An Employee-Owned Company

Conceptual Site Model - Technical Memorandum

Ely Copper Mine Superfund Site
Vershire, Vermont

Remedial Investigation / Feasibility Study
EPA Task Order No. 0024-RI-CO-017L

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

FOR

U.S. Environmental Protection Agency
Region 1

BY

Nobis Engineering, Inc.

Nobis Project No. 80024

July 2009

U.S. Environmental Protection Agency
Region 1
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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 0024-RI-CO-017L (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 Ely Copper Mine Superfund Site (also referred to as the Site) located in Vershire, 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 at the Ely Copper Mine Superfund Site, Orange County, Vermont. Piatak, ET. al. (2004).
- Geochemical Characterization of Slags, Other Mine Waste, and Their Leachate from the Elizabeth and Ely Mines (Vermont), the Ducktown Mining District (Tennessee), and the Clayton Smelter Site (Idaho). Piatak, et. al. (2003).
- Aquatic Life Use Attainment Assessment of Streams Influenced by the Ely Mine Site – Vermont, Ompompanoosuc River, Schoolhouse Brook and Schoolhouse Brook Tributary 3. VTDEC (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).
- Final Historic/Archaeological Mapping and Testing, Ely Mine Site. Public Archaeology Laboratory (PAL, 2005).
- 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).

- Spring Runoff Characterization, Ely Mine, Vershire, Vermont, Spring 2002. Holmes, et. al. (2002).

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

- Draft Field Sampling Plan, Ely Mine. URS (2004).

- Habitat Characterization Report, Ely Mine, Vershire, Vermont. URS (2005).

- Data Transmittal - Remedial Investigation Data, Ely Mine, Vershire, Vermont. URS (2008).

- 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 Site 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 Site is located approximately 4 miles southeast of the village of Vershire Center, and approximately five miles northwest of the village of West Fairlee in Vershire, Orange County, Vermont. The Site encompasses approximately 350 acres along the south slope of Dwight Hill, to the north of Schoolhouse Brook and South Vershire Road (Figure 2-1). The mine area includes features such as intact and collapsed adits, shafts, reservoirs, over 3,000 linear feet of underground workings (largely flooded) and remnant foundations of former mine operation buildings. Waste areas are sparsely vegetated and include former ore roast beds, waste rock and tailings piles, a former smelter area, and a slag pile (Piatak, et. al., 2004; URS, 2004; PAL, 2005). No buildings exist on the Site. The locations of the former Main Shaft Hoist, the Westinghouse Hoist House, smelter buildings, a World War I-era ore flotation separation plant and other structures associated with historic mining operations have been documented at the Site (PAL, 2005).

The Site landscape is a combination of barren open areas and patches of birch and evergreen trees. The south slope of Dwight Hill, which contains most of the waste rock associated with the mines, lies within the watershed of a small stream, Ely Brook, which flows south to join Schoolhouse Brook on the south side of South Vershire Road. Schoolhouse Brook borders the southern margin of the Site and flows eastward approximately 1.75 miles to its confluence with the east branch of the Ompompanoosuc River. Schoolhouse Brook and the E. Branch of the Ompompanoosuc River are used for recreational purposes and contain fisheries.

2.1.1 Topography

Site topography is dominated by the peak and steep south slope of Dwight Hill extending from an elevation of approximately 1,600 feet above mean sea level down to Schoolhouse Brook at an elevation of approximately 940, some 660 feet of relief. The main shaft and several adits leading to the underground workings are located along the steep, upper portion of this slope at the head of the valley. Most of the mine wastes lie within the more gently sloping, lower portions of this valley. The crest of Dwight Hill occurs along a northwest trending ridge which forms the northern boundary of the Ely Brook watershed. Underground workings extend approximately 3,000 feet to the northeast of the mine openings beneath and beyond the top of the ridge. North-south trending ridges to the west and east of the mine areas define two smaller upland valleys that merge into an open U-shaped valley facing south-southwest which define the Ely Brook watershed. The headwaters of Ely Brook are located in the western tributary valley, northwest of the mine areas. A tributary to Ely Brook drains the eastern tributary valley which contains a former reservoir and a series of beaver ponds located east of the Site. The northeast slope of Dwight Hill is moderately steep with an elevation drop of approximately 800 feet down to Route 113 to the east.

2.1.2 Population and Land Use

The Site is located in a Town of Vershire, Orange County, Vermont with a population of approximately 630 people (Town of Vershire website, 2000 Census). The Site is located in a rural, sparsely populated area of the town accessed by Beanville and South Vershire Roads, approximately 1.5 miles northwest of the Village of West Fairlee. It is estimated that less than 100 people live within a one mile radius of the Site. The nearest residents are located approximately ¼ mile east of the Site along Beanville 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 by Ely Mine Forest, Inc., and Green Crow Corporation. The land is undeveloped, and generally undisturbed since cessation of mining activities. The current land use of the Site is reportedly limited to management for commercial timber harvest. There are no residents or buildings on the Site. The Site is reportedly also frequented for limited recreational use by off-road vehicles, hunters, 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. It is 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 Pike Hill Copper Mine

The Pike Hill mines include three separate mine workings referred to as the Union, Eureka (a.k.a. Corinth), and Smith (a.k.a. Bicknell) mines located on Pike Hill in the Town of Corinth, Vermont discovered in 1845, after the Elizabeth and Ely deposits (Figure 2-3). The mines 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 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 Pike Hill. 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. 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, 2005; 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 or early 1950s portions of the ore dumps were trucked to the Elizabeth mine mill for processing. Remaining site buildings were destroyed by fire in 1960 (URS, 2007a). The property is currently privately owned and today encompasses approximately 216 acres containing remnant waste rock and tailings piles, open cuts in bedrock, flooded underground workings with limited mine openings. The Pike Hill Copper Mine was placed on the United

States (U.S.) Environmental Protection Agency (EPA) National Priorities List (NPL) in July 2004 due to the impacts of acid rock drainage on Schoolhouse Brook. Pike Hill Copper Mine is also eligible for the National Register of Historic Places due to its historical aspects (PAL, 2007).

2.1.3.3 Ely Copper Mine

The Ely 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 ore body was discovered in 1813 and explored in the 1830s. Significant mine activities began in 1853 and lasted until 1905. Mineralogy of the ore body was similar to that of the Elizabeth and Pike Hill Mines with ore consisting primarily of pyrrhotite, chalcopyrite and minor pyrite and sphalerite. Prior to 1867, ore was shipped to smelters along the east coast for processing. On-site smelting operations began in 1867 which were expanded over time to included a large 24-furnace smelter plant which was among the top ten copper producing operations for a period of its history, with an average annual production of 1 million pounds of ingot copper and 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). During World War I, a flotation separation mill was constructed and operated for a short period. During World War II, some waste ore material was scavenged for milling at the Elizabeth Mine.

The Ely Site encompasses approximately 350 acres, including areas containing an estimated 100,000 tons of 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 Site. 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. The Ely Mine site was added to the Superfund listing in September 2001 due to environmental impacts from acid rock drainage from the Site on Ely Brook and Schoolhouse Brook. The Site 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 Site (URS, 2004).

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. Site hydrogeology is based on a review of recent USGS reports including shallow soil and surface water characterization data; recent Site data collected by URS; a PAL report documenting surface features of the Site including details of Site topography and drainage; topographic map information of the Site vicinity; and historical information on the underground workings (Piatak et. al., 2006 and 2007; URS, 2008; PAL, 2007; White and Eric, 1944).

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 Ompompanoosuc 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-Buckland association described as being typical of soils formed in glacial till on upland terrain ranging from stony silty loam to very stony loam (PAL, 2005). In addition to natural soils, the Site includes large areas of manmade soil and disturbed soils as a result of historic mining activities including waste rock, slag, roasted ore, and tailings piles. The distribution of these piles are delineated along with historical mining features in Figure 2-3 (PAL, 2005). 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.

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, 2004; URS, 2008). Based on 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 in the vicinity of Ely Brook. This area is also overlain in part by waste rock and tailings piles which are estimated in the range of 5 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 crushing and 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 where oxidized to black where anoxic. The ore roast bed material is red as a result of the hematite rich composition of the oxidized ore. These beds are estimated to be 5-10 feet thick. The deposit of dark gray, glassy slag along S. Vershire Road is approximately 10 feet thick.

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 Dwight Hill and is composed primarily of siliciclastic metasedimentary rock (pelite and graywacke) representing a turbidite protolith, with 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 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. The ore body at the Ely Mine had an elongate shape and extended over 3,000 feet inclined at approximately 25 degrees formed along the crest of a fold in the bedrock layering along a trend of approximately N40E (Slack and others, 2001). The mineralogy of the ore at Ely Mine was similar to that at the Elizabeth and Pike Hill Mines and the ore is dominated by pyrrhotite and chalcopyrite, with minor sphalerite and pyrite. The dominant minerals in the host rock are quartz, feldspar, and muscovite.

2.2.3 Surficial Hydrology

The Site occurs along the central and eastern flank of a broad U-shaped valley. Ely Brook is the primary stream draining the valley defined by Dwight Hill to the north and two branching ridges west and east of the mine areas. The headwaters of Ely Brook lie to the northwest of the mine areas, while the headwaters of a tributary to Ely Brook located east of the mine areas drains through a series of beaver ponds and ultimately joins Ely Brook midway down the valley. Shallow groundwater and surface water flow at the Site mimics Site topography which directs flow toward Ely Brook, and southward toward Schoolhouse Brook. Ely Brook flows south along the central part of the valley, along the western margin of the mine waste areas extending approximately 0.8 mile from the headwater to the confluence with Schoolhouse Brook. At least six seeps feed small tributaries that drain south and west from the waste areas and discharge westward into Ely Brook. Schoolhouse Brook flows southeast from the Site approximately 1.75 miles to its confluence with the East Branch of the Ompompanoosuc River (also referred to as the Ompompanoosuc River). An unnamed, intermittent tributary drains the north slope of Dwight Hill, flowing approximately 1 mile northeast to the Ompompanoosuc River. The East Branch of the Ompompanoosuc River eventually joins the West Branch approximately 7 miles downstream which ultimately flows into the Connecticut River. The Ompompanoosuc River and Schoolhouse Brook are used for recreational purposes and contain fisheries.

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 aperture interconnected 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. In general, bedrock groundwater underlying the Site on the south side of Dwight Hill is anticipated to flow southward toward Schoolhouse Brook. Bedrock groundwater North of Dwight Hill and groundwater associated with the deeper portions of the flooded mine is anticipated to flow eastward toward the Ompompanoosuc River.

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, and in some cases essential analytical data which may be incorporated into the Site RI/FS database after data validation review. 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.

The USGS completed studies of metals in stream sediment in the watersheds of the area surrounding the mine and reported anomalous metal concentrations (primarily copper, zinc, manganese, and gold) and their relationship to the known ore deposit (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 USACE in cooperation with the USGS and CRREL completed a study of spring runoff from the Site to characterize the geochemical diversity of water sources in the Ely Brook Watershed which included sampling from seeps from mine waste areas, Ely Brook and tributaries, Schoolhouse Brook and Ompompanoosuc Brook. This study documented highly acidic and highly metal laden runoff from the mine areas (Holmes et. al., 2002). A summary of data collected during this study is provided in Table 3-1. Corresponding sample locations are shown in Figures 3-1 and 3-2.

In 2004 and 2007, USGS completed a series of studies of mine wastes at the Site which included sampling and analysis of the various solid mine waste materials and sediment to characterize the materials, assess their acid-generating potential, and evaluate their potential for leaching metals, with a comparison to the Elizabeth Mine wastes (Piatak et. al., 2004a; 2007). A separate study of the geochemistry of the slag material deposited along S. Vershire Road was also completed by USGS in 2004 in comparison to slags at other mine sites in North America (Piatak et. al. 2004b). This study included an evaluation of secondary minerals formed on the slag and the potential leachability of metals from the slag. A summary 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. Table 3-2 lists data available by sample type and location collected. Sample locations listed in these tables are shown in Figure 3-3.

From 2005 through 2007, URS, in conjunction with the USACE and EPA, completed preliminary field sampling investigations in support of the RI/FS. Work included a habitat characterization study of the Site and surrounding area which describes the terrestrial habitats, potential wetland areas, and potential terrestrial receptors at the Site (URS, 2005). Information from this report will be used as a basis to determine additional sampling in support of the terrestrial Baseline Ecological Risk Assessment (BERA) at the Site. In addition, field sampling investigations were completed which included test pits and boring in waste areas, monitor well installation, and collection of surface water, sediment, surface and subsurface soil, and groundwater samples from the Site. In addition, one off-site residential groundwater sample was collected. Preliminary analytical results were provided to EPA in March 2008 and a complete report with interpretation of these results is anticipated by the end of 2008. A summary of investigations is provided in Table 3-3. Sample locations are shown in Figures 3-4 to 3-7. These data are anticipated to be validated and incorporated directly into the analytical database for the RI/FS. These data along with USGS and USACE data form the basis of recommendations for additional sampling to complete the RI/FS investigation outlined in Section 8.0.

In 2007, Vermont Department of Environmental Conservation completed an aquatic life use attainment assessment of Ely Brook, Schoolhouse Brook, and the Ompompanoosuc River in conjunction with ongoing USGS studies. The VTDEC assessment included evaluation of Fish and macroinvertebrate data which indicated impairment for portions of Schoolhouse Brook and Ely Brook likely related to runoff from the Ely Mine Site (VTDEC, 2007).

In 2006 and 2007, USGS, in conjunction with EPA, collected data to support ongoing work on the aquatic Baseline Environmental Risk Assessment (BERA) for the Site. The study included a detailed characterization of surface water and sediment quality, an evaluation of fish and macroinvertebrate communities, and an evaluation of the toxicity of surface water, sediment and pore water. A summary of samples collected and parameters analyzed is included in Table 3-4. Sample locations are shown in Figure 3-8. Preliminary results indicate significant toxicity of sediments from Ely Brook and Schoolhouse Brook, but not from the Ompompanoosuc River (USGS, Unpublished 2008). A report summarizing the results and conclusions of these aquatic BERA investigations is anticipated by the end of 2008.

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, tailings, roasted ore, and slag 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 a series of mine waste areas extending from North to South along the central part of the valley along the southern slope of Dwight Hill (Figure 4-1). In addition, mine openings along the upper portions of the valley lead to underground workings extending approximately 3,000 feet northeast of surface waste areas, extending beneath the northern slope of Dwight Hill. Remnant historical and archaeological mine features (e.g. former building and equipment foundations and stone walls) are present around mine openings and within the mine waste areas. 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 the upper waste rock piles at the Site. Ore roasting generated hematite-rich, oxidized soils in an area downslope of the waste rock piles. At the bottom of the valley, the former smelter area is underlain in part by smelter wastes and slag. The slag heap associated with the former smelter lies partly beneath S. Vershire Road and extends along the north bank of Schoolhouse Brook.

Previous work by USGS, VTANR, and others have characterized significant impacts to Ely Brook and Schoolhouse Brook and biological impairments related to acid rock drainage emanating from the mining areas. 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 materials are similar in character to waste materials at the Elizabeth and Pike Hill Mines having been derived from ore deposits of very similar composition. Based on composite sample results from waste source areas at the Site, the waste materials appear to have similar acid-generating potential and typically contain copper concentrations above preliminary remediation goals (PRGs, residential). Some of the unoxidized flotation tailings at the Site tend to contain relatively higher concentrations of copper as a result of the higher concentration of sulfides in this material. In addition, these tailings may be more reactive than waste rock due to higher pyrrhotite concentrations.

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 at the Site have been defined based on the type of waste and their relative position with respect to the locations of former processing areas. These are consistent with waste source areas described in previous reports. The mine waste source areas and locations of the pertinent mine features and remnant historical features have been mapped in detail by PAL, as shown in Figure 2-3. The PAL map was used as the base to create the subsequent Study Area Plan (Figure 4-1) and Proposed Field Investigations figure (Figure 8-1).

4.1.1 Upper Waste Rock Piles

A series on overlapping waste rock piles are located along the steep upper portion of the south slope of Dwight Hill extending downslope from the Main Shaft down to the Burleigh Shaft. These waste rock piles are referred to as the Upper Waste Rock Piles and generally include a mixture of barren country rock from development of the mine openings and ore-bearing rock which has undergone varying degrees of crushing, cobbing and separation to remove the majority of the ore prior to transport downslope for more processing. As a result, material remaining in these piles would contain some small percentage of residual ore material, or what otherwise would be considered low-grade ore and barren rock. The material is generally poorly sorted and includes a broad range of particle sizes from sand and silt up to boulder-size material. The USGS divided the piles into six areas based on soil color variations, surface character, and topography and analyzed composite soil samples from each for comparison (see Figure 3-3; Piatak et. al., 2004a). Copper concentrations in the top foot of soil from the piles ranged from 1,240 ppm to 5,660 ppm and showed higher concentrations in the upper 2 inches than the underlying soil. Copper concentrations in soil from Areas 2 and 4 in Figure 3-3 were below the residential-PRG standards. The highest copper concentration was detected in Area 3. It is important to note that the PAL study includes a slightly different division and numbering sequence for the Upper Waste Rock Piles (PAL, 2005). An additional pile of waste rock is located immediately south of the Deep Adit location, upslope of the lowermost beaver pond and the former flotation mill. The composition of this pile has not yet been investigated. Due to its proximity to a mine opening, this pile will be included with the Upper Waste Rock Piles. 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. Several groundwater seeps emanate from within and around the waste rock piles in this area. Due to their proximity to mine openings, these materials may interact with mine drainage. Based on results from analysis of these seeps, these waste rock piles appear to have a significant impact on downgradient surface water quality (Holmes et. al. 2002; URS, 2008) downgradient of the Site.

4.1.2 Lower Waste Rock and Tailings Piles

An area of waste rock and tailings piles located downslope of and including the former flotation mill is identified as the Lower Waste Rock and Tailing Pile Area (Figure 4-1). This area is northwest of the Ore Roast Bed Area. The area is divided by the existing access road which extends north-south up the valley and branches to the east and west just south of the former mill location. The area extending south from the former mill and west of the access road is underlain by flotation tailings at least several feet thick (Piatak et. al., 2004a). The tailings were observed to be thinly layered with waste materials containing copper concentrations ranging from 1,510 ppm in a jarosite/muscovite rich layer up to 25,600 ppm in the deeper unoxidized pyrrhotite-rich layer. This material is distinctly more fine-grained (sand to silt-sized) than the waste rock pile material. A former ore wash house was reportedly located in this area just southwest of the existing access road intersection, which may have resulted in overlapping deposits of wastes with differing characteristics due to the different types of ore processing that occurred here. The area immediately east of the flotation tailings deposit and east of the access road contains a thin veneer of the remnants of a pile of washed ore that was transported to the Elizabeth Mine Site in 1949 for processing. Copper concentration in soil from this area range from 5,580 to 7,020 ppm (Piatak et. al., 2004a). An additional area of waste rock material is located south of the tributary to Ely Brook that drains the beaver ponds and extends west to Ely Brook. This area, like much of the rest of the Site waste areas, is largely devoid of vegetation.

The topography of this area is not that of a typical pile, but rather forms a uniform, gentle slope between the access road and Ely Brook. The southern limit of this waste area is demarked by a dense growth of evergreen trees which occupy an area of slightly higher elevation than the adjacent waste area. Soil copper concentrations up to 5,100 ppm were detected in this area (Piatak et al, 2004a). Due to the apparent compositional similarity and the spatial distribution along the central portion of the valley, the Lower Waste Rock Pile Area is proposed to be combined with the Ore Roast Bed Area (described below) into a single human health risk exposure area for risk characterization as discussed in Section 5.1.2 (Figure 4-1).

4.1.3 Ore Roast Bed Area

The Ore Roast Bed Area is located in an area approximately 180 feet wide and 900 feet long (north-south) east of the access road, immediately south of the Lower Waste Rock and Tailings Pile Area (Figure 4-1). The area is bounded on the west by a stone wall, and comprised of barren dark redbrown soil having copper concentration ranging from 1,630 to 2,040 ppm (Piatak et. al., 2004a). The area is generally flat lying and the eastern margin is marked by the adjacent forested hillside which slopes upward to the east. Waste material in this area includes remnant piles of partially roasted ore which remain after closure of the mine operation. The partially processed ore which was stockpiled in this area for roasting was typically layered with coarser material toward the bottom and finer material toward the top to enhance the roasting process, which lowered the sulfur content of the ore prior to transport to the smelter (PAL, 2005). Roasting oxidized the ore increasing the hematite (iron oxide) content of the material resulting in the dark reddish brown soil color (Piatak et. al., 2004a).

