DESIGN DOCUMENTS
FINAL USACE SUBMISSION

NON-TIME-CRITICAL REMOVAL ACTION CLOSURE DESIGN

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The Elizabeth Mine Site (the Site) is an abandoned copper and copperas (iron sulfate) mine located in the towns of Strafford and Thetford, Vermont (Figure 1). The Site is in the general vicinity of Copperas Hill and constitutes the largest mining complex of the Vermont Copper Belt. The Site encompasses approximately 970 acres south of Vermont Route 132 along the West Branch of the Ompompanoosuc River (WBOR) between Sargent Brook and Lord Brook and consists of numerous parcels. Property boundaries in the site vicinity are depicted on Figure 2.

Primary physical features associated with the mine are depicted on Figure 3 and include the following.

- Three open rock cuts (referred to as the North Open Cut, South Open Cut, and the South Mine).
- Two pit lakes (located within the South Open Cut and the South Mine).
- Two tailing dams, designated TP-1 and TP-2, which consist of approximately 34 acres of water-deposited tailing (e.g., fine sand and silt).
- A waste rock/heap leach pile, designated TP-3, which consists of approximately 13 acres of mine wastes and residual heap leach piles.
- A waste rock and waste ore pile, designated TP-4, which consists of an area that is less than one acre.
- A series of World War II (WWII)-era mine support buildings, which formerly housed the flotation mill and support operations.
- Subterranean mine workings (referred to as the Underground Workings) that extend approximately 8,000 feet in an approximately north-south orientation from south of the North Open Cut to areas north of the WBOR.

Other physical mine features include numerous adits, shafts, and vents that interconnect with the Underground Workings, the remains of historic (pre-WWII) mine processing areas, structures, and waste areas (e.g., smelter sites, roast beds).

The history of the Elizabeth Mine is described in detail in the *Historic American Engineering Record Documentation – Historic Industrial Landscape Documentation Report* (PAL, 2003).

1.1 PURPOSE AND SCOPE OF WORK

This Basis of Design Report presents the basis for design and construction requirements for the Non-Time-Critical Removal Action (NTCRA) control measures that address the primary sources of acid rock drainage (ARD) at the Site, including TP-1, TP-2, and TP-3. Remediation of the Copperas Factories, as specified in the Record of Decision (ROD) for the Site (EPA, 2006), is also included in the Basis of Design Report due to its location in the immediate area of the NTCRA activities and due to the associated human health risks identified during the Remedial Investigation (RI) (URS, 2006a).

The U.S. Environmental Protection Agency (EPA) is the lead governmental agency coordinating the Elizabeth Mine Removal Actions, and the U.S. Army Corps of Engineers (USACE) is providing technical assistance to EPA through an Interagency Agreement. Other government agency stakeholders include the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA). Technical support has also been provided to EPA and USACE by the U.S. Geological Survey. The State of Vermont is also a key stakeholder and supporting agency working in partnership with EPA.

Work activities completed for this report were performed by URS Corporation (URS) under USACE contract number W912WJ-05-D-0005 and in accordance with Task 9.0 of the March 5, 2007 Statement of Work for Pre-Design and Design Activities Supporting a NTCRA at the Elizabeth Mine.

The design summarized herein adheres to engineering principles and practices generally applied to jurisdictional water dams and civil designs, as appropriate. URS has adopted an approach that follows the current state of the practice as well as general criteria established by Federal and State Agencies. The design work presented herein has been completed under the direction of professional engineers from URS and under review by USACE, EPA, and the Vermont Agency of Natural Resources (VTANR).

1.2 DESIGN BACKGROUND

This Basis of Design Report addresses components of both the NTCRA and the Copperas Factories Remedial Action. Background information pertaining to each of these components is presented below.

1.2.1 Non-Time-Critical Removal Action

The EPA signed an Action Memorandum on September 3, 2002 (EPA, 2002) to document the activities to be performed as part of the NTCRA. The NTCRA area is defined on Figure 2. The applicable, relevant and appropriate regulations (ARARs) for the NTCRA, as identified by EPA in 2002, are provided in Appendix A. The EPA's stated goal for the NTCRA was protection of human health and the reduction of ecological risks to levels that would result in the recovery and maintenance of healthy local populations and communities of biota.

The specific cleanup objectives developed by EPA for the NTCRA were as follows:

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

The basic elements of the NTCRA are summarized below:

- **Surface water and groundwater diversion structures –** The installation of diversion ditches and drainage structures around the perimeter of TP-1, TP-2, and TP-3 to intercept and divert clean water around the tailing dams and waste rock/heap leach piles, to prevent clean water from contacting sulfide-bearing materials, and to intercept shallow groundwater that may be flowing into the tailing dams.
- **Slope stabilization –** Performance of design studies to identify stabilization requirements for the steep slopes of TP-1 and TP-2.
- **Infiltration barrier cover system –** The placement of an infiltration barrier cover over TP-1 and TP-2, likely consisting of a soil/vegetation layer, a drainage layer, a primary barrier, and possibly a secondary barrier to prevent water and oxygen from contacting the tailing, thus minimizing the ARD generation as seepage discharging from the toe of TP-1.
- **Collection and treatment of the seeps along the toe of TP-1 –** The installation of a collection system to capture the seeps that discharge ARD along the toe of TP-1, and a combination of aerobic and anaerobic biological treatment systems to treat the water.
- **Preservation of a portion of TP-3 –** Intact preservation of a portion of TP-3, with no cover or substantial regrading within the preserved area. Some limited work will likely be needed to minimize the erosion in the preservation area. Since the maintenance costs associated with the preservation of TP-3 will be paid for by the State of Vermont, EPA deferred to the State for a determination regarding the extent of TP-3 to be preserved.
- **Collection and treatment of runoff from TP-3 –** Collection of surface water runoff from the preserved portion of TP-3 in an interceptor trench installed along the downgradient edge of the waste rock and heap leach piles and treatment of the runoff using a combination of aerobic and anaerobic biological systems.

Greater details regarding the water treatment and infiltration barrier cover systems are provided in the Action Memorandum (EPA, 2002). One objective of the NTCRA was to consider whether a portion of TP-3 could remain intact in the interest of historic preservation. To preserve any undisturbed portion of TP-3 a separate water treatment system would be required. In 2003, VTANR and the State Historic Preservation Officer announced to the community that the State of Vermont could not support any option that would substantially increase the long-term operation and maintenance costs. As a result, options to preserve portions of TP-3, along with the collection and treatment of the run-off from the TP-3 waste piles were no longer considered as part of the NTCRA design.

As will be discussed in Section 1.3.1, EPA began a Time-Critical Removal Action (TCRA) in 2003 prior to the start of the NTCRA design based on concerns regarding the stability of the tailing dam TP-1. EPA began the design for the NTCRA in 2005.

1.2.2 Remedial Action

A ROD for the Site was issued in 2006 (EPA, 2006). The ROD, based on the RI and Feasibility Study (FS), confirmed that TP-1, TP-2, and TP-3 remain the most significant source areas for ecological impacts to Copperas Brook and the WBOR (Figure 3). The ROD also identified five other areas of the Site as potential current or future threats to human health and the environment. These areas are:

- Upper and Lower Copperas Factories;
- Source areas within the Lord Brook Watershed (South Mine, South Open Cut, and TP-4);
- Sediments in impacted tributaries to Lord Brook, Lower Copperas Brook, and the first few hundred feet of the WBOR Mixing Zone;
- World War II-era Infrastructure Area; and,
- Groundwater associated with the Underground Workings and the NTCRA source areas.

The Remedial Action for each of these five areas is summarized in the following sections. The design of the Remedial Action for the Upper and Lower Copperas Factories is presented in this Report. The design for the remaining components of the Remedial Action will be addressed in the Remedial Design Report.

1.2.2.1 Upper and Lower Copperas Factories

The remedial alternative specified in the ROD for the Copperas Factories, designated CF 4, includes placement of a 2-foot layer of soil over lead-contaminated soil within and surrounding the Upper and Lower Copperas Factories to eliminate human contact risk. Some consolidation of lead contaminated soil may be necessary. In particular, the design will consider which areas are suitable to be covered in-place. Both the Upper and Lower Copperas Factories are considered to be within one Area of Contamination and consolidation of material, if necessary, will not trigger federal or state land disposal restrictions or other placement requirements. The design and construction activities will attempt to preserve the exposed foundations of the Copperas Factories as visible features. To the extent federally-regulated wetlands are identified outside the limits of the waste management area, the altered resources will be restored. The design and construction activities will include measures to minimize the impacts on wetlands through the use of best management practices. The EPA has also determined that there will be unavoidable impacts to historic resources. Mitigation measures, if required under applicable historic preservation standards, will be undertaken. Long-term groundwater monitoring of the Copperas Factories covered area(s) will be conducted, as necessary, as part of the site-wide groundwater component of the remedy to evaluate water quality relative to federal and state groundwater standards.

The primary elements of alternative CF 4 are:

- Placing a sufficiently thick soil cover over contaminated soil with a lead concentration equal to or exceeding 400 milligrams per kilogram (mg/kg) to prevent direct human contact risk.
- Preserving Copperas Factory foundations to the extent possible or provide documentation of historic resources that must be disturbed.
- Preserving historic artifacts, to the extent practicable.
- Performing cover maintenance and inspections.
- Implementing institutional controls, such as restrictive covenants, to protect the cleanup action from damage. Periodic inspections would be performed to ensure compliance with the institutional controls.
- Reviewing the remedy, at a minimum, every five years to determine whether the cleanup action remains protective of human health and the environment.

The ARARs for the Copperas Factories Remedial Action, as identified by EPA in 2006, are provided in Appendix A. The design for the Copperas Factories component of the Remedial Action has been completed as a parallel design effort with the NTCRA design. The basis of design for the Copperas Factory Remedial Action has been included with the NTCRA Basis of Design Report due to the necessary integration of these activities.

1.2.2.2 Lord Brook Source Areas

The remedial alternative specified in the ROD for the Lord Brook Source Areas, designated LBSA 4, includes partial consolidation of surficial mine waste and surface water diversions to minimize the discharge of ARD from the three Lord Brook Source Areas (South Open Cut, South Mine, and TP-4; refer to Figure 3). To accomplish this, exposed waste rock from TP-4 and a portion of the waste rock from the South Mine will be consolidated into the dry portion of the South Open Cut and placed under a cover that will promote surface runoff. The majority of the buried waste rock surrounding the South Open Cut or South Mine will remain in place to minimize disturbance to the forest and the historic features. The amount of material removed from the South Mine area will be determined during design; it is possible that the pit lake within the South Mine may be drained to allow for the removal of waste rock that may be located beneath or adjacent to the pit lake. The South Mine pit lake would be allowed to re-establish itself. The South Open Cut pit lake will also remain and would be controlled by a dam located at the outlet. The design will determine the optimal location for a dam to prevent the uncontrolled release of water from the South Open Cut pit lake.

1.2.2.3 Impacted Sediments

The remedial alternative specified in the ROD for impacted sediment, designated SED 2, relies upon natural processes such as long-term burial and dispersion to change the distribution of contaminated sediments. The long-term result will be that the sediments are no longer toxic to aquatic organisms and the sediments do not cause the surface water to fail VWQS. The NTCRA and LBSA cleanup actions will eliminate the contaminant loading to Copperas Brook, WBOR, and the unnamed tributaries of Lord Brook, also reducing the acidity of the water and the leaching of contaminants into the waters. There is no construction activity associated with this alternative. The EPA will perform an initial baseline surface water, sediment, and biological monitoring program. Long-term monitoring of surface water, sediment, and the biological community will be performed. There will be a review of the remedy, at a minimum, every five years until sediment and water quality standards are achieved to determine whether the cleanup action remains protective of human health and the environment.

1.2.2.4 World War II-Era Infrastructure Area

The remedial alternative specified in the ROD for the WWI-Era Infrastructure Area, designated IA 4, relies upon successfully implementing the NTCRA to achieve VWQS at the point of compliance in Copperas Brook, downstream of TP-1. The only necessary activities to prevent an increase in acid rock drainage will be monitoring of the water quality at the compliance point, along with implementing and monitoring land use restrictions to control any alteration of the WWII-era Infrastructure Area in a manner that would expose waste rock and create additional ARD.

1.2.2.5 Site-wide Groundwater

The remedial alternative specified in the ROD for Site-Wide Groundwater, designated SW 2, includes land use restrictions to prevent future consumption of contaminated groundwater in limited areas of the Site. The contaminated groundwater is found within the Underground Workings of the Elizabeth Mine and within and adjacent to TP-1, TP-2, and TP-3. The TP-1 groundwater restriction may also extend into some of the WWII-era Infrastructure Area, depending on the extent of the final cover for TP-1. Some combination of local ordinances, deed notices, and/or restrictive covenants, coupled with periodic compliance monitoring, will be used to provide awareness that the these areas contain water that is unsuitable for ingestion and to prevent installation of water supply wells into these areas.

1.3 WORK COMPLETED TO DATE

Since the signing of the Action Memorandum for the NTCRA in September 2002, EPA has completed and/or initiated several activities at the Site. These include:

- Implementing the TCRA from 2003 through 2005;
- Initiating NTCRA design activities in 2005;
- Completing the RI and FS in 2006 with ROD signing also in 2006;
- Initiating Remedial Action design for the Copperas Factories in 2006;
- Implementing several limited NTCRA construction activities in 2006 and 2007; and,
- Initiating design for the remaining Remedial Action components in 2007.

A description of the completed TCRA and NTCRA activities is presented in the following two sections.

1.3.1 Time-Critical Removal Action

A geotechnical investigation of tailing dams TP-1 and TP-2, a stability evaluation of TP-1, and an evaluation of the TP-1 decant structure were initiated in the fall of 2002 and completed in 2003 as part of the RI and in support of removal actions at the Elizabeth Mine. The investigation is summarized in a URS report entitled *Geotechnical Investigation – Tailing Dams TP-1 and TP-2* (URS, 2003a), which is included as Appendix B.

Conclusions and recommendations based on the defined site conditions were developed. Key findings included:

- Internal erosion (piping) was occurring at critical areas of the north slope of TP-1. The rate of piping was intermittent and sporadic and tailing discharge volumes appeared to be increasing.
- TP-1 was marginally stable and the results showed that the north and west dam slopes did not meet accepted stability criteria.

- The decant structure showed signs of structural deterioration from sulfate and acid attack, and the flow capacity was reduced by approximately one-half due to blockage. The inlet was also prone to plugging with debris.

Three viable potential dam failure scenarios were identified which included:

- Internal dam erosion (piping) resulting from ongoing dam drainage, increases in surface water infiltration resulting from ponded water, or changes in pore pressure conditions.
- A north slope failure caused by an increase in pore water pressures and the resultant rise in the phreatic surface, or internal dam erosion (piping) and subsequent collapse of the resultant internal void.
- Overtopping, the result of a reduction in the decant pipe flow capacity from a debris plug, pipe collapse, or an extreme storm event.

Based on the conditions identified during the geotechnical investigation, EPA signed an Action Memorandum to initiate a TCRA in the spring of 2003. The TCRA actions were designed to increase the stability of TP-1 and reduce the potential for a dam failure, which posed a public health threat to inhabitants of downstream areas. The three-phase implementation of the TCRA was to accommodate work sequencing and seasonal limitations. Elements of the TCRA are presented on Figure 4. Phase 1 included readily implementable critical elements, Phase 2 included activities implementable during the initial construction season, and Phase 3 included elements that required advanced pre-design and design activities, resulting in implementation during subsequent construction seasons. As an interim measure prior to Phase 1, EPA mobilized high capacity pumps to the Site to provide standby bypass capacity in the event that the decant system became blocked or otherwise failed. In conjunction with the TCRA, EPA developed an Emergency Response Plan in coordination with local response officials.

The TCRA was completed in 2005. The design and supporting analyses for the TCRA activities are documented in the 2003 *TP-1 Decant Diversion and Spillway Design and Technical Specifications* (URS, 2003b) and the 2004 *Buttress Design Report* (URS, 2004). Phases of the TCRA implementation were as follows.

1.3.1.1 TP-1 Seepage Filters

Phase 1 of the TCRA was performed in the spring of 2003 and included installing an access road along the western edge and northwestern corner of TP-1 and placing temporary graded filters to mitigate piping at the toe of TP-1. A sand filter and gravel drain blanket were placed in seepage areas where piping of tailing was occurring, including the area at the base of the starter dam. The access road, which included temporary culverts to channelize surface water flow, had a localized effect on surface water flow patterns at the base of TP-1.

1.3.1.2 TP-1 Decant Diversion and Spillway

Phase 2 of the TCRA was performed during the fall of 2003 and included installing a 36-inch diversion pipe and spillway to replace the existing decant drainage system that formerly transmitted Copperas Brook through the lower portion of TP-1. The diversion construction included installing a drain pipe to intercept shallow groundwater flow toward TP-1 from the east. The inlet/outlet structures and the diversion pipe increased flow capacity for Copperas Brook to pass through TP-1.

The decant pond on the surface of TP-1 was reduced in size and the residence time of Copperas Brook on the TP-1 tailing surface was also reduced. As a result of the improved drainage of water off TP-1, downstream reaches of Copperas Brook experienced a higher energy flow condition during peak flow periods resulting from the ability of the decant diversion to transmit higher flow rates across TP-1. This condition has been somewhat altered by the interim NTCRA construction measures completed during 2007. The interim NTCRA construction measures altered the flowpath of Copperas Brook upstream of the decant diversion and cutoff drainages and surface water runoff from Gove Hill to the east.

1.3.1.3 TP-1 Buttress and Slope Regrade

Phase 3 of the TCRA was performed during 2004 and 2005. The buttress construction involved the placement of approximately 67,000 cubic yards (cyds) of soil obtained from both onsite and offsite sources to construct a soil buttress to stabilize the north face of TP-1. Additional and associated elements of the TCRA Phase 3 buttress construction included:

- Clearing approximately 15 acres north and east of the crest of TP-1 (including borrow area development);
- Removing approximately 30,000 cyds of eroded tailing from the toe of TP-1 with this material being relocated to the surface of TP-1;
- Installing a drain and filter system behind the buttress and installing sedimentation basins located between the buttress and Copperas Brook;
- Regrading the upper face of TP-1 above the buttress to flatten the slope and provide for controlled drainage;
- Regrading the surface of TP-1 to accommodate drainage control to the decant outlet (this included removing a portion of the volunteer vegetation on TP-1); and,
- Establishing vegetation on critical surfaces, including the buttress face and the upper regraded slope to provide stabilization and to limit erosion.

During construction, multiple former wooden decant structures were identified at the toe of TP-1. These structures were shown to be functioning as drains and were a conduit for piping of the tailing. Where encountered, each of these features was retrofitted with a discharge pipe to convey groundwater from the decant structures through the buttress and into the constructed surface water collection features.

The slopes were graded and the buttress was installed to stabilize the tailing dam and prevent the potential for a catastrophic event. A profile of the TP-1 buttress is provided as Figure 5. The installation of a toe drain, sand blanket behind the buttress, and the placement of pipes in the former decant structures were all implemented as measures to ensure the stability of the buttress and tailing dam. The buttress design promotes the drainage of the area at the toe of the tailing dam. The buttress was not designed to improve the water quality associated with the ongoing release of the seepage from TP-1. The NTCRA is tasked with the implementation of the measures necessary to improve water quality. Post-TCRA data suggests that the levels of iron in Copperas Brook and the WBOR have increased, at least during certain seasons as a result of the TCRA. The post-TCRA data is provided in Appendix C.

1.3.2 Non-Time-Critical Removal Action

The EPA identified several components of the NTCRA as ready for implementation in 2005, including diversion of surface water and shallow groundwater around TP-1 and TP-2, the grading and vegetative stabilization of the west side of the tailing dam, and the removal of tailing from a portion of Copperas Brook below TP-1. With the exception of the removal of tailing from a portion of Copperas Brook below TP-1 and installation of the TP-1 west side groundwater interceptor trench, these NTCRA components have been implemented, although currently the TP-2 surface water diversion has only been partially installed.

The NTCRA components complete through the 2007 construction season are shown on Figure 6 and discussed in the following sections. There were no additional construction activities performed in 2008 which were associated with the NTCRA components; however a pilot-scale horizontal drain installation program was performed in 2008 and is briefly summarized below.

The remaining components of the NTCRA have undergone design development during 2006 and 2007. These components include the final cover for TP-1 and TP-2 and the final closure of TP-3. In addition, a preliminary design for the treatment of water discharging from the TP-1 seeps has been developed. The final design for the TP-1 seepage has been delayed to allow for the completion of the design and implementation of other NTCRA measures that will substantially impact the long-term flow rate and loading that will be the basis of treatment design. A preliminary design to handle the current flow and loading has been developed by USACE in the event that interim treatment is implemented. The preliminary treatment system design will be presented in a separate USACE submittal.

1.3.2.1 TP-1 Western Side Stabilization and Diversion Channel

In August 2006, URS submitted the *Tailing Dam TP-1 Western Side Stabilization and Surface Water Channel Design, Elizabeth Mine, Strafford, Vermont* (URS 2006b) to USACE. Design activities presented in this report included stabilization of the west face of TP-1 and collection and diversion of surface water for the west side of TP-1. The work generally consisted of flattening the tailing dam exterior slope and constructing a surface water diversion channel near the toe of the regraded tailing dam. These activities were completed during 2006. A copy of the design report is included in Appendix B.

Due to the depth to the glacial till surface, the surface water diversion along the west side of TP-1 could not achieve shallow groundwater interception. In January 2009 URS submitted a conceptual layout for the TP-1 west side groundwater cut-off trench to USACE which provided the general alignment and conceptual details for a trench to intercept shallow groundwater present at the till surface in this area. As of the date of this report construction of this cut-off trench has not been scheduled. However, the drain will be constructed prior to closure of tailing piles. A copy of the conceptual layout is included in Appendix B.

1.3.2.2 TP-1 East Side Diversion Channel

In March 2007, URS submitted the *Tailing Dam TP-1 East Side Diversion Channel Design, Elizabeth Mine, Strafford, Vermont* (URS, 2007a) to USACE. Design activities presented in this report included constructing a diversion channel to intercept surface water and shallow groundwater before it reaches TP-1 and providing for future conveyance of surface water from upstream of TP-1, including Copperas Brook, around TP-1. These activities were completed during 2007. A copy of the design report is included as Appendix B.

1.3.2.3 TP-2 Diversion Channel

In July 2007, URS submitted the *Tailing Dam TP-2 Diversion Channel Design, Elizabeth Mine, Strafford, Vermont* (URS, 2007b) to USACE. Design activities presented in this report included constructing a diversion channel to intercept surface water and shallow groundwater before it reaches TP-2 and to provide for conveyance of Copperas Brook around TP-2. These activities were initiated in 2007 and are currently partially complete. A copy of the design report is included as Appendix B.

1.3.2.4 Pilot-Scale Horizontal Drain Installation – TP-1

Four horizontal drains were installed through the TP-1 buttress and starter dam during June 2008. The objective of the drain installation was to expedite dewatering of TP-1 by providing supplemental foundation drainage. Additionally, the horizontal drains were expected to lower the piezometric level behind the buttress and starter dam, shorten the seepage pathway for water in this area to discharge through the dam, and reduce the quantity of water that may be impacted by the oxidized tailing located near the outer shell of the dam. The overall effect was expected to result in a reduction in the iron load discharging from the buttress drains to Copperas Brook and subsequently to the WBOR. Drain installation followed methods provided in the workplan dated October 25, 2007 (URS, 2007c).

Following the drain installation field conditions were monitored through 2008 and the resultant data indicates the following:

- The piezometric level behind the buttress and starter dam was lowered by more than 5 feet following installation of the horizontal drains.
- The flow discharging from the 4 horizontal drains averages approximately 16 gallons per minute, while the average flow from the TP-1 buttress drainage system overall has remained relatively unchanged.

- Flow discharging through the newly-installed horizontal drains formerly discharged from a combination of HD-2, HD-3, TD-4, TD-5, and TD-6, which include several of the high-iron load drains.
- Total iron discharge from the TP-1 buttress drains has reduced since installation of the horizontal drains, however there has been a strong and prolonged declining trend in the iron discharge levels since Summer 2007.

Overall, the pilot drain installation met its objectives and the pilot project is considered a success. The four drains will remain open and become a component of the overall drain system for TP-1. Ongoing monitoring data will be used to determine whether an expanded drain installation program is warranted.

1.4 FIELD INVESTIGATIONS IN SUPPORT OF NTCRA

URS completed soil borings, monitoring wells, and vertical hydraulic permeability testing during the fall of 2005 and fall of 2007. URS and EPA have been collecting surface water analytical data and flow measurements from Copperas Brook, WBOR, and the buttress drains periodically throughout 2007 and 2008. A summary of these field activities as well as associated boring logs and analytical data are presented in Appendix C. Surface water data collected prior to October 2007 was provided as a separate submittal to USACE in November 2007 and is included in Appendix C.

1.5 REPORT ORGANIZATION

In addition to Section 1, the Basis of Design Report is organized as follows:

- **Section 2 Conceptual Site Model of the NTCRA Work Area**
  Section 2 provides a summary of site conditions pertinent to the closure design.
- **Section 3 Design Basis – Waste Rock Pile TP-3 Closure**
  Section 3 provides the following information:
  - Assessment of mine hazards.

    - Summary of geotechnical investigations.
    - Identification and evaluation of closure alternatives.
    - Design criteria.

- **Section 4 Design Basis – Tailing dams TP-1 and TP-2 Closure**

  Section 4 provides the following information:
    - Flow conditions and geochemistry characteristics of TP-1 seepage.
    - Summary of geotechnical investigations.
    - Identification and evaluation of closure alternatives.
    - Design criteria.

- **Section 5 Design Basis – Copperas Factories**

  Section 5 provides the following information:
    - Historic preservation criteria.
    - NTCRA closure interaction.
    - Design criteria.

- **Section 6 Construction Requirements**

  Section 6 provides the following information:
    - Construction documents.
    - Construction quantities.

The following conceptual site model defines the current understanding of environmental conditions at the Elizabeth Mine and provides the basis for the NTCRA control measures design. Based on the conditions defined herein, a numerical groundwater flow model has been prepared to support the basis of design. The groundwater model is discussed further in Section 4.3.

The NTCRA area, depicted on Figure 2, is located within the Copperas Brook watershed, which encompasses approximately 366 acres in the central portion of the Elizabeth Mine Study Area. Copperas Brook originates from seepages within waste rock pile TP-3 and flows northward for approximately 1.2 miles, partially through a 36-inch diameter pipe to carry the flow around TP-1, before discharging into the WBOR approximately 3 miles east of the Village of South Strafford. Figure 3 shows the primary physical features of the Copperas Brook watershed.

2.1 GEOLOGY

Waste ore and tailing material within the Copperas Brook Watershed are generally underlain by dense to very dense glacial till. The maximum observed till thickness is 87 feet, encountered at MW-18 located north of TP-1. The till thickness generally decreases with increasing elevation, and at one boring located upslope on TP-3 (TB-03) and one location adjacent to Mine Road (MW-21C) the till was not present between the overburden soil/mine waste materials and bedrock. Locally, the glacial till is overlain by alluvial deposits, waste ore, or tailing.

Bedrock outcrops are present at locations along the sides of the watershed (e.g., along Copperas Road south of the North Open Cut and in the vicinity of the Lower Copperas Factory). The bedrock underlying the Site is the Gile Mountain Formation, which consists of metamorphosed schistose-grade pelite, graywacke, and amphibolite (Howard, 1969; Seal et al., 2001a; Slack et al., 2001). Cross sections of the NTCRA area depicting these material types, their encountered and the inferred contacts, and zones of saturation, are presented on Figures 7 through 9.

2.2 HYDROGEOLOGY

Average annual precipitation for the region ranges from 36 to 40 inches per year (NOAA, 1997), including an average of 98 inches of snowfall occurring between November and April (NOAA, 2000). Site monitoring between 2002 and 2004 recorded an average annual precipitation of approximately 33 inches per year.

Groundwater within the Study Area originates as precipitation that infiltrates soils and mine wastes and travels to the water table, as leakage from stream beds that traverse the Study Area, and as lateral inflow from adjacent uplands. In addition to these sources of recharge, some bedrock groundwater at the Site is recharged by runoff from Copperas Hill that is intercepted by the North Open Cut. Recharge to the groundwater systems of the Study Area have been approximated from site conditions, with the typical rate of groundwater recharge for the watershed estimated to range from 4.7 and 7.1 inches per year. This estimate is consistent with recharge rates estimated at other sites exhibiting similar geologic and topographic conditions.

Based upon a review of site geology, groundwater measurements, and hydraulic properties (i.e., hydraulic conductivity data), three groundwater flow systems exist at the Site. These flow systems include:

- A shallow overburden groundwater flow system, which is present within waste ore, tailing, and alluvial deposits above the glacial till;
- An intermediate groundwater flow system which is present within the glacial till; and,
- A deep groundwater flow system within fractured bedrock.

2.2.1 Shallow Overburden Groundwater Flow System

Groundwater in the shallow overburden flow system is present under unconfined conditions, meaning that the water table (i.e., phreatic surface) serves as the upper boundary of the flow system and the bottom of the flow system is constrained by a low permeability glacial till. At the Site, the shallow overburden groundwater flow system is limited in lateral extent by areas of bedrock and till outcrops (e.g., at the west and south ends of TP-3), or areas where the shallow overburden thickness is limited. As defined by site borings, groundwater in the shallow overburden flow system is present at depths ranging from approximately 2 feet below ground surface (bgs) to more than 95 feet bgs at the former tailing crest of TP-1.

Groundwater in the shallow overburden flow system flows in a northeasterly direction across TP-3, then in a northerly direction across TP-1 and TP-2 and along the alignment of Copperas Brook. Due to the presence of surficial glacial till downgradient of TP-3, the overburden flow system is discontinuous in this area. The average horizontal hydraulic gradient is approximately 0.055. Equipotential contours for the shallow overburden groundwater system, depicted on Figure 10, indicate that shallow overburden groundwater converges toward Copperas Brook, the primary groundwater discharge feature.

2.2.2 Intermediate Groundwater Flow System

Where present, the glacial till unit is interpreted to behave as an aquitard (i.e., semiconfining layer) based upon the low hydraulic conductivity of this unit as compared to the generally higher hydraulic conductivities of the shallow overburden and bedrock groundwater systems, as well as observations of soil conditions (i.e., density and moisture content) during drilling. By definition, an aquitard is a stratigraphic unit (i.e., soil or rock layer) that may be sufficiently permeable to transmit water horizontally and vertically to overlying and underlying groundwater systems in quantities that are significant relative to groundwater flow, but which exhibits an insufficient permeability to provide for appreciable well yield (Freeze and Cherry, 1979).

Equipotential contours for the glacial till groundwater system are depicted on Figure 11. Similar to groundwater flow in the shallow overburden flow system, groundwater in the glacial till converges from surrounding, topographically higher elevations towards the tailing impoundments and follows a northerly flowpath along the alignment of Copperas Brook towards the WBOR with an average hydraulic gradient of 0.09. Groundwater elevation data collected from site monitoring wells is provided in Appendix C. The data define a strong downward gradient existing between the overburden and till flow zones beneath TP-1 and TP-2.

2.2.3 Deep Groundwater Flow System

Groundwater is present within shallow fractured bedrock across the Site. In locations beneath and downgradient of TP-1, TP-2, and TP-3, bedrock groundwater is present under confined conditions as evidenced by:

- Flowing artesian conditions observed in bedrock monitoring wells including MW-11C, MW-12C, and MW-13C associated with TP-3; and
- Artesian conditions at monitoring wells MW-18C and MW-20C associated with TP-1 and TP-2, and at MW-14C and MW-21C associated with TP-3.

In areas proximal to the North Open Cut, bedrock groundwater discharges into the excavations, which behave as a collection sink, as evidenced by flowing fractures visible in the side walls and as inferred from hydraulic data collected from boring MW-23C. Bedrock groundwater collected by the North Open Cut is transmitted through the interconnected Underground Workings toward the mine pool and ultimately the Artesian Vent discharge location.

