U.S. Department of Energy

Livermore Site Office, Livermore, California 94550

Lawrence Livermore National Laboratory

University of California, Livermore, California 94550

UCRL-AR-232231

Five-Year Review Report for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300

Authors:

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September 2007

*Weiss Associates, Emeryville, California

Environmental Protection Department

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Certification

I certify that the work presented in this report was performed under my supervision. To the best of my knowledge, the data contained herein are true and accurate, and the work was performed in accordance with professional standards.

J M Madrid 12/13/07

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Approval and Concurrence for the Five-Year Review for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300

Prepared by:

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Five-Year Review Summary Form

Site Identification		
Site name: Lawrence Livermore National Laboratory Site 300, High Explosives Process Area Operable Unit (OU)		
EPA ID: CA 2890090002		
Region: IX	State: California	City/County: San Joaquin/Alameda
Site Status		
NPL status: Final		
Remediation status: Operating		
Multiple OUs: Yes	Construction completion date: To be determined	
Has the site been put into reuse: No		
1.0REVIEW STATUS		
Reviewing agency: U.S. Department of Energy		
Author name: Valerie R. Dibley		
Author title: Assistant Site 300 Environmental Restoration Project Leader	Author affiliation: Lawrence Livermore National Laboratory	
Review period: September 2002 to September 2006		
Date(s) of site inspection: Not applicable		
Type of review: Statutory		
Review number: 1		
Triggering action: Interim Remedial Design for the High Explosives Process Area OU		
Triggering action date: August 15, 2002		
Due date: September 21, 2007		

Five-Year Review Summary Form (continued)

Deficiencies:

No deficiencies in the interim remedy were identified during this evaluation. However, continued management and optimization of the extraction wellfield upgradient of the private offsite water-supply Gallo-1 will be necessary to prevent migration of volatile organic compounds (VOCs) in ground water toward this well. In the future, additional extraction wells may be needed in the distal portions of the plume to fully capture contaminants migrating toward the site boundary.

Recommendations and Follow-up Actions:

This evaluation does not identify a need for changing the overall approach to cleanup for VOCs, high explosive compounds, or perchlorate in ground water in the High Explosives Process Area (HEPA) OU. The Department of Energy (DOE)/Lawrence Livermore National Laboratory (LLNL) have implemented or are in the process of implementing all the actions required in the Interim Site-Wide Record of Decision (ROD), the Remedial Design Work Plan for the Interim Remedies, and the Interim Remedial Design document for the HEPA OU.

Based on the results of the nitrate study discussed in Section 6.5.1, DOE/LLNL recommend implementing monitored natural attenuation as a health-protective, cost effective final remedy for nitrate in ground water.

The proposed cleanup standards for soil are based on industrial use. Because VOCs at concentrations exceeding those established for residential use may remain at the HEPA OU following the achievement of the proposed industrial cleanup standards for VOCs in subsurface soil, a land use control will be added that prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition will be included in the Final Site-Wide ROD scheduled for 2008. The Final Site-Wide ROD will also reference the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document into which this prohibition will be incorporated.

The action-specific applicable or relevant and appropriate requirements (ARARs) change identified in Section 6.2, and ARARs related to ground water cleanup, will be included in the Final Site-Wide ROD scheduled for 2008.

Once the extraction wellfields in the HEPA OU have operated long enough for capture zones to fully develop, DOE/LLNL will evaluate the extent of capture and the ability of the extraction wellfield to achieve ground water RAOs. This evaluation will be based on ground water elevation contours and concentration trends in extraction, performance monitoring, and guard wells. If data from this evaluation indicate that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. Modifications may include changes to the extraction well pumping strategy and/or installing additional extraction wells.

No other follow-up actions were identified related to this evaluation.

Protectiveness Statement:

The remedy at the HEPA OU is expected to be protective of human health and the environment upon completion (i.e., when cleanup standards are achieved) for the site's industrial land use. In the short-term, the remedy protects human health because exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of institutional controls, the Health and Safety Plan, and the Contingency Plan.

The proposed cleanup standards for HEPA OU ground water are drinking water standards, but will be finalized in a Site-Wide ROD scheduled for 2008. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario upon completion.

The proposed cleanup standards for VOCs in subsurface soil are to reduce concentrations to mitigate risk to onsite workers and prevent further impacts to ground water to the extent technically and economically feasible. Because some VOCs may remain in subsurface soil following the achievement of these proposed cleanup standards, a land use control will prohibit the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition will be included in the Final Site-Wide ROD scheduled for 2008. The Final Site-Wide ROD will also reference the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document into which this prohibition will be incorporated. This prohibition will remain in place until and unless a risk assessment is performed in accordance with then current U.S. Environmental Protection Agency (EPA) risk assessment guidance and is agreed by the DOE, the EPA, the Department of Toxic Substances Control, and the Regional Water Quality Control Board as adequately showing no unacceptable risk for residential or unrestricted land use.

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1. Introduction

The United States (U.S.) Department of Energy (DOE) has conducted a Five-Year Review of the remedial actions implemented at the High Explosives Process Area (HEPA) operable unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. DOE is the lead agency for environmental restoration at LLNL. The review documented in this report was conducted from September 2002 through September 2006. Parties providing analyses in support of the review include:

- U.S. DOE, Livermore Site Office.
- LLNL, Environmental Restoration Division.
- Weiss Associates.

The purpose of a Five-Year Review is to evaluate the implementation and performance of a remedy to determine whether the remedy will continue to be protective of human health and the environment. The Five-Year Review report presents the methods, findings, and conclusions of the review. In addition, the Five-Year Review identifies issues or deficiencies in the selected remedy, if any, and presents recommendations to address them. The format and content of this document is consistent with guidance issued by DOE (U.S. DOE, 2000) and the U.S. Environmental Protection Agency (EPA) (U.S. EPA, 2001a).

Section 121 of the Comprehensive Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment Reauthorization Act (SARA), requires that remedial actions which result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a five-year review. The National Contingency Plan further provides that remedial actions which result in any hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure be reviewed every five years to ensure protection of human health and the environment. Consistent with Executive Order 12580, other Federal agencies are responsible for ensuring that five-year reviews are conducted at sites where five-year reviews are required or appropriate.

This is the first Five-Year Review for the HEPA OU (OU 4). This review is considered a statutory review because: (1) contamination will remain onsite upon completion of the remedial action, (2) the Record of Decision was signed after October 17, 1986 (the effective date of the SARA), and (3) the remedial action was selected under the CERCLA. The triggering action for the first review was the August 15, 2002 submittal date of the Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (Madrid et al., 2002).

Five-year reviews are conducted individually for each OU at Site 300. The Final Site-Wide Record of Decision (ROD) triggers reviews for OUs 3 and 8 in accordance with EPA guidance. At the other OUs where construction began prior to the Site-Wide ROD as treatability studies and/or removal actions, DOE and the regulators agreed to use the completion of the OU-specific Remedial Design report as the trigger for the first five-year review.

The background and description of the HEPA OU are presented in Section 3. The following paragraphs include the descriptions and status of the other OUs and areas where environmental restoration activities are occurring at Site 300. Many of these areas and OUs were included in the Interim Site-Wide ROD for Site 300 (U.S. DOE, 2001).

General Services Area OU (OU 1) – Solvents containing volatile organic compounds (VOCs) were commonly used as degreasing agents in craft shops in this OU. In the 1960s and 1970s, rinse water from these operations was disposed of in dry wells and volatile organic compound (VOC)-contaminated debris was buried in trenches. Ground water cleanup began in 1991 and soil vapor extraction started in 1994. In 1995, a Final ROD for this OU was signed (U.S. DOE, 1997). Buildout of the remedial action was completed in 2004. Ground water and soil vapor extraction have been very successful in decreasing the concentration and mass of subsurface contaminants and in reducing the offsite extent of contamination. Remediation has already reduced VOCs in ground water to meet cleanup standards in the Eastern GSA. DOE has performed two Five-Year Reviews for the General Services Area OU (Ferry et al., 2001a and Dibley et al., 2006a). The next Five-Year Review is scheduled for 2011.

Building 834 OU (OU 2) – The Building 834 facilities have been in use since the late 1950s for experiments involving thermal cycling of weapons components. From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface with trichloroethylene (TCE) and silicone oils. Nitrate contamination in ground water results from septic-system effluent but may also have natural sources. Ground water and soil vapor extraction and treatment began in 1986 as treatability studies. Cleanup continued under an Interim ROD for the OU and later under the Interim Site-Wide ROD for Site 300. DOE has periodically modified and expanded the extraction wellfield and upgraded the treatment facilities, and is conducting treatability studies to evaluate *in situ* biodegradation. Construction of the interim remedy was completed in 2004. DOE has performed two Five-Year Reviews for the Building 834 OU (Ferry et al., 2002a and Dibley et al., 2007a). The next Five-Year Review for this OU is scheduled for 2012.

Pit 6 Landfill OU (OU 3) – From 1964 to 1973, waste was buried in nine unlined trenches and animal pits at the Pit 6 Landfill. Contaminants in the subsurface include VOCs, tritium, nitrate, and perchlorate. In 1971, DOE excavated portions of the waste contaminated with depleted uranium. In 1997, a landfill cap was installed as a removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of decreasing TCE concentrations and tritium activities in ground water, the presence of TCE degradation products, and the short half-life of tritium (12.3 years), the selected interim remedy for TCE and tritium at the Pit 6 Landfill is monitored natural attenuation. DOE is evaluating the source, extent, and natural degradation of perchlorate and nitrate. The interim remedy for these contaminants in ground water is continued monitoring. A Five-Year Review for this OU is scheduled for 2012.

Building 850 Firing Table (OU 5) – High explosives (HE) experiments have been conducted at the Building 850 Firing Table since 1958. Tritium was used in these experiments, primarily between 1963 and 1978. As a result of the dispersal of test assembly debris during explosions, surface soil was contaminated with metals, polychlorinated biphenyls (PCBs), dioxins, furans, HE compounds, and depleted uranium. Leaching from firing table debrisresulted in tritium and depleted uranium contamination in subsurface soil and ground

water. Nitrate has also been identified in ground water. PCB-contaminated shrapnel and debris was removed from the area around the firing table in 1998. The selected remedy for the Building 850 area includes excavation of the contaminated surface soil and a nearby sand pile as a final remedy and monitored natural attenuation of tritium in ground water as an interim remedy. DOE is currently evaluating alternate technologies to address the PCB-contaminated soil due to significant cost increases for offsite disposal of the soil. A Five-Year Review for this OU is scheduled for 2009.

Pit 7 Landfill Complex (OU 5) – The Pit 3, 4, 5, and 7 Landfills are collectively designated the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits in the 1950s through the 1980s. The Pit 4 and 7 Landfills were capped in 1992. Ongoing releases of contaminants to ground water are occurring. DOE has completed an area-specific Remedial Investigation/Feasibility Study (Taffet et al., 2005). The interim remedy for the Pit 7 Complex was selected in an Amendment to the Interim Site-Wide ROD in 2007 (U.S. DOE, 2007). The interim remedy is scheduled for implementation in 2007.

Pit 2 Landfill (OU 8) – The Pit 2 Landfill was used from 1956 to 1960 to dispose of firing table debris and gravel. No unacceptable risk or hazard to human health or ecological receptors has been associated with the Pit 2 Landfill. The selected interim remedy for the Pit 2 Landfill is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill. Deficiencies in the selected remedy were addressed in the Site-Wide Remediation Evaluation Summary Report (Ferry et al., 2006).

Building 854 OU (OU 6) – TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid, primarily between 1967 and 1984. Other contaminants in ground water include nitrate and perchlorate. Some TCE-contaminated soil was excavated in 1983. PCB, dioxin, and furan contaminated soil was excavated in 2005 to mitigate risk to onsite workers. Treatability studies to assess VOC, nitrate, and perchlorate extraction and treatment began in 1999. The selected interim remedy for this OU includes ground water and soil vapor extraction and treatment. The remedial design for the OU includes the construction and operation of three ground water and one soil vapor extraction and treatment systems. Buildout of the remedial action continues and construction completion is scheduled for 2007. A Five-Year Review for this OU is scheduled for 2008.

Building 832 Canyon OU (OU 7) – TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid at Buildings 830 and 832 between the late 1950s and 1985. Nitrate and perchlorate are also present in ground water. In 1999, DOE began a treatability study to evaluate ground water and soil vapor extraction at Building 832. The selected interim remedy for this OU includes continued soil vapor and ground water extraction and treatment. The remedial design for the OU includes the construction and operation of four ground water and two soil vapor extraction and treatment systems. Buildout of the remedial action continues and construction completion is scheduled for 2007. A Five-Year Review for this OU is scheduled for 2011.

Building 801 Dry Well and the Pit 8 Landfill (OU 8) – Waste fluid was discharged to a dry well located adjacent to Building 801D from the late 1950s to 1984, resulting in minor subsurface VOC contamination. The Pit 8 Landfill was used to dispose of debris from the Building 801 Firing Table until an earthen cover was installed in 1974. There is no evidence of a contaminant release from the landfill. No unacceptable risk or hazard was identified in either

area. The selected interim remedy for this area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill. A Five-Year Review for this OU is scheduled for 2012.

Building 833 (OU 8) – TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinsewater disposal, resulting in minor VOC contamination of the shallow soil/bedrock and perched ground water. The selected interim remedy for this area is continued monitoring. A Five-Year Review for this OU is scheduled for 2012.

Building 845 Firing Table and Pit 9 Landfill (OU 8) – High explosives experiments were conducted at the Building 845 Firing Table from 1958 to 1963. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and HE compounds. No ground water contamination has been detected. The Pit 9 Landfill was used to dispose of firing table debris generated at the Building 845 Firing Table. The debris buried in the pit may contain tritium, uranium, and/or HE compounds. However, there is no evidence of a contaminant release from the Pit 9 Landfill. No unacceptable risk or hazard was identified in either area. The selected interim remedy for this area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill. A Five-Year Review for this OU is scheduled for 2012.

Building 851 Firing Table (OU 8) – The Building 851 Firing Table has been used for high-explosives research since 1982. These experiments resulted in minor VOC, depleted uranium, metals, and HE contamination in soil and/or bedrock. Modeling indicated that these constituents in soil and bedrock do not pose a threat to ground water. While depleted uranium is present in ground water, activities are only a fraction of the MCL. No unacceptable risk or hazard was identified in this area. The selected interim remedy for this area is continued monitoring. A Five-Year Review for this OU is scheduled for 2012.

Advanced Test Accelerator (Building 865) – Building 865 facilities were used to conduct high energy laser tests and diagnostics in support of national defense programs from 1980 to 1995. The Building 865 Complex housed a 275-foot linear electron accelerator called the Advanced Test Accelerator (ATA). The ATA was designed to produce a repetitively-pulsed electron beam for charged particle beam research. A Characterization Summary Report for this area was submitted in 2006 (Ferry and Holtzapple, 2006). Impact to ground water and ecological receptors was identified from metals in surface soil. Freon 113, Freon 11, and Tetrachloroethylene (PCE), were identified as contaminants of concern (COC) in ground water. Due to the low concentrations, limited or localized extent, and future decontamination and decommissioning of the building, DOE recommended inclusion of the Building 865 into OU 8 for monitoring-only.

Building 812 – This facility has been in use since the 1960s. Gravel from the firing table was pushed into an adjacent ravine or to the side of the table. A Characterization Summary Report for this area was submitted in 2005 (Ferry and Holtzapple, 2005a). Depleted uranium has been identified as a COC in soil and ground water. Perchlorate and nitrate were also identified as COCs in ground water. A treatability study is planned for the extraction and treatment of ground water while the CERCLA pathway for this area is negotiated.

Sandia Test Facility – From about 1959 to 1960, Sandia National Laboratories (Livermore) operated a small, temporary firing table at Site 300. The facility consisted of a portable building with other structures built into the hillside and surrounded by sandbags. The facility may have been used to test or store high explosives. A Characterization Summary Report for this area was submitted in 2005 (Ferry and Holtzapple, 2005b). The characterization data indicate no releases of contamination have occurred to the environment as a result of activities in this area. DOE has proposed that the Sandia Test Site area be screened out as a contaminant release site and that no remedial action need be taken.

2. Site Chronology

The chronology of important environmental restoration events at the HEPA OU is summarized below.

1958–1989

- Surface spills at the drum storage and dispensing area for the former Building 815 steam plant resulted in TCE release to the ground surface from 1958 to 1986.
- Waste fluids were discharged to dry well 810A resulting in release of VOCs to the subsurface from 1959 to 1985.
- Wastewater containing HE compounds, nitrate, and perchlorate was discharged to former unlined rinsewater lagoons from the mid-to-late 1950s to 1985. Unlined HE rinsewater lagoons were capped and closed between 1985 and 1989. Two double-lined surface impoundments were installed in 1984.
- TCE was detected in ground water from former water-supply Well 6 in 1982. Well 6 was destroyed in 1986 and replaced with Well 20 in 1989.

1990

- LLNL Site 300 was placed on the National Priorities List.

1992

- A Federal Facilities Agreement for Site 300 was signed.

1994

- The Site-Wide Remedial Investigation report for Site 300 was issued (Webster-Scholten et. al., 1994).

1998

- The Building 815 Operable Unit Engineering Evaluation/Cost Analysis (Madrid and Jakub, 1998) proposed a Removal Action involving installation of offsite ground water compliance monitoring wells and ground water extraction and treatment from onsite wells to prevent offsite migration of TCE.
- An Action Memorandum for the Building 815 Removal Action (Jakub, 1998) authorized an early phase of ground water cleanup as a Non Time-Critical Removal Action.

- Capping and closure of the HE Burn Pits was completed in 1998. These pits, located in the vicinity of Building 829, had been used to burn HE particulates and cuttings, explosive chemicals, and explosives-contaminated debris from the late 1950s until 1998.

1999

- The Site-Wide Feasibility Study for Site 300 was issued (Ferry et al., 1999).
- Ground water extraction and treatment was initiated in the distal portion of the Building 815 VOC plume near the site boundary to prevent offsite plume migration.

2000

- Ground water extraction and treatment was initiated in the Building 815 source area.

