these areas.

5.2.1 Preliminary BERA Exposure Pathway Analysis

Potential ecological exposure pathways illustrate ways in which stressors (e.g. contaminants) are transferred from a contaminated medium to ecological receptors. The following is a list of exposure pathways by which terrestrial and wetlands receptors may be exposed to chemical contamination at the Site:

- Vascular plants - direct contact with soil, sediment and surface waters (wetlands only).
- Wetland sediment community - direct contact and ingestion of wetland surface water sediment, and ingestion of wetland biota.
- Vernal pool community (if present) - direct contact and ingestion of vernal pool water, sediments, and ingestion of vernal pool biota.
- Amphibians - direct contact with wetland sediment and surface water; and ingestion of aquatic vegetation and invertebrates.
- Soil invertebrate community - ingestion and direct contact with soil.
- Birds and mammals - ingestion of surface soil, surface water, and food (e.g.; plants, soil invertebrates, and small mammals).

These potential exposure pathways are illustrated in the ecological Exposure Pathway Analysis (Figure 5-2). It should be noted that the CSM also includes an evaluation of vernal pools will be done if present at the Site. Any vernal pools identified and assessed would be included the terrestrial BERA. A more detailed discussion of the vernal pool evaluation process is provided in Section 8.2 (Data Needs for the BERA).

5.2.1.1 Exposure Media and Routes of Exposure

In addition to the direct or indirect ingestion of contaminated soil, the potential for food chain impacts of bioaccumulative chemicals (e.g. metals) in terrestrial systems is well recognized. Because of the significant bioaccumulation potential associated with copper and several other metals present at the Site, and the potential risk to terminal receptors in the food chain, representative upper trophic level receptors are evaluated as part of the BERA. Because carnivores and omnivores generally represent the terminal receptors in terrestrial systems, avian and mammalian species foraging upon resident biota may be at substantially higher risk than those receptors at a lower trophic level. The ingestion of surface waters present at and downgradient from the Site is also a pathway of concern for most of the endemic, higher trophic level organisms.

5.2.1.2 Potentially Exposed Populations

Two populations were identified for potential exposures:

Terrestrial. The terrestrial BERA cannot evaluate potential adverse effects to every plant, animal or community present and potentially exposed at the Site. Therefore, receptors that are ecologically significant, of high societal value, highly susceptible, and/or representative of broader groups are typically selected for inclusion in the BERA. Table 5-7 is a list of proposed terrestrial receptors and communities to be evaluated and their associated exposure area(s). Specific exposure pathways for each receptor are provided in Figure 5-2.

Wetlands. As with the terrestrial BERA, the wetlands BERA cannot evaluate potential adverse effects to every plant, animal or community present and potentially exposed at the Site. Therefore, receptors that are ecologically significant, of high societal value, highly susceptible, and/or representative of broader groups are typically selected for inclusion in the BERAs. Table 5-8 is a list of proposed wetland receptors and communities to be evaluated and their associated exposure area(s). Specific exposure pathways for each receptor are provided in Figure 5-2; based on information available on specific wetlands sizes, the exposure and effects modeling for semi-aquatic receptors will be limited to Wetland 1 through Wetland 3, which are all greater than eight acres in size.

5.2.2 BERA Exposure Areas

The following contiguous areas are proposed as potential exposure areas for the terrestrial and wetlands BERAs; however, should additional information indicate the presence of hot spots or unique exposure conditions, these areas could be further subdivided to address risk at a more localized scale. It should be noted that existing waste and tailings piles (which have little or no vegetation and are known to contain contaminant levels and environmental conditions resulting in adverse ecological impacts) are not recommended for evaluation in the terrestrial BERA. It is assumed that the primary source areas will be addressed during subsequent remediation activities.

- Terrestrial habitat bordering the sources areas - due to their spatial separation, this exposure area will be divided into two units: Eureka and Union Mines; and Smith Mine

(further subdivisions may be required after additional Site reconnaissance). Biological and surface soil sampling for the terrestrial BERA will focus on transitions zones adjacent to and down-gradient from the waste piles; sampling in these areas will attempt to look at potential effects along a contaminant gradient.

- Pike Hill Brook Wetlands Complex - EPA has identified this area (Wetland 1 through Wetland 4) as a contaminant sink, and therefore a potential source, based on an exploratory XRF evaluation of sediment contaminant levels. Because of the unique biological and chemical processes present in these wetlands, they will be evaluated as a distinct exposure area for the BERA.

- Surface waters (i.e. Pike Hill Brook and tributary, Cookville Brook and tributary, and the Waits River) – the terrestrial BERA will evaluate the surface water ingestion pathways for appropriate target receptors; depending on data availability and further understanding of Site transport conditions, water chemistry data from some of these water bodies may be combined.

- Other riparian floodplain areas - if further investigation indicates contaminant migration into floodplain areas (note: these potential exposure areas and associated pathways should be investigated during the RI process).

5.2.3 BERA Exposure Parameters

As was previously presented, receptors or target communities will be evaluated as part of the BERA (see Section 5.2.1.2). The evaluation of plant, soil, sediment and amphibian communities will be accomplished using a combination of Site observations, community assessments, benchmark comparisons and toxicity testing (see Section 8.2.2 BERA Data Needs for a more detailed presentation of proposed evaluation approaches).

For individual receptor species (e.g. American robin, short-tailed shrew, mallard duck), two general modeling approaches exist for quantifying risk that differ dramatically in the level of effort involved and in their abilities to distinguish variability and uncertainty (Thompson and Graham, 1996). The most commonly used approach is the “point estimate” or “deterministic” approach, which involves selecting a single (conservative) value for each of the model inputs (parameters) from which a point estimate of risk (i.e. Hazard Quotient – HQ) is generated.

Choosing single values for inputs reduces the level of effort required for the exposure modeling process, but unavoidably limits the discussion of uncertainty and variability in the risk characterization.

Deterministic exposure modeling represents one of many ways to characterize exposure. As was previously mentioned, a number of receptor-specific exposure models will be incorporated in this BERA. In an attempt to limit the effort expended as part of the exposure modeling process and still identify potential ecological risks, a "tiered approach" that includes a conservative worst-case (i.e. Reasonable Maximum Exposure [RME]) and more realistic average (i.e. Central Tendency Exposure [CTE]) approach will be used). Whenever possible, species-specific exposure parameters will be taken from guidance provided in EPA's Wildlife Exposures Factors Handbook Volume I and II (EPA 1993a and 1993b) and Guidance for Developing Ecological Soil Screening Levels (EPA 2005). Specific exposure parameters that will be used in the modeling process will be provided to EPA prior to the initiation of the modeling process.

<u>Exposure models used in this BERA take the following general form:</u>

$$TDI = FT \times \left[\left(FIR \times \sum_{i=1}^{n} C_i \times P_i \right) + SIR \times C_{sed} + WIR \times C_w \right]$$

Where:

TDI	=	Total daily intake (mg/kg BW-day)
FT	=	Foraging time in the exposure area (unitless)
FIR	=	Body weight normalized food intake rate (kg WW/kg BW-day)
C_i	=	Concentration in the ith prey item (mg/kg WW)
P_i	=	Proportion of the ith prey item in the diet (unitless)
SIR	=	Sediment ingestion rate (kg DW/kg BW-day)
C_{sed}	=	Concentration in sediment (mg/kg DW)
WIR	=	Water ingestion rate (L/kg BW-day)
C_w	=	Concentration in water (mg/L)

Because of the difficulties in measuring intake of free-ranging wildlife, data on food intake rates (FIRs) are not available for many species. Using FIRs for captive animals potentially

underestimates the intake rates because these animals do not expend as much energy as their wild counterparts do, since activities for captive animals do not include behaviors such as foraging and avoiding predators. Therefore, allometric equations using measurements of free metabolic rates (FMRs) are used to determine FIRs.

The FMR represents the daily energy requirement that must be consumed by an animal to maintain among other things, body temperature, organ function, digestion, and reproduction. To maintain these physiological functions as well as to perform daily behavioral activities such as foraging, avoiding predators, defending territories, and mating, the animal must replace the lost energy by metabolizing and assimilating the energy in its food (i.e. its metabolic fuel). The balance between an animal's energy loss and replenishment is reflected in the quality and quantity of food in the animal's diet. Assuming that the animal's habitat supports a variety of food items, selection of diet may reflect a preference toward more energy-rich foods (i.e. higher gross energy), although one must consider the energy expended in pursuit of prey.

Not all food that is consumed by an animal is converted to usable energy. Depending on the digestibility of the dietary item and the physiology of a particular animal, a substantial portion of the energy may be lost through clearance. Assimilation Efficiency is a measure of the percentage of food energy (i.e. item-specific gross energy) that is assimilated across the gut wall and is available for metabolism.

The equation used to determine FIRs is as follows:

$$\text{FIR (kg WW/kg BW - day)} = \frac{\text{FMR}}{\sum_{i=1}^{n}\left(AE_i \times GE_i \times P_i\right)}$$

Where:

FIR	=	Body weight normalized field ingestion rate (kg WW/kg BW-day equals g WW/g BW-day)
FMR	=	Field metabolic rate (kcal/g BW-day)
AE_i	=	Assimilation efficiency of the ith food item (unitless)
GE_i	=	Gross energy of the ith food item (kcal/g)
P_i	=	Proportion of diet comprised of the ith food item (unitless)

5.2.4 BERA Bioavailability Considerations

A central underlying premise in evaluating the impacts of metals to ecological receptors is that they must be accumulated above, or in rare cases of deficiencies, depleted below normally regulated levels by the receptor in order for an effect to be elicited. The bioaccessibility, bioavailability, and bioaccumulation properties of inorganic metals in soil, sediments and aquatic systems are complex (McGreer and others, 2004). Similar to organic compounds, abiotic (i.e. pH, CEC, organic carbon) and biotic (i.e. uptake and metabolism) modifying factors determine the amount of inorganic metal that interacts at biological surfaces (i.e. gut lining, epithelial tissue, or root-tips) and that binds to and is absorbed across these membranes. To better characterize the risk presented by metals in the environment to ecological receptors, the processes that affects metal speciation and the effects of speciation on metals bioavailability must be addressed through data collection or, at a minimum, acknowledged in the uncertainty analysis when evaluating ecological risks at sites where metals are the primary contaminants of concern.

Once absorbed or assimilated into biota, metals are subject to numerous fate and transport processes including storage, metabolism, elimination and accumulation. Unlike organic contaminants, some metals are essential nutrients and when not present in sufficient concentration can limit growth, survival and reproduction; another critical factor that must be included in any ecological risk assessment that is focused on metal contamination. Other critical factors that need to be considered when evaluating metals-related ecological risk are: 1) metals naturally vary in concentration across geographic regions and endemic organisms have evolved under these conditions, therefore, making and understanding of local background concentrations is important; and 2) metals occur in mixtures and can interact with each other in numerous ways including synergistically and antagonistically.

The BERA approach presented in this document tries to address some of the key issues identified by EPA in its Framework for Metals Risk Assessment (EPA, 2007a), thereby reducing some of the uncertainties frequently encountered in ecological risk assessments at sites where metals are the primary contaminants of concern.

6.0 PRELIMINARY RESPONSE ACTION OBJECTIVES

This Section outlines the currently identified Applicable or Relevant and Appropriate Requirements (ARARs) for the Site, preliminary Project Quality Objectives, and preliminary approach to evaluating background conditions at the Site.

6.1 Preliminary Identification of ARARS

This section summarizes the preliminary identification of ARARs for the Site FS. The ARARs include those identified in the FS for the Elizabeth Mine Site (URS, 2006b). These ARARs will be reviewed throughout the RI program and revised as the FS process is implemented for the Site.

Section 121 of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (known as SARA), provides the statutory basis for ARARs. Specifically, Section 121(d) states that response actions must at least attain (or justify a waiver of) all ARARs or other federal environmental laws, more stringent state environmental laws, and state facility-siting laws.

A requirement may be either applicable or relevant and appropriate to remedial activities at a site (but not both). Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a site. These requirements would be legally applicable notwithstanding CERCLA.

If a requirement is not applicable, it may still be relevant and appropriate. The basic considerations are whether the requirement:

1. regulates or addresses problems or situations sufficiently similar to those encountered at the subject site (i.e. relevance); and

2. is appropriate to the circumstances of the release or threatened release, such that its use is well suited to the particular site.

A requirement might be relevant but not appropriate for a specific site; in this case, the requirement would not be an ARAR. Determining whether a requirement is relevant and appropriate is site-specific, is based on best professional judgment, and considers a number of factors including the characteristics of the remedial action, the hazardous substances present at the Site, and the physical circumstances of the Site and of the release. The EPA maintains in its guidance that portions of a requirement may be relevant and appropriate (EPA, 1992).

Compliance with all requirements found to be applicable or relevant and appropriate is required under CERCLA. Waivers of ARARs may be obtained under certain circumstances in the following six areas:

- interim measure;
- greater risk to health and the environment;
- technical impracticability;
- equivalent standard of performance;
- inconsistent application of state requirements; and,
- fund-balancing.

These waivers apply only to meeting ARARs with respect to remedial actions onsite; other CERCLA statutory requirements, such as the requirement that remedies be protective of human health and the environment, cannot be waived.

“To be considered” items are non-promulgated advisories, proposed rules, criteria, or guidance documents issued by federal or state governments that do not have the status of potential ARARs. However, these criteria and guidance are to be considered only when determining protective cleanup levels where no ARAR exists, or where ARARs are not sufficiently protective of human health and the environment. In these circumstances, “to be considered” values may be considered in establishing remedial objectives.

6.1.1 Chemical-Specific ARARs

Chemical-specific ARARs are based on health or risk-based concentration limits or discharge limitations in environmental media (i.e. water, air) for specific hazardous chemicals. These requirements may be used to set cleanup levels for the COCs (in this case, metals) in the designated media.

Sources for potential target cleanup levels include selected standards, criteria, and guidelines that are typically considered as ARARs for remedial actions conducted under CERCLA. The preliminary chemical-specific ARARs and other criteria or guidelines to be considered are discussed further below, and are summarized in Table 6-1. They are based on standards, guidelines, and criteria found in relevant literature, past discussions with appropriate Vermont regulatory agency personnel, and prior project experience.

6.1.2 Location-Specific ARARs

Location-specific ARARs are restrictions placed on the types of activities that may occur in particular locations. The preliminary location-specific ARARs for the Site are presented in Table 6-2. The location of a site may be an important characteristic in determining its impact on human health and the environment; thus, state standards often establish location-specific ARARs. These ARARs may restrict or preclude certain remedial actions or may apply only to certain portions of a site.

6.1.3 Action-Specific ARARs

Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken to implement a proposed alternative. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Since there are usually several alternative actions for any remedial site, very different requirements come into play. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative can be achieved. Preliminary action-specific ARARs are listed in Table 6-3.

6.2 Other Regulations or Restrictions Impacting RI/FS Activities

Other regulations that may be applicable to the RI/FS activities at the Site would include:

- Occupational Safety and Health Administration (OSHA) regulations for worker health and safety;
- Low Risk Site Handbook for Erosion Prevention and Sediment Control, VTDEC, August 2006;

- Construction General Permit (CGP) 3-9020, VTDEC, August 2006 for permitting stormwater discharges from construction activities to prevent erosion and control sediment discharges; and
- ASTM Guidance, as appropriate.

6.3 Preliminary Project Quality Objectives

The objectives of this project are to provide information to characterize the nature and extent of contamination at the Site, support evaluation of human health and ecological risks, and facilitate the evaluation of remedial options relating to historical mining activities at the Site. The data generated for this project will be used to assess potential impacts to Site media attributable to mine-related activities; to assess whether Site conditions pose an unacceptable risk to human health and ecological receptors; and support the selection and design of appropriate remedial actions to mitigate risks. Data generated from this project will vary in type, quality, and quantity dependent on the specific intended purpose and methods used. In general, data generated from field methods will tend to have the lowest quality and those generated by fixed, off-site laboratory analysis using established analytical methods will have the highest quality.

A sampling and analysis plan (SAP) consisting of a field sampling plan (FSP) and a quality assurance project plan (QAPP) will be prepared following the EPA QA/R5 requirements for QAPP development (EPA, 2001) to define quality assurance (QA) procedures that will be followed during the course of the project. Laboratory analytical data will be evaluated in terms of precision, accuracy, representativeness, completeness, comparability, and sensitivity to determine their usability for the intended purpose. Field data characterizing surficial soils and mine waste materials, groundwater, surface water, and sediment will be used to confirm the presence or absence of environmental impacts, define the nature and extent of identified impacts, support the human health and ecological risk assessments, and to develop and evaluate remedial alternatives.

The SAP will specify Data Quality Objectives (DQOs) and other QA procedures (e.g. standard operating procedures) that will be developed and followed to ensure that RI/FS field measurements, sampling methods, and analytical data provide information that is representative of actual field conditions, is of sufficient quality to support decision making, and is technically and legally defensible.

6.4 Site Background Analyte Evaluation

The following subsection describes the background analyte evaluation approach for soils, surface water, sediment, and groundwater at the Site.

A background analyte evaluation is required to provide a set of reference numbers for various media and chemical constituents that aid in the comparison of detected chemicals to chemicals attributed to former mining operations. The background data reflects conditions that are not influenced from releases at the Site, but result from natural or other non-mine related sources. These reference concentrations are specific to the areas in which the data are collected and are referred to as site-specific background or background in this report. The background data is not used to eliminate chemicals of potential concern (COPC), but rather is used to evaluate contribution to Site risks from non-mine related activities, and to distinguish those contributions from the risk contributed by the Site contaminants. Background is considered in risk management decisions under CERCLA and communication of risks in the decision making process.

Establishment of appropriate site-specific background concentrations requires a careful examination of the available data by statistical methods. Also required is the inclusion of practical considerations such as the quantity and quality of the data, and the resolution of issues such as the presence of unlikely chemical constituents in what are regarded as background sampling locations. The statistical methods that will be employed to characterize background data sets include: testing for the distribution of data; selection of parametric or non-parametric methods; determination and resolution of apparent outlier values; use of descriptive statistics; and finally, the establishment of the proposed background data set concentration measures using a 95 percent upper confidence limit (UCL) on the mean or other rule (i.e. the maximum), when all other statistic requirements are not met.

The initial findings of the RI field investigations will be used to determine which analytes and media are required in a background concentration evaluation as well as to design a specific background evaluation study. However, based on our current understanding of the Site indicating that the COPCs are limited to inorganic compounds, a background evaluation of VOCs, Pesticides/PCBs, and selected SVOCs (primarily PAHs) is not anticipated to be required. Ultimately, the selection of specific analytes for background evaluation and statistical analysis

will be based on a compound's potential risk to human health or the environment, as identified in the screening level risk assessment.

7.0 POTENTIAL REMEDIAL ALTERNATIVES

Section 7.0 present an overview of the process and selection of potential remedial alternatives for the Site, which are categorized by identified source areas. In addition, potential treatability studies have been presented based on review of the Site data and associated existing remedial technologies.

7.1 Development of General Response Actions

General Response Actions (GRA) are broad categories consisting of remedial technologies and process options that can be selected individually or in combination in order to meet the Remedial Action Objectives (RAOs) for the Site. GRAs are included in the FS process to give a range of responses for consideration for site remediation. GRAs would include: no action, limited action, containment, removal and disposal/discharge, in-situ treatment, ex-situ treatment and resource utilization.

7.2 Technology Evaluation

In this section, potentially applicable technology types and process options for each GRA identified above are presented and undergo an initial evaluation. The evaluation is provided in Tables 7-1 through 7-3, which are arranged by medium. For the purpose of this document, "technology types" refer to general categories of technologies, such as biological treatment, vertical barriers, and institutional controls, whereas "technology process options" refer to specific processes within each technology type, such as phytoremediation, slurry walls, and deed restrictions.

During the screening process, process options and entire technology types may be eliminated from farther consideration. As stated in Section 4.2.5 of *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988), the evaluation of process options at this stage is based upon three screening criteria:

- Effectiveness;
- Implementability : and
- Cost

Viable process options are retained for incorporation into remedial alternatives. Although the various process options are discussed and evaluated individually, combinations of process options are frequently used to accomplish site remediation. Possible combinations will be discussed during the development of remedial alternatives for each source area identified.

7.3 Evaluation Criteria

For any areas of the Site that are identified as requiring remedial action through the RI and HHRA/BERA, the FS will consider and develop remedial alternatives in accordance with CERCLA and National Contingency Plan (NCP) requirements as well as additional guidance documents available from the EPA. Alternative development is preceded by a brief description of the physical characteristics of each of the impacted areas. These are assessed against criteria specified in the NCP and EPA guidance. These criteria include the three screening criteria discussed above and the nine detailed criteria presented in the following paragraphs.

The EPA uses nine criteria to evaluate alternatives and select a final cleanup plan (called a remedial action) that meet the statutory goals of protecting human health and the environment, maintaining protection over time, and minimizing contamination. These nine criteria make up the assessment process used for all Superfund sites. Of the nine CERCLA-defined FS evaluation criteria, two criteria are threshold criteria and must be met by each remedial alternative to be considered applicable and appropriate for the remedy. These include:

- overall protection of human health and the environment; and
- compliance with ARARs.

Five of the remaining criteria are referred to as balancing criteria by which the alternatives are compared and upon which the analysis is based. These include:

- long-term effectiveness and permanence:
- reduction of toxicity, mobility, or volume;
- short-term effectiveness;
- implementability; and
- cost.

The remaining two modifying criteria, state acceptance and community acceptance will be considered thoroughly by EPA prior to selection of the Record of Decision (ROD) remedy.

7.4 Potential Remedial Alternatives

Based on the technologies and process options identified in Tables 7-1 through 7-3, a list of potential remedial alternatives has been developed for each potential source area. These potential remedial alternatives are preliminary and may not constitute all alternatives that would be initially screened and or retained for detailed evaluation during the FS.

The potential remedial alternatives, for each source area, would be arranged into GRAs as follows:

- No Action – required by CERCLA and NCP requirements. Developed as a baseline to compare against all other response actions.

- Limited Action – involves a form of legal and physical deterrent to the site in order to prevent exposure to site contaminants.

- Containment – a physical system (i.e. capping, etc.) to contain the site contaminants and prevent exposure.

- Removal and Disposal – active removal and disposal of site contaminants from source areas which usually includes off-site disposal at secure facilities.

- In-Situ Treatment – a chemical and/or biological treatment process to reduce or eliminate site contaminants.

- Ex-Situ Treatment – a physical removal of site contaminants and treatment via chemical and/or biological processes which either be on-site or off-site.

During the FS evaluation, remedial alternatives will be developed by source areas (i.e. mine wastes, wetland areas, surface water, sediments, groundwater, and underground workings) based on an evaluation of the above-noted GRAs through the initial screening process. Several

potential remedial alternatives will be retained for detailed evaluation and preferred alternatives ultimately selected for each source area.

7.5 Elizabeth Mine Site Remedy Review

While the Site has some unique characteristics, previous studies conducted at the Site have indicated that the geochemical composition of the mine waste, mine drainage and stream waters and sediments are very similar to the Elizabeth Mine Superfund Site (see Section 2.1.3.1). The Elizabeth Mine Site FS (URS, 2006b) was reviewed to evaluate potential remedial alternative available for the Site.

Following completion of the RI/FS, the EPA selected the following remedial actions for the five areas of the Elizabeth Mine Site:

- Lord Brook Source Area – consolidation of mine wastes and surface water diversion to eliminate ARD impacts to surface water.

- Upper and Lower Copperas Factories – capping of lead-containing surficial soil to prevent direct contact.

- Sediments – Monitored natural recovery of the sediments in Site surface waters.

- WWII Era Infrastructure Area – Monitoring of the surface water runoff to ensure no negative impacts to water quality downstream.

- Site Wide Groundwater – Long-term monitoring to prevent groundwater consumption.

These removal actions may be applicable to the Site and will be included in the Site evaluations.

7.6 Potential Treatability Studies/Pilot Testing

As the RI/FS process is conducted and Site investigation data is collected for the decision-making process, additional data may be collected and evaluated to support alternatives that are developed during the detailed analysis stage of the FS. This involves data collection and/or treatability studies. Treatability studies will be conducted in situations where there is a need to

collect additional data on certain technologies in order to determine if that technology is applicable to the Site. These studies may conducted at both a bench-scale and a pilot-scale.

The objectives of treatability studies are to achieve the following:

- Provide sufficient data to allow remedial alternatives to be fully developed and evaluated during the detailed analysis and to support the selected alternative remedial design; and

- Reduce cost and performance uncertainties for remedial alternatives to acceptable levels in order to select a remedy.

The decision to conduct treatability studies would consist of the following:

- Determine the data needs for the Site;
- Review existing Site data and available literature on technologies to determine if existing data are sufficient;
- Perform treatability tests to determine performance, operating parameters and relative costs of potential technologies; and
- Evaluate the data to ensure that PQOs are met.

Based on the potential remedial alternatives identified for the Site, a list of potential treatability studies are presented in Table 7-4; however, these studies are preliminary and would be updated based on the detailed analysis of alternatives performed during the FS.

8.0 PRELIMINARY DATA REQUIREMENTS FOR RI/FS

Section 8.0 presents requirements for additional data collection activities that are required to:

- determine surface water, sediment, soil, and groundwater quality at the Site, including downgradient areas affected by Site sources;
- identify and evaluate potential risks posed to human health and the environment; and
- provide characterization necessary to develop and evaluate remedial alternatives as part of a FS.

8.1 Data for Site Characterization

Based on a review of available Site information, a summary of the preliminary data needs to support the implementation of a remedy at the Site to mitigate potential human health and environmental impacts from the waste rock/tailings piles and underground workings was prepared. The following three general categories of Site characteristics require further evaluation and are discussed in more detail in following sections:

- Nature and extent of contamination in media (groundwater, surface water, sediment, soil, waste rock/tailings piles, mine pools, wetlands);
- Surface water hydrology; and
- Overburden and bedrock hydrogeology.

8.1.1 Nature and Extent of Contamination in Site Media

Results from previous USGS investigations have documented the contaminant characteristics of the on-site waste rock piles, tailings, surface water, sediment, and surface mine pool water (Piatak and others, 2006; Kiah and others, 2007). In order to assess the potential human health and environmental risks posed by the above media and groundwater, and sufficiently characterize source materials as a basis for evaluating remedial options, additional sampling and analysis is necessary. Characterization sampling for the aquatic ecological risk assessment is in progress by EPA and USGS and as such no additional sampling is needed for that purpose. In addition, the potential impact from the Site to wetlands along Pike Hill Brook downstream of the Site and the possibility that those wetlands may be source areas requires further evaluation. Proposed investigations are designed to supplement existing and ongoing/unpublished work being conducted by the EPA and USGS. Proposed sample locations for each media including the rationale and proposed parameters for each location are summarized in Table 8-1 and locations for on-site samples are shown on Figure 8-1.

8.1.1.1 Waste Rock/Tailings

The location and general characteristics of waste rock and tailings materials throughout the Site has been preliminarily defined by previous workers (PAL, 2007; Piatak and others, 2006). Additional work is needed to better define the vertical and lateral extent of waste rock and tailings piles, the extent of mine wastes in areas away from piles, and the chemical and physical characteristics of these materials. This information will be important in assessing the potential contaminant contribution of waste rock materials within each subarea. Data collected from

surface and shallow subsurface (0-10 ft) soil samples will also be used to support the human health risk assessment, where appropriate. Proposed soil boring and test pit locations are listed in Table 8-1 and shown on Figure 8-1. The rationale for each location is listed in the table along with soil parameters to be evaluated. Approximately three soil samples are anticipated for analysis from each boring including a surficial (0-0.5ft) and shallow subsurface (0.5-10ft) sample. The actual number of samples will be dependent on the visual character, stratification, and thickness of waste and underlying overburden encountered. Soil borings are proposed at locations where subsurface data is needed to define the thickness of waste piles and the underlying overburden with limited disturbance to the pile. These data will be essential for estimating waste volumes in addition to their character. In general, a limited number of borings are proposed through representative waste piles in each Site subarea allowing for representative analytical sampling of source materials. Some of these borings may be completed as monitoring wells if they penetrate saturated conditions.

Test pits are proposed along the margins of waste rock/tailings piles to verify and delineate the lateral extent of these potential source materials and may consist of a series of hand-dug pits spaced along a traverse. Alternately a backhoe with a narrow bucket may be used if shallow soils are difficult to penetrate with a shovel. Additional borings may be required in areas away from piles where the waste thickness is found to be greater than a few feet. Visual identification of waste material in conjunction with field X-ray fluorescence (XRF) analysis of select soil samples will be employed as necessary to provide verification of the lateral extent of waste areas.