4.1.4 Smelter Area

The Smelter Area is located immediately north of S. Vershire Road and includes a flatlying area containing numerous foundations and footings of the former smelter building and apparatus, including some of the former smelter bases made of stone. The area is bounded on the north by a stone wall and extends west to the access road. The former smelter building extended southeast to a point beneath the paved portion of S. Vershire Road (PAL, 2005). Several small waste piles of oxidized ore, refractory brick and magnesite refractory material exist on the eastern portion of the area. A low berm of soil containing slag extends approximately 150 feet along the southern margin of the area, limiting access from S. Vershire Road. Surface soil in the area has copper concentrations up to 2,780 ppm (Piatak et. al., 2004a). Due to the historical significance of the remnant features of the Site, subsurface explorations are unlikely in this area. As a result, the vertical extent of potential waste source materials is not known. A portion of the south side of the Smelter Area is believed to be underlain by the slag deposit extending beneath and to the south side of S. Vershire Road (PAL, 2005).

4.1.5 Slag Waste Pile

The Slag Waste Pile is a narrow area between S. Vershire Road and Schoolhouse Brook extending from Ely Brook south approximately 750 feet to a retaining wall. The deposit is at least 10 feet thick as evidenced by the exposed portions of the pile along the brook. The slag has a glassy to metallic luster and is purplish brown to gray in color and commonly displays the hemispherical shape of the slag pots that were used to transport the material. The slag deposit is believed to extend to the north beneath S. Vershire Road likely up to the foundation of the former smelter building (PAL, 2005). It is uncertain whether the deposit extends into or beneath the streambed of Schoolhouse Brook. The slag material and secondary minerals associated with weathering of the slag are described in detail by Piatak et. al. (2003), including an evaluation of the potential leachability of the slag. A composite sample of the weathered surfical material in the slag pile contains copper concentrations up to 6,880 ppm (Piatak et. al., 2004a).

4.1.6 Smoke Flue

The Smoke Flue is a unique feature of the Site and consists of a linear alignment of two parallel stone walls connected by overlying slabs of stone to form a flue extending approximately 1500 feet from the former smelter building upslope to the northeast to the top of the ridge. The flue was reportedly used unsuccessfully to try and direct exhaust from the smelter operations away from the valley. An 80 foot high lead-lined, wooded stack once existed at the top of the flue, although no remnants of this have been found. Although there are no known significant quantities of waste material associated with the flue, soils in the vicinity of the flue may have been impacted by smelter exhausts. Samples of surficial soil collected along the interior and at the uppermost end of the flue had copper concentrations ranging from 12 to 150 ppm (Piatak et. al., 2004a; URS, 2008).

4.1.7 Underground Workings

The extent of the underground workings of the Ely Mine 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 in Figure 4-1 (PAL, 2005). The surface projections of the mine workings are estimated in Figure 4-1 based on a cross-section of the ore zone compiled by White and Eric (1944). There are approximately 12 shafts, adit, vents or other openings that have been identified on maps of the Site (PAL, 2005). Many of these may not be accessible, or collapsed, and some may have never intersected the mine. The Main Shaft of the mine is the uppermost opening located along the steep slope above the Upper Waste Rock Piles at an elevation of approximately 1,375 feet. From this point, the underground workings that followed the ore body extend approximately 3,000 feet northward and descend some 1,500 feet vertically along a trend of N40E at an inclination averaging about 25 degrees over the length of the mine. A surface projection of the underground workings is shown in Figure 4-1. The mine extends beneath the northeast slope of Dwight Hill such that the workings lie between 500 and 1,500 feet below the ground surface beyond the peak of the ridge. There are no known mine openings north of the Main Shaft. Based on observations from the 1943 survey by the U.S. Bureau of Mines, and anecdotal evidence provided by spelunkers visiting the mine, the flooded level of the mine is estimated at 1,275 feet (White and Eric, 1944; PAL, 2008). Several adits accessed the mine at points further downslope surrounded by the Upper Waste Rock Piles. These lower mine openings may be sources of mine drainage to the surface. Due to the limited access to the mine, samples of water have not been collected directly from the mine pool. It is uncertain whether water draining from seeps in the vicinity of the Upper Waste Rock Piles is impacted largely from mine drainage, the waste rock piles or both. Copper concentrations in groundwater from seeps in the vicinity of the mine openings range from 1,140 to 77,000 ppb (Holmes et. al. 2002).

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 pool 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, water erosion of surface waste materials 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 materials, 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 Ely Brook, Schoolhouse Brook, Ompompanoosuc 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, 2004). Recent work by URS, soon to be published, included borings and test pits through waste piles, overburden, and shallow bedrock which will provide important documentation of the character and thickness of these materials. Preliminary analytical results from these investigations were used to assess the need for additional investigations of Site soils. However, boring logs were not yet available to interpret details of the overburden stratigraphy. 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 portion of the valley along Ely Brook. This area is also overlain in part by waste rock and tailings piles which are estimated up to 5 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 crushing and 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 flotation separation technology 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 areas have been preliminarily identified by PAL during the Site survey of archaeological features, and investigations by URS, 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 Dwight Hill, is composed of the Gile Mountain Formation, a psammitic pelite 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 zone consists of pyrrhotite and chalcopyrite, with minor sphalerite and pyrite and strike approximately N40E with a dip of about 25 degrees to the east (Slack and others, 2001). The ore was found to occur in overlapping elongate lenses. The location of the ore zone was projected on a cross-section such that the top of the zone lies between 500 and 1500 ft below the ground surface on the north slope of Dwight Hill (White and Eric, 1944). 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 by USGS documented the orientation of cleavage in the bedrock at the Site which is largely subparallel 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 Site is located in a broad but well-defined, moderately sloping valley which forms the headwaters to Ely Brook. As a result, the contribution of flow to Ely Brook from waste areas 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 Ely Brook are located at an elevation above and west of the Upper Waste Rock Piles. Considering the steep topography in the upper elevations of the Site, it is anticipated that during significant rain/snow melt events, precipitation will move downslope as overland flow and channelize further downslope. A portion of this 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, a portion of the precipitation on the waste rock piles in the upper elevations are is likely to infiltrate downward readily into the natural overburden and shallow bedrock. Rapid fluctuations in the flow of Ely Brook were observed during significant Spring rain events with a range of flow up to 36 cfs prior to entering Schoolhouse Brook (Holmes et. al., 2002). 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, although some flood storage capacity exists in the beaver ponds along the tributary draining the eastern portion of the valley. The ephemeral nature of the seeps at the Site also suggests that the base flow observed year round in Ely Brook and its tributary valleys is derived largely from bedrock groundwater discharging upward through the overburden. The volume of mine pool discharge directly from mine openings to the surface appears to be minor but this discharge may be obscured by waste rock piles as some of the seeps associated with the Upper Waste Rock Piles may be fed by mine discharge.

Results from sediment and surface water samples collected to date from on-site seeps and tributary streams indicate that these waters are impacted by acidification and elevated concentrations of metals. It is presumed that these metals are derived from the previously described mine waste piles resulting in exceedances of regulatory criteria along Ely Brook and Schoolhouse Brook (Holmes et. al.,2002; Piatak et. al. 2004). Copper concentrations in surface water entering Ely Brook from the Site ranges up to 76,000 ppb. The range of pH measured in the seeps that feed tributaries to Ely Brook was between 2.0 and 3.5 standard units (Holmes et. al., 2002). Copper concentrations in surface water entering Schoolhouse Brook from the Site ranged up to 3,400 ppb with a pH below 4.5 during Spring runoff. The sediment in the lower reach of Ely Brook downgradient of the waste rock piles has a copper concentration of up to 3,300 ppm that is comparable to the waste rock (URS, 2008).

Based on documentation of Site conditions in studies by USGS (Piatak et. al., 2004) and Holmes et. al. (2002), 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 Ely Brook and Schoolhouse Brook. Schoolhouse Brook extends approximately 1.75 miles from the Site to the confluence with the Ompompanoosuc River. Copper concentrations in surface water from Schoolhouse Brook immediately downstream of the Ely Brook confluence range up to 300 ppb, exceeding a chronic toxicity standard (Holmes et. al. 2002).

Based on existing data and unpublished results from recent USGS and EPA studies in progress, impacts to surface water quality and potential biological impairment from the Site beyond the confluence with the Ompompanoosuc River are likely within regulatory criteria, although results from the Spring runoff study (Holmes et. al., 2002) indicated elevated copper concentrations (up to 55 ppb at the confluence) extending up to 6.25 miles downstream (up to 24 ppb) of the Site.

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 deposits, and the character and thickness of the natural overburden soils at the Site is not known. Due to the moderate 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. Work in progress will provide a considerable amount of documentation to support the RI/FS Conceptual Site Model (URS, 2008). Preliminary evaluation of data from monitoring wells at the Site indicate that impacts from surface sources may be limited to shallow overburden groundwater. Copper concentrations detected in shallow overburden groundwater range up to 15,300 ppb, while in the shallow bedrock, concentrations up to 12 ppb have been detected.

Based on Site surface water characteristics, topography and 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 Dwight 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 the overburden and into the bedrock. However, during large rain and spring snow melt events, significant volumes of overland flow will likely be directed to the lower portions of the valley, due to the steep topography, thin overburden and limited infiltration capacity of the bedrock in these areas as evidenced by the flashy nature of Ely Brook (Holmes et. al., 2002). 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. Based on observations that the mine pool elevation may be at a stable level, there is likely some flow from mine openings at or very near the surface which is regulating the elevation of the top of the mine pool, 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 at shallow depths in the vicinity of the mine may migrate toward the mine pool during periods of significant recharge. If 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, which may be more likely with respect to the hydraulic head in deeper portions of the bedrock. Figure 4-2 illustrates the case where the hydrostatic head levels in the shallow bedrock in the vicinity of the mine are depressed due to the unrestricted flow from the mine opening. Based on the reported water level observed in the mine, flow directly from the uppermost part of the mine pool may be influencing shallow groundwater in these areas as evidenced by the locations of numerous seeps near mine openings (Holmes et. al., 2002; White and Eric, 1944; PAL, 2005; URS, 2008).

In general, on the south side of Dwight Hill, shallow groundwater will tend to flow south and southwest toward Ely Brook, mimicking the flow directions outlined by surface seeps and tributary streams leading to Ely Brook. Deep bedrock groundwater may be directed in a more southerly or southeasterly direction as Schoolhouse Brook is approached in response to regional scale discharge areas. The lower portion of the valley, below the elevation of the Upper Waste Rock Piles, where slope gradients are somewhat gentler and multiple groundwater seeps have been observed, defines an area of local discharge extending downslope to Schoolhouse Brook. 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 (Holmes et. al., 2002). Infiltration of snow melt and rainfall during the spring and periods of intense rainfall may also result in local mounding of groundwater in areas of thicker waste/fill material such as the Upper Waste Rock Piles and the Ore Roast Beds 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.

On the north side of Dwight Hill, the shallow overburden and groundwater is likely to be unimpacted by the mine due to the absence of surface mine waste. Shallow groundwater is directed toward two unnamed intermittent streams which discharge directly to the Ompompanoosuc River to the northeast. As a result, flow in these streams is also likely to be unimpacted by the mine. Deep bedrock groundwater is likely directed to the northeast in this area toward the Ompompanoosuc River. Importantly, the deep, flooded Ely mine shaft underlies this area and deep bedrock groundwater is anticipated to flow through the shaft toward the northeast and ultimately discharge to the Ompompanoosuc River, since there is not any significant outflow from the mine.

Based on limited Site information, and the preliminary interpretation of groundwater conditions previously described, waste material piles appear to have a limited impact on shallow groundwater and more directly affect overland flow in the Ely Brook Valley. 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 on 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. 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. Groundwater use in the vicinity of the Site is very limited with a very 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.

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 of 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. 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.

- 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 Exposure Pathway Analysis (see Section 5.1.1 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. See Table 5-2.

- 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. See Table 5-3.

- 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 collected by EPA Region 1 and USGS, subsistence level consumption of fish obtained from Ely Brook is not likely. It may be possible that Schoolhouse Brook and the Ompompanoosuc River can support subsistence level consumption. See Table 5-4.

- 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. See Table 5-5.

- 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. See Table 5-6.

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 Ely 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 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

Section 7 of the PAL report (PAL, 2005) was reviewed to determine a suitable manner in which to identify the soil EAs. A total of three soil EAs are proposed (see list below). Figure 4-1 provides the extent of the proposed EAs.

- Upper mine waste piles and mill site.
- Lower mine waste piles and roast beds.
- Smelter site, smoke flue and slag piles.

As presented in 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 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 Ely Mine. They include:

- Ely Brook and tributaries.
- Schoolhouse Brook - downstream to the Ompompanoosuc River.
- Ompompanoosuc 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.

Previous studies by EPA Region 1 and USGS have determined that Schoolhouse Brook and the Ompompanoosuc River are the only surface water and sediment exposure area that support edible fish communities. In areas where only a limited number of trout were collected, longnose and black dace may be used as a proxy for trout. The available dace data will be compared to the fish ingestion PRGs that will be calculated using the screening tool on the Risk Assessment Information Systems (RAIS) website. The default ingestion rate used in the screening calculation is 54 g/day. If the screening levels are exceeded, site-specific fish ingestion PRGs will be calculated using a more realistic fish consumption rate. 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 Ely 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). 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 are 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 (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. 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. 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 and the aquatic BERA that focuses on impacts to Ely and Schoolhouse Brooks, and the Ompompanoosuc River (EPA, 2007c). The aquatic BERA, which will be produced by EPA , 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. 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 of the BERA.

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 receptors may be exposed to chemical contamination at the Site:

- Vascular plants - direct contact with soil.
- 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).

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

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.

5.2.2 BERA Exposure Areas

The following contiguous areas are proposed as potential exposure areas for the terrestrial BERA; 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 piles, roast beds, slag piles etc. (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, the ecological exposure area will be divided into the same three units as the HHRA (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 source areas; sampling in these areas will attempt to look at potential effects along a contaminant gradient when present.

- Surface waters (i.e. Ely Brook, Schoolhouse Brook, and the Ompompanoosuc 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.

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 other terrestrial communities will be accomplished using a combination of Site observations, benchmark comparisons and quantitative exposure and effects modeling. Based on previous discussions with Region 1 EPA, it was agreed that soil-to-biota accumulation factors developed as part of the Pike Hill Mine Site BERA will be used to estimate tissue concentrations in dietary items used for the Ely Mine terrestrial exposure models. This approach eliminates the need to collect tissue chemistry data for plants, soil invertebrates and small mammals.

For individual receptor species (e.g. American robin, short-tailed shrew), 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.

Exposure models used in this BERA take the following general form:

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

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 i^{th} prey item (mg/kg WW)
P_i	=	Proportion of the i^{th} 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:

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

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 i^{th} food item (unitless)
- GE_i = Gross energy of the i^{th} food item (kcal/g)
- P_i = Proportion of diet comprised of the i^{th} 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 VTANR, 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 quality assurance project plan (QAPP) will be prepared consisting of a field sampling plan (FSP) and a sampling and analysis plan (SAP) 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 QAPP 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 other statistical requirements are not met.

Preliminary background soil samples were collected by URS during remedial investigation activities completed in 2007 (URS, 2008). Sixteen surface soil samples were collected from 5 locations and analyzed for metals from an area to the northeast of Dwight Hill as summarized in Table 3-3 and shown in Figure 3-7. Results from these initial findings will be used to determine which analytes and media are required to supplement this background concentration evaluation as well as to complete 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 presents 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 (waste piles, surface water, and sediment). 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, technology process options and entire technology types may be eliminated from further 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 technology process options are retained for incorporation into remedial alternatives. Although the various technology 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 waste, 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 be 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 treatment pilot 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 an 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 the 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.

In addition, an aerial survey is recommended to produce a detailed topographic base encompassing the entire Site area as a basis for accurate planning and documentation of field investigations and subsequent remedial design work. The current survey data extends upslope only as far as the upper waste piles. The additional survey should include the area overlying the underground workings north of Dwight Hill and the Smoke Flue northeast of the Smelter Area.

8.1.1 Nature and Extent of Contamination in Site Media

Results from previous USGS, EPA, and URS investigations have documented the contaminant characteristics of the on-site waste rock piles, tailings, seep, surface water, sediment, and groundwater (Piatak and others, 2004a and b; URS, 2008). 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. These proposed investigations are designed to supplement existing and ongoing/unpublished work being conducted by the EPA, URS, and USGS and to address existing data gaps. 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 in Figure 8-1. It is noted that 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.

8.1.1.1 Waste Source Areas

The locations and general characteristics of waste rock piles, tailings, ore roast beds, and slag materials throughout the Site have been preliminarily defined by previous workers (PAL, 2005; Piatak and others, 2004a and b; URS, 2008). A limited amount of additional work is needed to better define the vertical and lateral extent of waste piles, the vertical and lateral extent of mine wastes in areas away from piles, and the chemical and physical characteristics of these waste materials. This information will be important in assessing the potential contaminant contribution and volume of waste materials within each area. 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 in 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 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 and monitor well locations are proposed in waste areas to supplement existing data in each area allowing for representative analytical sampling of source materials.

Test pits are proposed along the margins of waste areas 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 soil samples will be employed as necessary to provide verification of the lateral extent of waste areas.

8.1.1.2 Soil

A limited number of surficial soil sample analyses are proposed in peripheral areas of the Site to evaluate metal concentrations in 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. This will allow for efficient assessment of the concentration of metals in surface soil within a few hundred feet of waste piles along 17 transects divided between the various waste source areas of the Site as shown in Figure 8-1. Samples of surficial soil will be analyzed at approximately 25 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 of transition zone soil samples to be used for the BERA described in Section 5.2.2. For correlation of XRF analysis with off-site laboratory results, 5% of the grid samples will be split for off-site analyses as indicated in Table 8-1.

Floodplain soil samples will be collected for off-site laboratory analysis at approximately 3 select locations along the lower reach of Ely Brook to assess the potential redistribution of waste rock/tailings material downgradient of waste areas as overbank deposits. These data will also be used to support terrestrial ecological risk assessment of riparian areas. Additional floodplain soil samples along Schoolhouse Brook will be considered subsequent to field inspection of the stream.

8.1.1.3 Sediment and Surface Water

Existing data from recent studies provide 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 in Figure 8-1 and listed in Table 8-1. These locations supplement existing data and will provide a basis for correlation with existing data. Sediment sample locations will include an attempt to assess the vertical thickness of impacted sediment in order to determine potential sediment volumes that would be considered as waste source material during the FS. Several sediment locations have been proposed for this purpose along the lower reaches of Ely Brook and along Schoolhouse Brook adjacent to waste source areas. Additional off-site sediment sample locations along Schoolhouse Brook will be identified as warranted in the field based on stream gradient, sediment size and thickness along the streambed and pending results of USGS/EPA studies. Sediment samples will also be collected from the small series of lower beaver ponds on the eastern portion of the Site to assess metal concentrations in accumulated sediment in these ponds.

Surface water samples will be collected at and downstream of a limited number of seeps that feed the on-site tributaries of Ely Brook to supplement existing data (URS, 2008). These data will be used for correlation with groundwater hydrogeologic data, lithologic/stratigraphic information, and soil data to assess the comparative potential impact from upgradient source areas. At the present time, it is assumed that existing surface water data is sufficient to characterize the remainder of the Ely Brook tributaries, Ely Brook, Schoolhouse Brook, and the Ompompanoosuc River. These data may also be used to support HHRA and BERAs, where appropriate. Surface water sampling parameters will include the full target analyte list (TAL) of metals, chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide, total suspended solids (TSS), and total dissolved solids (TDS) for all locations.

8.1.1.4 Groundwater

Groundwater samples are proposed over a network of existing and proposed 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 waste area, 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.

One deep bedrock well is proposed to sample groundwater from within the Ely Mine pool to assess whether this water is a potential source of contamination to existing and future drinking water sources. A well cluster located downgradient of the Lower Waste Piles 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.