2001

- An Interim Site-Wide ROD for Site 300 was signed. The Interim Site-Wide ROD specified continued ground water and soil vapor extraction, administrative controls (e.g., risk and hazard management), monitoring, and no further action for: (1) VOCs in soil and bedrock at the HE rinsewater lagoons, and (2) VOCs and high melting explosive/research department explosive (HMX/RDX) in soil and bedrock at the HE Burn Pits, as the components of the selected interim remedy for the HEPA OU. The Interim Site-Wide ROD did not contain ground water cleanup standards. These standards will be established in the Final Site-Wide ROD for Site 300.
- A Remedial Design Work Plan was issued that contained the strategic approach and schedule to implement the remedies in the Interim Site-Wide ROD (Ferry et al., 2001b).

2002

- The Interim Remedial Design Report for the HEPA OU was issued.
- The Compliance Monitoring Plan/Contingency Plan for Interim Remedies was issued (Ferry et al., 2002b).
- Ground water extraction and treatment was initiated in the proximal portion of Building 815 plume.

2003

- Ground water extraction and treatment was initiated in the Building 817 source area.

2005

- Ground water extraction and treatment was initiated in the Building 829 source area.
- Ground water extraction and treatment was initiated in Building 817 proximal area.
- The HE surface impoundments south of Building 817 were closed.

3. Background

3.1. Physical Characteristics

3.1.1. Site Description

LLNL Site 300 is a U.S. DOE experimental test facility operated by the University of California. It is located in the Eastern Altamont Hills 17 miles east of Livermore, California (Figure 1). At Site 300, DOE conducts research, development, and testing associated with high-explosive materials. During previous Site 300 operations, a number of contaminants were released to the environment. These releases occurred primarily from spills, leaking pipes, leaching from unlined landfills and pits, high-explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps). The climate at Site 300 is semi-arid; approximately 10 to 15 inches of precipitation falls each year, mostly in the winter.

The HEPA OU is located in the southeastern part of Site 300 (Figure 1). This area is characterized by steep, hilly terrain with northwest-southeast trending canyons and ridges. Facilities in the HEPA have been in use since the late 1950s for the chemical formulation, mechanical pressing, and machining of HE compounds into shaped detonation devices. Solid HE waste remaining after machining operations was incinerated at the HE Open Burn Facility located near Building 829 in the northern part of the HEPA OU. Liquid waste generated during machining operations was discharged to former unlined disposal lagoons.

In 1984, two double-lined HE surface impoundments were installed south of Building 817 to receive all HE process waste water and replace the unlined disposal lagoons. The surface impoundments allowed dissolved explosives chemicals in the wastewater to degrade from exposure to ultraviolet rays in sunlight. These surface impoundments were closed in 2005 under the oversight of the California Regional Water Quality Control Board (RWQCB).

In 1997, the Final Closure Plan for the HE Open Burn Facility at Building 829 was submitted to the regulatory agencies (Lamarre et al., 1997). This facility consisted of three unlined pits and an open-air burn unit to incinerate HE waste. As specified in the Final Closure Plan, this Burn Facility was dismantled, capped, and three deep ground water wells were installed in the regional $Tnbs_1$ aquifer for post-closure monitoring.

Twelve confirmed chemical release sites (source areas) have been identified in the HEPA OU. A former drum rack that was used to store and dispense TCE near Building 815 is considered to be the primary source of VOCs. The former unlined HE rinsewater disposal lagoons at Buildings 806, 807, and 817 and the dry well at Building 810 are considered the primary source areas of HE compounds and perchlorate. There are multiple natural and anthropogenic sources of nitrate in the ground water. Studies suggest that natural soil and septic discharges are probably a greater source of nitrate than discharge of HE-bearing waste fluids to the former lagoons and dry wells (Madrid et al., 2006).

3.1.2. Hydrogeologic Setting

This section describes the general hydrogeologic setting for the HEPA OU including the unsaturated zone and the six hydrostratigraphic units (HSUs) underlying the area. A conceptual

hydrostratigraphic column for the southeast corner portion of Site 300 including the HEPA is shown on Figure 2.

3.1.2.1. Vadose (Unsaturated) Zone

The thickness of the vadose zone in the HEPA varies from less than 20 feet (ft) in the Quaternary alluvial sand and gravel (Qal) of the Corral Hollow Creek floodplain to over 350 ft at the higher topographic elevations in the northwestern part of the OU. In some parts of the HEPA, limited amounts of perched ground water occur in the Tertiary Pliocene nonmarine sediments (Tps) and Tertiary Neroly Upper Siltstone/Claystone ($Tnsc_2$) stratigraphic units within the vadose zone.

3.1.2.2. Saturated Zone

The six HSUs in the HEPA OU are described below.

Qal HSU – The Qal/ HSU consists of alluvial sands and gravels with minor silts and clays located along the southern Site 300 border within the floodplain of Corral Hollow Creek. It ranges up to 35 ft in total thickness, but saturated thickness is spatially and temporally variable depending on seasonal rainfall. Ground water in this HSU flows generally to the east. The Qal HSU is recharged by surface runoff from nearby canyons, direct infiltration during seasonal rainfall events, and from below by confined ground water in bedrock aquifers that subcrop beneath the Qal. Corral Hollow Creek discharges to the east into the San Joaquin Valley.

Tpsg-Tps HSU – The Tertiary Pliocene sand and gravel (Tpsg-Tps) HSU consists of variably saturated, perched ground water present in Tertiary sand and gravel (Tpgs) and the underlying Tps claystones. Perched ground water is present at depths ranging from ground surface where it discharges at Spring 3 to 45 ft below ground surface (bgs) in the vicinity of Building 815. Ground water in this HSU flows to the southeast.

$Tnbs_2$ HSU – The Tertiary Neroly Upper Blue Sandstone ($Tnbs_2$) HSU is saturated beneath the southern part of the HEPA OU from Building 815 to the site boundary. Ground water in the $Tnbs_2$ HSU occurs under phreatic to confined and artesian flow conditions. Under unstressed, natural conditions, $Tnbs_2$ ground water levels in the southern part of the HEPA are higher than water levels in the overlying Qal HSU, indicating an upward hydraulic gradient. However, under stressed (pumping) conditions, this upward hydraulic gradient can be reversed if water levels in the $Tnbs_2$ HSU fall below water levels in the Qal HSU. Under these conditions, ground water from the Qal HSU flows downward into the $Tnbs_2$ HSU. The saturated thickness is variable in the $Tnbs_2$ HSU, ranging from 0 to 60 ft. Depth to ground water in the $Tnbs_2$ HSU ranges from 40 to 165 ft bgs. Ground water in this HSU flows to the southeast (Figure 3).

$Tnsc_{1b}$ HSU – Ground water occurs under unconfined to confined conditions in the Tertiary Neroly Lower Siltstone/Claystone ($Tnsc_{1b}$) HSU beneath the HEPA OU. The $Tnsc_{1b}$ HSU is saturated beneath the southern part of the HEPA with a saturated thickness of approximately 25 ft. Depth to ground water in this HSU ranges from 145 to 250 ft bgs. Ground water flow is to the southeast.

$Tnbs_1$ HSUs – The Tertiary Neroly Lower Blue Sandstone ($Tnbs_1$) HSU consists of Neroly Formation sandstone and conglomerate interbedded with siltstone and claystone and are present throughout the HEPA OU. There are two water-bearing zones in the $Tnbs_1$ stratigraphic unit,

separated by a 10-ft thick claystone (claystone marker bed) that exists throughout the southeast corner of Site 300. Ground water occurs under unconfined to confined and flowing artesian conditions in the upper and lower $Tnbs_1$ HSUs. The saturated thickness of the upper $Tnbs_1$ HSU ranges from 75 to 125 ft with depths to ground water ranging from 300 to 400 ft bgs. The saturated thickness of the lower $Tnbs_1$ HSU is greater than 150 ft with depths to ground water ranging from 400 to 500 ft bgs. Ground water flow is to the southeast.

The lower $Tnbs_1$ HSU is the main water-supply aquifer for Site 300. Site 300's water needs are supplied from Well 20 that is located in the southern part of the HEPA OU and is screened in the lower $Tnbs_1$ HSU.

3.2. Land and Resource Use

Prior to DOE establishing Site 300 as remote testing facility in 1955, the area was used for cattle grazing. Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. There have been no changes in land, building, or ground water use in the HEPA OU since the Interim Site-Wide ROD and none are anticipated. The HEPA is still used for machining and storage of HE and is accessible only to DOE/LLNL workers.

The HEPA OU extends to the southeastern site boundary. The land adjacent to the OU consists of private range-land and the Carnegie State Vehicular Recreation Area (SVRA). The nearest major population center (Tracy, California) is 8.5 miles to the northeast. There is no known planned modification or proposed development of the offsite range-land adjacent to the OU. The SVRA continues to expand its infrastructure to accommodate increased public usage.

At Site 300, ground water is used for a variety of needs including cooling towers, HE processing, and fire suppression. Bottled water is the primary source of onsite drinking water, however potable ground water from onsite water-supply Well 20, located in the HEPA OU, is available as necessary for potable supply. This well is screened in the Lower $Tnbs_1$ bedrock HSU at a depth of 387 to 518 ft bgs. Although several nearby ground water monitor wells screened in the shallower $Tnbs_2$ HSU contain TCE, TCE has not been detected in Well 20 because it is sealed through the shallow aquifer. The use of Well 18, also located in the southeast part of the HEPA OU, as a water-supply well was discontinued due to sporadic detections of TCE in samples from this well. Although Well 18 is inactive, it is considered a backup well to supply water for emergency fire suppression. There is no current onsite use of surface water by humans.

There are no environmentally sensitive areas on Site 300 property within the HEPA OU.

3.3. History of Contamination

Surface spills at the drum storage and dispensing area for the former Building 815 steam plant, where TCE was used to clean pipelines, resulted in release of TCE to the ground surface. This release site is the main source of TCE in ground water in the HEPA OU. Another minor source of TCE in ground water resulted from leaking contaminated waste stored at the former Building 829 Waste Accumulation Area. In addition, from 1959 to 1985, waste fluids were discharged to dry well 810A resulting in the release of VOCs to the subsurface. From the mid-to-late 1950s to 1985, rinsewater containing HE compounds was discharged to nine former

unlined rinsewater lagoons. The largest volumes of HE-bearing rinsewater were discharged from Buildings 806, 807, and 817 (Henry, 1981; Crow et al., 1986) to the former rinsewater lagoons. These former rinsewater lagoons are believed to have been the primary source of HE compounds (mainly RDX) and perchlorate in ground water. Three Resource Conservation and Recovery Act (RCRA)-regulated burn pits were located in the vicinity of Building 829 in which HE particulates and cuttings, explosive chemicals, and explosives-contaminated debris were burned. Reportedly, nearly 150 kilograms (kg) per month of explosives, reactive chemicals, and explosives-contaminated combustible waste were destroyed in these burn pits. The facility operated from the late 1950s until 1998 when the burn pits were capped and closed under RCRA. No significant contamination associated with the HE burn pits has been detected in environmental media.

3.4. Initial Response

DOE/LLNL began environmental investigations in the HEPA OU in the early 1980s to evaluate sources of contamination detected in former water-supply Well 6 and to determine if wastewater discharges into the unlined disposal lagoons had contaminated ground water. Since then, 194 boreholes have been drilled in the HEPA OU; 102 of these boreholes have been completed as ground water monitor or extraction wells (Figure 4). The geologic and chemical data from these wells and boreholes were used to characterize the site hydrogeology and to monitor temporal and spatial changes in saturation and dissolved contaminants. Site characterization activities also included analyses of water samples from springs, and passive and active vacuum induced soil vapor surveys.

As summarized in Section 2, remediation activities at the HEPA OU conducted prior to the 2001 Interim Site-Wide ROD included sealing and abandoning of former water-supply Well 6, decommissioning of the former rinsewater lagoons and dry wells, closure and capping of the former HE Burn Pit, and extraction and treatment of contaminated ground water.

3.5. Contaminants of Concern

Four COCs have been identified in HEPA OU ground water: (1) VOCs, (2) the HE compounds HMX and RDX, (3) perchlorate, and (4) nitrate. The HE compounds HMX and RDX were identified as COCs in surface soil. VOCs, HMX, and RDX are COCs in subsurface soil/rock. VOCs are COCs in surface water at Spring 5.

VOCs, primarily TCE, a suspected human carcinogen, are present in subsurface soil and rock, in surface water at Spring 5, and in ground water. The baseline human health risk assessment estimated an excess cancer risk of 5×10^{-6} to onsite workers inhaling VOCs evaporating from subsurface soil into outdoor ambient air in the vicinity of Building 815. An excess cancer risk of 1×10^{-5} was also estimated for onsite workers inhaling TCE and 1,1-dichloroethylene (DCE) volatilizing from surface water at Spring 5. An excess cancer risk of 3×10^{-6} was estimated for TCE, assuming human ingestion of contaminated ground water from a hypothetical well located at the Site 300 boundary.

The Compliance Monitoring Plan (Ferry et al., 2002) required that the risk associated with volatile contaminants in the subsurface migrating upward into indoor and outdoor ambient air and being inhaled by workers be re-evaluated annually using current data. DOE, EPA, and the

State regulatory agencies agreed that the risk would be considered successfully mitigated and risk management would be complete when the estimated risk is below 10^{-6} for two consecutive years. This risk re-evaluation was conducted for VOC inhalation in outdoor air near Building 815 and it was shown that the VOC inhalation risk remained below 10^{-6} in 2003 and 2004 (Dibley et al., 2006). Therefore, the risk associated with VOCs in subsurface soil has been successfully mitigated, and risk and hazard management is complete at Building 815.

The baseline ecological assessment determined that a risk from copper and cadmium existed for aquatic organisms, ground squirrels, and deer. Aquatic organisms are at risk from copper in the shallow, near surface ground water at Spring 5. The Toxicity Quotient using California Applied Action Levels exceeded 1 for copper in ground water samples from this location. Individual adult ground squirrels and individual adult and juvenile deer are at risk from ingestion of cadmium in surface soil. The combined oral and inhalation pathway Hazard Quotient exceed 1 for these species, which was driven by the oral pathway. Surveys for the presence of surface water at Spring 5, and algae and micro-invertebrate bioassays conducted to identify the true risk to aquatic organisms found no current adverse impact. Similarly, site-wide population surveys to identify the current risk to deer and ground squirrels found no adverse impacts.

The HE compounds HMX and RDX are human carcinogens present in surface soil, subsurface soil and rock, and ground water in the HEPA OU. The baseline human health risk assessment calculated an excess cancer risk of 2×10^{-6} for RDX assuming human ingestion of contaminated ground water from a hypothetical well located at the Site 300 boundary. There was no risk to onsite workers associated with HMX and RDX in surface and subsurface soil under an industrial land use scenario. There is no risk to offsite residents because this soil contamination is wholly contained onsite and there are no pathways through which offsite residents could be exposed.

The maximum perchlorate concentration detected in a ground water sample collected during first semester 2007 was 35 μg/L. Perchlorate, while not a carcinogen, interferes with iodide uptake into the thyroid gland. Because iodide is an essential component of thyroid hormones, perchlorate may disrupt thyroid functions by decreasing hormone production (U.S. EPA, 2005). There was no human health risk or hazard identified associated with perchlorate in ground water because there is no exposure pathway.

Elevated nitrate is present in ground water as a result of releases from a combination of natural and anthropogenic sources in the HEPA OU. In addition to natural soil nitrate and septic system discharges, HE- and nitrate-bearing wastewater was discharged to the former lagoons and dry wells in the HEPA OU. DOE/LLNL are conducting an ongoing study to evaluate potential natural and anthropogenic sources and their relative contribution to nitrate ground water loading in this OU and other parts of Site 300. Nitrate can cause non-carcinogenic health effects if ingested at elevated concentrations. There was no human health risk or hazard identified associated with nitrate in ground water.

Most ground water contamination at the HEPA OU is present in the $Tnbs_2$ HSU. It contains VOCs, RDX, perchlorate, and elevated nitrate and is the main focus of ground water remediation at this OU. The $Tnbs_2$ HSU was the main water-supply aquifer for Site 300 before contaminants were discovered in it during the mid-1980s. The current Site 300 water-supply well pumps from the deeper, uncontaminated $Tnbs_1$ HSU. Local ranchers pump water from offsite wells

completed in the $Tnbs_2$ HSU for domestic use and livestock watering. Guard wells and offsite water-supply wells are monitored regularly for HEPA COCs.

Contamination has not been detected in the $Tnsc_{1b}$ HSU throughout most of the HEPA OU. However, this HSU contains contaminants from sources in the Building 832 Canyon OU upgradient (northeast) of the HEPA OU. Limited amounts of perched ground water in the $Tnsc_{1b}$ HSU that is contaminated with TCE, perchlorate, and elevated nitrate occur beneath the former Building 829 HE Burn Pit and Waste Accumulation Area, located in the northwest part of the HEPA OU.

TCE, RDX, and perchlorate have been detected in the Tpsg sands and gravels of the Tpsg-Tps HSU in the vicinity of Building 815, although wells in this area have recently been dry. No contamination has been detected in the Qal HSU, the Tps portion of the Tpsg-Tps HSU, or the upper and lower $Tnbs_1$ HSUs in the HEPA OU.

A hydrogeologic cross-section showing the vertical distribution of total VOCs in the HEPA OU HSUs is shown in Figure 5.

3.6. Summary of Basis for Taking Action

Remedial actions were initiated in the HEPA OU to address unacceptable human health risks associated with onsite worker inhalation exposure to VOCs volatilizing from the subsurface soil to outdoor air in the vicinity of Building 815 and surface water at Spring 5. In addition, an unacceptable human health risk was associated with ingestion of contaminated ground water from a hypothetical well located at the Site 300 boundary.

4. Interim Remedial Actions

4.1. Interim Remedy Selection

The remedy selected for the HEPA OU is intended to achieve the following Remedial Action Objectives (RAOs):

Protection of Human Health:

- Restore ground water containing contaminant concentrations above cleanup standards that will be set in the Final Site-Wide ROD.
- Prevent human ingestion of the ground water containing VOC concentrations above the State and Federal drinking water Maximum Contaminant Levels (MCLs), or any more stringent water quality numeric limits.
- Prevent human inhalation of VOCs volatilizing from subsurface soil to ambient air that pose an excess cancer risk of 10^{-6} or a hazard index greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of 10^{-4}, or a cumulative hazard index (all non-carcinogens) greater than 1.
- Prevent human inhalation of VOCs volatilizing from surface water to air that pose an excess cancer risk greater than 10^{-6} or hazard index greater than 1, a cumulative excess

cancer risk (all carcinogens) in excess of 10^{-4}, or a cumulative hazard index (all noncarcinogens) greater than 1.