8.1.1.2 Soil

Surficial soil sample analyses are proposed along several radial transects located along the periphery of the Site, overlapping the limits of the waste rock/tailings pile areas to evaluate metal concentrations across the transition zone between areas of high metal concentration with little or no vegetation and vegetated areas. Field XRF analysis using a handheld analyzer to characterize a limited number of metals is proposed to allow for efficient assessment of the concentration of metals in surface soil within 200 feet of waste piles along at least two transects in each of the three mine areas as shown on Figure 8-1. Samples of surficial soil will be analyzed at approximately 10 foot intervals. Results will provide a screening level assessment of the distribution of metals concentrations. Additional transects will be analyzed as necessary to identify the appropriate location and orientation for the sample grids to be used for the BERA

described in Section 5.2.2. Once these grids locations are confirmed, the grid nodes will be analyzed using field XRF to provide a framework to select appropriate biota sample locations for risk characterization. For correlation of XRF analysis with off-site laboratory result, 10% of grid samples will be split for off-site analysis.

Floodplain soil samples will be collected for off-site laboratory analysis at select locations along the tributary to Pike Hill Brook between source areas and the Wetlands Complex to assess the potential redistribution of waste rock/tailings material downgradient of waste piles as overbank deposits. These data will also be used to support terrestrial ecological risk assessment of riparian areas.

8.1.1.3 Sediment and Surface Water

Existing data from recent EPA and USGS studies provides a considerable amount of sediment and surface water characterization data for the Site. Proposed surface water and sediment sample locations from on-site areas are shown on Figure 8-1 and listed on Table 8-1. These locations supplement existing data and will provide a basis for correlation with existing data. In addition to on-site samples, it is proposed that a limited number of additional sediment samples (5-10 locations) be collected from within established surface water channels of Pike Hill Brook between on-site source areas and the Wetlands Complex, and along the tributary to Cookville Brook to supplement existing data; assess whether these materials should be characterized as a source material; and obtain sediment thickness information to support estimates of sediment volume that may require remediation in off-site areas. Off-site sediment sample locations will be identified in the field based on stream gradient, sediment size and thickness along the streambed.

Surface water samples will be collected at and downstream of seeps that feed the on-site tributaries of Pike Hill Brook and Cookville Brook and the tributary stems for correlation with groundwater hydrogeologic data, lithologic/stratigraphic information, and soil data to assess the comparative potential impact from upgradient source areas. The existence of wetland areas/areas of ponded water (potential vernal pools) in the upper elevations of Pike Hill, downgradient of source areas along the western flank of Pike Hill should be investigated to determine whether additional surface water sampling is needed to characterize potential impacts to additional watershed areas. No vernal pool surface water sample locations are shown on Figure 8-1 as the need for these samples will be determined by field inspection.

These data may also be used to support human health and ecological risk assessments, where appropriate. Surface water sampling parameters will include the full target analyte list (TAL) of metals, cyanide and sulfate for all locations since these are the most prevalent Site-related substances identified in previous studies. Additional inorganic parameters listed in Table 8-1 will be analyzed only for select locations (approx 50% of the proposed wells) for the first round of sampling based on their location and likelihood of being impacted by Site sources in order to more fully characterize groundwater chemistry proximal to source areas. The list of parameters included for subsequent rounds will include at a minimum TAL metals and sulfate, with additional parameters added as necessary for locations identified in areas impacted by Site sources. A full list of organic parameters (VOCs, SVOCs, pesticides/PCBs) will be analyzed during the second round of sampling at select locations (estimate 5% of locations) identified as impacted by Site sources to assess whether these compounds are present in relation to historical Site activities. Results will determine whether a subset of parameters will be carried forward in subsequent rounds.

8.1.1.4 Groundwater

Groundwater samples are proposed over a network of clustered wells to assess the vertical and horizontal distribution of contamination in groundwater from on-site waste sources including the subsurface mine pools. The distribution of monitoring wells is designed to evaluate the contaminant contribution of each mine subarea, and the relative importance of overburden, shallow bedrock, and deep bedrock groundwater with regard to contaminant transport in relation to surface streams at the Site and potential off-site migration of bedrock groundwater contamination. Additional shallow overburden wells may be recommended if borings in waste piles indicate saturated conditions. One well is proposed to sample deep groundwater from within each of the Eureka and Union Mine pools to assess whether this water is a potential source of contamination to existing and future drinking water sources. A well cluster located above Richardson Road is proposed to assess the potential for off-site groundwater impacts from Site sources. Although the number and location of drinking water sources in the vicinity of the Site was not available, and therefore not specified in Table 8-1, accessible off-site drinking water sources within a half-mile radius of the Site should be sampled for analysis of metals and related parameters. Samples of the mine pools are proposed from accessible openings to the surface mine pools to assess whether this water is a potential source of contamination to surface water and for comparison with deeper mine pool samples. Three rounds of samples are proposed over a one year period during Spring, Summer/Fall and Winter conditions to

document significant seasonal variations (high, low, and average flow) in surface water, groundwater and mine pool characteristics. Groundwater sampling parameters will include the full TAL metals, cyanide and sulfate for all wells which include the most prevalent Site-related substances identified in previous studies. Additional inorganic parameters listed in Table 8-1 will be analyzed only for select wells (approx 50% of the proposed wells) for the first round of sampling based on their location and likelihood of being impacted by Site sources to more fully characterize groundwater chemistry proximal to source areas. The list of parameters included for subsequent rounds will include at a minimum TAL metals and sulfate, with additional parameters added as necessary for wells identified in areas impacted by Site sources. A full list of organic parameters (VOCs, SVOCs, pesticides/PCBs) will be analyzed during the second round of sampling in select wells (estimate 5% of locations) identified as impacted by Site sources to assess whether these compounds are present in relation to historical Site activities. Results will determine whether a subset of parameters will be carried forward in subsequent rounds.

8.1.1.5 Pike Hill Brook Wetland Complex

Based on preliminary results from EPA, USGS and others (unpublished), additional characterization of wetland soil and the relationship between surface water, soil, and groundwater is needed within the Wetland Complex. It is recommended that the existing grid of field XRF analyses be expanded to define the limits of the impacted area within each of the four wetlands. Additional soil cores should be analyzed based on results of the grid sampling to verify the vertical distribution of contamination. Depending on the results of the EPA/USGS study, and the preliminary model of groundwater flow proposed, hand-driven piezometers should be installed at multiple locations within each wetland, and where appropriate, nested piezometers to document the vertical and horizontal variations in groundwater conditions within the wetlands, in order to better define the mechanism responsible for the distribution and migration of metals through the Wetland Complex. Surface water samples should be collected in conjunction with wetland soil sampling, including the main channels of surface water flow through the wetlands. Recommended parameters for water and\ soil samples are listed in Table 8-1. In addition, a limited number of overburden monitor wells are recommended in upgradient and downgradient areas just beyond the wetland boundaries, to assess whether the impact to wetland soil is confined to the wetland footprint. Drinking water sources within a half-mile radius of the Wetlands Complex should be sampled to assess potential impact beyond the

Wetland Complex. The need for bedrock monitoring wells will be assessed once results from overburden and residential wells are evaluated.

8.1.2 Surface Water Hydrology

Surface water hydrology at the Site has been largely characterized by USGS at the main stem of the tributary to Pike Hill Brook that drains the Site, beginning at the weir immediately above Richardson Road (Kiah and others, 2007). Additional documentation of flow rates of individual seeps and tributary branches upstream within the source areas is proposed in conjunction with surface water sampling efforts to assess contaminant contributions from the upgradient subareas of the Site and the relationship between groundwater and surface water. Similarly, estimation of flow at multiple points along the tributary to Cookville Brook is recommended. The relationship between the surface mine pools and seeps immediately downgradient needs to be investigated to assess the potential contribution of discharge from the mine openings. In addition to water quality monitoring, this may include estimating flow rates/volumes and water levels at the mine openings.

8.1.3 Overburden and Bedrock Hydrogeology

Groundwater conditions at the Site have not been investigated to date. As such, the relationship between groundwater and surface water at the Site has not been documented. A monitoring well program has been developed to document the groundwater conditions in overburden soil, shallow bedrock, and deep bedrock in sufficient detail to understand the potential for groundwater interaction with Site sources and contaminant transport via groundwater. While much of the emphasis is on the relationship between shallow groundwater and surface water at the Site, the potential impact of the mine pools on deeper groundwater needs to be assessed to understand the potential impact to future drinking water sources in the area.

Monitoring well locations are shown on Figure 8-1 for the Site. Well locations were selected to allow documentation of a variety of hydrologic parameters including the saturated thickness of waste piles and overburden soil; the vertical and horizontal hydraulic gradients between surface water, overburden, shallow bedrock, and deep bedrock flow units; and the hydraulic conductivity of the various flow units. In addition, the wells allow documentation of water quality parameters essential to understanding the potential contaminant contributions from the various source areas at the Site and contaminant transport. Ultimately, these data will define the Conceptual

Site Model as a basis for remedial design. The rationale for individual well locations is summarized in Table 8-1.

Shallow overburden wells located within waste piles are designated where subsurface soil data is needed and well installation at these locations is considered optional pending field verification of saturated conditions. Additional shallow wells may be installed in borings where unanticipated saturated conditions are encountered. Shallow and deep overburden well installation depends on the field verification of a sufficient thickness of saturated overburden/source soil (generally over 20 ft). It is likely that at most locations only a shallow overburden/water table well will be installed (designated by an “A”). Shallow bedrock wells are proposed to assess the significance of contaminant transport within the upper 20 ft of the bedrock considering the likelihood of a thin overburden unit. Slug testing will be performed on shallow overburden and shallow bedrock wells to assess the hydraulic conductivity of each hydrogeologic unit. Deep bedrock boreholes/wells are located in close proximity to the mine pools to assess the potential for contaminant migration in the bedrock aquifer. These locations will be cored to allow direct characterization of the bedrock. Borehole geophysical logging will be performed prior to well installation to characterize various physical and hydraulic properties of the bedrock. In addition, based on results of core analysis and geophysical logging, packer testing of individual zones within the open borehole will be conducted to map characteristics of specific bedrock water-bearing zones (chemistry, hydraulic properties) and provide a basis for well completion specifications.

8.1.3.1 Underground Workings

Bedrock boreholes/wells are proposed to penetrate each of the mine pools of the Eureka and Union Mines at a location above the presumed hydrostatic head elevation of the pool. These locations are based on the structural data of the underground working and the observed mine pool elevations at existing mine openings (White and Eric, 1944). These boreholes/wells are positioned to intercept the mine pools at a location such that the mine is completely water-filled to avoid interaction with air in the mine. Only one deep downgradient bedrock borehole/well is proposed adjacent to the Smith Mine due to the surface accessibility of the mine pool and the relatively small, shallow nature of the underground workings. One borehole/well cluster including a deep bedrock well is located along the eastern, downgradient boundary of the Site to document groundwater conditions at the Site boundary. Additional bedrock wells are proposed in the areas immediately surrounding the mine pools to assess potential impact of the mine

pools on nearby bedrock groundwater. Depending on the results from samples from these wells, additional monitoring wells may be necessary to assess the potential impact on groundwater from unmined ore that likely exists in the bedrock in the immediate vicinity of the Site. The need, location and number of background wells will be determined based on results from the proposed on-site monitoring wells.

8.2 Data to Support Risk Assessments

In order to produce a technically defensible risk assessment (HHRA or BERA), it is important to collect enough samples to adequately characterize the contamination at a site and to estimate reliable exposure point concentrations (EPCs). The objective of this section is to present the minimum data requirements needed for the HHRA and BERA. The proposed Site characterization samples described in Section 8.1 will also be used in the HHRA and BERAs, when applicable.

The term “data gap” refers to an area for which information is limited or lacking. Some of these data gaps will need to be filled and these are referred to as “data needs.” Risk assessments require a certain amount of analytical data to allow for the development of EPCs, which are typically represented by 95 percent upper confidence limits of the mean (95% UCL). EPA recommends a minimum dataset sample size of 8-10 samples for the calculation of 95% UCLs (ProUCL Version 4.0 Guidance Manual). Other factors can also contribute to the amount of data needed for an exposure area including the variations in contamination within the area, the location and size of the area, and the specific uses of the area.

8.2.1 Human Health Risk Assessment Data Needs

Details on HHRA data needs by media are presented below.

8.2.1.1 Soil

As discussed in Section 5.1.2.1, a total of four soil EAs are proposed for the Site HHRA. The extent of each soil EA is based on the assumptions that the analytical results and Site use are relatively similar within each area. A phased approach is proposed to sample the soil EAs. The first phase is designed to meet the minimum data requirements assuming the Site is evaluated based on four EAs. It would include the collection of soil boring samples consisting of, at a minimum, one surface sample collected from 0 to 0.5 ft bgs and one subsurface sample

assuming homogeneity. Additional subsurface sample(s) may be collected from a soil boring location if the material was not similar. The decision to obtain multiple samples from different depths at a soil boring will be made by the field personnel performing the sampling activities. For HHRA use, subsurface samples will not be collected from depths greater than 10 ft bgs, the assumed maximum depth of potential future construction excavation and thereby the limit to likely human exposure. In addition to the soil boring samples, three discretionary surface soil samples for each EA will be collected from areas of obvious or presumed human use. The locations of these samples would be identified in the field. The proposed soil boring sampling locations (Figure 8-1) along with the additional discretionary sample locations will ensure that the sample size would meet the minimum data requirement and therefore would be appropriate for HHRA use. Upon review of the first phase samples, a determination will be made as to the appropriateness of the extent of the soil EAs. If samples from a specific area appear to be elevated, the soil EAs will be re-evaluated. If this occurs, a second phase sampling effort would be required to achieve an appropriate number of samples for each soil EA.

8.2.1.2 Surface Water and Sediment

As discussed in Section 5.1.2.2, the proposed HHRA includes a total of three surface water and sediment EAs for the Union and Eureka Mines study area and two EAs for the Smith Mine study area HHRA. For the surface water and sediment EAs, it is proposed that roughly eight samples are collected from each of the five EAs. Based on the information provided in recent reports from the USGS (Piatak and others, 2006; Kiah and others, 2007) and other ongoing Site work, it appears that adequate surface water and sediment data are available for two of the five proposed EAs: 1) Pike Hill Brook downstream to the Wetland Complex; and 2) the Unnamed tributary to Cookville Brook. It is also assumed that the surface water and sediment data needs for the Wetland Complex proposed for the BERA (see Section 8.2.2) will be sufficient for the HHRA. The only HHRA surface water and sediment EAs that require additional sampling are: 1) Pike Hill Brook wetlands complex discharge down stream to the Waits River; and 2) Cookville Brook downstream to the South Branch of the Waits River. Sediment samples will be collected from the top six inches.

8.2.1.3 Fish

As presented by the USGS during a stakeholder meeting conducted on March 13, 2008 in Pembroke, New Hampshire, an extensive fish study was conducted for the Site during which fish were collected from Pike Hill Brook, the tributary to Cookville Brook, and a reference

location. Because an extensive effort was made to collect available fish throughout the study area, it is assumed that the fish data collected to date will be the only fish data available for use in the HHRA.

Brook trout was the only species collected within the study area (at three locations) that is typically targeted by anglers, the other species collected included creek chub, common shiner, and longnose and blacknose dace. For the HHRA, brook trout data will be used when available. When brook trout data is not available, blacknose dace will serve as an edible fish surrogate.

8.2.1.4 Groundwater

Groundwater samples will be collected from the proposed on-site and off-site monitoring wells. An appropriate number of samples will be obtained to allow for the estimation of a temporal average. Groundwater samples will be collected from the overburden, bedrock, and mine pool.

8.2.2 Terrestrial and Wetlands BERA Data Needs

As discussed previously, there are minimum analytical data requirements necessary for conducting exposure assessments based on a modeling approach for characterizing risks. Rather than repeating some of the statistical requirements previously presented, the terrestrial and wetlands BERAs data needs are presented by exposure area and focus more on the types of information needed and general sample requirements. Specific details of the data requirements for any agreed upon data gaps will be provided in subsequent SAPs and QAPPs. Additional analytical parameters like SPLP metals and acid-base accounting (ABA) may be required for Site characterization purposes. It was assumed that data previously collected in the water bodies to support the aquatic BERA, and additional surface water and sediment samples recommended in the HHRA data needs discussion, are adequate for characterization purposes and any exposure needs (i.e. surface water ingestion) of the terrestrial portion of the BERA.

In addition to samples collected for chemical analysis, a vegetative community assessment and a vernal pool identification and evaluation are being proposed. The vegetative community assessment will provide valuable information on the status of the existing vegetative community and will support future exposure modeling exercises for terrestrial receptors. This assessment will follow procedures outlined in the Habitat Characterization Report for Ely Mine (URS 2005) and will use vegetative community descriptions provided by Thompson and Sorenson (2000).

8.2.2.1 Terrestrial Data Needs

Data collected for the terrestrial portion of the BERA will be collected using a two-phase approach in an effort to maximize efficiency when collecting fixed lab samples. The first phase will include the vegetative community assessment and the collection of surface soil samples (0-0.5 ft) that will be analyzed using XRF technology. Surface soil sampling transects both perpendicular and parallel to source areas, will be placed in several down-gradient locations where habitat conditions appear suitable for subsequent biological sampling (i.e. vegetation, soil invertebrates and small mammals). We assume that 10 samples per transect (i.e. 20 per location) will be adequate to determine the range of metal concentration for a location. Using the transect results, three grid areas (5 X 10 nodes, with 10 meter spacing) will be identified and positioned so that a range of metal concentrations in soil will be identified. At least one grid will be positioned down-gradient of Smith Mine.

The second phase of the field effort will use transect and grid results to place small mammal traps across the concentration gradient with a goal of collecting 20- 30 small mammals for whole body analysis. Whenever possible, soil invertebrates and vegetation samples will be collected within 10 meter circular plots centered on successful mammals trapping points. One composite surface soil sample will be collected for each plot and this sample will be submitted for TAL metals analysis. If an adequate soil invertebrate sample cannot be collected within the small mammal plot area, the grid sampling XRF results will be used to identify appropriate invertebrate sampling locations (a target sample size of 20-30 invertebrate samples is recommended); composite surface soil samples will also be collected within the area excavated for invertebrate samples. Adequate vegetation mass will be collected from either the small mammal plots or the soil invertebrate sampling locations, with a proposed target sample size of 20-30 vegetation samples. This approach will allow for the evaluation of trophic transfer within the system and will provide the basis for the development of site-specific bioaccumulation factors. An additional 10-20 soil background and 5-10 biota background samples (vegetation, soil invertebrates and small mammals) will also be collected. Laboratory parameters, in addition to TAL metals, that will be evaluated are presented in Table 8-2.

8.2.2.2 Wetlands Data Needs

Vernal pools constitute a unique and increasingly vulnerable type of wetland. Vernal pools are inhabited by many species of wildlife, some of which are totally dependent on vernal pools for survival. It is therefore important to identify the presence and status of any vernal pools at the

Site prior to the development of remedial alternatives. If present, vernal pools will be evaluated following guidelines provided by the Vermont Wetlands Bioassessment Program (VTANR, 2003).

Several field activities are proposed for the Pike Hill Brook wetland complex in addition to surface water and sediment chemical characterization:

- Preliminary amphibian and biota assessment.
- Wetland vegetative community assessment and mapping.
- Benthic community assessment.
- Sediment toxicity testing.

The primary reasons for the recommended information collection are the high concentrations of copper that have been identified in the wetland sediments and the fact that previous Site visits have failed to identify the presence of emergent aquatic invertebrates or amphibians.

Table 8-2 provides a summary of the potential data needs identified for both the terrestrial and wetland portions of the BERA.

8.3 Data to Evaluate Remedial Alternatives

In addition to the data collected during the RI to support Site characterization and risk assessment decisions, data will be required to assess the various remedial alternatives for the Site. Based on potential technologies and process options identified in Tables 7-1 to 7-3, selected data parameters have been identified that are recommended to be collected during the RI. These parameters and others would continue to be evaluated throughout the RI process and modified as necessary.

- **Monitored Natural Attenuation – Water and Sediments -** Several possible attenuation reactions can occur including sorption in aerobic environments, sorption/co-precipitation of carbonates, and sorption/precipitation in anaerobic environments. Several relevant parameters to monitor would include: abundance/stability of host minerals (typically Fe and Al hydroxides); pH buffer capacity; solid-phase sulfide accumulation; redox buffer capacity; and sulfate reducing capacity.

- **Solidification/Stabilization -** Compatibility of potential binder material with Site contaminants would need to be known. Contaminant concentrations are included in the Site investigation program.

- **Ex-Situ Treatment – Neutralization -** Choice of chemicals (neutralizers) would be depends on the chemical characteristics of the impacted surface waters. Therefore, water pH and metals concentrations, including iron, copper, manganese, and aluminum would be needed.

- **Ex-Situ Treatment – Reverse Osmosis and Ion Exchange -** This technology is effective for ARD, however, some pre-treatment may be required, so data collected for water hardness and total suspended solids (TSS) would be needed.

8.4 Site Management, Access, and Sequencing of Activities

In order to complete Site activities in a timely and cost-effective manner, site access and the sequencing of field activities must be evaluated. Due to the limited road access and open areas for staging, careful coordination will be needed to ensure smooth, safe implementation of the various phases of site activities. The steep terrain and safety concerns regarding the stability of waste piles and underground working must be evaluated to determine the most feasible approach. The anticipated relative sequence of data collection activities is outlined below. In general, supplemental sampling to support risk characterization will follow Site characterization sampling:

- Site reconnaissance to evaluate Site access, locate and mark proposed sample/monitoring locations, mine hazard assessment;
- Soil borings, monitor well installation, and well development;
- Test pits and on-site field XRF surveys of surface soils and test pits;
- XRF survey of BERA soil grids;
- Groundwater, residential well, surface water, and sediment sampling, floodplain soil sampling, hydraulic testing of wells; and
- Subsequent rounds of groundwater, residential well, and surface water sampling.

Some well installation work may require special coordination to complete borehole geophysical work prior to final casing installation. In addition, the sequencing of well installation will depend

on the type and availability of rig/equipment used for the particular installations such that all overburden wells are completed during one mobilization using the same equipment and all bedrock wells are completed during one mobilization. These activities will be coordinated as to minimize rig movements.

Site characterization sampling and BERA sampling associated with the Pike Hill Brook Wetland Complex will be coordinated with on-site activities to the extent feasible to maximize the available equipment and personnel, however access, permit constraints, and wetland conditions may require these activities to be conducted as a separate phase of work.

Field sampling and data collection activities at on-site areas must be coordinated to minimize Site disturbance and utilize existing access roads wherever possible. Site activities must be conducted in such a way as to respect the conditions of access agreement with property owners. In addition, due to the historical significance of Site features, a historical resource specialist will be consulted prior to intrusive or other Site activities that might disturb Site features or the landscape to obtain concurrence on the approach. As necessary, photo documentation by a certified professional will be used to document Site conditions, assist in determining the best approach to gathering data while limiting Site disturbance, and appropriate restoration. Boring, test pit, and monitor well locations will be moved as necessary to optimize data collection and Site preservation.

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TABLES

Table 3-1
Summary of Mine Waste Samples Collected by USGS
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Mine Area	Sample ID	Sample Type		Location, sample type	Parameters	Reference
Smith	04Smith1	WR piles	composite	Upper WR pile at mine	Mineralogy (XRD), bulk chemistry for major and trace elements (ICP-AES and -MS), ABA (AP, NP, and NNP, paste pH), modified field-leach test (major, trace elements and anions via ICP-AES, -MS and ion chromatography, test kits for dissolved total iron and ferrous iron)	Piatak and others (USGS), 2006
Smith	04Smith1-1	rock	grab	Upper WR pile at mine		
Smith	04Smith1-2	mineral	grab	Upper WR pile at mine		
Smith	04Smith2	WR piles	composite	Middle WR pile near adit		
Smith	04Smith3	WR piles	composite	Lower WR pile near adit		
Smith	04Smith4	Hardpan	grab	Downslope of lower WR pile		
Smith	04Smith5	Soil	composite	Downslope of lower WR pile		
Smith	04Smith6	Soil	grab	Background soil near headwaters of trib to CKBK		
Smith	04Smith7	Soil	grab	Background soil near headwaters of trib to CKBK		
Eureka	04PKHL1	WR piles	composite	WR piles at top of Pike Hill		
Eureka	04PKHL2	WR Piles	composite	WR piles at top of Pike Hill		
Eureka	04PKHL2-1	rock	grab	WR piles at top of Pike Hill		
Eureka	04PKHL3	WR Piles	composite	WR piles above Eureka adit		
Eureka	04PKHL3-1	mineral	grab	WR piles above Eureka adit		
Eureka	04PKHL4-A	mineral	grab	Main Eureka adit		
Eureka	04PKHL4-B	mineral	grab	Main Eureka adit		
Eureka	04PKHL4-C	mineral	grab	Main Eureka adit		
Eureka	04PKHL4-D	mineral	grab	Main Eureka adit		
Eureka	04PKHL4-E	mineral	grab	Main Eureka adit		
Eureka	04PKHL4-F	mineral	grab	Main Eureka adit		
Union	04PKHL5-A	mineral	grab	Union Adit north of Eureka main adit		
Union	04PKHL5-B	mineral	grab	Union Adit north of Eureka main adit		
Union	04PKHL5-C	mineral	grab	Union Adit north of Eureka main adit		
Union	04PKHL6	mineral	grab	Union main adit/haulageway		
Eureka/Union	04PKHL7	WR Piles	composite	WR piles below Eureka and Union adits		
Eureka	04PKHL8	mineral	grab	Upper Eureka Adit		
Eureka/Union	04PKHL9	WR Piles	composite	Burned flotation tailings pile above road		
Eureka/Union	04PKHL9-A	Tailings	grab	Burned flotation tailings pile above road		
Eureka/Union	04PKHL9-B	Tailings	grab	Burned flotation tailings pile above road		
Eureka/Union	04PKHL9-C	Tailings	grab	Burned flotation tailings pile above road		
Eureka/Union	04PKHL10	Tailings	composite	Tailings below road		
Eureka/Union	04PKHL11	WR Piles	composite	Lower Union/Eureka WR Piles		
Eureka/Union	05PKHL11-Dup	WR Piles	composite	Lower Union/Eureka WR Piles		
Eureka/Union	04PKHL11-A	Tailings	grab	Lower Union/Eureka WR Piles		
Eureka/Union	04PKHL11-1	rock	grab	Lower Union/Eureka WR Piles		
Eureka/Union	04PKHL12	Ferricrete	grab	Seep below lower Union/Eureka WR piles		
Eureka/Union	04PKHL13	WR piles	composite	Lowermost Union/Eureka WR piles		
Eureka/Union	04PKHL13-A	rock	grab	Lowermost Union/Eureka WR piles		
Eureka/Union	04PKHL13-B	Ferricrete	grab	Lowermost Union/Eureka WR piles		
Eureka/Union	04PKHL14	mineral	grab	Lower Union/Eureka WR piles		

Table 3-2
Summary of Surface Water, Seep, and Mine Pool Samples Collected by USGS
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

USGS 2007 Station ID	USGS Sample ID	Corresponding Sediment Sample ID	Location	Aqueous Parameters	Reference
0	PKHL-9	NA	Trib to PHB at lower Eureka/Union waste pile	Dissolved and total acid soluble cations, anions and alkalinity, DOC, pH, temperature, specific conductance, DO, ORP, dissolved ferrous iron, dissolved total iron.	USGS-2006, 2007
1*B	PKHL-10	01139830-SD	Trib to PHB at weir, 800 ft downstream of site 0		
2B	PKHL-11	011398302-SD	Background, Trib to PHB upstream of Site at Richardson Rd		
2A	PKHL-16	NA	PHB at Richardson Road, 0.5 miles downstream from Site 1		
3B	01139832	01139832-SD	PHB at Carpenter Place, 0.7 miles downstream of site 1		
4*B	PKHL-12	01139833-SD	PHB at Pike Hill Rd, above wetlands, 1.1 miles downstream from site 1		
4AB	01139834	NA	PHB below Pike Hill Road, above wetlands, 1.6 miles from Site 1		
5*B	PKHL-13	01139838-SD	Between PHB wetlands, 3 miles downstream of site 1		
5A	PKHL-17	NA	Background, Trib to PHB at wetlands, 900 ft upstream from site 5		
6B	PKHL-14	01139839-SD	PHB in wetlands at Miller Road, 3.8 miles downsteam of site 1		
7B	01139840	01139840-SD	PHB at mouth		
8B	PKHL-15	01139826-SD	Waits River 1.8 miles upstream from confluence with Pike Hill Brook		
9	01139841	01139841-SD	Waits River 0.8 miles downstream of confluence with PHB, at Village Road		
10B	CKBK-1	01139940-SD	Tributary to Cookville Brook below Smith mine		
NA	PKHL-1	NA	Eureka Mine pool at Main Adit		
NA	PKHL-2	NA	Trib to PHB downstream of Eureka/Union lowermost waste pile		
NA	PKHL-4	NA	Union Mine pool at upper adit, perched		
NA	PKHL-5	NA	Union Mine pool, main adit		
NA	PKHL-6	NA	Surface seep below Union main adit		
NA	PKHL-7	NA	Seep at Eureka/Union lower waste pile		
NA	PKHL-8	NA	Seep at Eureka/Union lower waste pile		
NA	CKBK-2	NA	Entering tributary to Cookville Brook. Aluminum precipitate near Smith		
NA	CKBK-3	NA	Background, upstream of Smith mine road at headwaters of unnamed tributary to Cookville Brook		
NA	CKBK-4	NA	Ponded water north of Smith mine adit/shaft		
NA	CKBK-5	NA	Smith Mine pool at adit/shaft		