With the exception of monitoring well couplet MW-14B/C, which has consistently exhibited downward vertical hydraulic gradients from the glacial till into the underlying bedrock, hydraulic data collected from bedrock monitoring wells MW-13C, MW-18C, and MW-20C and associated nested wells completed in shallow overburden and/or glacial till (i.e., MW-13B, MW-18B, and MW-20B) indicate that bedrock groundwater discharges upward into the overlying overburden deposits (Appendix C). As shown on Figure 12, bedrock groundwater flows from the area of the North Open Cut in an east/northeasterly direction and converges with flow from surrounding topographically higher elevations towards the tailing impoundments. Equipotential contours suggest that bedrock groundwater continues to flow parallel to the alignment of Copperas Brook towards the WBOR under an average hydraulic gradient of 0.12.

2.2.4 Groundwater Flow Conditions

The local groundwater flow regime underlying Copperas Brook is comprised of two flow systems (shallow and deep) that are capable of yielding appreciable quantities of water. The shallow overburden groundwater flow system is comprised of limited saturated thicknesses of waste ore at TP-3, tailing in TP-1 and TP-2, alluvial soils (e.g., at MW-13A) and fill (e.g., at MW-19A). The deep groundwater flow system resides in fractured bedrock. These flow systems are separated by an intermediate flow system comprised of the saturated glacial till. Due to its low permeability, the glacial till behaves as an aquitard, limiting the rate of groundwater movement between the shallow and deep flow systems. Groundwater equipotential contour maps developed for the shallow, intermediate, and deep groundwater systems define flow towards and along the alignment of Copperas Brook. Based upon upward hydraulic gradients observed at all but one monitoring well cluster (i.e., MW-14B/C) and artesian flow observed at three monitoring wells (i.e., MW-01B, MW-11B, MW-13C), and an abandoned residential bedrock well near monitoring wells MW-14B/C, groundwater flowing away from the recharge areas is interpreted to flow upward into the overlying shallow overburden and intermediate (glacial till) groundwater systems before discharging to Copperas Brook.

Hydraulic conductivity testing was performed at site monitoring wells and test borings in accordance with the site Field Sampling Plan (URS, 2003c). Water level recovery data and well construction data were used to estimate the hydraulic conductivity of the geologic materials screened by the monitoring wells using standard analytical equations developed by Bouwer (1989) and Hvorslev (1951). Hydraulic conductivity results for the Site are presented in the RI Report and supplemented by additional testing data from monitoring wells installed subsequently (Appendix C). These data indicate that both shallow groundwater and fractured bedrock flow systems are capable of transmitting appreciable amounts of water. The geometric mean hydraulic conductivity of the shallow groundwater flow zone is $3x10^{-4}$ centimeters per second (cm/sec). The geometric mean hydraulic conductivity of the shallow bedrock zone is $1x10^{-4}$ cm/sec. These two flow systems are separated by glacial till, which exhibits a lower geometric mean hydraulic conductivity of $2x10^{-5}$ cm/sec. For the glacial till, this conductivity value is biased high, as for the RI well screens were generally installed in the more permeable zones of the formation to facilitate the characterization of groundwater chemistry. In addition, at several locations vertical zones within the glacial till were not water-bearing. Based on these data and findings, the glacial till is believed to generally behave as an aquitard that limits the rate of groundwater movement flowing between these two systems.

The hydraulic conductivity of the tailing varies by location within the dam as a result of the depositional method of formation. Field testing has characterized the permeability of the outer sand shell of TP-1 as being on the order of $1x10^{-3}$ to $1x10^{-4}$ cm/sec, with some discrete layers having a lower permeability. It is inferred through site observations that the TP-2 sand shell exhibits similar permeabilities. The tailing slimes located in the decant pond area exhibit much lower permeabilities, on the order of $1x10^{-5}$ to $1x10^{-6}$ cm/sec. The average permeability of the tailing is $2x10^{-4}$ cm/sec. Testing of the near-surface tailing on TP-1 and TP-2 generated a mean vertical hydraulic conductivity of $1x10^{-6}$ cm/sec for the tailing slimes and $1x10^{-3}$ cm/sec for coarser surficial materials.

Groundwater seepage velocities for the shallow, intermediate, and deep flow systems were estimated in the RI and are summarized in Table 1.

TABLE 1
PROBABLE RANGE OF GROUNDWATER SEEPAGE VELOCITIES

Groundwater System	Probable Range of Groundwater Seepage Velocity (feet/day)
Shallow Overburden Groundwater System	1.3 to 2.1
Intermediate (Glacial Till) Groundwater System	0.06 to 0.11*
Deep (Bedrock) Groundwater System	5.0 to 50.4

*As noted previously in the discussion of hydraulic conductivity test results, the estimated groundwater seepage velocities for the glacial till are understood to be biased high.

2.3 SOURCE AREA CHARACTERIZATION

The ROD identified TP-1, TP-2, and TP-3 as the primary ARD source areas at the Site. Additional characterization of these areas was performed as part of the NTCRA pre-design activities, as noted in Section 1.4 and detailed in Appendix C. Excluding surficial soil and terrestrial samples, sample collection and monitoring points located in and around the source areas are shown on Figure 13. Characteristics of these source areas, as well as of the Copperas Factories, are discussed in the following sections.

2.3.1 TP-3

TP-3 encompasses approximately 12.8 acres of waste ore, waste rock, and former heap leach piles. Topography in this area is steeply sloped (33 percent grade), with several terraces existing between the North Open Cut and Mine Road. The TP-3 waste materials contain copper at concentrations ranging from 850 to 6,600 mg/kg and total sulfur ranging from 1- to 5-percent by weight. The paste pH of the wastes ranges from 2.1 to 3.6 standard units (SU). Two former adits are buried beneath TP-3. Adit No. 2 is located within the footprint of TP-3 and is believed to have a minimal effect on surface water drainage patterns. Adit No. 3 is located downslope from TP-3 adjacent to Mine Road. This feature affects local surface water runoff patterns by acting as a sink (i.e., drain). The locations of the adits are shown on Figure 3.

TP-3 is highly eroded, with an extensive network of gullies and erosion rills revealing timbers and planks from the former roasting operations. This erosion has resulted in waste ore containing elevated concentrations of metals being carried into Copperas Brook during storm events and snowmelt, as evidenced by observation of surficial material erosion and the significant deposition of waste material in the lower stream channel of Copperas Brook as far north as TP-2. TP-3 was identified as a major source of metals and acidity in Copperas Brook during early Site investigations (Hammarstrom et al., 2001 and 2003; Seal et al., 2001a and 2001b), a finding documented in the ROD.

Several key factors contribute to the significance of TP-3 as a source of metals and ARD including:

- Steep topography which promotes erosion;
- A large area with limited waste thickness which promotes ready access to atmospheric oxygen;
- Base metal-rich character of the wastes;
- Sand- to cobble-sized sulfidic waste on the surface, which provides a supply of exposed sulfides for reaction;
- Unsaturated condition of the waste piles and the distribution of material grain sizes which transfer moisture and allow for oxygen entry; thereby advancing the ARD-generating processes throughout the thickness of the waste piles; and,
- Engineering of the landscape to maximize percolation, infiltration-driven contact with the ore, and collection of the infiltrate as surface water within the lower TP-3 area.

TP-3 is underlain by bedrock or by glacial till. Anecdotal information regarding the operation of TP-3 suggest that the till was removed in areas to create preferred drainage pathways for the copperas leachate to be transported from the roast piles to the production areas located downslope. Testing confirms that the glacial till is not acid producing (paste pH values near neutral, and positive net neutralizing potential [NNP]), although in select samples the shallow till exhibited elevated concentrations of base metals and acidity, likely due to the downward migration of ARD into the till. Through visual assessments from rock coring performed within TP-3, near surface bedrock is not characterized as being ore-bearing. This is in contrast to the observations of the east wall of the North Open Cut, which shows rock adjacent to the North Open Cut in this location contains sulfides associated with the mined ore shoot.

Based on analytical testing of surficial and subsurface samples collected from TP-3, as well as surface water samples collected from the headwaters of Copperas Brook located within the TP-3 footprint, TP-3 wastes are sources of metals and acidity to Copperas Brook and to local groundwater. The oxidative weathering of the pyrrhotite-containing waste ore generates acidity and is a source of base metals and inorganic constituents including aluminum, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, sulfate, thallium, and zinc.

The steep portion of TP-3 located adjacent to the North Open Cut does not contain a persistent saturated zone within the waste. However, lower TP-3 located adjacent to Mine Road does include an area of continual saturation.

2.3.2 TP-1 and TP-2

Both TP-1 and TP-2 were constructed by tailing slurry deposition onto an aggraded tailing beach. As a result of this depositional process, the coarsest tailing fraction is located along the face of the dam within the outer sand shell and the finer tailing slimes are located beyond the beach area in the vicinity of the tailing pond. The grain size distribution and the distribution and concentration of metals within TP-1 and TP-2 are highly variable, likely the result of variations in both mined ore and the effectiveness of the beneficiation process over time. The average sulfur content of the tailing is approximately 10 percent by weight; the average iron content of the tailing is between 8 and 20 percent by weight.

The exposed surficial tailing materials are oxidized and exhibit acidic paste pH conditions, high Acid Generating Potential (AGP), and contain elevated concentrations of metals including aluminum, cadmium, chromium, cobalt, copper, iron, molybdenum, nickel, thallium, and zinc. The oxic tailing exhibited paste-pH values typically less than 3 SU and negative NNP indicative of acid producing potential (NNP values between -20 and -100). Efflorescent salts are commonly observed surrounding the wetted perimeter of the decant pond, likely the result of the upward capillary draw of pore fluids or evaporation of surface water. Samples of the oxic tailing collected from the tailing surface were tested following Synthetic Precipitation Leaching Procedure (SPLP) and leachate generated from the testing contained elevated concentrations of aluminum, cadmium, copper, iron, and zinc, relative to surface water quality criteria.

At depth, the tailing material is anoxic, black in color, with near-neutral paste pH conditions (i.e., generally between 6 and 7.5 SU) and NNP values indicative of acid producing potential (NNP values typically less than -100). Analytical tests performed on the anoxic tailing identified elevated concentrations of aluminum, cadmium, chromium, copper, iron, and zinc. Samples of anoxic tailing were tested following SPLP procedures and leachate generated during the testing process was not found to contain elevated concentrations of base metals with the exception of manganese.

Although groundwater monitoring did not indicate the presence of significant groundwater mounding within the tailing piles, portions of TP-1 and TP-2 are saturated. Groundwater within the tailing piles generally exists only within the anoxic material; however, saturated oxidized tailing were formerly located near the toe of TP-1. Groundwater contained within this oxidized tailing exhibited strong oxidizing conditions with high acidity/low pH, and high dissolved base metal content. Geochemistry of the groundwater within the anoxic tailing is characterized as exhibiting near-neutral pH and depleted dissolved oxygen levels. The tailing is underlain by glacial till, which appears to represent a semi-permeable barrier to flow, as noted previously. The glacial till is not acid producing and contains some calcite and mafic silicate minerals that contribute to the Acid Neutralizing Potential.

Due to the flat surface of TP-1 and low flow velocities within the decant pond area, the tailing surface contributes little direct sediment load to Copperas Brook below the decant pond, except possibly during extreme high-flow events where short-circuiting of the pond may occur. However, the stream channel of Copperas Brook in areas downstream of the decant diversion outlet bisects a fan of eroded tailing material located below the toe of TP-1. The steepness of the original TP-1 crest in combination with the fine-grained tailing properties and lack of vegetation contributed to significant tailing erosion from the face of TP-1, with materials redeposited in areas extending beyond the toe of TP-1. A portion of the tailing debris fan immediately adjacent to the base of TP-1 was removed as part of the TCRA construction, however, tailing materials near and within the Copperas Brook channel downstream of the decant diversion outlet remained following TCRA completion. This redeposited tailing is highly susceptible to entrainment by the high surface water velocities of the scour channel in this area. Similar erosive processes occur along the crest of TP-2; however, the toe of TP-2 is currently situated within the tailing footprint of TP-1 so this migration of material is confined to areas within the perimeter of the tailing features.

Groundwater from within the tailing dams contribute to seepage emanating from the toe of TP-1. The former (pre-TCRA) seeps were anoxic, with near neutral pH, depleted concentrations of dissolved oxygen, and elevated concentrations of iron, with dissolved ferrous iron (Fe^{+2}) to total iron ratios of between 0.49 to 1.0. Recent samples collected from the 4-inch drains installed at the seep locations as part of the TCRA are similarly anoxic and exhibit surface water standards exceeding criteria for dissolved-phase cadmium, iron, lead, and zinc. The sample from the eastern-most location also exhibited surface water standards exceeding criteria for dissolved-phase aluminum and copper.

When exposed to oxygen, the anoxic seep flow undergoes geochemical changes resulting from the oxidation and hydrolysis of the ferrous iron to ferric iron, thereby completing the pyrrhotite oxidation process that was oxygen-limited within the tailing pile. These changes result in the reduction of pH and the precipitation of ferric iron oxyhydroxides.

2.3.3 Copperas Factories

The former Copperas Factories are situated east of TP-3 adjacent to Copperas Brook and Mine Road. The remains of the former Copperas Factories include two stone foundations and debris scatter areas associated with the former copperas processing operations. The foundations, identified by Public Archaeology Laboratory, Inc. (PAL) as the Upper and Lower Copperas Factories, formerly housed evaporators, crystallizers, and packaging operations which were in operation during the early and mid 1800s prior to the shift in mine extraction from copperas to copper. Copperas processing reportedly included evaporation using lead-lined vats. The Upper Copperas Factory foundation is located along the downgradient side of TP-3 adjacent to Copperas Brook. The Lower Copperas Factory is located further downslope from TP-3 and south of Copperas Brook. The Upper Copperas Factory was reportedly 267 feet long and 94 feet wide during its largest recorded configuration in 1827 and 1842 (PAL, 2003). An 1870s account reported by PAL (2003) provided dimensions for the lower structure as approximately 120 feet long by 75 feet wide. The factories and surrounding area downslope of the TP-3 waste piles were identified in the ROD as containing elevated levels of lead in the surficial soils. Based on findings from the pre- and post-ROD field sampling, the elevated lead concentrations in this area are located in close proximity to the Copperas Factories and there is no indication of transport of significant concentrations of lead to other locations or media within the watershed.

2.4 NATURE AND EXTENT OF IMPACTS

In general, analytical results indicate that soil degradation due to mining activities within the NTCRA area are restricted to the identified source areas and immediately surrounding areas. Waste ore in TP-3 and tailing in TP-1 and TP-2 are acid generating and contain elevated concentrations of cadmium, copper, iron, selenium, thallium, and zinc. Analytical data from eroded tailing samples collected at the toe of TP-1 are consistent with the low pH, low alkalinity, and elevated metal concentration detected in shallow groundwater samples collected from this area. Soil samples from these source areas exceed site-specific, baseline ecological risk assessment (BERA)-based delineation criteria for metals including cadmium, copper, selenium, and zinc, as well as less frequent criteria exceedance of molybdenum and thallium. The findings pertaining to soils in the NTCRA area are as follows:

- Soil containing elevated lead concentrations exceeding the human health-based criteria was detected in samples collected near the copperas factory foundations. Lead concentrations in these soils also exceed risk-based effects levels for some wildlife populations. The lead is likely related to lead-lined vessels used during copperas production.

- Copper and selenium were detected at concentrations exceeding the delineation criteria in floodplain soils throughout the downstream Copperas Brook drainage. However, concentrations decreased with distance from the source area and floodplain soils located along the channel downstream of the source areas were not identified as posing an unacceptable ecological or human health risk.
- The BERA did not address TP-1, TP-2 and TP-3 because these areas were identified as a major source of contamination and identified for cleanup as part of the NTCRA. However, the BERA evaluated soil conditions in the vegetated areas bordering the waste piles and concluded that metal concentrations in these soils were not of a magnitude that presented risk of adverse alterations to populations or communities of ecological receptors inhabiting or utilizing these areas.

Surface water impacts related to source areas extend from the upstream origin of Copperas Brook at TP-3 to the WBOR as summarized below.

- The dominant source of non-ferrous base metals is TP-3, which on average accounted for over 80 percent of the copper, 25 percent of the sulfate, and 30 percent of the iron reaching the WBOR from Copperas Brook during pre-NTCRA conditions.
- The upper surface of tailing dams TP-1 and TP-2 also contributed a notable load of metals to Copperas Brook during pre-NTCRA conditions, although to a lesser degree and more intermittently.
- The tailing fan located immediately north of TP-1 contributed a significant load of base metals to Copperas Brook, although this area was partially remediated as part of the TCRA implementation.
- The seepage from the toe area of TP-1 (following the TCRA this flow emanates from the buttress drainage system) contributed 70 percent of the iron and 60 percent of the sulfate reaching the WBOR from Copperas Brook during pre-NTCRA conditions.
- Because the toe seepage rates remain relatively constant throughout the year, the seeps at the toe of TP-1 dominate the chemical characteristics of Copperas Brook during low-flow periods when the upper reaches of Copperas Brook (upstream of TP-1) exhibit negligible flow contributions. During high-flow events (i.e., storm flow events), the overall watershed, and the upper reaches in particular, exhibit acute and sudden responses to precipitation events, during which time runoff from TP-3 dominates the chemistry of Copperas Brook.
- During normal or low-flow conditions, the ARD-related metals in Lower Copperas Brook surface water are present almost entirely in their dissolved phase, which is primarily due to the low pH of the Copperas Brook surface water.

During high-flow storm runoff events, sampling results indicate that high sediment load entrained in the flow emanating from TP-3 also contributes a significant total-phase metal fraction to Copperas Brook. Similarly, high sediment load has been observed during high flow periods from the TCRA sediment basin (which collects TP-1 seepage flows) and from the channel bisecting the TP-1 tailing fan area.

- Samples collected from Copperas Brook do not meet Vermont Department of Environmental Conservation Class B aquatic life use criteria. Copperas Brook is considered to be severely impacted based on fish and benthic community assessments.
- Surface water toxicity results indicate measurable effects associated with exposure to surface water collected from Copperas Brook. The surface water of Copperas Brook caused 100 percent mortality to test organisms even at a test-dilution of 10 percent.

Results of the BERA indicate that the effects of exposure to surface water in and along Copperas Brook may present an unacceptable risk of harm to the periphyton community, the benthic macroinvertebrate community, the fish community, and the woodland amphibian community.

Sediments exceed delineation criteria for copper and selenium throughout Copperas Brook. The origin of these sediment impacts is through one or more of the following mechanisms: (1) The metals are part of the mineralogy of waste ore that has been chemically weathered (either in place or in adjacent areas) to sediment-sized particles and these particles have been physically transported by runoff or stream flow and then deposited along the channels of the drainageways; (2) the metals have co-precipitated with metal hydroxides; or (3) metals have sorbed from surface water onto metal oxyhydroxide coatings in the sediment.

Sediment impacts related to mine wastes extend from TP-3 to the mouth of Copperas Brook and discharge into the WBOR within an area designated as the WBOR Mixing Zone. Iron precipitation and waste ore are also present within the stream channel and within the sediment of Copperas Brook during storm flow events. Sediment toxicity testing indicates significant mortality in test organisms resulting from exposure to

Copperas Brook sediment. Due to steep channel gradients and frequent high flow rates within Copperas Brook, the channel is predominantly self scouring, with materials generally being transported toward, and discharging into, the WBOR.

The BERA concluded that the effects of exposure to Copperas Brook sediment may present an unacceptable risk of harm to the benthic macroinvertebrate community, the fish community, and the woodland amphibian community.

Groundwater impacts beneath and immediately downgradient of TP-1, TP-2, and TP-3 present an unacceptable risk to human health. The extent of groundwater impacts associated with the waste piles does not extend beyond the immediate areas of TP-1, TP-2, and TP-3. Groundwater impacts related to the source areas are summarized below.

- Analytical results from shallow overburden groundwater within TP-3 indicate that cadmium, copper, manganese, and nickel are present at concentrations exceeding Maximum Contaminant Levels (MCLs); however, the shallow overburden groundwater impacts are generally limited to groundwater within the waste material and immediate surrounding areas.
- Data indicate that ARD impacts exist within the glacial till and shallow bedrock beneath TP-3, likely related to surficial impacts from TP-3 as opposed to deeper impacts from the Underground Workings. The distribution of groundwater exceeding criteria in these zones indicate that reductions in till and bedrock groundwater quality are generally limited to areas underlying TP-3 due to upward hydraulic gradients in bedrock groundwater and the low permeability of the overlying glacial till down-valley from TP-3.
- In the deep anoxic tailing groundwater zone, only manganese and thallium (one sample only) exceeded groundwater criteria in the samples collected. These data indicate that the anoxic tailing in the northern portion of TP-1 is not a source of ARD impacts to groundwater.
- The till groundwater samples collected from beneath the tailing areas did not exhibit ARD impacts, with only manganese detected at concentrations above the MCL.

For waste ore located in downslope areas of TP-3, the upward hydraulic gradients within the bedrock limit the potential for downward migration of impacts. Groundwater discharges to surface water in these areas, as well as at locations further downslope where

Copperas Brook first is channelized from the coalescing runoff channels and seeps of TP-3. These upward hydraulic gradients limit the lateral extent of ARD to downgradient areas immediately east of TP-3. Bedrock groundwater affected by TP-3 is interpreted to discharge upward into the shallow overburden near the toe of TP-3 where the till is not present and into the glacial till in the areas between Copperas and Mine Roads. A portion of this groundwater discharges as seepage into the headwaters of Copperas Brook and the remainder is incorporated into the shallow overburden groundwater system that flows in a northeasterly direction toward MW-13A and eventually discharges to Copperas Brook east of Mine Road.

As the groundwater flow path lengthens, ARD is likely to be attenuated through dilution, neutralization, and pH-induced adsorption mechanisms as flowpaths encounter carbonate minerals within the till and the bedrock.

The downgradient extent of groundwater quality reduction from TP-3 is defined within the footprint of the lower TP-3 area by the MW-13A location where shallow impacts representative of ARD were noted (Figure 13). However, the MW-13A well screen is located within waste ore materials likely placed at this location either through fill placement or through erosional deposition. Downgradient of this point along the Copperas Brook channel, the overlying alluvium was observed to be absent in places. In areas upslope from the TP-2 borings, data indicated that there was no saturated unit overlying the glacial till (i.e., boring locations MW-22A and MW-29B). Therefore, ARD in groundwater from TP-3 is believed to extend only as far as the waste ore debris fan located downstream from TP-3. The general location of the downgradient extent of the TP-3 debris fan is depicted on Figure 13.

Groundwater impacts from TP-1 were identified in monitoring wells located within and adjacent to the waste material distributed across the toe of TP-1 where the water table was formerly located in oxidized tailing. In general, impacted groundwater has low pH values and elevated specific conductance, sulfate, and dissolved-phase aluminum, cadmium, copper, iron, lead, manganese, nickel, strontium, thallium, and zinc as compared to the MCLs (where applicable) and background conditions.

Data from shallow overburden monitoring well couplets indicate that groundwater near the surface is more oxidized as compared to deeper groundwater flowing in the underlying alluvium at these locations. The higher oxidation of the shallower groundwater is indicative of the greater potential for acid generation. Samples collected from the underlying glacial till in this area did not exhibit chemistry indicative of ARD impacts.

Shallow groundwater samples collected from downgradient areas beyond the extent of tailing also did not exhibit chemistry indicative of ARD impacts and provided for delineation of the shallow groundwater quality reductions at the toe of TP-1 prior to implementation of the TCRA. The groundwater flowpath in this area is relatively short and through attenuation processes (as described above) and surface water discharge, groundwater quality impacts are confined within the tailing depositional area immediately downgradient of the tailing fan. The majority of the tailing at the toe of TP-1, including the majority of the materials screened by groundwater monitoring wells/probes with impaired groundwater quality, was excavated and relocated to the unsaturated areas on TP-1 during the TCRA. The sample collected from P-3 in 2007 contained no ARD impacts, indicating that the removal of the tailing in this area has substantially reduced the magnitude and extent of ARD in shallow groundwater at the toe of TP-1. Cadmium, manganese, and lead exceeded MCLs at MW-5, which is screened in the shallow veneer of overburden soils at the toe of TP-1 to the east of P-3. This well is located in an area where waste was not removed as part of the TCRA. The chemistry at MW-05 is indicative of groundwater impacts associated with oxidized tailing as identified in the ROD; however the groundwater at this location is de minimis in nature and extent.

2.5 SOURCE AREA CONDITIONS SUMMARY

In summary, the conceptual model of the Copperas Brook Watershed defines the source areas for the NTCRA as follows:

- TP-3 consists of sulfide- and metal-bearing mine wastes including waste ore, waste rock, and heap leach piles located at the top of the Copperas Brook drainage basin. TP-3 materials are unconsolidated, steeply sloped, highly erodable, and generally free of vegetative cover. The major transport mechanisms for the TP-3 waste are erosion and surface water run-off, both of which transport contamination downstream from TP-3 to lower reaches of Copperas Brook.
- The TP-3 waste material is exposed to atmospheric conditions resulting in continual production of ARD as water cycles through the sulfide-bearing waste. TP-3 represents the most significant source of ore-content metals, including copper and zinc (but excluding iron), to Copperas Brook and the WBOR.
- The TP-3 waste materials are underlain by glacial till and bedrock. The unconsolidated, coarse-grain materials have high infiltration rates and are generally free-draining; there is no permanent water table located within the TP-3 wastes. Resulting from its origin as a functional feature of the copperas production infrastructure, TP-3 directs infiltration through the waste area, concentrating the discharge at the base of the upper area adjacent to the Upper Copperas Factory. The headwaters of Copperas Brook also originate in this area. The residence time for precipitation transfer is short and the storm hydrograph shows a rapid peak. Bedrock groundwater underlying the feature discharges into the lower portions of TP-3, contributing to the base flow of Copperas Brook and contributing additional water to the ARD generating process.
- TP-1 and TP-2 are tailing impoundments that fill the former Copperas Brook valley downstream of TP-3. The tailing generally overlies channel alluvium or organic material, representative of the former valley surface. These materials are underlain by a down-valley thickening sequence of glacial till. The till exhibits poor groundwater conductance and is considered an aquitard, although in areas near the base of the thickest sequence of glacial till the hydraulic conductivities were higher, possibly reflecting conditions of the underlying regolith. Based on hydraulic conditions between the till and the tailing, groundwater is generally discharging from the tailing into the underlying glacial till unit; however most of the groundwater within the tailing impoundment ultimately discharges from the toe of TP-1 as shallow groundwater or surface water.
- The bases of the tailing impoundments are saturated. Groundwater contained within the anoxic tailing found at depth in the tailing impoundments exhibits low concentrations of the non-iron contaminants of concern (i.e., cadmium, copper, zinc); however, concentrations of manganese, sulfate, and iron are elevated. Iron concentrations in groundwater in the vicinity of the oxidized tailing present at the

former face of the tailing dam are significantly elevated. As a result, the drainage emanating from the toe of TP-1 represents the most significant source of iron to Copperas Brook and the WBOR.

- When complete, the NTCRA diversion channels will isolate the tailing impoundments from surface water run-on, and from shallow groundwater inflow, in some areas. This includes the interception of surface water run-on and shallow groundwater inflow to TP-2 and to the east side of TP-1; and the interception of surface water run-on to the west side of TP-1.

The conceptual model of the Copperas Brook Watershed defines the Copperas Factories source area for the Remedial Action as follows:

- The Upper and Lower Copperas Factories consist of stone foundations and debris scatter areas containing elevated levels of lead in the surficial soils. There is no indication of transport of significant concentrations of lead to other locations or media within the watershed.

2.6 CLOSURE OBJECTIVES

The objectives of the NTCRA, as defined by EPA in the Action Memo (EPA, 2002), are as follows:

1. Achieve water quality standards in the WBOR by preventing or minimizing discharge of water with mine-related contaminants to Copperas Brook and the WBOR.
2. Minimize erosion and transport of tailing, mine wastes, or contaminated soil into the surface waters of Copperas Brook and the WBOR.
3. Provide for long-term stability of the waste piles and tailing dams.
4. Consider measures to minimize and avoid an adverse effect on historic resources at the Site.
5. Comply with all ARARs.

These objectives are the basis of the NTCRA closure design which is presented in the following sections of this report. The design addresses each of the defined NTCRA source areas, as well as the Copperas Factories as stated previously, and accounts for the characteristics and conditions of each feature as presented in the preceding discussion.

TP-3 is one of the three waste areas targeted for response action as part of the NTCRA (Figure 2). TP-3 is the major source of inorganic constituents to downstream surface water, including cadmium, copper, and zinc. To achieve the NTCRA objectives, the design focused on alternatives that would reduce the discharge from the TP-3 area to levels that would potentially result in Copperas Brook meeting water quality criteria downstream of TP-1.

3.1 PHYSICAL CONDITIONS OF WASTE ROCK PILE TP-3

TP-3 is a 12.8-acre mine waste feature located north and east of the North Open Cut, extending to the east beyond Mine Road. It consists of an estimated 150,000 cyds of waste ore, waste rock, and heap leach piles with measured thicknesses up to 24 feet. Copperas Brook originates within the footprint of TP-3. With the exception of the area adjacent to Mine Road, topography in this area is steeply sloped (33 percent grade), with several terraces and incised channels located between the North Open Cut and Mine Road. The unconsolidated and largely unvegetated waste ore piles that comprise TP-3, coupled with the steep topography, result in mass erosion from the feature during periods of surface water runoff.

3.2 MINE HAZARD ASSESSMENT

URS oversaw a mine hazard assessment of TP-3 in May 2007 which included a review of available geologic reports, mine process and mineral exploration documentation, interviews with spelunkers familiar with the mine, and a site reconnaissance. Findings of the mine hazard assessment are based on available records, personal interviews, and visual observations from ground surface. It should be noted that subsurface conditions may vary from those inferred, and recommendations made are provided as general guidance only. The mine hazard assessment evaluated ground stability in the vicinity of the North Open Cut and adits, manways, and shafts in the vicinity of the NTCRA work area (Figure 3). The mine hazard assessment findings associated with each feature are provided in the following paragraphs.

3.2.1 North Open Cut

The west wall of the North Open Cut is the foot wall of the mined ore-body and consists of a bedding dip that slopes eastward at an approximately 80-degree angle toward the floor of the North Open Cut. The lip of the wall appears to have a 10- to 15-foot cover of natural soils. The west wall face appears to be generally stable; however, slabs of rock could slip from the wall into the North Open Cut along the strataform surface behind the cut face. The east wall of the North Open Cut is the hanging wall of the mined orebody and is covered by a band of waste rock ranging up to approximately 10 feet thick. Below the surface waste rock, the east wall is underlain by approximately 10 to 15 feet of poor, to very poor quality weather-weakened rubble-like rock material followed by relatively fresh but broken fair quality rock. East wall stability is highly suspect, and the failure of even a small element of this rock could initiate failure of neighboring masses resulting in a more extensive failure. Failure could be initiated if the rock is subjected to even modest vibrations of earth-moving equipment or impact of falling rock or soil debris. The North Open Cut itself is unsafe for personnel-operated earth-moving equipment.

3.2.2 The 1898 Adit

The 1898 Adit is believed to be approximately 8 feet wide by 8 feet high and was approximately 1,400-feet-long at the time of mining. The floor of the 1898 Adit rises at approximately a 5.4 percent grade. The ground surface above the initial 100 linear feet of adit adjacent to the portal has caved and the resulting scarp of the 50-foot wide cave-in is approximately 10 to 12-feet high. No rock is exposed in the cave-in.

Verbal accounts indicate that the 1898 Adit was not formally closed at the cessation of mining operations, other than construction of a fenced enclosure across the adit portal. According to spelunker reports, there is a pool of water contained within the Adit and behind the surface collapse.