Protection of the Environment:

- Restore water quality, at a minimum, to water quality numeric limits that are protective of beneficial uses (i.e., MCLs), and to prevent plume migration to the extent technically and economically practicable. Maintain existing water quality that complies with water quality numeric limits.
- Ensure ecological receptors important at the individual levels of ecological organization (listed threatened or endangered, State of California species of special concern) are not exposed to contamination where relevant hazard indices exceed 1.
- Ensure existing contaminant conditions do not change so as to threaten wildlife populations and vegetation communities.

There is no remedial action objective for human health protection/applicable or relevant and appropriate requirements (ARAR) compliance for ingestion of surface waters (i.e., water from springs) because there is not a complete exposure pathway for ingestion of surface waters for humans at Site 300. Humans do not drink water from Site 300 springs. In addition, the springs in which contaminants are detected do not produce a sufficient quantity of water to be used as a water-supply (greater than 200 gallons per day). Since there is no complete exposure pathway for human ingestion of surface water at the site, a remedial action objective was not developed for this pathway.

In the Interim Site-Wide ROD, the remedy for the HEPA OU was selected based on its ability to meet the above RAOs. The selected interim remedy for the HEPA OU consists of:

1. No Further Action for VOCs and HE compounds in soil and bedrock. No further action was accepted for these COCs in surface soil and subsurface soil/bedrock because: (1) source control measures have already been implemented to prevent further impact to ground water, (2) there is no risk or hazard to human health or ecological receptors posed by these contaminants, and (3) ground water COC contamination is addressed through ground water extraction and treatment.
2. Ground water monitoring to evaluate the effectiveness of the remedial action in reaching remediation goals.
3. Risk and hazard management to prevent contaminant exposure to humans and impacts to ecological receptors until cleanup standards are achieved through active remediation.
4. Controlling offsite contaminant migration by extracting and treating ground water at the leading edge of the Building 815 TCE ground water plume.
5. Mitigating risk and controlling contaminant source area and ground water plume migration by extracting and treating ground water to remove VOCs, HE compounds, nitrate, and perchlorate released from Building 815, the former rinsewater lagoons, and the HE Burn Pits. Ground water extraction and treatment is also the remedy for aquifer restoration.

4.2. Interim Remedy Implementation

Ground water extraction and treatment systems (GWTS) have been operating in the HEPA OU since 1999. There are six GWTSs currently operating in the OU: Building 815-Source (815-SRC), Building 815-Proximal (815-PRX), Building 815-Distal Site Boundary (815-DSB), Building 817-Source (817-SRC), Building 817-Proximal (817-PRX), and Building 829-Source (829-SRC). The location of ground water extraction wells and treatment systems are shown in Figure 4.

These treatment systems all utilize aqueous-phase granular activiated carbon (GAC) to remove VOCs and HE compounds (mainly RDX) from extracted ground water. Ion-exchange resin is used to remove perchlorate from ground water, where present. Initially, an anaerobic bioreactor and misting were used for nitrate treatment. In 2005, DOE/LLNL presented the results of a study that demonstrated that naturally-occurring *in situ* denitrification processes in $Tnbs_2$ HSU ground water are attenuating nitrate; converting it to non-toxic nitrogen (N_2) gas. As a result, EPA, the California Department of Toxic Substances Control (DTSC), and the RWQCB approved reinjection of nitrate-bearing effluent from HEPA OU facilities into the $Tnbs_2$ HSU as a treatability study.

The 815-SRC GWTS removes TCE, RDX, and perchlorate from extracted ground water. This facility has been operating since September 2000. Initially, the facility consisted of aqueous-phase GAC, an ion-exchange system, and an anaerobic bioreactor for nitrate destruction, and the treated effluent was discharged to a misting system. The anaerobic bioreactor has been decommissioned and the treated effluent is now injected into well W-815-1918 for *in situ* denitrification in the $Tnbs_2$ HSU.

The 815-PRX GWTS removes TCE and perchlorate from extracted ground water. This facility has been operating since October 2002. Originally, the facility consisted of aqueous-phase GAC, an ion-exchange system, and the treated effluent was discharged to a misting system for nitrate treatment. The treated effluent is now injected into well W-814-2134 for *in situ* denitrification in the $Tnbs_2$ HSU.

The 815-DSB GWTS treats low concentrations (less than 10 micrograms per liter [µg/L]) of TCE in ground water extracted near the Site 300 boundary. The 815-DSB has been operating since September 1999. The GWTS originally consisted of a solar-powered aqueous-phase GAC treatment unit. In April 2005, it was connected to site power for continuous operation. The treated effluent is discharged to an infiltration trench.

The 817-SRC GWTS removes RDX and perchlorate from extracted ground water. This facility has been operating since September 2003 and consists of a solar-powered aqueous-phase GAC treatment unit with an ion-exchange system. Treated effluent is injected into well W-817-06A for *in situ* denitrification in the $Tnbs_2$ HSU.

The 817-PRX GWTS removes TCE, perchlorate, and RDX from extracted ground water. This facility began operating in September 2005 and consists of aqueous-phase GAC and ion-exchange units. Treated effluent is injected into well W-817-2109 for *in situ* denitrification in the $Tnbs_2$ HSU.

The 829-SRC GWTS removes TCE, nitrate, and perchlorate from the ground water and treats nitrate. This facility began operating in August 2005 and consists of aqueous-phase GAC, ion-

exchange, and a bioreactor for nitrate treatment. Treated effluent is injected into upgradient well W-829-08 for *in situ* denitrification.

4.3. System Operations/Operation and Maintenance

In general, the HEPA OU extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during this review. All required documentation is in place and treatment system operations and maintenance (O&M) activities are consistent with established procedures and protocols. O&M procedures are contained in the following documents:

- Health and Safety Plan and Quality Assurance/Quality Control Plan for the O&M of the HE Process Area Treatment Facilities, contained within the Interim Remedial Design report.
- Operations and Maintenance Manual for Miniature Treatment Units, Ground Water Treatment Units, and Solar Treatment Units, Volume 13 (Martins, 2007).
- Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation (LLNL, 2004).
- Integration Work Sheet Safety Procedure #1341: Ground Water and Soil Vapor Treatment Facility Operations at Site 300.
- HE Process Area Substantive Requirements issued by the California RWQCB.
- Site-Wide Compliance Monitoring Plan/Contingency Plan for Interim Remedies at LLNL Site 300.
- LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (Goodrich and Wimborough, 2006).

Monitoring and optimizing the performance and efficiency of the extraction and treatment systems comprises a large portion of the HEPA OU O&M activities. Ground water treatment system effluent is monitored to ensure compliance with discharge requirements. Treatment system parameters such as pressure and flow are recorded to anticipate potential mechanical problems and monitor system performance.

The major O&M activities for the HE Process Area ground water extraction and treatment systems include:

- Maintaining the particulate filters.
- Maintaining the injection wells and infiltration trenches used to discharge treated ground water.
- Protecting the units from freezing in cold weather.
- Replacing spent GAC and resin.
- Routinely inspecting and maintaining extraction well pumps, pipelines, and flow meters.

The budgeted and actual environmental restoration costs for the HEPA OU are tracked closely and are consistently within or near the allocated budget. Table 1 presents the actual costs for the last five fiscal years, 2002 through 2006.

4.4 Institutional Controls

Institutional/land use controls are non-engineered actions or measures used to prevent or limit the potential for human exposure to contamination at the HEPA OU and to protect the integrity of the remedy. The general types of institutional/land use controls that are used to prevent human exposure to contamination at the HEPA OU include:

- Access controls – Measures such as fences, signs, and security forces that are used to prevent exposure by controlling and/or restricting access to areas of contamination.
- Administrative controls – Measures such as pre-construction review and controls for limiting or restricting access to contaminated areas and prohibitions on water-supply well drilling.

Table 2 presents descriptions of: (1) the institutional/land use control objective and duration, (2) the risk necessitating land use controls, and (3) the specific institutional/land use controls and implementation mechanisms used to prevent exposure to contamination at the HEPA OU. Figure 6 shows the specific areas of the HEPA OU where the institutional/land use controls will be maintained or implemented.

Monitoring and inspection of the HEPA OU will continue to be performed throughout the remediation period to determine whether the institutional/land use controls remain protective and consistent with all remedial action objectives. In addition, DOE will continue to review facility and land use to evaluate changes in exposure pathway conditions that could affect the risk assessment assumptions and calculations.

Institutional/land use controls are included in the Risk and Hazard Management Program contained in the Site-Wide Compliance Monitoring Plan. Any new or modified institutional/land use controls resulting from the Five-Year Review process will be incorporated in the Risk and Hazard Management Program contained in the revised Site-Wide Compliance Monitoring Plan. Risk and hazard monitoring results conducted during the year are submitted to the EPA and State regulatory agencies in the Annual Site 300 Site-Wide Compliance Monitoring Reports. In addition, DOE will work with LLNL Site 300 Management to incorporate these institutional/land use controls into the Site 300 Integrated Strategic Plan or other appropriate institutional planning documents.

The land use controls and requirements described herein are only applicable to the HEPA OU and associated contaminated environmental media that are being addressed through the CERCLA process. DOE has implemented, and will continue to maintain, and enforce these institutional/land use controls at the HEPA OU for as long as necessary to keep the selected remedy protective of human health and the environment.

The institutional/land use controls described in this section and in Table 2, and Figure 6 showing the specific areas of the HEPA OU where the institutional/land use controls will be implemented and maintained, will be included in the Final Site-Wide ROD.

If DOE later transfers these procedural responsibilities to another party by contract, property transfer agreement, or through another means, DOE will retain ultimate responsibility for the integrity of the remedy. In the event that the property is transferred in the future, DOE will execute a land use covenant at the time of transfer in compliance with California Code of Regulations Title 22, Division 4.5, Chapter 39, Section 67391.1. If the Site 300 property were to be transferred to an entity outside the U.S. DOE, the necessary institutional/land use controls would be determined prior to the property transfer based on: (1) the intended land use subsequent to the property transfer, and (2) contamination and associated risk, if any, remaining at the HEPA OU.

The institutional controls were reviewed and are still effective for preventing exposure to contaminated media.

5. Five-Year Review Process

The Five-Year Review of the HEPA OU at LLNL Site 300 was led by Claire Holtzapple, Site 300 Remedial Project Manager for the DOE/National Nuclear Security Administration-Livermore Site Office. The following team members assisted in the review:

- Valerie Dibley, Deputy Project Leader, LLNL.
- Vic Madrid, Environmental Scientist, LLNL.
- Michelle Denton, Hydrogeologist, Weiss Associates.
- Zafer Demir, Hydrogeological Engineer, LLNL.
- Leslie Ferry, Project Leader, LLNL.

This Five-Year Review consisted of examining relevant project documents and site data:

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300.
- Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300.
- Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300.
- Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300.
- Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300.
- Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300.
- Semi-annual Site-Wide Compliance Monitoring Reports that include evaluations of remediation progress in the HEPA OU (Dibley et al., 2004a; 2004b; 2005a; 2005b; 2006b; 2006c; and 2007b).

This Five-Year Review evaluates subsurface contaminant concentration and remediation system performance data collected through calendar year 2006.

The completed report will be placed in the information repositories in the Visitor's Center at the LLNL Livermore Site and at the Tracy Public Library. Notice of its completion will be placed in the Tracy Press and local contacts will be notified by letter.

6. Five-Year Review Findings

6.1. Interviews and Site Inspection

DOE/LLNL meets monthly with the EPA, RWQCB, and DTSC Remedial Project Managers (RPMs) and quarterly with community action group at Technical Assistance Grant Meetings to discuss remediation activities, issues, and cleanup status and progress.

There is a continuous presence of Site 300 Environmental Restoration Project staff at Site 300 that inspect: (1) the extraction wellfield and treatment facilities weekly, and (2) the monitoring wellfield during ongoing, continuous sampling activities. The Site 300 Environmental Restoration Project conducts regular self-assessment inspections of all facilities and DOE conducts quarterly inspections of remediation activities at Site 300. The date of the last DOE quarterly inspection was September 18, 2007. The RWQCB RPM performs site inspections twice a year, and EPA and DTSC RPMs perform site inspections as requested. The most recent regulatory inspections/tour occurred as follows: EPA in May 2005, DTSC in April 2006, and the RWQCB in April 2007.

6.2. Changes in Cleanup Standards and To-Be-Considered Requirements

The following action-specific ARAR has been adopted since the Site-Wide Interim ROD was signed in 2001:

- The California Code and Regulations, Title 22, Section 67391.1 was adopted April 19, 2003. It contains requirements for imposing legal limitations on future site uses and activities through a land use covenant. There is no impact on the protectiveness of the remedy related to the new requirement for a land use covenant at the time of property transfer.

This action-specific ARAR and ARARs related to ground water cleanup will be established in the Final Site-Wide ROD scheduled for 2008.

6.3. Changes in Land, Building, or Ground Water Use

There have been no changes in land, building, or ground water use in the HEPA OU since the Interim Site-Wide ROD. The OU is still used for the formulation, mechanical pressing and machining of HE compounds and is accessible only to DOE/LLNL workers. Shallow contaminated ground water in the $Tnbs_2$ and $Tnsc_{1b}$ HSUs underlying the OU is not used for onsite water-supply. Ground water from the $Tnbs_2$ HSU is pumped from offsite water-supply Gallo-1 for domestic and livestock watering use at the Gallo ranch south of the HEPA OU. Monthly ground water samples are collected from this well and analyzed for COCs that may be present in upgradient ground water at Site 300. The 815-DSB GWTS was installed upgradient of

the Gallo well to prevent offsite migration of contaminant plumes toward this well. Ground water from Well 20, screened in the lower $Tnbs_1$ HSU, is used for Site 300 water-supply.

6.4. Changes in Exposure Pathways, Toxicity, and Other Contaminant Characteristics

There have been no changes in exposure pathways, toxicity, and other contaminant characteristics in the HEPA OU since the Interim Site-Wide ROD was signed in 2001. However, in August 2001, U.S. EPA's Office of Research and Development released the draft "Trichloroethylene Health Risk Assessment: Synthesis and Characterization" that has since been undergoing external peer review (U.S. EPA, 2001b). This assessment indicates that, for those who have increased susceptibility and/or higher background exposures, TCE could pose a higher risk than previously considered. Since review of the toxicity value for TCE may continue for a number of years, this issue will be updated in future Five-Year Reviews.

6.5. Data Review and Evaluation

6.5.1 Ground Water Remediation Progress

Although the first ground water extraction and treatment system was installed at the HEPA OU in late 1999, ground water remediation is still in its early stages. Most treatment facilities are less then 5 years old and extraction wellfield buildout is scheduled to be completed in 2007. As a result, significant reductions in contaminant concentrations and mass in ground water have not yet been realized through the OU. For example, remediation has not yet resulted in significant changes to the extent of VOC contamination in ground water. However, some progress in ground water remediation has been accomplished as shown in Figure 7 by the reduction in the highest VOC concentrations (greater than 50 µg/L). This progress was evaluated by:

- Reviewing COC concentration trends in ground water over time.
- Reviewing dissolved-phase ground water COC mass removal data.
- Evaluating extraction wellfield capture zones.

Because the remediation efforts in HEPA OU are relatively recent and progress is not yet evident on an OU-wide scale, this evaluation focuses primarily on areas where ground water remediation has been underway long enough to measure progress. For this reason, the discussion of remediation progress is presented by treatment facility areas in the chronological order that they were installed.

VOC remediation at the 815-DSB – The 815-DSB GWTS was installed in 1999 to hydraulically control and prevent offsite migration of the VOC plume originating from the Building 815 source area. Because the primary objective of this facility is to prevent offsite VOC plume migration, the most indicative measure of progress is concentrations trends in downgradient guard wells, used to detect plume migration. During the first few years of operation, VOCs were sporadically detected at a maximum concentration of 1.5 µg/L. As a result, extraction well flow rate was increased and an additional extraction well was added to the

wellfield to increase hydraulic capture. In addition, the facility was converted from solar power to site power to ensure continuous operation. Since these modifications, VOCs have not been detected in any of the guard wells. The 815-DSB GWTS is located at the leading edge of the VOC plume, and therefore draws in upgradient contaminated ground water. This phenomenon is shown by time-series plot of VOC concentrations in the 815-DSB extraction well indicating increasing concentrations over time (Figure 8). Therefore, concentrations trends in extraction wells and treatment facility influent are not good indicators of remediation progress. The 815-PRX GWTS was installed to minimize accelerating upgradient plume migration toward the site boundary by pumping at the 815-DSB GWTS.

As of the first Semester of 2005, the 815-DSB GWTS has removed 0.11 kg of VOCs from ground water. Figure 9 shows the cumulative mass of VOCs removed from ground water by treatment facilities in the HE Process Area including the B815-DSB facility. Because only very low VOC concentrations are present in ground water at the leading edge of the plume and the facility's main objective is to prevent offsite plume migration, high mass removal rates are not expected.

Conservative estimates of ground water capture by the B815-DSB extraction wellfield are presented in Figure 10. The capture plots shown in Figure 10 show the estimated extent capture at 10-year pumping intervals from 10 to 60 years. Because the capture zones presented in Figure 10 are the most conservative representation of the predicted capture zones, the actual capture in the field is expected to be larger. The extent of capture and the ability of the extraction wellfield to achieve ground water RAOs will be evaluated on an ongoing basis. If this evaluation indicates that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. However, the pumping strategy for the ground water extraction wells at the site boundary must be conducted to achieve a balance between preventing offsite plume migration and preventing accelerated migration of contaminants in the upgradient part of the plume toward the site boundary. Over-pumping of ground water from wells at the site boundary could result in more rapid migration of upgradient contamination toward the site boundary and lengthen cleanup times for this area.

VOCs, RDX, and perchlorate remediation at the 815-SRC – The 815-SRC GWTS was installed in late 2000 to: (1) initiate cleanup of the Building 815 source area, and (2) partially offset the impact of pumping at the site boundary by reducing the VOC concentrations at the source.