Notes:
*Continuous monitoring of streamflow, specific conductance, pH, and water temp., with monthly water quality samples between Oct 04 to Sept 06
Four synoptic samples were collected from loc 1 to 9 (Nov04, Apr05, June05, Dec05); 3 samples from loc 10 (Nov04,June05, Aug05)
Additional samples were collected at loc 1 and 5 during rain and snow melt events.
Water samples were collected at loc 1 and 5 between Nov04-Dec05; Loc 4 from June05-Dec05
B = Macroinvertebrate biota sample location
NA = Not applicable

Table 3-3
Summary of Sediment Samples Collected by USGS
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Sample ID	Corresponding Water Loc ID	Location	Parameters	Reference
01139940-SD	10, CKBK-1	Tributary to Cookville Brook below Smith mine	Composite samples analyzed for Mineralogy (XRD), bulk chemical analysis for major and trace elements by ICP-AES and-MS, Se by HG-AAS.	USGS-2006
01139830-SD	1, PKHL-10	Trib to PHB at weir, 800 ft downstream of site 0		
01139830-SD-BC	none	PHB downstream of Loc 1 below confluence with first clean tributary		
011398302-SD	2, PKHL-11	Background, trib to PHB upstream of site		
01139833-SD	4, PKHL-12	PHB at Pike Hill Road, above PHB wetlands 1.1 miles downstream from site 1		
01139838-SD	5, PKHL-13	Between PHB wetlands 3 miles downstream of site 1		
01139839-SD	6, PKHL-14	PHB at Miller Road in wetlands 3.8 miles downsteam of site 1		
01139826-SD	8, PKHL-15	Background, Waits River at Rte 25, 1.8 miles upstream from confluence with Pike Hill Brook		
01139832-SD	3, 01139832	PHB at Carpenter Place, 0.7 miles downstream of site 1		
01139840-SD	7, 01139840	PHB at mouth		
01139841-SD	9, 01139841	Waits River at Village Road, 0.8 miles downstream of confluence with Pike Hill Brook		

Table 3-4
Summary of Macroinvertebrate Biota Samples Collected by USGS
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Location ID	Corresponding Water/Sediment Sample ID	Location	Parameters	Reference
1	PKHL-10, 01139830-SD	Trib to PHB at weir, 800 ft downstream of site 0	Benthic Macroinvertebrates: VT-DEC Method, 300-individual count taxonomic ID, and metriccs (abundance, dominance, richness, composition, functional feeding groups, diversity/evenness, and biotic indices)	USGS-2007
2	PKHL-11, 011398302-SD	Background, tributary to PHB upstream of site		
3	01139832-SD	PHB at Carpenter Place, 0.7 miles downstream of site 1		
4	PKHL-12, 01139833-SD	PHB at Pike Hill Road, above wetlands 1.1 miles downstream from site 1		
4A	01139834	PHB above wetlands at Pike Hill Road, 1.6 miles from Site 1		
5	PKHL-13, 01139838-SD	Between PHB wetlands 3 miles downstream of site 1		
6	PKHL-14, 01139839-SD	PHB at Miller Road in wetlands 3.8 miles downsteam of site 1		
7	01139840-SD	PHB at mouth		
8	PKHL-15, 01139826-SD	Background, Waits River 1.8 miles upstream from confluence with Pike Hill Brook		
9	01139841-SD	Waits River at Village Road, 0.8 miles downstream of confluence with Pike Hill Brook		
10	CKBK-1, 01139940-SD	Tributary to Cookville Brook below Smith mine		

Table 3-5
Summary of Aquatic Assessment Samples Collected by EPA, USGS, FWS, and USACOE
in Fall 2007 (Unpublished Results)
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Sample ID	Sample Type	Location	Parameters	Reference
Wetland 1-1	Soil Core	Wetland 1, central area	Wetland soil cores sampled in August 2007 and analyzed for major ions, trace elements, total carbon, AVS/SEM, total sulfur, grain size, VOCs, SVOCs, pest/PCBs.	EPA/USGS-2008, unpublished
Wetland 2-1	Soil Core	Wetland 2, central area		
Wetland 3-1	Soil Core	Wetland 3, near outlet		
Wetland 3-2	Soil Core	Wetland 3,central area		
Wetland 3-3	Soil Core	Wetland 3, near channel upstream of 3-2		
Wetland 3-4	Soil Core	Wetland 3, southern margin		
Wetland 3-5	Soil Core	Wetland 3, northern margin		
Wetland 3-6	Soil Core	Wetland 3, western , upstream margin		
Wetland 4-1	Soil Core	Wetland 4, central area		
Wetland 4-2	Soil Core	Wetland 4, south margin		
100+ Locations in Wetlands 1 through 4	Soil Grab	Grid throughout	Wetland soil sampled in July 2007 at over 100 locations throughout Wetlands 1 through 4, analyzed by field XRF for Cu, Fe, Pb, and Zn. Samples collected from 0-0.5' and 0.5-1'	
Wetland 3-1 through 3-5)	Surface/Pore Water	See locations above	In August 2007, surface water and pore water collected (pore water at depths of 1' and 2') for major ions, trace elements, specific conductance, pH, temp, ORP, DO, nutrients, DOC, and alkalinity.	
1	SW/PW/Sed/ Biota/Tox	At weir on trib to PHB at Site	**Surface Water:** Nutrients, DOC, alkalinity, suspended sediment, major ions, trace elements, mercury. **Pore Water:** Nutrients, DOC, alkalinity, major ions, trace elements, mercury. **Sediment:** Total carbon, major ions, trace elements, Se, Hg, AVS/SEM, total S, grain size, centrifuged trace elements. **Macroinvertebrates:** Identification and enumeration. **Fish:** Identification, enumeration, trace elements, Hg. **Toxicity:** Surface and Pore Water; Sediment, 28 day amphipod servival and 10 day midge survival.	
4	SW/PW/Sed/ Biota/Tox	PHB at Pike Hill Road crossing.		
4A	SW/PW/Sed/ Biota/Tox	PHB below Pike Hill Road crossing, upstream of Wetland 4.		
4C	SW/PW/Sed/ Biota/Tox	PHB upstream of Wetland 3		
4E	SW/PW/Sed/ Biota/Tox	PHB downstream of Wetland 3		
5	SW/PW/Sed/ Biota/Tox	PHB at road crossing of Pike Hill Road downstream of Wetland 2		
5A	SW/PW/Sed/ Biota/Tox	Reference tributary to PHB upgradient of Wetland 2		
6	SW/PW/Sed/ Biota/Tox	PHB downstream of Wetland 1		
10	SW/PW/Sed/ Biota/Tox	Trib to CKBK		
10A	SW/PW/Sed/ Biota/Tox	Headwaters of Trib to CKBK		
10B	SW/PW/Sed/ Biota/Tox	Trib to CKBK headwaters, downstream of 10A		
10C	SW/PW/Sed/ Biota/Tox	Trib to CKBK in wetland before confluence		
10D	SW/PW/Sed/ Biota/Tox	CKBK upstream of site, reference		
11	SW/PW/Sed/ Biota/Tox	Trib to CKBK between 10 and 10B		
12	SW/PW/Sed/ Biota/Tox	Trib to CKBK between10 and 11		

Table 5-1
Human Health Risk Assessment Exposure Areas
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Proposed Exposure Area	Description of Proposed Exposure Area (see Appendix B of the 2007 PAL Report)
SOIL	
Union Mine Waste Piles	Waste Rock Piles 1 through 7 and 39; Berms 2 through 6 and 8
Eureka Mine Tailings Piles	Magnetic Separation Waste Material Pile; Magnetic Separation Tailings Piles 1, 2, 3; Burnt Flotation Tailings Piles 1 and 2
Eureka Mine Waste Piles	Waste Rock Piles 9 through 37 and 40; Berm 7
Smith Mine	Waste Rock Pile 38; Berm 1
Surface Water and Sediment	
Pike Hill Brook Downstream to Wetlands Complex	A 3.5 km reach of Pike Hill Brook.
Pike Hill Brook Wetlands Complex	A wetlands area of approximately 100 acres.
Pike Hill Brook Wetlands Complex Downstream to Waits River	A 3 km reach of Pike Hill Brook.
Unnamed Tributary to Cookville Brook	A 1.6 km reach.
South Branch of Waits River (Cookville Brook and tributaries)	A 8 km reach.
Fish	
Areas where edible fish or surrogates have been collected (i.e., Pike Hill Brook, tributary to Cookville Brook, and a reference area).	
Groundwater	
Eureka and Union Mines	Monitoring wells associated with the Eureka and Union Mines.
Smith Mine	Monitoring wells associated with the Smith Mine.
Off-Site	Monitoring wells located off-site.

Table 5-2
Recreational Visitor Exposure Parameters
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

	Adolescent Recreational Visitor		Adult Recreational Visitor	
	All Pathways			
Receptor Age	10-18 years		Adult	
ED (years)	8	Estimated	24	(1)
BW (kg)	52	(2)	70	EPA, 2002a
AT-Cancer (days)	25550	EPA, 1989	25550	EPA, 1989
AT-Noncancer (days)	2920	Calculated	8760	Calculated
	Soil Exposure Specific			
ABS (unitless)	COPC specific (EPA, 2004)			
EF_{soil} (days/year)	104	(3)	104	(3)
IRS (mg/day)	100	EPA, 2002a	100	EPA, 2002a
FI	1		1	
SA_{soil} (cm^2/day)	5900	(4)	6900	(4)
AF (mg/cm^2)	0.2	(5)	0.2	(5)
IRA (m^3/day)	3	(6)	3	(6)
PEF (m^3/kg)	Calculated	(7)	Calculated	(7)
	Mine Pool Water Exposure Specific			
$EF_{mine\ pool\ water}$ (days/year)	5	(8)	5	(8)
IRW_{inc} (L/hr)	0.05	EPA, 1989	0.05	EPA, 1989
ET (hrs/day)	1	Estimated	1	Estimated
Kp (cm/hr)	COPC specific (EPA, 2004)			
$SA_{mine\ pool\ water}$ (cm^2/day)	2100	(9)	2500	(9)

Notes:
(1) Adult visitor is assumed to be a local resident.
(2) Average body weight for males and females ages 10 to 18, see Tables 7-6 and 7-7 of EPA, 1997.
(3) Exposure is assumed to occur 3 times a week from April through November (8 months) (4.33 weeks/month). The visitors are not assumed to visit the site during December, January, February, and March.
(4) Assumes that the head, hands, forearms, lower legs and feet are exposed. Calculated using data from Exhibit C-1, EPA, 2004.
(5) Geometric mean for heavy equipment operators, EPA, 2004.
(6) Assumes the inhalation rate for outdoor workers involved with moderate activities (1.5 m^3/hour) for a total of 2 hours.
(7) PEF will be based on truck traffic on unpaved roads.
(8) Exposure is assumed to occur once a month from May through September.
(9) Assumes that the face, hands, and forearms are exposed. Calculated using data from Exhibit C-1, EPA, 2004.

Definitions

ABS = dermal absorption factor
AF = soil-to-skin adherence factor
AT-Cancer = carcinogenic averaging time
AT-Noncancer = noncancer averaging time
BW = body weight
ED = exposure duration
EF = exposure frequency
ET = exposure time
FI = fraction ingested
IRA = air inhalation rate
IRS = incidental soil ingestion rate
IRW_{inc} = incidental surface water ingestion rate
Kp = dermal permeability coefficient
PEF = particulate emission factor
SA = exposed skin surface area

Table 5-3
Swimmer/Wader Exposure Parameters
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

	Adolescent Swimmer/Wader		Adult Swimmer/Wader	
	All Pathways			
Receptor Age	10-18 years		Adult	
ED (years)	8	Estimated	24	(1)
EF (days/year)	22	(2)	22	(2)
BW (kg)	52	(3)	70	EPA, 2002a
AT-Cancer (days)	25550	EPA, 1989	25550	EPA, 1989
AT-Noncancer (days)	2920	Calculated	8760	Calculated
	Sediment Exposure Specific			
ABS (unitless)	COPC specific (EPA, 2004)			
IRSED (mg/day)	100	EPA, 2002a	100	EPA, 2002a
FI	1		1	
$SA_{sediment}$ (cm^2/day)	5900	(4)	6900	(4)
AF (mg/cm^2)	0.32	(5)	0.32	(5)
	Surface Water Exposure Specific			
IRW_{inc} (L/hr)	0.05	EPA, 1989	0.05	EPA, 1989
ET (hrs/day)	2	Estimated	2	Estimated
Kp (cm/hr)	COPC specific (EPA, 2004)			
$SA_{surface\ water}$ (cm^2/day)	14900	(6)	18000	(6)

Notes:

(1) Adult visitor is assumed to be a local resident.

(2) Exposure is assumed to occur once a week from May through September (4.33 weeks/month).

(3) Average body weight for males and females ages 10 to 18, see Tables 7-6 and 7-7 of EPA, 1997.

(4) Assumes that the head, hands, forearms, lower legs and feet are exposed. Calculated using data from Exhibit C-1, EPA, 2004.

(5) Geometric mean for reed gatherers, EPA, 2004.

(6) Assumes body is fully immersed while swimming. Calculated using data from Exhibit C-1, EPA, 2004.

Definitions

ABS = dermal absorption factor
AF = soil-to-skin adherence factor
AT-Cancer = carcinogenic averaging time
AT-Noncancer = noncancer averaging time
BW = body weight
ED = exposure duration
EF = exposure frequency
ET = exposure time
FI = fraction ingested
IRSED = incidental sediment ingestion rate
IRW_{inc} = incidental surface water ingestion rate
Kp = dermal permeability coefficient
SA = exposed skin surface area

Table 5-4
Fish Consumer Exposure Parameters
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

	Young Child Fisherman		Adult Fisherman	
Receptor Age	1-6 years		Adult	
IRF (kg/day)	TBD		TBD	
EF (days/year)	350		350	
ED (years)	6	Estimated	24	EPA, 2002a
BW (kg)	15	EPA, 2002b	70	EPA, 2002a
AT-Cancer (days)	25550	EPA, 1989	25550	EPA, 1989
AT-Noncancer (days)	2190	Calculated	8760	Calculated

Definitions
AT-Cancer = carcinogenic averaging time
AT-Noncancer = noncancer averaging time
BW = body weight
ED = exposure duration
EF = exposure frequency
IRF = fish ingestion rate

Table 5-5
Resident Exposure Parameters
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

	Child Resident		Adult Resident	
	All Pathways			
Receptor Age	1-6 years		Adult	
ED (years)	6	EPA, 2002a	24	EPA, 2002a
BW (kg)	15	EPA, 2002b	70	EPA, 2002a
AT-Cancer (days)	25550	EPA, 1989	25550	EPA, 1989
AT-Noncancer (days)	2190	Calculated	8760	Calculated
	Soil Exposure Specific			
IRS (mg/day)	200	EPA, 2002b	100	EPA, 2002a
EF_{soil} (days/year)	150	Region 1	150	Region 1
FI	1		1	
ABS (unitless)	COPC specific (EPA, 2004)			
SA (cm^2/day)	2800	EPA, 2004	5700	EPA, 2004
AF (mg/cm^2)	0.2	EPA, 2004	0.07	EPA, 2004
PEF (m^3/kg)	Calculated	(1)	Calculated	(1)
IRA (m^3/day)	10	EPA, 2002b	20	EPA, 2002a
	Groundwater Exposure Specific			
$EF_{groundwater}$ (days/year)	350	EPA, 2002a	350	EPA, 2002a
IRW (L/day)	1	EPA, 2002b	2	EPA, 2002a
Kp (cm/hr)	COPC specific (EPA, 2004)			
$SA_{bathing/showering}$ (cm^2/day)	6600	EPA, 2004	18000	EPA, 2004
T_{event} (hrs/event)	1	EPA, 2004	0.58	EPA, 2004

Notes:
(1) PEF will be based on wind erosion using regional-specific data.

Definitions

ABS = dermal absorption factor
AF = soil-to-skin adherence factor
AT-Cancer = carcinogenic averaging time
AT-Noncancer = noncancer averaging time
BW = body weight
ED = exposure duration
EF = exposure frequency
FI = fraction ingested
IRA = air inhalation rate
IRS = incidental soil ingestion rate
IRW = water ingestion rate
Kp = dermal permeability coefficient
PEF = particulate emission factor
SA = exposed skin surface area

Table 5-6
Construction Worker Exposure Parameters
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

	Construction Worker	
Receptor Age	Adult	
IRS (mg/day)	330	EPA, 2002a
FI	1	
EF (days/year)	60	(1)
ED (years)	1	(2)
ABS (unitless)	COPC specific (EPA, 2004)	
SA (cm^2/day)	3300	EPA, 2004
AF (mg/cm^2)	0.24	(3)
BW (kg)	70	EPA, 2002a
IRA (m^3/day)	20	EPA, 2002a
PEF (m^3/kg)	Calculated	(4)
AT-Cancer (days)	25550	EPA, 1989
AT-Noncancer (days)	365	Calculated

Notes:
(1) Assumes the construction worker is exposed 5 days per week for a total of 12 weeks.
(2) Assumes the construction is exposed for 1 year.
(3) Geometric mean for utility workers, EPA, 2004.
(4) PEF will be based on truck traffic on unpaved roads.

Definitions
ABS = dermal absorption factor
AF = soil-to-skin adherence factor
AT-Cancer = carcinogenic averaging time
AT-Noncancer = noncancer averaging time
BW = body weight
ED = exposure duration
EF = exposure frequency
FI = fraction ingested
IRA = air inhalation rate
IRS = incidental soil ingestion rate
PEF = particulate emission factor
SA = exposed skin surface area

Table 5-7
Terrestrial Receptors, Environmental Communities, and Exposure Areas
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Receptor/Community	Exposure Area
Vascular plants	Terrestrial habitats (Eureka/Union and Smith Mines)
Soil invertebrate/microbes	Terrestrial habitats (Eureka/Union and Smith Mines)
Herbivorous birds/mammals Song sparrow Meadow vole	Terrestrial habitats (Eureka/Union and Smith Mines) Surface waters
Omnivorous birds/mammals Red-winged blackbird White-footed mouse	Terrestrial habitats (Eureka/Union and Smith Mines) Surface waters
Invertivorous birds/mammals American robin Short-tailed shrew	Terrestrial habitats (Eureka/Union and Smith Mines) Surface waters
Carnivorous birds/mammals American kestrel Mink	Terrestrial habitats (Eureka/Union and Smith Mines) Surface waters

Table 5-8
Wetland Receptors, Environmental Communities, and Exposure Areas
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Receptor/Community	Exposure Area
Vascular plants	Pike Hill Brook Wetlands (Nos. 1-4)
Sediment community	Pike Hill Brook Wetlands (Nos. 1-4)
Amphibian community	Pike Hill Brook Wetlands (Nos. 1-4)
Herbivorous birds/mammals Mallard Muskrat	Pike Hill Brook Wetlands (Nos. 1-3)
Insectivorous birds/mammals Little brown bat Tree swallow	Pike Hill Brook Wetlands (Nos. 1-3)
Piscivorous birds/mammals Belted kingfisher Mink	Pike Hill Brook Wetlands (Nos. 1-3)

Table 6-1
Preliminary Chemical-Specific ARARs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Requirement	STATUS
STATE ARARs	
Vermont Water Quality Standards, Appendix C (Nat. Res.Brd, Water Res. P. 12-004-052)	Applicable
FEDERAL ARARs	
Federal Clean Water Act (CWA), Federal Ambient Water Quality Criteria, 40 CFR Part 122.44	Applicable
EPA National Recommended Water Quality Criteria – EPA 822-R-02-047, EPA 2002.	To Be Considered
EPA National Recommended Water Quality Criteria – EPA 822-R-02-047, EPA 2002.	To Be Considered
EPA Residential Risk Based Concentrations (RBCs) (Region III) and Preliminary Remediation Goal (PRGs) (Region IX) – Residential	To Be Considered
EPA Risk Reference Doses (RfDs)	To Be Considered
EPA Carcinogen Assessment Group, Cancer Slope Factors (CSFs)	To Be Considered
Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems (MacDonald et al., 2000)	To Be Considered
Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments (Long et al. 1995)	To Be Considered
Preliminary Remediation Goals for Ecological Endpoints, Efroymson et al., August 1997	To Be Considered
Memorandum: OSWER Directive: Clarification to the 1994 Revised Interim Soil Lead (Pb) Guidance for CERCLA Sites and RCRA Corrective Action Facilities, EPA/540/F-98-030, August 1998	To Be Considered

Table 6-2
Preliminary Location-Specific ARARs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Requirement	Status
STATE ARARs	
Vermont Wetlands Act, 10 VSA § 905; Vermont Wetland Rules (Nat. Res. Brd., Water Res. P. 12-004-056)	Applicable
Vermont's Land Use and Development Law (Act 250), 10 VSA Chapter 151	Applicable
Vermont Regulation of Stream Flow, 10 VSA Chapter 41	Applicable
Vermont Endangered Species Law, 10 VSA, Chapter 123, § 5402(a).	Applicable
FEDERAL ARARs	
Federal Protection of Wetlands, Executive Order 11990, 40 CFR 6, App. A	Applicable
Federal Clean Water Act, Section 404, 33 USC § 1344; 40 CFR Part 230; 33 CFR Parts 320-323	Applicable
Federal Floodplain Management, Executive Order 11988, 40 CFR 6, App. A	Applicable
Federal Fish and Wildlife Coordination Act; 16 USC 661 *et seq*., as amended; 40 CFR 6.302	Applicable
Federal Endangered Species Act of 1973 (ESA), 16 USC 1531 *et seq*.; 33 CFR Part 320	Applicable
National Historic Preservation Act (NHPA), Section 106, 16 USC 470 *et seq*., 36 CFR Part 800	Applicable
Archeological and Historic Preservation Act, 16 USC 469 *et seq*., 36 CFR, Part 65	Applicable

Table 6-3
Preliminary Action-Specific ARARs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Requirement	Status
STATE ARARs	
Vermont Groundwater Protection Act (10 VSA §§ 1390-94) and Vermont Groundwater Protection Rule and Strategy, Env. Prot. R. Ch. 12-702 and 703	Applicable
Vermont Water Pollution Control Act, 10 VSA Chapter 47; Vermont Water Quality Standards, Ch. 1, 2, and 3 and Appendix C and D; and Vermont National Pollutant Discharge Elimination System (NPDES) Regulations Ch. 13 (Nat. Res. Brd., Water Res. P. 12-004-052)	Applicable
Vermont Solid Waste Management Rules (VSWMR), Env. Prot. R. Ch. 6	Relevant and Appropriate
Vermont Stormwater Management Act, 10 VSA § 1263 and §1264; Vermont Stormwater Management Rule, Env. Prot. R.Ch. 18	Applicable
Vermont Air Pollution Control Act, 10 VSA Chapter 23 and Air Pollution Control Regulations, Env. Prot. R. Ch. 5	Applicable
Vermont Waste Management Act, 10 VSA Chapter 159 and Hazardous Waste Management Regulations, Env. Prot. R. Ch. 7	Relevant and Appropriate
Vermont Dam Statute, 10 VSA Chapter 43	Applicable
Vermont Underground Injection Control Rule (Env. Prot. R.Ch. 11)	Relevant and Appropriate
Vermont Handbook for Erosion Prevention and Sediment Control, Working Interim Document, Released in 2003 (VTDEC, 2003)	To Be Considered
FEDERAL ARARs	
Resource Conservation and Recovery Act, 42 USC §§ 6901-6992; 40 CFR Part 264	Relevant and Appropriate
Federal Clean Water Act, Section 402 – National Pollution Discharge Elimination System (33 USC 1342; 40 CFR 122-135, 131)	Relevant and Appropriate
Federal Clean Water Act – Groundwater Injection Standards, 40 CFR 144, 146, 147	Relevant and Appropriate
Federal Clean Water Act – Stormwater Requirements for Construction Sites; 40 CFR 122.26	Applicable
Federal Surface Mining Control and Reclamation Act of 1977, 30 USC §§ 1201-1328; 30 CFR 816 and 817	Relevant and Appropriate
EPA, Specifications for *Geotechnical Analysis for Review of Dike Stability*, EPA Contract No. 68-03-3183	To Be Considered

Table 7-1
Screening of Potential Treatment Options for Waste Piles
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
No Action	No Action	No Action	In accordance with CERCLA and NCP requirements, a No Action response must be developed to provide a baseline against which other response actions can be compared. The no action response may be selected in instances where existing site conditions do not pose a risk to human health and the environment or any further action would pose a greater threat. Although the no action response may include some type of environmental monitoring, actions taken to reduce the potential for exposure (i.e., institutional controls and engineered controls) should not be incorporated.	Not effective for waste piles containment, reduction and/or remediation.	Implementable.	None.
Limited Action	Institutional Controls	Land Use Restrictions	The purpose of a land use restriction is to prevent specific uses of or activities at a property or a portion of a property in order to minimize potential exposures to humans and the environment. Land use restrictions may be put into place to protect against potential hazards present at a site, to preserve an implemented remedial action, or to restrict future land uses. Land use restrictions can be implemented by altering the deed or title of record or through re-zoning of the property. These alterations would remain in effect in perpetuity, regardless of changes in ownership of the property	May not meet cleanup goals as the sole application, but may be used in conjunction with other options. This process option would aid in deterring land use practices that would cause increased exposure risks to human receptors.	Implementable. Requires agreement by current land owner and possibly public acceptance.	Low capital and O&M costs.
		Informational/ Educational Devices	Informational/educational devices consist of meetings or literature aimed at raising the public's knowledge of the site and addressing their concerns. Topics addressed by these devices could include the potential hazards posed by contaminants, potential hardships that may be temporarily encountered during implementation of the remedial alternative, and the purpose and effectiveness of the remedial actions taken.	May not meet cleanup goals for the Site as the sole application, but may be used in conjunction with other options. Informational/educational devices would effectively inform the public about the Site.	Implementable.	Low capital and O&M costs.
	Engineered Controls	Engineered Controls	Engineered controls are physical deterrents that serve to restrict access to the site, thereby impeding the potential for exposure to contaminants. Fencing could be installed around the perimeter(s) of the source area(s) to prohibit human and animal access to the area. Posted warnings identify potential hazards present at the Site and discourage trespassing and misuse. Security systems and patrols also deter trespassing and misuse.	May not meet cleanup goals for the Site as the sole application, but may be used in conjunction with other options. These items would effectively restrict access to the Site, thereby impeding the potential for exposure to contaminants.	Implementable.	Low capital and O&M costs.
Containment	Surface Controls	Grading	Grading is the practice of reshaping the ground surface to planned contours that function to improve the flow of surface water and increase the stability of sloped surfaces. The grading is designed to reduce ponding and erosion.	Grading would be effective in minimizing erosion. It would not effectively satisfy the cleanup goals for the Site as a sole application, but may be used in conjunction with other process options.	Site conditions such as steep slopes and shallow soils may impact implementability. The large size of some waste ore/rock materials increases difficulty and slows progress. Overall, grading is implementable.	Moderate capital and low O&M costs.
		Revegetation	Vegetation protects soil from water and wind erosion. The aboveground portions of the plants protect the soil by slowing the velocity of surface water flow, thereby minimizing surface scouring and encouraging infiltration of water into the soil. Plants may also filter sediment and other materials out of run-off. Root systems aid in the stabilization of soil by holding soil particles in place.	This process option would be effective in increasing infiltration and minimizing erosion. It would not effectively achieve the cleanup goals for the Site as a sole application, but may be used in conjunction with other process options.	Revegetation is a common practice; therefore materials, equipment, and skilled workers are readily available. This process option would need to occur after some type of treatment action is taken because the current material characteristics are not suitable for vegetation.	Low capital and O&M costs.
		Mulching and Erosion Control Mats	Mulches (e.g., wood chips and straw) and erosion control mats (e.g., jute mesh) are typically applied to form a temporary protective cover for soil while awaiting the establishment of vegetation. These items provide an environment that is favorable for seed germination and growth in addition to reducing overland flow, water loss and impact from precipitation. Potential benefit is to increase water infiltration to the soil.	This process option would be effective in reducing run-on and erosion. It would not effectively satisfy the cleanup goals for the Site as a sole application, but may be used in conjunction with other process options.	Materials are widely available and simple to apply.	Low capital and O&M costs.
		Retaining Walls	Retaining walls are used to improve slope stability and prevent erosion. They can also be employed to control water flow. Retaining walls can be used during or after construction activities.	This process option would be effective in increasing slope stability and minimizing erosion. It would not effectively achieve the cleanup goals for the Site as a sole application, but may be used in conjunction with other process options.	This process option would most likely be accomplished with the use of conventional equipment and methods. Site conditions such as steep slopes and shallow soils may impact implementability.	Moderate capital and low O&M costs.