Based on current conditions, ground surface beneath the Adit within approximately 150 feet of the adit portal is not stable and traffic across this area could initiate further cave-in failures. The risk of traffic-induced ground failure further west along the adit alignment is lower.

3.2.3 Adit No. 2

Adit No. 2 is approximately 200 feet long and is located on the east side of Copperas Hill approximately 225 feet east and 50 feet north of the North Open Cut. The only surface evidence of this adit is a shallow, east-facing scarp in the soils. It is unclear if this adit is the Upper Adit, opened in 1831 or a shallow adit excavated by Tyson in the 1880s. It is assumed that this adit had about a 6-foot vertical profile and sloped upward at a slope of around 3 to 5-percent. The estimated combined thickness of the overlying material is about 10 feet in the inlet portal, thereby resulting in the initial 100 feet of adit being driven through soils. Based on observed conditions and assumed rock contacts and adit dimensions, traffic across the initial 150 feet of adit length could initiate cave-in failure. The risk of traffic-induced ground failure further west along the adit alignment is lower.

3.2.4 Adit No. 3

Adit No. 3 is located along Mine Road approximately 800 feet south-southwest of the intersection of Copperas Road. According to historic information (Kierstead, 2001), the original adit portal was located approximately 100 to 200 feet east of the current location. There is no visual evidence of the former/original portal in the area.

This adit is assumed to have an upward slope of approximately 3 to 5-percent. Based on observed conditions and assumed rock contacts and adit dimensions, it is estimated that traffic over the initial 150 feet of the adit alignment could initiate adit collapse. The risk of traffic-induced ground failure further west along the adit alignment is lower.

3.2.5 Tyson Manway/Air Shaft

The Tyson Manway/Air Shaft is visible as a 4-foot by 4-foot opening in the weathered rock approximately 250 feet north-northeast of the northern face of the North Open Cut. The cavern associated with this shaft is understood to be at least 100 feet wide and up to 200 feet in height. The crown of the void under the Tyson Manway/Air Shaft is capped by approximately 25 to 30 feet of rock (as reported). The thin rock thickness and the layered nature of the schists could result in a rockfall within the cavern and possible ground failure over the void. Proper precautions should be employed when working with equipment in this area. Recommended equipment setbacks associated with this feature are depicted on Drawing C-008 (Appendix D).

3.2.6 Tyson Shaft No. 1

Tyson Shaft No. 1 is located 100 feet north of the Tyson Manway/Air Shaft. The upper portion of this shaft has caved or been filled in, as the entry is evidenced by a low soil scarp. Tyson Shaft No. 1 appears to have penetrated the Tyson Manway/Air Shaft cavern roof on its western side. Reportedly, ground cover above the cavern crown is approximately 125 feet thick. Proper precautions should be employed when working in this area and heavy equipment should not operate near the shaft as natural events, vibrations, or weight could renew caving in and around the shaft that could result in expansion of the caving cone. Recommended equipment setbacks associated with this feature are depicted on Drawing C-008 (Appendix D).

3.2.7 Tyson Shaft No. 2

Tyson Shaft No. 2 is located approximately 100 feet north-northwest of Tyson Shaft No. 1. The shaft site is evidenced by an approximately 50-foot-diameter, 25- to 30-foot-deep cave-in crater. Shaft failure may be relatively recent due to the lack of vegetation within the crater. Ground cover over the cavern is estimated to be approximately 200 feet thick and the rock body over the cavern likely exceeds 150 feet thick. Proper precautions should be employed when working in the area of this feature. Recommended equipment setbacks associated with this feature are depicted on Drawing C-008 (Appendix D).

3.2.8 Additional Areas of Concern

According to an 1874 property plan presented by Kierstead (Kierstead, 2001), an unmarked shaft may be associated with Adit No. 3 and located in the vicinity of Copperas Road along the adit trace. Non-intrusive field reconnaissance activities in this area failed to identify the feature at ground surface. The feature is identified on the associated design drawings and call-out is made for excavations to be performed in the area of this feature to attempt to locate the structure prior to excavation of TP-3. It is recommended that this feature be field located at the start of work in the area and an engineering evaluation made concerning stability based on the findings and observations made.

Additionally, work activities in the vicinity of TP-3 may encounter unknown shafts, adits, trenches, or other mine exploration or operational features which pose a potential worker hazard. The contractor should be experienced in mine reclamation and should incorporate precautions and appropriate safety measures consistent with industry standards.

3.3 FIELD INVESTIGATIONS

Field investigations were performed to collect pre-design data necessary to assess the following:

- Further evaluate material types, thickness, and variability within TP-3.
- Determine the limit of excavation associated with TP-3.

Other activities performed onsite which generated data used in the NTCRA closure design have been presented in earlier site documents, including the *Remedial Investigation Report* (URS, 2006a).

Each phase of the current investigation activities is discussed in the following paragraphs.

3.3.1 TP-3 Test Pits

Eighteen test pits were excavated in the area on and around TP-3 during November 2006. Test pit locations are shown on Drawing C-003 of Appendix D. Test pit excavation was performed by Northwoods Excavating of Thetford Center, Vermont under the direction of Weston Solutions, Inc. and observed by URS and PAL. Test pits were excavated using a Kobelco Model 70SR track-mounted backhoe capable of a maximum excavation depth of approximately 15 feet. The test pits were logged and photographed, and bag and bucket samples were collected from selected depths to characterize the subsurface soils in the test areas. After each excavation was complete, the open test pit was backfilled. Test pit logs (WS-100 through WS-117) are presented in Appendix C.

The test pits were excavated to depths of between 1 and 13 feet from the existing ground surface. In general, test pits on TP-3 and along Copperas Road consisted of approximately 3 to 5 feet of loose, moist waste rock underlain by dense to very dense glacial till. The dense till was difficult to excavate and the cobble and boulder content was visually estimated to be less than 5 percent. Nine of the 16 test pits advanced on TP-3 and along Copperas Road terminated at the bedrock surface with minimal glacial till observed. The remaining seven test pits on TP-3 were advanced in mid-slope areas and terminated in very dense glacial till. A mixture of fill soil and waste rock was encountered at depths of up to 13 feet in the two test pits excavated west of Mine Road (i.e., WS-116 and WS-117). Glacial till was not encountered at these locations.

3.3.2 Delineation of Excavation Limit

URS performed multiple reconnaissance events across the perimeter of TP-3 to qualitatively determine the excavation limit. The excavation limit provided in the design is based on field observations of surficial and near surface (i.e., less than 1-foot below grade) soils and includes those generally contiguous areas where the ground surface is composed primarily of waste rock, waste ore, and mining debris. In most areas the excavation limit also corresponds to the vegetative boundary, although in central areas of

TP-3 located in the vicinity the Upper Copperas Factory the boundary bisects wooded terrain. In this area it was determined that significant amounts of waste rock and waste ore was present at ground surface which could act as continued sources of ARD to the watershed if left unaddressed; therefore the area was included within the excavation limit boundary.

The current design also considers data collected during fall 2007 which included the advancement of soil borings within and adjacent to Mine Road for the purpose of identifying waste thickness and type in this area. Specific data collected during fall 2007 is summarized in Appendix C.

The excavation limit was marked out in the field, and was surveyed using Global Positioning System equipment.

3.4 CLOSURE ALTERNATIVES IDENTIFICATION AND EVALUATION

The waste rock pile TP-3 adversely impacts water quality in Copperas Brook by contributing ARD and sulfidic ore-containing sediments to the brook. In accordance with the NTCRA Work Plan, the closure design of TP-3 required determination of the disposition of the waste rock pile in a manner which would meet the NTCRA closure requirements, which include:

- Isolating waste rock from direct contact with surface water run-on and from contact with surface water flow in channels,
- Isolating waste rock from direct precipitation,
- Collecting and treating seepage to meet water quality standards, as necessary, and
- Meeting applicable regulatory solid waste closure requirements.

Based on evaluations of technologies for controlling and/or treating ARD summarized in the Engineering Evaluation and Cost Analysis (EE/CA), EPA concluded that source control was the preferred approach to address site sources. Source control measures, as noted in Section 1.2.1 were identified based on their ability to meet the following objectives:

- Allow for the achievement of VWQS as well as other applicable standards in the WBOR by preventing or minimizing discharge of water with mine-related metals contamination to Copperas Brook.
- Minimize the erosion and transport of waste ore into the surface waters of Copperas Brook.
- Modify the slope configurations of TP-3 as necessary to provide for an acceptable level of long-term stability.
- Consider measures to minimize and avoid an adverse effect on historic resources at the Site.
- Comply with all applicable Federal and State regulations.
- Minimize costs associated with potential long-term water treatment.

Additionally, the overall project requirement under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) is to meet water quality criteria at the point of compliance following removal and remediation activities. EPA has defined the point of compliance for the project as the reach of Copperas Brook located immediately downstream of TP-1. Based on these objectives and requirements, TP-3 closure alternatives were identified during NTCRA planning meetings with USACE, EPA, and VTANR and included:

- Excavation and Relocation, and
- In-Place Consolidation and Cover.

3.4.1 Excavation and Relocation

The TP-3 excavation and relocation alternative includes the following elements:

- Excavating the waste ore piles from the identified footprint of TP-3, as shown on Drawing C-003 (Appendix D).
- Placing the waste on the surface of TP-1 in such a way as to facilitate final grading requirements of the TP-1 tailing dam closure.
- Abandoning any mine features, as necessary, to protect wildlife habitat.

- Creating positive drainage, as feasible, in areas adjacent to the North Open Cut where in-place ore deposits are exposed at ground surface, and directing surface runoff from these areas into the underground workings.
- Covering the exposed bedrock and till subgrade, as necessary, to promote vegetative growth and to limit erosion.
- Providing for drainage pathways across the excavated surface.
- Replacing Copperas Road and Mine Road in their current configurations, integrating surface water drainage features.
- Neutralizing and vegetating remaining perimeter waste ore to limit ARD generation.
- Redirecting flows from the upper portion of the watershed, which are currently discharging into the North Open Cut, into Copperas Brook.
- Allowing for observation by historic resource experts during the disturbance of any historic resources associated with the waste rock pile.

3.4.2 In-place Consolidation and Cover

The TP-3 in-place consolidation and cover alternative includes the following elements:

- Relocating waste within the footprint of TP-3 (see Drawing C-003, Appendix D) to allow for stable grades and slopes.
- Providing a cover layer which will limit infiltration into the waste.
- Providing for surface water drainage pathways across the regraded waste areas.
- Replacing Copperas Road and Mine Road in their current configurations, integrating surface water drainage features.
- Neutralizing and vegetating remaining perimeter waste ore to limit ARD generation.
- Addressing groundwater seepage at the TP-3 toe-of-slope area to limit ARD generation.
- Allowing for archaeological data recovery associated with disturbance of any historic resources within TP-3.

This alternative does not incorporate waste neutralization technologies, which were formally evaluated as part of the EE/CA and not advanced as an element of the design.

Based on subsurface explorations, TP-3 is underlain by bedrock in the south and by glacial till in the north. Field investigations have found that both the underlying till and bedrock are generally free of sulfide mineralization, with the exception of the area located along the east rim of the cut. The bedrock subgrade elevation has an approximate slope of 3 horizontal (H):1 vertical (V); the glacial till subgrade elevation has an approximate slope of 2H:1V, whereas the existing surface slopes of the waste ore pile range from approximately 1.8H:1V to 5H:1V. The State of Vermont closure requirements for solid waste specifies a maximum grade of 3H:1V. Since the underlying slopes are generally as-steep as allowable for closed waste piles, total available waste storage capacity is restricted by site conditions. To maximize waste storage potential, the conceptual in-place closure concept incorporated vertical retaining walls combined with 3H:1V surface slopes. The regraded waste footprint is located within the existing TP-3 area between the Upper Copperas Factory and Copperas Road. The conceptual waste cell is shown on Figure 14 and incorporates a gabion retaining wall at the toe and 3H:1V surface slopes.

Based on the inferred geometry of the subgrade, the maximum waste containment of the storage cell as configured on Figure 14 is approximately 80,000 yards. Upslope, west of Copperas Road, the subgrade is too steep to allow for a significant volume of waste to be closed-in-place and contributes negligible additional storage volume. Based on this assessment, the in-place closure alternative could not be satisfactorily completed within the footprint of TP-3, and significant waste relocation (i.e., a minimum of 45 percent) would still be required to meet the NTCRA objectives.

Additional issues also exist with the in-place closure alternative, those include:

- Currently there is groundwater discharging from the bedrock near the area of the Upper Copperas Factory, and this groundwater is generally flowing under artesian pressure (as defined by MW-13C, MW-11C, and periodically at MW-12C - see Figures 9 and 12). Any waste ore relocated into groundwater discharge areas near the toe of the waste closure area would result in seepage flows which would need to be discharged through the vertical retaining walls, and this flow would result in ARD to Copperas Brook if left unaddressed. Either long-term treatment of groundwater or subgrade preparatory neutralization of the waste ore would be a necessary component of this closure alternative. Currently there is an approximately 10-fold dilution occurring in Copperas Brook between TP-3 and the reach downstream of TP-1. Given the ARD characteristics of TP-3, it is unlikely that the resultant concentrations from the TP-3 toe seepage area if left undisturbed would allow for water quality standards to be met at the point of compliance.

- URS also reviewed the in-place closure options outside the specified State ARARs pertaining to slope and grades. It is our opinion that in order to close the entire waste volume of TP-3 in place, incorporating the requirements outlined at the beginning of this section, 2.4H:1V to 2.5H:1V slopes would likely be the flattest attainable slope. Veneer stability concerns with these slopes would add significant complexity to both design and to the construction means and methods. There would also be minimal added in-place storage volume generated by the steepened surface slopes and a net export of material would still be required. Due to these issues, URS did not recommend that a close-in-place alternative using steeper slopes be carried forward into the design alternative evaluation.
- Waste ore associated with the lower portion of TP-3 is present adjacent to and beneath Mine Road. This waste is located below the groundwater table and is within the groundwater discharge area; as such it would not be suitable to close this waste in-place without either incorporating ARD treatment into the alternative or fully neutralizing the waste left in-place in these areas.
- The manway located north of the North Open Cut is currently exposed and believed to be a potentially integral component to the existing bat habitat at the mine. URS understands that project stakeholders including USFWS and VTANR will be looking to maintain the current function of the manway as it pertains to ventilation and air flow to the Mine. This will require that the waste regrading be limited in the vicinity of the manway so as to limit disturbances to the existing ground configuration around the manway.
- The undesignated shaft associated with Adit No. 3 is projected to be located along the trace of the adit in the vicinity of Mine Road. This feature will need to be located through excavation and closed in accordance with state-of-the-practice methods prior to waste closure over the feature. The remaining identified mine openings, including shaft Nos. 1 and 2, the undefined shaft associated with Adit No. 3, and Adit No. 2 will also require closure as part of waste removal and surface grade completion.
- It is understood by URS that the nature of the in-place consolidation methods dictated to be employed due to the terrain and cover requirements would substantially alter the viewshed and maintaining some portion of the waste within the existing footprint of TP-3 has limited historic resource preservation benefit as a result of the disturbance.

3.4.3 Alternative Evaluation and Selection

The two closure alternatives detailed in the preceding sections were developed to meet the objectives of the NTCRA by achieving isolation of the TP-3 mine waste from surface water and groundwater to minimize ARD, and allow for water quality standards for the WBOR and Lower Copperas Brook to be met. The excavation/relocation alternative meets the objectives. The waste relocation alternative would allow for the construction of a single waste cell which could be designed to isolate the waste from surface water and groundwater to facilitate the closure of TP-1. It was determined that the optimal disposition area for the TP-3 waste would be the TP-1 surface. Refer to Section 4.0 for the TP-1 closure design discussion. Based on subgrade information obtained during the RI and predesign activities, significant areas of residual sulfide mineralization within the subgrade materials (i.e., till or bedrock) were not observed. Therefore clean closure is believed to be largely achievable using available construction practices.

However, due to the present geometry of TP-3 and the geometry of the subgrade as defined through subsurface excavations and borings, there is insufficient area within the TP-3 footprint to allow for in-place closure of the entire waste volume. In total, it is estimated that no more than 55 percent of the TP-3 waste ore could be closed and covered in-place. The remaining waste volume would require relocation and cover, similar to the excavation and relocation alternative. Complete closure for this alternative would therefore require multiple waste cells, which would increase maintenance costs. Additionally, groundwater seepage in the area of the waste cell would significantly increase the complexity of the closure design, both through the required dissipation of pore water in the area beneath the cover system and the need to treat any significant seep flows as ARD sources. The alternative would provide little historic preservation benefits due to the extent of disturbance and cover requirements.

Based on these fundamental and significant limitations the in-place consolidation and cover alternative was dropped from further consideration and the excavation relocation alternative was carried forward into design.

3.5 DESIGN APPROACH

The approach for the NTCRA TP-3 closure design was prepared during NTCRA planning meetings, with input provided by USACE, EPA, and VTANR. The approach is consistent with the current state of the practice for mitigation of sulfidic mine wastes. The following sections provide details of the design criteria and the design hydrology.

3.5.1 Design Criteria

The design criteria were determined during design planning activities and are based on ARARs presented in Appendix A. For the closure of TP-3, the design criteria identify parameters specific to waste rock removal and subgrade treatment, surface water management, and slope and roadway restoration which provide the basis for the design. Each of these parameters is presented in the following sections.

3.5.1.1 Waste Rock Removal

The design criteria for waste rock excavation and removal and mine features excavation include the following:

- Excavate waste rock within the designated limit of waste to either bedrock or glacial till. A depiction of the waste volume in plan view is provided in Appendix E.
- Small areas of waste rock that are located beyond the excavation limit shall be closed in-place by covering with lime and topsoil and revegetating.
- Excavate ferricrete and altered glacial till.
- Dispose of waste rock on TP-1.
- Manage waste rock placement on TP-1 so as to compliment final contouring of TP-1, conform to phased-construction requirements, and minimize time that waste is left uncovered prior to final cover placement.
- Follow construction precautions identified by the design for each feature.

3.5.1.2 Surface Water Management

Surface water management design criteria are as follows.

- Design permanent surface water structures for the modeled 100-year peak flow.
- Design the temporary detention basin structure for the modeled 25-year peak flow.
- Divert surface water on the west side of the North Open Cut by upgrading existing berms and channels.
- Divert surface water around the north end of the North Open Cut.
- Convey surface water over the bedrock surface along existing drainage alignments, as possible. Some field modification of bedrock slopes are anticipated to allow for creation of defined channels. Some field modifications of the drainage pathway are anticipated to bypass any areas of residual ore exposed in the bedrock surface.
- Convey surface water on the south end of the area along existing alignment over bedrock.
- Create a cross-slope diversion berm and use Copperas Road to divert surface flow on soil slopes into the bedrock channels.
- Divert stream flow away from the Upper Copperas Factory, as required by the Copperas Factory closure (Section 6).
- Place high density polyethylene culverts under Copperas Road.
- Construct a temporary, construction-period sediment basin at Mine Road using a culvert/temporary riser inlet. Interim-period sediment basin shall meet Vermont Storm Water Management standards.
- Create a rip-rap-lined channel below Mine Road for Copperas Brook.

3.5.1.3 Slope and Roadway Restoration

Slope and roadway restoration design criteria address subgrade treatment, mine feature closure, and roadway replacement. The parameters include the following:

<u>Subgrade Treatment</u>

- Ore-bearing subgrade likely to be encountered around the perimeter of the North Open Cut shall be graded to drain into the cut.

- Cover the exposed slopes with bark mulch, stone, or similar type material based upon constructed grade and revegetate, as required.
- Clean the bedrock surface through water jetting or mechanical scraping to remove residual waste rock from surface fissures and joints, as practicable.
- Assess the stability of exposed rock slope and take appropriate action, as needed.

Mine Features Closure

- The open manway located north of the North Open Cut is to be closed in general accordance with Bat Conservation International guidance (Tuttle and Taylor, 1998) on protection of bats in mines.
- Any other mine openings exposed during TP-3 closure will be evaluated and closed as directed by the engineer following structural considerations.

Roadway Replacement

- Copperas Road is to be reconstructed. The design incorporates appropriate Vermont Agency of Transportation standards for roadway design.
- Access to property beyond TP-3 via Copperas Road shall be maintained during construction activities to the extent practical.
- Copperas Road shall be a single lane 12-foot travel way with 2-foot-wide shoulders, and gravel surface reconstructed at the same location and approximate grade as existing roadway.
- Mine Road shall be closed to vehicle access during construction, with work performed during non-school busing periods.
- Mine Road shall be a 24-foot travel way with 2-foot-wide shoulders, gravel surface, and reconstructed along same alignment and grade. The road embankment shall provide construction-period sediment detention.
- Roadways shall be designed and constructed to pass the 100-year design storm without failing.

3.5.2 Design Hydrology

URS conducted a surface water runoff analysis for the watershed associated with TP-3 in support of the closure design. Rainfall-runoff modeling was conducted to estimate the peak flow for the 25-year and 100-year, 24-hour storm events at key locations along the flow path of the sub-watershed. The surface water hydrologic analysis of the basins was completed using HydroCAD version 7.0 from Applied Microcomputer Systems.

The design peak flows that leave the temporary sediment basin have been evaluated and the stabilized outlet has been revised accordingly (Sheet C-010, Appendix D). The maximum flow to the outlet in the design storm event is 36 cubic feet per second (cfs) at a maximum velocity of 8.3 feet per second. See Reach 9R in the HydroCAD output (Appendix F). A detailed discussion of the work performed and the modeling output is provided in Appendix F.

3.6 TP-3 CLOSURE DESIGN

The TP-3 closure implementation plans will address the management of TP-3 waste from an acid generating perspective and the TP-1 and TP-2 closure design will address anticipated issues with loading, settlement, and stability resulting from placing TP-3 on TP-1. It is expected that discharge from the reclaimed TP-3 area will not require treatment and that water quality standards will be met in Copperas Brook at the compliance point below TP-1. The design details for the closure of TP-3 are provided on Drawings C-003, and C-005 through C-010 of Appendix D. Referenced Technical Specifications are provided in Appendix G.

TP-1 and TP-2 are the tailing areas targeted for response action as part of the NTCRA. The tailing contributes acidity, base metals, and is the major source of iron to Copperas Brook and the WBOR. To achieve the NTCRA objectives, the closure design includes elements that would reduce the discharge from TP-1 and TP-2 to levels that would potentially result in Copperas Brook meeting water quality criteria downstream of TP-1. A detailed summary of URS' design evaluation for this component of the NTCRA is presented below.

4.1 PHYSICAL CONDITIONS OF TAILING DAMS TP-1 AND TP-2

Tailing dam TP-1 is located east of TP-3 and is the primary tailing depositional feature. It consists of tailing deposited during the WWII-era milling operation. This feature covers approximately 27 acres and contains approximately 2,400,000 cyds of tailing. TP-1 is contiguous with TP-2, which covers an additional 7 acres and contains approximately 400,000 cyds of tailing.

During milling operations, Copperas Brook was diverted through TP-2 and across and through TP-1 via reinforced concrete pipes. With completion of the early phases of the NTCRA in 2006 and 2007, Copperas Brook has been largely diverted around the perimeter of the tailing dams with the final diversion structures to be completed at time of, or following, TP-3 closure.

Monitoring of groundwater levels within and beneath the tailing dams is performed though the existing network of monitoring wells, piezometers, and test borings located within the footprint of TP-1 and TP-2. As part of the closure activities, the engineer will identify a subset of these wells which will be abandoned or closed prior to construction of the cover system. The remaining groundwater monitoring locations will be upgraded during closure of the tailing dams to allow for long-term use as site monitoring points. The upgrades to these wells will be performed in a manner specified in the engineer.

4.2 GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations were performed to collect pre-design data necessary to assess the following:

- Evaluate material types, thickness, and variability within the TP-1 decant pond area.
- Evaluate engineering properties of tailing samples collected from the TP-1 decant pond area.
- Collect field measurements to evaluate TP-1 tailing settlement using a settlement test pad.

Other activities performed onsite which generated data used in the NTCRA closure design are presented in earlier Site documents, including the *Remedial Investigation Report* (URS, 2006a), the *Geotechnical Investigation and Analysis Report of Tailing Dams TP-1 and TP-2* (URS, 2003a) (and provided in Appendix B), and the previously issued NTCRA design reports (Appendix B). Each phase of the current geotechnical investigation activities is discussed in the following paragraphs.

4.2.1 Field Investigations

Pre-design field investigations performed in support of the NTCRA tailing closure include installing soil borings and collecting undisturbed tailing samples for laboratory analyses, and performing a test settlement pad.

4.2.1.1 TP-1 Soil Borings

On May 15 and 16, 2007, two borings were advanced into the TP-1 tailing to obtain laboratory samples for geotechnical analyses. The borings were completed as short-screened groundwater monitoring wells in an attempt to screen across the water table at each location. The boring locations are shown on Drawing C-002 (Appendix D). Boring logs for the TB-22 and TB-23 are provided in Appendix C.

4.2.1.2 TP-1 Settlement Test Pad

In conjunction with the tailing excavation associated with the NTCRA construction performed during 2007, a portion of the excavated dry TP-2 tailing was placed as a controlled-fill on TP-1, instrumented for settlement data collection, and monitored following placement. The objectives of the test pad were to 1) validate, by field measurements, laboratory estimates of settlement, and 2) obtain an understanding of the time-rate of settlement.

The test pad was constructed on June 6, 2007 using tailing from TP-2 and was 50 feet square and 4 feet thick. The pad subgrade consisted of regraded tailing from the TCRA activities overlying undisturbed tailing. A settlement plate on the original ground surface was installed prior to test pad construction and 9 rebar survey points (i.e., pins) were installed on the pad surface. The change in elevation of the plate and pins were surveyed and recorded a total of 7 times over a 20-day period. In-place density of the tailing was also determined at 23 locations across the test pad. Both the survey data and the density data were provided to URS for analysis, and are included in Appendix H.

4.2.2 Laboratory Testing

Laboratory tests were conducted on samples collected from the TP-1 decant pond area to measure engineering properties of the tailing and to perform one-dimensional consolidation tests.

A standard one-dimensional consolidation test was performed on five samples (i.e., TB-22A [5.85 feet bgs], TB-22 [29.15 feet bgs], TB-23 [4.25 feet bgs], TB-23 [6.45 feet bgs], and TB-23 [8.5 feet bgs]) in accordance with American Society of Testing and Materials (ASTM) Method D2435. The samples tested consisted of silt (ML) and silty and clayey sands (SM and SC) with percent fines ranging from 34 to 98 percent. Results of the laboratory testing are provided in Appendix H.

4.3 DESIGN CLOSURE ANALYSIS

As discussed in Section 2.4.3, the high acid generating potential of the tailing, as well as the leachable constituents of the tailing, impact surface water quality downgradient of the tailing dams through water runoff and seepage as well as from erosion and transport of tailing to downstream areas. The NTCRA closure objectives for TP-1 and TP-2 are therefore to restrict water contact with the tailing to the extent practical and to eliminate erosion of tailing into surface water channels. To achieve the closure objectives, a cover which reduces infiltration and provides for grades sufficient to promote positive drainage and allows revegetation is required. Closure must comply with ARARS (Appendix A). Based upon discussions with Federal and State regulators, the minimum acceptable grade for the surface of TP-1 and TP-2 is 2 percent after allowing for settlement.

To achieve the minimum slopes, filling or regrading is required. Based on post-TCRA ground topography of TP-1, achieving a minimum 2 percent closure surface grade for TP-1 through placement of surface fill requires a minimum of approximately 156,000 cyds of fill placement (Appendix E). This fill volume includes additional volume necessary to allow for anticipated settlement following placement of the surface fill. The fill thickness necessary to reach final grade has been evaluated for settlement as well as for slope stability as discussed later within this section. As discussed in Section 3.4, the closure alternatives analysis performed for waste rock pile TP-3 requires relocation and isolation of the TP-3 waste rock and waste ore. During project planning meetings it was established that using the TP-3 waste rock as fill on TP-1 would provide for the necessary fill on TP-1 to achieve the design slopes, as well as provide for a suitable relocation area for the TP-3 wastes where the wastes could be effectively isolated. For these reasons, it was concluded that surface regrading was less cost effective and relocating TP-3 waste rock onto TP-1 would maximize project benefits by fulfilling the following project requirements:

- Provide for the necessary fill placement on TP-1 to achieve the minimum design grades necessary for closure.

- Provide a final disposition location for TP-3 waste rock that would achieve waste isolation.

In order to meet water quality criteria at the point of compliance downgradient of the tailing dam, analyses were performed to evaluate the type of cover system necessary. Cover system options included infiltration barriers and vegetative covers. Three-dimensional groundwater flow modeling using MODFLOW was performed to simulate flow in and around the tailing and to evaluate the effect of groundwater perimeter diversions and cover systems on TP-1 toe-seepage rates (Appendix I). The groundwater model was used in conjunction with the Hydrologic Evaluation of Landfill Performance (HELP) model to predict resultant infiltration rates for differing cover options (Appendix J).

The tailing analysis performed using the HELP model indicated that a soil/vegetation cover would not significantly reduce infiltration compared to existing conditions. Findings from the HELP model indicate that, excluding the decant pond influences, infiltration through a soil/vegetation cover would be slightly elevated above pre-NTCRA levels, whereas infiltration through a geomembrane cover would be reduced from pre-NTCRA levels by approximately 99.99 percent (Appendix J). Infiltration rates predicted by the HELP model for the differing cover system scenarios were then applied to the MODFLOW simulations following scaling to accommodate calibration differences between the two models.

MODFLOW modeling of pre-NTCRA conditions indicate that significant inflows to the tailing impoundments (i.e., over 70 percent of the total water inflow) originate from surface infiltration, either generated from direct precipitation or from the infiltration of surface water (e.g., the decant pond and surface water channels). The model findings also indicate that nearly all of the water outflow from the tailing discharges through the TP-1 buttress and horizontal drains. These findings are depicted schematically on Figure 15 (below), and are supported by the findings of a water balance assessment performed to support earlier phases of the RI (Appendix K).

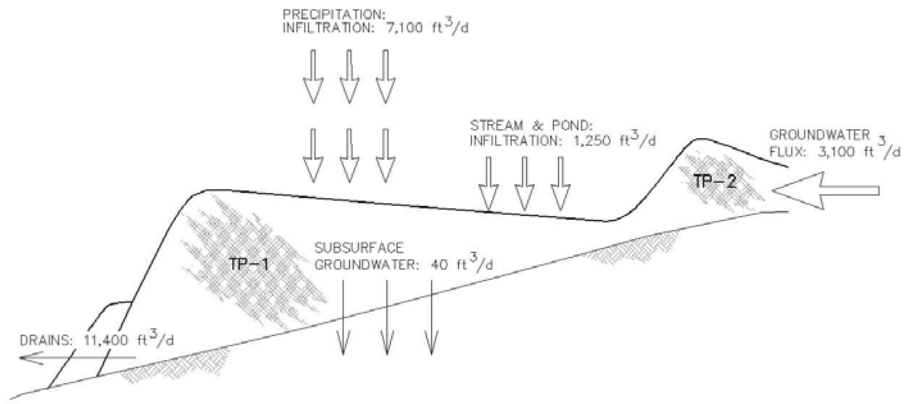

FIGURE 15
MODFLOW WATER BALANCE – TAILING IMPOUNDMENTS

The groundwater flow model was used to assess the impacts on flow and seepage discharge rates for two types of cover systems: 1) a soil cover; and 2) a geocomposite membrane cover system. The groundwater flow model predicts that, in combination with the effects of the NTCRA perimeter surface water diversion channels, the effective elimination of the surface infiltration to the tailing impoundments will result in a decrease in the seepage flow rates discharging from the toe of TP-1 by more than 80 percent compared to pre-NTCRA levels. The model predictions for the cover system alternatives are provided on Table 2.