Building 815 is the primary source of VOC ground water contamination in the HEPA OU. Although the 815-SRC GWTS is located in the Building 815 source area, the highest VOC concentrations are located more than 500 ft downgradient. Because there are no confirmed VOC release sites in this downgradient area, the VOC plume appears to be detached from its source, suggesting that the VOC source at Building 815 is depleted. As presented in Figure 11, VOC concentrations in 815-SRC extraction wells show a slightly decreasing trend from an historical maximum concentration of 14 μg/L to a maximum of 7 μg/L in the first semester of 2005.

The 815-SRC GWTS also treats RDX in ground water that has migrated to this area from the rinsewater lagoon sources at Buildings 806 and 807. As shown in Figure 11, RDX concentrations in the 815-SRC extraction wells increased from 30 to 100 μg/L between 1987 and 2000, prior to the start of pumping. RDX concentrations in ground water decreased following the start of ground water extraction and treatment in 2000. The 815-SRC GWTS was shut down

for extensive maintenance for several months in 2003, during which time RDX concentrations rebounded to 130 µg/L. This concentration rebound is likely the result of the re-establishment of the equilibrium between the sorbed and dissolved phases of RDX when pumping stopped in 2003. RDX concentrations again decreased when pumping was reinitiated. However, these data indicate that the remediation of RDX in ground water may be significantly limited by sorption kinetics.

As shown in Figure 11, perchlorate concentrations in both the 815-SRC extraction well (W-815-02) and treatment facility influent have increased slightly since ground water extraction and treatment started. This slightly increasing trend is the result of this well capturing higher perchlorate concentrations from upgradient ground water.

The 815-SRC GWTS has removed over 0.05 kg of VOCs, 0.5 kg of RDX, and 0.11 kg of perchlorate from ground water. Figures 9, 12, and 13 show the cumulative mass of VOCs, RDX, and perchlorate respectively, removed from ground water by treatment facilities in the HEPA OU including the 815-SRC GWTS as presented in the Site-Wide Remediation Evaluation Summary Report. Because contaminant mass removal in this area is limited by very low extraction well yield, DOE/LLNL recently began reinjecting treated effluent upgradient to increase the hydraulic gradient and flush contaminants toward the extraction well. Another extraction well was also installed to increase mass removal.

Conservative estimates of ground water capture by the 815-SRC extraction wellfield are presented in Figure 10. The capture plots shown in Figure 10 show the estimated extent of capture at 10-year pumping intervals from 10 to 60 years. The capture zones presented in Figure 10 are the most conservative representation of the predicted capture zones. The actual capture in the field is expected to be larger, primarily because of the fractured nature of the $Tnbs_2$ HSU. Because the FEFLOW model conservatively simulated the $Tnbs_2$ HSU as a porous medium equivalent, the estimated capture zones are conservatively smaller.

Once the extraction wellfields in the HEPA OU have operated long enough for capture zones to fully develop, DOE/LLNL will evaluate the extent of capture and the ability of the extraction wellfield to achieve ground water RAOs. This evaluation will be based on ground water elevation contours and concentration trends in extraction, performance monitoring, and guard wells. If data from this evaluation indicate that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. Modifications may include changes to the extraction well pumping strategy and/or installing additional extraction wells.

VOCs and perchlorate remediation at the 815-PRX – The 815-PRX GWTS was installed in late 2002 to: (1) remove COC mass in the plume downgradient of the Building 815 source area, and (2) minimize the impact of pumping at the site boundary by reducing the VOC concentrations in upgradient ground water.

As shown in Figure 14, VOC concentrations in extraction well W-818-08 have decreased slightly from a pre-remediation concentration average of 62 µg/L to an average of 52 µg/L following the start of remediation. Concentrations in downgradient monitor wells indicate progress is being made toward slowing migration of the plume toward the site boundary.

As shown in Figure 14, perchlorate concentrations in 815-PRX extraction wells have been relatively stable with concentrations of 6 to 10 µg/L. However, perchlorate has not been

detected in downgradient monitor wells, indicating that the 815-PRX extraction wells are adequately capturing the perchlorate plume in this area and preventing migration toward the site boundary.

The 815-PRX GWTS has removed over 0.32 kg of VOCs and 0.06 kg of perchlorate from ground water. Because contaminant mass removal in this area is limited by very low extraction well yield, DOE/LLNL began reinjecting treated effluent upgradient in late 2005 to increase the hydraulic gradient and flush contaminants toward the extraction well. Another extraction well was added to increase mass removal.

RDX and perchlorate remediation at the 817-SRC – The 817-SRC GWTS was installed in late 2003 to remove COC mass in the former rinsewater lagoon source areas. As shown in Figure 15, RDX concentrations in extraction well W-817-01 have significantly decreased from an historical maximum of 204 µg/L in 1992 to less than 50 µg/L in the first semester of 2005. While perchlorate concentrations indicate a decreasing trend over time, concentrations have been relatively constant since remediation began in 2003. Conservative estimates of ground water capture by the 817-SRC extraction wellfield at 10-year pumping intervals from 10 to 60 years are presented in Figure 10. Because the capture zones presented in Figure 10 are the most conservative representation of the predicted capture zones, the actual capture in the field is expected to be larger. The extent of capture and the ability of the extraction wellfield to achieve ground water RAOs will be evaluated on an ongoing basis. If data from this evaluation indicate that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. Because this facility was installed relatively recently, it is too early to assess its performance.

RDX and perchlorate remediation at the 817-PRX – The 817-PRX GWTS was installed in late 2005 to remove COC mass downgradient of the former rinsewater lagoon source areas. Conservative estimates of ground water capture by the 817-PRX extraction wellfield at 10-year pumping intervals from 10 to 60 years are presented in Figure 10. Because the capture zones presented in Figure 10 are the most conservative representation of the predicted capture zones, the actual capture in the field is expected to be larger. The extent of capture and the ability of the extraction wellfield to achieve ground water RAOs will be evaluated on an ongoing basis. If data from this evaluation indicate that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. Because this facility was installed very recently, it is too early to assess its performance.

TCE, perchlorate, and nitrate remediation in the 829-SRC – The 829-SRC GWTS was installed in late 2005 to remove COC mass in the vicinity of the former Building 829 Waste Accumulation Area. Because this facility was installed very recently, it is too early to assess its performance.

Natural Attenuation of Nitrate in Ground Water – DOE/LLNL conducted a study to determine if denitrification processes are naturally attenuating nitrate in $Tnbs_2$ HSU ground water at Site 300. Data obtained as part of this study indicate that denitrification processes are naturally attenuating nitrate in the confined, oxygen-depleted region of the $Tnbs_2$ HSU in the HEPA OU as discussed below:

- Both nitrate and dissolved oxygen concentrations in ground water decrease significantly as ground water flows from unconfined to confined conditions in the $Tnbs_2$ HSU.

- Low dissolved oxygen concentrations in the downgradient, confined region of the $Tnbs_2$ HSU are conducive for anaerobic bacteria to metabolize nitrate, converting it to harmless nitrogen (N_2) gas.
- Stable isotope signatures (i.e., $\delta^{15}N$ and $\delta^{18}O$) of nitrate in ground water indicate a trend of isotopic enrichment that is characteristic of denitrification.
- Dissolved nitrogen gas concentrations, the product of denitrification, are highly elevated in nitrate-depleted ground water in the confined region of the $Tnbs_2$ HSU (Beller et al., 2004).

Nitrate (as NO_3) concentrations have been relatively high and constant over time in recharge-area monitoring wells screened in the unconfined $Tnbs_2$ HSU, with concentrations typically ranging from 70 to 100 milligrams per liter (mg/L). Nitrate concentrations have been relatively low and constant over time in the downgradient, confined $Tnbs_2$ HSU region, typically ranging from in concentration from less than 0.1 to 3 mg/L. This suggests a balance between the rates of nitrate loading in the upgradient, unconfined region of the HSU and removal by denitrification in the downgradient, confined HSU area. Anaerobic bacteria present in the oxygen-depleted, confined region of the $Tnbs_2$ HSU provide the main mechanism for denitrification. Based on the results of this study, monitored natural attenuation would be a health-protective, cost-effective final remedy for nitrate in ground water in the $Tnbs_2$ HSU.

These data indicate that nitrate in HE Process Area ground water support the presence of the elements that are important to establishing an MNA remedy: (1) the contamination is not currently posing an unacceptable risk, and (2) stable nitrate concentration contours. Natural attenuation is demonstrated through the formation of geochemical indicators of denitrification (e.g., isotopic enrichment in nitrogen-15 and excess nitrogen gas).

6.5.2. Risk Mitigation Remediation Progress

This section summarizes the results of the annual risk re-evaluation conducted for the HEPA OU to assess the progress of the remediation effort in mitigating risk to onsite workers and at a hypothetical well located at the Site 300 boundary. Risks from HEPA OU COCs were summarized in Section 3.5 and in the Interim Site-Wide ROD.

The risks associated with VOCs in the HEPA OU were re-evaluated in 2003 and 2004 as part of the Risk and Hazard Management Program. Ground water extraction at Building 815 has contributed to reducing the human health risk due to inhalation of VOC vapors outside Building 815 to a level that is no longer of concern (less than 10^{-6}).

DOE/LLNL were unable to re-evaluate VOC inhalation risk to onsite workers at Spring 5 from 2003 through 2006 due to lack of water in this spring. However, the baseline risk was calculated from VOC concentrations in well W-817-03A located adjacent to Spring 5 since the actual flow in the spring is generally too low to measure and the spring consists primarily of moist soil with wetland vegetation. No one regularly works in the vicinity of Spring 5 and VOC concentrations in ground water that feeds the spring have decreased from 150 µg/L in 1987 to 50 µg/L in 2005. Therefore the cancer risk estimated in the baseline risk assessment has decreased correspondingly over time. In addition, more than half of the estimated risk resulted from the presence of 1,1-DCE, which has not been detected in ground water in the area since 1987.

The baseline risk assessment estimated unacceptable cancer risks in ground water in the HEPA OU, assuming human ingestion of contaminated ground water that migrated offsite to a hypothetical well located at the Site 300 boundary. These risks were based on modeling of offsite migration of contaminated ground water in the absence of ground water remediation. Ground water extraction and treatment began in 1999 immediately upgradient of the site boundary to prevent offsite contaminant migration. As a result of onsite ground water remediation efforts, contaminant concentrations in upgradient ground water have substantially decreased since the baseline risk assessment was performed.

6.5.3. New Sources, Releases, or Contaminants

Ground water data indicate that there are no new sources, releases, or contaminants in the HEPA OU since the selection of the interim remedy in 2001.

6.5.4. New Technology Assessment

No new technologies have been identified that are capable of accelerating or achieving cleanup in a more cost-effective manner in the HEPA OU.

7. Technical Assessment

The protectiveness of the HEPA interim remedy was assessed by determining if:

1. The interim remedy is functioning as intended at the time of the decision documents.
2. The assumptions used in the decision-making process are still valid.
3. Any additional information has been identified that would call the protectiveness of the interim remedy into question.

This review determined that the interim remedy for the HEPA OU was protective, based on the following:

- On April 19, 2003, the California Code of Regulations, Title 22, Section 67391.1 was adopted that contains requirements for imposing legal limitations on future site uses and activities through a land use covenant. However, there is no impact on the protectiveness of the remedy related to this new requirement for a land use covenant at the time of property transfer. There have been no other changes in location-, chemical-, or action-specific ARARs or to-be-considered requirements since the Interim Site-Wide ROD for Site 300 was signed, nor have there been changes in exposure pathways, toxicity, and other contaminant characteristics.
- There have been no changes in land, building, or water use in the HEPA OU since the Interim Site-Wide ROD for Site 300 was signed.
- All required institutional controls are in place and no current or planned changes in land use at the site suggest that they are not or would not be effective.
- The interim remedy is functioning as intended. Ground water extraction and treatment is reducing contaminant concentrations and mass in the subsurface.

- The treatment systems are performing as designed and will continue to be operated and optimized.
- System operation procedures are consistent with requirements.
- Costs have been consistently within budget.
- No early indicators of potential interim remedy failure were identified.
- The Health and Safety Plan and Site-Wide Contingency Plan are in place, sufficient to control risks, and properly implemented.
- There have been no changes in risk assessment methodologies that would call the protectiveness of the interim remedy into question.
- No additional information has been identified that would call the protectiveness of the interim remedy into question.

8. Deficiencies

No deficiencies in the interim remedy were identified during this evaluation. However, continued management and optimization of the extraction wellfield upgradient of the private offsite water-supply Gallo-1 will be necessary to prevent migration of VOCs in ground water toward this well. In the future, additional extraction wells may be needed in the distal portions of the plume to fully capture contaminants migrating toward the site boundary.

9. Recommendations and Follow-Up Actions

This evaluation does not identify a need for changing the overall approach to cleanup for VOCs, HE compounds, or perchlorate in ground water in the HEPA OU. DOE/LLNL have implemented or are in the process of implementing all the actions required in the Interim Site-Wide ROD, the Remedial Design Work Plan for the Interim Remedies, and the Interim Remedial Design document for the HEPA OU.

Based on the results of the nitrate study discussed in Section 6.5.1, DOE/LLNL recommend implementing monitored natural attenuation as a health-protective, cost effective final remedy for nitrate in ground water.

The proposed cleanup standards for soil are based on industrial use. Because VOCs at concentrations exceeding those established for residential use may remain at the HEPA OU following the achievement of the proposed industrial cleanup standards for VOCs in subsurface soil, a land use control will be added that prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition will be included in the Final Site-Wide ROD scheduled for 2008. The Final Site-Wide ROD will also reference the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document into which this prohibition will be incorporated.

The action-specific ARAR change identified in Section 6.2, and ARARs related to ground water cleanup, will be included in the Final Site-Wide ROD scheduled for 2008.

Once the extraction wellfields in the HEPA OU have operated long enough for capture zones to fully develop, DOE/LLNL will evaluate the extent of capture and the ability of the extraction wellfield to achieve ground water RAOs. This evaluation will be based on ground water elevation contours and concentration trends in extraction, performance monitoring, and guard wells. If data from this evaluation indicate that the existing extraction wellfield will not achieve ground water RAOs, modifications to the wellfield will be implemented. Modifications may include changes to the extraction well pumping strategy and/or installing additional extraction wells.

No other follow-up actions were identified related to this evaluation.

10. Protectiveness Statement

The remedy at the HEPA OU is expected to be protective of human health and the environment upon completion (i.e., when cleanup standards are achieved) for the site's industrial land use. In the short-term, the remedy protects human health because exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of institutional controls, the Health and Safety Plan, and the Contingency Plan.

The proposed cleanup standards for HEPA OU ground water are drinking water standards, but will be finalized in a Site-Wide ROD scheduled for 2008. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario upon completion.

The proposed cleanup standards for VOCs in subsurface soil are to reduce concentrations to mitigate risk to onsite workers and prevent further impacts to ground water to the extent technically and economically feasible. Because some VOCs may remain in subsurface soil following the achievement of these proposed cleanup standards, a land use control will prohibit the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition will be included in the Final Site-Wide ROD scheduled for 2008. The Final Site-Wide ROD will also reference the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document into which this prohibition will be incorporated. This prohibition will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and is agreed by the DOE, the EPA, the DTSC, and RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use.

11. Next Review

The next statutory review will be conducted within five years of the signature date of this report (2012).

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Acronyms and Abbreviations

ARARs	Applicable or relevant and appropriate requirements
ATA	Advanced Test Accelerator
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Contaminant of concern
DCE	Dichloroethylene
DOE	Department of Energy
DSB	Distal Site Boundary
DTSC	Department of Toxic Substances Control
EPA	Environmental Protection Agency
ft	Feet
GAC	Granular activated carbon
GWTS	Ground water treatment system
HE	High explosives
HEPA	High Explosives Process Area
HMX	High-Melting Explosive
HSU	Hydrostratigraphic unit
kg	Kilogram
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum contaminant level
mg/L	Milligrams per liter
MSL	Mean sea level
O&M	Operation and maintenance
OU	Operable unit
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethylene
PRX	Proximal
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDX	Research Department explosive
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendment Reauthorization Act
SRC	Source
SVRA	Carnegie State Vehicular Recreation Area
TCE	Trichloroethylene
$Tnbs_1$	Tertiary Neroly Lower Blue Sandstone
$Tnbs_2$	Tertiary Neroly Upper Blue Sandstone

$Tnsc_2$	Tertiary Neroly Upper Siltstone/Claystone
Tps	Tertiary Pliocene nonmarine sediments
Tpsg	Tertiary Pliocene sand and gravel
VOCs	Volatile organic compounds
U.S.	United States
µg/L	Micrograms per liter

Figures

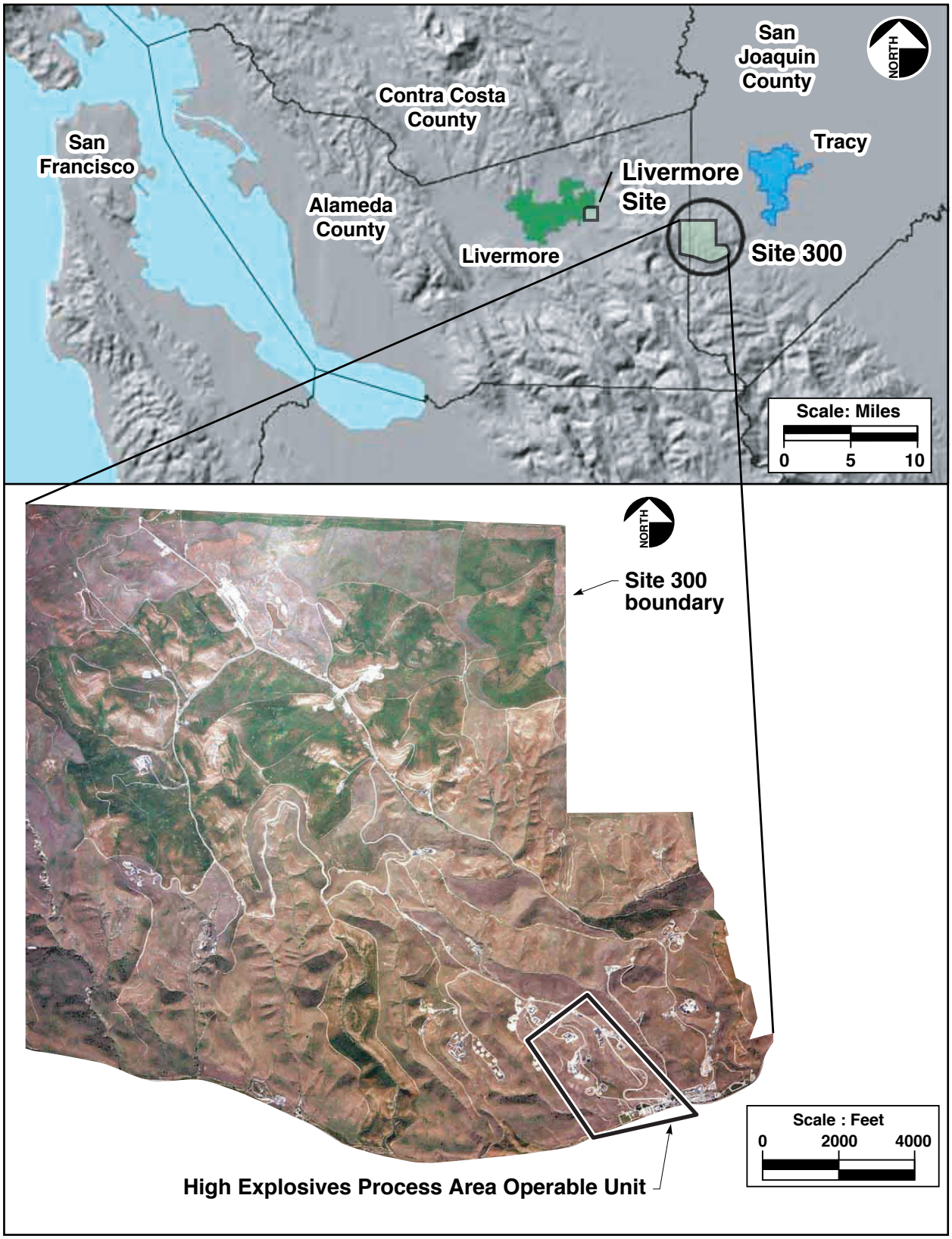

Figure 1. Location of LLNL Site 300.