Table 7-1
Screening of Potential Treatment Options for Waste Piles
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Containment	Capping Systems	RCRA Subtitle C Cap	RCRA Subtitle C caps, used for hazardous waste applications, employ low-permeability and high-permeability earthen materials and low-permeability synthetic products. RCRA Subtitle C caps typically consist of the components listed below, from top to bottom: Vegetative Layer (6 inches of topsoil); Protective Layer (1 to 1 ½ feet soil); Drainage Layer (1 foot of sand); Primary Synthetic Barrier (40-mil geosynthetic membrane); Secondary Synthetic Barrier (geosynthetic clay liner); Gas Vent Layer (1 foot of sand or geosynthetic material); and Foundation Layer (native soil).	This type of cap would be protective of human health and the environment by effectively prohibiting direct contact with contaminants and reducing contaminant migration. However, a system that incorporates multiple low permeability layers is not warranted or required given the characteristics of the material to be contained.	Materials, equipment, and skilled laborers are readily available. Site conditions, such as steep slopes and shallow soils, may impact implementability. The pitch of the sideslopes will ideally fall between 4 and 18 degrees in order to allow the cap to shed water as well as facilitate the use of conventional construction equipment. Fill may need to be transported to these areas and grading would need to be performed in order to achieve these slopes. Improvements to access routes may also be necessary. Increased exposure risks to workers handling the material would be mitigated using proper personal protective equipment (PPE) and environmental construction protocols. Permits would need to be obtained. Institutional controls would be required as well to ensure the long-term protectiveness of the cap.	High capital and moderate O&M costs.
		Vermont Solid Waste (RCRA Subtitle D) Cap	RCRA Subtitle D caps, used for non-hazardous waste landfills, typically consist of three components (from top to bottom): Vegetative Layer (6 inches of topsoil); Earthen/Synthetic Barrier (geosynthetic clay liner); and Foundation Layer (native soil).	This type of cap would be protective of human health and the environment by effectively prohibiting direct contact with contaminants and reducing contaminant migration. Given the waste type present at the Site, a RCRA Subtitle D cap would provide adequate protection of human health and the environment.		Moderate capital and O&M costs.
Removal and Disposal	Excavation	Excavation	Excavation refers to the removal of impacted waste piles for ex-situ treatment and/or on-site consolidation or off-site disposal.	Excavation would be effective in removing the contaminated media from the subsurface, thereby eliminating the source of surface water and groundwater impacts emanating from an area of concern.	Skilled technicians and equipment are readily available. Risks to workers and the surrounding community would be minimized using environmental construction protocols for control of contamination, including air monitoring, dust suppression techniques, and PPE. The large size of some of the waste ore/rock increases difficulty and slows progress. Diversion of surface water and erosion controls would be required	High capital and low O&M costs.
	Disposal	On-Site Consolidation	On-site consolidation consists of merging waste rock piles into an engineered containment cell within the remedial area.	An on-site consolidation cell would minimize the surface area upon which impacted material resides. It would be effective in preventing direct contact exposures to human and environmental receptors. The long-term effectiveness and permanence of the cell would be ensured through the implementation of land use restrictions and a groundwater monitoring program.	Materials, equipment, and skilled laborers are readily available. Site conditions, such as steep slopes and shallow soils, may influence implementability. The large size of some of the waste piles may increase difficulty and slow progress. Access routes at the Site will likely require significant improvement. Exposure risks posed to workers handling impacted material would be mitigated through the use of adequate PPE and environmental construction protocols. No impacted materials would be transported offsite under this process option. Since capping is incorporated with this process option, other implementability issues that are relevant to the site are discussed in that row.	Moderate to high capital and moderate O&M costs.
		Off-Site Disposal	This process option would entail the transport of waste piles from the site to a licensed, off-site disposal facility.	Off-site disposal is applicable to the contaminants present at the Site. This process option would reduce the on-site volume of contaminants and prevent exposure to human and environmental receptors via placement of impacted materials in a licensed, off-site disposal facility.	The large size of some of the waste ore/rock increases difficulty and slows progress. These wastes would likely need to be crushed to facilitate transport as well as to be accepted at a landfill. Stabilization of the contaminants prior to transport/disposal may also be required to prevent leaching. Significant improvements and/or the construction of new roads may be required to facilitate construction and transport traffic. Further, there would be increased risks to workers handling the material as well as increased risks and significant disturbance to communities along the transportation route. Given these limitations and taking into consideration the significant on-site consolidation capacity, off-site disposal is not a practical or viable option.	High capital and no O&M costs.

Table 7-1
Screening of Potential Treatment Options for Waste Piles
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
In-Situ Treatment	In-Situ Biological Treatment	Enhanced Bioremediation	Enhanced bioremediation uses amendments to stimulate microorganisms, enabling them to convert contaminants into less harmful forms. Bioremediation cannot degrade inorganic contaminants, however, bioremediation can be used to change the valence state of inorganics resulting in adsorption, immobilization and accumulation of inorganics in microorganisms (FRTR, 2005).	This technology has the potential to transform inorganic contaminants into states exhibiting decreased mobility, bioavailability, and toxicity, although high concentrations of heavy metals may be toxic to the microorganisms. The rate at which bioremediation occurs will decrease in colder temperatures.	This process option is not applicable to waste piles due to delivery and mixing issues.	Low capital and moderate O&M costs.
		Phytoremediation	Phytoremediation employs specifically selected plants to remove, store, or reduce the toxicity of contaminants. While high contaminant concentrations can be toxic to most plants, hyperaccumulator plants have the ability to handle significant amounts of inorganic contaminants. Phytoremediation is applicable to a wide range of inorganic contaminants.	The effectiveness of this technology, in general, would be driven by the ability to find plants that are compatible with the types of contaminants, contaminant concentrations, and climate of the Site. Phytoremediation would only be effective in remediating contamination within reach of the plant roots (i.e., shallow contamination) and the majority of the contamination at the Site is deeper.	In its current state, phytoremediation is not applicable to these areas. A soil layer for vegetative support would need to be formed. Further, for some Site areas the steep slope faces would require leveling and/or significant erosion control measures in order to sustain vegetation. Institutional controls would need to be implemented in order to protect the plants against dangerous land uses as well as to prevent potential receptors from contacting the plants.	Moderate capital and O&M costs.
	In-Situ Physical/ Chemical Treatment	Electrokinetic Separation	Electrokinetic separation involves the application of a low voltage direct current across a pair of electrodes (anode and cathode) that has been implanted on opposite sides of a contaminated soil mass. Contaminants are transported toward either of the electrodes via electroosmosis (water transport from anode to cathode) and electromigration (ion transport to the oppositely-charged electrode). Additives may be applied to the subsurface to augment the movement of contaminants. These chemicals need to be neutralized or recovered after the completion of the process. Once the contaminants are concentrated at either electrode, they are typically extracted for treatment/disposal.	Conditions in the areas of concern are not in the optimum range for treatment by electrokinetic separation, which has been demonstrated to be most effective in treating clayey soils with a moisture content between 14-18%. Additionally, there is the potential for this process to produce undesirable by-products.	A site investigation for subsurface obstructions, particularly those that are highly conductive or insulative and would disrupt this technology, should be performed. This technology is also relatively energy-intensive, which would increase overall costs.	Moderate capital and low O&M costs.
		Soil Flushing	Soil flushing, a flushing solution (typically water or water containing an additive to enhance contaminant solubility) is applied to subsurface soils by means of injection or infiltration. The flushing solution causes contaminants to partition into the aqueous phase. The flushing solution and contaminants in groundwater are then carried toward a capture zone and brought to the surface where the contaminants are separated from the flushing solution. The flushing solution can then be revitalized and reused or treated/discharged.	Soil flushing would not be effective in treating the waste piles because the metals are ingrained in the waste rock and therefore are not amenable to flushing.	If preferential pathways exist, there is an even greater potential for the off-site migration of contaminants and/or flushing solution. The separation of surfactants from recovered fluids for reuse in the process is a major factor in the cost. Treatment of the recovered fluids results in process sludges and residual solids that would require treatment and disposal. The generation of these materials would cause increased exposure risks to workers handling the materials as well as to communities along the transportation route (see Off-Site Disposal above).	High capital and low O&M costs.
		Solidification/ Stabilization (S/S)	In this process, the soil is mixed with a binder that functions to physically entrap contaminants (solidification) and/or chemically react with contaminants to reduce their mobility (stabilization). The binder is typically delivered to the subsurface via auger mixing or high-pressure injection. The binder can consist of many materials, including Portland cement, bitumen, pozzolans, and polymers. The selection of the binder is dependent upon compatibility with the contaminants at the site.	S/S would effectively immobilize inorganic contaminants. Leachability testing is usually performed to ensure the effectiveness of the process.	Since these areas primarily consists of waste rock, in-situ S/S would not be implementable due to difficulties with binder delivery and mixing.	Moderate capital and low O&M costs.
		Vitrification	In-situ vitrification (ISV) involves the application of an electric current to produce very high subsurface temperatures to melt earthen materials within the treatment zone. Innovative forms of this process, such as Planar ISV, incorporate moving electrodes that allow the melting process to begin at specified locations in the subsurface. As a consequence, treatment can be focused directly on the contaminated region and greater depths can be attained in comparison to conventional techniques. Organic contaminants and some volatile inorganic contaminants are destroyed or volatilized; off-gases are typically collected by a vacuum hood placed over the treatment area and treated prior to discharge. The electric current is removed once the entire treatment zone becomes molten. The treatment zone cools to form a vitrified mass. Inorganic contaminants are integrated into the hardened mass, thereby immobilized.	The migration of contaminants may be encouraged during treatment, when the soil is molten. However, the end product of ISV, a chemically-stable, leach-resistant glass and crystalline material, would effectively immobilize inorganic contaminants. Assessments to date demonstrate that the vitrified end-product appears to be unaffected by temperature cycling and other environmental stressors.	ISV can typically be implemented in a relatively short amount of time. However, it is extremely energy intensive. Moreover, the waste ore/rock, due to its large and generally coarse nature, is not amenable to treatment via ISV.	High capital and low O&M costs.

Table 7-1
Screening of Potential Treatment Options for Waste Piles
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Ex-Situ Treatment (assuming excavation)	Ex-Situ Physical/ Chemical Treatment	Chelation/ Complexation	Chelation/complexation is mainly used for controlling the leaching of metals. Chelation/complexation, immobilizes metals by forming a stable bond, or complex, between a metal cation and a ligand (chelating agent). The stability of the chelation depends on the number of bonds formed between the chelating agents and the target cation: as the number of bonds increases, the stability of the resulting complex increases and so does the degree of immobilization of the metal contaminant within the complex. The efficiency of chelation/complexation is ion-specific and depends on the chelating agent, pH, and dosage.	Can be effective in reducing leachable metals concentrations to meet TCLP requirements, however, contaminant concentrations would not decrease. Treated material would then require disposal. Technology would require significant bench-scale studies to identify appropriate agents.	Implementable. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Low capital and O&M costs.
		Physical Separation	Physical separation acts to concentrate contaminants into a reduced volume for subsequent treatment. Physical separation consists of sorting soil particles based on physical characteristics to reduce the volume of contaminated material. Most separation processes are based on one of the following physical characteristics: particle size, density, or magnetism.	The waste ore/rock material is not amenable to the physical separation process to isolate contaminants.	Implementable. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risk could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Soil Washing	Soil washing acts to concentrate contaminants into a reduced volume for subsequent treatment. Soil washing involves vigorously mixing contaminated soil with a wash solution, causing contaminants to be dissolved or suspended in the wash solution. The solution is then recovered and treated. Contaminants often bind to the finer fraction of a soil matrix (e.g., clay and silt), therefore soil washing often incorporates some type of physical separation process.	Soil washing is not applicable to the mineralogy of the waste piles.	Implementable. Site conditions such as steep slopes and shallow soils may impact implementability. The typically large grain size of the waste piles increases difficulty of application and slows progress. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risk could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Chemical Extraction	Chemical extraction acts to concentrate contaminants into a reduced volume for subsequent treatment. Chemical extraction is similar to soil washing, but differs in that a chemical extractant, rather than a water-based solution, is used to encourage contaminant separation from the soil matrix. Acid extraction, which uses hydrochloric acid as an extractant, is commonly used to treat heavy metals. Hydrocyclones are used to separate the soil and extractant, which then undergo treatment/disposal.	This process option involves a form of re-mining of the waste material. The composition of the waste piles is not amenable to the mineralogy of the waste ore/rock.	Implementable. This process would produce a significant amount of residual sludge that would require transport to an off-site facility for treatment and disposal. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Chemical Reduction/Oxidation	Chemical reduction/oxidation (redox) involves adding an oxidizing or reducing agent to the contaminated material, creating a redox reaction that results in a more stable, less toxic compound. Common oxiding agents include ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.	Incomplete redox reactions and intermediate compounds may occur and have the potential to not improve overall conditions. This process option is a reversible mechanism and would therefore be ineffective in reducing the volume, toxicity, and mobility of the impacted material, nor would it provide protection of human health and the environment.	Implementable. Site conditions such as steep slopes and shallow soils may impact implementability. The large size of the waste piles increases difficulty of application and slows progress. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Solidification/ Stabilization (S/S)	In this process, the soil is mixed with a binder that functions to physically entrap contaminants (solidification) and/or chemically react with contaminants to reduce their mobility (stabilization). A pug mill or rotating drum mixer is commonly used to blend the soil with the binder. The binder can consist of many materials, including Portland cement, bitumen, pozzolans, and polymers. The selection of the binder is dependent upon compatibility with the contaminants at the site.	S/S would effectively immobilize inorganic contaminants. Leachability testing is usually performed to ensure the effectiveness of the process.	Implementable. The need to crush the waste piles would hinder progress. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
Resource Utilization	Resource Utilization	Resource Utilization	Resource utilization is analogous to re-mining the site. This process option involves transporting impacted waste piles to an off-site processing facility where metals would be recovered for use as a commercial product.	This process option would facilitate the partial or complete removal of contaminant sources from the Site. Resource utilization would meet the potential cleanup goals at the Site by removing a source of surface and groundwater contamination. It would be effective in minimizing the amount of waste requiring treatment/disposal. However, the composition of the waste piles is not amenable to re-mining.	Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols. The potential for re-mining copper at the Site would likely be difficult to implement because of the composition of the waste piles as well as the quality and low quantity of metal in the waste piles. Therefore, this option is not considered feasible to implement.	Variable

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
No Action	No Action	None	In accordance with CERCLA and NCP requirements, a No Action response must be developed to provide a baseline against which other response actions can be compared. The no action response may be selected in instances where existing site conditions do not pose a risk to human health and the environment or any further action would pose a greater threat. Although the no action response may include some type of environmental monitoring, actions taken to reduce the potential for exposure (i.e., institutional controls and engineered controls) should not be incorporated.	May not meet the potential cleanup goals for the Site.	Implementable.	None.
Limited Action	Institutional Controls	Land Use Restrictions	The purpose of a land use restriction is to prevent specific uses of or activities at a property or a portion of a property in order to minimize potential exposures to humans and the environment. Land use restrictions may be put into place to protect against potential hazards present at a site, to preserve an implemented remedial action, or to restrict future land uses. Land use restrictions can be implemented by altering the deed or title of record or through re-zoning of the property. These alterations would remain in effect in perpetuity, regardless of changes in ownership of the property.	May not meet the potential cleanup goals for the Site as the sole application, but may be used in conjunction with other options. This process option would aid in deterring land use practices that would cause increased exposure risks to human receptors.	Implementable. Requires agreement by current land owner and possibly public acceptance.	Low capital and O&M costs.
		Informational/ Educational Devices	Informational/educational devices consist of meetings or literature aimed at raising the public's knowledge of the site and addressing their concerns. Topics addressed by these devices could include the potential hazards posed by contaminants, potential hardships that may be temporarily encountered during implementation of the remedial alternative, and the purpose and effectiveness of the remedial actions taken.	May not meet the potential cleanup goals for the Site as the sole application, but may be used in conjunction with other options. Informational/educational devices would effectively inform the public about the Site.	Implementable.	Low capital and O&M costs.
	Engineered Controls	Engineered Controls	Engineered controls are physical deterrents that serve to restrict access to the site, thereby impeding the potential for exposure to contaminants. Fencing could be installed around the perimeter(s) of the source area(s) to prohibit human and animal access to the area. Posted warnings identify potential hazards present at the Site and discourage trespassing and misuse. Security systems and patrols also deter trespassing and misuse.	May not meet the potential cleanup goals for the Site as the sole application, but may be used in conjunction with other options. These items would effectively restrict access to the Site, thereby impeding the potential for exposure to contaminants.	Implementable.	Low capital and O&M costs.
Limited Action	Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored natural attenuation (MNA) uses naturally occurring processes such as dilution, volatilization, biodegradation, and sorption, to address contamination. While MNA cannot degrade inorganic contaminants, it may transform them into states that pose a relatively low risk to potential receptors. Metals precipitation, sorption of contaminants onto soil particles or into the soil matrix, and partitioning into organic matter reduce the mobility and bioavailability of contaminants. Redox reactions can transform the valence states of some inorganic contaminants into less soluble, and consequently less mobile, and/or less toxic forms.	Natural processes could be used to attenuate the contaminants of concern at the Site. However, significant modeling would be necessary to ensure that off-site migration of contaminants would not occur and that exposure pathways would not be completed prior to acceptable levels being reached. The permanence of the attenuation mechanism must also be evaluated to ensure that the mechanism would not be reversible. Long-term monitoring is required to confirm effectiveness. Could also be effective in combination with source control measures.	Implementable. Does not involve any intrusive activities. MNA would be a long-term process, during which time the Site may not be available for productive use. Land use restrictions and/or engineered controls may also need to be implemented in conjunction with MNA to protect human health.	Low capital and low O&M costs.

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Containment	Vertical Barriers	Sealable Joint Sheet Piling	A sealable joint sheet piling system can be used for containment. The sheet piling is installed using the same equipment and techniques as conventional pile driving. To prohibit water and dissolved contaminants from flowing underneath, the sheet pile wall is usually keyed into a unit that is capable of acting as an aquitard (e.g., bedrock or glacial till).	If implementable, this process option would effectively contain surface water at the Site. Sealable joint sheet piling is an effective containment technique, but does not remove or treat the contaminants present in the surface water.	Subsurface obstructions and lack of sufficient overburden to support the wall restrict implementability. This option is not practical because there is not enough overburden soil to support a sheet pile wall; depth to bedrock is shallow.	High capital and low O&M costs.
	Collection	Surface Water Collection System	Diversion channels, retention ponds, trenches and other techniques are available to control surface water. Trenches effectively accumulate surface water while impeding it from flowing beyond a particular location. Diversion channels are used to intercept surface water and convey it in an engineered path to a specific discharge or collection point, such as an equalization or retention pond. These water management techniques are typically used to: (1) direct water away from a particular area, such as an excavation or area of impact; (2) minimize erosion; and (3) collect surface water for equalization or treatment prior to discharge.	Effective as a component of a water treatment system.	Implementable. An extensive collection, pumping, and transport system would be required to collect surface water, transport the water to a flow equalization tank, and then transport the water from there to the treatment process options. The equalization basin would have to be very large to even out the anticipated flow range. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	Low-moderate capital and low O&M costs.
Ex-Situ Treatment	Active Vertical Barriers Ex-Situ Physical/ Chemical Treatment	Neutralization	Common neutralizers include limestone and hydrated lime, calcium oxide, kiln dust, trapzene, calcium hydroxide, caustic soda, soda ash, and ammonia. All can be used in mechanized systems to increase the pH of the waste stream and cause the precipitation of metals such as iron, manganese, and aluminum. The choice of chemicals to be used depends on the chemical characteristics of the impacted surface water and site accessibility.	Alkaline chemicals have been shown to be effective in treating ARD; bench/pilot scale testing required to demonstrate effectiveness of particular chemical. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system.	Readily implementable as pretreatment for other process options. An extensive collection and pumping system would be required. Site conditions such as steep slopes and shallow soils may impact implementability, and surface water hydraulics and hydrologic conditions will affect system design. Neutralization systems require monitoring and maintenance, and some chemicals, such as caustic soda and ammonia, are dangerous to handle.	Low capital costs, moderate O&M costs.
		Precipitation/ Coagulation/ Flocculation	During the precipitation process, very fine particles are held in suspension by electrostatic surface charges, and these charges create repulsive forces that prevent aggregation and reduce the effectiveness of solid-liquid separation processes. To enhance precipitation, coagulants and flocculation are used to increase particle size through aggregation. Coagulants most often used to overcome the repulsive forces are inorganic electrolytes (such as alum, lime, ferric chloride, and ferrous sulfate), organic polymers, and synthetic polyelectrolytes. The presence of polymers, in particular cationic polymers, can cause problems with some treatment systems, and this must be taken into account if a polishing step will be needed. After coagulant addition, the water is mixed in slow-mix reactors (flocculators) to promote contact between the particles and flocculant settling. As flocculation occurs, the particles increase in mass and settle out of solution at a faster rate.	Effective of the system relies on adequate solids separation techniques (e.g., flocculation, clarification, and/or filtration). Polymer would be needed to achieve adequate settling of solids. Generates significant waste streams and would require significant power requirements. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system. Polymers may hinder RO membranes; pilot testing required.	Implementable. Labor intensive and specialized skills would be required to operate the equipment. An extensive collection and pumping system would be required. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	Moderate capital costs, high O&M costs

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
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GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Ex-Situ Treatment	Active Vertical Barriers Ex-Situ Physical/ Chemical Treatment	Filtration	Flocculation is typically followed by filtration, which involves the flow of water through a filtration media at low speed. Sand or some other type of granular material is regularly used in applications where the filter media acts like a sieve, separating particles based on size. The filter media allows water molecules and those smaller in size to pass, but obstructs larger particles. To selectively filter out components of the water stream, a filter media such as activated alumina could be used to adsorb the contaminants. As with other water treatment technologies, the filtration process is typically repeated several times to remove as many contaminants as possible.	Filtration is, like reverse osmosis and distillation, a relatively slow process. It requires low water velocity through the system to achieve adequate contact with the filtration media and it may require re-circulating the waste stream several times to attain the desired effluent.	Implementable. In comparison to other treatment technologies, such as reverse osmosis and distillation, filtration does not require a source of heat or pressure. Accordingly, filtration requires less energy, which reduces overall costs. Also, less water is wasted in the filtration process in comparison to reverse osmosis or distillation, which improves the efficiency of the process.	Moderate capital costs, high O&M costs
		Reverse Osmosis	If a semi-permeable membrane is placed between two separate solutions of differing concentration, water will naturally migrate from the weaker solution through the membrane to the stronger solution until an equilibrium concentration is reached; this process is called osmosis. In reverse osmosis, pressure is exerted on the side with the concentrated solution (referred to as the concentrate) to force the water molecules across the membrane to the less concentrated side (referred to as the permeate). The pore spaces in the membrane are large enough to allow water molecules to pass, but obstruct ions and larger molecules. For instance, salt, fluoride, manganese, iron, lead, and calcium molecules are larger than water molecules and would therefore be excluded from passage and remain in the concentrate. However, reverse osmosis would not restrict molecules smaller than those of water from passing through to the permeate.	Effective in treating ARD. Pretreatment for hardness and TSS removal would be required. Generates significant waste streams. Would require additional post treatment technologies to achieve potential cleanup goals. Maintenance of a reverse osmosis system typically involves periodic replacement of the membrane. The length of time between replacements is heavily dependent upon the characteristics of the concentrate (i.e., temperature, pressure, and concentration of dissolved solids). In general, increasing the water temperature enhances the efficiency of the system; the optimum temperature varies according to the type of membrane used. The pressure required for the system is determined by several factors, including the type and concentration of contaminants in the concentrate. As the contaminant concentration in the concentrate increases, the amount of pressure required to effectively operate the system will also increase.	Implementable. Would require two-stage RO unit and evaporator to reduce volume of reject solution (which ranges from 10 to 15% of total flow). Labor intensive and specialized skills would be required to operate the equipment. An extensive collection and pumping system would be required. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	High capital costs, high O&M costs
		Distillation	In the distillation process, impacted water is heated until it reaches its boiling point and begins to vaporize. The water is maintained at that temperature until all of the water has vaporized. The water vapor then travels through a condensation coil where it is cooled, condensed back into liquid form, and discharged into a receiving tank. A chiller and/or cooling tower is required to condense the steam. It is important to note that contaminants with boiling points equal to or lower than that of water will not be removed by this process. Constituents such as metals, whose boiling points are higher than that of water, remain in the original tank in the form of sediment. The process is commonly repeated several times to achieve greater water purity.	Effective. Pretreatment for hardness removal would be required. Distillation is an energy-intensive and relatively slow process, particularly when the water needs to be treated several times to achieve treatment goals. The increased hydrogen content of the treated water tends to cause it to be acidic. Process would generate significant waste streams and have significant power requirements. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system.	Implementable. Maintenance of a distillation unit primarily involves cleaning out and disposing of the sediment on the boiler side of the unit. Disposal of the resulting metals-containing sediment may be expensive due to its nature and the consequent need to meet LDR requirements. May have material compatibility problems (i.e., require use of high nickel alloy in place of stainless steel). Would require a major cooling water source to condense the steam (i.e., chiller and cooling tower); highly energy intensive. Labor intensive and specialized skills would be required to operate the equipment. An extensive collection and pumping system would be required. Surface water hydraulics and hydrologic conditions would impact implementability.	Very high capital costs, high O&M costs
		Adsorption via Activated Alumina	Activated alumina is a common adsorbent that is made by industrially processing aluminum ore to generate a highly porous and adsorptive medium with substantial surface area. It can be employed to adsorb a variety of contaminants, most notably, fluoride, arsenic, and selenium.	Pretreatment for hardness removal would be required. Would generate significant waste streams and have significant power requirements. Activated alumina is not flexible and cannot be modified to site contaminants like ion exchange resins. Data not currently available to support the use of this technology for heavy metals removal, except for arsenic and fluoride. Therefore, effectiveness not demonstrated for Pike Hill Copper Mine Site.	Implementable. Activated alumina likely would require regeneration off-site, and activated alumina would need to be replaced after only 10 regenerations. Most suitable as a post-treatment technology. Labor intensive and specialized skills would be required to operate the equipment. An extensive collection and pumping system would be required. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	High capital costs, high O&M costs

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
Pike Hill Copper Mine Superfund Site
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GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Ex-Situ Treatment (assuming excavation)	Ex-Situ Physical/ Chemical Treatment	Electrodialysis	Electrodialysis involves the movement of ions across alternating cation and anion exchange membranes in response to an applied electrical current. As described by Farrell et al (2003), when a feed solution containing both positive and negative ions is passed through the membrane stack to which a voltage has been applied, the ions migrate towards their respective electrodes. The cation exchange membranes allow the cations to pass while inhibiting the anions, and the anion exchange membranes allow the anions to pass while inhibiting the cations. This process creates streams of dilute ion concentration (diluate) and streams rich in ion concentration (concentrate). An ionic rinse solution is circulated past the electrodes to maintain conductivity of the membrane stack while preventing potentially corrosive ions from the feed solution from contacting the electrodes.	Effective in treating ARD. Would require pre-treatment to handle elevated hardness and provide TSS removal. Would generate significant waste streams, have significant power requirements, and would require additional post-treatment technologies to achieve potential cleanup goals for the site.	Implementable. However due to nature of site ARD this technology would be unfavorable to implement; vendors for this technology application are not readily identified.	High capital costs, high O&M costs
		Ion Exchange	Ion exchange is a chemical reaction wherein an ion from solution is substituted for a similarly charged ion on the exchange resin. Ion exchange resins consist of synthetic organic polymers that contain ionic functional groups to which exchangeable ions are attached. Inorganic or natural polymeric materials, such as zeolites, may also be used. However, synthetic organic resins are typically preferred because their characteristics can be tailored to specific applications. The maximum number of exchanges per unit of resin depends on the number of mobile ion sites, which differs from resin to resin (REMCO, 2005). After the resin capacity has been exhausted, the resins can be regenerated for reuse.	Effective. Would require pre-treatment to handle elevated hardness and to provide TSS removal. Would generate significant waste streams and have significant power requirements. Roughing ion exchange canisters would be installed upstream of polishing resin canisters.	Implementable. The regenerant solution would have to be treated via evaporation to reduce the volume to be manifested off site. Labor intensive and specialized skills would be required to operate the equipment. An extensive collection and pumping system would be required. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	High capital costs, high O&M costs
Ex-Situ Treatment	Passive Ex-Situ Physical/ Chemical Treatment	Settling Ponds	Settling ponds are used to collect treated or partially treated waters discharging from an ALD or OLC. These ponds allow iron and other precipitates to settle and are useful in providing a more constant flow rate into a downgradient treatment cell (e.g., SRB bioreactor). Settling ponds should be sized to allow a retention time of approximately 14 days.	Effective in allowing iron and other precipitates to settle and in equalizing flow. Aeration required for iron removal. To achieve aeration by passive means, site must have sufficient topographic relief and area to allow for a number of small settling ponds in series. Passive oxygenating structures such as riffles are then placed in between each pond. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system.	Implementable. Site conditions such as steep slopes and shallow soils, and surface water hydraulics and hydrologic conditions, may impact implementability.	Moderate capital and O&M costs.
Ex-Situ Treatment	Passive Ex-Situ Physical/ Chemical Treatment	Diversion Wells with Limestone Treatment	This system is useful for treating small streams of ARD. They utilize cylindrical wells (1.5 to 1.8 m in diameter and 2 to 2.5 meters deep) made of concrete or metal and filled with limestone. The waste stream flows through a pipe to the bottom of the well, is discharged, and then flows up through the limestone. Water flow through the well is designed to be sufficiently turbulent to prevent the coating of the limestone with iron precipitate.	Dissolution of limestone adds alkalinity and raises pH. Iron and metal precipitate coating is prevented by turbulence of the flow through the well, although periodic replenishment of limestone is needed. Because the limestone needs to be changed out frequently (i.e., monthly or even more frequently), these systems are not entirely passive. Because they lack settling ponds, diversion wells work best on water with low metal concentrations; this could limit their effectiveness at the Pike Hill Copper Mine Site. For some ARD sources, unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system.	Implementable. Site conditions such as steep slopes and shallow soils, and surface water hydraulics and hydrologic conditions, may impact implementability.	Moderate capital and O&M costs
		Successive Alkalinity Producing System (SAPS)	The goal of a successive alkalinity producing systems (SAPS) is to add alkalinity to ARD and then precipitate iron hydroxides upon subsequent oxygenation using two separate steps to limit iron hydroxides from armoring the limestone. A SAPS is a variant of the anaerobic systems used mainly to treat coal mine drainage. Successive Alkalinity Producing Systems can be designed specifically for those instances that are not appropriate for ALDs (i.e., waters with DO concentrations greater than 5 mg/L and high concentrations of oxidized Fe+3).	Effective. Must be followed by a settling pond to allow iron hydroxides to precipitate and settle out. May require several treatment cells in series to eliminate short-circuiting that lowers effectiveness in removing copper and zinc as sulfides. Also, uniform flow rates and even flow distribution through the substrate are critical for effective SAPS bioreactor treatment. Can be difficult to ensure that anoxic conditions are maintained; would require alkalinity addition as a buffering agent. Bench/pilot-scale testing would be required to demonstrate effectiveness. Likely would need to be combined with additional treatment technology/technologies to meet potential cleanup goals.	Implementable, simple construction. Difficult to maintain and still preserve anaerobic conditions. Surface water hydraulics and hydrologic conditions would impact implementability.	Moderate capital costs, moderate O&M costs