TABLE 2
GROUNDWATER MODEL SIMULATION RESULTS
TP-1 AND TP-2 CLOSURE

MODELED CONDITION	ANTICIPATED TP-1 SEEPAGE RATES (GPM)
Pre-NTCRA Baseline Conditions	**55-65**
Post-NTCRA with Soil Cover	**45-55**
Post-NTCRA with Geocomposite Membrane Cover	**5-12**

The groundwater modeling is summarized in Appendix I.

Due to the significant iron loading from the TP-1 seeps impacting Copperas Brook and the WBOR, EPA concluded that it is more cost effective to minimize infiltration, to the extent practicable, as part of the tailing dam closure and reduce the amount of residual seepage which may require treatment. This conclusion is also consistent with requirements associated with the relocation of TP-3 waste rock onto TP-1. Due to the high AGP of the TP-3 waste rock, and the higher base-metals content of this material compared to the underlying tailing, either an infiltration barrier or waste neutralization would be required in order for the TP-3 wastes to be placed on TP-1 as part of permanent closure. Acid Base Accounting (ABA) data from TP-3 obtained during the RI show that waste neutralization would require a 20 percent addition by volume, or more than 30,000 cyds of calcium carbonate (Appendix K). Because the waste neutralization approach to the closure of the TP-3 waste ore would not achieve the infiltration reduction levels being sought to reduce the flow rates of the TP-1 buttress drains, the TP-3 waste neutralization alternative was eliminated from consideration.

4.4 DESIGN APPROACH

The NTCRA closure approach for TP-1 and TP-2 was determined during NTCRA planning meetings attended by USACE, EPA, and VTANR and is consistent with the current state of the practice for closure of tailing dams. The following sections provide details of the design criteria and the design hydrology.

4.4.1 Design Criteria

The design criteria were determined during design planning activities and are based on ARARs presented in Appendix A. The design criteria identified parameters specific to waste rock fill placement, tailing closure, and surface cover. Each of these parameters is presented in the following sections.

4.4.1.1 Waste Rock Fill Placement

Waste rock fill placement design criteria include the following:

- Final TP-1 and TP-2 subgrades are achieved by minor tailing regrade activities (discussed in the following section), and by placement of TP-3 waste rock.

- Waste rock fill shall be nominally compacted to create a relatively uniform, dense fill, minimizing nesting of large-sized materials, wood, or other debris.
- Placement of waste rock shall be performed to minimize infiltration through the regraded waste and into the tailing pile during placement.
- The top 6 inches of the fill surface shall be suitable as a geomembrane base layer, consisting of either tailing or sand fill.

4.4.1.2 Tailing Regrade

Tailing regrade design criteria include the following:

- The TP-1 slope extending from the dam crest to the buttress, and the TP-2 crest slope, shall not exceed 3H:1V.
- Existing vegetation shall be stripped from the tailing surface prior to liner placement.
- The regraded tailing surface shall be suitable as liner subgrade.

4.4.1.3 Infiltration Barrier Cover System

In order to meet the stated NTCRA objectives, the infiltration barrier cover system for Tailing Dams TP-1 and TP-2 must have the following characteristics:

- Cover exposed tailing, or tailing currently staged under temporary soil cover.
- Incorporate a low permeability layer.
- Provide for long-term stability.
- Be designed to incorporate the total volume of the following:
    - Waste rock from TP-3;
    - Lead-containing soil and waste from the remedial activities performed at the Copperas Factories (see Section 5);
    - Tailing previously excavated from TP-2;
    - Tailing from regrading of TP-1 and TP-2;
    - Stripped vegetation and cover soil from theTP-1 slope regrade;
    - Tailing and/or waste rock generated during excavation for the groundwater cut-off trench located adjacent to the western edge of TP-1;
    - Tailing excavated from the tailing fan located below TP-1; and

  - Other miscellaneous sources of tailing and waste rock generated during implementation of the closure.
- Comply with Vermont Solid Waste rules.
- Be cost effective; in particular, limit the use of clean onsite soils to achieve sub grade elevations and the use of imported off-site soils and stone.
- Require relatively low maintenance activities.

The EPA identified four components of the infiltration barrier cover system in the 2002 NTCRA Action Memorandum (EPA, 2002): (1) Soil/vegetation layer to support vegetative cover; (2) Geosynthetic drainage layer to allow for drainage of water that permeates the soil layer and does not allow water to pond on top of the barrier layer; (3) Barrier layer that prevents water from flowing into the tailing and includes a geomembrane as the top layer; and, (4) Cover system with a final grade that promotes drainage off the cover and prevents ponding on the primary barrier layer.

To achieve the NTCRA objective for closure, the TP-1 and TP-2 cover system includes the following elements:

- Regrading of TP-2 to create stable, maximum 3H:1V side slopes and a top slope of approximately 5 percent; but no less than 2-percent;
- Filling the top surface of TP-1 with waste rock and tailing to achieve a minimum slope of 2-percent (accounting for settlement);
- Regrading a portion of the north face of TP-1 to achieve a maximum slope of 3H:1V;
- Placing a 60-mil (0.06-inch-thick) geosynthetic membrane (i.e., geomembrane), made of linear low-density polyethylene (LLDPE) over TP-1 and TP-2;
- Placing a soil layer above the geomembrane consisting of 18 inches of screened onsite common borrow and 6 inches of topsoil;
- Constructing a subsurface drainage system consisting of a geocomposite drainage net and perforated piping network on the side slopes and a geocomposite drainage net on the flatter areas of the cap (i.e., on slopes less than 5-percent);
- Establishing a stable grass cover; and
- Constructing surface drainage features including on-cap broad grass swales with stone centers, and perimeter grass and riprap channels.

The following sections of the report provide the design details of each of the cap elements.

4.4.1.3.1 Subgrade Preparation

Subgrade material shall be generated from the regrading of the tailing slopes currently in excess of 3H:1V; former vegetated cover materials from the tailing top surface and side slopes; tailing excavated from the south side of TP-2; and waste rock from the TP-3 excavation. The subgrade configuration incorporating these materials is designed to assure that a minimum 2 percent slope will be achieved following settlement. The subgrade plan assumes a conservative, neat-line estimate of the available waste rock and tailing volume to be relocated onto TP-1 as subgrade fill. The subgrade plan also accounts for settlement of TP-1 resulting from fill placement using conservative soil parameters and assumptions, as discussed in Section 4.4.3. In the event that more waste materials are obtained from the fill sources, grades can be increased without adversely affecting the intent of the design.

Significant details of sub grade preparation are as follows:

- Waste rock and tailing shall be placed on TP-1 in layers and nominally compacted to create a stable mass;
- Waste rock and tailing shall be managed during fill placement in a manner consistent with the project Workplans addressing waste relocation and placement;
- Nesting of cobbles, boulder, wood debris and other deleterious material shall be avoided;
- The upper 6 inches of fill shall consist of tailing or imported sand-sized material and be suitable as a geomembrane base layer;
- Waste ore or waste rock, regardless of particle size, is specifically not to be used in the upper 6 inches of fill;
- Relocated waste rock and tailing shall be placed under a functioning geomembrane cap at the end of each construction season; and
- The sub grade topography of TP-1 shall be shaped to create drainage toward either internal drainage swales or to the diversion channels on the east side of TP-1.

4.4.1.3.2 Geosynthetic Liner

A geomembrane shall be used to create the low permeability layer in the infiltration barrier cover system. Three alternative materials were initially considered to create the barrier layer, a geomembrane, a geocomposite clay layer (GCL), or a compacted low permeability soil. While all three materials have been used in similar situations (i.e., waste pile covers, tailing covers and landfill caps), a geomembrane liner was selected for the following reasons:

- geomembrane has the lowest overall permeability (1 x 10^{-11} cm/sec or less) for the design setting;
- geomembrane is compatible with the chemical environment of the waste rock and tailing, unlike GCL which may degrade under acidic conditions;
- geomembrane can be installed with a high degree of quality assurance;
- geomembrane is very durable (Appendix K) with a service life conservatively estimated to exceed several hundred years (Bonaparte et al, 2002; Koerner et al, 2005); and
- geomembrane is cost-competitive with alternative materials.

Based on the geometry of the cover and the nature of the materials, a composite barrier (i.e., a geomembrane combined with a GCL) was also evaluated. The HELP and MODFLOW design models were used to evaluate potential TP-1 infiltration and drain flow rates considering barrier materials and their infiltration properties, surface grades, and cover system drainage properties. Due primarily to the relatively flat surface grades of the design, the composite barrier is not predicted to appreciably reduce residual infiltration compared with a single layer geocomposite barrier, and would require significant additional cost.

Differing geomembrane liner materials and thicknesses were also considered, and based on the specifics of the design application and material properties, the geomembrane shall be a 60-mil LLDPE material and shall be selected by the engineer through testing as specified in Technical Specification 02561 (Appendix G) and ASTM D2565. The technical specification outlines the testing specifications for the LLDPE material and includes test methods, quality control and installation requirements.

Preventing penetration of the geomembrane by rocks, stones, and other sharp objects is also critical to successful installation. The specification requires that the geomembrane be placed on a smooth tailing or sand subgrade with a minimum thickness of 6 inches. Therefore the subgrade must be free of cobbles, gravel and other sharp objects and deleterious materials that could damage the geomembrane. The drainage layer above the geomembrane will provide a protective cushion against damage from stones in the overlying vegetation support layer. Beneath the stone toe berms, where the drainage layer is not used, a 24-ounce geotextile cushion will be used to provide the surface protection of the geomembrane. The analysis used to develop the cushion specification is presented in Appendix K.

4.4.1.3.3 Subsurface Drainage

Water infiltrating into the 2-foot thick soil cover will be restricted vertically by the geomembrane. Therefore, a subsurface drainage system is required to minimize lateral seepage forces from causing a slope failure on the side slopes of TP-1 and TP-2, and to sufficiently drain soils on the flatter areas on top of TP-1 and TP-2 to limit the buildup of hydraulic head on top of the geomembrane barrier layer and therefore reduce infiltration through the barrier layer. The drainage system is also designed to limit prolonged periods of soil saturation that may result in grass kill.

Side slope subsurface drainage was evaluated using the unit-gradient method and the design uses a conventional geocomposite drain net (GCD) with a lateral piping system to assure that unacceptable seepage forces do not develop. The design analysis of the side slope drainage system is provided in Appendix K. Drawings C-012 and C-014 through C-016 (Appendix D) show the layout and details of the side slope drainage system.

As the flat slopes of TP-1 and TP-2 are not at risk of slope failure, the unit gradient method used to evaluate drainage requirements for the side slope areas was not used for the flat slopes. In place of the unit-gradient method, an analysis was performed to evaluate the drainage potential of the system given design storm events (i.e., 3/8- to 1/2-inch over a 24-hour period). This allows for proper drainage to provide for adequate grass cover. The design of the subsurface drainage system on the relatively flat slopes of TP-1 and TP-2 incorporates a GCD with mid-slope drain pipes that will provide drainage of infiltration resulting from design storm events. The GCD will be a triaxial GCD rather than a bi-axial GCD. A tri-axial GCD has three ribs of high density polyethylene plastic that form the open internal structure of the grid. Bi-axial GCD has two ribs of material in the grid. Three ribs create a deeper, more open architecture in the horizontal plane of water movement. Recent studies have shown that a tri-axial GCD results in a higher long-term transmissivity than a bi-axial GCD. Because of the tri-axial GCD's deeper structure, there is less potential for clogging with sediment and bioaccumulation. The layout and details of the top drainage system is shown on Drawing C-012 (Appendix D). The analyses supporting the design of the drainage system is provided in Appendix K.

4.4.1.3.4 Gas Venting

During their operational periods, tailing dams are typically considered inert with regard to gas generation as they contain de minimis amounts of organic matter that might produce gases during decomposition. However, since the cessation of tailing deposition in the 1950s TP-1 and TP-2 were substantially revegetated and received off-site fill from various sources that contained organic debris. This material, as well as a portion of the fill to be placed on TP-1 during closure, contains organic matter. All these materials will be located beneath the barrier layer after closure.

Due to the presence of these materials beneath the geosynthetic liner, a gas venting system was considered as part of the design evaluation. However, at the direction of EPA, and based on the recommendation of the Value Engineering Study, the gas venting system has been removed from the final design due to the apparent low risk of significant gas generation from within the covered waste.

4.4.1.3.5 Soil/Vegetative Cover

The soil/vegetative cover will consist of 18 inches of onsite glacial till common borrow and 6 inches of topsoil. Under direction of the Engineer, site-specific testing will be performed prior to construction to determine the maximum acceptable stone size for the common borrow. The common borrow will be screened to limit the maximum stone size consistent with this maximum dimension, as necessary. The topsoil will be either natural topsoil or amended common borrow and will be vegetated. Technical specification 02200 and 02900 (Appendix G) provide the details on the materials and installation of the soil/vegetative cover. The topsoil will be seeded by the contractor so as to establish vegetation.

The 24 inches of soil cover above the GCD and geomembrane will provide long-term protection against mechanical damage and freezing of the geosynthetics. The estimated frost depth for a snow-free, turf-covered cap at the Site is approximately 21 inches (see Appendix K). Experience with similar vegetative support/topsoil layers in New England has shown that the planned soil/topsoil thickness will support long-term grass growth provided maintenance (i.e., annual mowing and periodic fertilization) is performed. It should be noted that the rooting depth for the grasses that will be seeded is expected to be between 1 and 2 feet.

4.4.1.3.6 Surface Drainage

Surface water will be conveyed off the tailing pile caps using broad, grass-lined drainage swales. Top cap drainage will be toward the east-side diversion channel, in the direction of original tailing deposition. A riprap perimeter channel along the east side of TP-1 will convey surface water to the existing decant diversion pipe inlet. The surface drainage system is designed to convey the 24-hour 100-year rainfall event.

Storm water will sheet flow to proposed cap swales where the runoff will be transported to the perimeter swale and to the decant diversion inlet. The existing decant diversion outlet currently conveying Copperas Brook will continue to be used once the cap has been constructed. Modeling of the 100-year storm across the cover system indicates that there will be only minimal ponding above the decant diversion pipe inlet and no flooding of the cover. This modeling analysis is provided in Appendix F.

Because the cover system drainage swales are at relatively flat grades, the design includes a stone-center drainage element to the swales. The stone center element will provide for localized drainage and will limit wet spots and saturated soils typically observed in broad, low gradient, grass-lined swales. The configuration of the surface drainage network is shown on Drawing C-013 (Appendix D) and details of the perimeter channel and decant inlet are shown on Drawing C-014 (Appendix D).

The surface drainage system has been designed to limit erosion of the NTCRA cap to less than 2 tons per acre per year once vegetation is fully established, the generally recognized criteria for waste pile covers (e.g., landfills). The revised universal soil loss equation calculations which indicate that soil loss will be only fractions of a ton per acre per year are presented in Appendix K. For the interim period immediately following construction until such time as vegetation is fully established, the contractor will be responsible for implementing erosion control measures in accordance with the project workplans and as directed by the engineer.

4.4.1.3.7 Access Roads

The cover system design includes a system of roads on TP-1 and TP-2 to permit vehicle access for maintenance and monitoring purposes. The general road layout was reviewed and approved by the State prior to incorporation into the design to ensure that State maintenance requirements are met. The layout of the roads is shown on Drawings C-013 and C-018 of Appendix D.

4.4.1.4 TP-1 Spillway

As part of the 2003 TCRA stability analysis of the TP-1 tailing dam, the capacity of the tailing dam to safely convey the peak runoff from the Probable Maximum Precipitation (PMP) event was evaluated. That analysis indicated that an emergency spillway would be required to reduce the risk that the tailing dam would overtop during a PMP event. This spillway installed in 2003 was constructed on glacial till located beyond the east abutment of the tailing dam.

The NTCRA closure design is not intended to pass the PMP event without damage; however, as with the TCRA activities, the design is to provide adequate protection of the dam against overtopping failure, and to provide adequate protection of the TP-1 buttress against dam failure resulting from out-of-bank flows from Copperas Brook. The NTCRA closure of TP-1, TP-2, and TP-3 alters the hydrology and hydraulics of the Copperas Brook watershed both within and upstream of the tailing impoundments. To support the current design a re-evaluation of the impact of the PMP event to the tailing dam and modified emergency spillway was performed. The evaluation used essentially the same methodology as that performed in 2003 (URS, 2003a). The re-evaluation took into account the following significant changes:

- Stripping waste rock from TP-3 and adding additional contributing drainage from the area west of the North Open Cut.
- Constructing the TP-1 and TP-2 perimeter diversion channels.
- Altering the grades of TP-1.
- Modifying the dam spillway as part of the TP-1 east side perimeter diversion.

The PMP routing study is provided in Appendix F. In summary, the study found that:

- Water will be temporarily stored on TP-1 during a PMP event, but the dam will not overtop.
- The modified emergency spillway will convey runoff safely around the dam. The emergency spillway riprap will be displaced during peak runoff but erosion will be confined to the glacial till beneath and adjacent to the spillway and erosion of the tailing dam is unlikely.

- If site grades are left as-is, water discharging from the spillway may flow along the toe of the existing buttress under a Probable Maximum Flood (PMF) event. While the potential for eroding the buttress appears low, the NTCRA closure design includes an option to raise and riprap reinforce the perimeter access road below TP-1 (see Drawing C-017 of Appendix D) to restrict Copperas Brook from reaching the buttress toe during a PMF event. This design element will be implemented at the direction of the engineer based on Site conditions following tailing excavation and removal from this area.

The spillway assessment also included an evaluation of rip-rap stability for modeled flow conditions associated with the 24-hour 100-year rainfall event, as well as an assessment of the conveyance requirements to pass flows from this design storm through the culvert structure at the TP-1 perimeter road, which crosses the lower portion of the spillway. These assessments are provided in Appendix F, and the associated design elements are provided on the design drawings of Appendix D.

4.4.1.5 Copperas Brook Tailing Fan

Prior to construction of the TCRA, tailing eroded from the face of TP-1 was present across the TP-1 toe area, including within and across the Copperas Brook stream channel. During construction of the TCRA, a significant portion of this tailing was excavated and relocated to TP-1. As part of the closure of TP-1 and TP-2, the remaining tailing from this area which is located in unvegetated areas prone to mobilization during high flows, or which is in contact with surface water, will be removed.

4.4.1.5.1 Tailing Excavation

The extent of tailing to be excavated beyond the TP-1 and TP-2 footprint has been delineated by URS based on the following factors:

- The surface exposure of tailing (i.e., any large areas of surface-exposed tailing were designated for excavation).
- The location of the tailing relative to Copperas Brook or the Buttress drainage flowpaths (i.e., readily mobilized tailing by surface water was designated for excavation).

The area of tailing designated for excavation is shown on Drawing C-017 (Appendix D). Excavated tailing is to be relocated onto TP-1 or TP-2 and used as fill beneath the barrier layer to achieve final grades.

4.4.1.5.2 Stream Restoration

As the majority of the tailing is located within the flow channel of Copperas Brook, or the discharge channel from the sedimentation basin below TP-1, channel restoration activities are required to be performed following tailing excavation.

Project discussions were held amongst USACE, EPA, USFWS, VTANR, and URS to establish the design guidelines for stream restoration. Because the locations of tailing excavation were below TP-1, design hydrology did not require dam safety to be taken into account. Therefore, stream restoration methods were incorporated into the design to generally replicate the existing stream channel configuration. The intent of the channel restoration is to allow for the establishment of a functional channel through the reach resulting in limited channel movement and stability under non-storm-flow conditions. However, erosion during storm events, as is occurring currently, is anticipated and could result in maintenance requirements over time. The channel design structures used in the stream restoration effort create channel function, however as defined by the stream restoration intent, they are not designed to pass a specified storm-flow event.

The restored channel profile, anticipated to accommodate grades as high as 10 percent, include low-gradient (i.e., 2 percent) reaches separated by boulder-lined grade drop structures. The low-gradient channel reaches will be unarmored. The typical channel cross-section depicted on Drawing C-018 of Appendix D includes a defined low-flow channel with a floodplain. The low-flow channel has been sized to be generally sufficient to accommodate the 2-year post-NTCRA design flows for the channel reach without overbank flow. However this evaluation is only approximate as it is based on a projected, post-tailing excavation topography for the reach which cannot be fully defined until the tailing excavation is complete.

The transition between the constructed and natural channel reaches at the upstream and downstream end of the stream restoration area will include boulder placement to provide for energy dissipation. The existing Jeep Road crossing of the lower spillway located immediately upstream of the stream restoration area is to be removed. In the event future site access requires replacement of this crossing, the engineer will provide direction for the methods to be used so as to be protective of the stream restoration area.

4.4.2 Design Hydrology

URS conducted a surface water runoff analysis for the watershed associated with TP-1 and TP-2 in support of the closure design. Rainfall-runoff modeling was conducted to estimate the peak flow for the 100-year, 24-hour storm event at key locations along the flow path of the sub-watershed. The surface water hydrologic analysis of the contributing basins was completed using HydroCAD version 7.0 from Applied Microcomputer Systems. A detailed discussion of the work performed and the modeling output is provided in Appendix F.

As discussed in Section 4.4.1.4, URS also performed a PMP analysis of the associated watershed to evaluate the closure design for dam safety conditions under this maximum flow event using a HEC-RAS computer model. A detailed discussion of the work performed and the analyses performed is provided in Appendix F. The PMP study concluded the following:

- Peak discharge through the spillway is 4,200 cubic feet per second (cfs). This flow will damage the spillway but, because the spillway is underlain by glacial till below the predicted PMF water surface elevation, erosion of the tailing dam will not occur.
- Water will pool behind the spillway to a maximum elevation of 1063.6 feet. This will flood a small portion of the TP-1 cover but will not overtop the tailing dam, which has a low-point elevation of 1,066 feet at the corner of dam at the spillway.
- Below the spillway, flood water could flow over the existing access road (depth of 2 feet) and, possibly reach the toe of the buttress. The access road adjacent to the spillway will be raised 3 feet to prevent this from occurring (see Drawing C-017

Appendix D). The design also includes an option to raise the TP-1 perimeter road adjacent to the stream restoration area for similar purposes. The final determination to include this design element will be made by the engineer following completion of the toe tailing excavation, once the final grades associated with the tailing excavation can be determined.

4.4.3 TP-1 Settlement Analysis

Settlement of the tailing in TP-1 is caused by consolidation of the tailing resulting from stress increases induced by the fill placement and by post-closure dewatering (i.e., groundwater drain-down). Using a combination of field and laboratory derived soil property data, computer modeling was performed to conservatively calculate the settlement for 217 discrete node locations across the tailing impoundments. Predicted settlement levels were contoured to identify the extent of settlement on the top surface of tailing, assuming full drain-down. The intent of this analysis was to predict the amount of settlement that may occur under realistic, but conservative conditions (i.e., assumptions used were those that would create the greatest amount of settlement under realistic conditions) and incorporate that amount of settlement into the subgrade plan to ensure that the minimum grades (i.e., 2 percent slopes) would be maintained after primary settlement occurs. The settlement calculations were performed iteratively along with the grading analysis to generate the final subgrade plan. The settlement analysis is provided in Appendix H.

The analysis found that settlement ranges from negligible levels along the eastern side of TP-1 to between 0.5 and 0.75 feet through the center and in the northwestern portion of TP-1 where fill depths required to achieve the final subgrade are greatest. The settlement was found to be primarily derived from fill and cover placement, with dewatering stress settlement being less significant. The tailing deposition methods used at the site and the tailing properties create a subsurface profile that has a relatively uniform settlement profile over large distances. Significant localized differential settlement is not predicted for TP-1 and TP-2 based on the data collected and analyzed to date. This observation is also consistent with experience at other mine sites of similar size and with similar tailing properties.

Because the final surface slope of the closed tailing impoundments must be at least 2 percent and surface drainage swales have relatively flat slopes, the potential differential settlement across the top of TP-1 was found be large enough to impact the final, post-settlement cover topography. Therefore, a final grading plan for TP-1 immediately following closure but prior to any settlement, was developed through an iterative process such that the post-settlement slopes would met the design requirements and assure surface drainage. This final grading plan is shown on Drawing C-013 (Appendix D). It should be noted that the actual settlement of the surface of TP-1 caused by cover placement and dewatering will likely be less then that predicted from the settlement analysis for the following reasons:

- The analysis assumes the tailing is normally consolidated, whereas there is some evidence that much of the tailing exhibits varying degrees of pre-consolidation (see the settlement pad report in Appendix H), therefore fill-induced settlement will be less.
- The fill-induced settlement will happen relatively rapidly and some amount of settlement will occur before final grading is complete, resulting in lesser amounts of post-construction settlement.
- The analysis assumes complete dewatering of the tailing, a condition which may not be ultimately achieved based on groundwater modeling.

4.4.4 Slope Stability Evaluation

The following sections describe the TP-1 and TP-2 dam stability evaluations performed as part of the NTCRA closure design. These evaluations included both new assessments and the application of previous assessments for conditions which are the same as those previously evaluated.

The evaluation criteria used are those established during the initial phases of TCRA design (URS, 2003b) and are based on criteria established by the EPA, USACE, the State of Vermont, and current state-of-the-practice for tailing and water dams. Established criteria stipulate a calculated Factor of Safety (FOS) of not less than 1.5 for steady-state seepage conditions and no less than 1.1 for post-earthquake loading conditions. The current state of the practice for tailing dams considers an FOS of 1.5 and above suitable for steady-state seepage conditions and an FOS above 1.0 to 1.3 (depending on site conditions and analytical approach) suitable for post-earthquake loading conditions.

4.4.4.1 TP-1 North and West Slopes

The stability of the TP-1 north slope following construction of the buttress (URS, 2004) and the TP-1 west slope following regrading (URS, 2006b) were evaluated for both steady-state drained and post-earthquake loading conditions at the time of the earlier NTCRA designs. These stability analyses determined that the earlier design conditions, which are unchanged for the NTCRA closure design, meet or exceed acceptable stability criteria. The applicability of these analyses to current conditions is as follows:

- Regrading will flatten the eastern end of the north face of TP-1 from approximately 2.5H:1V to 3H:1V, and the steep eroded face TP-2 to 3H:1V or flatter. Once closed, the east side of the north face of TP-1 will have flatter slopes than those evaluated by URS as part of the earlier TCRA design (URS, 2004). The 3H:1V design slope has no significant increase in design crest height (elevation 1067 feet versus 1070 feet). Therefore, the FOS determined previously for this TP-1 slope are a conservative estimate of the post-closure FOS.
- For the western end of the north face of TP-1, and for the western slope of TP-1, both of which will not be altered by the NTCRA closure, the stability analyses previously performed is directly applicable to the post-closure condition as the nominal addition of cover soil to these slopes will not significantly change the parameters related to slope stability.
- The regrading of the TP-2 crest slope is considered to be the same in terms of slope-stability assessment purposes (i.e., in both geometry and geotechnical properties) as the western slope of TP-1, which was previously analyzed by URS as part of the earlier phases of the NTCRA design (URS, 2006b). Therefore, the results of those prior analyses can be applied to the evaluation of the TP-2 slope.

Findings from the previous stability analyses performed for the TCRA and NTCRA are summarized below. The previously referenced reports should be reviewed for details, supporting documentation, and stability modeling output.

4.4.4.1.1 Cross Section Geometry

Steady-state drained stability and post-earthquake slope stability analyses were completed for three cross-sections on the north face of TP-1 and three cross-sections on the west side of TP-1. The slopes were evaluated for static and post-earthquake loading conditions using the pre-existing phreatic surface.

The geometry of TP-1 at the study sections is based on existing topography as provided by USACE. The proposed geometry is the post-regrade slopes following the TCRA buttress and the NTCRA west side diversion construction activities, as discussed above. The internal geometry selected for the outer sand shell and slime interface, tailing embankment section, starter dam, and foundation contact are the same as those established for prior slope stability analyses performed as part of the TP-1 Geotechnical Investigation Report (URS, 2003a).

4.4.4.1.2 Phreatic Surface

The existing internal phreatic surface for the tailing dam is based on the approximate water-level elevations measured at the time of test pitting and piezometer readings measured on September 4, 2003 which included the broadest coverage of measurement points relative to the study sections. A review of this monitoring event relative to the current water-level dataset indicates that conditions measured on September 4, 2003 remain representative of existing conditions.

4.4.4.1.3 Material Properties

Material properties applied in the steady-state and post-earthquake models are based on material characterization presented in the TCRA Buttress Design Report (URS, 2004). The engineering properties of the tailing sand, slime, and foundation material are based on results of Standard Penetration Tests data, Cone Penetration Test soundings, and geotechnical laboratory results, and are compared with published data. The material properties for the buttress fill are based on laboratory testing completed as part of this report.

4.4.4.1.4 Analysis Procedure

The limit-equilibrium slope stability analysis method was used to evaluate the stability at each study section using the computer program UTEXAS3 (Wright, 1991). An automatic search procedure was first applied using Spencer's method of slices to find critical circular shear surfaces (i.e., the shear surface corresponding to the lowest FOS); however, to better represent the critical failure plane the analysis procedure was modified to incorporate a manual search method. As a result, the failure surfaces analyzed are manually selected and may not represent the absolute theoretical minimum FOS.

A liquefaction analysis performed as part of the 2003 Geotechnical Investigation Report showed that liquefaction is not predicted to occur for the 2,500-year return period. However, even though liquefaction was not expected to occur under the design events, a reduction in the drained tailing shear strength of 20-percent was assumed for the post-earthquake analysis. This reduction is explained in detail in the Geotechnical Investigation Report.

4.4.4.1.5 Results

The existing (post TCRA) TP-1 slopes, whether unaltered by the closure or regraded, and the regraded TP-2 slopes will have a steady-state seepage FOS and a post-earthquake FOS that exceeds the established minimum FOS for tailing dams. The calculated FOS for the steady-state seepage and post-earthquake stability at each section analyzed are summarized in Table 3 below.

TABLE 3
SLOPE STABILITY FACTORS OF SAFETY

Location	Steady-State Seepage	Post-Earthquake	Comment
TP-1 Eastern End	> 2.0	> 1.7	Regraded to 3H:1V
TP-1 Center Section	> 1.9	> 1.7	Unchanged from 3.5H:1V
TP-1 Western End	2.4	> 1.8	Unchanged from 3H:1V
TP-2	2.4	> 1.8	Regraded to 3H:1V

For a more detailed presentation of the slope stability analysis performed, please refer to the previously referenced reports.

4.4.4.2 Veneer Stability

Critical to the installation of the cover is the interface shear strength between the various layers in the cover system. The shear strength must be adequate, with a FOS to prevent sliding of the geomembrane and overlying cover soil (i.e., veneer failure). The critical interfaces are:

- Tailing subgrade/geomembrane,
- Geomembrane/GCD, and
- GCD/vegetative support soil.

To assure the selected cover system materials have the required interface shear strength, a testing procedure using the specific materials that will be used, or exist, on TP-1 and TP-2 slopes will be undertaken (see Technical Specification 02561 – Appendix G). To be acceptable, the interface shear strength must be adequate to produce the factors of safety for the various analytical scenarios as noted in Technical Specification 02561 (Appendix G).

4.4.4.3 TP-1 Crest Height Extension

The placement of the cover system on TP-1 will result in an increase in elevation of up to 5 feet along portions of the top crest of the tailing dam. The impact on the stability FOS resulting from this increase was evaluated using the same analytical approach used in the buttress analysis performed in 2004. Cross Section B from that study was selected for re-evaluation as being the critical section. The same material strength data, phreatic surface location and embankment geometry was used for the current assessment. A height increase of 10 feet, rather than 5 feet, was assumed to take into account possible over-filling and/or surcharging. The calculated FOSs are acceptable based on the criteria established for evaluating dam stability presented previously. The slope stability analysis is provided in Appendix K.