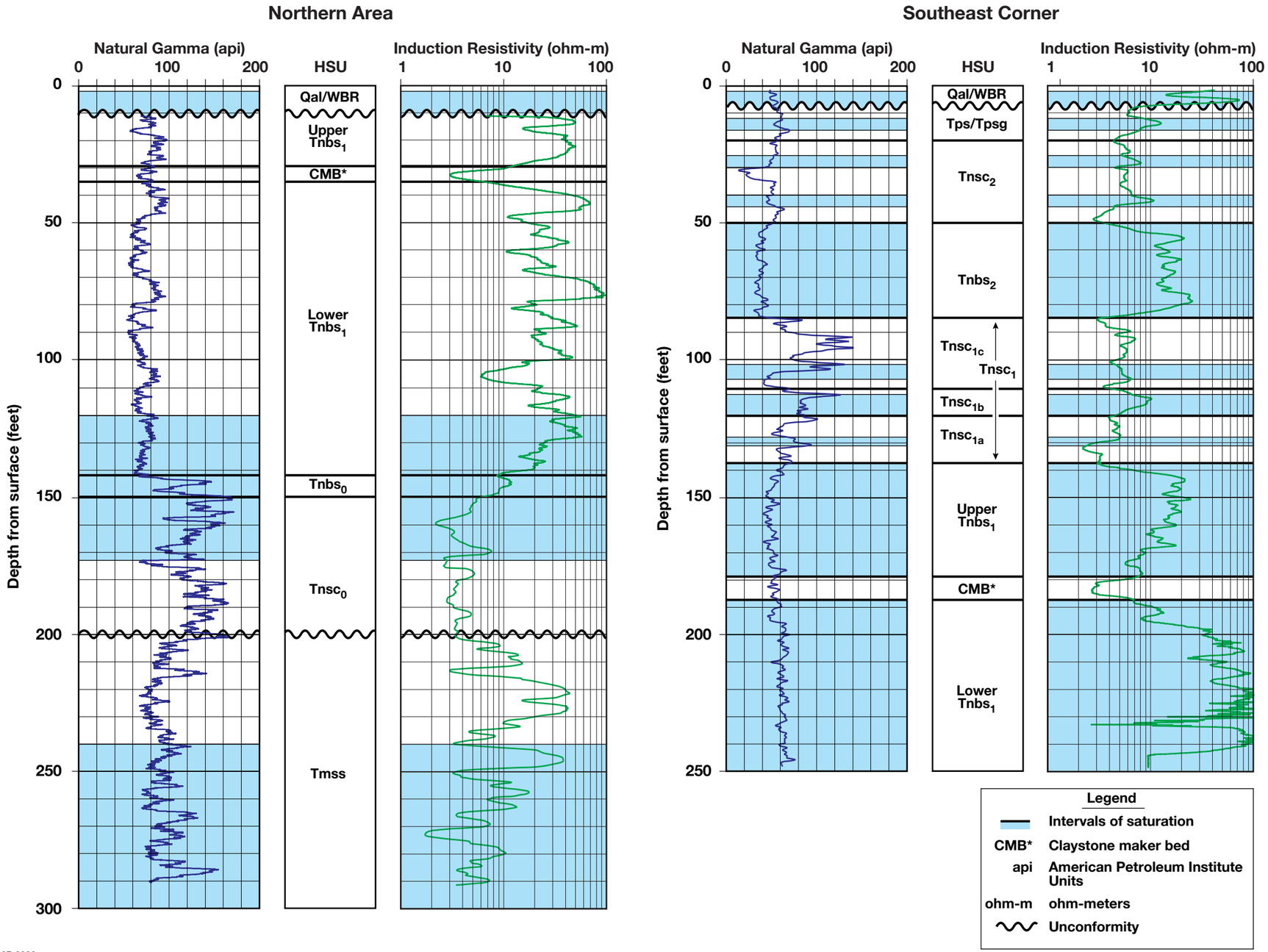

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Figure 2. Composite hydrostratigraphic columns for Site 300 showing saturated hydrostratigraphic units (HSUs).

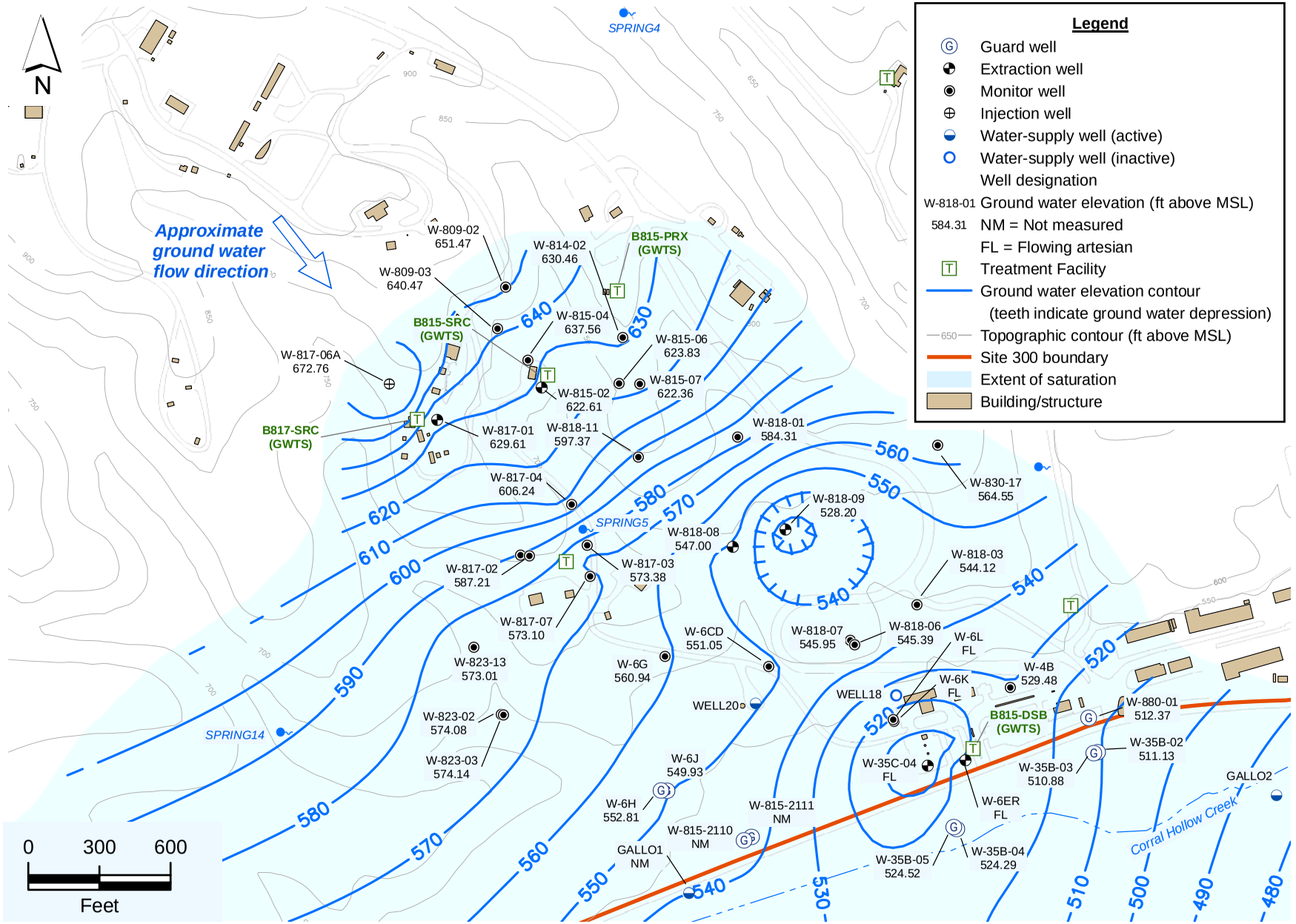

Figure 3. High Explosive Process Area Operable Unit potentiometric surface and ground water flow direction in the $Tnbs_2$ hydrostratigraphic unit (1st Semester 2005).

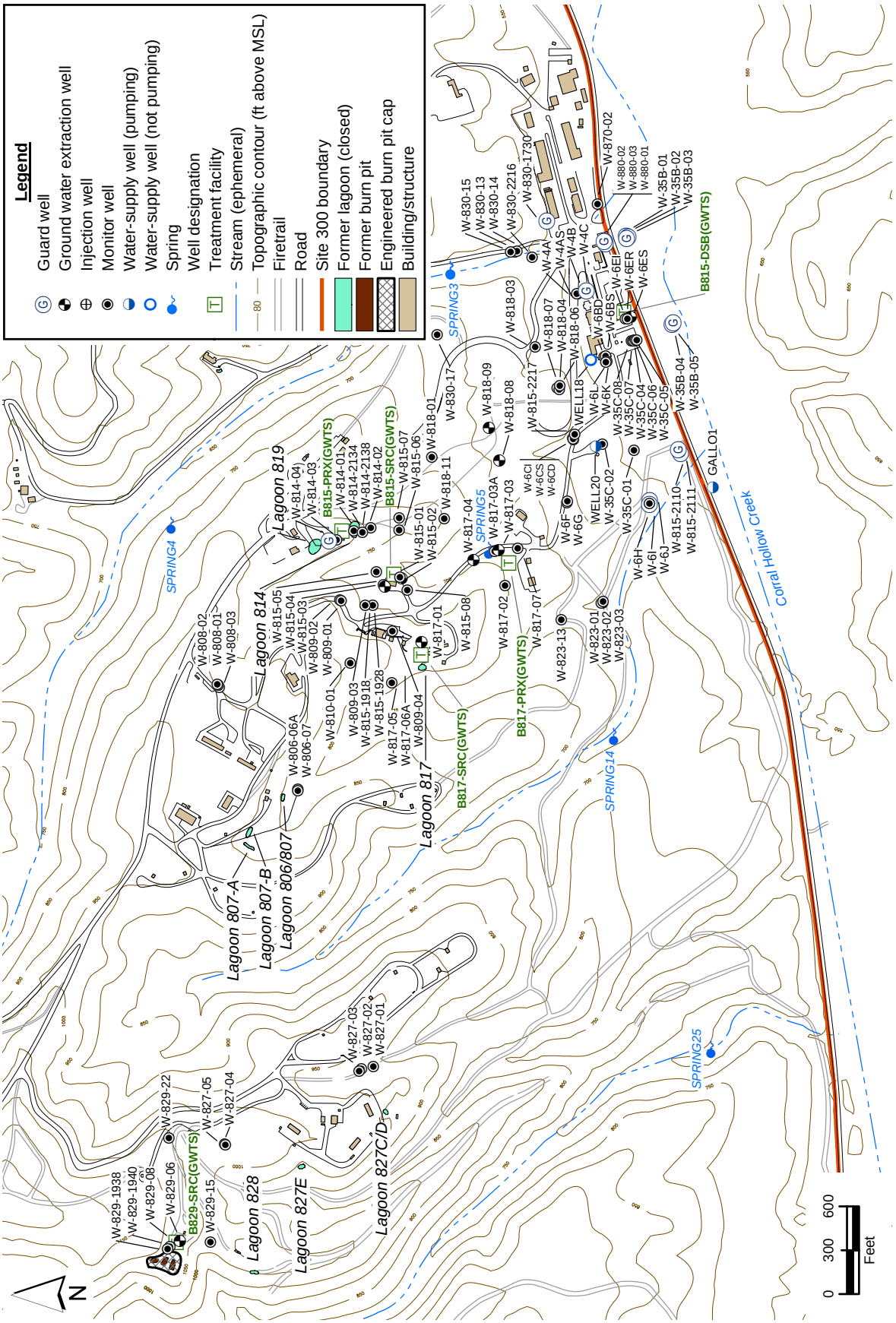

Figure 4. High Explosives Process Area Operable Unit site map showing monitor, extraction, injection, and water-supply wells, and treatment facilities.