Three rounds of samples are proposed for new wells to be collected 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. Existing wells have been sampled twice to date in many cases and will require only one additional sampling event. 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.

8.1.2 Surface Water Hydrology

Surface water hydrology at the Site has been preliminarily characterized by Holmes and others (2002) and the USGS (unpublished) at the main stem of Ely Brook that drains the Site, beginning at the weir immediately above S. Vershire Road. 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. The most efficient methods used to estimate flow rates of small flows will be determined after inspection of the individual locations but will likely utilize a simple temporary weir. The relationship between the surface mine pool and seeps immediately downgradient in the Upper Waste Pile Area 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 of the mine pool.

8.1.3 Overburden and Bedrock Hydrogeology

Shallow groundwater conditions at the Site have been investigated by URS and formal interpretation of these data are pending (URS, 2008). As such, the relationship between groundwater and surface water at the Site has not been fully documented. Preliminary results indicate that impact to shallow bedrock groundwater from overlying waste source areas is limited. Additional monitor wells have been proposed to supplement existing data 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 pool on deeper groundwater needs to be assessed to understand the potential impact to future drinking water sources in the area.

Proposed monitor well locations are shown in 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 proposed where subsurface soil data is needed and where saturated conditions within the waste piles may be ephemeral. Shallow and deep overburden well installations depend on 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. 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. Some bedrock cores may be recovered 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.

A surface water/sediment metal concentration anomaly was previously identified by USGS and EPA along the upper reach of Ely Brook in the vicinity of the first tributary confluence (unpublished data). Recent results from samples collected by URS (2008) do not elucidate this anomaly. It is proposed that a series of 7 pore water samples be collected upstream and downstream of this confluence as shown in Figure 8-1, to assess whether the anomaly might be related to contaminated discharge from groundwater localized in this area. Based on these results, additional sediment sampling and/or well installation might be proposed to assess the origin of this anomaly.

8.1.3.1 Underground Workings

One bedrock well is proposed to penetrate the Ely Mine pool at a location above the presumed hydrostatic head elevation of the pool to avoid installing a flowing well (MW-24D; Figure 8-2). This location is based on the structural data of the underground working and the observed mine pool elevation reported by the U.S. Bureau of Mines (White and Eric, 1944). This well is positioned to intercept the mine pool at a location such that the mine is completely water-filled to avoid interaction with air in the mine. One borehole/well cluster including a deep bedrock well is located downgradient of the Lower Waste Piles along the southern portion of the Site. Additional bedrock wells are proposed in the area immediately surrounding the mine pool northeast of Dwight Hill to assess potential impact of the mine pool on nearby deep bedrock groundwater. One deep bedrock well is proposed proximal to the Ompompanoosuc River as a downgradient monitoring point at the Site boundary to assess potential off-site impact from the underground workings. 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 and off-site bedrock 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

The data collected by URS (URS, 2008) and aquatic-specific data collected by EPA and USGS (13 March 2008 presentation), in conjunction with site characterization and BERA data proposed in this Section 8, provides adequate data for the HHRA. At this time, the collection of additional data is not considered necessary for the HHRA.

8.2.2 Terrestrial 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 BERA 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 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 for characterization purposes are adequate for the BERA.

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 collection of surface soil samples (0-0.5 ft) that will be analyzed using XRF technology. Several XRF surface soil sampling transects will be placed throughout the study are to determine the extent of contamination (see Figure 8-1), proposed transect locations were placed where habitat conditions appear suitable for proposed ecological receptors and where existing data is either sparse or where high copper concentrations indicate that the extent of contamination may not have been identified. It is assumed that 5-10 samples will be required per transect and that the sample spacing will be approximately one sample every 25 feet. The result of the XRF sampling will help determine the number and location of future surface soil confirmation samples. At this time, it is assumed that 20-25 confirmation samples will be required to support the terrestrial BERA. The tentative locations of the XRF transects are provided in Figure 8-1. Laboratory parameters for confirmation samples are presented in Table 8-2.

The second phase of the field effort will include the collection of small mammal and soil invertebrate samples for whole body analysis to provide real data for inclusion in the trophic models that will be used in the BERA. Approximately 5-10 individuals for each biota will be collected per exposure area and background area (only composite to meet mass requirements) at locations selected based on their habitat setting with respect to identified mine waste, and visual observations (see Figure 8-1 for conceptual station locations). Laboratory parameters will be evaluated for TAL metals, percent lipids, and percent moisture as presented in Table 8-2. The need for this type of data is to help reduce uncertainty and provide more realistic exposure information as was illustrated in the aquatic BERA where modeled risks were driven by the use of BSAFs for aquatic invertebrates. There was no intention to develop soil accumulation factors (for small mammals or soil invertebrates) for the Site, but given the extensive surface soil data that exists and is proposed, it may be possible to develop these values, although soil accumulation factors tend to be highly variable (i.e., highly uncertain) and therefore you can save money and time collecting tissue data to start with.

8.2.2.1 Vernal Pool Data Needs (if present)

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).

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 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 chosen based 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.

- **Geotechnical Characteristics –** Should consolidation of mine wastes and/or sediments be a remedial alternative for consideration during the FS stage, then several key geotechnical characteristics would be valuable to gather during the RI. These characteristics would be:

  - Soils classification of materials through the mine wastes and sediments. This information would be collected from the RI sample locations included for other purposes. These samples should be collected at a minimum of 3 locations per source area at the Site.

- Soil density and void ratio. A minimum of one sample for each soil strata per source area.
- Grain size analysis. A total of 20-30 tests for all source areas combined.
- Soil compaction tests (Proctor test). A minimum of one sample for each soil strata per source area.
- Direct shear test for soil stability. A minimum of 2-3 for each soil strata per source area.
- Volume ratio of boulders versus sand-type soils within the mine waste per source area.

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, steep terrain, and limited areas for staging, careful coordination will be needed to ensure the smooth and safe implementation of the various phases of Site activities. The steep terrain and safety concerns regarding the stability of waste piles and underground workings 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;
- Test pits and on-site field XRF surveys of surface soils and test pits;
- Soil borings, monitor well installation, and well development;
- Groundwater, residential well, surface water, and sediment sampling, floodplain soil sampling, terrestrial risk surface soil sampling, hydraulic testing of wells; and
- Subsequent rounds of groundwater, residential well, and surface water sampling.

Some bedrock well installation work may require special coordination to collect 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.

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 Samples Collected by USACE During Spring Runoff in 2002
Ely Copper Mine Superfund Site
Vershire, Vermont

2002 Station ID	Loc Type	Sampling	Location	Aqueous Parameters	Reference
EB-1	Stream	1-3 grab samples were collected per location during a 2 week spring runoff and rain event period.	Ely Brook main stem at most upstream intersection with access road.	pH, temp, specific conductance, air temp, rainfall. Transducer at Ely Brook weir. Cations (filtered/unfiltered metals) by ICP-MS and AES, anions by ion chromatography, alkalinity, DO, hydrogen, sulfur isotope (results not reported). Total and ferrous iron, Dissolved and total acid soluble cations, anions and alkalinity, DOC, pH, temperature, specific conductance, DO, ORP, dissolved ferrous iron, dissolved total iron. Parameters collected every 20 min,sampled 1/hr for 1 day at locations EB-6, SB-2, and OR-2. Continuous monitoring of parameters at EB weir.	USGS-2006, 2007
EB-2	Tributary		Ely Brook tributary at lowest beaver pond outfall above access road.		
EB-2a	Tributary		Ely Brook tributary at beaver pond outflow above tributary draining ES-8 and above EB-2 adjacent to open field.		
EB-3	Tributary		Ely Brook tributary, 20M downstream of access road culvert/crossing in lower waste pile area.		
EB-4	Tributary		Ely Brook tributary draining upper waste pile area, upstream of confluence with EB-3 tributary.		
EB-5	Stream		Ely Brook main stem, downstream of confluence of EB-3 trib at S. end of Lower waste pile area below small falls.		
EB-6	Stream		Mouth of Ely Brook, below road, just upstream of confluence with SHB.		
EB-7	Tributary		Ely Brook ephemeral tributary draining from roast beds.		
SB-1	Stream		Schoolhouse Brook (SHB) 10 m upstream of confluence with Ely Brook.		
SB-2	Stream		SHB 325 m downstream of confluence with Ely Brook, downstream of slag area, upstream of tributary to SHB.		
SB-3	Stream		SHB at Rte 113 crossing adjacent to school.		
OR-1	Stream		Ompompanoosuc River (Omp R) upstream of SHB confluence at West Fairlee Hill Rd Bridge.		
OR-2	Stream		Omp R. downstream of SHB confluence at Cross Rd/West Fairlee Rd. Bridge.		
OR-3	Stream		Omp. R. downstream of OR-2 at Sawnee Bean Rd. Bridge.		
ES-1	Seep		Seep near NW margin of Upper Waste Piles		
ES-2	Seep		Seep at bottom of Upper Waste Piles		
ES-3	Seep		Seep near middle of Upper Waste Piles		
ES-4	Seep		Seep east of ES-3 in middle of Upper Waste Piles		
ES-5	Seep		Seep east of ES-3 in middle of Upper Waste Piles, immediately east of ES-4.		
ES-6	Seep		Seep at eastern margin of Upper Waste Piles.		
ES-7	Seep		Seep southeast of ES-6 and Upper Waste Piles and upgradient of beaver ponds.		
ES-8	Seep		Seep draining collapsed adit area, south of Upper Waste Piles draining to beaver ponds.		
ES-9	Seep		Seep draining tailings area to EB tributary south of access road.		
ES-10	Seep		Seep in Lower Waste Pile Area draining to EB tributary from beaver ponds.		
ES-11	Seep		Seep draining area immediately north of roast beds, east of access road.		
ES-12	Seep		Seep draining collapse vent area SW of Upper Waste Piles.		

Table 3-2
Summary of Waste Area Soil Samples Collected by USGS
Ely Copper Mine Superfund Site
Vershire, Vermont

Sample/Loc ID	Sample Type		Location and Data Collected	Parameters	Reference
02Ely1A	Soil/Waste Rock	comp.	Top of Smoke Flue in wooded area, surface soil grab sample. Collected 10/02.	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)	USGS, 2004a and b, 2007
02Ely1B	Soil/Waste Rock	comp.	Upper waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely1A. Collected 10/02.		
02Ely2A	Soil/Waste Rock	comp.	Upper waste rock pile, SW below road. soil composite sample, 30 aliquots per sample. Surface soil only. Collected 10/02		
02Ely2B	Soil/Waste Rock	comp.	Upper waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely2A. Collected 10/02.		
02Ely3	Soil/Waste Rock	comp.	Upper waste rock pile, boulder slope above Ely2, soil composite sample, 30 aliquots per sample. Surface soil only. Collected 10/02.		
02Ely4A	Soil/Waste Rock	comp.	Upper waste rock pile, S-Central part of piles, soil composite sample, 30 aliquots per sample. Surface soil only. Collected 10/02.		
02Ely4B	Soil/Waste Rock	comp.	Upper waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely4A. Collected 10/02.		
02Ely5A	Soil/Waste Rock	comp.	Upper waste rock pile, S-East part of piles, soil composite sample, 30 aliquots per sample. Surface soil only. Collected 10/02.		
02Ely5B	Soil/Waste Rock	comp.	Upper waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely5A. Collected 10/02.		
02Ely6A	Soil/Waste Rock	comp.	Upper waste rock pile, above seeps, soil composite sample, 30 aliquots per sample. Surface soil only. Collected 10/02.		
02Ely6B	Soil/Waste Rock	comp.	Upper waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely6A. Collected 10/02.		
ES-4	Ferricrete at Seep	grab	ES-4 location of Holmes and others, 2002. Seep within Upper Waste Rock Piles. Colected 10/02		
Ely00JH24	Surf. Soil	comp.	Flotation Mill Area soil. Collected 6/00		
98JH-Ely-EB	Surf. Soil/WR	comp.	Lower Waste Rock Pile Area along access road. Sampled 8/98.		
Ely00JH22	Surf. Soil/WR	comp.	Replicate of 98JH-Ely-EB. Lower Waste Rock Pile Area along access road. Sampled 6/00.		
02Ely7A	Surf. Soil/WR	comp.	Lower Waste Rock Pile Area above the access road. Replicate of 02Ely9. Collected 10/02		
02Ely7B	Soil/Waste Rock	comp.	Lower waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same locations as 02Ely7A. Collected 10/02.		
02Ely8A	Surf. Tailings	grab	Flotation Mill tailings downslope from mill foundation. Oxidized surface material. Sampled 10/02		
02Ely8B	tailings	grab	Grey and yellow layered tailings at a depth of 35-46cm (14-18 inches) above black tailings. Same location as 02Ely8A. Sampled 10/02		
02Ely8C	Unox. Tailings	grab	Black unoxidized tailings from 71-91cm depth (28-36 inches). Same location as 02Ely8A. Sampled 10/02		

Table 3-2
Summary of Waste Area Soil Samples Collected by USGS
Ely Copper Mine Superfund Site
Vershire, Vermont

Sample/Loc ID	Sample Type		Location and Data Collected	Parameters	Reference
02Ely9A	Surf. Soil/WR	comp.	Lower Waste Rock Pile Area above the access road. Replicate of 02Ely7A. Collected 10/02		
02Ely9B	Soil/Waste Rock	comp.	Lower waste rock pile soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Replicate sample of 02Ely7B. Collected 10/02.		
02Ely10A	Surf. Soil/WR	comp.	Partially roasted ore from Ore Roast Bed area. Sampled 10/02.		
02Ely10B	Soil/Waste Rock	comp.	Ore roast bed area soil composite sample, 30 aliquots per sample. Subsurface up to 25 cm/10 inches depth. Same location as 02Ely10A. Collected 10/02.		
02Ely11	Surf. Soil	comp.	Smelter Site surface soil composite sample. Sampled 10/02.		
02Ely12	Slag	comp.	Composite of small pieces of slag at the base of the weathered slag pile. Sampled 10/02.		
02Ely13	Surf. Soil	grab	Top of Smoke Flue in wooded area, surface soil grab sample. Collected 10/02.		
Ely-SD-09	Sediment	grab	Sample of Ely Brook sediment downstream of culvert/upstream of SHB. Sampled 12/05.	Mineralogy (XRD, SEM, EPMA, R/TLM), bulk chemistry for major and trace elements (ICP-AES and -MS), sequential extraction leach test.	
00JH34	Slag	grab	Grab slag sample from N bank of SHB. Dark gray with red and brown coatings.	Mineralogy (XRD), bulk chemistry for major and trace elements (ICP-AES and -MS), modified field leach test	
00JH38	Slag	grab	Grab slag sample from N. bank of SHB. Dark gray with brown and green coatings.		
01JH31A	Waste Rock	grab	Upper Mine Waste Pile, brown, gray and red WR fragments.		
01JH31B	Waste Rock	grab	Upper Mine Waste Pile, brown, gray and red WR fragments.		
01JH34a	Slag	grab	Grab slag sample from N bank of SHB. Gray, irridescent, brown and green coatings.		
01JH34b	Slag	grab	Grab slag sample from N. bank of SHB. Gray to black, flow banding, irridescent brown and red coatings.		

Table 3-3
Summary of Samples Collected During 2006 and 2007
Ely Copper Mine Superfund Site
Vershire, Vermont

Sample/Loc ID	Sample Type		Location	Parameters	Reference
MW-01 through MW-16	Groundwater	grab	Site-wide, 13 shallow OB, 4 deep OB/till, 11 shallow bedrock, 2 deep bedrock. 1 to 3 rounds per well.	Total/dissolved TAL metals; acidity, alkalinity,carbonate, chloride, hydroxide,nitrate, sufate, sulfide, and standard field parameters. Sampling completed 12/06, 6/07, and 11/07.	URS, 2008
SW-04 to SW-52	Surface Water	grab	Site-wide, 25 locations sampled including seeps. 1 sample per location.	Same as groundwater above. Sampled 5/07	
SED-17C to SED-57C	Sediment	grab	Site-wide, 13 locations. 1 sample per location, 3 inch depth	Total TAL metals. Percent moisture. Sampled 10/07	
BK-07 to BK-15	Surf. Soil	grab	Background soil from off-site. 5 Locations, 16 samples, 3 samples per location up to 1 foot depth.	Total TAL metals. Sampled 10/07	
NF-01 to NF-17	Surf. Soil	grab	Site Perimeter. Natural forest soil. 17 locations, 35 samples, 2 samples per location up to 1 foot depth.	Total TAL metals. Sampled 10/07	
SA-01 to SA-31	Surf. Soil/WR	grab	Site-wide. Source areas. 31 samples plus dups. 0-6 inch depth	Total TAL metals. Sampled 10/07	
TR-01 to TR-09	Surf. Soil/WR	grab	9 Transects along waste area margins. 54 samples, 3-5 samples per transect, up to 2 samples per location up to 1 foot depth.	Total TAL metals. Sampled 10/07	
TZ-01 to TZ-45	Surf. Soil	grab	Site-wide perimeter transition zone samples in vegetated areas. 45 locations, 90 samples, 2 per location up to 1 foot depth.	Total TAL metals. Sampled 10/07	
TP-01 to TP-109	Surf/SubSurf. Soil	grab	16 test pit locations in waste source areas. Varying sample depths up to 9 feet.	Total TAL metals, SPLP (13) metals, ABA, sulfur, sulfate. Sampled 5/07.	
SB-01 to SB-08	NS	NS	No samples were collected from 10 soil borings in the ore roast beds and upper waste rock piles.		

Table 3-4
Summary of Aquatic Assessment Samples Collected by USGS and EPA
Ely Copper Mine Superfund Site
Vershire, Vermont

Location ID	Corresponding Loc ID (Holmes and others 2002)	Sample Type	Location	Parameters	Reference
EB-1080M	EB-1	Metals in sediment, surface and pore water; invert. richness; sed. tox. testing	Most upstream Ely Brook main stem location at access road crossing.	Surface water and sediment samples were collected in August, 2006. Invertebrate and fish sampling was conducted in Sept, 2006. Water and bulk sediment toxicity tests were conducted. Pore water and surface water were collected at most locations. Analyses for TAL metals and standard field and inorganic parameters were completed in addition to flow at each location.	USGS/EPA, Unpublished 2008
EB-770M	Downstream of EB-1	Metals in sediment, surface and pore water; invert. richness; sed. tox. testing	Ely Brook main stem downstream of confluence of 1st tributary (draining seep ES-12).		
EB-600M	Downstream of EB-1	Metals in sediment, surface and pore water; invert. richness; sed. tox. testing	Ely Brook main stem upstream of 2nd tributary draining upper waste rock/tailings area and beaver ponds.		
EB-90M	Upstream of EB-6	Metals in sediment, surface and pore water; invert. richness; sed. tox. testing	Ely Brook main stem at weir above S. Vershire Road.		
EM-Pond1	Upstream of SB-2	Metals in SW; dipnet surv.	Reservoir feeding east tributary of Ely Brook, upstream of beaver ponds.		
EM-Pond2	Upstream of EB-2	Metals in SW; surface water tox. test; dipnet surv.	Ely Brook east tributary, uppermost beaver pond below reservoir.		
EM-Pond3	Upstream of EB-2	Metals in SW; surface water tox. test; dipnet surv.	Ely Brook east tributary, second beaver pond below reservoir.		
EM-Pond4	Upstream of EB-2	Metals in SW; surface water tox. test; dipnet surv.	Ely Brook east tributary, third beaver pond below reservoir.		
EM-Pond5	Upstream of EB-2	Metals in SW; surface water tox. test; dipnet surv.	Ely Brook east tributary, fourth beaver pond below reservoir.		
EM-Pond6	Upstream of EB-3	Metals in SW; surface water tox. test; dipnet surv.	Small ponded area on east side of upper waste pile area, draining to tributary of Ely Brook.		
SB-3670M	Upstream of SB-1	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	Schoolhouse Brook (SHB) at the falls upstream of EB confluence.		
SB-3245M	Upstream of SB-2	Metal in SW	SHB immediately downstream of conflence with Ely Brook.		
SB-3125M	Upstream of SB-2	Metal in SW	SHB adjacent to slag pile area.		
SB-3100M	Upstream of SB-2	Metals in SW; invert. richness; fish tissue.	SHB at east end of slag pile area.		
SB-2860M	Downstream of SB-2	Metal in SW	SHB immediately downstream of 1st tributary.		
SB-2400M	Downstream of SB-2	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	SHB upstream of 2nd tributary below the EB confluence.		