4.4.4.4 Buttress Top Extension

The top of the buttress fill on TP-1 (see Toe Detail B, Drawing C-015 of Appendix D) will be raised approximately 4 feet using stone fill. A stability analysis of the extension was performed using methods and data from earlier assessments. The calculated FOSs are acceptable based on the criteria established for evaluating dam stability presented previously. The slope stability analysis is provided in Appendix K.

4.5 TP-1 AND TP-2 CLOSURE DESIGN

The design details for the closure of TP-1 and TP-2 are provided on Drawing C-002, and C-012 through C-018 of Appendix D. Technical Specifications are provided in Appendix G.

The proposed remediation of the Copperas Factories component of the Remedial Action incorporates cover-in-place methods as well as excavation and consolidation methods to address the identified areas of lead-impacted soils within and around the Copperas Factories. Presented below is a detailed summary of URS' design evaluation for the remediation of the Copperas Factories.

5.1 PHYSICAL CONDITIONS OF THE COPPERAS FACTORIES

The remains of the former Copperas Factories include stone foundations and debris scatter associated with the former copperas processing operations. The foundations (identified as the Upper and Lower Copperas Factories) formerly housed evaporators, crystallizers, and packaging operations which were active during the early and mid 1800s. As discussed in Section 2.3, processing of copperas in these areas included evaporation in lead-lined vats. Likely, as a result of this process, lead-impacted soils are present in and around both the Upper and the Lower Copperas Factories, as depicted on Figure 4. The current extent of lead impacts is based on findings documented in the ROD, supplemented by additional EPA characterization data collected during 2007. This supplemental EPA data and supporting figures are presented in Appendix C.

5.2 REMEDIAL APPROACH

The Copperas Factories remediation involves a combination of in-place covering of lead-impacted material with the possibility of some excavation and consolidation of lead-impacted material either within the Copperas Factories footprint or within a designated lead-waste disposal area on TP-1 or TP-2. Both the in-place covering and the consolidated lead disposal area include placement of a 2-foot thick cover over the waste to isolate the wastes from direct contact, in accordance with the ARARs (Appendix A).

The CF-4 alternative selected in the ROD specified that soil contaminated with lead above the cleanup level would be covered in-place or consolidated within the Copperas Factories footprint and covered with 2 feet of soil or stone. The in-place cover option was selected as the alternative most consistent with the requirement of the National Historic Preservation Act (NHPA). The review of the design by the historic preservation experts revealed that some quantity of lead contaminated soil may need re-location outside the Copperas Factories footprint to achieve the optimal compliance with the historic preservation objectives. Specifically, the historic preservation concept would require minimizing any areas where fill or the required cover placement would substantially alter the landscape. As a result, the design includes the option for soil to be excavated, relocated, and covered onsite, within the defined area of concern (AOC) for the NTCRA/RA. The specific location will be on the surface of either TP-1 or TP-2. In addition, the design requires testing of the soil to determine if the excavated material that may be relocated to TP-1 or TP-2 would qualify as a hazardous waste, and if so, pre-treatment of the soil to render it non-hazardous may be required prior to final placement. The elimination of the characteristics of a hazardous waste will allow for the cover system on TP-1 and TP-2 to remain a solid waste closure cover system, rather than a hazardous waste closure cover system. The Remedial Action design includes ARAR tables and other requirements associated with the excavation, relocation, and on-site covering of the lead contaminated soil, which were included as part of the CF-2 alternative in the Feasibility Study (URS, 2006c).

The design documents a remedial approach that attempts to preserve the exposed foundations of the Upper and Lower Copperas Factories as visible features. The primary elements of the Copperas Factories Remedial Action are:

- Remediate lead-impacted soil at the Upper and Lower Copperas Factories through in situ covering or excavation and relocation to the designated lead-waste disposal area.
- Place a sufficiently thick soil cover over soil with a lead concentration equal to or exceeding 400 mg/kg to prevent direct human contact risk.
- Preserve Copperas Factory foundations, to the extent possible, or document historic resources that must be disturbed.
- Preserve historic artifacts, to the extent practicable.

Institutional controls (e.g., restrictive covenants) to protect the Remedial Action from damage will be required upon completion of the remedial construction.

5.2.1 Historic Preservation Criteria

Based on meetings held on May 1, 2007 and October 4, 2007, the NHPA-expert consultant identified the following historic preservation criteria for the Copperas Factories:

- **Do not over-restore the factory sites**: The overall design philosophy should be to maintain the existing first impression of the visual approach to the exposed Copperas Factory foundations and their appearance as abandoned ruins.
- **Maintain existing topography**: Ideally, remove contaminated soil from the top of the walls and from below the walls and replace with clean material to match the existing grade. Where the elevation of existing soil is uneven against the bottom of the walls, approximate the uneven elevation with the fresh material. Do not alter surface grades within the proximity of the foundation walls.
- **Promote stability of stone walls**: Remove the small tree stumps in the middle of the foundations and cut the large tree stumps level, allowing a little bit of crown fill on the top and access to the historic structure. Do not remove tree stumps close to the inside or outside of the walls as that may destabilize the walls; cut those stumps level. As a precautionary step, the external stone foundations could be “wrapped” with geotextile and slightly tensioned cables for the duration of the work and then removed. Should individual stones start to shift, they would be held in place. The barrier would also minimize incidental contact and make an obvious visual barrier. Loose stones found during excavation or dislodged during construction can be placed back on the walls.
- **Historic Data Recovery**: Historic data recovery will be performed in support of the closure design with the findings incorporated into the design and construction as warranted.
- **Design Components**:
    - Backfill Design: Materials should be selected of uniform texture and consistency. Provisions should be made to ensure soils drain well, as water freeze/thaw cycles can damage the old walls. Keeping water away from and drained from fill will help preserve the foundations.
    - Choice of Materials: Choose capping and soil stabilization materials that will not detract from the formal elements of the existing stone wall (i.e. avoid large-diameter stone riprap).
    - Geotextiles: Use of geotextiles should be considering as a marker layer and physical barrier between in situ soils and backfill. Furthermore,

geotextiles can provide additional strength to wall/fill by tending to hold materials together so they act as more of a unit. Geotextiles might be used against the stone foundation where soil is removed (on the inside or outside) and replaced with fill. This will give added strength and if individual stones in the wall start to shift, they will encounter the resistance of the fabric backed by the fill rather than straight fill.

- **In-Situ Artifact Preservation**: Cast iron stanchions, rails, plates, plumbing, furnace parts, etc. should be removed and deposited in an artifact repository or preserved in-place, if possible, prior to commencement of work.
- **Equipment Selection**: Construction equipment should be selected to minimize direct contact, vibration, and earth pressure. Smaller equipment with an adequate reach should be utilized when working close to the walls.
- **Site Supervision**: Supervisors should be cognizant of the sensitivity of the historic foundations and be closely engaged with all facets of the site work. Equipment operators should be highly skilled, experienced, and attentive.

5.2.2 Relationship with NTCRA Closure Activities

The Upper Copperas Factory is located within the TP-3 limit of waste identified for removal. The lead containing soils associated with the Lower Copperas Factory extend into the TP-3 waste rock identified for removal. Therefore, the lead removal associated with these features must consider both the high acid generating potential of the TP-3 waste ore and the elevated lead content. Mixing of these materials and subsequent placement in a manner consistent with only lead closure requirements (i.e., isolation using a 2-foot soil cover) may result in the long-term generation of acid rock drainage through infiltration, as well as the potential for lead mobilization through the generation of acidic pore water. For this reason, based on the acid-base accounting characteristics of the waste ore, neutralization of the lead-containing waste ore may be necessary. In the event that neutralization of the waste is deemed to be required by the engineer due to the location of the final material placement relative to surface drainage and infiltration potential, lime will be added and mixed into the wastes at a rate not less than 20 percent by volume. Refer to Appendix K for supporting calculations. Following mixing, the lead-containing materials will be closed as noted above

5.3 DESIGN APPROACH

The approach for the Copperas Factories design is as follows:

- To the extent practical, place an in situ cover with a minimum of 24 inches of clean soil or stone over the lead-containing wastes.
- Consolidate the remaining portion of lead-containing wastes from both the Upper and Lower Copperas Factories into a designated waste cell located on TP-1 or TP-2. The cell shall be closed using interim stabilization methods pending final closure of the tailing impoundments.
- Perform confirmation tests at the time of closure to document that all identified lead-impacted materials are closed in accordance with these requirements.
- The Copperas Factories foundation walls will be left undisturbed, as practicable.
- Surface water drainage will be routed through the remediated area to minimize impact to the historic features and to the constructed cover systems.
- An historical resource data recovery program will take place either prior to or coincident with the lead remediation activities in this area.

5.4 COPPERAS FACTORY CLOSURE DESIGN

The Copperas Factory closure design has been developed in order to maintain the factory features to the extent possible. The design will incorporate the findings of data recovery with the possibility of recreating the outline of the Factories and roads through post-closure landscaping. Some excavation and consolidation may occur to accommodate historical preservation objectives. Finally, surface water drainage will be routed to minimize impact on closed areas of lead-containing materials and on the foundation structures, with particular care taken to preserve the walls. The design details for the closure of the Copperas Factories are provided on Drawing C-004 of Appendix D. Technical Specifications are provided in Appendix G.

6.1 DESIGN DRAWINGS AND TECHNICAL SPECIFICATIONS

Design drawing and technical specifications for the NTCRA closure are provided in Appendix D and G, respectively.

6.2 QUANTITIES

Estimates of quantities associated with the TP-1, TP-2 and TP-3 closure design and the Copperas Factories remediation are presented in Table 4. These quantities do not include any contingency for such factors as swell/shrink of compacted soil, construction overage, damage, or waste.

ABA	Acid Base Accounting
AGP	Acid Generating Potential
ARARs	Applicable, Relevant and Appropriate Regulations
ARD	Acid Rock Drainage
ASTM	American Society for Testing and Materials
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
cm/sec	centimeter per second
cyds	cubic yards
EE/CA	Engineering Evaluation and Cost Analysis
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
FOS	Factor of Safety
FS	Feasibility Study
GCD	Geocomposite Drain Net
GCL	Geocomposite Clay Layer
H	Horizontal
HELP	Hydrologic Evaluation of Landfill Performance
LLDPE	linear low-density polyethylene
MCLs	Maximum Contaminant Levels
mg/kg	milligrams per kilogram
NHPA	National Historic Preservation Act
NNP	Net Neutralization Potential
NOAA	National Oceanic and Atmospheric Administration
NTCRA	Non-Time-Critical Removal Action
PAL	Public Archaeology Laboratory
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RI	Remedial Investigation

ROD	Record of Decision
SPLP	Synthetic Precipitation Leaching Procedure
SU	Standard Units
TCRA	Time-Critical Removal Action
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
V	Vertical
VTANR	Vermont Agency of Natural Resources
VWQS	Vermont Class B Water Quality Standard
WBOR	West Branch of the Ompompanoosuc River
WWII	World War II

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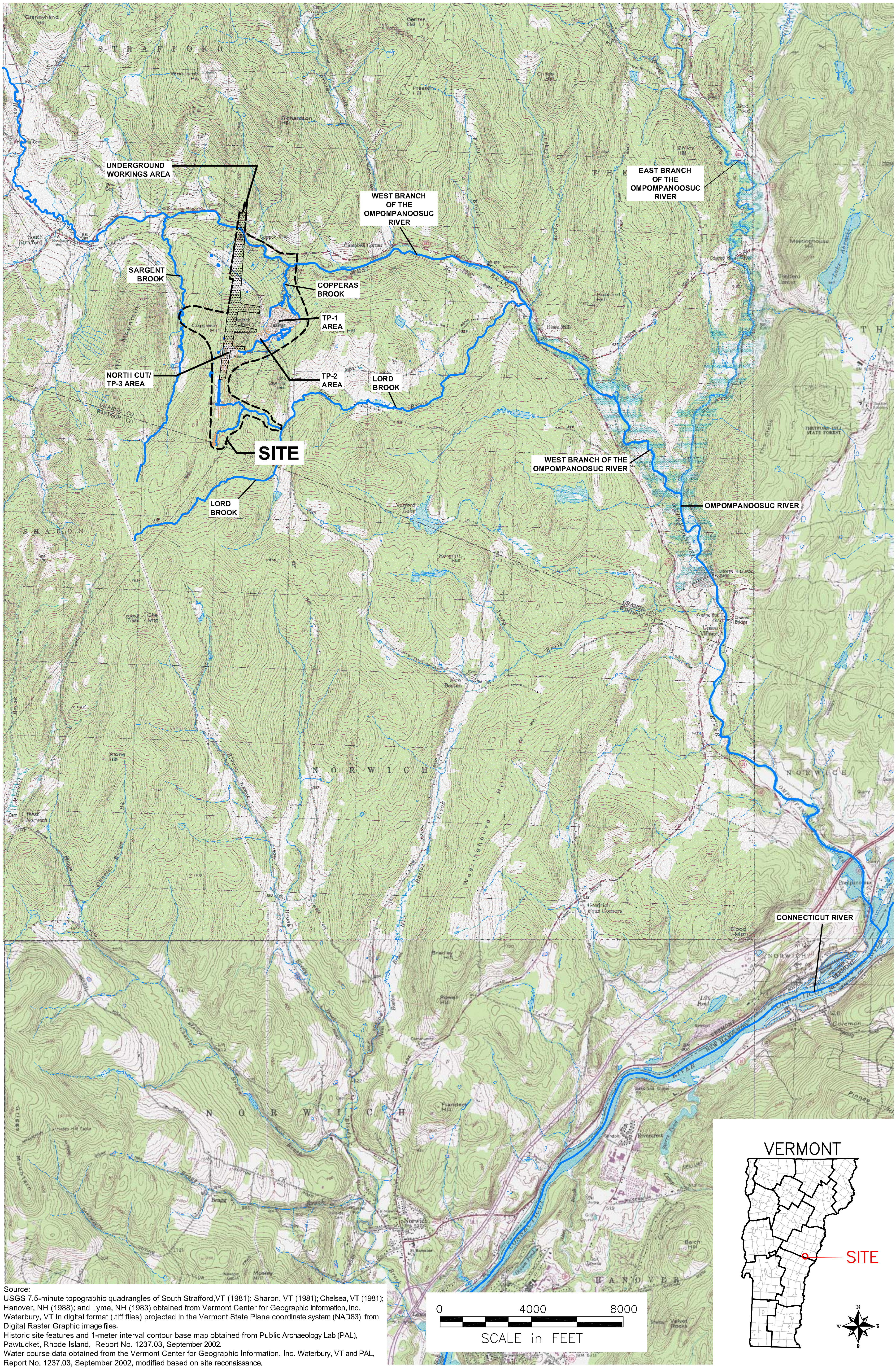
TABLE 4
CONSTRUCTION QUANTITIES

TABLE 4
CONSTRUCTION QUANTITIES
NTCRA CLOSURE DESIGN
Elizabeth Mine
Strafford, Vermont

Item	Quantity	Unit	Comments
Mobilization	1	LS	For entire NTCRA Closure
Erosion and Sedimentation Control	1	LS	For entire NTCRA Closure
Site Preparation	5	Acres	
Copperas Factories Excavation	550	CY	Upper and Lower Factories
Copperas Factories Lead Sampling	1	LS	Sample Program
Copperas Factory Preparation	1	LS	Lower Factory
Adit/Shaft Closures	4	EA	
TP-3 Excavation	150,000	CY	Includes filling on TP-1
Stone Cover	6,000	CY	
Bedrock Surface Preparation	8	Acres	
Copperas Road Reconstruction	900	LF	
Mine Road Reconstruction	400	LF	
Rip Rap Channel	200	LF	At Mine Road
Diversion Swale Above North Cut	750	LF	
Temporary Sediment Basin	1	LS	
Tailing Regrade	25,000	CY	TP- 1 and TP-2
TP-1 & TP-2 Subgrade Preparation	38	Acres	
Tailing Sand Fill	25,000	CY	
Geomembrane	1,730,000	SF	
Geotextile Cushion	42,000	SF	
HT Drainage Geocomposite	400,000	SF	
LT Drainage Geocomposite	1,300,000	SF	
Side Slope Collector Pipe	1,200	LF	
Side Slope Lower Drainage Pipe	3,000	LF	
Collector Pipe System	10,000	LF	
Vegetative Support Layer	92,000	CY	
Topsoil Layer	35,000	CY	Includes off cap areas
Perimeter Swale	1,100	LF	
Toe Berm	5,600	LF	
Cap Roads	4,000	LF	Includes off cap extensions
Perimeter Road Grade Increase	750	LF	
Stream Excavation	11,000	CY	
Stream Restoration	700	LF	
Revegetation	50	Acres	

Quantities based on design drawings. No construction contingencies have been included.

FIGURES



Source:
USGS 7.5-minute topographic quadrangles of South Strafford,VT (1981); Sharon, VT (1981); Chelsea, VT (1981); Hanover, NH (1988); and Lyme, NH (1983) obtained from Vermont Center for Geographic Information, Inc. Waterbury, VT in digital format (.tiff files) projected in the Vermont State Plane coordinate system (NAD83) from Digital Raster Graphic image files.
Historic site features and 1-meter interval contour base map obtained from Public Archaeology Lab (PAL), Pawtucket, Rhode Island, Report No. 1237.03, September 2002.
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.

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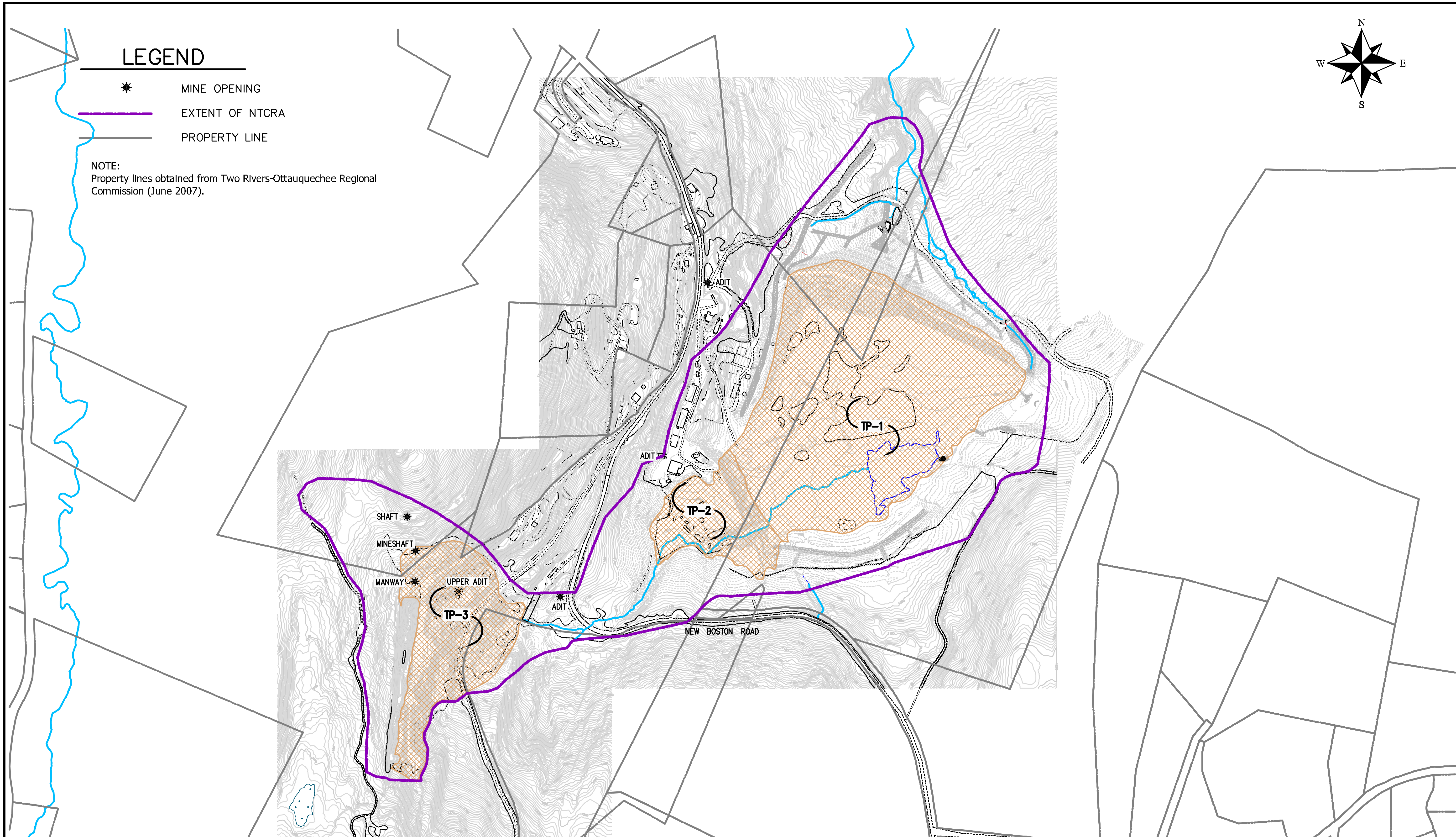
PROJECT NO: 39459945		CLIENT: U.S. ARMY CORPS OF ENGINEERS	TITLE: SITE LOCUS
DESIGN: FS	SCALE: 1"=4000'	PROJECT: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT	FIGURE NO: 1
APPROVED: JCC	DATE: MARCH 2009	U.S. Army Corps Of Engineers New England District	
DRAWN: CAM	FILE NO: EM_BASE		

P:\Project\USACE_13846\39459197_067\RI_FS\Figures\EM_BASE.dwg, FIG 1 SITE LOCUS, 3/25/2009 10:10:12 AM



P:\acad-project\USACE-ELIZABETH-MINE-STRAFFORD-VT\dwg\NTCRA Basis Of Design.dwg, FIG 2 NTC REMOVAL, 3/25/2009 10:18:01 AM

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U.S. Army Corps Of Engineers
New England District

0 500 1000
SCALE IN FEET

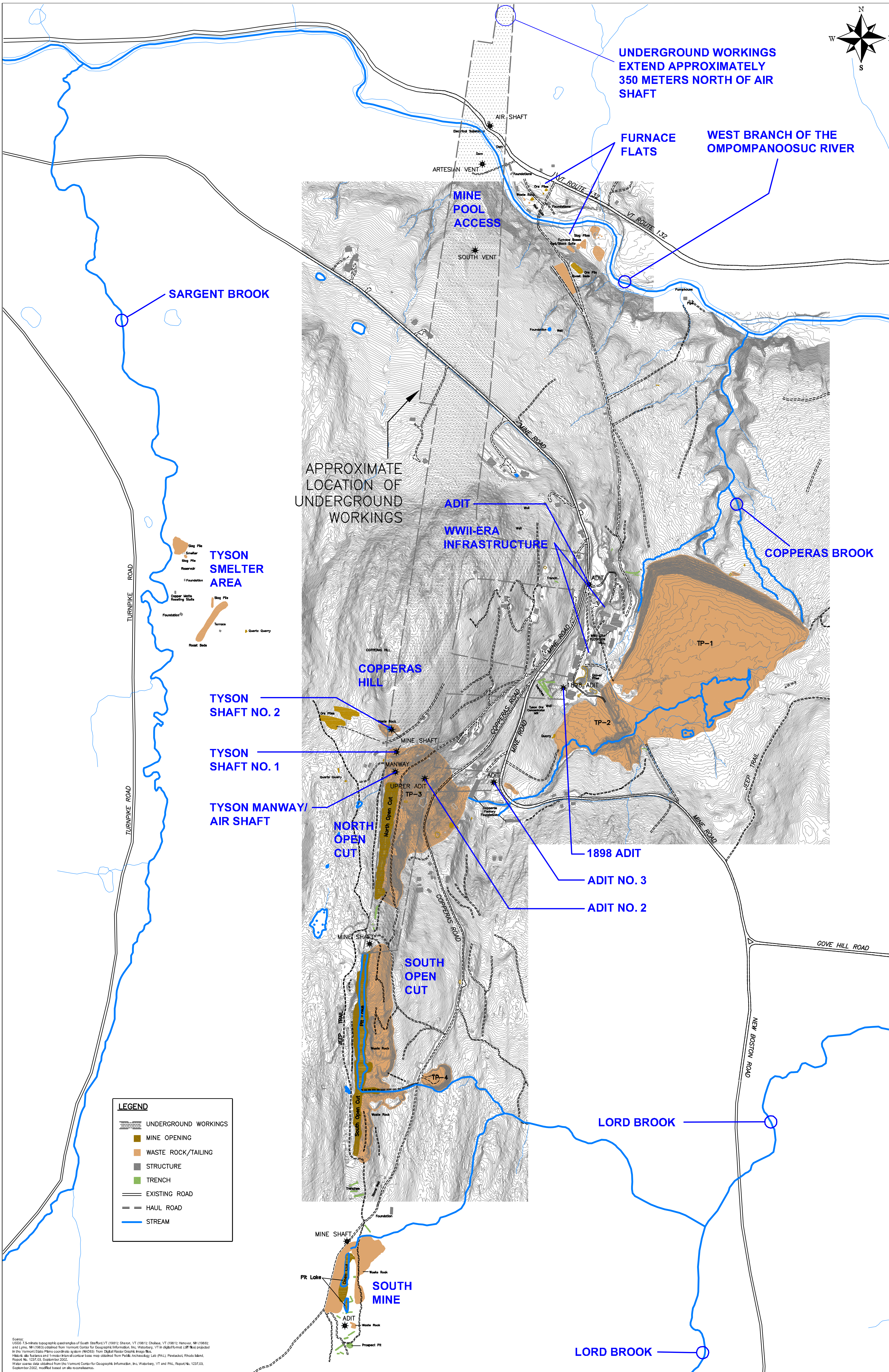
PROJECT NO:	39459945		
DESIGN:	CAM	SCALE:	1" = 500'
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	CAM	FILE NO:	NTCRA BASIS OF DESIGN

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

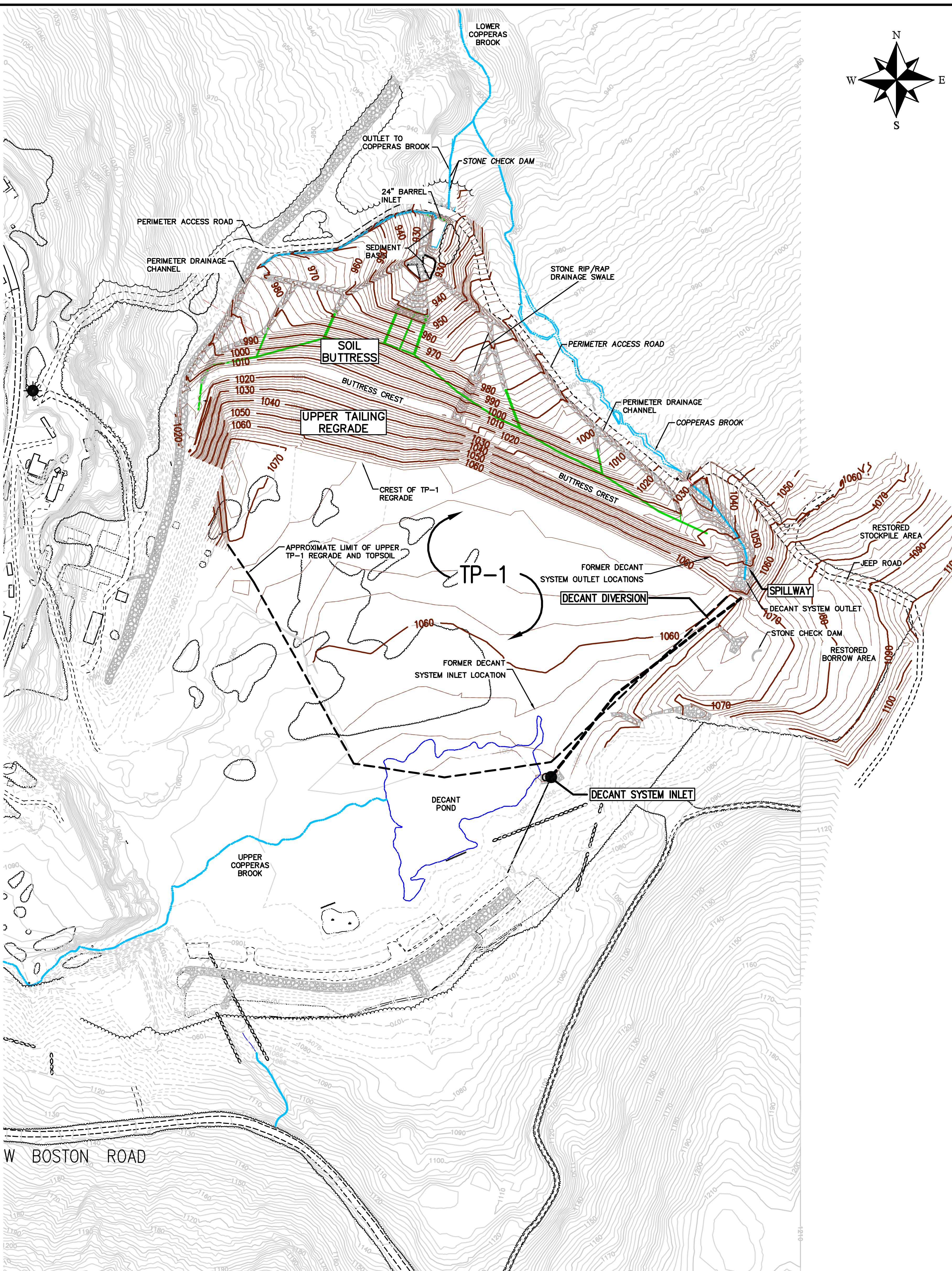
TITLE: NON-TIME-CRITICAL REMOVAL ACTION AREA

FIGURE NO.: 2



P:\Project\USACE_13846\39459197_067\RI_FS\Figures\EM_BASE.dwg, FIG 3 PRIMARY FEATURES, 3/25/2009 10:04:27 AM

URS Corporation, 477 Congress Street, Suite 900, Portland, ME 04101-3453, Tel: 207.879.7686, Fax: 207.879.7685	U.S. Army Corps Of Engineers New England District	SCALE in METERS (0, 100, 200)	
PROJECT NO: 39459945		CLIENT: U.S. ARMY CORPS OF ENGINEERS	TITLE: PRIMARY PHYSICAL FEATURES
DESIGN: FS	SCALE: AS SHOWN	PROJECT: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT	FIGURE NO: 3
APPROVED: JCC	DATE: MARCH 2009		
DRAWN: CAM	FILE NO: EM_BASE		



0 250 500

SCALE IN FEET

LEGEND

EXISTING TOPOGRAPHIC CONTOURS (AERIAL)

EXISTING TOPOGRAPHIC CONTOURS (SURVEYED)

TIME-CRITICAL REMOVAL ACTION CONSTRUCTION ELEMENT, TOPOGRAPHIC CONTOUR

TOE DRAINS & HORIZONTAL DRAINS

STONE RIPRAP

NOTE:
TP-1 SEEPAGE FILTERS CONSTRUCTED IN 2003 AT FORMER TOE AREA. FEATURES WERE REMOVED DURING BUTTRESS CONSTRUCTION.