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Ex-Situ Treatment	Active Ex-Situ Biological Treatment	Sulfate-Reducing Bacteria (SRB) Bioreactors	The chemical processes in anaerobic bioreactors are bacterial oxidation of organic matter with concomitant reduction of DO, ferric iron (Fe+3), and sulfate. Because sulfate-reducing bacteria (SRB) play a major role in this type of bioreactor, the anaerobic bioreactor is often called an SRB bioreactor. As sulfate reduction occurs, the produced sulfide then reacts with iron, copper, zinc, and cadmium to form metal sulfides. Reduction occurs in the absence of oxygen, which requires that flow be uni-directional and preferably vertical throughout the organic bioreactor material (i.e., substrate) within the subsurface.	Effective. Must contain microenvironments that allow an entire consortium of microorganisms to prosper; a pH of 5.5 or higher is preferred. Uniform flow rates and even flow distribution through the substrate are critical in effective SRB bioreactor treatment. Accordingly, the bioreactor must be appropriately engineered to maximize vertical flow and, as with SAPS, to minimize short-circuiting. Anaerobic systems are sensitive to temperature changes, substrate changes, and pH changes. Effectiveness at the Pike Hill Copper Mine may be limited due to seasonal low temperatures. Potential for discharge of excess sulfide to receiving streams.	Implementable. Flow equalization required. System difficult to maintain and still preserve anaerobic conditions. Site conditions such as steep slopes and shallow soils, as well as surface water hydraulics and hydrologic conditions, may impact implementability.	Low-moderate capital costs, moderate O&M costs
		Liquid-Reactant (Semi-active) Bioreactors	In the liquid-reactant bioreactor, an alcohol such as methanol, ethanol, or ethylene glycol is added at a controlled rate based on the stoichiometric relation between the alcohol and the sulfate being reduced. Sodium hydroxide is also added to bring the pH to a level in which the SRB can reproduce. The reaction rate can be better controlled than in an SRB.	Effective. Overcome problems with SRB bioreactors related to decreased permeability over time, decreasing reaction rates over time, and freezing in the winter months. Sizing of the system for effective treatment is dependent on sulfate loading, metal loading, residence time, and water acidity levels.	Implementable. Flow equalization required. System difficult to maintain and still preserve anaerobic conditions. Site conditions such as steep slopes and shallow soils, as well as surface water hydraulics and hydrologic conditions, may impact implementability.	Low-moderate capital costs, high O&M costs
In-Situ Physical/ Chemical Treatment	Active In-Situ Physical/ Chemical Treatment	Contact Treatment Application	A chemical reagent such as lime, Bauxsol, or molasses can be added directly to a standing water body to precipitate out metals. The amount of reagent applied would depend on the composition of the pit lake water and the desired quality of the treated water. Reagent blends and application strategies could be varied to achieve the desired treated water quality. Computer modeling is typically used to select the most appropriate blend and required addition rates, followed by laboratory trials.	Short-term effectiveness is high; one-time application of reagent (i.e., lime, Bauxsol, molasses) treats water column. The precipitate forms a blanket of sediment on the bottom of the water body. If left in place, this layer acts to separate the stored acidity and trace metals in the natural sediment from the surface water. Metals retained in reactive media reportedly remain chemically bound to media and if removal is necessary, the material can be handled as a non hazardous waste (as defined by TCLP data). However, long-term effectiveness is limited at Pike Hill Copper Mine due to continued runoff of ARD and neighboring waste piles. Continuous applications would be required to be effective.	Implementable, but the need for continuous applications at Pike Hill Copper Mine would render this option impractical.	Moderate capital costs, high O&M costs
	Passive In-Situ Physical/ Chemical Treatment	Reactive Media Contact Cells	Treatment cells are constructed of vessels filled with reactive media such as limestone, Bauxsol, apatite or EHC-M. Impacted water is passed through a cell or a series of cells. The medium is effective at neutralizing the acid in the ARD and at removing metals from the water and binding them into a highly stable form. The metals are bound to the reactive medium and spent material can be handled as a non-hazardous waste based on TCLP data. For some media, the water is mechanically aerated prior to contact with the pellets to ensure that the dissolved oxygen (DO) concentration is higher than saturation to enhance performance efficiency.	Effectiveness dependent upon treatment media used in cell (e.g., limestone, Bauxsol or apatite) and on water chemistry. A treatability study using a treatment cell filled with Bauxsol would be required. May require use in combination with additional treatment technology to meet effluent standards.	Implementable. Surface water hydraulics and geochemistry would impact implementability.	Moderate capital costs, low-moderate O&M costs
In-Situ Physical/ Chemical Treatment		Anoxic Limestone Drains (ALDs)	An ALD is a trench filled with crushed high-calcium limestone, sealed with geotextile or plastic, and covered with clay or soil to prevent oxygen inflow. It is typically built into a hillside or tailing pile to capture ARD that has not yet been exposed to oxygen. As the acidic water flows through the ALD, the acid dissolves some of the limestone, which adds alkalinity to the water and raises the pH.	Dissolution of limestone adds alkalinity and raises pH, but coating of limestone by iron and aluminum precipitates can reduce the performance over time, especially in low flow conditions. Requires removal of DO and Fe3+ concentrations before treatment. Problems with long term effectiveness include difficulty in maintaining anoxic conditions within the drains. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system. Effectiveness at the Pike Hill Copper Mine may be limited due to seasonal low temperatures.	Implementable. Difficult to maintain anaerobic conditions. Surface water hydraulics and hydrologic conditions would impact implementability.	Moderate capital and O&M costs.
	Passive In-Situ Physical/ Chemical Treatment	Open Limestone Channels (OLCs)	The OLC is a variant of the ALD and is used to treat discharges that are oxygenated and contain Fe+3 or high aluminum content. The OLC can be effective in adding alkalinity to ARD and raising the pH. However, OLCs require an environment that will self-scour the exposed limestone surface. OLCs must have significant vertical gradient to allow for turbulent flow to strip off precipitates and must contain a number of small ponding areas between turbulent points to collect the resultant precipitates.	Effective for treatment of discharges that are oxygenated and contain Fe+3 or high aluminum content. Effective in adding alkalinity to ARD and raising the pH. Scouring limestone with high pressure spray system with heat trace would be necessary to reduce armoring of limestone and increase effectiveness. Effectiveness at the Pike Hill Copper Mine may be limited due to seasonal low temperatures.	Implementable. While cover would minimize precipitation infiltration and afford some protection against freezing, OLC must be open to oxygen to prevent going anaerobic. Multiple channels could be installed with different elevations to successively handle increasing flows. Site conditions such as steep slopes and shallow soils may impact implementability. Systems with sufficient topographic relief (between 45 and 60 percent slopes) are more cost-effective, more easily monitored, and more effective. Surface water hydraulics and hydrologic conditions would impact implementability.	Moderate capital costs, moderate O&M costs

Table 7-2
Screening of Potential Treatment Options for Surface Water and Wetlands Complex
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GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
In-Situ Physical/ Chemical Treatment (cont.)	Passive In-Situ Physical/ Chemical Treatment (cont.)	Lime Dosing Wheel	Lime dosing systems uses water wheels to drive an auger that adds lime pellets to the ARD stream at precise dosing levels proportional to the ARD flow rate. Following dosing, the effluent is aerated and metals are precipitated in a settling basin or tank. The system supplies alkalinity along with aeration to precipitate metals as oxides and hydroxides. The system operates solely on water power, operates 24-hours per day, and requires only periodic monitoring.	Effective at removing metals including aluminum, copper, iron, manganese, and zinc. Maintaining proper hydraulic residence time is one of the most important design factors for effective treatment.	Implementable, simple construction. Operational problems reported associated with clogging of the inlet with iron hydroxides, and accumulation of granular lime below the dispenser.	Low capital and moderate O&M costs
		Limestone Sand Treatment	This low cost, low tech option involves the periodic placement of limestone sand in the headwaters of an ARD-impacted stream. During periods of high flow, the current carries the sand downstream, where it mixes with natural sediments and increases the pH. The sand must be replenished frequently depending on flooding frequency. Limestone sand addition is most effective for streams that have low pH, but also relatively low dissolved metal concentrations. Iron and/or aluminum hydroxides precipitate in the stream, but probably over a shorter stretch than without treatment. Downey et al (1994) emphasize the importance of particle size, purity, and mass of the limestone for successful treatment.	Effective in neutralizing acid in stream; coating of limestone particles with iron oxides can occur, but the agitation and scouring of limestone in the streambed keeps fresh surfaces available for reaction. Replenishing the limestone sand is needed at least twice a year, and maybe more often depending on site conditions. Most effective application would be just prior to spring runoff flows. Unlikely to meet potential cleanup goals alone, but could be used as a component of a water treatment system.	Readily implementable during all but winter months. Sediments would require periodic removal, dewatering and disposal.	Low capital and high O&M costs
	Active In-Situ Biological Treatment	Constructed Aerobic Wetlands	Aerobic wetlands and subaerobic wetlands are similar to natural wetlands in that the water flows mainly over the substrate surface. This type of wetland is well understood because it has a relatively long application history in municipal sewage treatment systems. Aerobic wetlands are typically shallow excavations filled with one to three feet of soil, gravel, and/or rocks in a hummocky pattern. The designed hummocks allow for variations in water depth of between one inch to approximately one foot to form a diversity of microenvironments. In these microenvironments, consortia of micro- and macro-organisms carry out a wide variety of biogeochemical processes.	Effective as a component of water treatment system; would not generally address potential cleanup goals as a sole treatment process. Often included as a final process step in system containing other passive treatment methods (e.g., ALDs, OLCs, and/or anaerobic bioreactors.) Have been used to successfully treat manganese, which will pass through ALDs, OLCs, and SRB bioreactors. Effectiveness at the Pike Hill Copper Mine may be limited due to seasonal low temperatures and ice cover may cause dormancy, and aerobic system may go anaerobic when iced over. Potential for discharge of excess sulfide to receiving stream.	Implementable. COCs in surface water would prohibit use as primary treatment. Space requirements would be significant. Site conditions such as steep slopes and shallow soils may impact implementability. Surface water hydraulics and hydrologic conditions would impact implementability.	Moderate capital and low-moderate O&M costs

Table 7-3
Screening of Potential Treatment Options for Sediment and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
No Action	No Action	No Action	In accordance with CERCLA and NCP requirements, a No Action response must be developed to provide a baseline against which other response actions can be compared. The no action response may be selected in instances where existing site conditions do not pose a risk to human health and the environment or any further action would pose a greater threat. Although the no action response may include some type of environmental monitoring, actions taken to reduce the potential for exposure (i.e., institutional controls and engineered controls) should not be incorporated.	May not meet potential cleanup goals specified for the Site.	Implementable.	No capital or O&M costs.
Limited Action	Institutional Controls	Land Use Restrictions	The purpose of a land use restriction is to prevent specific uses of or activities at a property or a portion of a property in order to minimize potential exposures to humans and the environment. Land use restrictions may be put into place to protect against potential hazards present at a site, to preserve an implemented remedial action, or to restrict future land uses. Land use restrictions can be implemented by altering the deed or title of record or through re-zoning of the property. These alterations would remain in effect in perpetuity, regardless of changes in ownership of the property.	May not meet potential cleanup goals specified for the Site as the sole application, but may be used in conjunction with other options. This process option would aid in deterring land use practices that would cause increased exposure risks to human receptors.	Implementable. Requires agreement by current land owner and possibly public acceptance.	Low capital and O&M costs.
		Informational/ Educational Devices	Informational/educational devices consist of meetings or literature aimed at raising the public's knowledge of the site and addressing their concerns. Topics addressed by these devices could include the potential hazards posed by contaminants, potential hardships that may be temporarily encountered during implementation of the remedial alternative, and the purpose and effectiveness of the remedial actions taken.	May not meet potential cleanup goals specified for the Site as the sole application, but may be used in conjunction with other options. Informational/educational devices would effectively inform the public about the Site.	Implementable.	Low capital and O&M costs.
	Engineered Controls	Engineered Controls	Engineered controls are physical deterrents that serve to restrict access to the site, thereby impeding the potential for exposure to contaminants. Fencing could be installed around the perimeter(s) of the source area(s) to prohibit human and animal access to the area. Posted warnings identify potential hazards present at the Site and discourage trespassing and misuse. Security systems and patrols also deter trespassing and misuse.	May not meet potential cleanup goals specified for the Site as the sole application, but may be used in conjunction with other options. These items would effectively restrict access to the Site, thereby impeding the potential for exposure to contaminants.	Implementable.	Low capital and O&M costs.
Containment	Monitored Natural Recovery	Monitored Natural Recovery (MNR)	Monitored natural recovery would leave contaminated sediments in place to allow for ongoing aquatic, sedimentary, and biological processes to contain, destroy, or otherwise reduce the bioavailability of the contaminants in order to protect receptors (NRC, 1997). MNR differs from “no action” alternatives in that source control, assessment, modeling, and monitoring efforts are required to verify that remediation (i.e., environmental processes to permanently reduce risk) is taking place (SERDP & ESTCP, 2004).	Natural processes could be used to immobilize the contaminants of concern at the Site. However, significant modeling would be necessary to ensure that downstream migration of contaminants would not occur. It would also be necessary to demonstrate that the mechanism that would immobilize the contaminants (if any) would not be reversible.	Implementable. MNR may require a long timeframe to achieve the potential cleanup goals specified for the Site. Institutional controls and/or engineered controls may need to be implemented in conjunction with MNR to protect human health. A long-term sediment quality monitoring program would need to be implemented to track changes to sediment quality over time.	Low capital and O&M costs.
	Engineered Capping	Natural Material Capping (e.g., riprap)	Impacted sediments remain in-situ and are covered by a non-synthetic media (i.e., sand, riprap) sized to provide erosion protection compatible with stream velocities. Thickness of cap is dependent on nature of COCs in-situ but must be sufficient to isolate impacted sediments from benthic communities.	While this technology could be used to effectively isolate sediment from potential ecological receptors, verification of the process effectiveness could be difficult. Effectiveness could be impaired by freeze-thaw process, wetting-drying process, and high flow velocity scour events.	Not readily implementable. Requires detailed pre-design and design analyses to select material and determine placement. Required increase in sediment bed thickness associated with process may limit implementability in small channels and channels with minimal flow areas and wetted perimeters. Surficial water hydraulic and hydrological conditions of the site (e.g., steep gradients) could impact implementability.	Moderate capital costs, low to moderate O&M costs
		Synthetic Material Capping (e.g., Aqua-Block, FabriForm)	A synthetic cap is similar to a natural cap, however, impacted in-situ sediments are covered with synthetic non-natural material that encapsulates the media, providing protection from migration and isolation from benthic environment. Cap materials include concrete (or similar) or engineered composite material (i.e., Aqua Block).	As with natural capping material, this technology could be used to effectively isolate sediment from potential ecological receptors. However, effectiveness could be impaired by freeze-thaw process, wetting-drying process, and high flow velocity scour events.	Not readily implementable. Requires detailed pre-design and design analyses to select the material and determine placement. Required increase in sediment bed thickness associated with process may limit implementability in small channels and channels with minimal flow areas and wetted perimeters. Site conditions such as steep slopes may also impact implementability, as would surficial water hydraulic and hydrological conditions of the site (e.g., steep gradients).	High capital and O&M costs

Table 7-3
Screening of Potential Treatment Options for Sediment and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Removal and Disposal	Excavation	Hydraulic Dredging	Hydraulic dredging employs equipment that loosens the sediment then vacuums it into a pipeline leading to the shore or to a transfer vessel on the water. Recovered sediments then undergo treatment/disposal as necessary.	This technology could be effective in removing sediments from streams. Engineering controls would be required to limit mobilization of sediments into surface water, resulting in transport further downstream.	Not implementable for scale of tributaries with impacted sediments within project watersheds. Surficial water hydraulic and hydrological conditions of the site would adversely impact implementability in large water bodies.	Very high capital and low O&M costs.
		Mechanical Dredging	Mechanical dredging utilizes physical processes to excavate impacted sediment and remove it from the water column. Recovered sediments then undergo treatment/disposal as necessary. Typically generates higher solids-content dredged slurry than hydraulic processes.	This technology could be effective in removing sediments from streams. Engineering controls would be required to limit mobilization of sediments into surface water, resulting in transport further downstream.	Implementable for scale of impacted tributaries within project watershed. Site conditions such as steep slopes and shallow soils may impact implementability. Surficial water hydraulic and hydrological conditions of the site would impact implementability.	Low capital and low O&M costs.
Removal and Disposal	Water Disposal (assuming dredging)	Open-Water or In-Water Disposal	Open-water disposal involves using earthen and/or synthetic materials to cover impacted sediments, thereby isolating them from the environment. The cap can be constructed over sediments that are left in place or over sediments that have been dredged and deposited. In addition to biological and chemical characterization, a significant level of effort is involved in analyzing the physical properties of the impacted sediment, capping materials, and host waterbody in order to minimize, to the extent practicable, water-column dispersion and bottom spreading during placement. See Engineered Capping for more information on the types of cover systems available.	Capping does not aim to reduce the volume or toxicity of the contaminants; it functions to impede migration. Capping also mitigates the potential for exposure by human and ecological receptors, benthic organisms in particular. Open-water disposal would effectively isolate impacted sediment, thereby achieving relevant RAOs.	Not implementable for scale of tributaries with impacted sediments within project watersheds. Surficial water hydraulic and hydrological conditions of the site would adversely impact implementability in large water bodies.	Moderate capital and O&M costs.
	Land Disposal (assuming dredging)	On-Site Consolidation	On-site consolidation consists of merging soil/waste piles into an engineered containment cell within the remedial area.	An on-site consolidation cell would be as effective as off-site disposal in preventing exposures to human and environmental receptors. The long-term effectiveness and permanence of the cell would require suitable engineering design, the implementation of land use restrictions, and the implementation of a groundwater monitoring program.	Sediments would likely be consolidated on Site, and would likely require dewatering with possible treatment/disposal of the decant water. In comparison to off-site disposal, on-site consolidation of waste materials would involve lesser exposure risks to workers and the surrounding community because the waste material would not require as much handling and no transport of materials off-site would be involved. Haulage roads within the Site property would likely need to be improved or new ones build to facilitate the transport of materials to the consolidation unit.	High capital and moderate O&M costs.
Removal and Disposal	Land Disposal (assuming dredging)	Off-Site Disposal	This process option consists of the transport of waste piles from the Site to a licensed, off-site disposal facility.	This process option is applicable to the contaminants present at the Site. Off-site disposal would remove the contaminants from the Site for placement in a permitted, offsite disposal facility, thereby preventing exposure to human and environmental receptors.	Impacted sediments within the unnamed tributary exhibit concentrations of potentially leachable contaminants. Impacted sediment may require dewatering prior to disposal, and the decant water would also require treatment/disposal. There would be increased risks to workers handling the material as well as increased risks to communities along the transportation route. These risks would be mitigated through the use of standard environmental construction protocols (e.g., use of PPE, decontamination of equipment prior to leaving the Site, and tarped truck beds). Haulage roads within the Site property would likely need to be improved or new ones build to facilitate the transport of materials to the consolidation unit.	High capital and no O&M costs. Assumes hazardous waste landfill
Ex-Situ Treatment (assuming dredging)	Ex-Situ Biological Treatment	Phytoremediaton	Phytoremediation employs specifically selected plants to remove, store, or reduce the toxicity of contaminants. While high contaminant concentrations can be toxic to most plants, hyperaccumulator plants have the ability to handle significant amounts of inorganic contaminants. Phytoremediation is applicable to a wide range of inorganic contaminants.	The effectiveness of this technology, in general, would be driven by the ability to find plants that are compatible with the types of contaminants, contaminant concentrations, and climate of the Site. Phytoremediation would only be effective in remediating contamination within reach of the plant roots (i.e., shallow contamination) and the majority of the contamination at the Site is deeper.	Contaminant concentrations may be too high for successful plant growth. Plant growth may be hindered by acidic soil conditions due to ARD. Bioavailability of metal species would need to be assessed. Institutional controls would need to be implemented in order to protect the plants against dangerous land uses as well as to prevent potential receptors from contacting the plants.	Low to moderate capital and moderate O&M costs.

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Screening of Potential Treatment Options for Sediment and Wetlands Complex
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

GRA	Technology	Process Option	Description	Effectiveness	Implementability	Cost
Ex-Situ Treatment (assuming dredging)	Ex-Situ Biological Treatment	Enhanced Bioremediation	Enhanced bioremediation uses amendments to stimulate microorganisms, enabling them to convert contaminants into less harmful forms. Bioremediation cannot degrade inorganic contaminants, however, bioremediation can be used to change the valence state of inorganics resulting in adsorption, immobilization and accumulation of inorganics in microorganisms (FRTR, 2005).	This technology has the potential to transform inorganic contaminants into states exhibiting decreased mobility, bioavailability, and toxicity, although high concentrations of heavy metals may be toxic to the microorganisms. The rate at which bioremediation occurs will decrease in colder temperatures.	Implementable. Sediment pH may adversely affect microorganism population. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Low capital and moderate O&M costs.
	Ex-Situ Physical/ Chemical Treatment	Chelation/Complexation	Chelation/complexation is mainly used for controlling the leaching of metals. Chelation/complexation, immobilizes metals by forming a stable bond, or complex, between a metal cation and a ligand (chelating agent). The stability of the chelation depends on the number of bonds formed between the chelating agents and the target cation: as the number of bonds increases, the stability of the resulting complex increases and so does the degree of immobilization of the metal contaminant within the complex. The efficiency of chelation/complexation is ion-specific and depends on the chelating agent, pH, and dosage.	Can be effective in reducing leachable metals concentrations to meet TCLP requirements, however, contaminant concentrations would not decrease. Treated material would then require disposal. Technology would require significant bench-scale studies to identify appropriate agents.	Implementable. Sediment dewatering may be required, generating potentially impacted liquid waste stream. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
Ex-Situ Treatment (assuming dredging)	Ex-Situ Physical/ Chemical Treatment	Soil Washing	Soil washing acts to concentrate contaminants into a reduced volume for subsequent treatment. Soil washing involves vigorously mixing contaminated soil with a wash solution, causing contaminants to be dissolved or suspended in the wash solution. The solution is then recovered and treated. Contaminants often bind to the finer fraction of a soil matrix (e.g., clay and silt), therefore soil washing often incorporates some type of physical separation process.	Not applicable to the sediment mineralogy.	Implementable. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Chemical Extraction	Chemical extraction acts to concentrate contaminants into a reduced volume for subsequent treatment. Chemical extraction is similar to soil washing, but differs in that a chemical extractant, rather than a water-based solution, is used to encourage contaminant separation from the soil matrix. Acid extraction, which uses hydrochloric acid as an extractant, is commonly used to treat heavy metals. Hydrocyclones are used to separate the soil and extractant, which then undergo treatment/disposal.	This process option involves a form of re-mining of the waste material. The composition of the sediment is not amenable to the mineralogy of the sediment.	Implementable. This process would produce a significant amount of residual sludge that would require transport to an off-site facility for treatment and disposal. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	High capital and low O&M costs.
Ex-Situ Treatment (assuming dredging)	Ex-Situ Physical/ Chemical Treatment	Chemical Reduction/Oxidation	Chemical reduction/oxidation (redox) involves adding an oxidizing or reducing agent to the contaminated material, creating a redox reaction that results in a more stable, less toxic compound. Common oxiding agents include ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.	Incomplete redox reactions and intermediate compounds may occur and have the potential to not improve overall conditions. This process option is a reversible mechanism and would therefore be ineffective in reducing the volume, toxicity, and mobility of the impacted material, nor would it provide protection of human health and the environment.	Implementable. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
		Solidification/ Stabilization	In this process, the soil is mixed with a binder that functions to physically entrap contaminants (solidification) and/or chemically react with contaminants to reduce their mobility (stabilization). A pug mill or rotating drum mixer is commonly used to blend the soil with the binder. The binder can consist of many materials, including Portland cement, bitumen, pozzolans, and polymers. The selection of the binder is dependent upon compatibility with the contaminants at the site.	Solidification/stabilization would effectively immobilize inorganic contaminants.	Implementable. Site conditions such as steep slopes and shallow soils may impact implementability. Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols.	Moderate capital and low O&M costs.
Resource Utilization	Resource Utilization	Resource Utilization	Resource utilization is analogous to re-mining the site. This process option involves transporting impacted wastes an, off-site process facility where metals would be recovered for use as a commercial product.	Resource utilization could meet potential cleanup goals at the Site by removing a source of surface water contamination. It would be effective in minimizing the amount of waste requiring treatment/disposal. This process option could be used in conjunction with other remedial options for the Site.	Handling of any impacted material at the Site would increase risks of exposure to workers as well as communities along the transportation route. These risks could be mitigated through the use of PPE and other standard environmental protocols. The potential for re-mining copper at the Site would likely be difficult to implement because of the composition of the waste ore/rock as well as the quality and low quantity of metal in the waste piles. Therefore, this option is not considered feasible to implement.	High capital and no O&M costs.