Table 3-4
Summary of Aquatic Assessment Samples Collected by USGS and EPA
Ely Copper Mine Superfund Site
Vershire, Vermont

Location ID	Corresponding Loc ID (Holmes and others 2002)	Sample Type	Location	Parameters	Reference
SB-1360M	Downstream of SB-2	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	SHB immediately upstream of 4th tributary downstream of EB confluence.		
SB-140M	Downstream of SB-3	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	SHB upstream of confluence with Omp. R.		
SB-20M	Downstream of SB-3	Metals in sediment, surface and pore water; sed. tox. testing.	SHB immediately upstream of confluence with Omp. R.		
OR-24050M	Downstream of OR-1	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	Omp. R. Immediately downstream of West Farlee Bridge crossing.		
OR-23630M	Upstream of OR-2	Metals in SW; invert. richness; fish tissue.	Omp. R. immediately downstream of SHB confluence.		
OR-23200M	Upstream of OR-2	Metals in sediment, surface and pore water; invert. richness; fish tissue; sed. tox. testing.	Omp. R. downstream of OR-23630M.		

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

Proposed Exposure Area	Description of Proposed Exposure Area (see Section 7 of the 2005 PAL Report)
Soil	
Upper Mine Waste Piles south to Mill Site	Mine openings, development rock piles, dump piles (4 and 6 through 9) and flotation mill site
Lower Mine Waste Piles and Roast Beds	Dump piles 11 and 12, and roast beds
Smelter Site, Smoke Flue, and Slag Piles	Smelter subsite, smoke flue area and slag heap
Surface Water and Sediment	
Ely Brook	Ely Brook and tributaries to confluence with Schoolhouse Brook
Schoolhouse Brook	From sample location SB-3670M to confluence with Ompompanoosuc River
Ompompanoosuc River	From sample location OR-24056M to OR-23200M
Fish	
Areas where edible fish or surrogates have been collected (i.e., Schoolhouse Brook and Ompompanoosuc River – including background areas).	
Groundwater	
Ely Mine	Monitoring wells associated with the Ely Mine.
Off-Site	Monitoring wells located off-site.

Table 5-2
Recreational Visitor Exposure Parameters
Ely Copper Mine Superfund Site
Vershire, 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
Ely Copper Mine Superfund Site
Vershire, 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
Ely Copper Mine Superfund Site
Vershire, 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
Ely Copper Mine Superfund Site
Vershire, 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 (Future)
Ely Copper Mine Superfund Site
Vershire, 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[1]
Ely Copper Mine Superfund Site
Vershire, Vermont

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

[1] Proposed based on existing site knowledge, may change based on future investigation.

Table 6-1
Preliminary Chemical-Specific ARARs
Ely Copper Mine Superfund Site
Vershire, 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 Risk-based Regional Screening Levels for residential soil and fish consumption	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
Ely Copper Mine Superfund Site
Vershire, 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
Ely Copper Mine Superfund Site
Vershire, 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
Ely Copper Mine Superfund Site
Vershire, 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.

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.

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.

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 risks 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
Ely Copper Mine Superfund Site
Vershire, 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.

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

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 the 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

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 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

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 Site 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 the Site 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 the Site 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 Site 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 Site 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

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 Site 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

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
Ely Copper Mine Superfund Site
Vershire, 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.

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
Ely Copper Mine Superfund Site
Vershire, 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™)

Monitor Well Installations and Groundwater Sampling

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Smelter/Slag Area						
Existing URS wells (11 overburden and bedrock wells).	See Figure 8-1	Characterization of metal concentration variations in shallow overburden and shallow bedrock groundwater across the Site over the course of a yearly seasonal cycle. Water level information from the wells will also be used to assess groundwater flow conditions as a basis for the CSM.	Low Flow	A:WT 10, C: 25	See MW-14C,D	
MW-14C,D [1]	Adjacent to access road near lower reach of Ely Brook	Shallow and deep bedrock well location added to existing shallow overburden well location situated in the center and lowermost portion of the Ely Brook Valley to assess the potential bedrock groundwater impact from upgradient waste sources including sediment in Ely Brook, waste rock/tailings piles and the Mine Pool. This location provides an intermediate evaluation point between bedrock wells at locations MW-20 and MW-01/02. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	C: 25 D: 150	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 including existing 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.	2 semiannual rounds
Lower Waste Piles and Roast Bed						
Existing URS wells (5 overburden and bedrock wells).	See Figure 8-1	Characterization of metal concentration variations in shallow overburden and shallow bedrock groundwater across the Site over the course of a yearly seasonal cycle. Water level information from the wells will also be used to assess groundwater flow conditions as a basis for the CSM.	Low Flow	A:WT 10, C: 25	See MW-14C,D	
MW-20A,C,D	South of Lower Waste Piles, west of roast beds	Assess the hydrologic and water quality relationship between surface water in this area and shallow overburden, shallow bedrock, and deep bedrock groundwater. The deep bedrock well will be used to assess potential impact on deep bedrock groundwater from the waste piles and mine pool, due to its location in the central part of the valley between the waste sources and Schoolhouse Brook. The location is also intermediate between the deep well MW-19D at the head of the valley and the bedrock welss MW-01/02C adjacent to Stony Brook. The shallow overburden and shallow bedrock wells will asess potential impacts from the upgradient roast beds. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	A:WT 10 C: 25 D: 150	See MW-14C,D	
MW-21A,C	Downgradient of former washhouse area/flotation tailings pile adjacent to tributaries to Ely Brook	Assess hydrologic and water quality relationship between surface water, shallow overburden/waste rock and shallow bedrock. The location of the well pair between branches of overland streams in the waste rock will allow assessment of the saturated thickness of the waste and the relationship between groundwater and these streams.	Low Flow	A:WT 10-20, B: 20-30, C: 50	See MW-14C,D	
MW-22A	Southwest of access road, south of flotation mill	Assess the saturated thickness and water quality of overburden/tailings for comparison with downgradient data. The well is located on the downgradient side of the tailings area, between the tailings and the waste rock pile area, and will assist in evaluating the extent of the tailings horizontally and vertically. Water level and water quality data will allow assessment of the relative contaminant contribution of the tailings to the nearby stream.	Low Flow	A:WT 10	See MW-14C,D	
MW-23A	Middle of Roast Bed Area	Shallow overburden well situated upgradient of location where a stream crosses the roast beds. This location will allow detailed evaluation of the soil character through a cross-section of the roast bed and underlying till. Water level and quality information from this well will be used to assess the saturated thickness of the overburden/waste groundwater and the stream. This data will be correlated with downgradient results from location MW-20 to asses the overall potential impact of the roast beds on SW/GW quality.	Low Flow	A:WT 15	See MW-14C,D	

Monitor Well Installations and Groundwater Sampling (Cont.)

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Upper Waste Piles						
Existing wells (12 URS overburden and bedrock wells and 2 Bureau of Mines [BOM] bedrock wells)	See Figure 8-1	Characterization of metal concentration variations in shallow overburden and shallow bedrock groundwater across the Site over the course of a yearly seasonal cycle. Water level information from the wells will also be used to assess groundwater flow conditions as a basis for the CSM.	Low Flow	A:WT 10, C: 25	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	2 rounds coincident with new wells
MW-17A	Southeast of lower beaver ponds	Monitor the water table and water quality adjacent to the beaver ponds and upgradient of the Lower Waste Pile Area to assess GW flow in this area upgradient of impacted areas. This well will provide information to put a boundary on the southeastern extent of the shallow groundwater impact of ARD/AMD emanating from the Upper Waste Pile Area and Lower Adit that is interpreted to discharge to the Beaver Ponds. Water level information will help clarify the CSM for groundwater flow in the vicinity of the Beaver Ponds. The well depth will be determined by the elevation of the water table encountered whether in overburden or shallow bedrock.	Low Flow	A:WT 10	See MW-14C,D	
MW-18A	At top of slope on pile adjacent to access road.	To allow monitoring of the saturated thickness of overburden within the Upper Waste Rock Piles to assess the interaction of groundwater with waste rock in the vicinity of seeps. The boring will also be used to sample/document the character of the waste rock pile soil (layering, compositional, and grain size variability, variations in degree of oxidation, saturation). Depending on the thickness and elevation of groundwater encountered (water table) the well may be installed in waste rock, underlying till, or shallow bedrock.	Low Flow	A:WT 10	See MW-14C,D	
MW-19A,C,D	Northernmost portion of pile in vicintiy of seeps	Assess the hydrologic and water quality relationship between seeps in this area and shallow overburden, shallow bedrock, and deep bedrock groundwater. The deep bedrock well will be used to assess potential impact from the mine pool on the south side of Dwight Hill. The overburden and shallow bedrock wells be installed as far upgradient of the main portion of the Upper Waste Rock Piles to assess potential groundwater quality impact from the small waste rock areas on the steep upper slope surrounding the shafts and adits. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	A:WT 10 C: 25 D: 150	See MW-14C,D	
PW-1 through PW-7	Ely Bk and Tributary west of access road, north of lower tailings piles	Pore water (PW) sample locations to assess water quality of shallow groundwater discharging to the stream branches in vicinity of surface water/sediment anomaly. Data to be used to evaluate likely source of the elevated metal concentrations in this location. Temperature measurements and other field parameters will help to clarify the source of detected copper concentrations in SW/SED.	Low Flow	PW: <1ft	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	One Round

Monitor Well Installations and Groundwater Sampling (Cont.)

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
Underground Workings						
MW-24C,D	Northeast of Main Shaft Opening	Shallow bedrock well above the mine pool and deep bedrock well to penetrate the mine pool at a location below which the mine is completely flooded to assess potential groundwater impact from the mine pool on the north side of Dwight Hill. Chemistry of the water directly from the mine pool will be used to define the source for future modeling of potential groundwater impacts. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	C: 100 D: 300	See MW-14C,D	
MW-25C,D	Northeast of Main Shaft Opening	Shallow and deep bedrock well location several hundred feet east/downgradient of the mine pool to assess potential bedrock groundwater impact from the mine pool. This location lies between the mine shaft and the Ompompanoosuc River in the likely direction of groundwater migration from the mine pool to assess the potential impact of the mine pool on surrounding bedrock groundwater. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	C: 100 D: 350	See MW-14C,D	
MW-26D	Northwest of underground workings	Deep bedrock well upgradient of the underground workings to assess potential groundwater impact from the mine pool. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	D: 350	See MW-14C,D	
MW-27D	East of underground workings near Omp. R.	Deep bedrock well downgradient of the underground workings near the Ompompanoosuc River to assess potential groundwater impact from the mine pool and serve as sentinel well at the Site boundary. The location is situated along the eastern extent of a prominent E-W lineament which transects the surface projection of the mine shaft and the tributary draining watershed overlying the mine pool. Geophysical logging and hydraulic testing of the deep bedrock well will allow characterization of the bedrock and water-bearing fractures.	Low Flow	D: 350	See MW-14C,D	

Residential Drinking Water Sampling

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Frequency
TBD	Est 10 residences in the vicinity of the Site	Locations TBD within approximately one half-mile of the Site to assess local groundwater quality relative to the Site and potential impact of the mine site on local drinking water.	Grab	TBD	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide	1 round

Soil Borings

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Lower Waste Piles and Roast Bed						
SB-09	Flotation tailings pile south of mill	In general, subsurface soil samples will be collected from each distinct overburden lithologic unit within and below each waste pile. Depending on lithologic variability and thickness approximately 3 samples per boring may be collected for analysis. At Location SB-9, soil samples will be collected to assess the character of the flotation tailings immediately downgradient from the mill for comparison with soil downgradient of the former wash house.	HSA[2] split-spoon grab sample	>2'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples)	3 per boring
MW-20A	South of Lower Waste Piles, west of roast beds	Assess the character of the overburden/fill in this area for comparison with upgradient areas. Define the limit of the tailings area.	See SB-09			
MW-21A	Downgradient of former washhouse area/flotation tailings pile	Assess the character of the tailings immediately downgradient from the former wash house for comparison with tailings adjacent to the flotation mill.	See SB-09			
MW-22A	Southwest of access road, south of flotation mill	Assess the character of the flotation tailings immediately downgradient from the mill for comparison with soil downgradient of the former wash house.	See SB-09			
MW-23A	Middle of Roast Bed Area	Subsurface soil samples will be collected from each distinct overburden lithologic unit within and below the roast beds. Depending on lithologic variability and thickness approximately 3 per boring samples may be collected for analysis.	See SB-09			
Upper Waste Piles						
MW-17A	Southeast of lower beaver ponds	Subsurface soil samples will be collected from each distinct overburden lithologic unit to assess potential impact to nearby beaver ponds and downgradient seeps.	See SB-09			
MW-18A	At top of slope on Pile 9 adjacent to access road.	Subsurface soil samples will be collected from each distinct overburden lithologic unit within and below the waste rock pile. Depending on lithologic variability and thickness approximately 3 per boring samples may be collected for analysis.	See SB-09			
MW-19A	Northernmost portion of Pile 8 in vicintiy of seeps	See MW-18A	See SB-09			

Test Pits

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Lower Waste Piles and Roast Bed						
TP16	West of Tailings area, east of Ely Brook	Test pit between Ely Brook and an eastern tributary to delineate the western margin of flotation tailings by visual inspection.	Backhoe or shovel	<5'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples)	~3
Upper Waste Piles						
TP15	West margin upper waste piles	Test pit to delineate the lateral and vertical extent of waste rock material by visual inspection along the western margin of Pile 9 (PAL, 2005).	See TP16			

Surficial Soil Sampling

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Smelter/Slag Area						
SS-1 to SS-7	Smoke flue and access road	Shallow soil samples will be collected at the top of the Smoke Flue, and along the access road to the Smoke Flue in the vicinity of anomalous lead concentrations in soil detected during perevious investigations. One sample will be collected along the slope adjacent to the smoke flue for comparison with soil data from within the flue. Results from XRF field screening of surficial soil will be used to locate sample points. Note: No soil samples are proposed in the vicinity of the former smelter building due to limitations on disturbing historical artifacts at the Site.	Shovel or hand auger	0-1'; 1-2'	TAL metals	2 per location
SS-8 to SS-9	Forested zone	Sample data will be used to characterize the terrestrial ecological risk associated with the forested habitat within this exposure area.	Shovel or hand auger	0-1'	TAL metals, total organic carbon (TOC) (for 50% of the sample group), paste pH, paste conductivity, cation exchange capacity (CEC)	1 per location
SS-10	Ely Brook western floodplain	Sample data will be used to characterize the terrestrial ecological risk associated with overbank floodplain soils/sediments using 1 surface soil sample collected from the surficial organic layer at a location selected based on the XRF data resulting from T4 (see below).	Shovel or hand auger	0-1'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples)	1 per location
Lower Waste Piles and Roast Bed						
SS-11 and SS-12	Ely Brook western floodplain	Sample data will be used to characterize the terrestrial ecological risk associated with overbank floodplain soils/sediments using 1 surface soil sample collected from the surficial organic layer at a location selected based on the XRF data resulting from T5 and T6 (see below).	Shovel or hand auger	0-1'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples)	1 per location
MW-23A	Within Roast Bed Area	One surficial soil sample per location to be collected for assessing human health exposure risk and waste characterization related to the Roast Bed Area.	Shovel or hand auger	0-2'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples)	1 per location
MW-20A to MW-22A, SS-30	Lower Waste Piles and Flotation Mill	One surficial soil sample per location to be collected for assessing human health exposure risk and waste characterization. Includes ore bin soil pile.	See MW-23A			
SS-13 to SS-30	Lower Waste Piles transition zones	Sample data will be used evaluate two data gaps: 1. Characterize terrestrial ecological risk associated with each identified terrestrial habitat bordering the source areas at the site.	Shovel or hand auger	0-1' (surficial organic layer)	TAL metals, TOC (for 50% of the sample group), paste pH, paste conductivity, CEC	1 per location
		2. Assess the lateral extent of sources in the transition zones and adjacent to small tributaries.	Shovel or hand auger	1-2' (soil underlying organic layer)	On-site XRF analysis by portable analyzer and/or mobile lab for a select set of source and transport indicator metals to be determined during QAPP development based on existing site data. 10% of XRF samples will be submitted for confirmatory laboratory analyses of TAL metals.	1 per location
Upper Waste Piles						
SS-31 to SS-33	Downslope of Upper Waste Piles and adjacent to small tributaries	Sample data will be used to assess human health exposure risk, characterize sources, and determine the lateral extent of waste adjacent to small tributaries.	See MW-23A			
SS-34 to SS-39	Adjacent to mine openings upslope of Upper Waste Piles	Sample data will be used to assess human health exposure risk, characterize sources, and evaluate the potential impact on runoff entering/discharging from mine openings.	See MW-23A			

XRF Field Screening Transects

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Smelter/Slag Area						
T1 to T3	3 transects distributed withint the Smelter/Slag Area exposure area.	Provide data adjacent to identified mine waste areas to define the lateral distribution of metal concentrations in surface soils. Samples will be collected in 25 foot intervals along each transect at a sample depth below the organic leaf litter. The XRF results will be used to delineate Site metal sources and transition zones, and to select terrestrial ecological risk sample locations.	Shovel or hand auger	0-1'	On-site XRF analysis by portable analyzer and/or mobile lab for a select set of source and transport indicator metals to be determined during QAPP development based on existing site data. 10% of XRF samples will be submitted for confirmatory laboratory analyses of TAL metals.	~8
T4	1 transect across the main Ely Brook stem withint the Smelter/Slag Area exposure area.	The purpose of this transect is the same as shown below for T5 and also includes an assessment potential impacted soil in the area of a former impoundment west of Ely Brook and north of the former sawmill.	Shovel or hand auger	0-5'	See T1-T3	~22 (18 Ely Brook, 3 floodplan, and 1 forested zone)
Lower Waste Piles and Roast Bed						
T5	1 transect across the main Ely Brook stem within the Lower Waste Piles and Roast Bed exposure area.	Multi-purpose XRF field screening transect to evaluate three data gaps: 1. Establish lateral extent and depth profiles of waste within the Ely Brook channel for excavation geometry and volume analysis - including an estimated 6 sample stations distributed across the Ely Brook channel, each with three depth intervals sampled (surface, subsurface waste, and unimpacted soil/sediment or deapest feasible sample depth)	Shovel or hand auger	0-5'	See T1-T3	~18
		2. Assess overbank floodplain sediments for terrestrial ecological risk using 1 surface soils sample station every 25'.	Shovel or hand auger	0-1'	See T1-T3	~2
		3. Investigate the lateral distribution of metal concentrations to provide lateral source delineation in the forested areas between Ely Brook and the ore roast bed area.	Shovel or hand auger	0-2'	See T1-T3	~5
T6	1 transect across the main Ely Brook stem within the Lower Waste Piles and Roast Bed exposure area.	The purpose of this transect is the same as shown above for T5 and also extended into the forested zone west of Ely Brook to provide lateral source delineation in this transition zone and forested area.	Shovel or hand auger	0-5'	See T1-T3	~33 (18 Ely Brook, 1 floodplan, 10 forested zone east, and 4 forested zone west)
T7 to T11	5 transects distributed withint the Lower Waste Piles and Roast Bed exposure area.	See T1-T3				~8
Upper Waste Piles						
T12 to T17	6 transects distributed withint the Upper Waste Piles exposure area.	See T1-T3				Between 5 and 16 per transect (see Figure 8-1)

Sediment Sampling

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Smelter/Slag Area						
SD-58 to SD-59	Schoolhouse Brook	Sediment sampling to assess the thickness of impacted sediment in downgradient areas. Data to be used to evaluate whether sediment should be considered a waste source material. Thickness of stream sediment will be documented by hand augering/tube coring as feasible.	Shovel, hand auger, or tube sampler	0-2'	TAL Metals, ABA, Past pH, paste conductivity, SPLP Metals (10% of samples), TOC, grain size.	One per location
SD-60	Ely Brook	See SD-58 to SD-59				
Lower Waste Piles and Roast Bed						
SD-61 to SD-66, SD-72 and SD-73	Ely Brook and tributaries	See SD-58 to SD-59				
Upper Waste Piles						
SD-67 to SD-71	Beaver Ponds and tributaries	See SD-58 to SD-59				