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DESIGN: CAM		SCALE: 1"=250'	
APPROVED: JCC		DATE: MARCH 2009	
DRAWN: CAM		FILE NO: NTCRA BASIS	

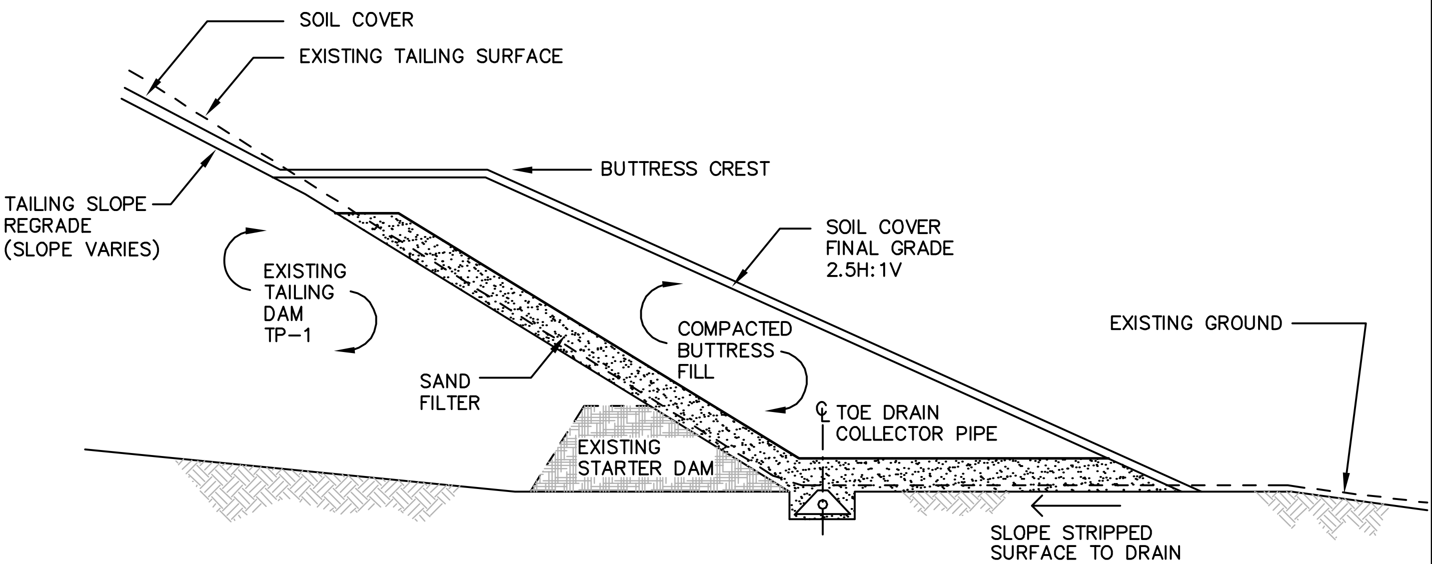
CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJ: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

U.S. Army Corps Of Engineers New England District

TITLE: TIME-CRITICAL REMOVAL ACTION ELEMENTS

FIGURE NO.: 4



NOTE:
STARTER DAM IS PRESENT BEHIND BUTRESS ONLY IN AREA ADJACENT TO THE STONE APRON/UPPER SEDIMENTATION POND.

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SCALE:	NO SCALE
DATE:	MARCH 2009
FILE NO:	NTCRA BASIS
DESIGN:	CAM
APPROVED:	JCC
DRAWN:	CAM

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJ: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

PROJECT NO: 39459945

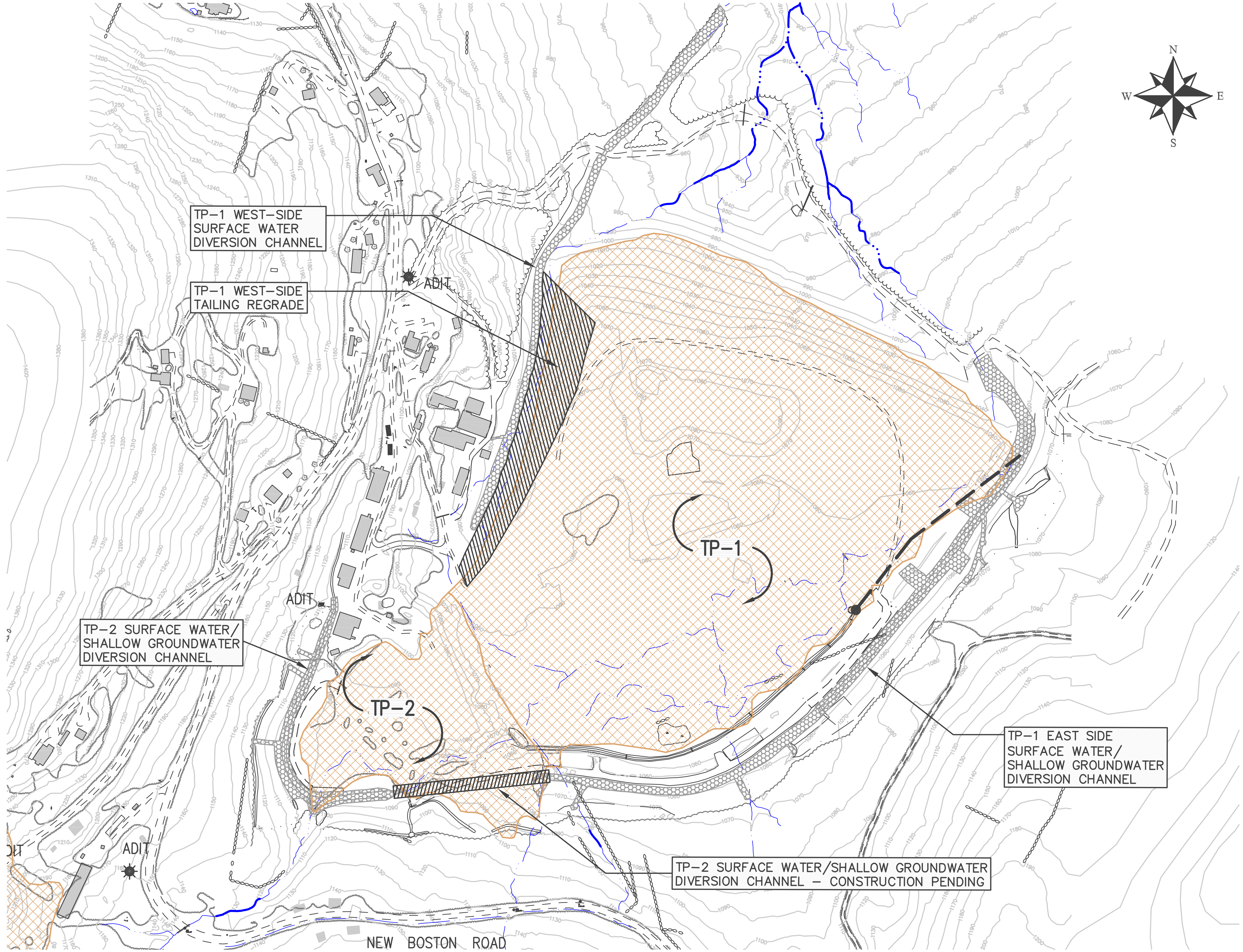
TITLE: TP-1 BUTTRESS SECTION VIEW

FIGURE NO.: 5

P:\acad-project\USACE-ELIZABETH-MINE-STRAFFORD-VT\dwg\NTCRA Basis Of Design.dwg, FIG 6 NTCRA COMPONENTS, 4/2/2009 10:48:00 AM

LEGEND

- TOPOGRAPHIC CONTOURS (SURVEYED)
- TREELINE
- STONE RIPRAP



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SCALE IN FEET

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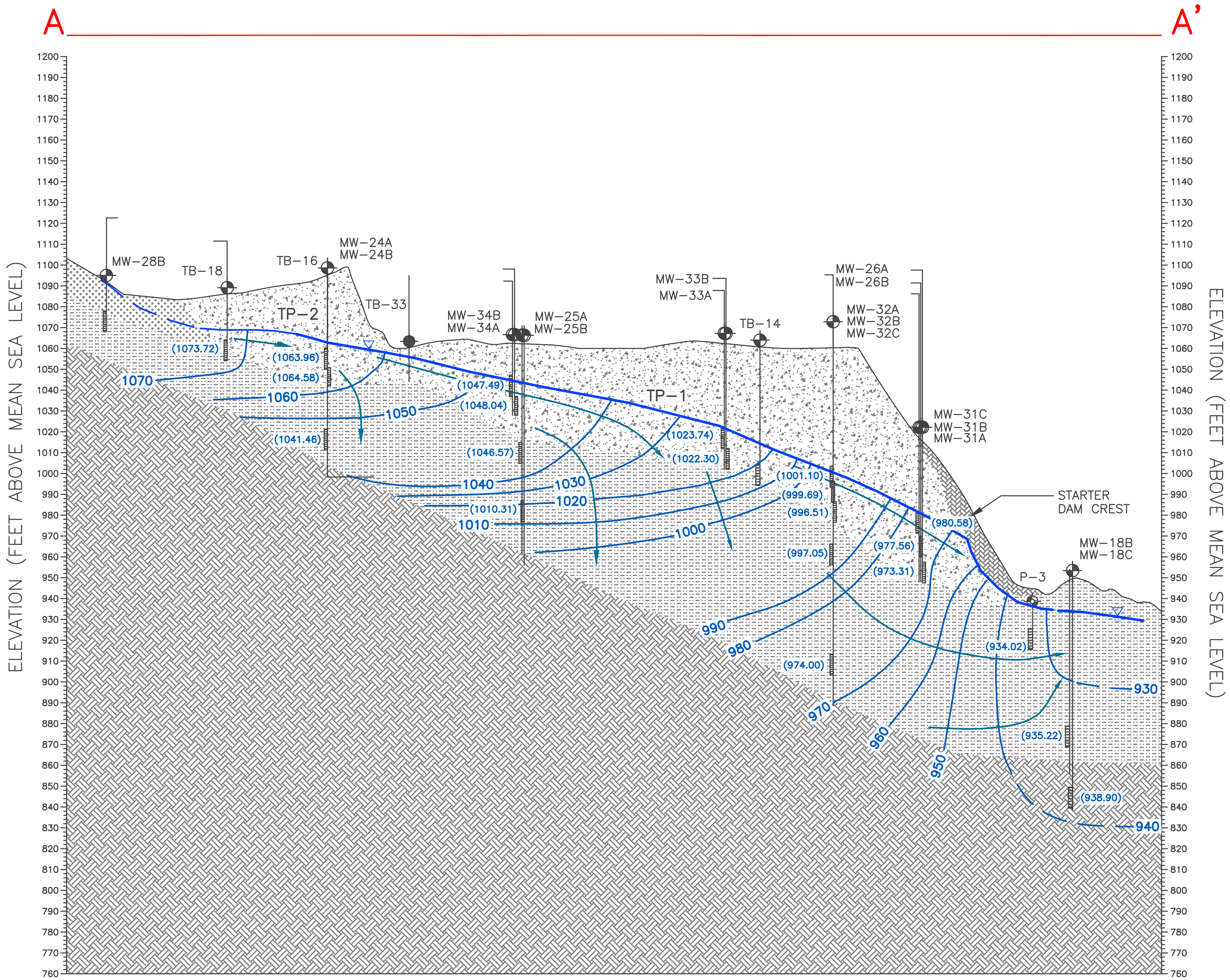
PROJECT NO:	39459945		
DESIGN:	CAM	SCALE:	1" = 300'
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	CAM	FILE NO:	NTCRA BASIS OF DESIGN

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT

TITLE: NON-TIME-CRITICAL REMOVAL ACTION COMPONENTS DECEMBER 2007 CONDITIONS

DRAWING NO.: 6



LEGEND

MW-11C — MONITORING WELL

TB-14 — TEST BORING

SCREENED INTERVAL

BEDROCK – GILE MOUNTAIN FORMATION – GRAY, SCHIST, ACCESSORY MINERALS INCLUDE GARNET, MICA, BIOTITE, GRAPHITE, QUARTZ AND CHALCOPYRITE

GLACIAL TILL – GRAY TO OLIVE GRAY, CLAYEY SILT GRAVELLY SILTY SAND, MEDIUM DENSE TO VERY DENSE, FINE SAND, OFTEN CONTAINS FINE TO COARSE ANGULAR TO SUBROUNDED GRAVEL

TAILING – GRAY TO BLACK SILTY SAND TO CLAYEY SILT, LOOSE/VERY SOFT TO DENSE/VERY STIFF, SULFUR ODOR. COLOR IS YELLOW AT SURFACE WHERE TAILINGS ARE OXIDIZED.

TP-1 BUTTRESS (COMPACTED GLACIAL TILL).

OVERBURDEN – SILTY SAND WITH ORGANIC MATTER

(1047.87) — GROUNDWATER ELEVATION DECEMBER 2007

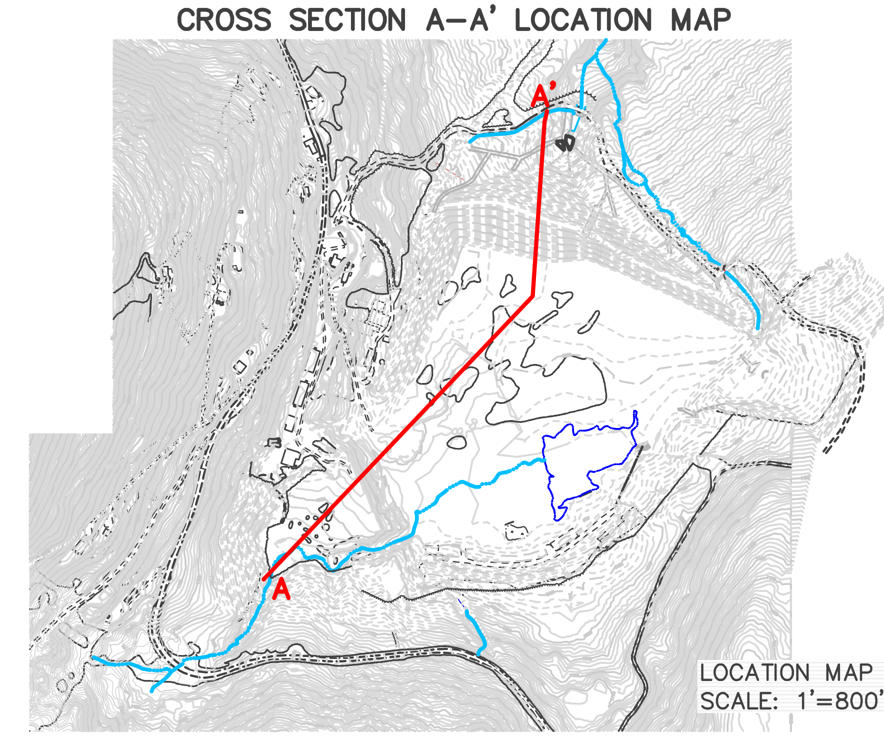
1040 — GROUNDWATER EQUIPOTENTIAL CONTOUR DASHED WHERE INFERRED

APPARENT GROUNDWATER FLOW DIRECTION

NOTES:

1. TOPOGRAPHY SHOWN DEPICTS POST TIME-CRITICAL REMOVAL ACTION CONDITIONS.
2. TB-14 REMOVED DURING 2004 IMPLEMENTATION OF TIME-CRITICAL REMOVAL ACTION.
3. MW28B REMOVED DURING 2007 IMPLEMENTATION OF NON-TIME-CRITICAL REMOVAL ACTION.
4. VERTICAL EXAGGERATION = 5X

CROSS SECTION A-A' LOCATION MAP



LOCATION MAP
SCALE: 1'=800'

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0 300 600
HORIZONTAL SCALE IN FEET

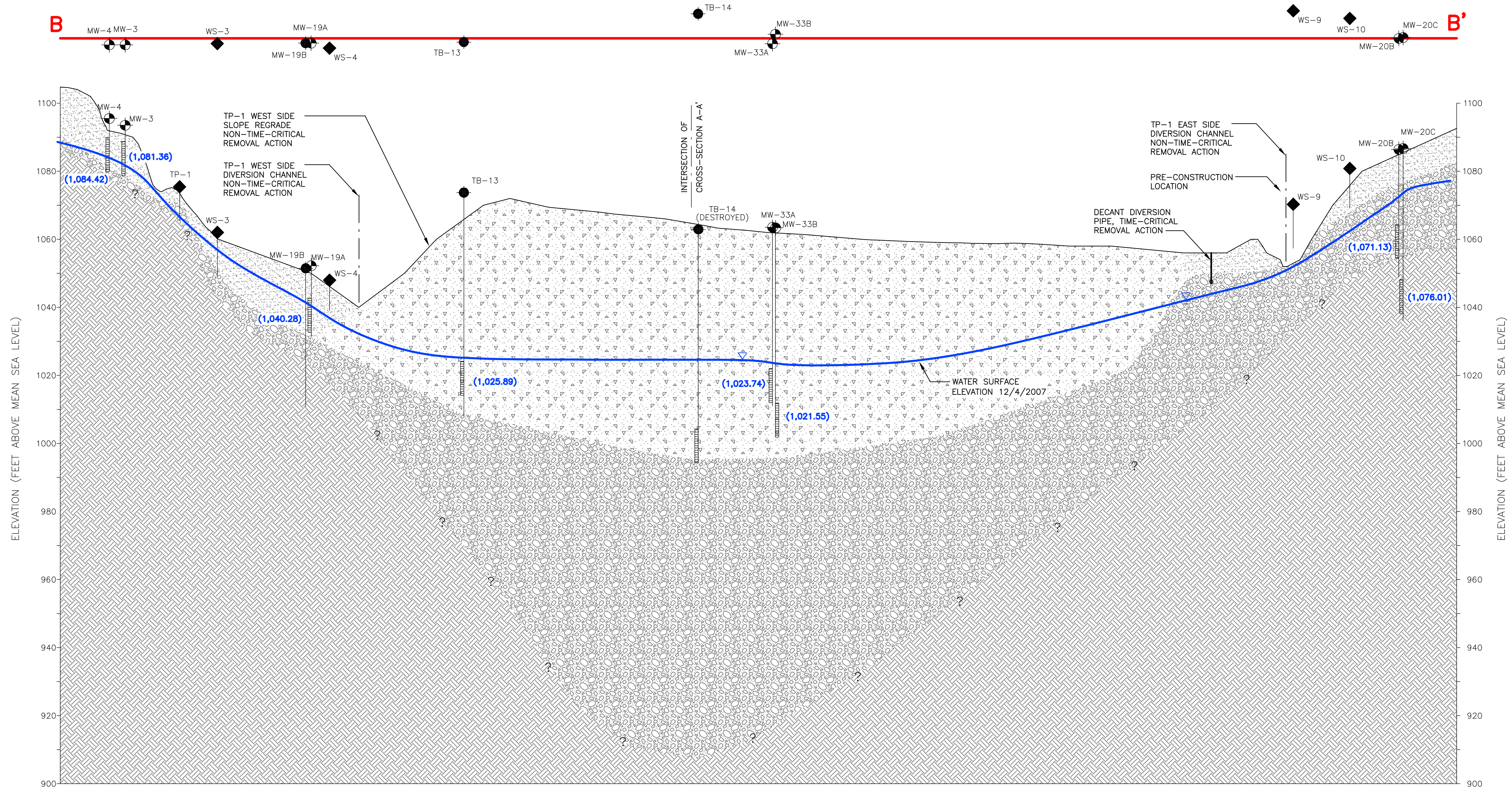
PROJECT NO:	39460215		
DESIGN:	FS	SCALE:	1" = 300'
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	FS/CAM	FILE NO:	Xsections

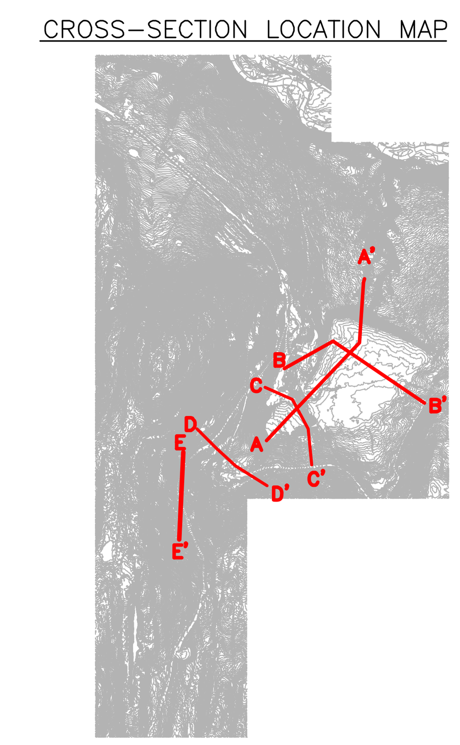
CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT

TITLE: GEOLOGIC CROSS SECTION A-A'

FIGURE NO.: 7





LEGEND

- MW-11C / PZ-01 — MONITORING WELL/PIEZOMETER
- TB-14 — TEST BORING
- WS-10 — TEST PIT
- WELL SCREEN INTERVAL
- BEDROCK – GILE MOUNTAIN FORMATION – GRAY, SCHIST, ACCESSORY MINERALS INCLUDE GARNET, MICA, BIOTITE, GRAPHITE, QUARTZ AND CHALCOPYRITE
- GLACIAL TILL – GRAY TO OLIVE GRAY, CLAYEY SILT GRAVELLY SILTY SAND, MEDIUM DENSE TO VERY DENSE, FINE SAND, OFTEN CONTAINS FINE TO COARSE ANGULAR TO SUBROUNDED GRAVEL
- TAILING – GRAY TO BLACK SILTY SAND TO CLAYEY SILT, LOOSE/VERY SOFT TO DENSE/VERY STIFF, SULFUR ODOR. COLOR IS YELLOW AT SURFACE WHERE TAILING OXIDIZED.
- ALLUVIAL – BROWN TO DARK BROWN SILTY SAND WITH ORGANIC MATTER, LOOSE
- FILL – SILTY GRAVELLY SAND TO SANDY GRAVEL, MEDIUM DENSE TO DENSE COLOR FROM REDDISH BROWN, GRAY, LIGHT GRAY TO OLIVE GRAY.
- ▽(939.9) — GROUNDWATER ELEVATION, 12/4/2007

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1" = 20' VERT
1" = 100' HORZ
SCALE IN FEET

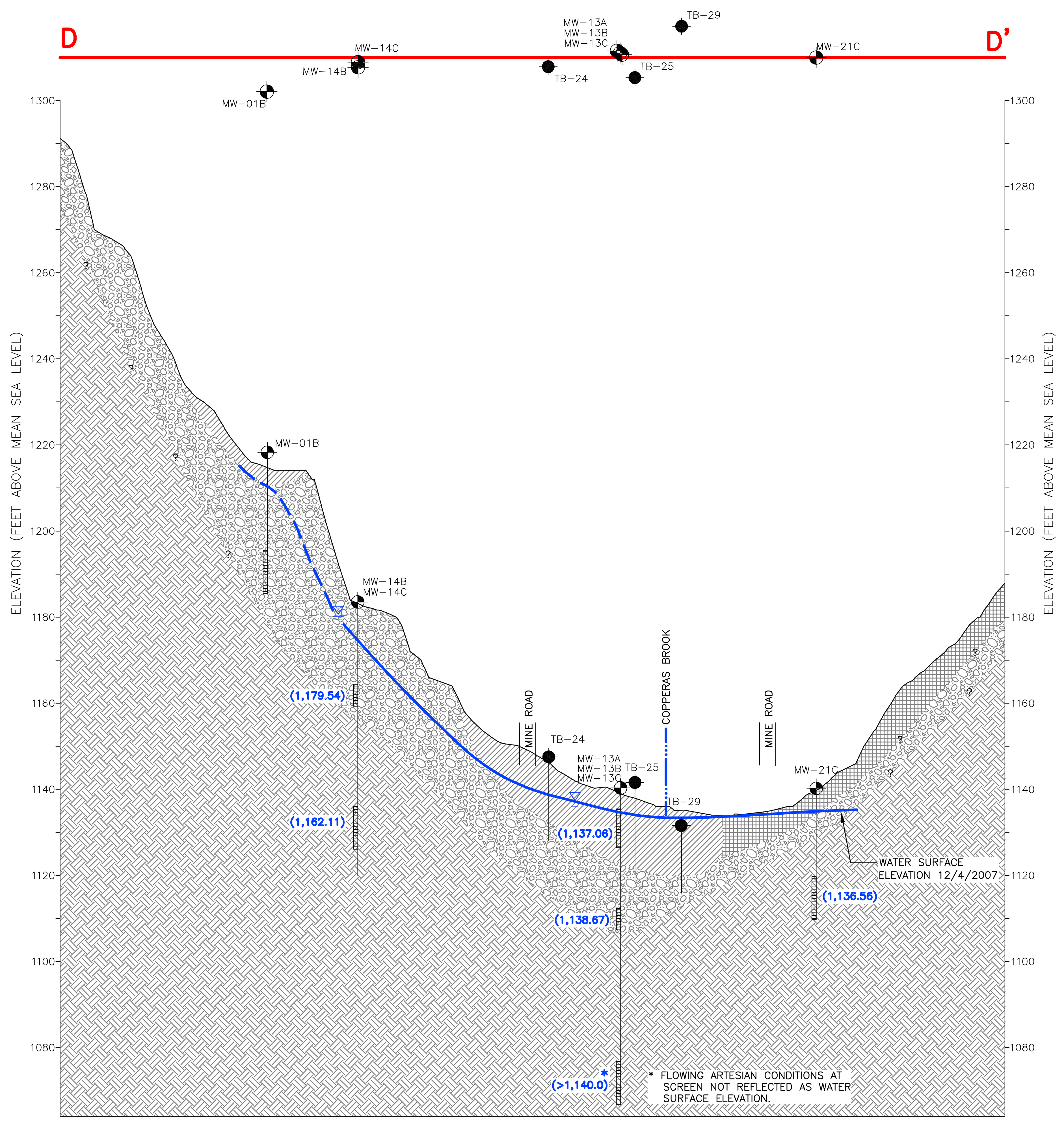
PROJECT NO: 39459945	
DESIGN: FS/CAM	SCALE: 1"/100'H;1"=20'V
APPROVED: JCC	DATE: MARCH 2009
DRAWN: CAM	FILE NO: EM_A-A'2008

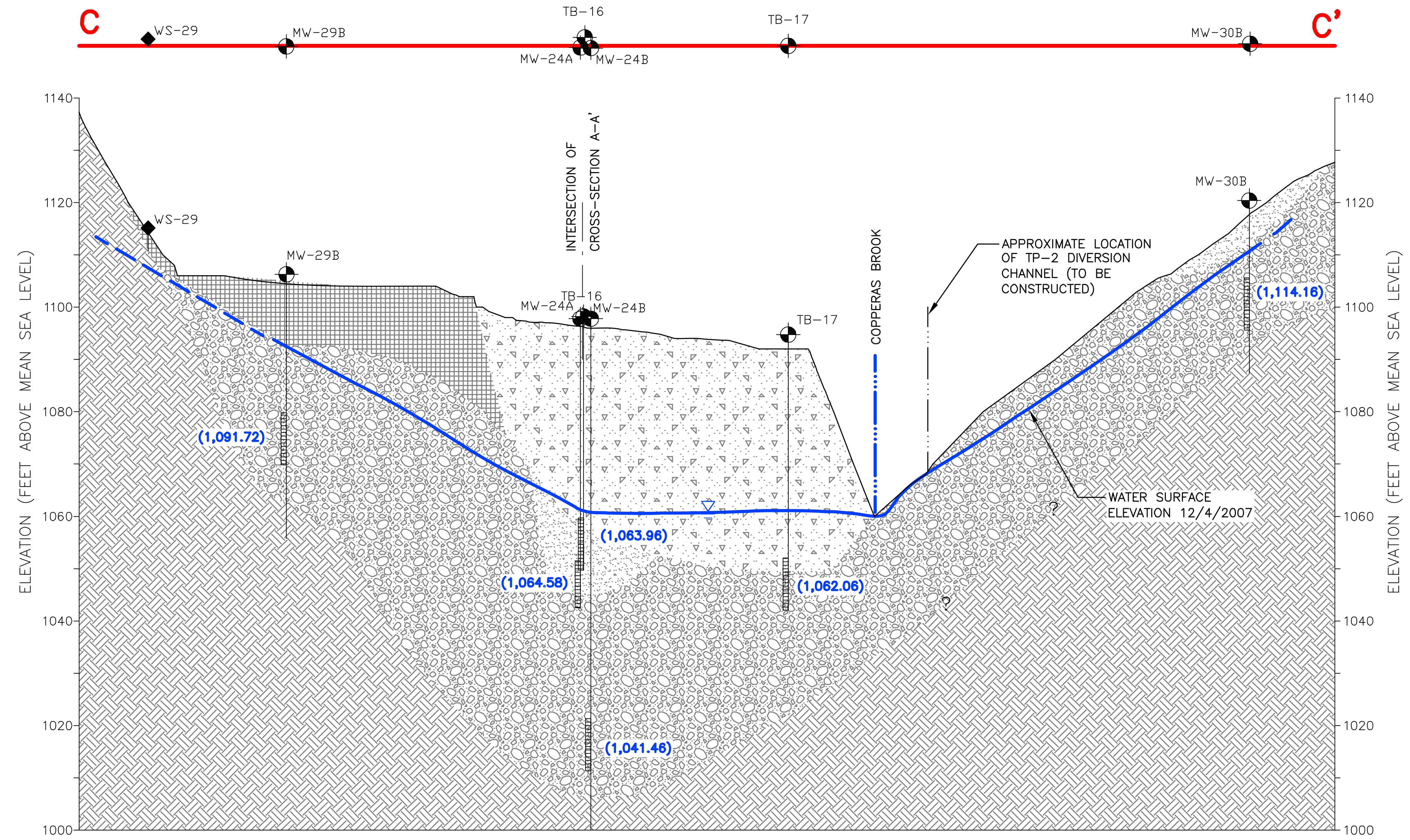
CLIENT: U.S. ARMY CORPS OF ENGINEERS

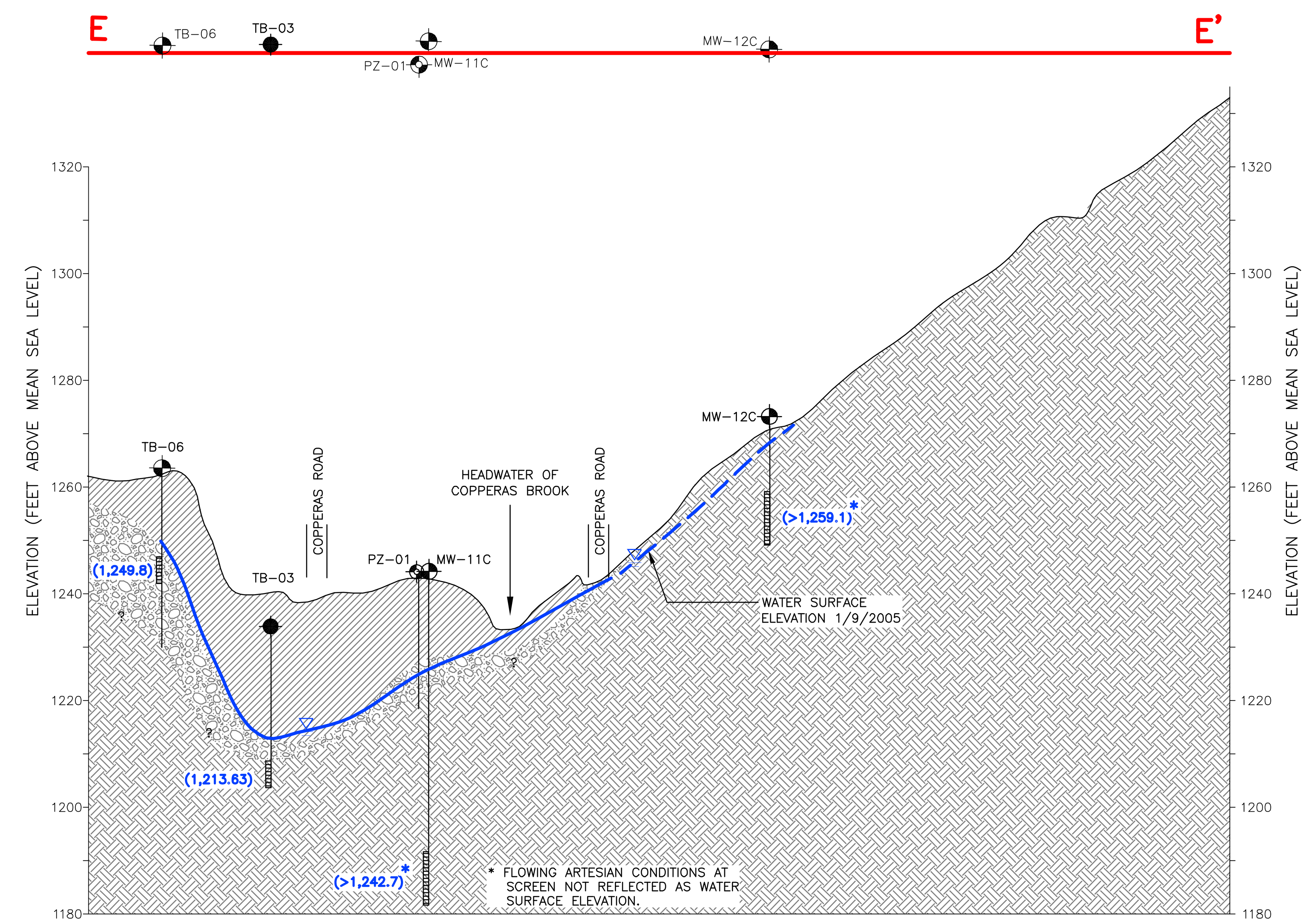
PROJECT: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

TITLE: GEOLOGIC CROSS-SECTION B-B'

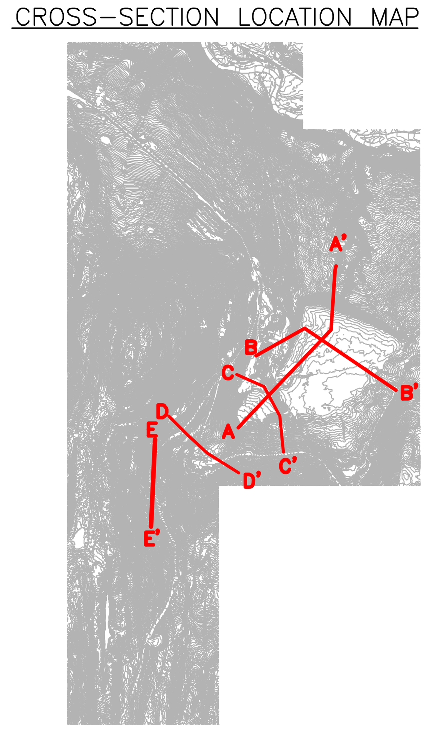
FIGURE NO: 8







CROSS-SECTION LOCATION MAP



NOT TO SCALE

LEGEND

- MW-11C / PZ-01 — MONITORING WELL/PIEZOMETER
- TB-14 — TEST BORING
- WS-10 — TEST PIT
- WELL SCREEN INTERVAL
- BEDROCK – GILE MOUNTAIN FORMATION – GRAY, SCHIST, ACCESSORY MINERALS INCLUDE GARNET, MICA, BIOTITE, GRAPHITE, QUARTZ AND CHALCOPYRITE
- GLACIAL TILL – GRAY TO OLIVE GRAY, CLAYEY SILT GRAVELLY SILTY SAND, MEDIUM DENSE TO VERY DENSE, FINE SAND, OFTEN CONTAINS FINE TO COARSE ANGULAR TO SUBROUNDED GRAVEL
- TAILING – GRAY TO BLACK SILTY SAND TO CLAYEY SILT, LOOSE/VERY SOFT TO DENSE/VERY STIFF, SULFUR ODOR. COLOR IS YELLOW AT SURFACE WHERE TAILING OXIDIZED.
- ALLUVIAL – BROWN TO DARK BROWN SILTY SAND WITH ORGANIC MATTER, LOOSE
- FILL – SILTY GRAVELLY SAND TO SANDY GRAVEL, MEDIUM DENSE TO DENSE COLOR FROM REDDISH BROWN, GRAY, LIGHT GRAY TO OLIVE GRAY.
- WASTE ROCK – YELLOWISH BROWN TO RED MEDIUM TO FINE SAND AND MEDIUM TO FINE ANGULAR TO SUBROUNDED GRAVEL.
- (939.9) — GROUNDWATER ELEVATION, AS SHOWN

NOTE: CONDITIONS SHOWN REPRESENT FIELD CONDITIONS FOLLOWING COMPLETION OF THE 2007 NTCRA CONSTRUCTION ACTIVITIES.