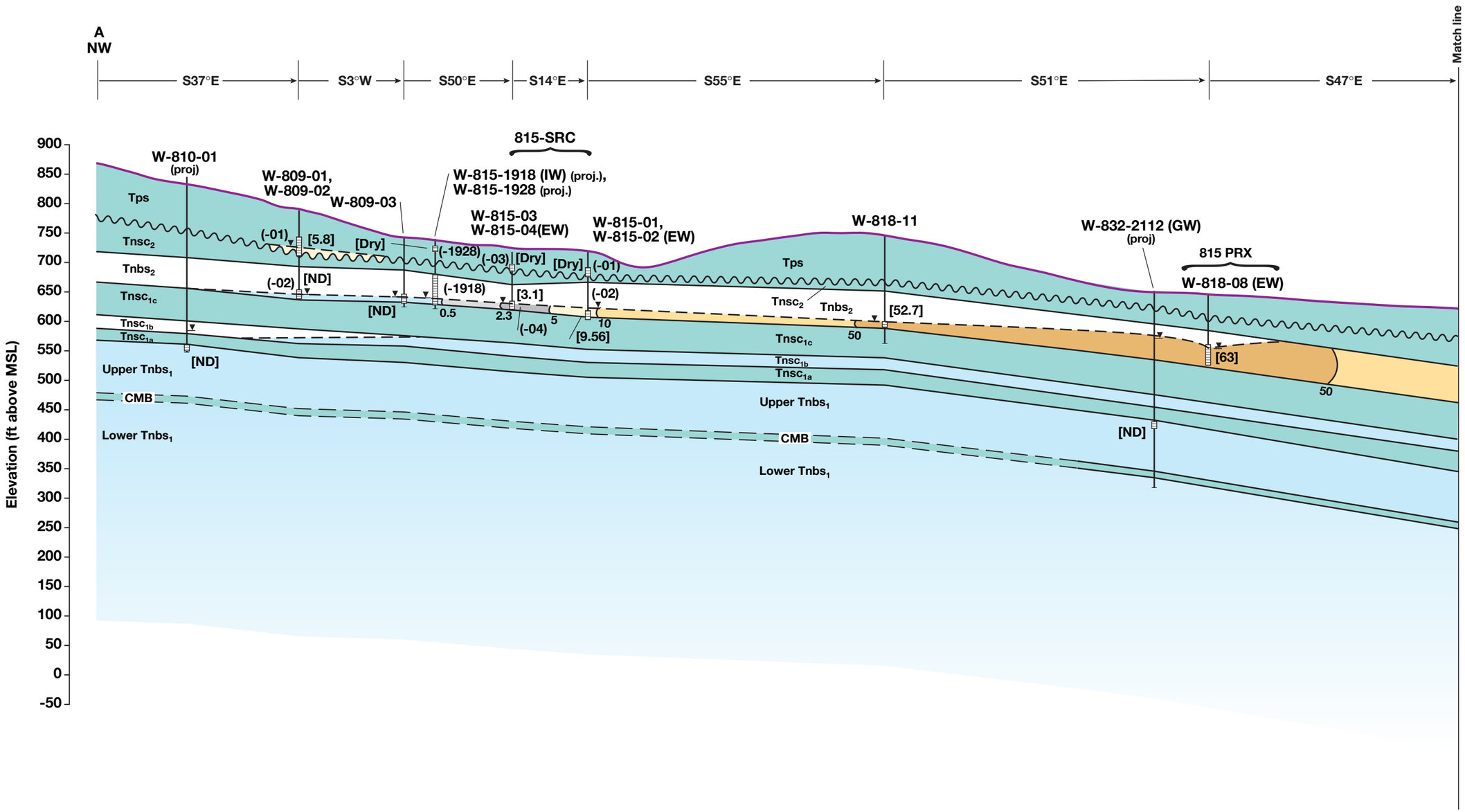

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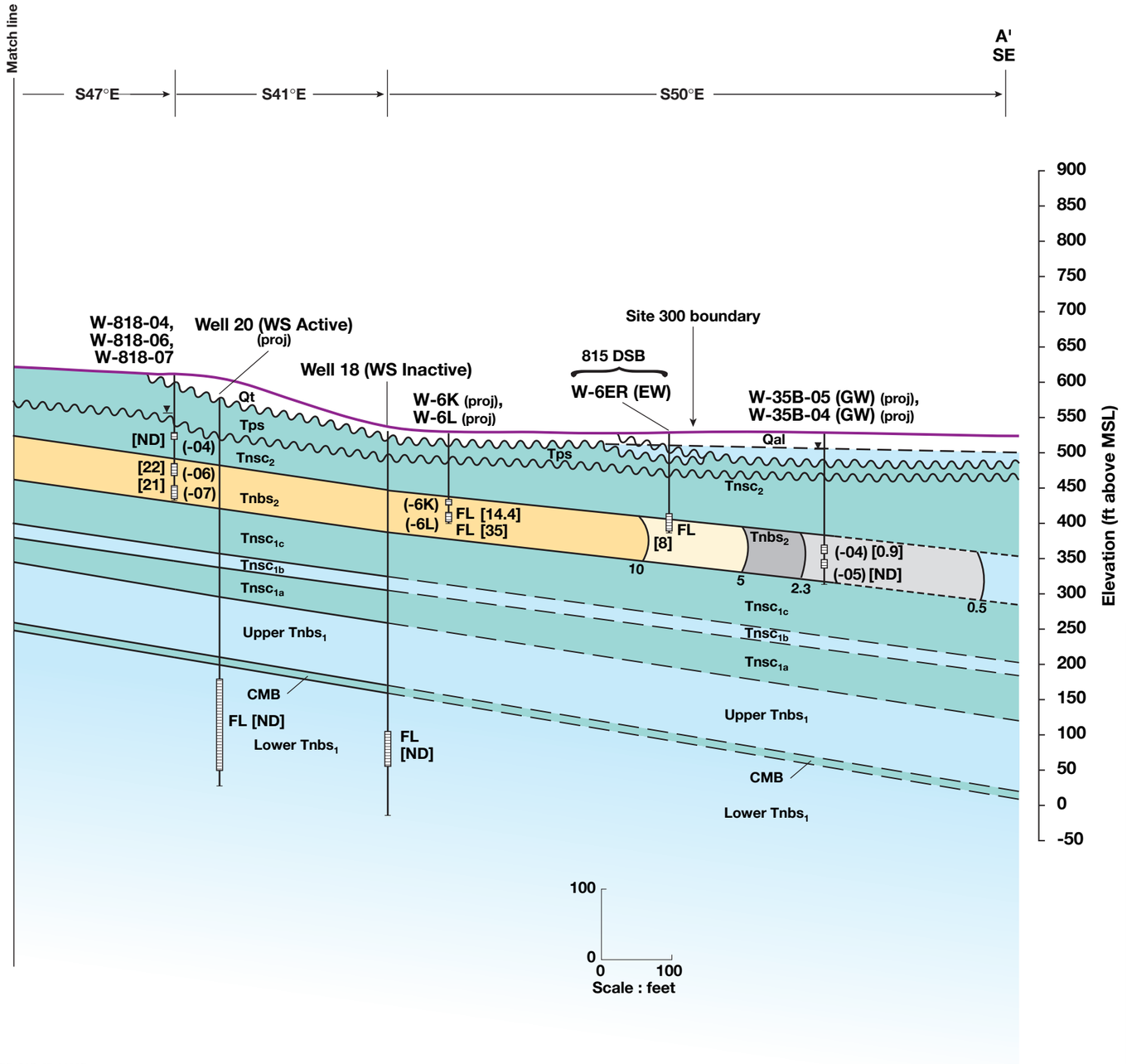
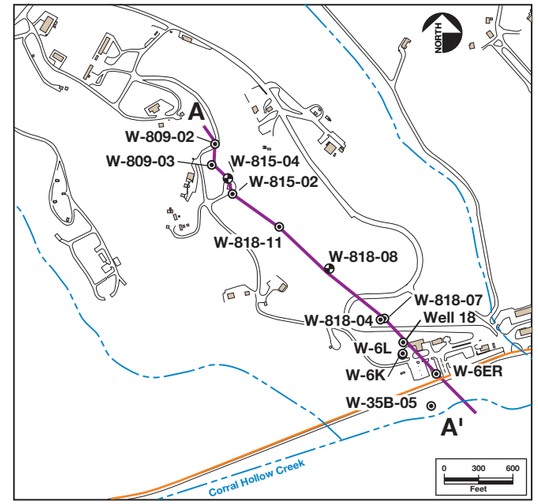
Figure 5. High Explosives Process Area Operable Unit Hydrogeologic Cross-section A-A'.





Legend

Qal	Quaternary alluvial deposit
Qt	Quaternary terrace deposit
Tps	Tertiary Pliocene nonmarine sediments
$Tnsc_2$	Tertiary Neroly Formation, upper siltstones and claystones
$Tnbs_2$	Tertiary Neroly Formation, upper blue sandstone
$Tnsc_1$	Tertiary Neroly Formation, middle siltstone and claystone [$Tnsc_{1c}$ (Upper), $Tnsc_{1b}$ (Middle), $Tnsc_{1a}$ (Lower)]
$Tnbs_1$	Tertiary Neroly Formation, lower blue sandstone
CMB	Claystone marker bed
	Low permeability confining layer

Ground surface
Unconformity
Stratigraphic contact
Potentiometric surface

Total VOC concentrations (µg/L)

<0.5	5 – 10
0.5 – 2.3	10 – 50
2.3 – 5	>50

(EW)	Extraction well
(GW)	Guard well
(IW)	Injection well
(WS)	Water supply well

W-809-01 Well ID
Location of well or borehole
Ground water elevation
[100] Screened interval
Borehole total depth
TVOC concentration, µg/L
[ND] Non-detected

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Figure 5. High Explosives Process Area Hydrogeologic Cross-section A-A' (continued).

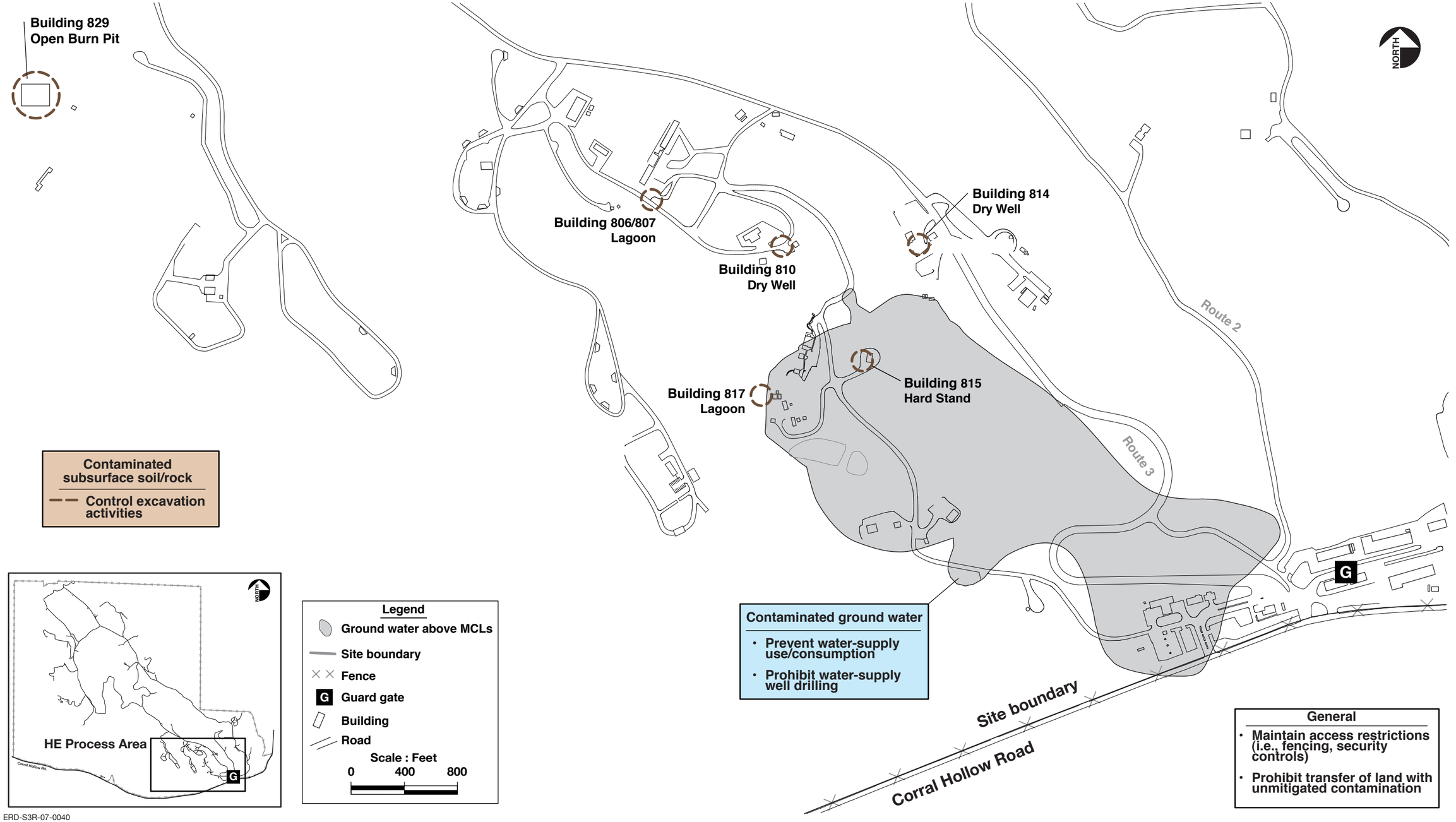

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Figure 6. High Explosives Process Area Operable Unit institutional/land use controls.

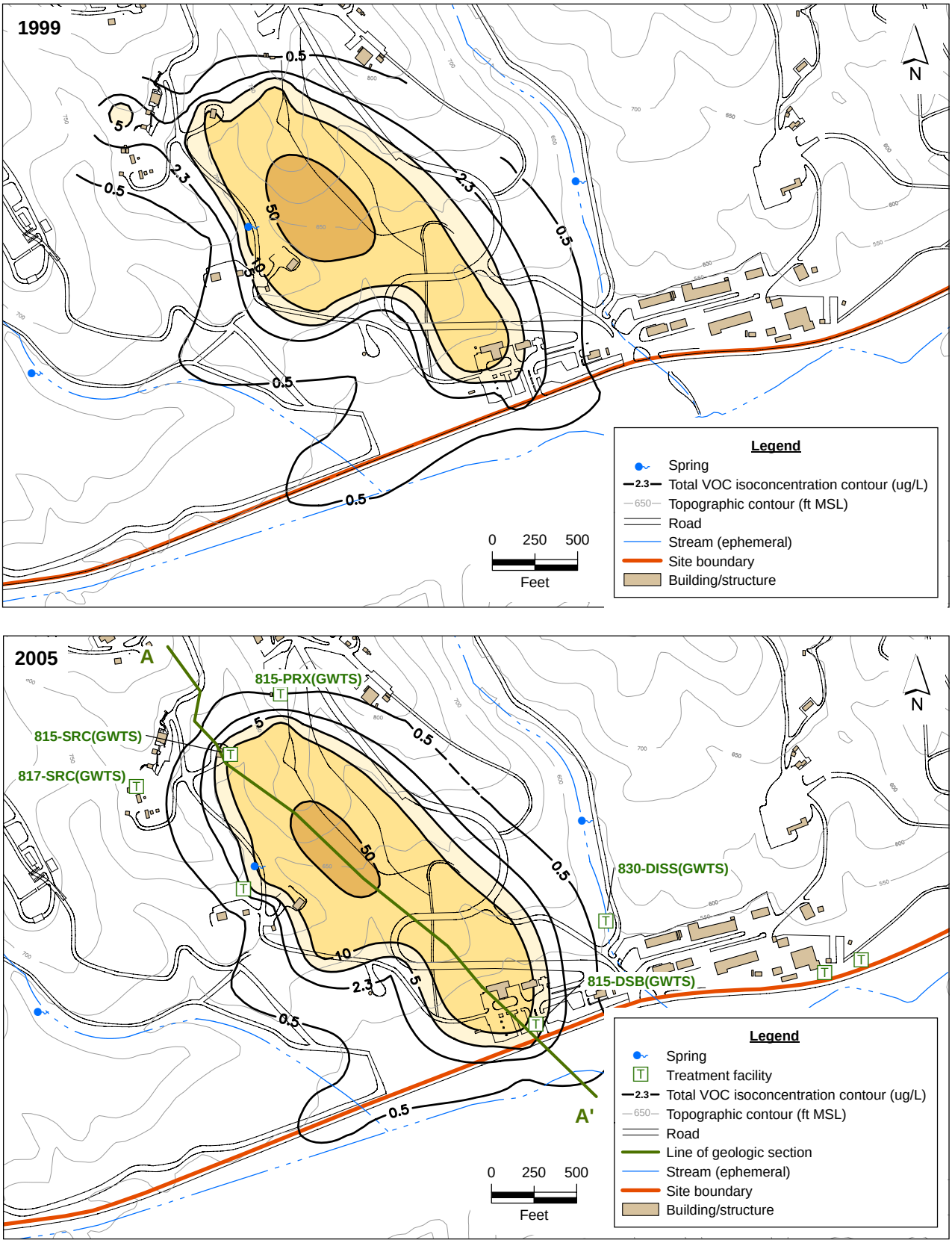


Figure 7. Comparison of the distribution of total VOCs in the High Explosives Process Area Operable Unit $Tnbs_2$ hydrostratigraphic unit in 1999 and 1st Semester 2005.

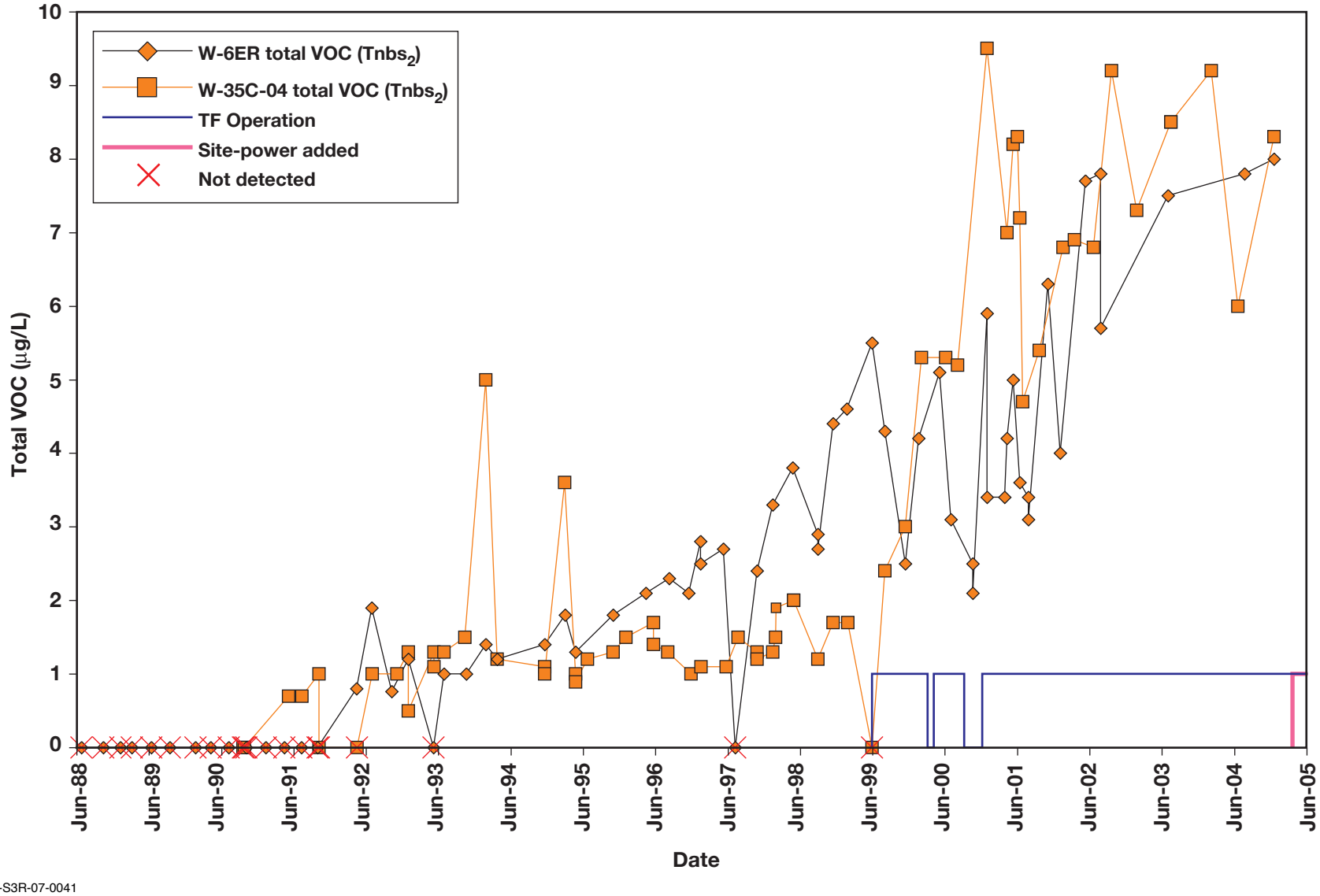


Figure 8. Time-series plots of total VOCs in ground water at the Building 815-Distal Site Boundary Area.