Table 7-4
Potential Treatment Pilot Studies
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Remedial Technology	Testing Program
Capping	Bench: soil density and bearing capacity vs. moisture curves for capping materials
Surface Water Diversion	Pilot: in-place testing of geotexiles for erosion control in grass ditches
Sediment Dredging	Pilot: to assess sediment suspension or production rates
Biological & Chemical Treatment	Bench: define rate constants, minimal-maximal loading rates and retention times, optional pH and temperature, oxygen transfer characteristics, sludge generation and characteristics, chemical type and dose rates.
Monitored Recovery	Pilot: passive treatment using sulfate-reducing bacteria batch treatment cells and contact-derived treatment media (Bauxsol™)

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Monitor Wells/Groundwater Sampling: A = Shallow OB, B = Deep OB, C = Shallow BR, D = Deep BR						
Union Mine Area						
MW-01A,B,C,D	At bottom of the valley above Richardson Road	To assess overburden and shallow bedrock groundwater conditions at the downgradient boundary of the site. Deep bedrock well used to assess potential off-site impacts and for comparison with off-site well data.	Low Flow	A:WT 10, B: 20, C: 50, D:100	TAL Metals (total and dissolved), total cyanide, sulfate for all wells. Chloride, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity for select wells (approx 50% of wells). VOCs, SVOCs, Pest/PCBs for select wells during Round 2 (approx 5% of wells). **Note:** The list of parameters included after the initial round will include at a minimum TAL metals and sulfate, with additional parameters added as necessary for wells identified in areas impacted by site sources. Results will determine whether a subset of parameters are carried forward in subsequent rounds.	3 semiannual rounds
MW-02A,B,C	Downgradient of lowermost Union Mine waste rock pile	Characterization of overburden and shallow bedrock groundwater downgradient of the lowermost Union Mine pile. Used for comparison with upgradient and downgradient well data and surface water data to document variations in contaminant contribution from site subareas.	Low Flow	A:WT 10-20, B: 20-30, C: 50	same as above	3 semiannual rounds
MW-03A,B,C,D	Immediately downgradient of largest Union Mine waste rock pile	Critical monitoring location centrally located in the valley at a point where multiple tributaries coalesce to form the main tributary stem to Pike Hill Brook. Overburden and shallow bedrock wells will be used to monitor the relative groundwater contaminant and flow contribution to surface water. Comparison of data from upgradient and downgradient wells will allow evaluation of the relative contaminant contribution of this large pile subarea. In addition a deep bedrock well at this location will be used to assess potential downgradient impact of the Union Mine pool.	Low Flow	A:WT 10-20, B: 20-30, C: 50 D:100	same as above	3 semiannual rounds
MW-04A	Lowlying area adjacent to largest Union Mine WR pile	Assess saturated thickness of overburden between the largest Union WR pile and the main valley tributary, upgradient of the largest seep area.	Low Flow	A:WT 10-20	same as above	3 semiannual rounds
MW-05A	Within one of the uppermost Union WR Piles	Assess saturated thickness of overburden/WR behind a wall/dam that feeds a seep on the north side of the valley. This location is also downgradient of the Union Mine adit and will be used to assess potential AMD contribution from this adit.	Low Flow	A:WT 10-20	same as above	3 semiannual rounds
MW-06A,C,D	North and upslope of Union Mine WR piles and underground workings	Assess overburden and shallow bedrock quality upgradient of mine areas. Deep bedrock well will be used to assess potential impact of Union Mine pool.	Low Flow	A:WT 10-20 C: 50 D:150	same as above	3 semiannual rounds

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Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Union Mine Area (cont.)						
MW-07A,B,C	Central part of valley upgradient of Union Mine piles, North of Eureka Mine piles.	Monitor water quality in overburden and shallow bedrock in the upper part of the valley to assess potential impacts from the upper Union Mine workings.	Low Flow	A:WT 10-20, B: 20-30, C: 50	same as above	3 semiannual rounds
MW-08A,C,D	West of the Union Mine Adit	Document shallow groundwater quality conditions upgradient of Union Mine area for comparison with downgradient data. Deep bedrock well to assess potential impact of Union Mine pool.	Low Flow	A:WT 10, C: 30 D:150	same as above	3 semiannual rounds
MW-09D	South of Union Mine Adit	Bedrock well to penetrate the Union Mine pool in a flooded portion of the mine to assess mine pool water quality.	Low Flow	D: 115	same as above	3 semiannual rounds
Eureka Mine Area						
MW-10A,B.C	Downgradient of flotation tailings pile	Assess water quality impact in overburden and shallow bedrock from tailings pile for correlation with nearby seep data.	Low Flow	A:WT 10-20, B: 20-30, C: 50	same as above	3 semiannual rounds
MW-11A,B	Upgradient of flotation tails adjacent to mill foundation	Assess the saturated thickness and water quality of overburden upgradient of the flotation tailings for comparison with downgradient data. Also to assess the potential impact from fill in the vicinity of the former mill.	Low Flow	A:WT 10-20, B: 20-30	same as above	3 semiannual rounds
MW-12A,B,C,D	Downgradient of Eureka WR piles below Eureka Adit	Characterization of overburden and shallow bedrock groundwater downgradient of the Eureka Mine WR piles below the Eureka Adit. Used for comparison with upgradient and downgradient well data to document variations in contaminant contribution from site subareas. Deep bedrock well to assess potential impact from Eureka and Union Mine pools.	Low Flow	A:WT 10-20, B: 20-30, C: 50 D:125	same as above	3 semiannual rounds
MW-13A	Within Eureka Mine WR pile below Eureka Adit	Assess the saturated thickness in WR/overburden in the WR piles below the Eureka Adit. Assess relationship between surface mine pool and seeps.	Low Flow	A:WT 10-20	same as above	3 semiannual rounds
MW-14A,B,C,D	Downgradient of the Eureka Mine underground workings, upgradient of the former mill.	Characterization of overburden and shallow bedrock groundwater upgradient of the lower Eureka WR and flotation tailings piles, and deep bedrock groundwater downgradient of the Eureka Mine pool. Used for comparison with upgradient and downgradient well data to document variations in contaminant contribution from site subareas.	Low Flow	A:WT 10-20, B: 20-30, C: 50, D:100	same as above	3 semiannual rounds
MW-15A,C,D	West of the Eureka Adit	Document shallow grounwater conditions upgradient of the Eureka Adit/Lower WR piles. Deep bedrock well to assess potential impact of the Eureka Mine pool.	Low Flow	A:WT 10, C: 30 D:100	same as above	3 semiannual rounds

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Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Eureka Mine Area (cont.)						
MW-16A,C	Downgradient of Eureka WR piles between the Eureka Shaft and the Eureka Adit.	Characterization of overburden and shallow bedrock groundwater downgradient of the middle area of Eureka WR piles, and bedrock groundwater downgradient of the Eureka Mine pool in the adit area. Used for comparison with upgradient and downgradient well data to document variations in contaminant contribution from site subareas.	Low Flow	A:WT 10 C: 30	same as above	3 semiannual rounds
MW-17A,C,D	Along watershed divide near peak of Pike Hill, west of upper adit site.	Document shallow groundwater quality conditions upgradient of WR piles and along the western margin of the Pike Hill watershed. Deep bedrock well used to assess potential impact of Eureka Mine pool.	Low Flow	A:WT 10, C: 50, D:100	same as above	3 semiannual rounds
MW-18D	Southeast of the Eureka Mine Adit	Bedrock well to penetrate the Eureka Mine pool in a flooded portion of the mine to assess mine pool water quality.	Low Flow	D: 80	same as above	3 semiannual rounds
MW-19A,C,D	East of the Eureka Mine underground workings and upper adit site.	Assess shallow gorundwater quality downgradient of the Upper Cut area. Deep bedrock well for evaluating potential impact from Eureka Mine pool.	Low Flow	A:WT 10, C: 30 D:100	same as above	3 semiannual rounds
Smith Mine Area						
MW-20 A,C,D	Downgradient of WR pile at main shaft	Assess shallow groundwater conditions downgradient of WR pile. Deep bedrock well to assess potential impact of Smith Mine pool.	Low Flow	A:WT 10, C: 30 D: 75 dep. on mine depth	same as above	3 semiannual rounds
MW-21A,C	Immediately downgradient of WR pile east of adit.	To assess shallow overburden/bedrock groundwater conditions downgradient of the mine site.	Low Flow	A:10 C:30	same as above	3 semiannual rounds
Residential Drinking Water						
Residential Drinking Water	Est 30 residences in the vicinity of the On-site Site Source Areas	Locations TBD within approximately one half-mile of on-site sources.	Grab	TBD	same as above	3 semiannual rounds

Table 8-1
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Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Soil Sampling						
Soil Borings/Monitor Wells						
Union Mine Area						
SB-01	Within lowermost Union Mine WR pile	Subsurface soil samples will be collected from the surficial soil (0-0.5'), subsurface soil (composite from 0.5-10'), and distinct overburden lithologic unit observed within and below each waste pile. Depending on lithologic variability and thickness approximately 3 per boring samples may be collected for analysis. The 0-0.5 and <10' depth samples will be used for Human health risk assessment in addition to site characterization.	HSA grab/ composite	0'-Top of Bedrock	Parameters below are specified for site characterization. TAL metals will also be used for HHRA: TAL Metals from all samples. ABA, Paste pH, paste conductivity one subsurface sample per boring. SPLP Metals (10% of subsurface samples).	Approx 3 per boring
SB-02	Within WR pile below ramp, S. of SB-01	same as above	same as above	same as above	same as above	same as above
SB-03	Within the largest Union Mine WR pile	same as above	same as above	same as above	same as above	same as above
SB-04	Within upper Union WR pile	same as above	same as above	same as above	same as above	same as above
SB-05	Berm immediately east of Union Mine Adit	same as above	same as above	same as above	same as above	same as above
MW-03	Immediately downgradient of largest Union Mine waste rock pile	same as above	same as above	same as above	same as above	same as above
MW-04	Lowlying area adjacent to largest Union Mine WR pile	same as above	same as above	same as above	same as above	same as above
MW-05	Within one of the uppermost Union WR Piles	same as above	same as above	same as above	same as above	same as above
Eureka Mine Area						
SB-06	Flotation tailings pile	Subsurface soil samples will be collected from the surficial soil (0-0.5'), subsurface soil (composite from 0.5-10'), and distinct overburden lithologic unit observed within and below each waste pile. Depending on lithologic variability and thickness approximately 3 per boring samples may be collected for analysis. The 0-0.5' and <10' depth samples will be used for Human health risk assessment in addition to site characterization.	HSA grab/ composite	0'-Top of Bedrock	Parameters below are specified for site characterization. TAL metals will also be used for HHRA: TAL Metals from all samples. ABA, Paste pH, paste conductivity one subsurface sample per boring. SPLP Metals (10% of subsurface samples).	Approx 3 per boring
SB-07	Flotation tailings pile	same as above	same as above	same as above	same as above	same as above
SB-08	Flotation tailings pile	same as above	same as above	same as above	same as above	same as above

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Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Eureka Mine Area (cont.)						
SB-09	Flotation tailings pile	same as above	same as above	same as above	same as above	same as above
SB-10	Mag. Sep.tailings pile	same as above	same as above	same as above	same as above	same as above
MW-11	Upgradient of flotation tails adjacent to mill foundation	same as above	same as above	same as above	same as above	same as above
SB-11	WR pile below Eureka adit	same as above	same as above	same as above	same as above	same as above
SB-12	WR pile below Eureka adit	same as above	same as above	same as above	same as above	same as above
SB-13	WR pile upslope from the Eureka adit.	same as above	same as above	same as above	same as above	same as above
SB-14	WR pile below Upper Eur. adit site	same as above	same as above	same as above	same as above	same as above
SB-15	WR pile west of Upper Adit	same as above	same as above	same as above	same as above	same as above
SB-16	WR pile above Upper Eur. Adit/cut	same as above	same as above	same as above	same as above	same as above
SB-17	Westernmost Eureka WR pile near peak of Pike Hill.	same as above	same as above	same as above	same as above	same as above
SB-18	WR pile west of Open Cut	same as above	same as above	same as above	same as above	same as above
SB-19	WR pile near Cuprum Shaft	same as above	same as above	same as above	same as above	same as above
MW-13	Eureka WR Pile beow Eureka adit	same as above	same as above	same as above	same as above	same as above
Smith Mine Area						
SB-20	WR pile at shaft	Subsurface soil samples will be collected from the surficial soil (0-0.5'), subsurface soil (composite from 0.5-10'), and distinct overburden lithologic unit observed within and below each waste pile. Depending on lithologic variability and thickness approximately 3 per boring samples may be collected for analysis. The 0-0.5 and <10' depth samples will be used for human health risk assessment in addition to site characterization.	HSA grab/ composite	0'-Top of Bedrock	Parameters below are specified for site characterization. TAL metals will also be used for HHRA: TAL Metals from all samples. ABA, Paste pH, paste conductivity one subsurface sample per boring. SPLP Metals (10% of subsurface samples).	Approx 3 per boring
SB-21	Within WR pile east of adit.	same as above	same as above	same as above	same as above	same as above

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Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Smith Mine Area (cont.)						
SB-22	Within WR pile east of adit.	same as above	same as above	same as above	same as above	same as above
SB-23	WR pile North of shaft	same as above	same as above	same as above	same as above	same as above
Test Pits						
Union Mine Area						
TP-01 through TP-018	Margins of WR piles	Shallow test pits will be excavated to delineate the lateral extent of waste rock material by visual inspection and field XRF analysis. Off-site analytical sampling will be limited and biased toward locations of unimpacted/natural-appearing soils that constrain waste limits. Assume one grab soil sample per test pit from 0-0.5'. Additional waste samples may be collected if wastes are observed that have not previously been documented in the adjacent pile.	Backhoe or shovel	<5'	Field XRF on select samples for limited number of metals.TAL Metals on all off-site samples. ABA, Paste pH, paste conductivity, SPLP Metals on 10% of off-site samples.	Approx 1 per location
Eureka Mine Area						
TP-19 through TP-37	Margins of WR and tailings piles	Shallow test pits will be excavated to delineate the lateral extent of waste rock material by visual inspection and field XRF analysis. Off-site analytical sampling will be limited and biased toward locations of unimpacted/natural-appearing soils that constrain waste limits. Assume one grab soil sample per test pit from 0-0.5'. Additional waste samples may be collected if wastes are observed that have not previously been documented in the adjacent pile.	Backhoe or shovel	<5'	same as above	Approx 1 per location
Smith Mine Area						
TP-38 through TP-41	Margins of 3 WR piles	Shallow test pits will be excavated to delineate the lateral extent of waste rock material by visual inspection and field XRF analysis. Off-site analytical sampling will be limited and biased toward locations of unimpacted/natural-appearing soils that constrain waste limits. Assume one grab soil sample per test pit from 0-0.5'. Additional waste samples may be collected if wastes are observed that have not previously been documented in the adjacent pile.	Backhoe or shovel	<5'	same as above	Approx 1 per location

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Floodplain Soil Sampling						
FP-01 and FP-02	Two Transects across the main on-site tributary stem below Union WR piles	Surficial soil samples from floodplain areas to characterize overbank sediments for site characterization and assessing potential terrestrial ecological risk. Number of samples to be determined by areal extent of sediments observed, estimate up to 6 samples per transect at 0-0.5' depth. Only two locations on-site are currently proposed. Additional off-site locations may be proposed for sampling based on field observations of downstream floodplain areas.	Shovel	0-2'	TAL Metals on all samples. ABA, Paste pH, paste conductivity, SPLP Metals on 10% of samples, organic carbon (50%), CEC(25%)	Approx.6 samples per location
Additional Off-Site FP Samples	Additional Transects across PHB at off-site Locs	Surficial soil samples from floodplain areas to characterize overbank sediments for site characterization and assessing potential terrestrial ecological risk. Number of samples to be determined by areal extent of sediments observed, estimate up to 6 samples per transect at 0-0.5' depth. Off-site locations may be proposed for sampling based on field observations of downstream floodplain areas between the site and the PHB Wetland Complex.	Shovel	0-2'	See above	Approx.6 samples per location
Terrestrial Habitat Soil Samples For Terrestrial BERA Only						
Eureka, Union, and Smith Mine Area BERA EA Grids	Loc TBD, One per each mine area.	Samples will be collected for field XRF analysis at three (5 x 10 node) sampling grids that extend radially from source areas along an expected migration path [one surface soil (0-12 cm) grab sample will be collected at each grid node for XRF analysis, 50 spls/grid]. For correlation of XRF analysis with off-site laboratory result, 10% of samples will be split for off-site analysis. Each grid will be positioned to capture exposure conditions along a concentration gradient, beginning in the transition zone adjacent to one or more of the existing waste piles (Note:XRF analysis to help determine grid placement will be completed prior to grid sampling). Composite surface soil samples (0-12cm) will be collected for off-site analysis at locations where biota sampling is successful. It is estimated that between 20-60 composite surface soil samples will be collected from the site (see text for discussion). Background: An additional 10-20 grab samples for off-site analysis will be needed to characterize background levels for inorganics. Samples will be collected in non-impacted areas that will also be suitable for background plant, soil invertebrates and small mammals sample collection.	Shovel	0-12cm/5"	TAL metals (all samples), organic carbon (50%), paste pH(25%), paste conductivity(25%), CEC(25%)	20-60 samples excluding bkg samples
Soil Background	Loc TBD beyond source areas	Estimate 20 surficial soil samples from areas beyond site source areas to establish Site background soil concentrations for comparison with site characterization, BERA and HHRA sample data.	Shovel	0-12cm/5"	TAL metals (all samples), organic carbon (50%), paste pH(25%), paste conductivity(25%), CEC(25%)	20 Spls

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Sediment Sampling						
SD-01 through SD-18	Downgradient of Eureka/Union Mine Areas	Shallow sediment samples colocated with surface water samples from defined channels below seeps and within tributary stem to evaluate whether sediment should be considered a waste source material.	Bucket auger, shovel or tube sampler	0-2'	TAL Metals on all samples. ABA, Paste pH, paste conductivity, SPLP Metals on 10% of samples.	One per location
SD-19 through SD-23	Downgradient of Smith Mine Area	Shallow sediment samples colocated with surface water samples from defined channels below seeps and within tributary stem to evaluate whether sediment should be considered a waste source material.	Bucket auger, shovel or tube sampler	0-2'	same as above	One per location
Offsite PHB-Wetland Complex	Loc TBD along PHB	No additional sediment samples needed for HHRA. Samples to be collected for characterization only to determine nature and extent of off-site waste deposition.	Bucket auger, shovel or tube sampler	TBD visually	same as above	One per location
PHB Wetlands Complex	See Below	See Wetland Complex Sampling. Characterization and BERA sampling described below will be sufficient for HHRA.	NA	NA	NA	NA
PHB Wetlands to WR	5 Loc TBD	Additional sediment samples estimated to supplement existing data for HHRA.	Bucket auger, shovel or tube sampler	0-0.5'	TAL Metals.	Approx 5 samples
Trib Cookville Bk	NA	No additional sediment samples needed for HHRA	NA	NA	NA	NA
South Branch WR (CkBk and Tribs)	8 Loc TBD	Additional sediment samples estimated to supplement existing data for HHRA.	Bucket auger, shovel or tube sampler	0-0.5'	TAL Metals.	Approx 8 samples
Surface Water Sampling						
SW-01 through SW-18	Downgradient of Eureka/Union Mine Areas below seeps and along tributary to PHB	Surface water samples colocated with sediment samples to assess water quality in the tributary headwaters. Data will be used to assess relative contaminant contributions from various waste source areas. Surface water sampling parameters will include the full target analyte list (TAL) of metals, cyanide and sulfate for all locations since these are the most prevalent site-related substances identified in previous studies. Additional inorganic parameters listed in Table 8-1 will be analyzed only for select locations (approx 50% of the proposed wells) for the first round of sampling based on their location and likelihood of being impacted by site sources in order to more fully characterize groundwater chemistry proximal to source areas. The list of parameters included for subsequent rounds will include at a minimum TAL metals and sulfate, with additional parameters added as necessary for locations identified in areas impacted by site sources. A full list of organic parameters (VOCs, SVOCs, pesticides/PCBs) will be analyzed during the second round of sampling at select locations (estimate 5% of locations) identified as impacted by site sources to assess whether these compounds are present in relation to historical site activities. Results will determine whether a subset of parameters will be carried forward in subsequent rounds.	Dipper-Grab	NA	TAL Metals (total and dissolved), total cyanide, sulfate for all locations. Chloride, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, TSS, TDS for select locations (approx 50% of locations). VOCs, SVOCs, Pest/PCBs for select locations during Round 2 (approx 5% of locations). **Note:** The list of parameters included after the initial round will include at a minimum TAL metals and sulfate, with additional parameters added as necessary for locations identified in areas impacted by site sources. Results will determine whether a subset of parameters are carried forward in subsequent rounds.	3 semiannual rounds
SW-19 through SW-23	Downgradient of Smith Mine Area along upper reach of trib. to Cookville Bk	same as above	same as above	same as above	same as above	same as above

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
SW-24 through SW-28	Samples from the various accessible Union.Eureka mine openings	Mine pool samples from the accessible Union/Smith Mine openings for comparison with USGS sample results, downgradient surface water and groundwater results, and deep mine pool sample results. Metals results to also be used for HHRA.	same as above	same as above	same as above	same as above
SW29	Sample from the surface of the Smith Mine pool	Mine pool sample from the Smith Mine shaft for comparison with USGS sample results, downgradient surface water and groundwater results, and deep mine pool sample results. Metals results to also be used for HHRA.	same as above	same as above	same as above	same as above
Offsite PHB-Wetland Complex	NA	No additional surface water samples needed for HHRA	NA	NA	NA	NA
PHB Wetlands Complex	See Below	See Wetland Complex Sampling. Characterization and BERA sampling described below will be sufficient for HHRA.	NA	NA	NA	One per location
PHB Wetlands to WR	5 Loc TBD	Additional surface water samples estimated to supplement existing data for HHRA.	Dipper-Grab	NA	TAL Metals (total and dissolved).	Approx 5 samples
Trib Cookville Bk	NA	No additional surface water samples needed for HHRA	NA	NA	NA	NA
South Branch WR (CkBk and Tribs)	8 Loc TBD	Additional surface water samples estimated to supplement existing data for HHRA.	Dipper-Grab	NA	TAL Metals (total and dissolved).	Approx 8 samples
Vernal Pools	TBD	In early spring (late April/early May), a vernal pool presence evaluation will be conducted. All isolated depressional wetlands, with no permanent inlet or outlet will be identified and mapped. All mapped pools will be visited a second time (approx. 4-6 weeks later) to determine if vernal pool characteristics as defined by Vermont DEC are present. Surface water samples will be collected from each positively identified vernal pool and a qualitative assessment of pool conditions will be determined using Vermont DEC guidelines (VDEC 2003). Surface water sampling and pool evaluations would be conducted in 2009.	Dipper-Grab	NA	TAL metals (total and dissolved for surface water), pH, conductivity, alkalinity, sulfate, chloride and nitrate	One per location
Other HHRA Sampling						
Fish Sampling	None	No additional fish sampling is anticipated as existing fish sampling data is assumed to be sufficient to support HHRA	NA	NA	NA	NA
Earthworm/Plant Tissue/Small Mammal BERA Sampling						
Soil Invertebrates	At 3 mine area EA grids	At soil grid sampling locations, where habitat conditions are suitable, earthworm samples will be collected and submitted for subsequent contaminant analysis. Soil samples surrounding the invertebrate sample location will be used to develop soil/invertebrate BAFs (see BERA surface soil samples). A minimum of 20-30 composite invertebrate samples will be collected from the site along a soil metals concentration gradients. Background: 5-10 background earthworm samples will be collected in association with the background soil samples.	Shovel	0-12cm/5"	TAL metals (all samples) and percent lipid (50%)	25-40 samples incl. bkg

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Plant Tissue	At 3 mine area EA grids	At soil grid sampling locations, where habitat conditions are suitable, vegetative and reproductive plant tissue will be collected for subsequent contaminant analysis. Soil samples surrounding the plant sample location will be used to develop soil/plant BAFs (See BERA surface soil samples). A minimum of 20-30 composite samples will be collected from the site along soil metals concentration gradients. Background: 5-10 background plant tissue samples will be collected in association with the background soil samples.	TBD	NA	TAL metals	25-40 samples incl. bkg
Small Mammals	At 3 mine area EA grids	At soil grid sampling locations, where habitat conditions are suitable, small mammal whole-body will be collected for subsequent contaminant analysis. Soil samples surrounding the small mammal sample location will be used to develop soil/small mammal BAFs (See BERA surface soil samples). A minimum of 20-30 individual samples will be collected from the site along metals concentration gradients. Background: 5-10 background samples will be collected in association with the background soil samples	TBD	NA	TAL metals (all samples) and percent lipid (50%)	25-40 samples incl. bkg
Pike Hill Brook Wetland Complex Sampling - Wetlands 1 Through 4						
Sediment Benthic Community	TBD Along Contaminant gradient within each wetland	Evaluate sediment community composition along a contaminant gradient throughout each wetland and compare with an appropriate reference area. 5-10 surface sediment samples (five replicates each) should be collected for offsite lab analysis for benthic macroinvertebrate enumeration and community metric development (following VTDEC guidelines), at least 3-5 samples from a reference wetland should also be submitted for evaluation.	Grab	0-6cm/2.5"	TAL metals, AVS/SEM, organic carbon, paste pH and conductivity, CEC. Grain size	25-45 samples total incl ref.
Field XRF samples	Grid Throughout Wetlands 1 through 4, exclusive of USGS sample areas	Locations TBD based on results of USGS Study and field inspection. Grid sampling will be employed to characterize gross distribution of metals in the wetlands.	Grab	TBD	Limited metals list TBD based on results from USGS study.	TBD
Wetland Soil Cores	TBD select locations based on XRF results	Locations TBD based on results of USGS Study and field inspection	Hand driven	TBD	TAL Metals, ABA, Paste pH, paste conductivity, SPLP Metals (10% of samples), AVS/SEM, organic carbon, CEC, grain size.	TBD
Piezometers	TBD within wetlands 1 through 4	Locations TBD based on results of USGS Study and field inspection. Nested pairs of piezometers may be needed depending on thickness of overburden flow units.	Hand driven	TBD	See groundwater samples below.	TBD
Overburden monitor wells	TBD peripheral to wetlands 1 through 4	Locations TBD based on results of USGS Study and field inspection. One well downgradient of each wetland to assess potential impact of wetland sediment and surface water on gorundwater.	HAS	15'	No soil analyses proposed. See groundwater samples below	TBD
Groundwater Samples	Piezometers and MWs	Locations TBD based on results of USGS Study and field inspection. Sampling from piezometers and peripheral overburden wells.	Grab	TBD	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	3 semiannual rounds

Table 8-1
Summary of Preliminary Recommendations for Field Sampling
for RI/FS Investigation
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Loc ID	Loc Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Residential Drinking Water	Est 30 residences in the vicinity of the Wetlands	Locations TBD within approximately one half-mile of the wetlands complex.	Grab	TBD	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	3 semiannual rounds
Surface Water/Pore Water Samples	TBD within wetlands 1 to 4	Locations TBD based on results of USGS Study and field inspection. Colocated with core samples and piezometer sample locations.	Grab	TBD	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	3 semiannual rounds
Sediment Toxicity Testing	TBD within wetlands 1 to 4	After completing the aforementioned activities in the wetland complex, evaluate the utility of conducting sediment toxicity testing for establishing ecologically-based clean-up levels. 5-7 composite sediment samples collected from a range of contaminant levels or one highly contaminated sample (serially diluted) and submitted to a toxicity lab for a chronic evaluation (endpoints: growth, lethality and reproduction); sediment chemistry analyses as previously described, at least 3-5 samples from the reference wetland should also be submitted for evaluation.	TBD	TBD	Chronic evaluation (endpoints: growth, lethality and reproduction); TAL metals, AVS/SEM, organic carbon, paste pH and conductivity, CEC. Grain size.	8-12 Samples incl ref.