Surface Water Sampling

Location ID	Description	Purpose/Rationale	Sampling Method	Depth (ft)	Parameters	Number of Samples
Smelter/Slag Area						
3 existing surface water sample locations previously sampled by URS (SW-04, -09, and -38)	Ely and Schoolhouse Brooks	Surface water samples to assess water quality in the tributary headwaters and potential contributions from the mine pool. Data will be used to assess relative contaminant contributions from various waste source areas and in support of human and ecological risk characterization.	Dipper-Grab	NA	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide, TSS, TDS	2 semiannual rounds
Lower Waste Piles and Roast Bed						
7 existing surface water sample locations previously sampled by URS (SW-12, -13, -32, -34, -36, -41, -51)	Ely Brook, tributaries, and waste pile seeps	Surface water samples to assess water quality in the tributary headwaters and potential contributions from the mine pool. Data will be used to assess relative contaminant contributions from various waste source areas and in support of human and ecological risk characterization.	Dipper-Grab	NA	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide, TSS, TDS	2 semiannual rounds
SW-72, SW-73, and SW-82 to SW-84	See above					
Upper Waste Piles						
10 existing surface water sample locations previously sampled by URS (SW-17, -29, -40, -42, -43, -45, -46, -47, -48, -49)	Ely Brook, tributaries, and waste pile seeps	Surface water samples to assess water quality in the tributary headwaters and potential contributions from the mine pool. Data will be used to assess relative contaminant contributions from various waste source areas and in support of human and ecological risk characterization.	Dipper-Grab	NA	TAL Metals (total and dissolved), chloride, sulfate, carbonate, bicarbonate, hydroxide, sulfide, nitrate/nitrite nitrogen, total acidity, alkalinity, total cyanide, TSS, TDS	2 semiannual rounds
SW-71 and SW-74 through SW-81	See above					

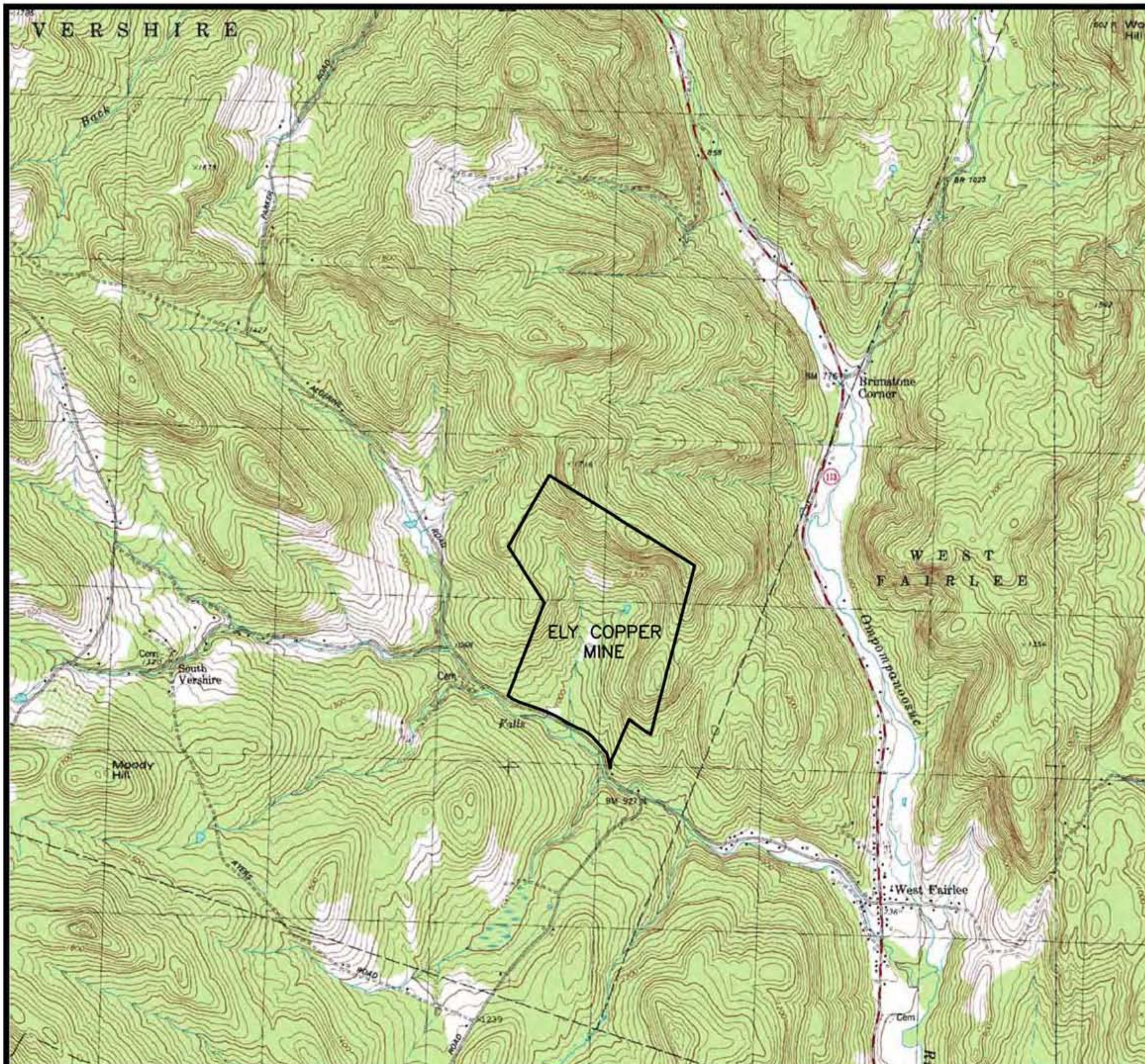
Notes:
1. For monitoring well designations: A = shallow overburden, B = deep overburden, C = shallow bedrock, D = deep bedrock.
2. HSA is equivalent to "hollow-stem auger".

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.	Approximately 20-25 surface soil grab samples will be collected and analyzed to define nature and extent of contamination. Surface soil samples submitted for laboratory analyses will be selected based on a review of XRF field screening data. Samples will be collected from the surficial organic layer and/or surface soils overlying waste rock that may be present at the locations (the sample will not include underlying waste rock). This sample interval is assumed to be between 0-1 feet below ground surface. For additional information regarding these samples refer to the report text, Table 8-1, and Figure 8-1 (conceptual sample locations). **Background**: Off-site background surface soil samples collected by URS (URS 2008) and site-specific surface soils samples collected in vegetated areas (e.g., NF – natural forest samples) that are similar in concentration to off-site background levels will be used. **Analyses:** TAL metals (all samples), total organic carbon (TOC) (for 50% of the sample group), paste pH, paste conductivity, cation exchange capacity (CEC)
Surface Water Bodies	
Assumed no additional (beyond the additional recommended Ely Brook characterization samples) data required at this time.	NA
Vernal Pools	
Vernal pool identification and evaluation: In May 2009, Site vernal pool evaluation was completed and resulted in the identification and mapping of four vernal pools, VP-1 through VP-4 (Figure 8-1). These vernal pools will be visited a second time during July 2009 to determine if vernal pool characteristics are present, as defined by Vermont DEC, and to perform surface water sampling.	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)

Table 8-2
Baseline Ecological Risk Assessment Data Needs
Ely Copper Mine Superfund Site
Vershire, Vermont

Proposed Exposure Area/Information Needs	Sample Requirements
Terrestrial Biota – Small Mammals	
Small mammal will be collected in vegetated area downgradient of "waste piles" for each exposure area.	Approximately 5-10 individuals will be collected per exposure area and background (only composite to meet mass requirements) at locations selected based on their habitat, setting with respect to identified mine waste, and visual observations (see Figure 8-1 for conceptual station locations). **Analyses**: Whole body samples will be analyzed for TAL metals and % lipids. Sample metrics (species, sex, weight, length, and reproductive status) will be recorded.
Terrestrial Biota – Soil Invertebrates	
Soil invertebrate samples will be collected in vegetated area downgradient of "waste piles" for each exposure area.	Approximately 5-10 composite samples will be collected per exposure area and background at locations selected based on their habitat, setting with respect to identified mine waste, and visual observations (see Figure 8-1 for conceptual station locations) **Analyses**: TAL metals and % moisture. Species included identified to Order.

FIGURES



NORTH

USGS TOPOGRAPHIC MAP

VERSHIRE, VERMONT

1983

APPROXIMATE SCALE
1 INCH = 3,000 FEET

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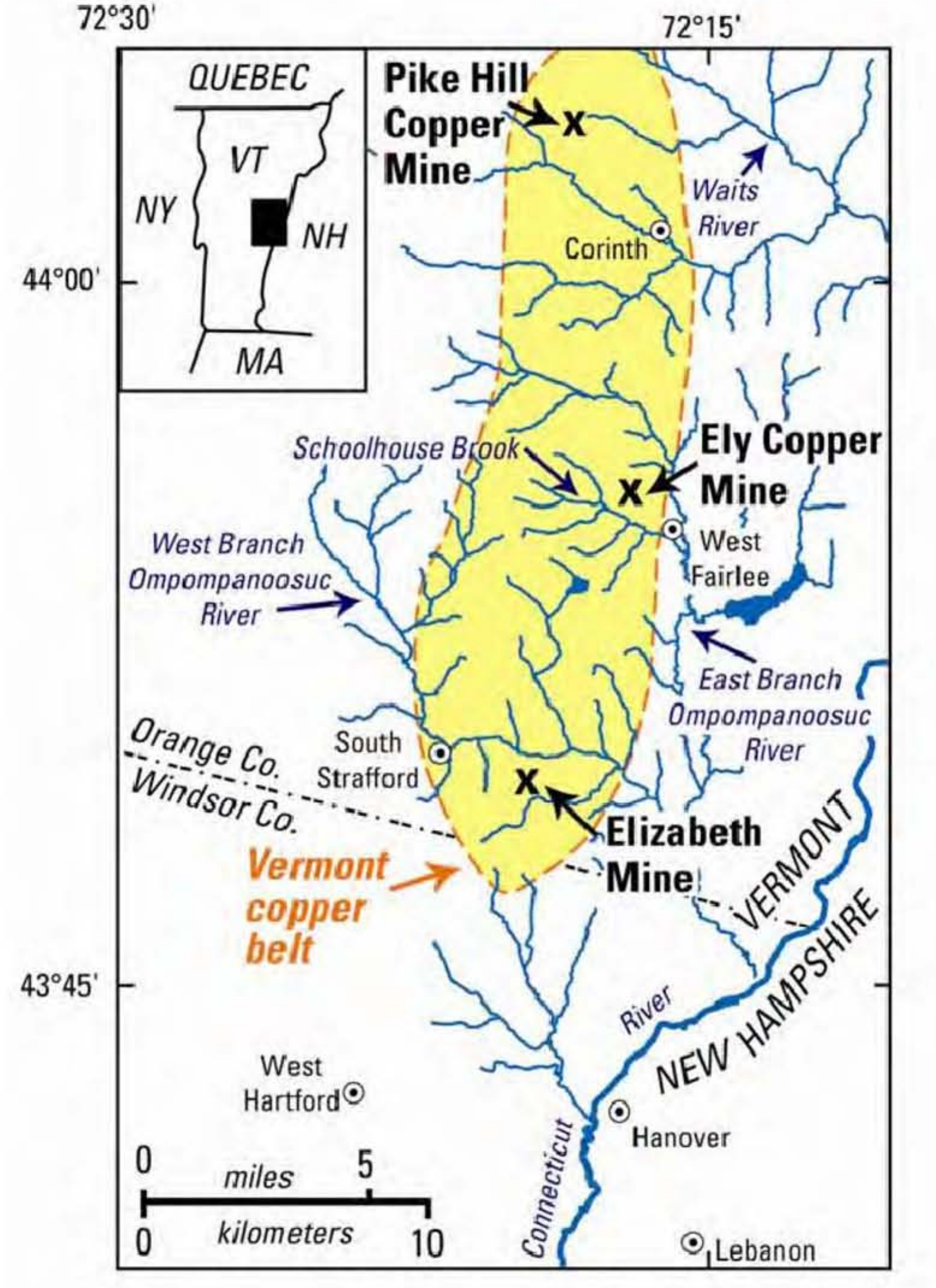
QUADRANGLE LOCATION

FIGURE 2-1

LOCUS PLAN
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

PROJECT: 80024.00	JUNE 2009



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, ORANGE COUNTY, VERMONT; SCIENTIFIC INVESTIGATIONS REPORT 2006-5303."

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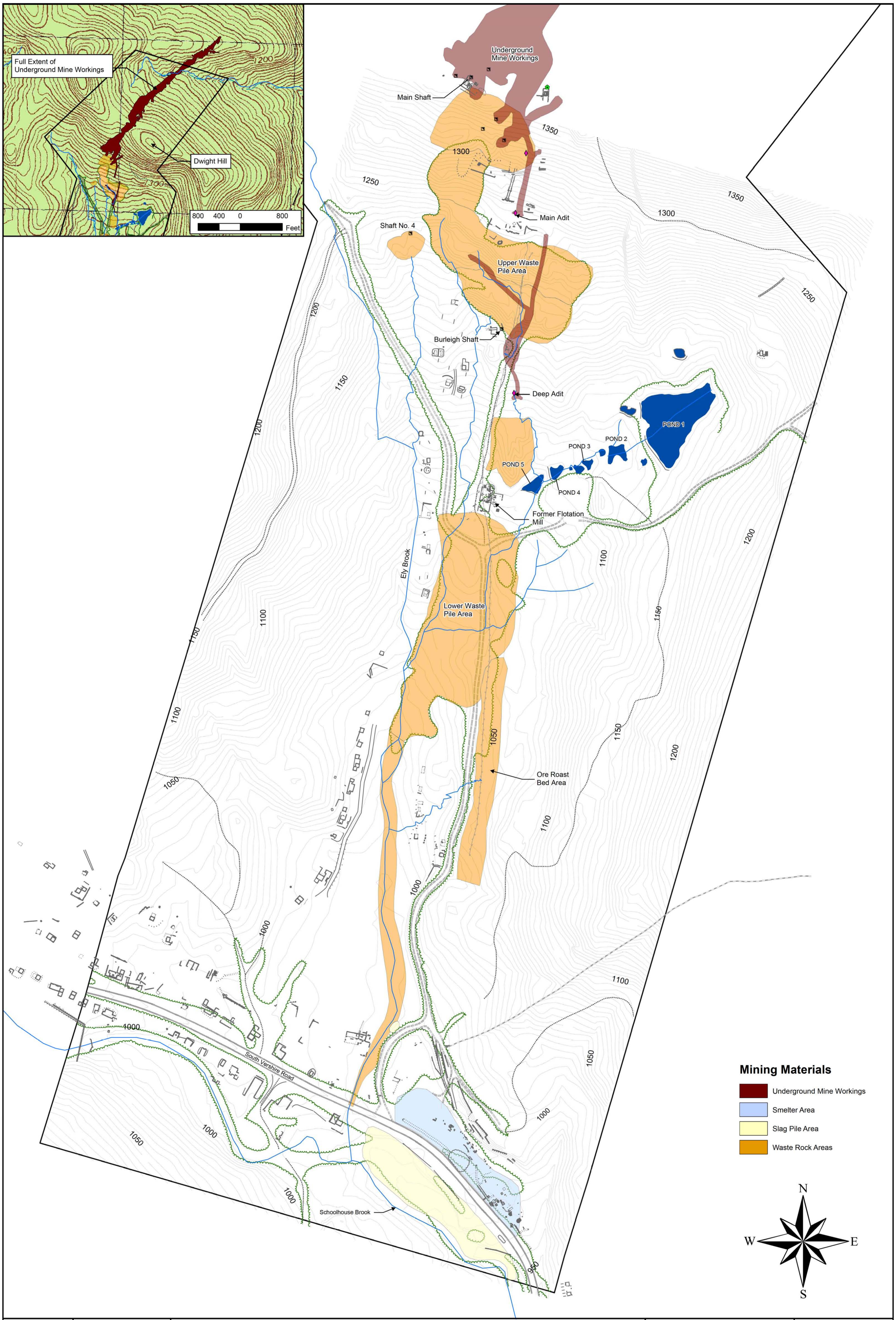
FIGURE 2-2

VERMONT COPPER BELT
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

DRAWN BY:	ML	APPROVED BY:	AB
PROJECT:	80024.00	JUNE 2009	

J:\80000 EPA RAC2 Region 1\80000 Task Orders\80024 Ely Copper Mine\CAD\dwg\80024-COPPER-BELT-FIG.dwg



Drawn By: JDF	Checked By: AJB
Filename: Site Sketch.mxd	
Date: 6/17/09	Revision No. 00

APPROXIMATE SCALE
150 75 0 150 300
Feet

Shaft
Adit
Prospect Tunnel
Drill Hole
Smoke Flue
Treeline
Paved Road
Gravel Road
Trail
Historic Feature
Parcel Boundary
1050 Topographic Contour (ft-msl)
Stream
Railroad

FIGURE 2-3

SITE SKETCH

ELY COPPER MINE
VERSHIRE, VERMONT

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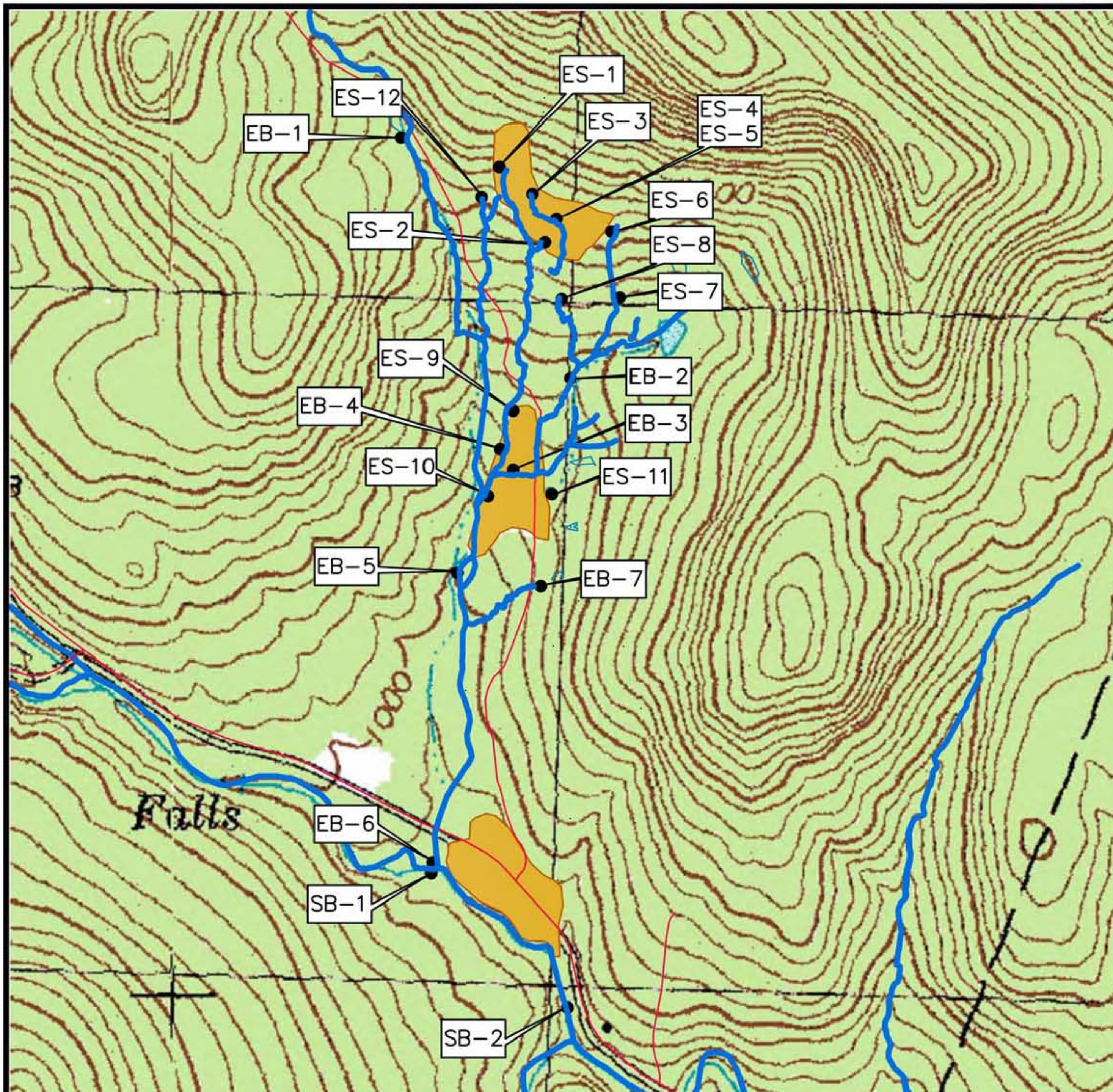

NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "SPRING RUNOFF CHARACTERIZATION ELY MINE, VERSHIRE, VERMONT, SPRING 2002."