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1" = 20' VERT
1" = 100' HORZ
SCALE IN FEET

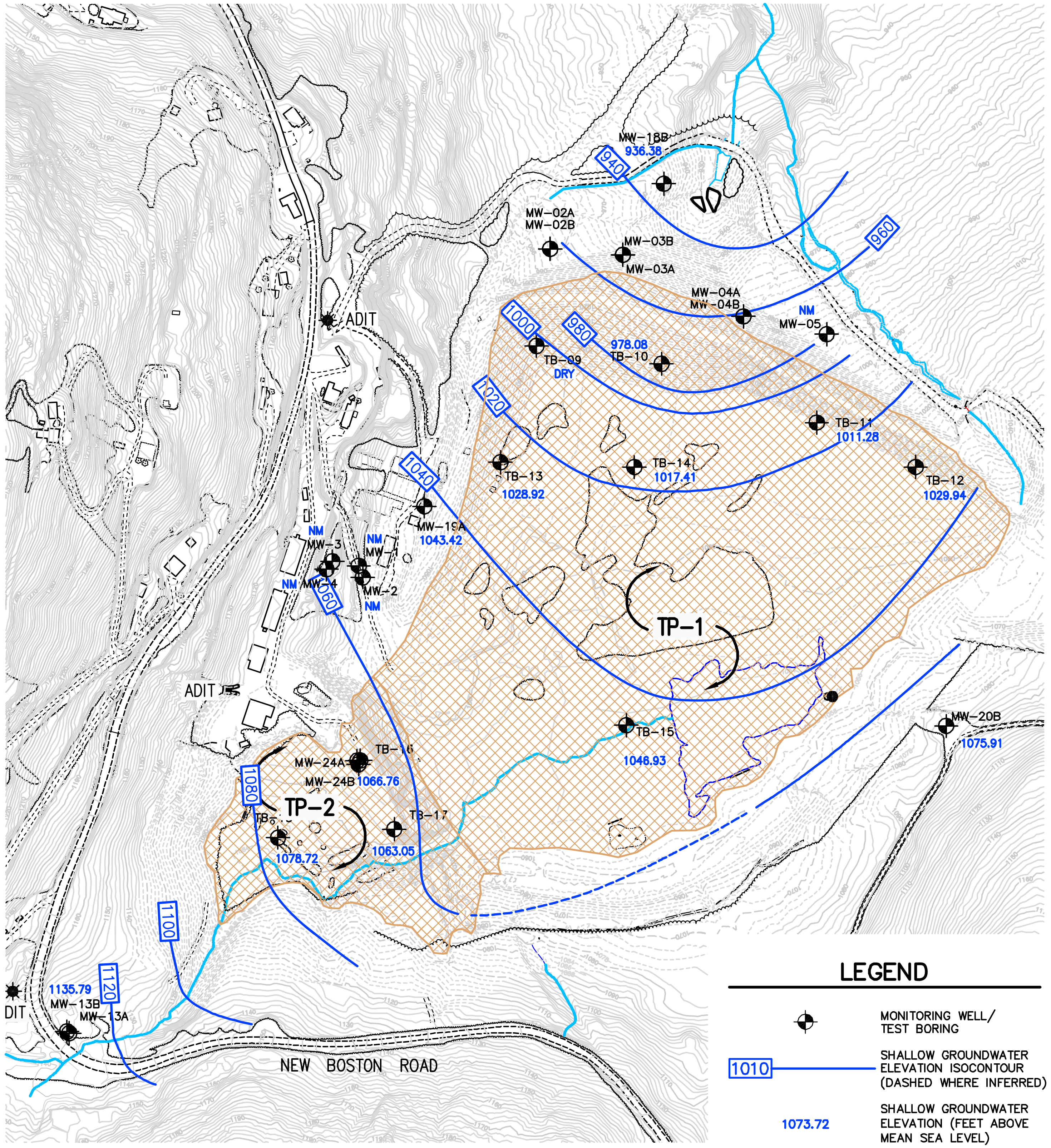
PROJECT NO:	39459945		
DESIGN:	FS/CAM	SCALE:	1"/100'H:1"=20'V
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	CAM	FILE NO:	EM_A-A'2008

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

TITLE: GEOLOGIC CROSS-SECTIONS C-C', D-D' & E-E'

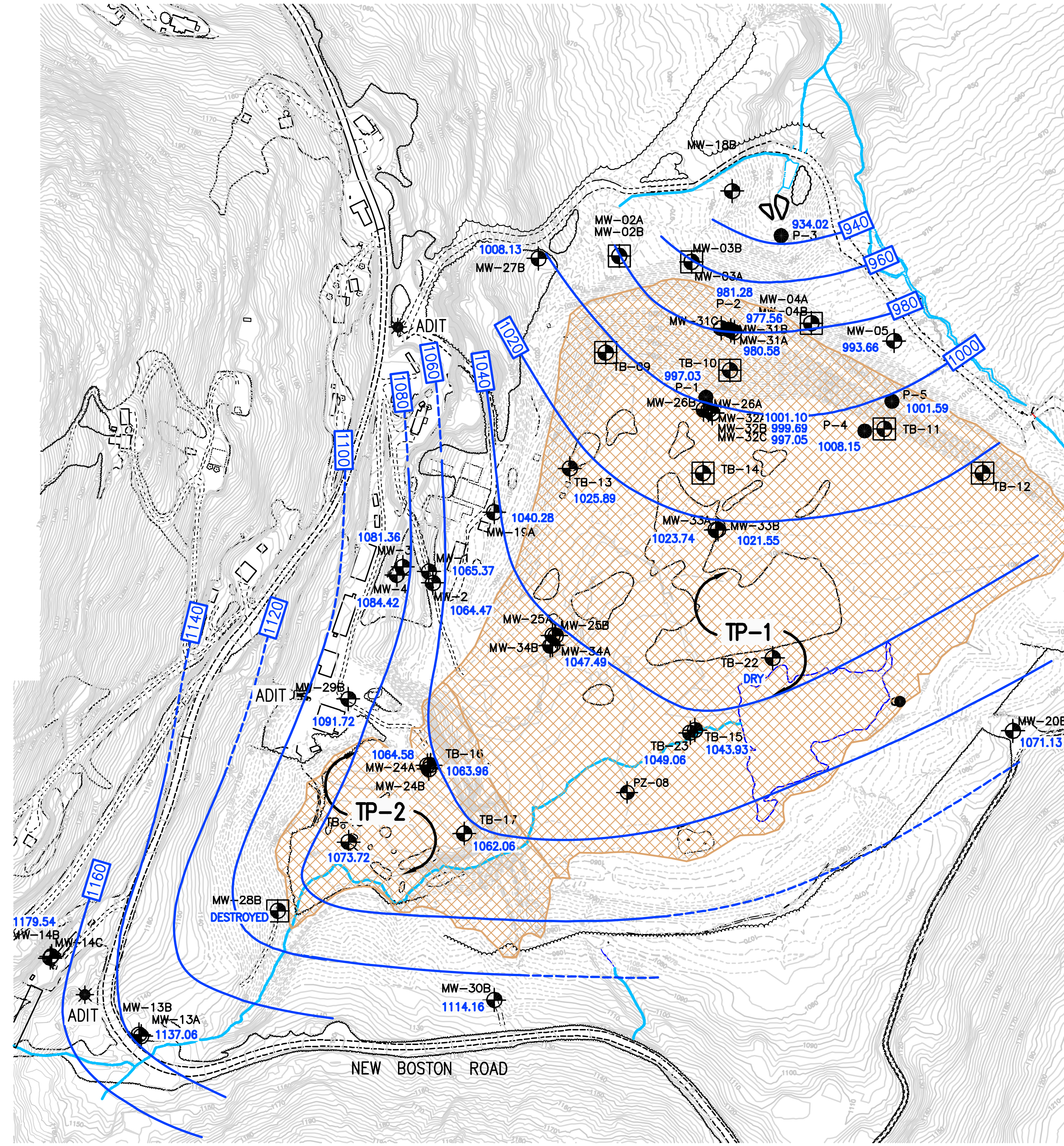
FIGURE NO: 9



PRE-BUTTRESS
MAY 10, 2004

LEGEND

(symbol)	MONITORING WELL/ TEST BORING
1010	SHALLOW GROUNDWATER ELEVATION ISOCONTOUR (DASHED WHERE INFERRED)
1073.72	SHALLOW GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)
(symbol)	DESTROYED MONITORING WELL



POST-BUTTRESS
DECEMBER 4, 2007

NOTE: CONTOURS REFLECT WATER TABLE CONDITION WHERE MULTIPLE SCREEN DEPTHS ARE PROVIDED.

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U.S. Army Corps Of Engineers
New England District

0 350 700
SCALE IN FEET

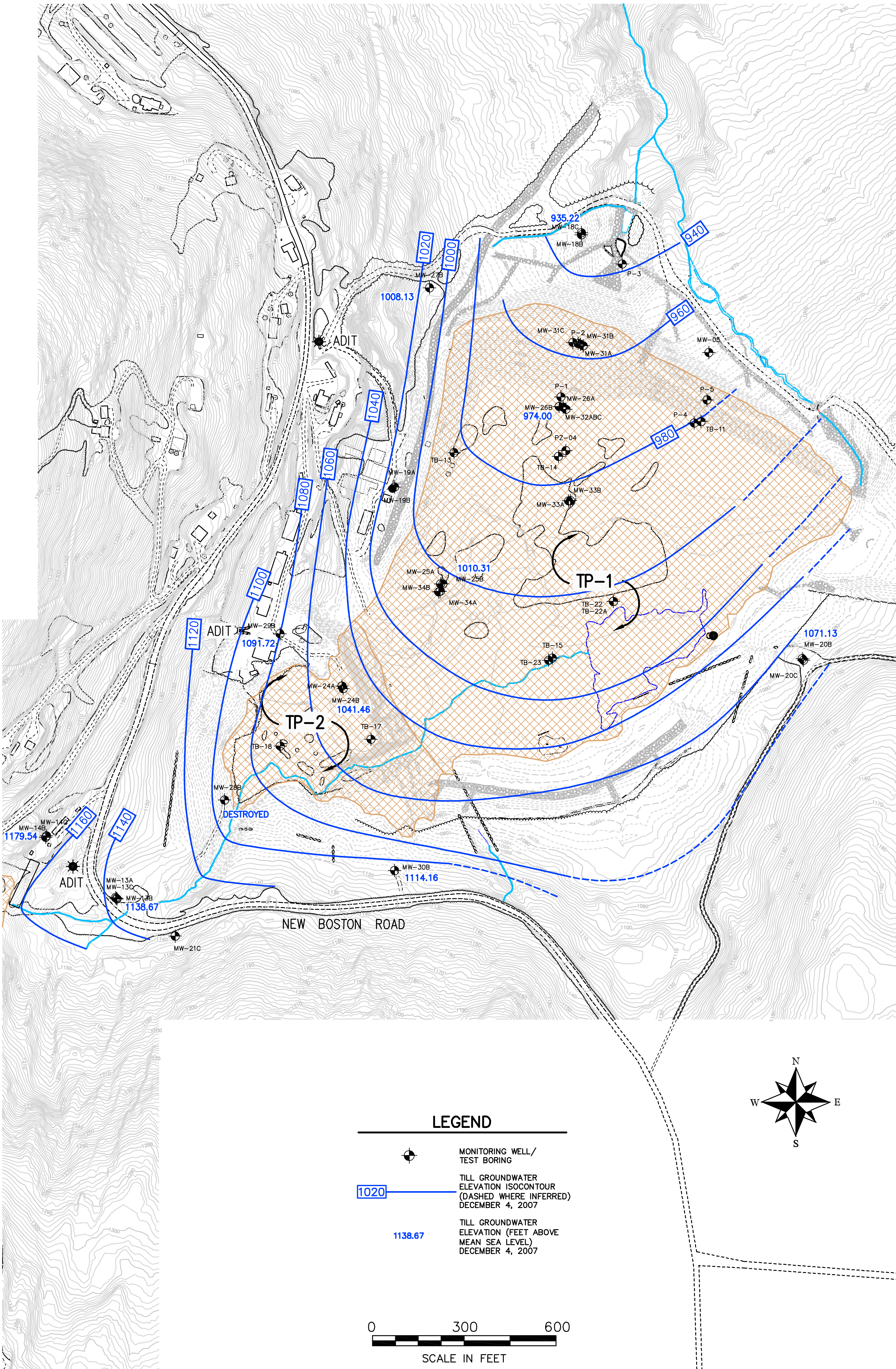
PROJECT NO:	39459945		
DESIGN:	CAM	SCALE:	1" = 350'
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	CAM	FILE NO:	NTCRA BASIS OF DESIGN

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

TITLE: TP-1 & TP-2
SHALLOW GROUNDWATER
EQUIPOTENTIAL CONTOURS

FIGURE NO.: 10



LEGEND

MONITORING WELL/ TEST BORING

1020 — TILL GROUNDWATER ELEVATION ISOCONTOUR (DASHED WHERE INFERRED) DECEMBER 4, 2007

1138.67 — TILL GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL) DECEMBER 4, 2007

0 300 600

SCALE IN FEET

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PROJECT NO:	39459945		
DESIGN: CAM	SCALE: 1"=300'		
APPROVED: JCC	DATE: MARCH 2009		
DRAWN: CAM	FILE NO: NTCRA BASIS		

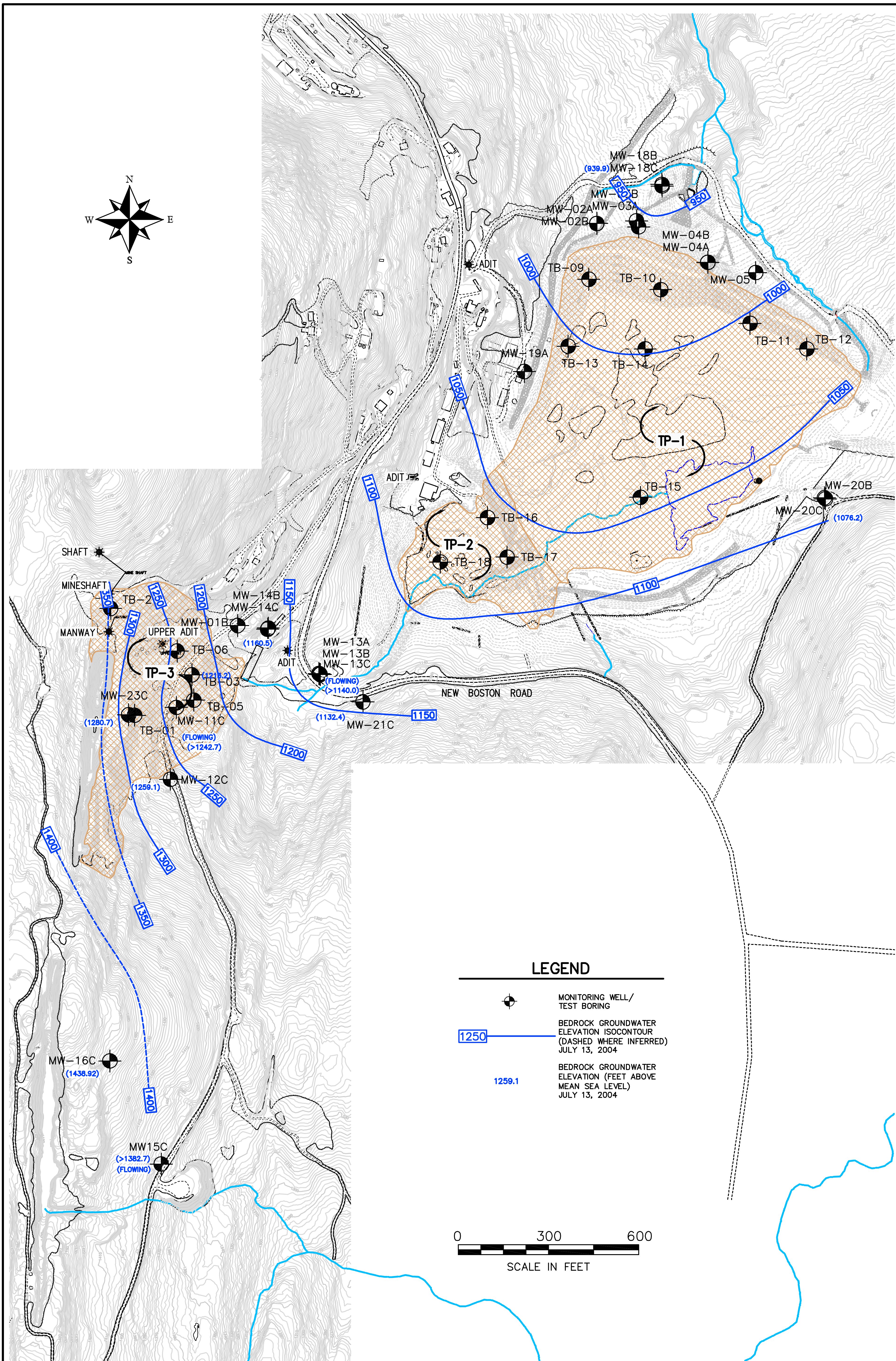
CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJ: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT

U.S. Army Corps Of Engineers New England District

TITLE: GROUNDWATER EQUIPOTENTIAL CONTOURS TILL – DEC 2007

FIGURE NO.: 11



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PROJECT NO:	39459945		
DESIGN: CAM	SCALE: 1"=300'		
APPROVED: JCC	DATE: MARCH 2009		
DRAWN: CAM	FILE NO: NTCRA BASIS		

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJ: ELIZABETH MINE
BASIS OF DESIGN REPORT
STRAFFORD, VERMONT

U.S. Army Corps Of Engineers
New England District

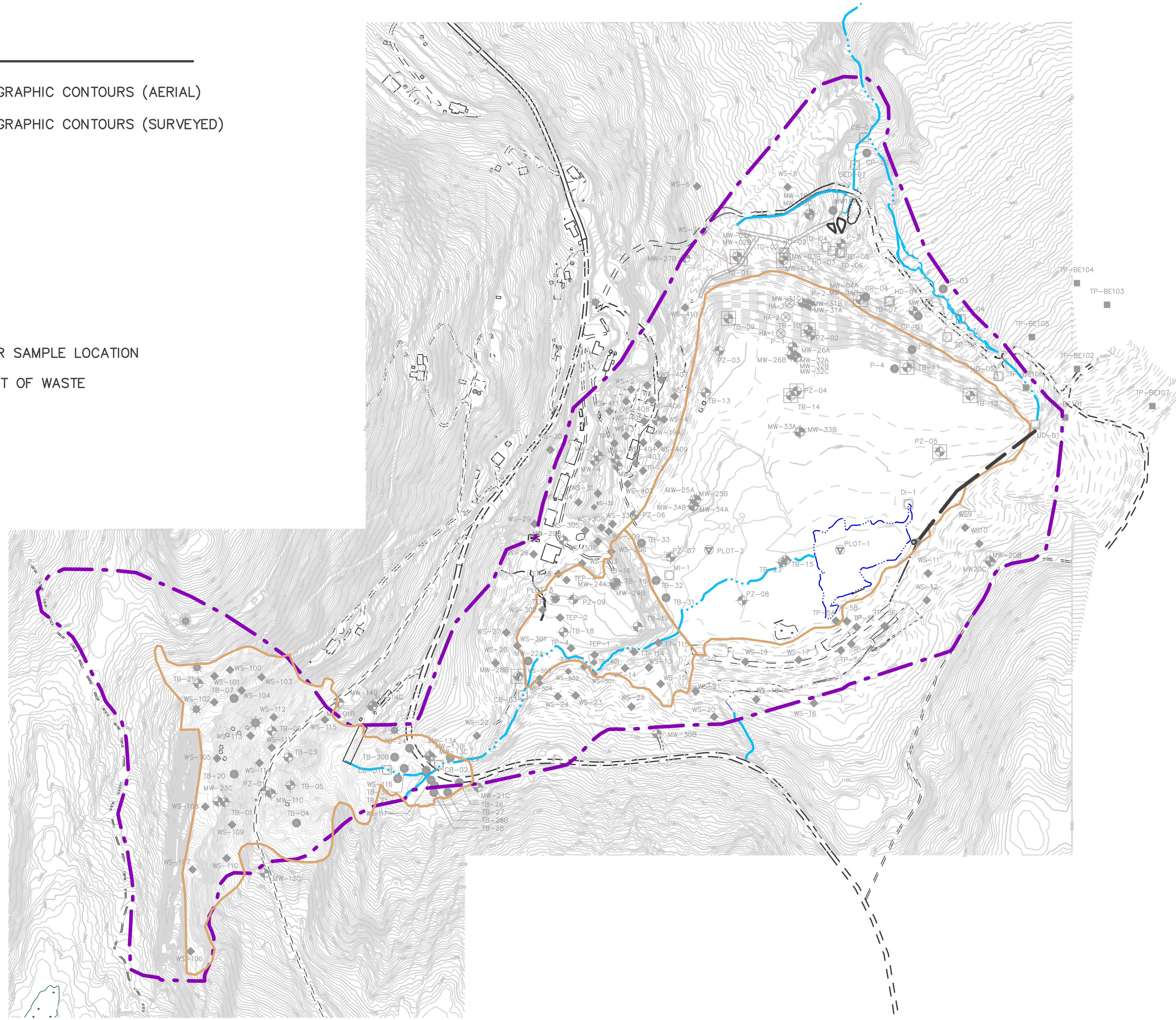
TITLE: GROUNDWATER EQUIPOTENTIAL CONTOURS BEDROCK – JULY 2004

FIGURE NO.: 12

P:\acad-project\USACE-ELIZABETH-MINE-STRAFFORD-VT\dwg\NTCRA Basis Of Design.dwg, FIG 12 GWFLOW BEDROCK JULY 04, 3/25/2009 11:19:41 AM

LEGEND

- PRE-EXISTING TOPOGRAPHIC CONTOURS (AERIAL)
- PRE-EXISTING TOPOGRAPHIC CONTOURS (SURVEYED)
- EXTENT OF NTCRA
- MONITORING WELL
- TEST BORING
- TEST PIT
- DESTROYED MONITORING WELL
- MINE ADIT/SHAFT
- EPA SURFACE WATER SAMPLE LOCATION
- APPROXIMATE EXTENT OF WASTE



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URS

URS Corporation
477 Congress Street, Suite 900
Portland, ME 04101-3453
Tel: 207.879.7686
Fax: 207.879.7685
www.urscorp.com

U.S. Army Corps Of Engineers New England District

0 450 900

SCALE IN FEET

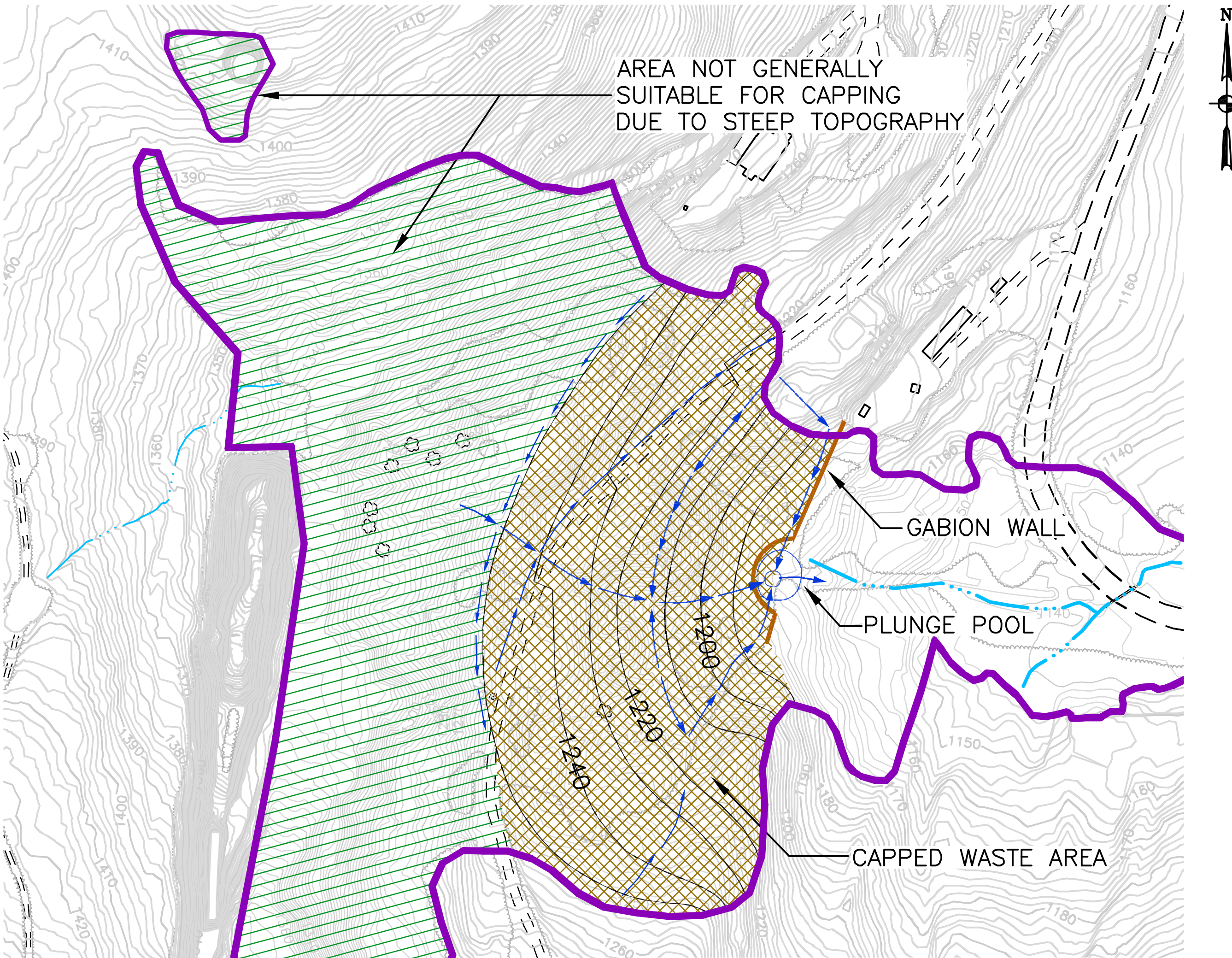
PROJECT NO:	39459945		
DESIGN:	CAM	SCALE:	1" = 450'
APPROVED:	JCC	DATE:	MARCH 2009
DRAWN:	CAM	FILE NO:	NTCRA BASIS OF DESIGN

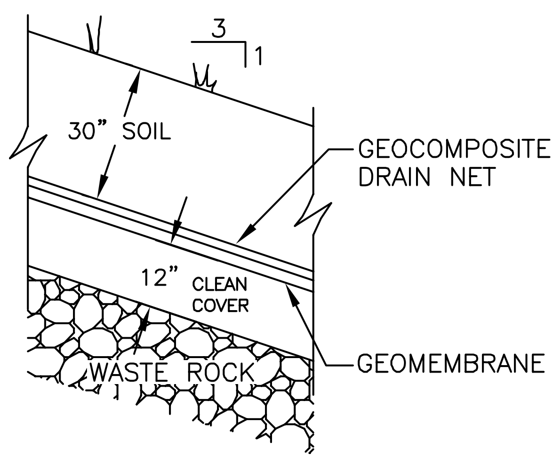
CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT

TITLE: NON-TIME-CRITICAL REMOVAL ACTION SAMPLE LOCATIONS

FIGURE NO.: 13





TYPICAL CAP SECTION, CONCEPTUAL

NTS

LEGEND

- RIPRAP CHANNEL
- GABION WALL
- CAPPED AREA
- LIMIT OF WASTE

0 200 400

SCALE IN FEET

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SCALE:	1" = 200'
DATE:	MARCH 2009
FILE NO:	TP3LAYERS
DESIGN:	DWA
APPROVED:	JCC
DRAWN:	LRH