Table 8-2
Baseline Ecological Risk Assessment Data Needs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Proposed Exposure Area/Information Needs	Sample Requirements
Terrestrial Habitats	
Surface Soil samples: Surface soils with adequate spatial coverage to provide sufficient chemistry data for a range of contaminant concentrations in impacted habitats bordering the source areas. Site-specific surface soil background chemistry information to assess natural levels for inorganics.	A sufficient number of samples will be collected and analyzed to define nature and extent of contamination. Composite surface soil samples (0-12cm) will be collected at locations where biota sampling is successful. It is assumed that between 20-60 composite surface soil samples will be collected (see text for discussion). **Background**: An additional 10-20 grab samples will be needed to characterize background levels for inorganics. Samples will be collected in non-impacted areas that will also be suitable for background plant, soil invertebrates and small mammals sample collection. **Analyses:** TAL metals (all samples), organic carbon (50%), paste pH (25%), paste conductivity (25%), CEC (25%)
Vegetative community assessment: A vegetative community analysis similar to the one conducted at the Ely Mine site (URS, 2005). Information on community composition and spatial coverage would be required. During this field activity, attention would also be given to identifying areas of stressed vegetation.	Sufficient spatial coverage to develop a GIS-based vegetation map based on the natural communities classification system proposed by Thompson and Sorenson (2000). Recent (less than 10 years old) aerial photographs of the site are needed. All relevant field observations should be spatially-referenced and included as data layers in GIS (e.g., location of stressed vegetation).
Soil invertebrate (earthworm) samples: At soil grid sampling locations, where habitat conditions are suitable, earthworm samples will be collected and submitted for subsequent contaminant analysis (soil samples surrounding the invertebrate sample location will be collected used to develop soil/invertebrate BAFs).	A minimum of 20-30 composite samples will be collected along a soil metals concentration gradient. **Background:** 5-10 background samples will be collected in association with the background soil samples **Analyses:** TAL metals (all samples) and percent lipid (50%)
Plant tissue samples: At soil grid sampling locations, where habitat conditions are suitable, vegetative and reproductive plant tissue will be collected for subsequent contaminant analysis (soil samples surrounding the plant sample location will be collected used to develop soil/plant BAFs).	A minimum of 20-30 composite samples will be collected along a soil metals concentration gradient. **Background:** 5-10 background samples will be collected in association with the background soil samples **Analyses:** TAL metals

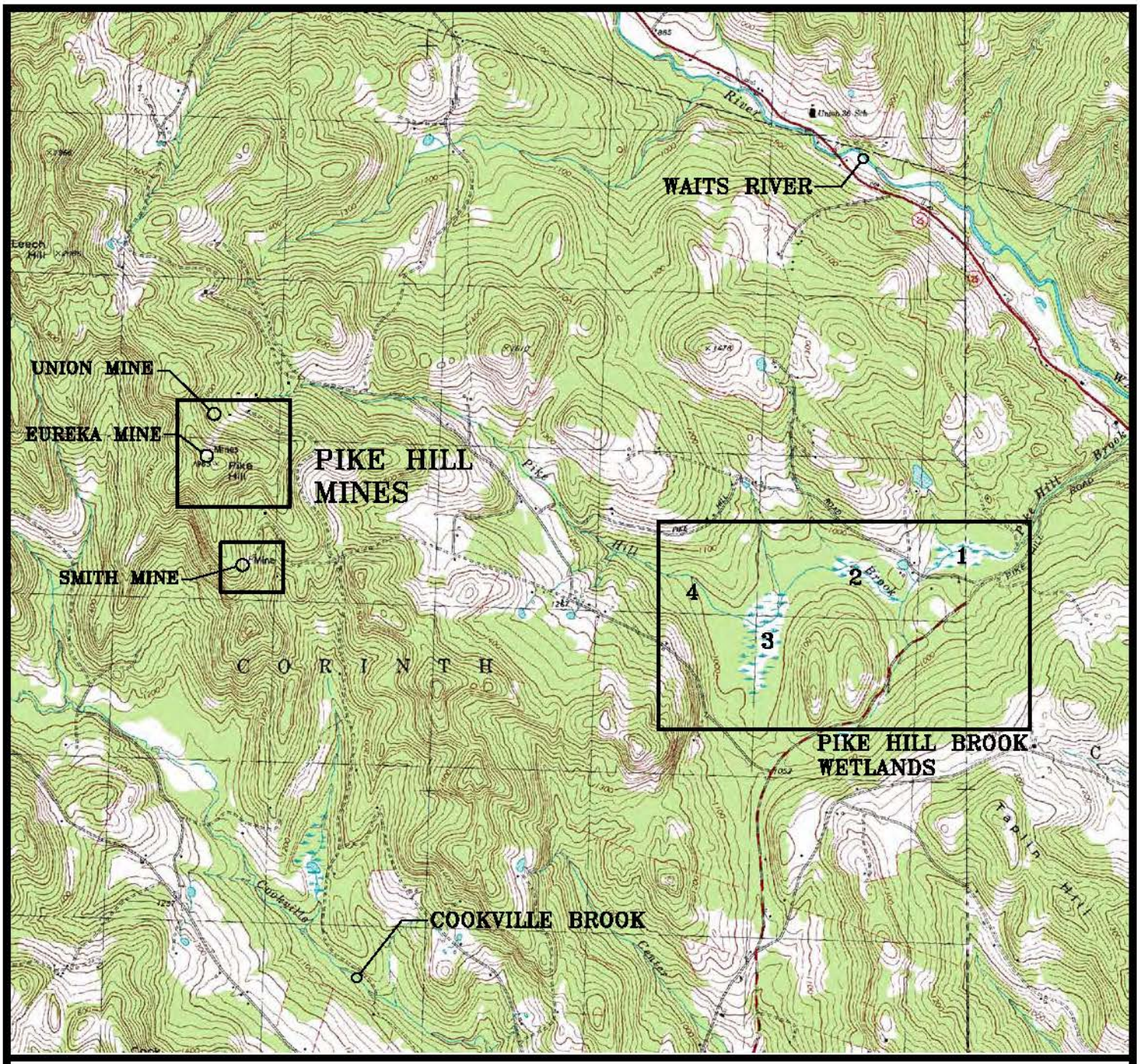
Table 8-2
Baseline Ecological Risk Assessment Data Needs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Proposed Exposure Area/Information Needs	Sample Requirements
Terrestrial Habitats (cont.)	
Small mammal samples: At soil grid sampling locations, where habitat conditions are suitable, small mammal whole-body will be collected for subsequent contaminant analysis (soil samples surrounding the small mammal sample location will be collected used to develop soil/small mammal BAFs).	A minimum of 20-30 individual samples will be collected along a soil metals concentration gradient. **Background:** 5-10 background samples will be collected in association with the background soil samples **Analyses:** TAL metals (all samples) and percent lipid (50%)
Vernal Pools	
Vernal pool identification and evaluation: In early spring (late April/early May), a vernal pool presence evaluation will be conducted. All isolated depressional wetlands, with no permanent inlet or outlet will be identified and mapped. All mapped pools will be visited a second time (approx. 4-6 weeks later) to determine if vernal pool characteristics as defined by Vermont DEC are present.	Surface water samples will be collected from each positively identified vernal pool and a qualitative assessment of pools conditions will be determined using Vermont DEC guidelines (VDEC 2003). Surface water sampling and pool evaluations would be conducted in 2009. **Analyses**: TAL metals (total and dissolved for surface water), pH, conductivity, alkalinity, sulfate, chloride and nitrate (Note: At this time a complete vernal pool assessment as recommended by the Vermont Wetlands Bioassessment Program is not proposed)
Surface Water Bodies	
Assumed no additional (beyond HHRA recommendations and aquatic BERA data) data required at this time.	NA
Pike Hill Brook Wetlands	
Preliminary amphibian and biota assessment	In late April/early may, in conjunction with the site visit and vernal pool evaluation an amphibian call survey will be conducted at all four wetlands following USGS North American Amphibian Monitoring guidelines (http://www.pwrc.usgs.gov/naamp/). In addition, all accessible wetland perimeters will be search for amphibian egg masses and adults. A qualitative dipnet survey will be performed at each wetland to assess the presence and composition of benthic organisms (all samples will be returned to the sampling location after a brief inspection for benthic invertebrates.
Wetland vegetative community assessment and mapping	With the aid of recent aerial photographs (< 10 years old) a vegetative community assessment will be conducted. Vegetative communities within each of the 4 Pike Hill Brook wetlands will be identified to community type as defined by Thompson and Sorenson (2000). All community boundaries digitized and incorporated into the project-wide GIS database. The overall functional quality of each wetland will also be assessed using Vermont's Wetland Evaluation form and procedures. (A formal wetlands delineation is not proposed at this time, but may be required prior to any remedial activities.)

Table 8-2
Baseline Ecological Risk Assessment Data Needs
Pike Hill Copper Mine Superfund Site
Corinth, Vermont

Proposed Exposure Area/Information Needs	Sample Requirements
Pike Hill Brook Wetlands (cont.)	
Sediment collection and surface water: An extensive surface sediment collection program will be developed to assess the spatial extent of contamination with the four identified wetland areas. Several surface water samples will also be collected synoptically form each wetland.	A sufficient number of samples will be collected to define nature and extent of contamination. A minimum of 5-50 surface sediment (0-6 cm) grab samples distributed evenly throughout the each wetland area (Nos.1-4) will be collected and analyzed. Assuming wetland # 4 (5 samples), # 3 (50 samples), # 2 (25 samples) and # 1 (25 samples) **Background**: An appropriate reference wetland should be indentified and sampled (10-15 surface sediment and 5-10 surface water samples collected and analyzed). **Analyses:** Sediment: TAL metals, AVS/SEM, organic carbon, paste pH, CEC, grain size. Surface water: TAL metals (total and dissolved), field pH, field D.O., field conductivity
Sediment benthic community assessment: Evaluate sediment community composition along a contaminant gradient throughout the marsh and compare with an appropriate reference area.	5-10 surface sediment samples (five replicates each) should be collected and shipped to an offsite lab for benthic macroinvertebrate enumeration and community metric development (following VTDEC guidelines), at least 3-5 samples from the reference wetland should also be submitted for evaluation. **Analyses:** TAL metals, AVS/SEM, organic carbon, paste pH and conductivity, CEC. Grain size
Amphibian community assessment: Evaluate the amphibian community composition within the wetland complex and compare to a suitable reference area.	In the spring an amphibian call survey should be conducted on at least 2 evenings, following USGS-North American Amphibian Monitoring Program guidance; survey should be conducted for the Pike Hill wetland and reference wetland. The wetland perimeters should also be searched for amphibian egg masses
Sediment toxicity testing (invertebrate and/or amphibian): After completing the aforementioned activities in the wetland complex, evaluate the utility of conducting sediment toxicity testing for establishing ecologically-based clean-up levels.	5-7 composite sediment samples collected from a range of contaminant levels or one highly contaminated sample (serially diluted) and submitted to a toxicity lab for a chronic evaluation (endpoints: growth, lethality and reproduction); sediment chemistry analyses as previously described, at least 3-5 samples from the reference wetland should also be submitted for evaluation.
Riparian floodplain	
Survey for floodplain contamination: Conduct a survey along all surface water bodies that tries to identify areas where contaminants may have left the water channel and migrated into the floodplain. A description of the identified areas will be provided to the project team and subsequent sampling needs will be identified.	This survey can be conducted as part of the vegetation survey. All areas identified will be photographed, assigned to a terrestrial or wetland community type and added to the GIS system. In formation will also be provided to the project management team for potential sample collection and analyses.

FIGURES



NORTH

USGS TOPOGRAPHIC MAP

EAST CORINTH, VERMONT

1973

APPROXIMATE SCALE
1 INCH = 3,000 FEET

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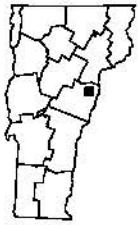


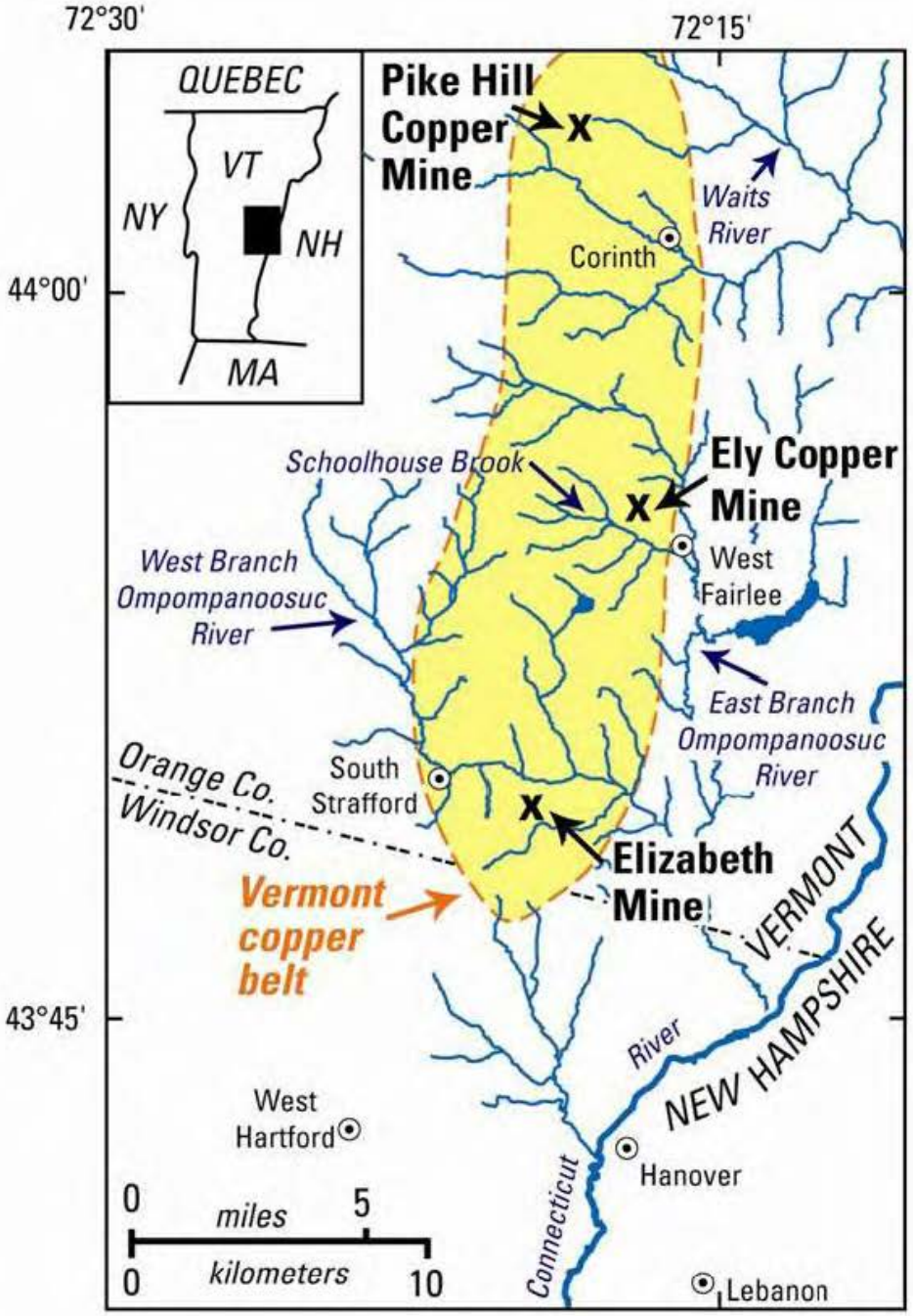
QUADRANGLE LOCATION

FIGURE 2-1

LOCUS PLAN
PIKE HILL COPPER MINE
SUPERFUND SITE
CORNITH, VERMONT

PROJECT: 80025.00

MAY 2008



NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "USGS GEOCHEMICAL CHARACTERIZATION OF MINE WASTE, MINE DRAINAGE, AND STREAM SEDIMENTS AT THE PIKE HILL COPPER MINE SUPERFUND SITE SITE, ORANGE COUNTY, VERMONT; SCIENTIFIC INVESTIGATIONS REPORT 2006–5303."

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FIGURE 2–2

VERMONT COPPER BELT
PIKE HILL COPPER MINE
SUPERFUND SITE
CORINTH, VERMONT

DRAWN BY:	ML	APPROVED BY:	AB
PROJECT:	80025.00	MAY 2008	

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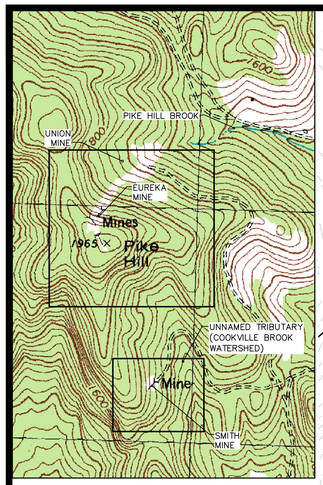

OVERVIEW MAP

LEGEND

- SITE BOUNDARY
- OTHER PROPERTY LINE
- ROAD
- EPHEMERAL STREAM
- CHANNEL
- MINE SHAFT
- MINE OPENING
- ADIT
- DAM
- WELL
- FOUNDATION
- BERM/VEGETATED WASTE ROCK
- WASTE ROCK
- BURNT FLOTATION TAILINGS
- MAGNETIC SEPERATION TAILINGS

UNION MINE

EUREKA MINE

SMITH MINE

GRAPHIC SCALE

100 0 50 100 200 400

(IN FEET)
1 inch = 100 ft.

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DESIGN	AB
DRAFTING	ML
CHECKED	AB
APPROVED	AB

DATE	REVISIONS	BY

PIKE HILL COPPER MINES
SUPERFUND SITE
CORINTH, VERMONT

MAY 2008

SITE SKETCH
UEREKA, UNION AND SMITH MINES

PROJECT NO. 80025.00

FIGURE
2-3

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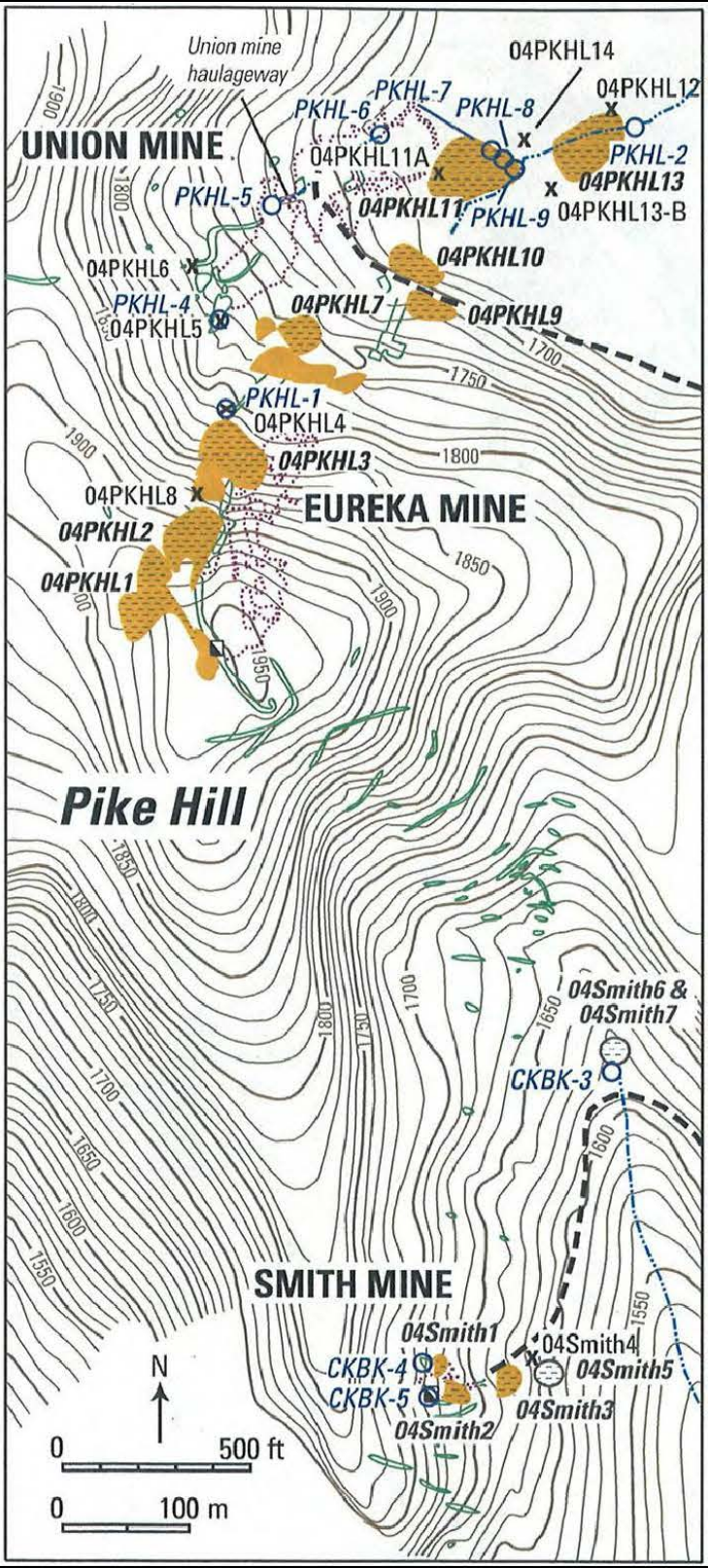

EXPLANATION

- Shaft
- Trench, pit, or open cut
- Underground workings
- Mine-waste dump
- Mine access road
- 1600 Contour interval in feet
- ***Composite sample***
- x Grab sample
- *Water sample*
- Intermittent stream

NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "USGS GEOCHEMICAL CHARACTERIZATION OF MINE WASTE, MINE DRAINAGE, AND STREAM SEDIMENTS AT THE PIKE HILL COPPER MINE SUPERFUND SITE SITE, ORANGE COUNTY, VERMONT; SCIENTIFIC INVESTIGATIONS REPORT 2006–5303."

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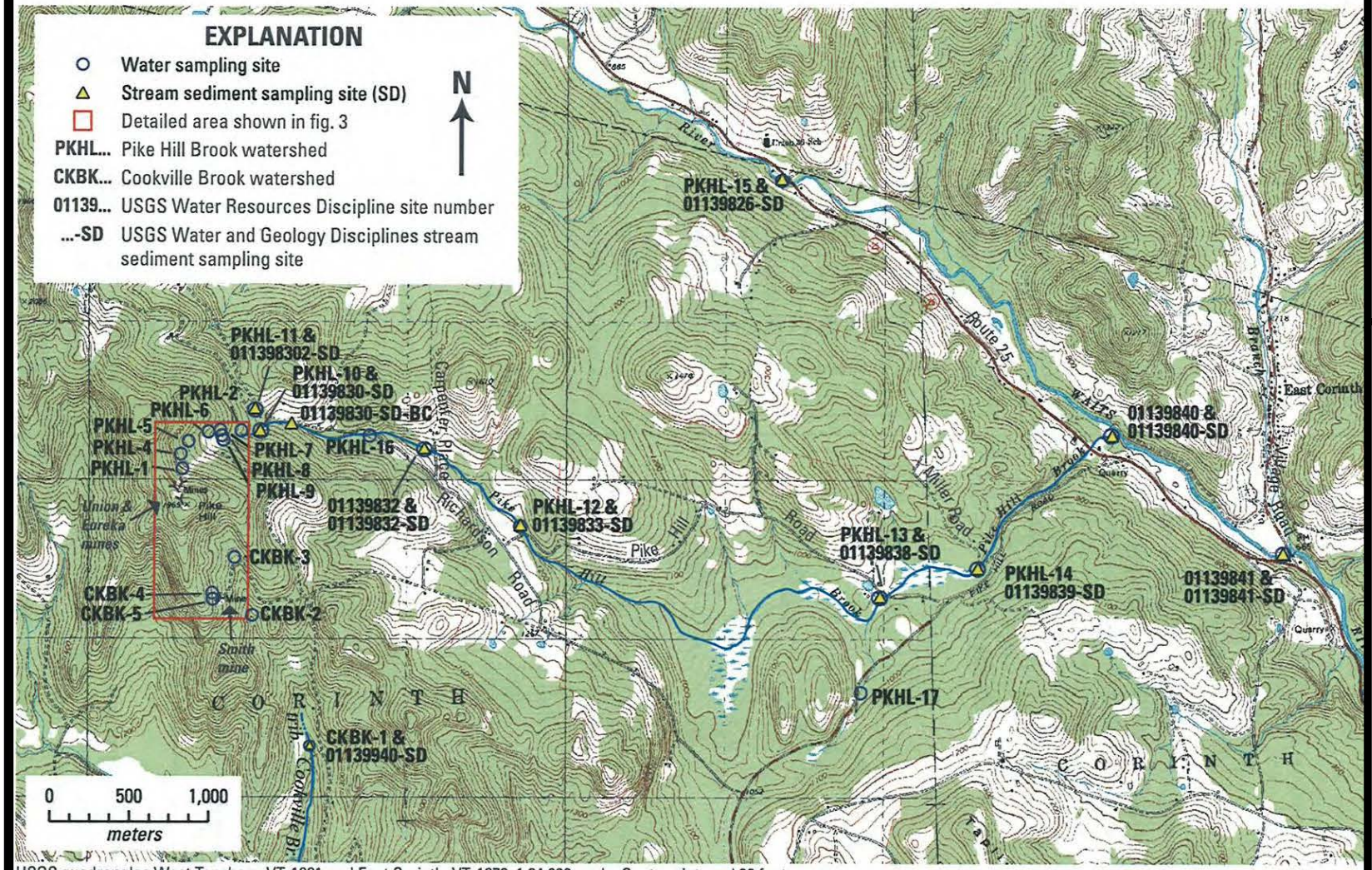
FIGURE 3–1

USGS WASTE ROCK AND SOIL SAMPLE LOCATIONS
PIKE HILL COPPER MINE
SUPERFUND SITE
CORNITH, VERMONT

DRAWN BY:	ML	APPROVED BY:	AB
PROJECT:	80025.00	MAY 2008	

J:\80000 EPA RAC2 Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025 00–WASTE–ROCK–AND–SOIL–LOCATIONS.dwg



USGS quadrangles West Topsham, VT, 1981 and East Corinth, VT, 1973, 1:24,000 scale. Contour interval 20 feet.
Vermont State Plane Coordinate System.

NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "USGS GEOCHEMICAL CHARACTERIZATION OF MINE WASTE, MINE DRAINAGE, AND STREAM SEDIMENTS AT THE PIKE HILL COPPER MINE SUPERFUND SITE SITE, ORANGE COUNTY, VERMONT; SCIENTIFIC INVESTIGATIONS REPORT 2006–5303."

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USGS SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS
PIKE HILL COPPER MINE SUPERFUND SITE
CORNITH, VERMONT

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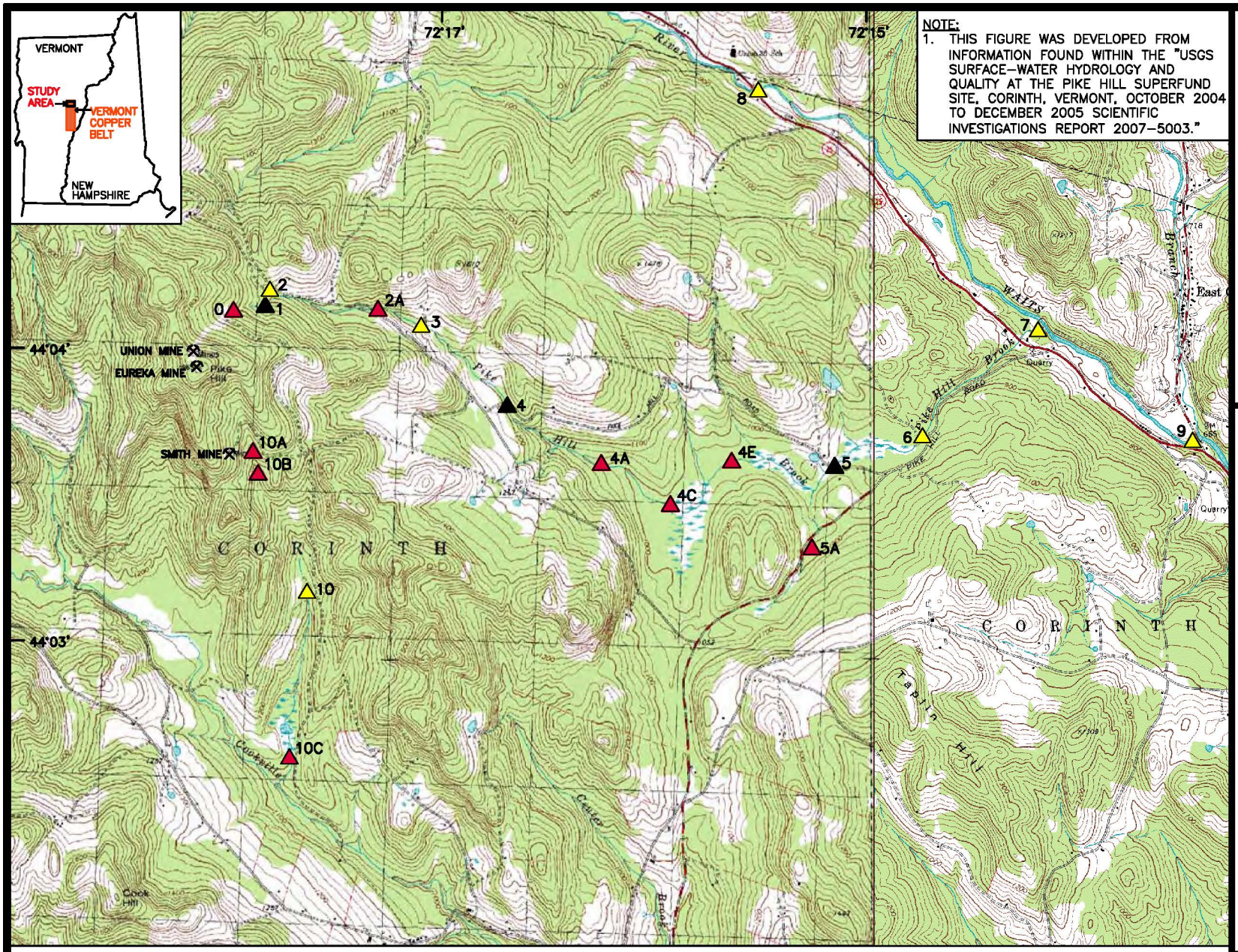
FIGURE 3–2



NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "USGS SURFACE-WATER HYDROLOGY AND QUALITY AT THE PIKE HILL SUPERFUND SITE, CORINTH, VERMONT, OCTOBER 2004 TO DECEMBER 2005 SCIENTIFIC INVESTIGATIONS REPORT 2007-5003."