NORTH

0 700 1400

SCALE IN FEET

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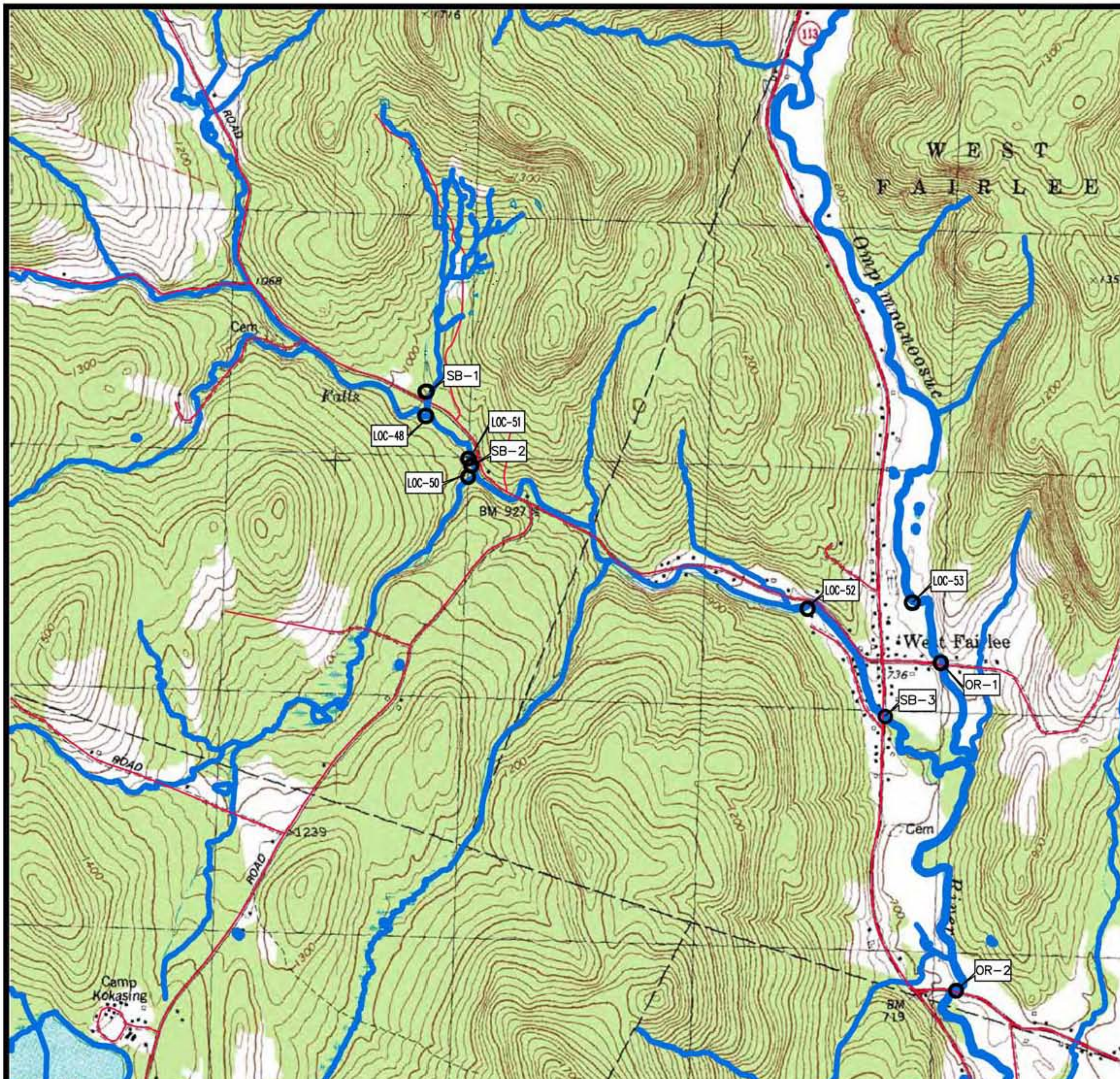
FIGURE 3-1

USACE ON-SITE SEEP AND SURFACE WATER SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

PROJECT: 80024.00 JUNE 2009



LEGEND

O SAMPLE SITE AND IDENTIFIER

NOTE:

1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "SPRING RUNOFF CHARACTERIZATION ELY MINE, VERSHIRE, VERMONT, SPRING 2002."

NORTH

0 2000 4000

SCALE IN FEET

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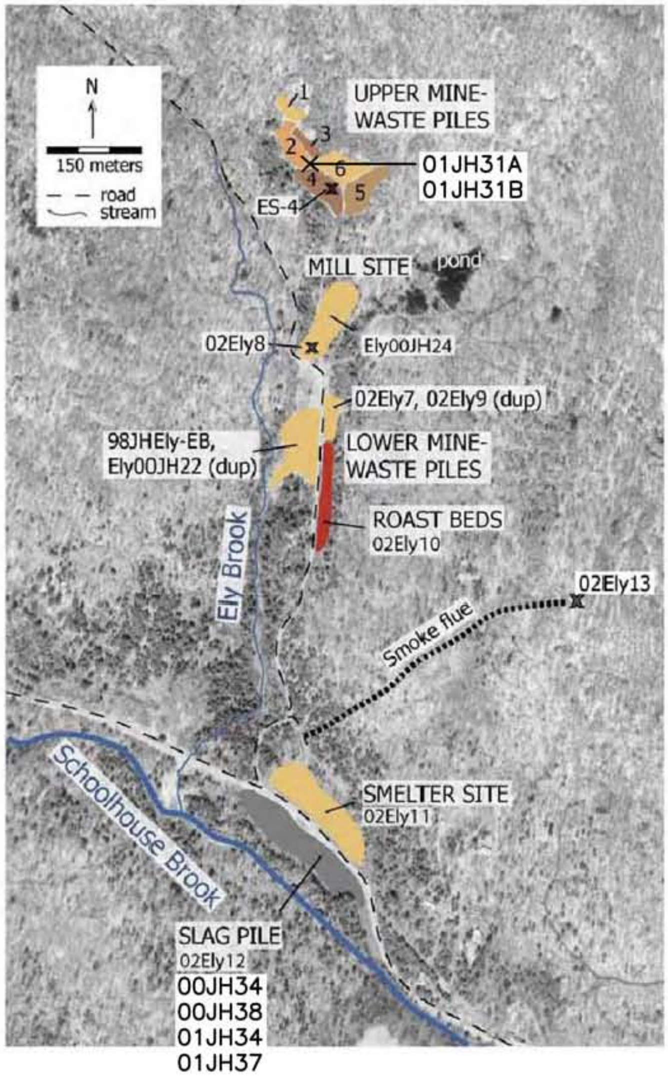
FIGURE 3-2

USACE OFF-SITE
SURFACE WATER SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

PROJECT: 80024.00	JUNE 2009



NOTE:
1. THIS FIGURE WAS DEVELOPED FROM INFORMATION FOUND WITHIN THE "USGS GEOCHEMICAL CHARACTERIZATION OF MINE WASTE, AT THE ELY COPPER MINE SUPERFUND SITE, ORANGE COUNTY, VERMONT; SCIENTIFIC INVESTIGATIONS REPORT 2004-1248."

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FIGURE 3-3

USGS MINE WASTE SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

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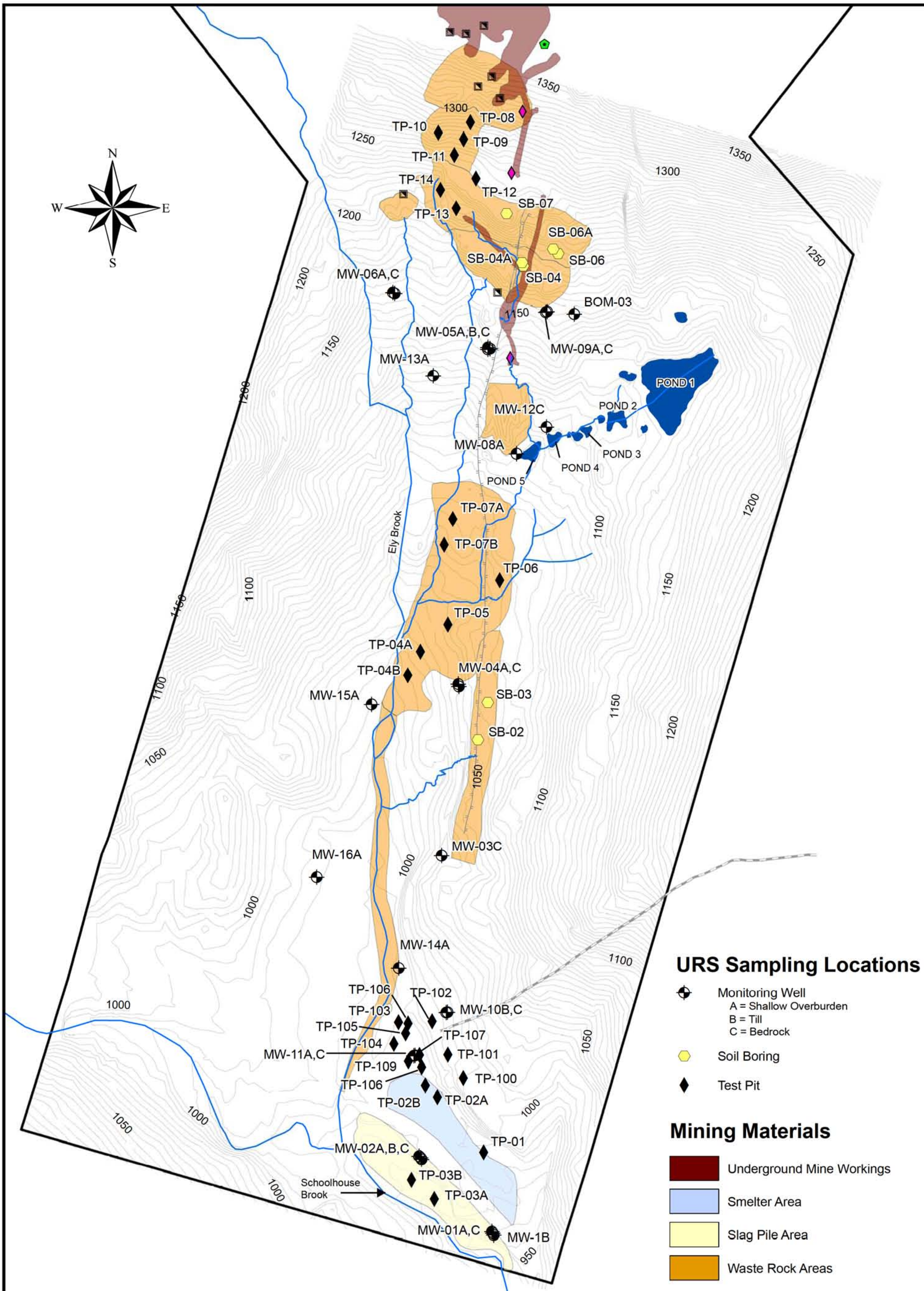
PROJECT:	80024.00	JUNE 2009	



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Filename: URS SB/TP/MW Locations.mxd

Date: 6/17/09 | Revision No. 00

APPROXIMATE SCALE 160 80 0 160 320 Feet

Shaft · Adit · Prospect Tunnel · Drill Hole · Smoke Flue · Parcel Boundary · Stream · Railroad · 1050 Topographic Contour (ft-msl)

FIGURE 3-4

URS SOIL BORING, TEST PIT AND MONITORING WELL LOCATIONS
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VERSHIRE, VERMONT

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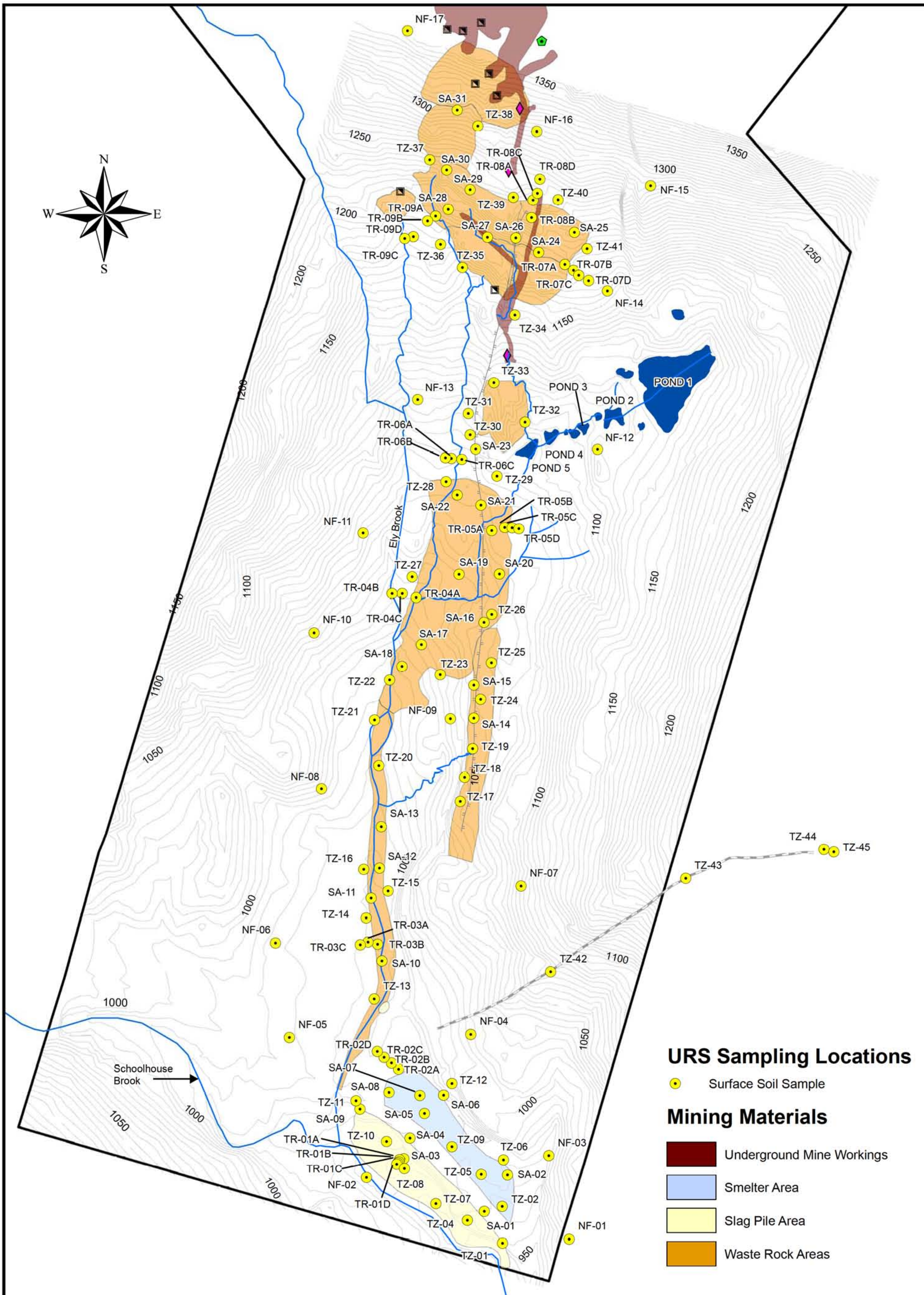

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Filename: URS SS Locations.mxd	
Date: 6/17/09	Revision No. 00

APPROXIMATE SCALE

160 80 0 160 320 Feet

- Shaft
- Adit
- Prospect Tunnel
- Drill Hole
- Smoke Flue
- Parcel Boundary
- Stream
- Railroad
- 1050 Topographic Contour (ft-msl)

FIGURE 3-5

URS SURFACE SOIL SAMPLE LOCATIONS
ELY COPPER MINE
VERSHIRE, VERMONT

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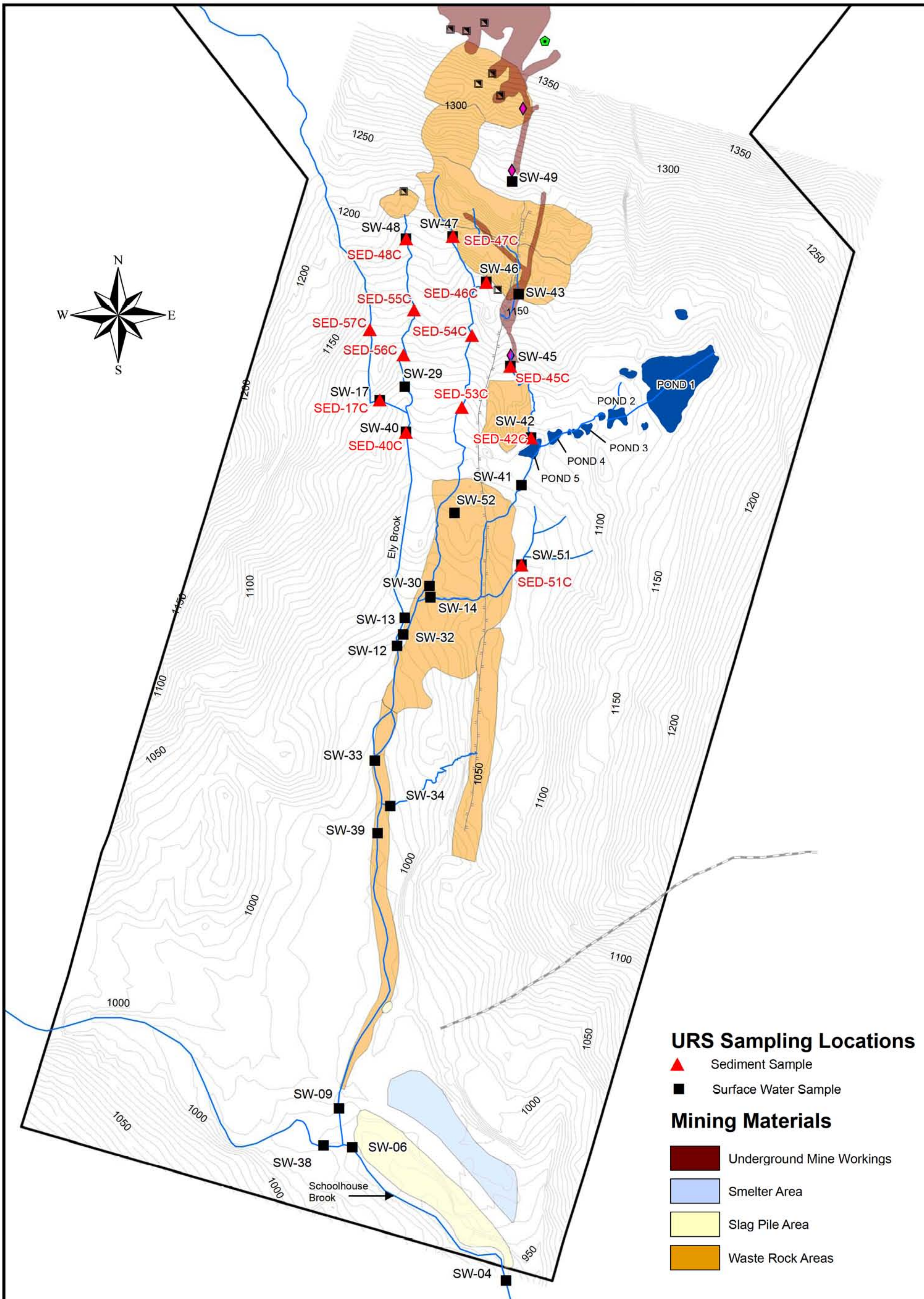

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Filename: URS SS Locations.mxd	
Date: 6/17/09	Revision No. 00