CLIENT: U.S. ARMY CORPS OF ENGINEERS

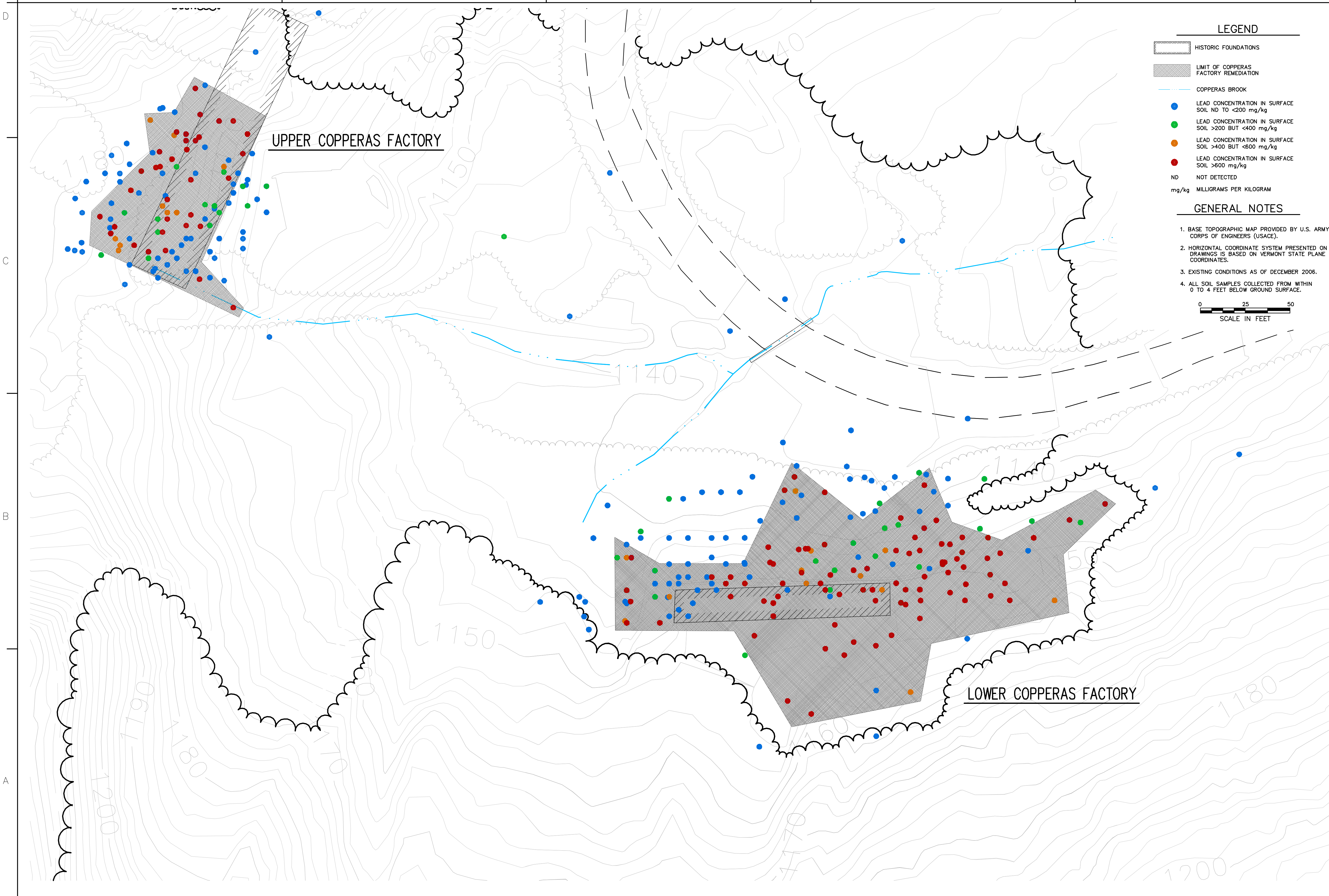
PROJ: ELIZABETH MINE BASIS OF DESIGN REPORT STRAFFORD, VERMONT

PROJECT NO: 39459945

TITLE: TP-3 CLOSE-IN-PLACE REMOVAL OPTION

FIGURE NO.: 14

P:\acad-project\USACE-ELIZABETH-MINE-STRAFFORD-VT\dwg\NTCRA Closure.dwg, UPPER AND LOWER COPPERAS FACTORY LEAD REMOVAL, 3/25/2009 1:12:10 PM



GENERAL NOTES

1. BASE TOPOGRAPHIC MAP PROVIDED BY U.S. ARMY CORPS OF ENGINEERS (USACE).
2. HORIZONTAL COORDINATE SYSTEM PRESENTED ON DRAWINGS IS BASED ON VERMONT STATE PLANE COORDINATES.
3. EXISTING CONDITIONS AS OF DECEMBER 2006.
4. ALL SOIL SAMPLES COLLECTED FROM WITHIN 0 TO 4 FEET BELOW GROUND SURFACE.

US Army Corps of Engineers
New England District

USACE
NEW ENGLAND DISTRICT
CONCORD, MASSACHUSETTS

URS

ELIZABETH MINE
STRAFFORD, VT

Mark	Description	Date	Appr.

Date: MARCH 2009
Rev. –
Design file no.
Project #: 3945945
File name: NTCRA Closure.dwg
Plot date:
Plot scale: AS SHOWN
Designed by: DWA/GJB
Dwn by: GJB
Ckd by: DWA
Reviewed by: JCC/CNH/MAG
Submitted by: URS CORPORATION

LEAD IN SOIL AT UPPER AND LOWER COPPERAS FACTORIES

FIGURE:
16

APPENDIX A – APPLICABLE, RELEVANT and APPROPRIATE REGULATIONS
A.1. – NTCRA Area ARARs from Action Memorandum
A.2. – Copperas Factory ARARs from Record of Decision

A.1. – NTCRA Area ARARs from Action Memorandum

ARARs, CRITERIA, ADVISORIES, AND GUIDANCE
ACTION MEMORANDUM
ELIZABETH MINE SITE
SOUTH STRAFFORD, VERMONT

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL LOCATION-SPECIFIC	Protection of Wetlands (Executive Order 11990), 40 CFR 6.302(a) and 40 CFR 6, App. A (Policy on Implementing E.O. 11990)	Applicable	Prohibits activities that adversely affect a wetland unless there is no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Avoid, to the extent possible, the long- and short-term adverse effects associated with destruction, occupancy and modification of wetlands.	<u>Alternatives 2B, 2C, 3B, 3C, 3D:</u> The wetlands located on TP-1 and adjacent to TP-1 are severely degraded and will be impacted (destroyed) by the cleanup action. These impacts are unavoidable in order to implement the cleanup action and no practicable alternative is available. A complete wetland delineation will be performed during the design and a mitigation program will be developed to compensate for the loss. The design will include measures to mitigate adverse effects of the action including, but not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas. EPA sought public comment regarding the potential impacts to wetlands at the Site.
FEDERAL LOCATION-SPECIFIC	Clean Water Act, Sec. 404 (33 U.S.C. 1344); 40 CFR 230 and 33 CFR 320-330)	Applicable	Prohibits the discharge of dredge or fill material into a wetland if a practicable alternative with lesser effects is available.	<u>Alternatives 2B, 2C, 3B, 3C, 3D:</u> The wetlands located on TP-1 and adjacent to TP-1 will be filled (destroyed) by the cleanup action. These impacts are unavoidable in order to implement the cleanup action and no practicable alternative is available. A full wetland delineation will be performed during the design and a mitigation program will be developed to compensate for the loss. EPA sought public comment regarding the potential impacts to wetlands at the Site.
FEDERAL LOCATION-SPECIFIC	Rivers and Harbors Act of 1899; 33 USC 403 et seq.; 33 CFR Parts 320-323	Applicable	Any excavation from, deposition of material in, or any obstruction or alteration of any "navigable water of the U.S." must comply with these requirements.	<u>Alternatives 2B, 2C, 3B, 3C, 3D</u>: The cleanup will involve excavation from, deposition of material within, and the alteration of a navigable water of the US. The design of the cleanup will fully address the requirements of this regulation with respect to the re-location of Copperas Brook.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 2 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL LOCATION-SPECIFIC	Floodplain Management (Executive Order 11988, 40 CFR 6.302(b) and 40 CFR 6, App. A (Policy on Implementing E.O. 11988)	Applicable	Federal agencies are required to avoid, whenever possible, impacts associated with the occupancy and modification of a floodplain. Promotes the preservation and restoration of floodplains so their natural and beneficial value can be realized.	Alternatives 2B, 2C, 3B, 3C, 3D: No mapped floodplain exists within the area subject to the cleanup action. However, action will be taken within the potential 100 year flood elevation of Copperas Brook (were it to be mapped). The design of the cleanup will take this regulation into account to mitigate adverse effects of action within the floodplain including, but are not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas. EPA sought public comment regarding the potential impacts to floodplain at the Site.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 3 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL LOCATION-SPECIFIC	Fish and Wildlife Coordination Act; 16 USC 661-666; 16 USC 2901, 40 CFR Part 6.302(g)	Applicable	Consultation with the U.S. Fish and Wildlife Service and appropriate state wildlife agency is required for an modification of a body of water to develop measures to prevent, mitigate, or compensate for losses of fish and wildlife.	Alternatives 2B, 2C, 3B, 3C, 3D: EPA will consult with the USFWS during the design of the modifications to Copperas Brook. There are no current fish or wildlife value to the stretch of Copperas Brook that will be impacted by the cleanup action.
STATE LOCATION-SPECIFIC	Vermont's Land Use and Development Law (Act 250), Title 10 V.S.A. Chapter 151	Applicable	Issues to be addressed in assessing compliance with Act 250 include: • impact on wetlands (Class One, Two, and Three) (criterion 1(G)), • erosion control (criterion 4) • construction-related dust (criterion 8), and • impact on historic sites (criterion 8).	Alternatives 2B, 2C, 3B, 3C, 3D: Activities at the site will comply with applicable requirements of Act 250. The design will include measures to assess, minimize, and mitigate impacts on wetlands and the use of best management practices for erosion control and dust suppression. The activities related to compliance with the NHPA are expected to address the impact on historic sites.
STATE LOCATION-SPECIFIC	Vermont Wetlands Rules (Vermont Agency of Natural Resources, Water Resources Board, 12-004-056	Applicable	These regulations establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and set forth allowed and conditional uses for these wetlands. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 V.S.A. Chapter 151, above).	Alternatives 2B, 2C, 3B, 3C, 3D: No Class One wetlands are present at the Site. Class Two wetlands are present, but severely degraded, and will be impacted. The design and implementation of the cleanup will address the requirements of these rules including the identification of any appropriate mitigation for the loss of wetlands.
STATE LOCATION-SPECIFIC	Vermont Regulation of Stream Flow, Title 10, V.S.A. Chapter 41	Applicable	Regulates and permits activities in streams to protect against damage to fish life and to prevent creation of flood hazards	Alternatives 2B, 2C, 3B, 3C, 3D: The components of the cleanup relating to re-location of Copperas Brook will be designed and implemented to meet these requirements.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 4 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL LOCATION-SPECIFIC	National Historic Preservation Act (NHPA); 16 USC 470, 36 CFR 800.1	Applicable	Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the SHPO, the EPA has determined the Elizabeth Mine Site eligible for the National Register.	Alternatives 2B, 2C, 3B, 3C, 3D: There are no historic landmarks at the site. There will be an adverse effect to historic properties at the Site. EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties
FEDERAL LOCATION-SPECIFIC	Archeological and Historic Preservation Act (16 USC 469 et seq.)	Applicable	This statute requires that, whenever any federal agency finds or is made aware that its activity in connection with any construction project or federally licensed project, activity, or program may cause irreparable loss or destruction of significant scientific, pre-historical, historical, or archeological data such agency shall undertake the recovery, protection, and preservation of such data or notify the Secretary of the Interior. The undertaking could include a preliminary survey (or other investigation as needed) and analysis and publication of the reports resulting from such investigation.	Alternatives 2B, 2C, 3B, 3C, 3D: The MOA developed to address the NHPA and the associated implementation activities will take into account the presence of archaeological data at the Site. The design will include measures to identify the presence of significant scientific, pre-historical, historical, or archeological data, and if such data are encountered during implementation of the cleanup, steps to recover, protect, and preserve such data.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 5 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
STATE CHEMICAL-SPECIFIC	Vermont Water Pollution Control (Vermont Water Quality Standards, Appendix C), Title 10, V.S.A. Chapter 47	Relevant and Appropriate	Establishes numerical and biological water quality standards for surface waters.	Alternatives 2B, 2C, 3B, 3C, 3D: These criteria were used to define the extent of impact from the release at the site and in the development of the Ecological Risk evaluations. These criteria will also be used to establish measurement criteria to evaluate the success of the cleanup
FEDERAL CRITERIA, ADVISORIES and GUIDANCE CHEMICAL-SPECIFIC	U.S. EPA. 1996. ECO Update: Ecotox Thresholds. Intermittent Bulletin Volume 3, No. 2.; U.S. EPA. 1999. National Recommended Water Quality Criteria - Correction. EPA Publ. 822-Z-99-001; Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision (Suter and Tsao, 1996)	To Be Considered	These guidances list surface water and sediment criteria that are considered proactive for aquatic organisms.	Alternatives 2B, 2C, 3B, 3C, 3D These guidances were used to establish standards for surface water criteria for the Ecological Risk evaluation where federal and state numerical water quality criteria or sediment criteria were not available.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 6 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL CRITERIA, ADVISORIES and GUIDANCE CHEMICAL-SPECIFIC	ORNL Toxicological Benchmarks for Screening contaminants of Potential Concern for Effects on Sediment Associated Biota: 1997 Revision (Jones et al., 1997); MacDonald et al., 2000 Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environm. Toxicol 39:20-31; Ministry of Environment and Energy of Ontario (MOE). 1994. Proposed Guidelines for the Clean-Up of Contaminated Sites in Ontario.; Long et al., 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management, V. 19: 81-97.	To Be Considered	These guidances list surface water and sediment criteria that are considered proactive for aquatic organisms.	Alternatives 2B, 2C, 3B, 3C, 3D: These guidances were used to establish standards for surface water criteria for the Ecological Risk evaluation where federal and state numerical water quality criteria or sediment criteria were not available.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 7 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL CRITERIA, ADVISORIES and GUIDANCE CHEMICAL-SPECIFIC	Region III Residential Risk Based Concentrations (RBCs), Region IX Preliminary Remediation Goal (PRGs) – Residential	To Be Considered	RBCs and PRGs provide criteria for evaluation on residential soil samples.	Alternatives 2B, 2C, 3B, 3C, 3D: RBCs and PRGs were considered in assessing the human health implications of the mine site.
FEDERAL CRITERIA, ADVISORIES and GUIDANCE CHEMICAL-SPECIFIC	USEPA Risk Reference Doses	To Be Considered	Risk reference doses (RfDs) are estimates of daily exposure levels that are unlikely to cause significant adverse non-carcinogenic health effects over a lifetime.	Alternatives 2B, 2C, 3B, 3C, 3D: RfDs shall be considered in assessing the health implications at the mine site.
FEDERAL CRITERIA, ADVISORIES and GUIDANCE CHEMICAL-SPECIFIC	USEPA Carcinogen Assessment Group, Cancer Slope Factors (CSFs)	To Be Considered	CSFs are used to compute the incremental cancer risk from exposure to site contaminants and represent the most up-to-date information on cancer risk from USEPA's Carcinogen Assessment Group.	Alternatives 2B, 2C, 3B, 3C, 3D: CSFs shall be considered to assess health risks associated with the mine site.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 8 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
FEDERAL ACTION-SPECIFIC	Clean Water Act - National Pollutant Discharge Elimination System, 40 CFR Part 122 – 125, 131	Applicable	These regulations contain discharge limitations, monitoring requirements and best management practices for discharges into navigable waters, i.e., surface waters.	Alternatives 2B, 2C, 3B, 3C, 3D: Any point source discharge to Site surface water will comply with these regulations. The effluent from the passive treatment systems for TP-3 and TP-1/TP-2 will be designed and implemented to meet these requirements.
FEDERAL ACTION-SPECIFIC	CWA – Stormwater requirements for construction sites; 40 CFR 122.26; (60 FR 50804), September 29, 1995	Applicable	Applicable to construction activity including clearing, grading and excavation, except operations that result in the disturbance of less than five acres of total land area.	Alternatives 2B, 2C, 3B, 3C, 3D: Construction activities will comply with these requirement through the use of best management practices during activities that disturb earth or tailings. The activities at the Site are expected to disturb more than 5 acres of land area.
Federal ACTION-SPECIFIC	Surface Mining Control and Reclamation Act (30 C.F.R. 816 and 817	Relevant and Appropriate	Provides closure guidelines for coal sites. Design criteria for the closure of tailings at coal sites are relevant and appropriate for use for the closure of the tailings at this Site.	Alternatives 2B, 2C, 3B, 3C, 3D: Cleanup actions will be designed and implemented to meet these requirements.
STATE ACTION-SPECIFIC	Vermont Water Pollution Control, Title 10, V.S.A. Chapter 47	Applicable	Establishes water quality standards for surface waters.	Alternatives 2B, 2C, 3B, 3C, 3D: Any point source discharge to Site surface water will comply with these regulations. The effluent from the passive treatment systems shall design to meet the applicable water quality criteria as dictated in these standards.

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
STATE ACTION-SPECIFIC	Vermont Solid Waste Management Rules (Vermont Agency of Natural Resources, Department of Environmental Conservation, Solid Waste Management Division, 12-036-003)	Applicable	These rules govern the management and handling of non-hazardous waste. These rule contain design standards for closure of solid waste facilities. Specific requirements may be waiveD under the regulations under certain circumstances provided that: 1) The waiver proposed does not endanger or tend to endanger human health or safety; (2) Compliance with the rules from which waiver is sought would produce serious hardship without equal or greater benefits to the public. (3) The waiver granted does not enable the applicant to generate, transport, treat, store, or dispose of hazardous waste in a manner which is less stringent than that required by the provisions of Subtitle C of the Resource Conservation and Recovery Act of 1976, and amendments thereto, codified in 42 U.S.C. Chapter 82, subchapter 3, and regulations promulgated under such subtitle.	Alternatives 2B, 2C, 3B, 3C, 3D: EPA has determined that certain requirements of the VT Solid Waste Management Rules (VT SWMR) cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that: The proposed alternative measures to the requirements of the VT SWMR will not endanger or tend to endanger human health or safety; compliance with certain VT SWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public; the material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and there is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VT SWMR. However, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment. The specific alternative measures proposed to the particular requirements of the VT SWMR are: (1) The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VT SWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation; (2) Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VT ANR accepting the responsibility for the maintenance of the treatment system; and (3) Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation. Alternatives 2B, 2C, and 3B would comply with the VT SWMR as described above. Alternatives 3C and 3D would not comply with the VT SWMR as they do not include a cover system on the non-slope areas of TP-1 and TP-2 that comply with the VT SWMR.

Table 4-2: ARARs, CRITERIA, ADVISORIES, AND GUIDANCE (Page 10 of 10)

AUTHORITY	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
STATE ACTION-SPECIFIC	Vermont Air Pollution Control, Title 10 V.S.A. 551 Chapter 5 and 23	Relevant and Appropriate	Establishes air quality standards and the allowable emissions including HAPs and VOCs. Standards for particulate matter are 150 micrograms per cubic meter, 24 hour average.	Alternatives 2B, 2C, 3B, 3C, 3D: Cleanup actions will be designed and implemented to meet these requirements.
FEDERAL GUIDANCE, ADVISORIES and GUIDANCE ACTION-SPECIFIC	EPA/625/4-91/025 "Design and Construction of RCRA/CERCLA Final Covers"	To Be Considered	Provides guidelines for proper design and construction of caps and covers.	Alternatives 2B, 2C, 3B, 3C, 3D: This guidance will provide design criteria for the design of the cap and cover for the alternative.
FEDERAL GUIDANCE, ADVISORIES and GUIDANCE ACTION-SPECIFIC	EPA Contract No. 68-03-3183 "Geotechnical Analysis for review of Dike Stability"	To Be Considered	Provides guidelines for proper construction safety design.	Alternatives 2B, 2C, 3B, 3C, 3D: This guidance will applied to the design of the slope stabilization measures of the tailings and rock piles.
FEDERAL GUIDANCE, ADVISORIES and GUIDANCE ACTION-SPECIFIC	USACE EM 1110-2-1902 "Minimum Factors of Safety: Table 1"	To Be Considered	Provides factors of safety for proper construction safety design.	Alternatives 2B, 2C, 3B, 3C, 3D: These factors of safety will be applied as design criteria with respect to the slope stability of the tailings and rock piles.

A.2. – Copperas Factory ARARs from Record of Decision

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
CHEMICAL-SPECIFIC ARARS			
STATE ARARs - None			
FEDERAL ARARs			
EPA Residential Risk Based Concentrations (RBCs) (Region III) and Preliminary Remediation Goal (PRGs) (Region IX) – Residential	To Be Considered	RBCs and PRGs provide criteria for evaluation of chemical concentrations in residential soil samples.	The covering of the lead contaminated soil will address all the contact risks identified.
EPA Risk Reference Doses (RfDs)	To Be Considered	Risk reference doses (RfDs) are estimates of daily exposure levels that are unlikely to cause significant adverse non-carcinogenic health effects over a lifetime.	The covering of the lead contaminated soil will address all the contact risks identified.
EPA Carcinogen Assessment Group, Cancer Slope Factors (CSFs)	To Be Considered	CSFs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from EPA's Carcinogen Assessment Group.	The covering of the lead contaminated soil will address all the contact risks identified.
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	This directive clarifies the existing 1994 Revised Interim Soil Lead Guidance for CERCLA Sites (OSWER Directive 9355.4-12) to promote national consistency in decision-making at CERCLA lead sites across the country.	The covering of the lead contaminated soil will address all the contact risks identified.
Guidelines for Carcinogen Risk Assessment EPA/630/P-03/001F (March 2005) Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens EPA/630/R-03/003F (March 2005)	To Be Considered	Provides guidance on conducting risk assessments involving carcinogens.	Until updated or replaced, these guidances will be used by EPA to evaluate all risk assessments on carcinogenicity conducted in the future at the Site.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
LOCATION-SPECIFIC ARARS			
STATE ARARs			
Vermont Wetlands Act, 10 VSA § 905; Vermont Wetland Rules (Nat. Res. Brd., Water Res. P. 12-004-056)	Applicable	These standards establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and set forth allowed and conditional uses for these wetlands. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 V.S.A. Chapter 151, below)	No Class One or Class Two wetlands are present in the area to be impacted by these alternatives. Only Class Three wetlands are located in the area of this alternative. Alternative CF-4 would have an unavoidable undue adverse impact on Class Three wetlands in the vicinity of the upper and lower Copperas Factories and portions of Copperas Brook between TP-3 and Mine Road.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
Vermont's Land Use and Development Law (Act 250), 10 VSA Chapter 151	Applicable	Issues to be addressed in assessing compliance with Act 250 include substantive environmental and facility siting requirements associated with: • will not result in undue water and air pollution (including construction-related dust) (criterion 1); • protection of headwaters (criterion 1(A)); • will meet all standards for disposal of wastes (criterion 1(B)); • floodways (criterion 1(D)); • streams (criterion 1(E)); • impact on state-regulated wetlands (Class One, Two, and Three; (criterion 1(G)); • erosion control (criterion 4); and • impact on historic sites (criterion 8(A)).	Alternative CF-4 will be designed to minimize impacts on the regulated criterion, including wetlands, erosion control and dust mitigation, and historic sites as appropriate. The EPA has determined that unavoidable impacts to wetlands, streams, headwaters, floodways, and historic resources are necessary to abate the threat from lead-impacted soil.
Vermont Regulation of Stream Flow, 10, V.S.A. Chapter 41	Applicable	Regulates and permits activities in streams to protect against damage to fish life, prevent creation of flood hazards, and protect from damaging the rights of riparian owners.	Alternative CF-4 will be designed to minimize the impact of the cleanup on Upper Copperas Brook.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
FEDERAL ARARs			
Protection of Wetlands (Executive Order 11990), 40 Part 6, App. A	Applicable	Prohibits activities that adversely affect a federally-regulated wetland unless there is no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Avoid, to the extent possible, the long- and short-term adverse effects associated with destruction, occupancy and modification of wetlands.	The EPA has determined that unavoidable impacts to the wetlands would occur to abate the public health threat from the soil impacted with lead. A wetlands delineation would be implemented as a component of the design for Alternative CF-4. The design and implementation of Alternative CF-4 includes all practicable measures to minimize harm to wetlands and restore wetland impacted by the implementation of the alternative. The EPA has identified CF-4 as the least damaging practicable alternative. EPA has sought public comment regarding the disturbance of federal-regulated wetlands.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
Clean Water Act, Sec. 404 (33 USC § 1344); 40 CFR 230 and 33 CFR 320-330))	Applicable	Prohibits the discharge of dredge or fill material into a federally-regulated aquatic ecosystem, if a practicable alternative with lesser effects is available. Any alternative selected that may dredge or fill a wetland area would need to comply with the 404(b) guidelines. A finding that No Practicable Alternative was available and that the general prohibitions in 40 C.F.R. 230.10 and the factual determinations of 40 C.F.R. 230.11 would need to be completed for any alternative that may dredge and fill a water of the U.S.	Alternative CF-4 may involve limited disturbance and dredging or filling of the wetland and Copperas Brook adjacent to the Copperas Factories. The implementation would use best management practices (BMPs) to minimize the impacts of the cleanup, particularly on downstream surface water resources. The EPA has identified CF-4 as the least damaging practicable alternative.
Fish and Wildlife Coordination Act; 16 USC 661-666; 16 USC 2901, 40 CFR Part 6.302(g)	Applicable	Consultation with the U.S. Fish and Wildlife Service and appropriate state wildlife agency is required for modification of endangered or threatened species habitat and/or body of water to develop measures to prevent, mitigate, or compensate for the loss of fish and wildlife.	The EPA will consult with the U.S. Fish and Wildlife Service regarding endangered species and federal wetlands issues within Alternative CF-4.
Floodplain Management, Executive Order 11988, 6, App. A	Applicable	Federal agencies are required to avoid, whenever possible, impacts associated with the occupancy and modification of a floodplain. Promotes the preservation and restoration of floodplains so their natural and beneficial value can be realized.	Remedial activities along Copperas Brook will not cause increased flooding of downstream floodplains.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
National Historic Preservation Act (NHPA); 16 USC 470 *et seq.*; 36 CFR Part 800	Applicable	Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the State Historic Preservation Officer (SHPO), the EPA has determined the Elizabeth Mine Site eligible for the National Register. The consultation is to identify potential adverse effects on historic properties and seek ways to avoid, minimize or mitigate any such effects on historic properties.	The EPA has determined that unavoidable adverse impacts will occur to historic resources at the Site. Alternative CF-4 would result in the disturbance of the location of the former Copperas Factories. The exposed stone remnants of the buildings would be left intact, if possible. The removal and consolidation of lead-contaminated soil and restoration of the disturbed area may also impact some of the timber within Copperas Brook. The EPA will consult with the SHPO and the community regarding the loss of historic resources.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
Archeological and Historic Preservation Act, 16 USC 469 *et seq*.; 36 CFR Part 65	Applicable	This standard requires that, whenever any federal agency finds or is made aware that its activity in connection with any construction project or federally licensed project, activity, or program may cause irreparable loss or destruction of significant scientific, pre-historical, historical, or archeological data such agency shall undertake the recovery, protection, and preservation of such data or notify the Secretary of the Interior. The undertaking could include a preliminary survey (or other investigation as needed) and analysis and publication of the reports resulting from such investigation.	A data recovery plan will be developed as part of the design for this alternative to document historic resources that will be disturbed. Data recovery would occur prior to excavation.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
ACTION-SPECIFIC ARARS			
STATE ARARs			
Vermont Waste Management Act, 10 VSA Chapter 159, and Hazardous Waste Management Regulations, Env. Prot. R. Ch. 7	Relevant and Appropriate - Applicable to activities that handle hazardous waste	Establishes requirements for the identification and management of hazardous waste. These regulations apply to the soil contaminated with lead. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations 40 CFR 264. Since the lead was released into the soil prior to 1900, the requirements are relevant and appropriate, rather than applicable, for waste left in place. The contaminated soil will be managed within one Area of Contamination (AOC); therefore, placement will not occur.	Lead has not been found in the groundwater or sediments near the Copperas Factories; therefore, only closure and post closure requirements that prevent direct human contact with the lead are relevant and appropriate. Long-term monitoring of the area to determine that the covered lead does not pose a future risk to human health or the environment is required. Alternative CF-4 would potentially consolidate the lead-impacted soil within the AOC and not trigger treatment or land-disposal restrictions.
Vermont Stormwater Management Act, 10 VSA § 1263 and § 1264; Vermont Stormwater Management Rule, ENV. Prot. R. Ch. 18]	Applicable	Construction activities that create more than one acre of impervious surface, including roads, must implement measures to address the storm-water discharges from the impervious surfaces.	Alternative CF-4 would include measures to comply with these requirements through the design of measures to mitigate the release of stormwater from impervious surfaces.
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	Establishes water quality standards for surface waters and applies to alternatives that call for monitoring surface water bodies on and off of the site. The regulations stipulate requirements for discharges to surface waters, compliance with NPDES standards, and meeting stormwater management requirements.	Construction activities in and adjacent to Copperas Brook will not violate water quality standards.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
Vermont Air Pollution Control Act, 10 VSA Chapter 23 and Air Pollution Control Regulations, Env. Prot. R. Ch. 5	Relevant and Appropriate	10 VSA Chapter 23 establishes authority for a coordinated statewide program of air pollution prevention, abatement and control. Chapter 5 of the EPR lists prohibited activities affecting air quality and establishes primary and secondary ambient air quality standards for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. The secondary standard for particulate matter is 150 micrograms per cubic meter, 24 hour average, not to be exceeded more than once per year.	The design for Alternative CF-4 would include requirements to comply with the particulate matter and sulfur oxide requirements.
Vermont Handbook for Erosion Prevention and Sediment Control, Working Interim Document, Released in 2003.	To Be Considered	A compilation of information from various sources released by the Vermont Department of Environmental Conservation for use in developing the erosion prevention and sediment control plans required for construction-related stormwater discharge permitting.	The manual will be used as guidance in the development of the Erosion Prevention and Sediment Control Plan.
FEDERAL ARARs			
Clean Water Act – Stormwater Requirements for Construction Sites; 40 CFR 122.26	Applicable	Applicable to construction activity including clearing, grading and excavation, except operations that result in the disturbance of less than five acres of total land area.	Construction activities and long-term maintenance will use best management practices to comply with these requirements.

ROD Table 93
ARARS for Alternative CF-4 In-place Covering of Lead-Impacted Soil
Copperas Factories
Elizabeth Mine Site, Strafford, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	Action Taken to Comply with ARARs
Clean Water Act , Section 402, 33 USC 1342 and National Pollutant Discharge Elimination System regulations, 40 CFR Part 122 – 125, 131	Applicable	These regulations contain discharge limitations, monitoring requirements and best management practices for discharges into navigable waters, i.e., surface waters.	Construction activities in and adjacent to Copperas Brook will not violate water quality standards.
Resource, Conservation and Recovery Act, 42 USC §§ 6901-6992; 40 CFR Part 264	Relevant and Appropriate	Vermont is delegated to implement these standards through its Hazardous Waste Management Regulations (see above).	Lead has not been found in the groundwater or sediments near the Copperas Factories; therefore, only closure and post-closure requirements that prevent direct human contact with the lead are relevant and appropriate. Long-term monitoring of the area to determine that the covered lead does not pose a future risk to human health or the environment is required. Alternative CF-4 would potentially consolidate the lead-impacted soil within the AOC and not trigger treatment or land-disposal restrictions.