BASE FROM U.S. GEOLOGICAL SURVEY
WEST TOPSHAM, 1981, 1:24,000 AND
EAST CORINTH, 1973, 1:24,000
VERMONT STATE PLAN COORDINATE SYSTEM

EXPLANATION

- 2 SYNOPTIC SAMPLING SITE WITH IDENTIFICATION
- 1 CONTINUOUS AND SYNOPTIC SAMPLING SITE WITH IDENTIFICATION
- 5A ADDITIONAL SAMPLING SITE WITH IDENTIFICATION
- MINE

0 0.25 0.5 0.75 1 MILE
0 0.25 0.5 0.75 1 KILOMETER

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WATER SAMPLING SITE LOCATIONS
PIKE HILL COPPER MINE
SUPERFUND SITE
CORNITH, VERMONT

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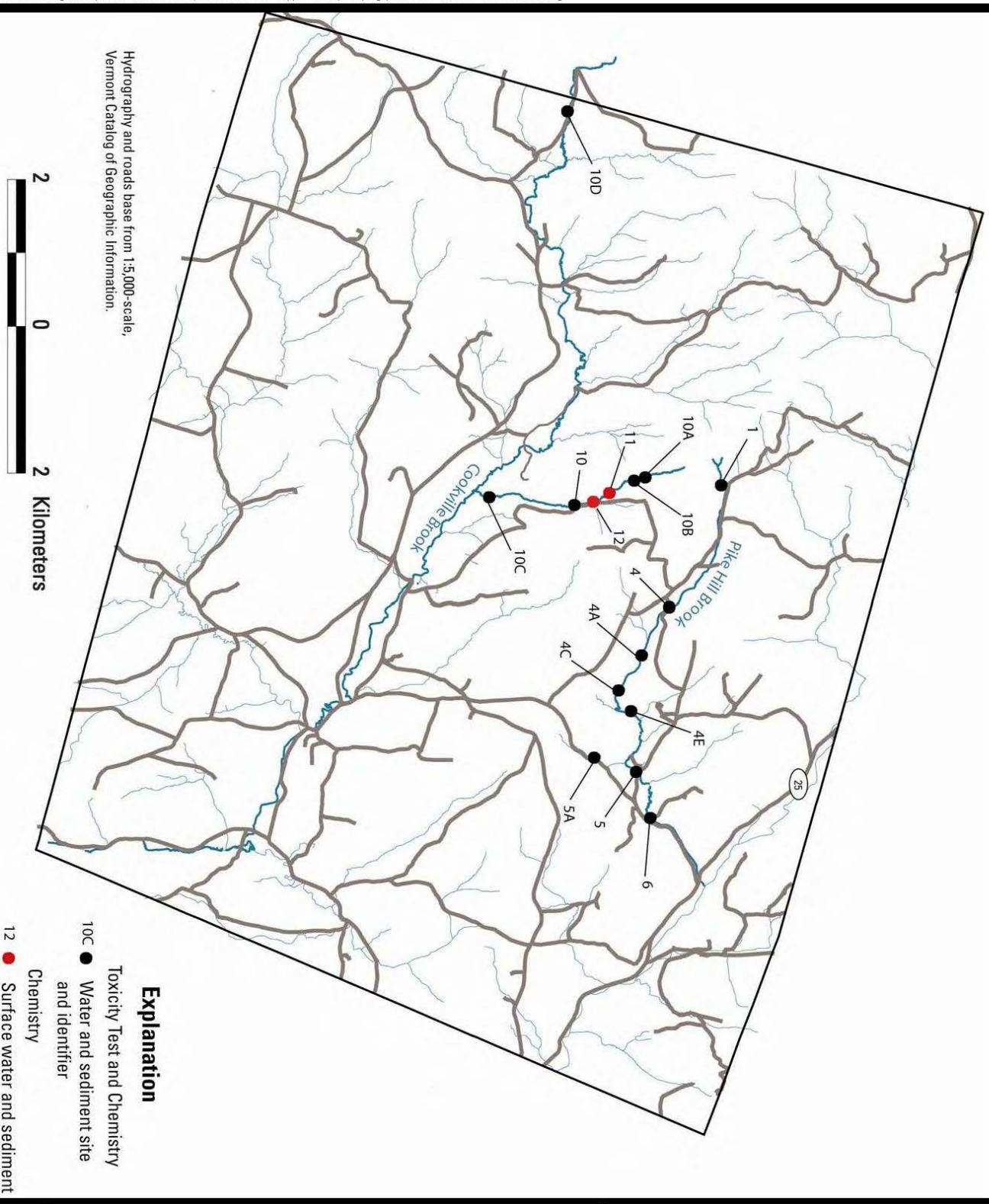
FIGURE
3-3

J:\80000 EPA RAC2 Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025.00-AQAUTIC-ASSESSMENT.dwg



LOCATION OF AQUATIC ASSESSMENT
(USGS 2007 UNPUBLISHED)
SURFACE WATER, PORE WATER, SEDIMENT,
MACROINVERTEBRATES, FISH & TOXICITY TESTING
PIKE HILL COPPER MINE
SUPERFUND SITE
CORINTH, VERMONT

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FIGURE 3-4

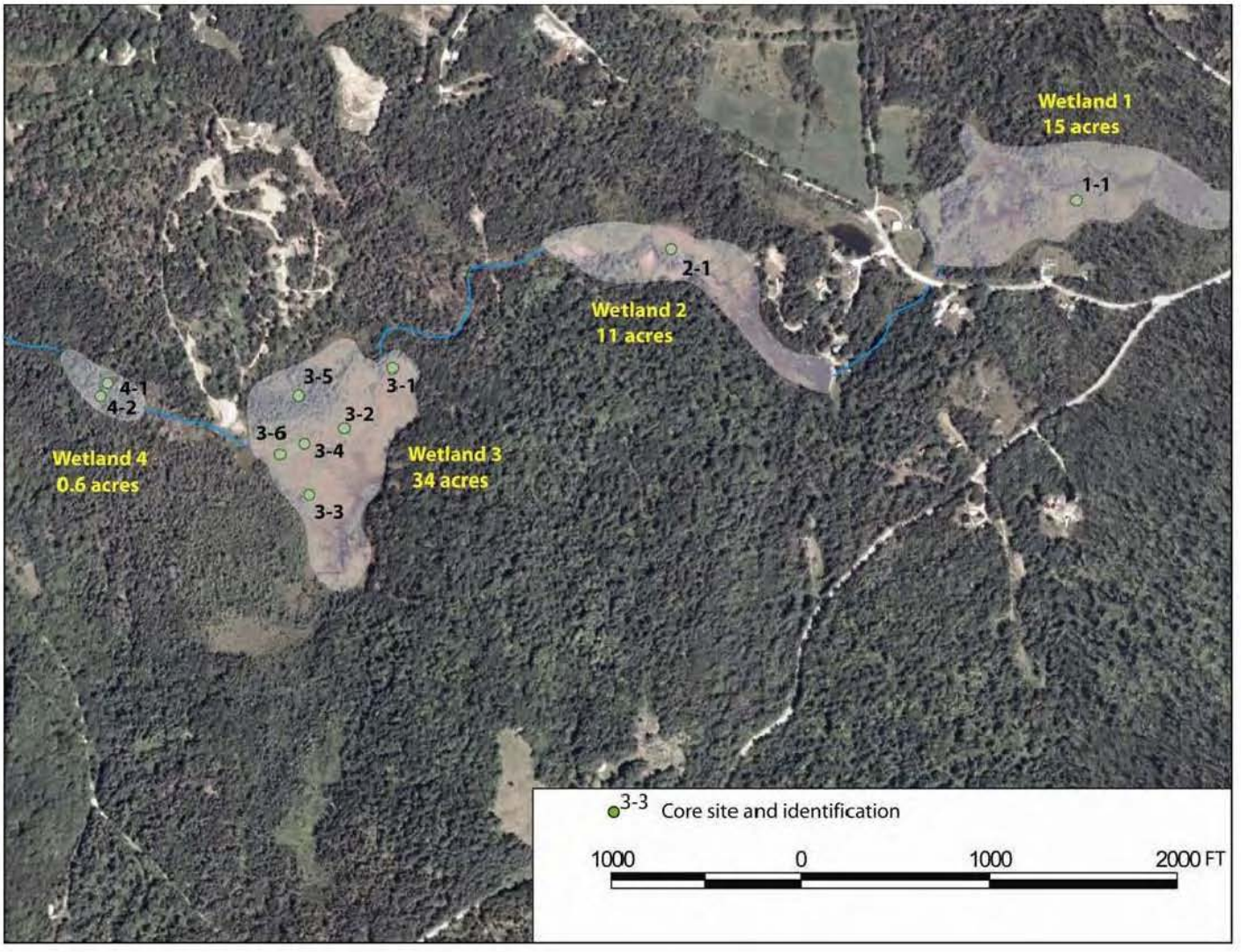

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FIGURE 3-5

PIKE HILL BROOK WETLAND COMPLEX AND
SOIL CORE LOCATIONS
(USGS 2007 UNPUBLISHED)
PIKE HILL COPPER MINE
SUPERFUND SITE
CORINTH, VERMONT

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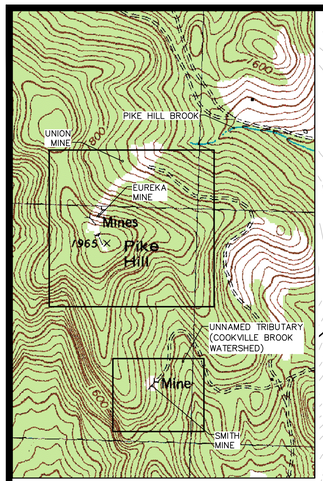
J:\80000 EPA RAC2 Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025.00-PIKE-HILL-WETLANDS.dwg



OVERVIEW MAP

LEGEND

- SITE BOUNDARY
- OTHER PROPERTY LINE
- ROAD
- EPHEMERAL STREAM
- CHANNEL
- MINE SHAFT
- MINE OPENING
- ADIT
- DAM
- WELL
- FOUNDATION
- BERM/VEGETATED WASTE ROCK
- WASTE ROCK
- BURNT FLOTATION TAILINGS
- MAGNETIC SEPERATION TAILINGS

UNION MINE

UNION MINE WASTE PILE PROPOSED EXPOSURE AREA

EUREKA MINE

EUREKA MINE TAILINGS PILE PROPOSED EXPOSURE AREA

EUREKA MINE WASTE PILE PROPOSED EXPOSURE AREA

BERA SAMPLING GRID (SURFACE SOIL, VEGETATION, INVERTEBRATES, SMALL MAMMALS)

PIKE HILL BROOK WATERSHED

COOKVILLE BROOK WATERSHED

GRANITE QUARRY

GRANITE CUTTING AREA

GENERAL STORE

DOMESTIC TRASH DUMP

PROPOSED LANDFILL LOCATION

GRAPHIC SCALE

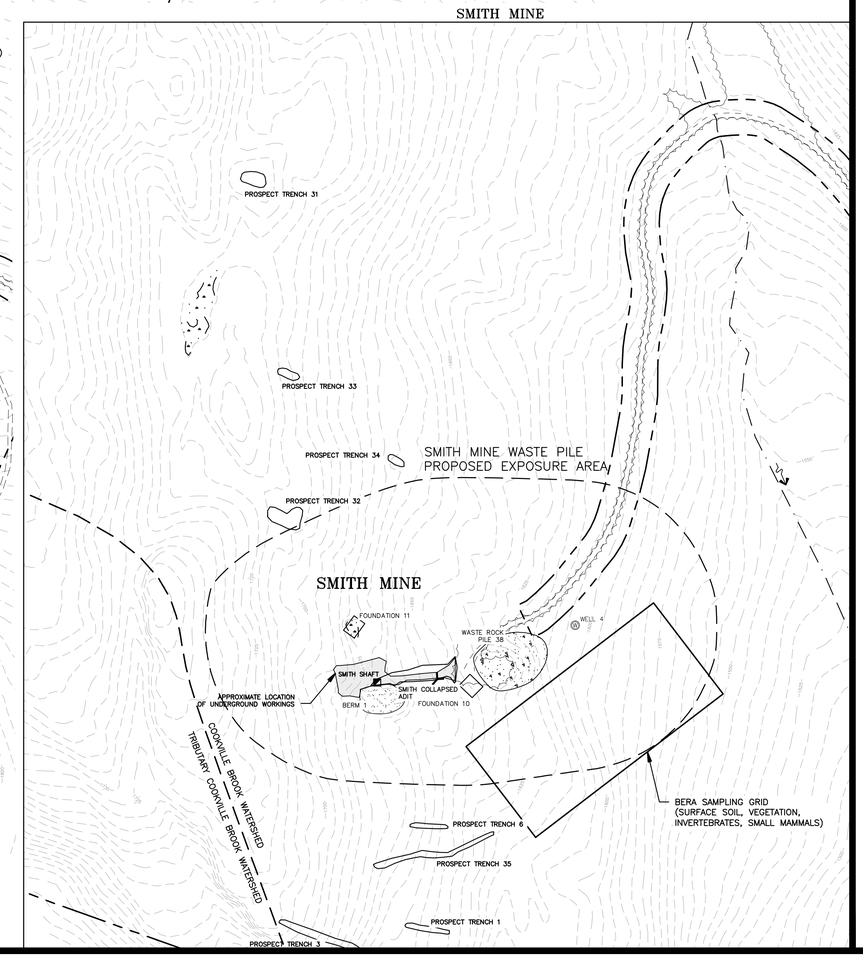
100 0 50 100 200 400

(IN FEET)
1 inch = 100 ft.

NOTE:

1. THREE (3) DISCRETIONARY SAMPLES (SURFACE) WILL ALSO BE COLLECTED BASED ON SITE OBSERVATIONS. AREAS OF OBVIOUS HUMAN USE WILL BE TARGETED.

SMITH MINE



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DATE	REVISIONS	BY

PIKE HILL COPPER MINES
SUPERFUND SITE
CORINTH, VERMONT

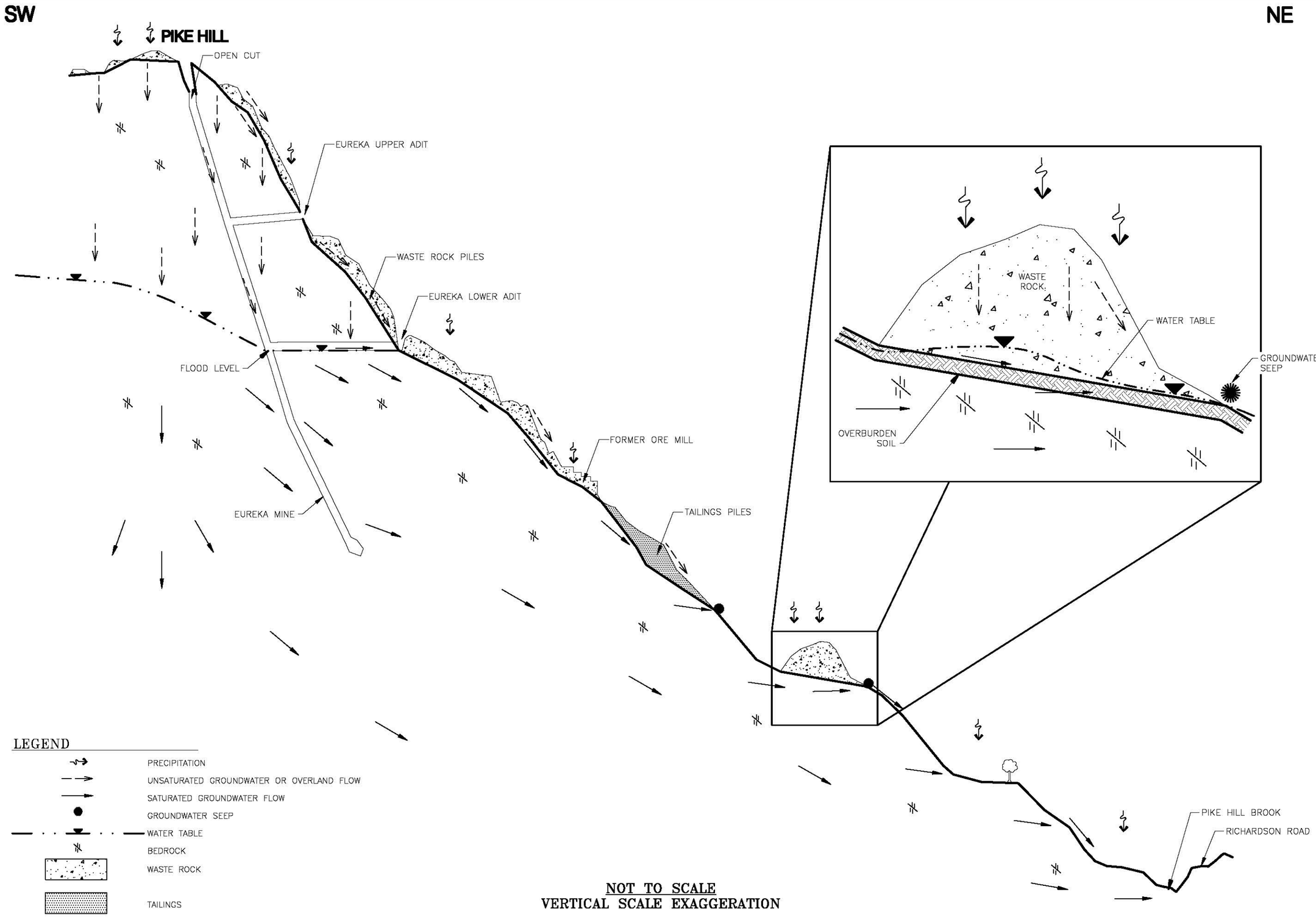
MAY 2008

STUDY AREAS
UEREKA, UNION AND SMITH MINES

PROJECT NO. 80025.00

FIGURE
4-1

J:\80000 EPA RACO Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025-05-PIKE-HILL-MINES.dwg



NOT TO SCALE
VERTICAL SCALE EXAGGERATION

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SUPERFUND SITE
CORINTH, VERMONT

MAY 2008

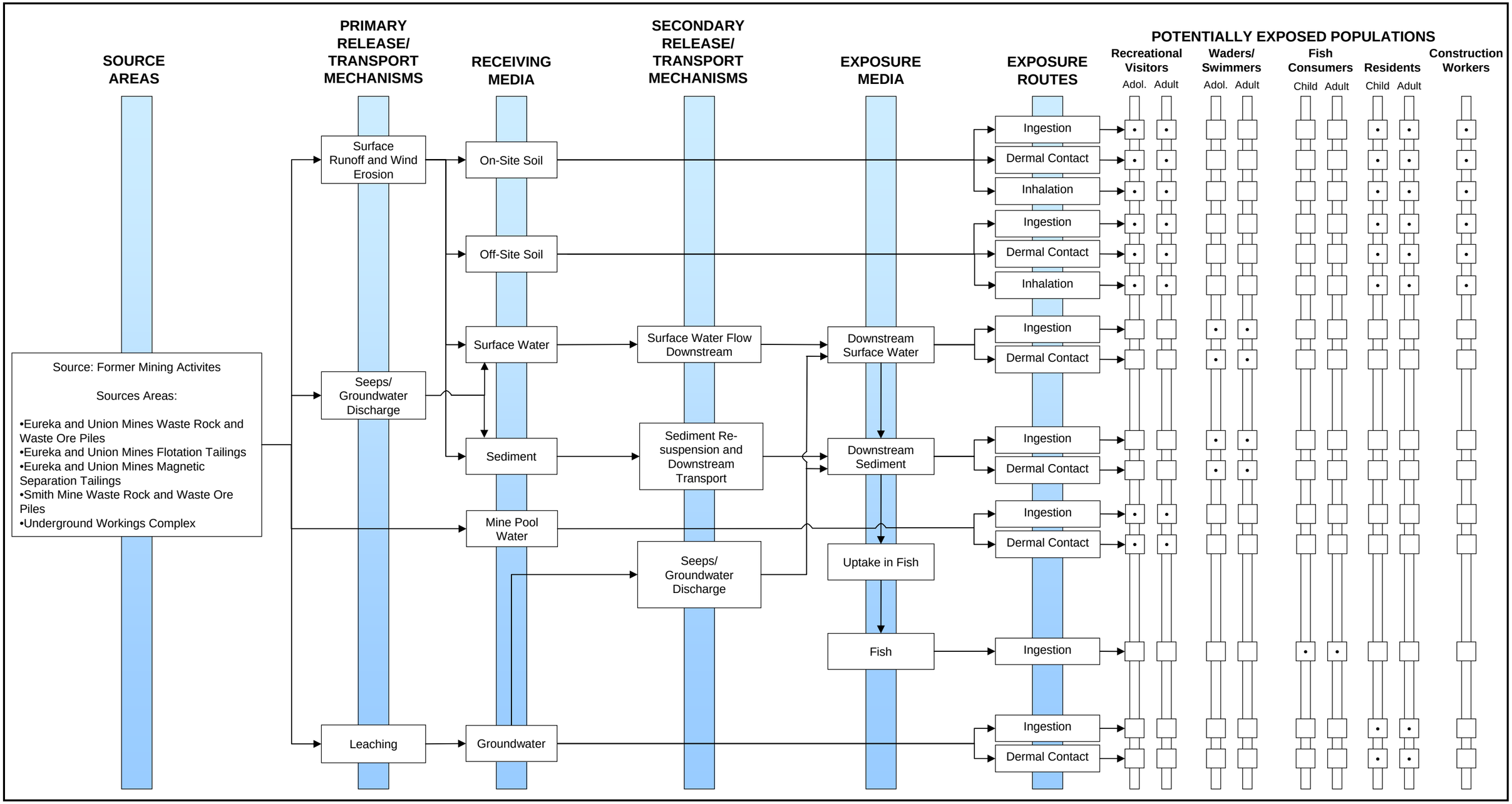
SCHEMATIC INTERPRETATION OF GROUNDWATER FLOW

PROJECT NO. 80025.00

FIGURE 4-2

J:\80000 EPA HAC2 Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025.00-PIKE-HILL-MINES.dwg

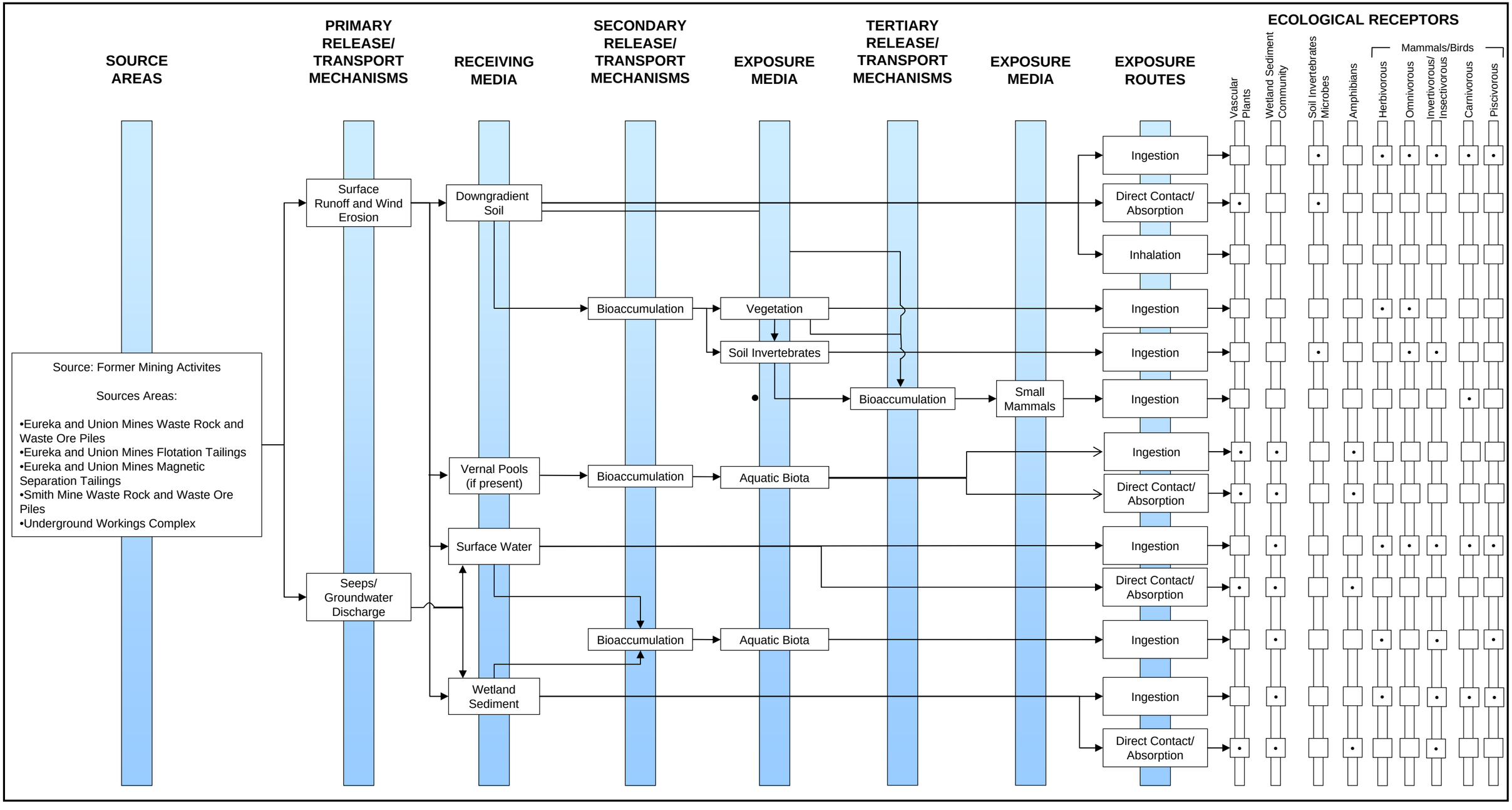
Figure 5-1
Human Health Exposure Pathway Analysis



• = Complete exposure pathway

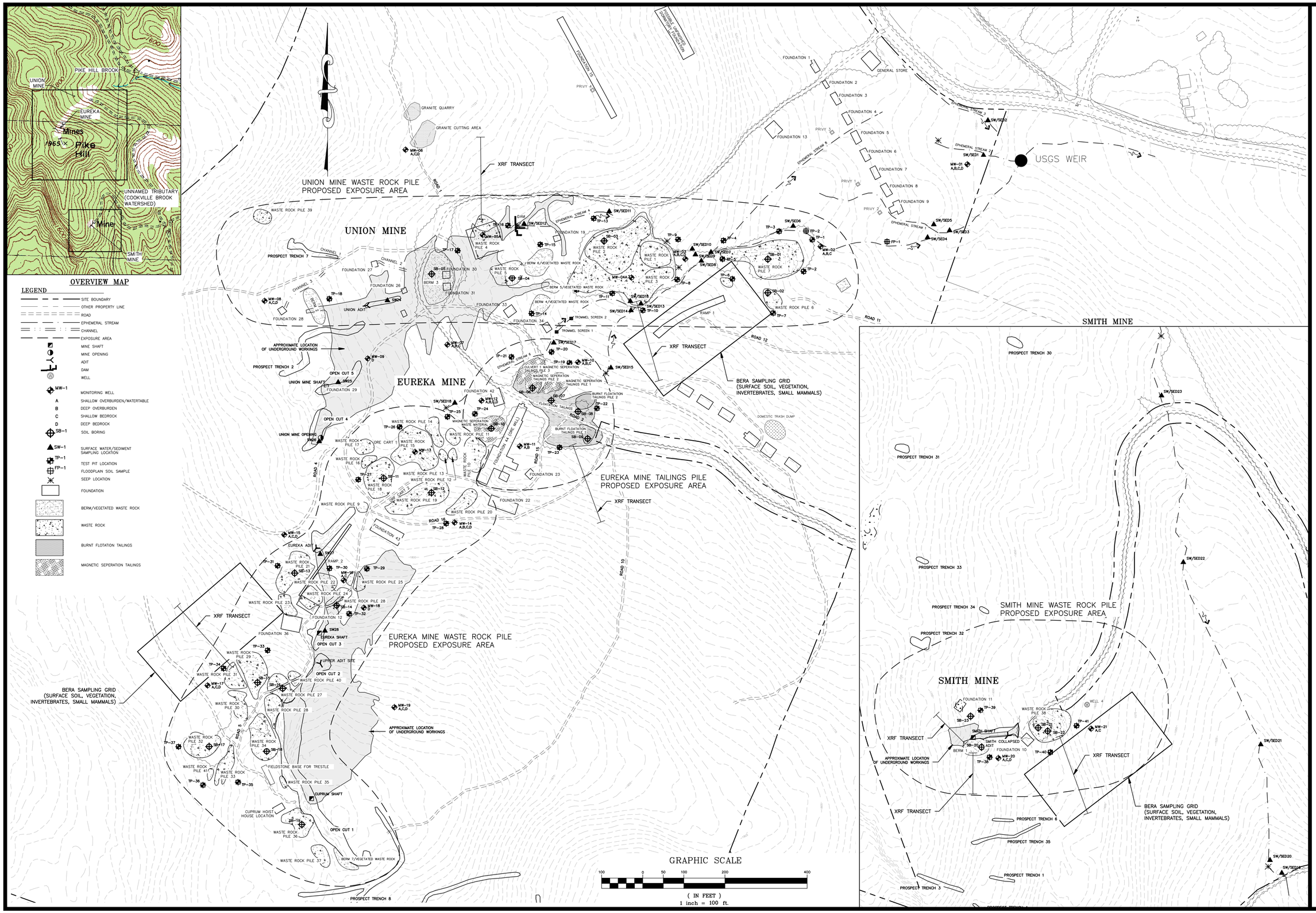
= Incomplete exposure pathway

Figure 5-2
Ecological Exposure Pathway Analysis



• = Complete exposure pathway.

= Incomplete or insignificant exposure pathway.



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PIKE HILL COPPER MINES
SUPERFUND SITE
CORINTH, VERMONT

MAY 2008

PROPOSED FIELD INVESTIGATION
SITE CHARACTERIZATION

PROJECT NO. 80025.00

FIGURE
8-1

J:\80000 EPA R1&2 Region 1\80000 Task Orders\80025 Pike Hill Copper Mine\CAD\dwg\80025.00-PHC-HILL-MINES.dwg