APPROXIMATE SCALE
160 80 0 160 320 Feet

Shaft
Adit
Prospect Tunnel
Drill Hole
Smoke Flue
Parcel Boundary
Stream
Railroad
1050 Topographic Contour (ft-msl)

FIGURE 3-6
URS SURFACE WATER & SEDIMENT SAMPLE LOCATIONS
ELY COPPER MINE
VERSHIRE, VERMONT

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Concord, NH 03301
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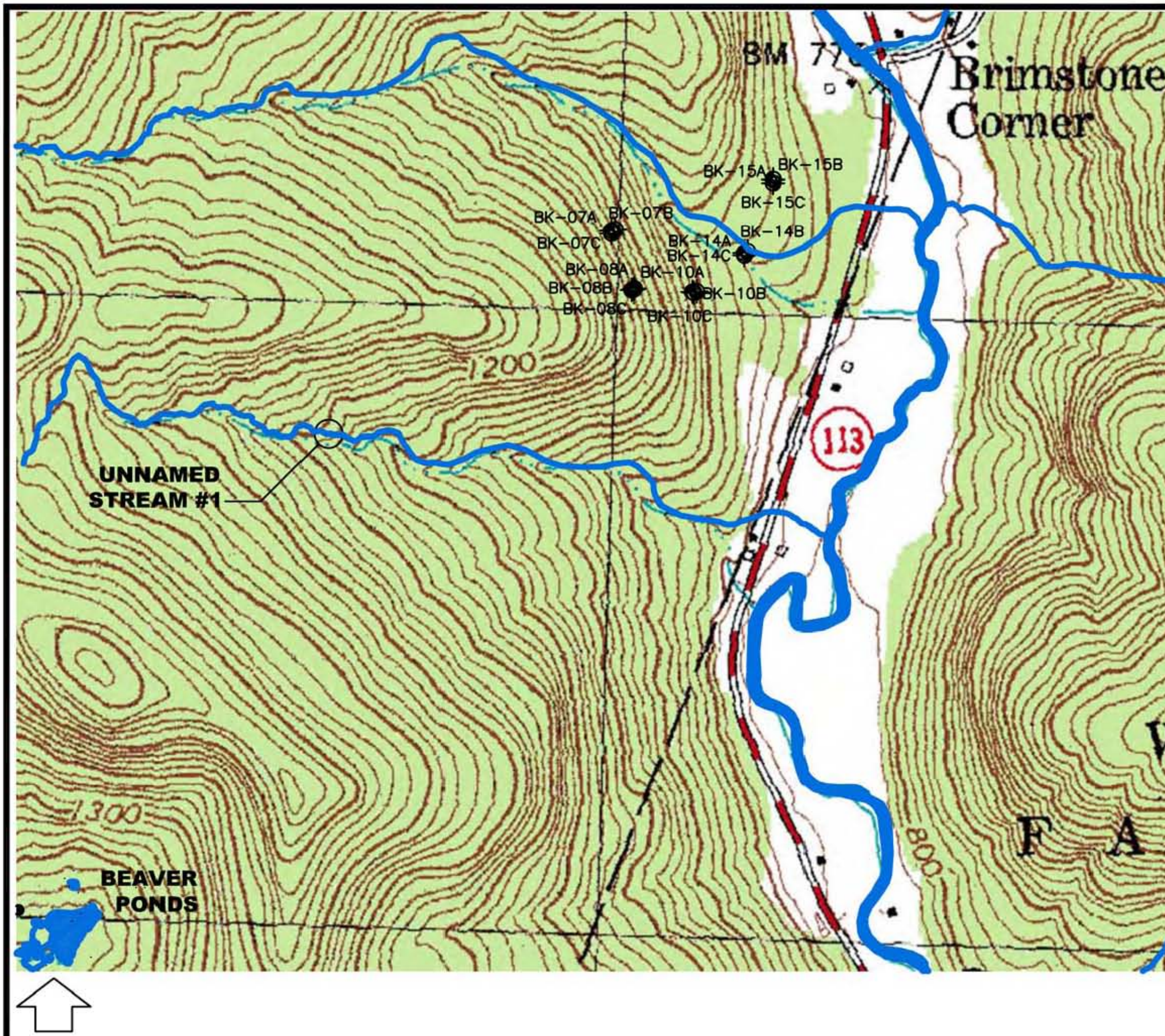
fax (603) 224-2507
www.nobisengineering.com



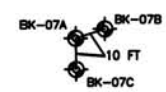
SOURCES:

USGS 7.5-MINUTE TOPOGRAPHIC QUADRANGLES OBTAINED FROM VERMONT CENTER FOR GEOGRAPHIC INFORMATION, INC. WATERBURY, VT IN DIGITAL FORMAT (.TIFF FILES). PROJECTED TO THE VERMONT STATE PLANE COORDINATE SYSTEM (NAD83) FROM DIGITAL RASTER GRAPHIC IMAGE FILES.

WATER COURSE DATA OBTAINED FROM THE VERMONT CENTER FOR GEOGRAPHIC INFORMATION, INC. WATERBURY, VT AND PAL, REPORT NO. 1237.03, SEPTEMBER 2002, MODIFIED BASED ON SITE RECONAISSANCE.

THE SAMPLE INFORMATION IN THIS FIGURE WAS PROVIDED BY URS CORPORATION.

TYPICAL SPATIAL ARRANGEMENT OF BACKGROUND SAMPLES:



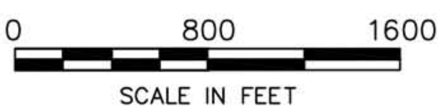


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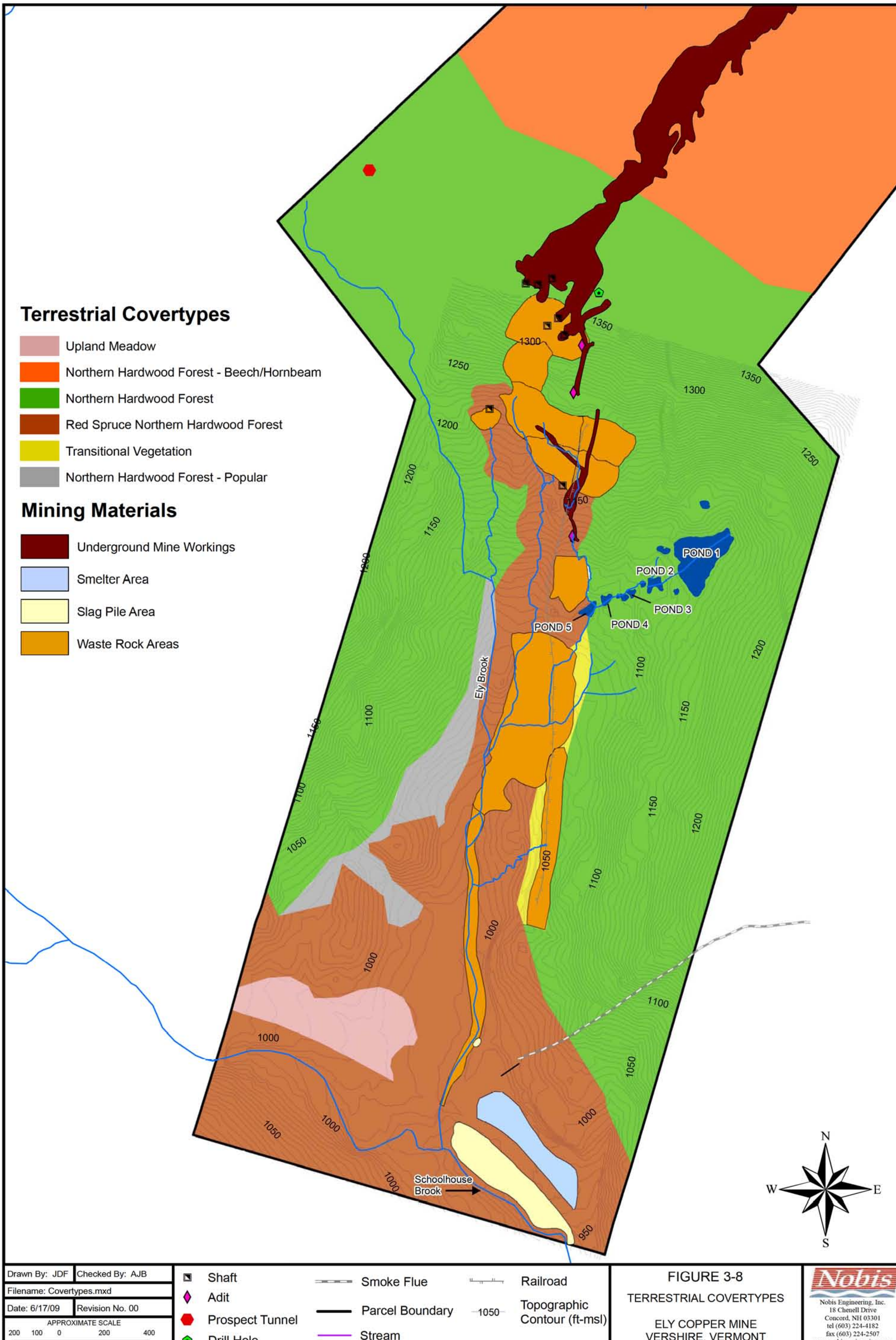
FIGURE 3-7

BACKGROUND SOIL SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

PROJECT: 80024.00 | JUNE 2009



Terrestrial Covertypes
Upland Meadow
Northern Hardwood Forest - Beech/Hornbeam
Northern Hardwood Forest
Red Spruce Northern Hardwood Forest
Transitional Vegetation
Northern Hardwood Forest - Popular
Mining Materials
Underground Mine Workings
Smelter Area
Slag Pile Area
Waste Rock Areas
POND 1
POND 2
POND 3
POND 4
POND 5
Ely Brook
Schoolhouse Brook
N
S
E
W
Drawn By: JDF
Checked By: AJB
Filename: Covertypes.mxd
Date: 6/17/09
Revision No. 00
APPROXIMATE SCALE
200 100 0 200 400
Feet
Shaft
Adit
Prospect Tunnel
Drill Hole
Smoke Flue
Parcel Boundary
Stream
Railroad
1050
Topographic Contour (ft-msl)
FIGURE 3-8
TERRESTRIAL COVERTYPES
ELY COPPER MINE
VERSHIRE, VERMONT
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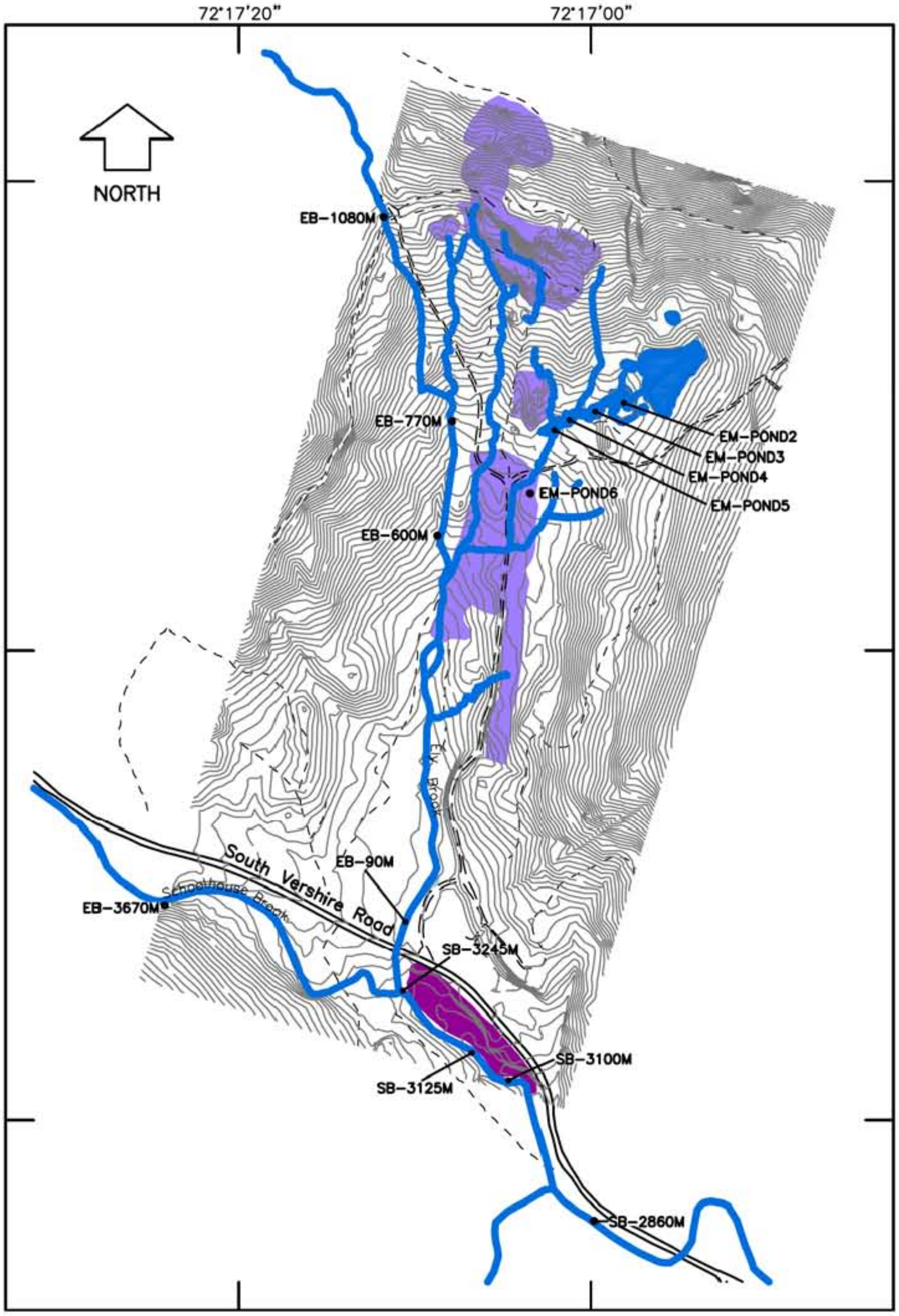

LEGEND

- MINE WASTE (WASTE ORE, TAILINGS OR ROAST BEDS)
- SLAG
- EB-500M ● SAMPLE SITE AND IDENTIFIER

NOTES:

1. THE SAMPLE INFORMATION IN THIS FIGURE WAS PROVIDED BY URS CORPORATION.
2. SAMPLE LOCATIONS ARE USGS UNPUBLISHED 2008.

0 800 1600

SCALE IN FEET

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FIGURE 3-9

USGS/EPA AQUATIC ASSESSMENT
ON-SITE SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

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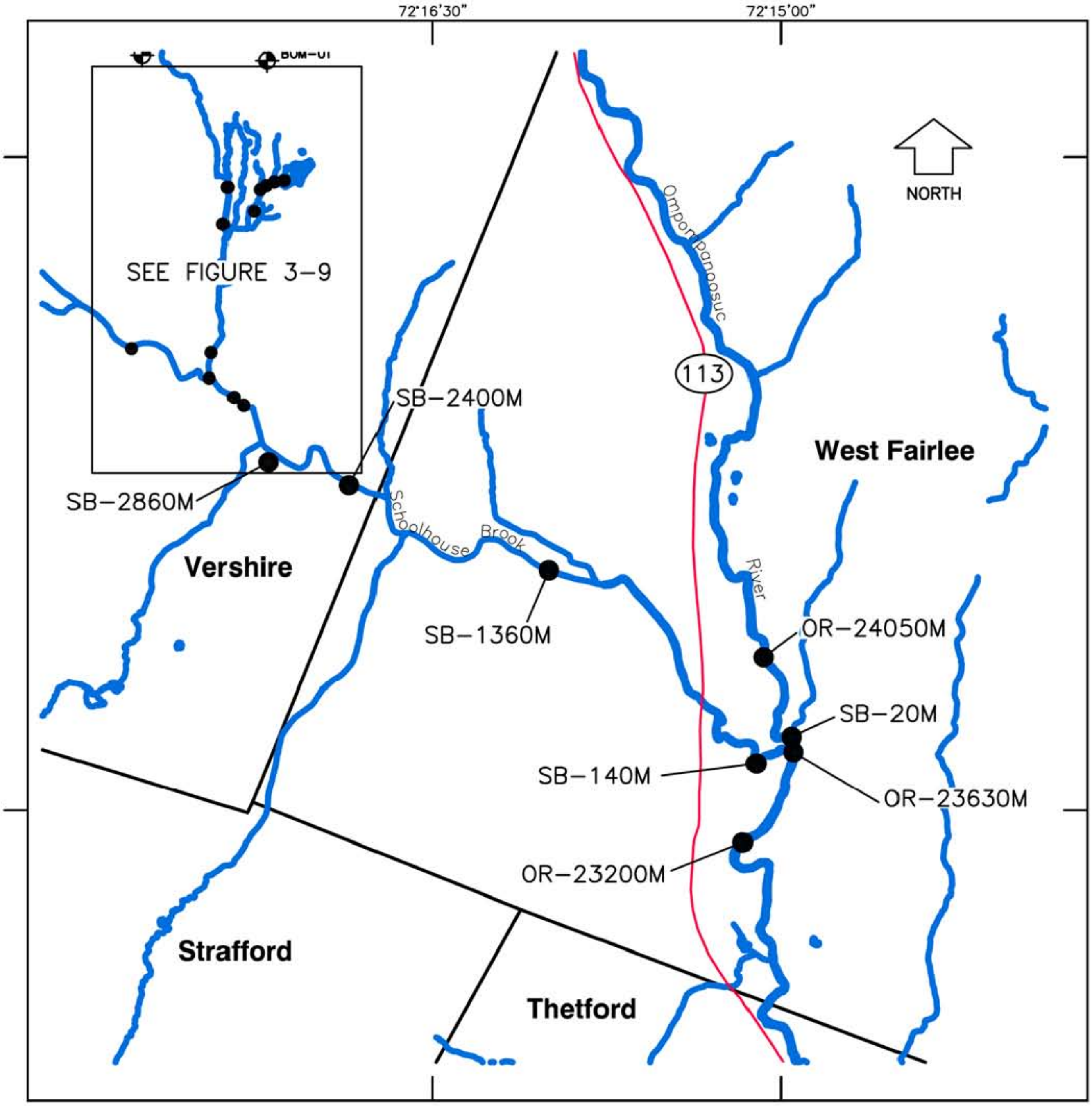

LEGEND

SB-1360M ● SAMPLE SITE AND IDENTIFIER

NOTES:

1. THE SAMPLE INFORMATION IN THIS FIGURE WAS PROVIDED BY URS CORPORATION.
2. SAMPLE LOCATIONS ARE USGS UNPUBLISHED 2008.

0 2000 4000

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FIGURE 3-10

USGS/EPA AQUATIC ASSESSMENT
OFF-SITE SAMPLE LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

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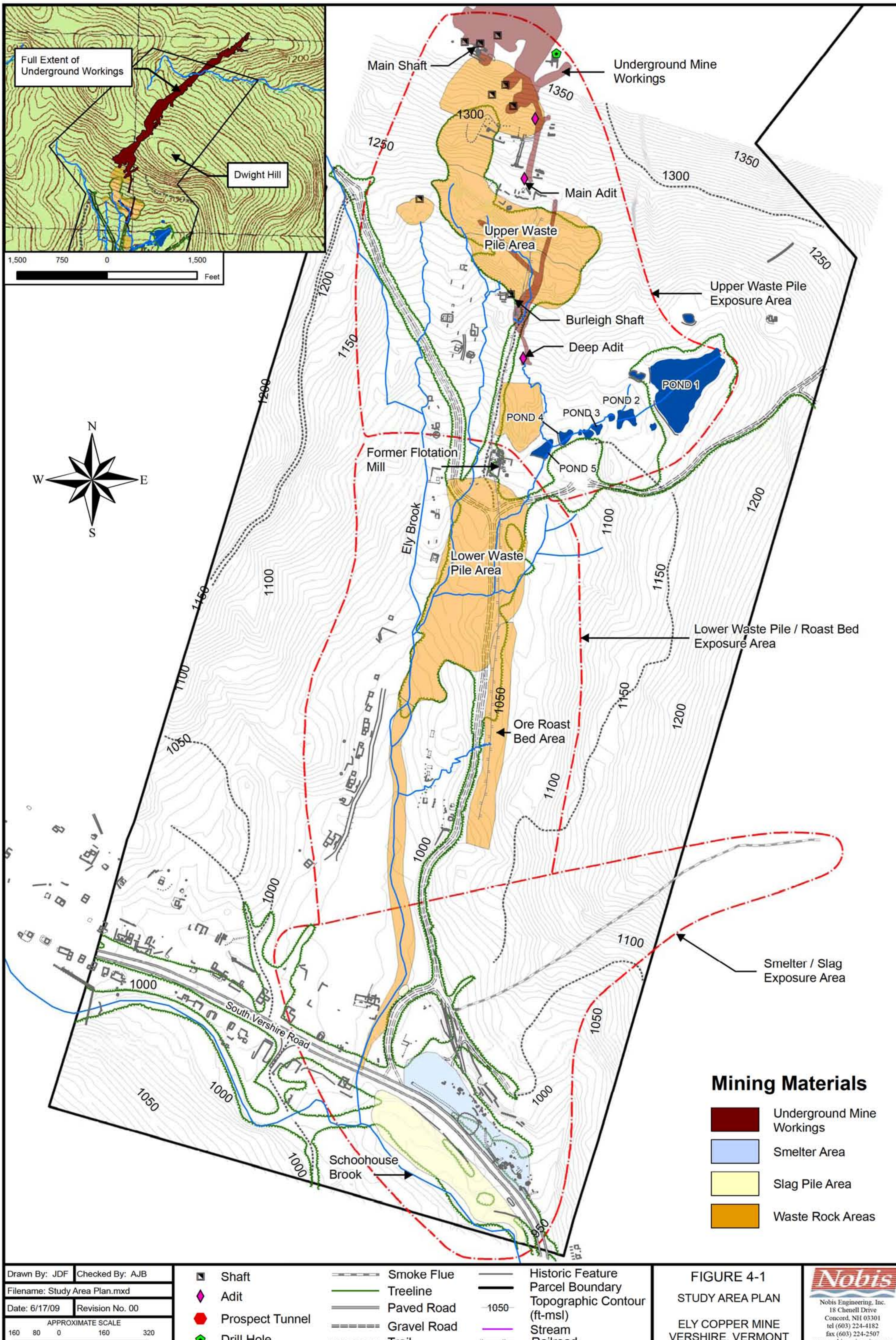

Full Extent of Underground Workings
Dwight Hill
1,500 750 0 1,500 Feet
Main Shaft
Underground Mine Workings
Main Adit
Upper Waste Pile Area
Burleigh Shaft
Deep Adit
Upper Waste Pile Exposure Area
POND 1
POND 2
POND 3
POND 4
POND 5
Former Flotation Mill
Ely Brook
Lower Waste Pile Area
Lower Waste Pile / Roast Bed Exposure Area
Ore Roast Bed Area
Smelter / Slag Exposure Area
South Vershire Road
Schoohouse Brook
N
S
E
W
Mining Materials
Underground Mine Workings
Smelter Area
Slag Pile Area
Waste Rock Areas
Drawn By: JDF
Checked By: AJB
Filename: Study Area Plan.mxd
Date: 6/17/09
Revision No. 00
APPROXIMATE SCALE
160 80 0 160 320 Feet
Shaft
Adit
Prospect Tunnel
Drill Hole
Smoke Flue
Treeline
Paved Road
Gravel Road
Trail
Historic Feature
Parcel Boundary
Topographic Contour (ft-msl)
Stream
Railroad
FIGURE 4-1
STUDY AREA PLAN
ELY COPPER MINE
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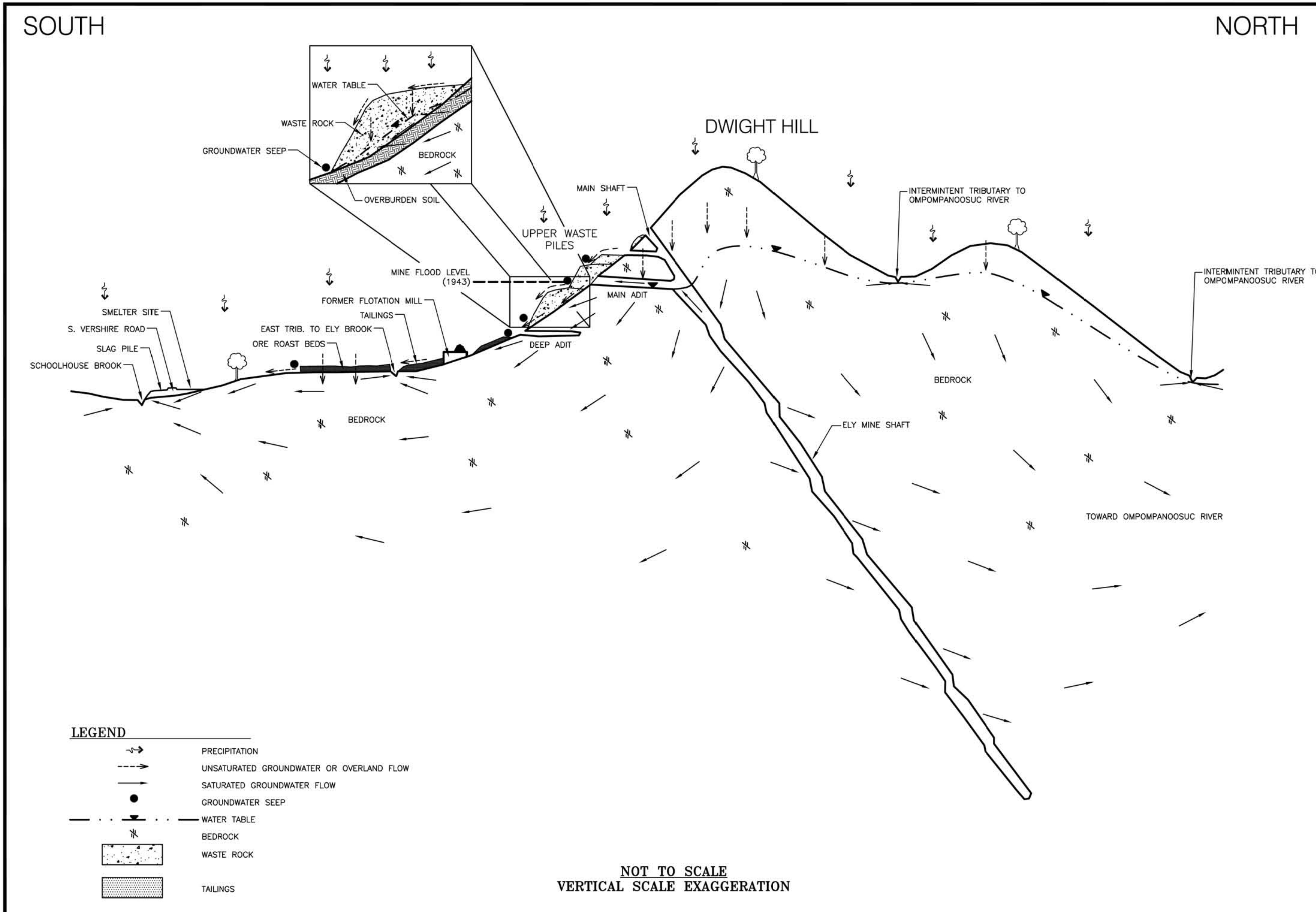
www.nobisengineering.com



DESIGN	AB
DRAFTING	ML
CHECKED	AB
APPROVED	AB

ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

JUNE 2009

SCHEMATIC INTERPRETATION OF GROUNDWATER FLOW

PROJECT NO. 80024.00

FIGURE 4-2

J:\80000 EPA RAC2 Region 1\80000 Task Orders\80024 Ely Copper Mine\CAD\dwg\80024-SCHEMATIC-XSECTION.dwg

Figure 5-1
Human Health Exposure Pathway Analysis

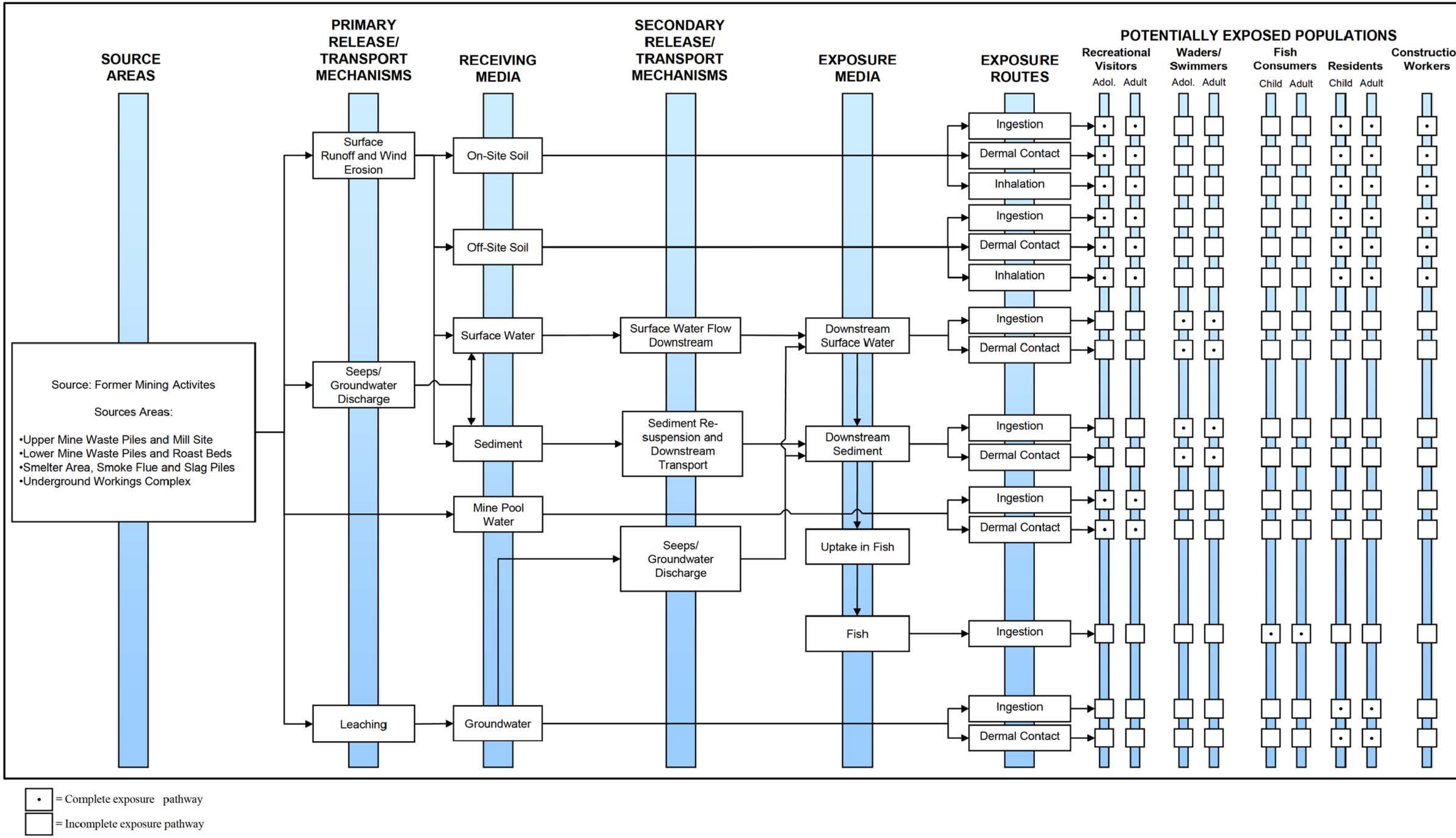
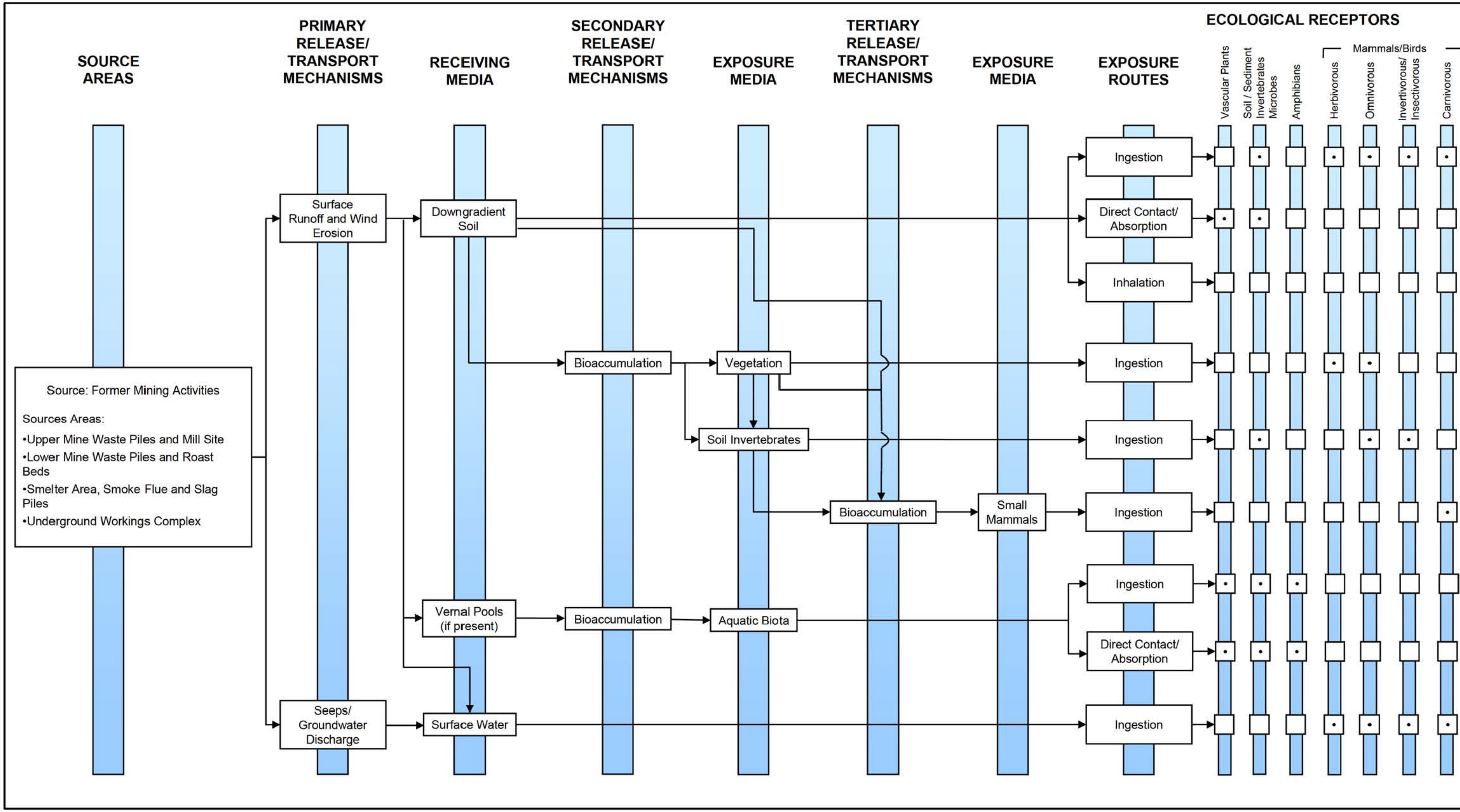


Figure 5-2
Ecological Exposure Pathway Analysis



• = Complete exposure pathway.

☐ = Incomplete or insignificant exposure pathway.

Drawn By: JDF	Checked By: AJB
Filename: MW Locations.mxd	
Date: 6/17/09	Revision No. 03

APPROXIMATE SCALE
140 70 0 140 280 Feet

- Shaft
- Adit
- Prospect Tunnel
- Drill Hole
- Smoke Flue
- Treeline
- Paved Road
- Gravel Road
- Trail
- Parcel Boundary
- Exposure Area Boundary
- 1050 Topographic Contour (ft-msl)
- Stream
- Railroad

FIGURE 8-1

PROPOSED FIELD INVESTIGATIONS
ELY COPPER MINE
VERSHIRE, VERMONT

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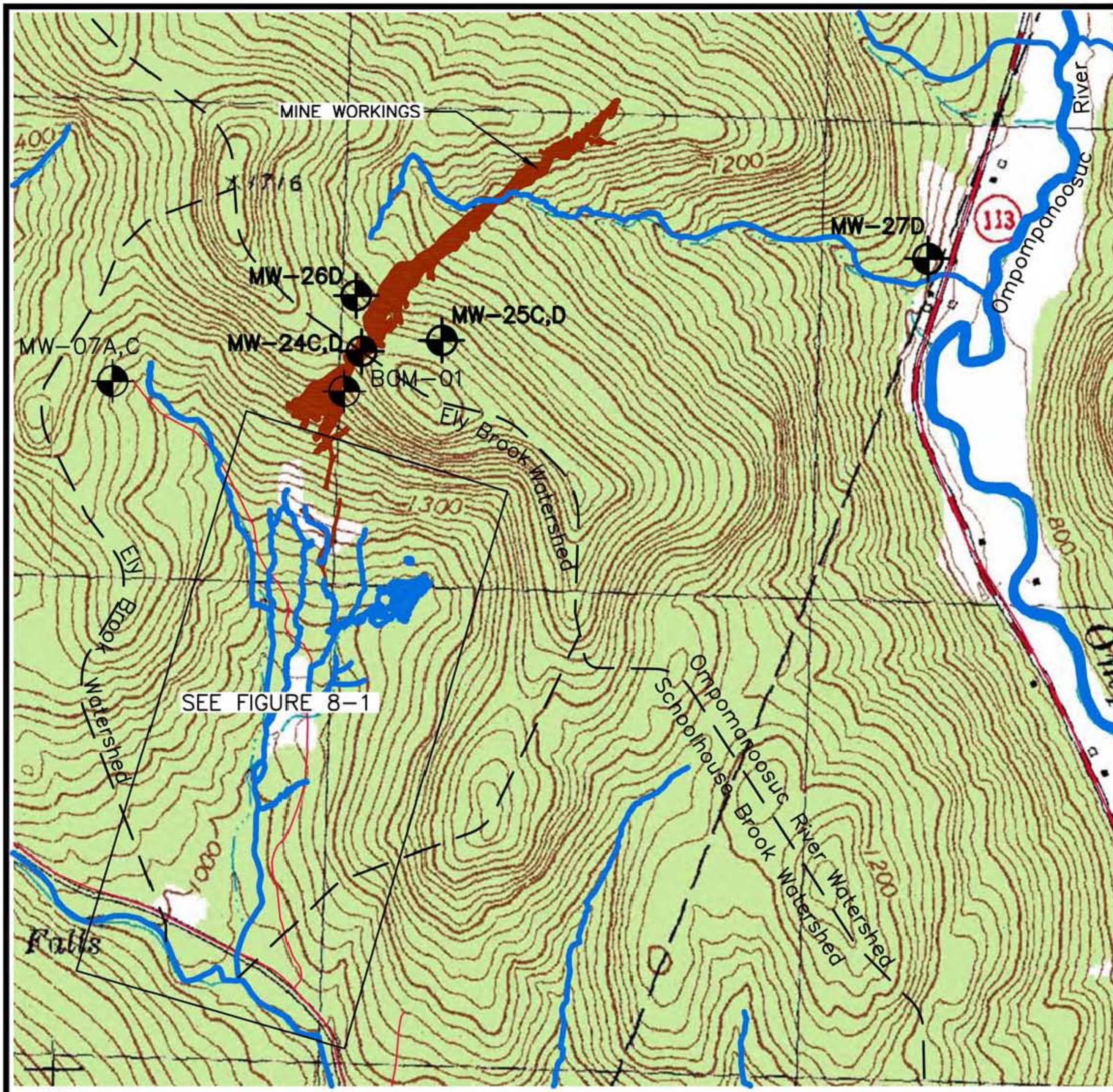

LEGEND

BOM-01 EXISTING MONITORING WELL

MW-25C,D PROPOSED MONITORING WELL

NORTH

0 2000 4000

SCALE IN FEET

Nobis

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FIGURE 8-2

PROPOSED OFF-SITE MONITORING WELL LOCATIONS
ELY COPPER MINE
SUPERFUND SITE
VERSHIRE, VERMONT

PROJECT: 80024.00 | JUNE 2009