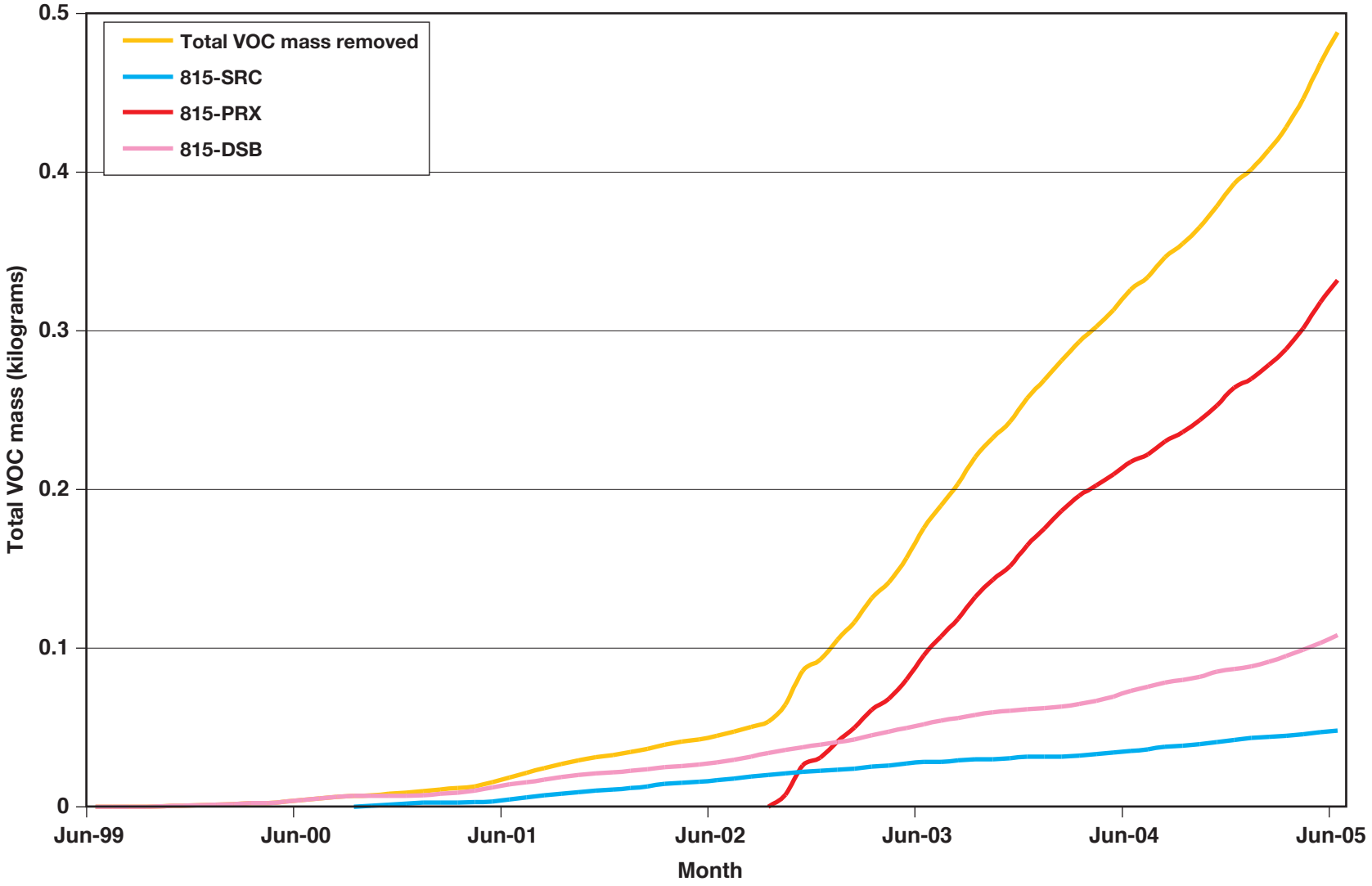


Figure 9. Time-series plots of cumulative mass of total VOCs removed by ground water extraction from the High Explosives Process Area Operable Unit ground water.

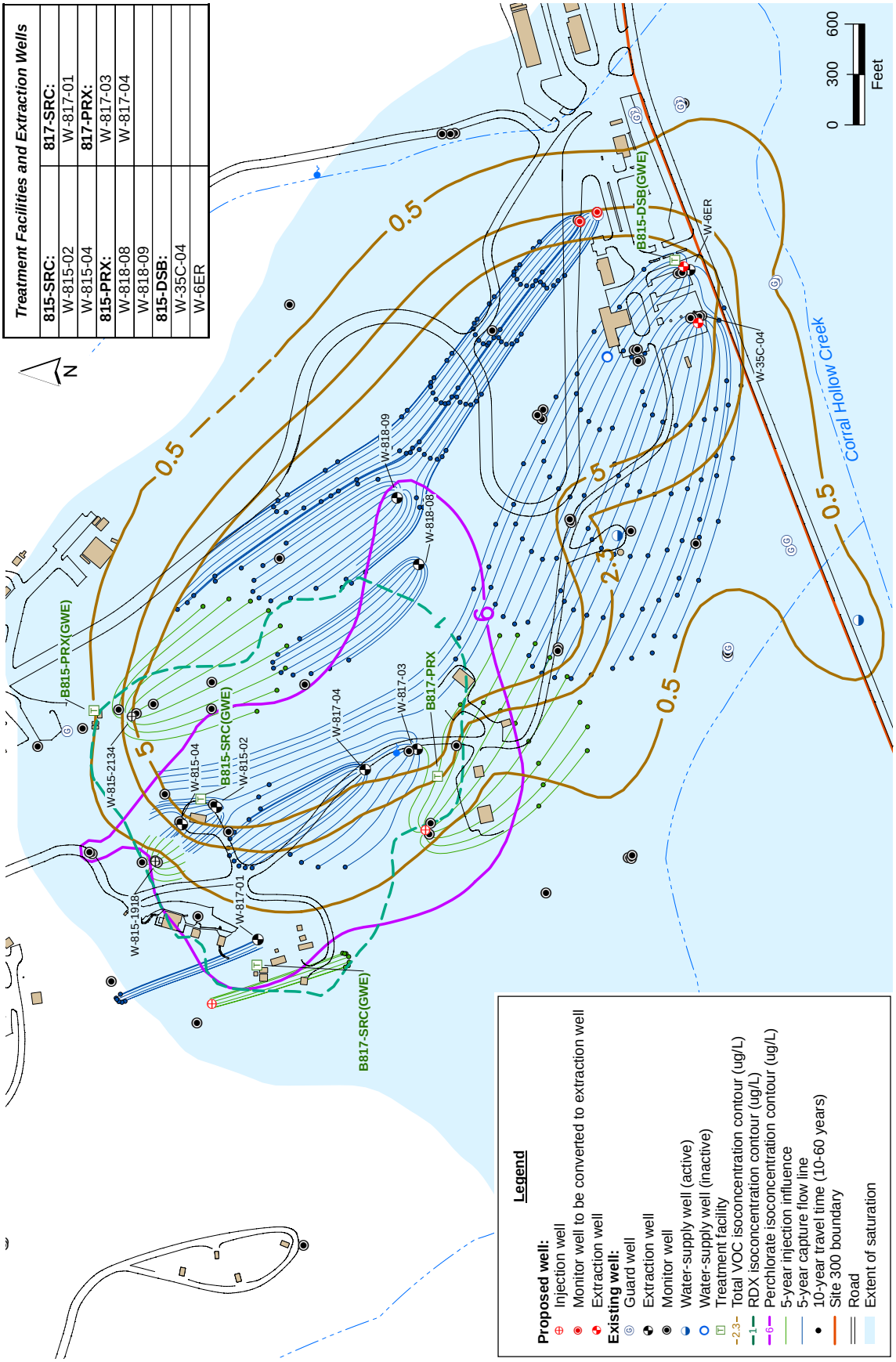
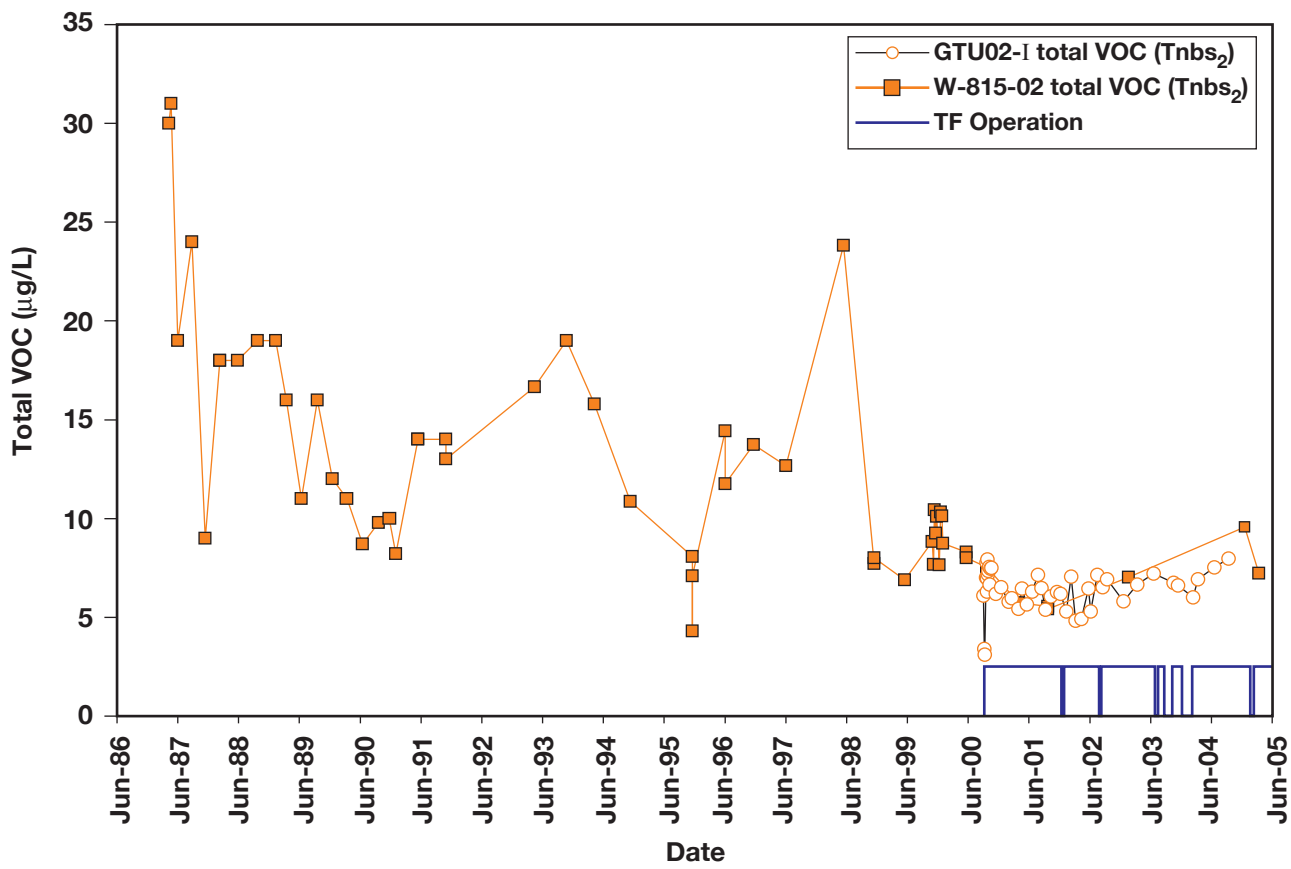
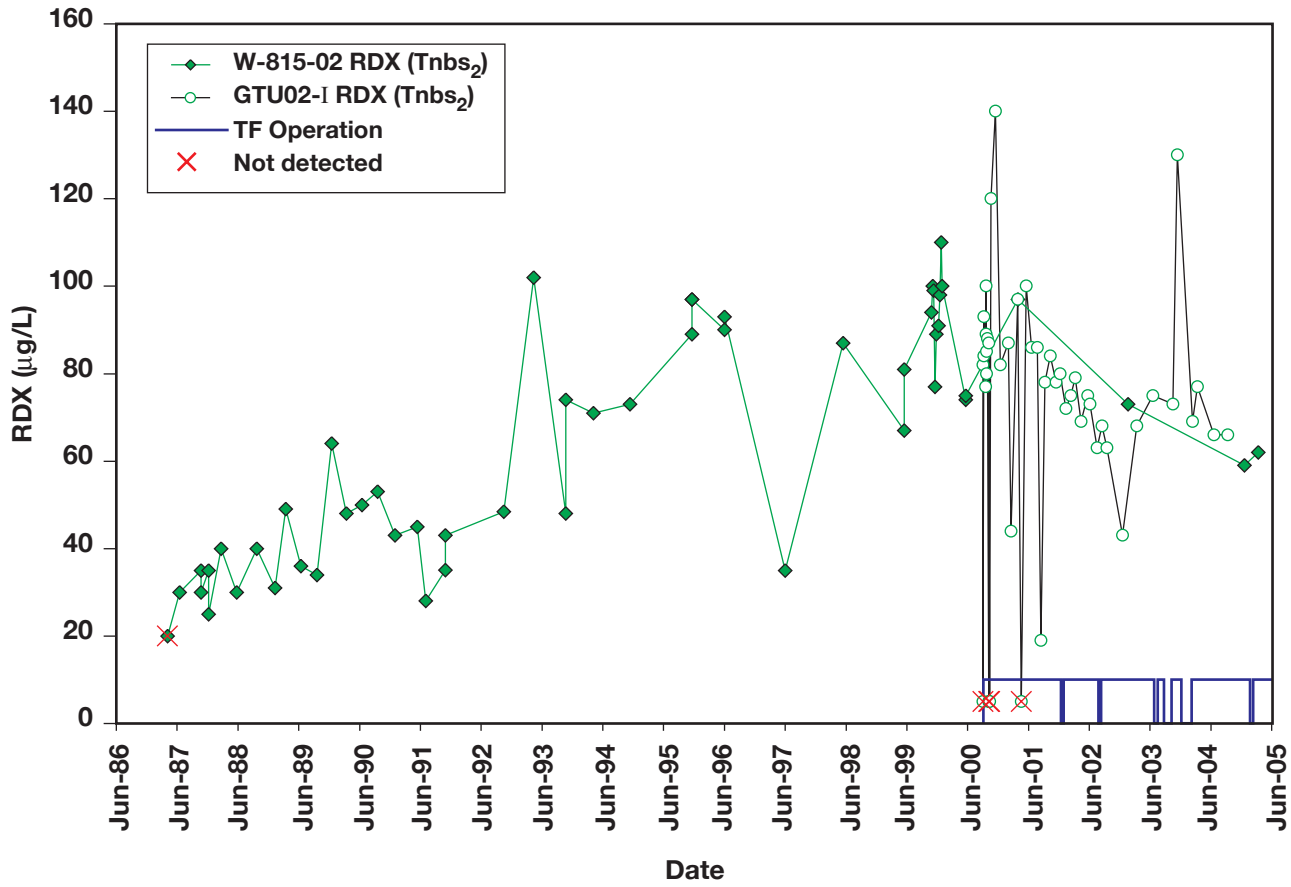


Figure 10. Capture zone analysis results for the design remedial extraction wellfield at the High Explosives Process Area Operable Unit.

a)



b)



c)

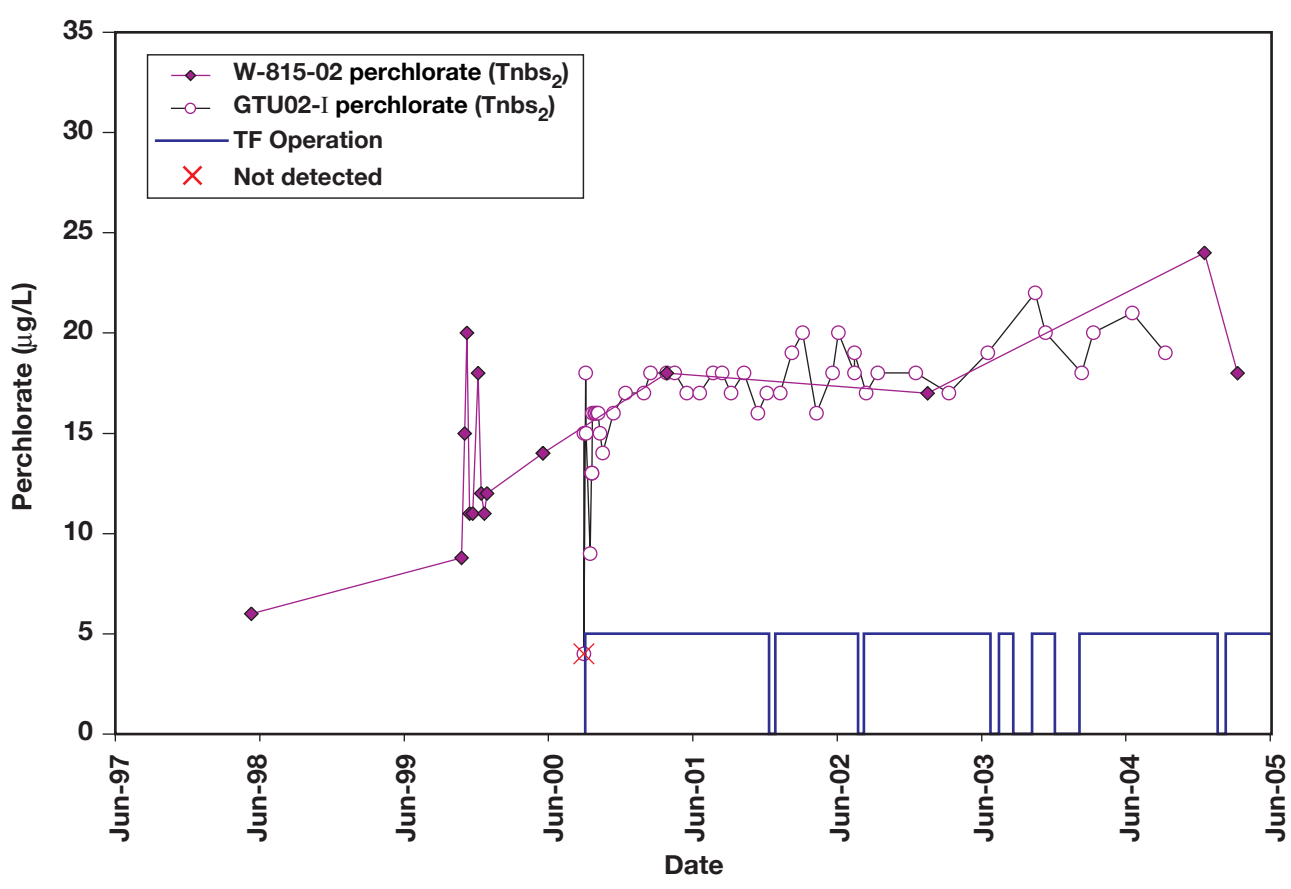


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Figure 11. Time-series plots of a) total VOCs, b) RDX, and c) perchlorate in ground water at the Building 815-Source Area.

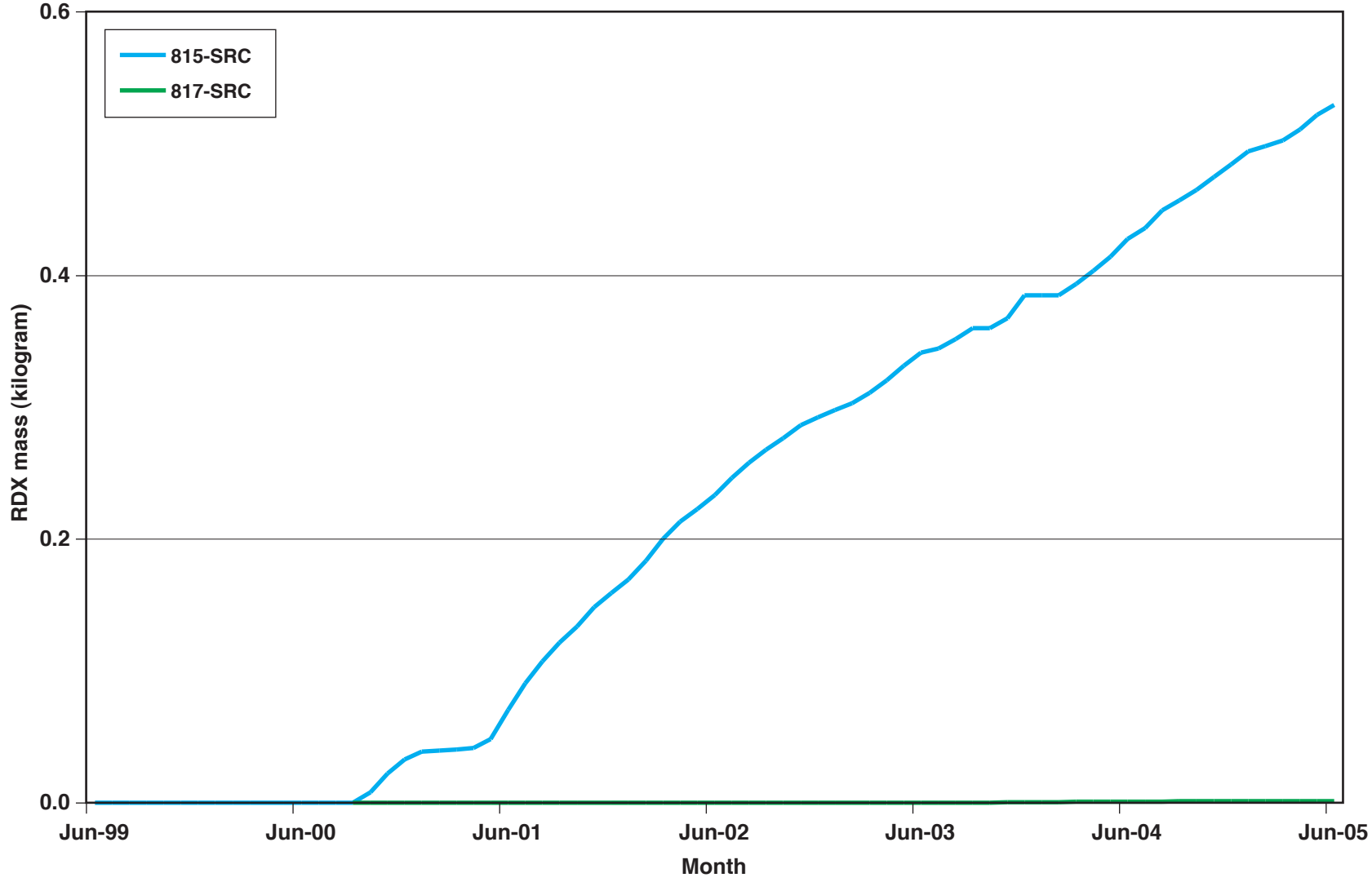

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Figure 12. Time-series plots of cumulative mass of RDX removed by ground water extraction from the High Explosives Process Area Operable Unit ground water.

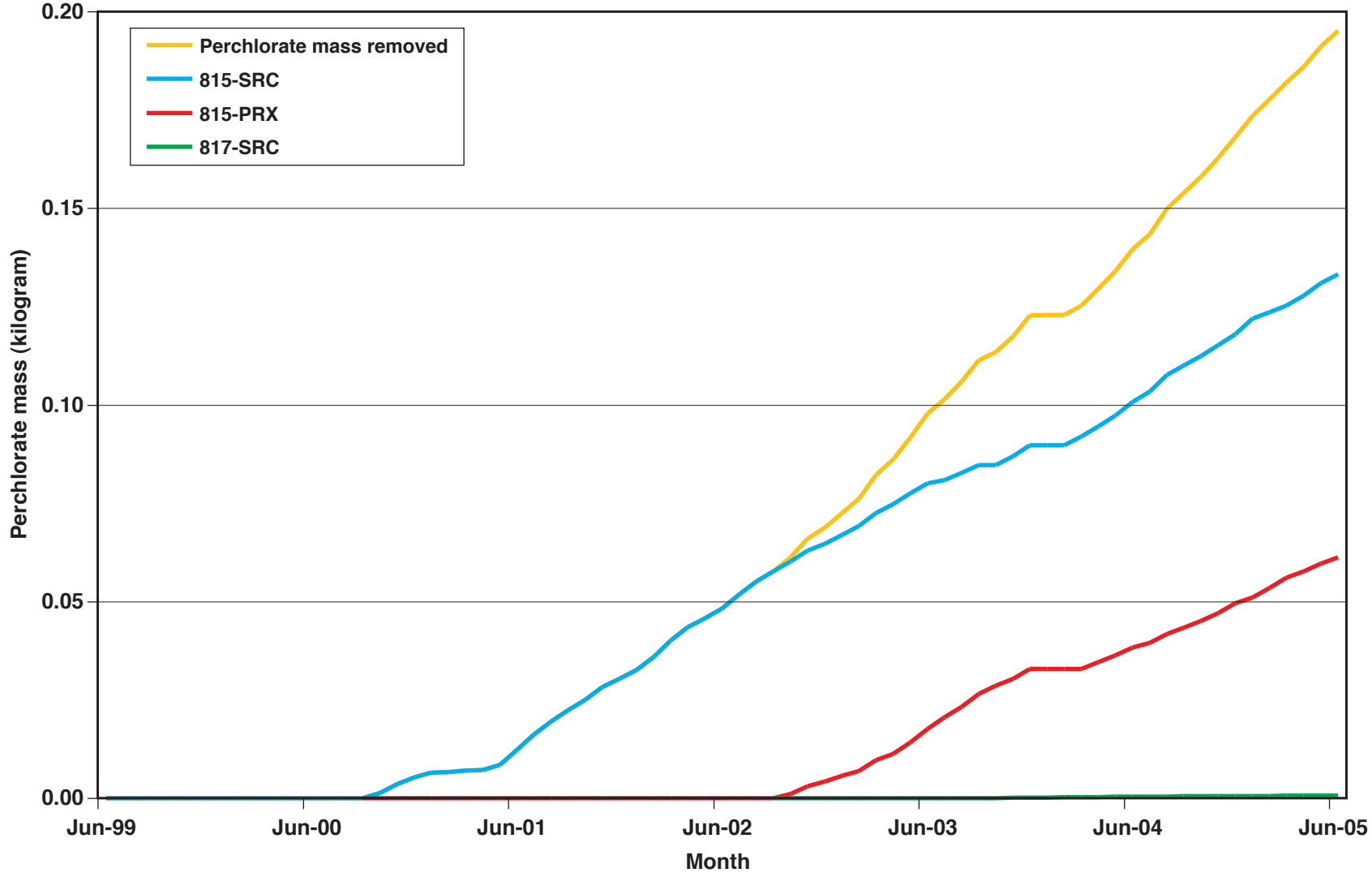
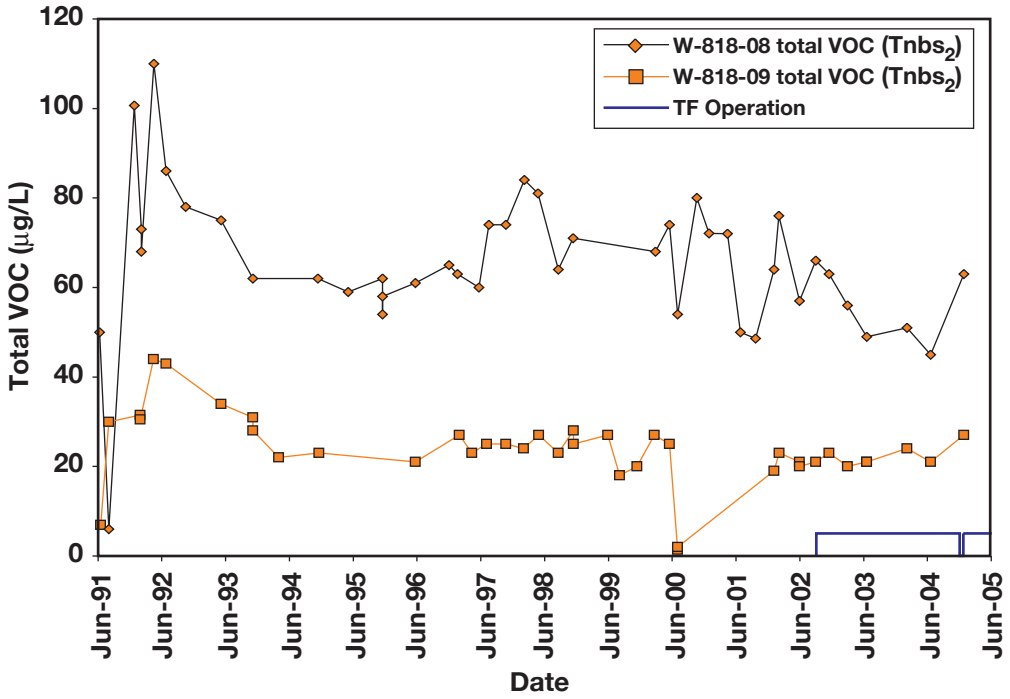
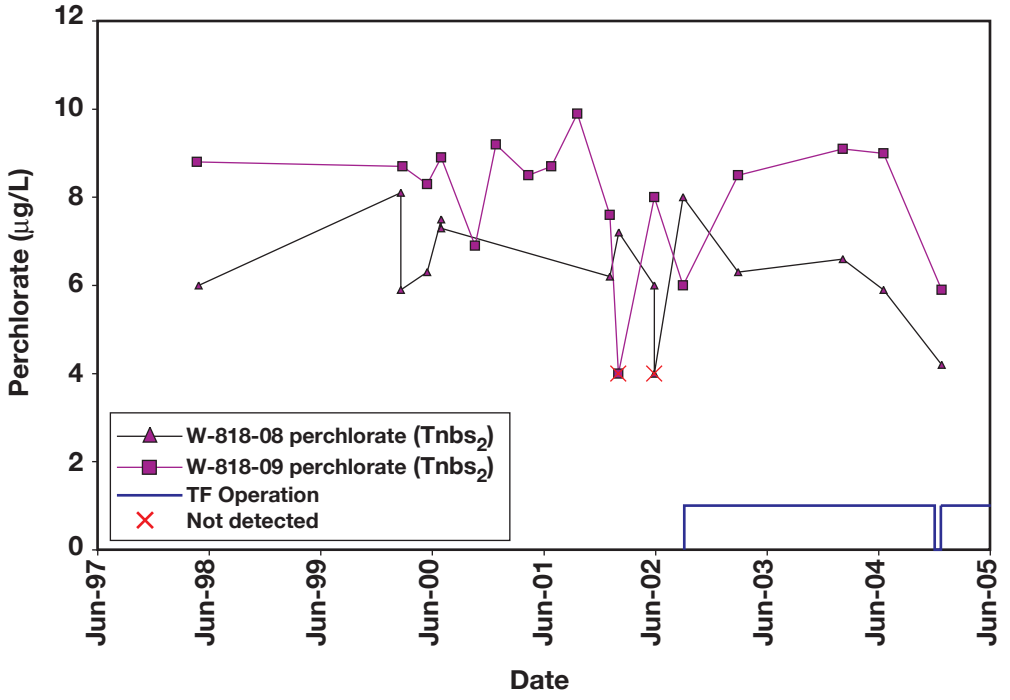


Figure 13. Time-series plots of cumulative mass of perchlorate removed by ground water extraction from the High Explosives Process Area Operable Unit ground water.

a)

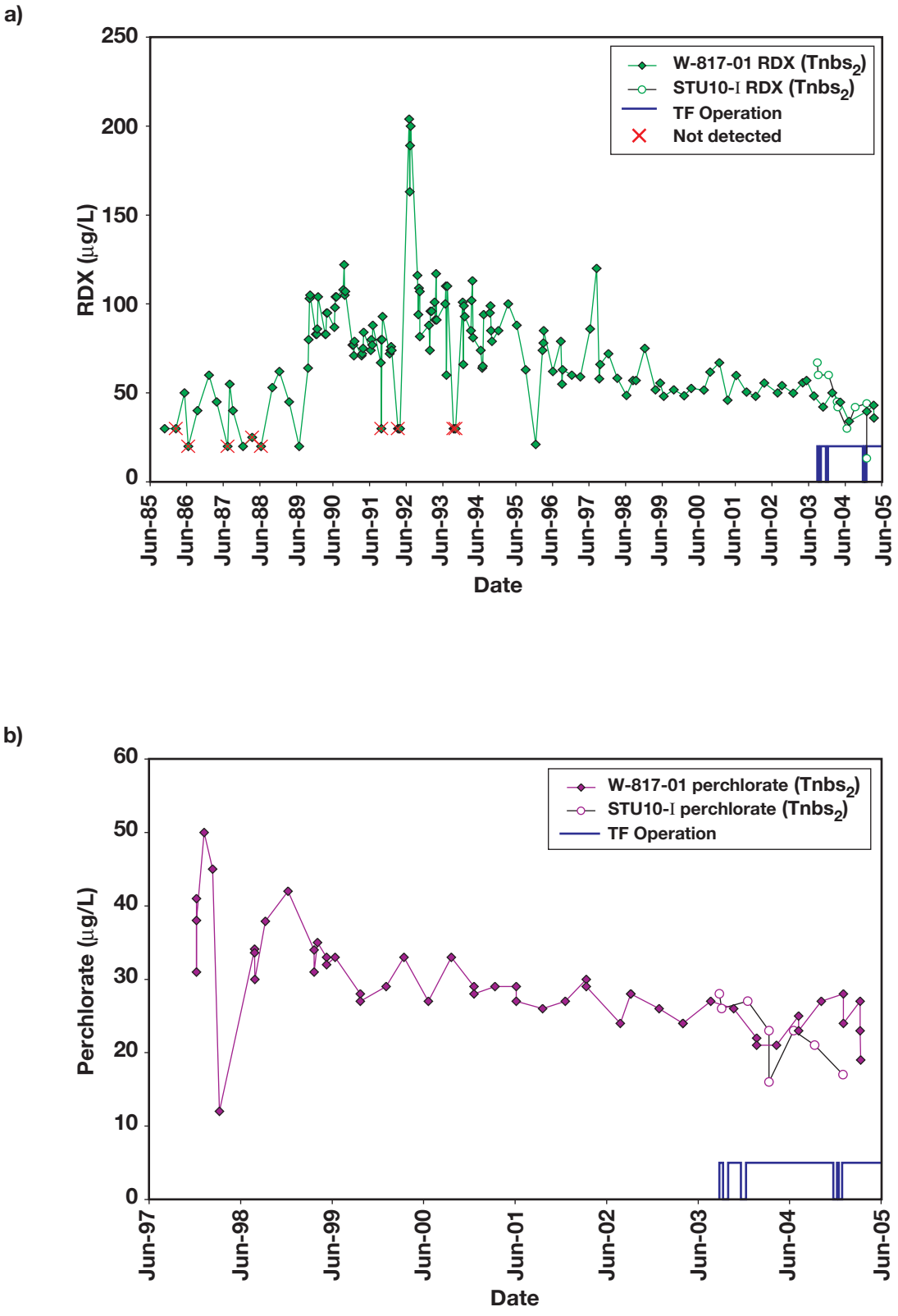


b)



ERD-S3R-07-0046

Figure 14. Time-series plots of a) total VOCs, and b) perchlorate in ground water at the Building 815-Proximal Area.



ERD-S3R-07-0047

Figure 15. Time-series plots of a) RDX, and b) perchlorate in ground water at the Building 817-Source Area.

Tables

Table 1. Actual annual costs for the High Explosives Process Area Operable Unit for fiscal years 2002 through 2006.

Fiscal Year	Annual Budget	Actual Annual Cost
2002	**$1,051,384**	**$1,036,717**
2003	**$923,693**	**$721,407**
2004	**$604,493**	**$594,565**
2005	**$1,568,297**	**$1,198,818**
2006	**$983,144**	**$908,994**

Table 2. Description of institutional/land use controls for the High Explosive Process Area (HEPA) Operable Unit (OU).

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Prevent water-supply use/consumption of contaminated groundwater until ground water cleanup standards are met.	VOCs, RDX, nitrate, and perchlorate concentrations in ground water exceeding drinking water standards.	There are two onsite water-supply wells in the HEPA OU (Wells 18 and 20). Contamination in HEPA ground water is contained in an aquifer that is 250 ft above, and hydraulically separated from the deeper, clean aquifer in which Well 20 is screened. While Well 18 is no longer used as a water-supply well, it is a backup well for emergency fire suppression. Well 18 is cased through the contaminated aquifer. Therefore, onsite workers are not at risk from drinking contaminated water from Wells 18 and 20. Well 18 and 20 are sampled monthly for contamination. Any proposed well drilling activities would be submitted to LLNL Work Induction Board, and are reviewed by LLNL Environmental Restoration Division to ensure that new water-supply wells are not located in areas of ground water contamination. Prohibitions on drilling water-supply wells in areas of ground water contamination will be incorporated into the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning documents. Ground water extraction is underway at the site boundary to prevent offsite migration of the VOC plume. Therefore, land use controls are not needed to prevent offsite water-supply use/consumption of contaminated ground water.
Control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers.	Potential exposure to VOCs, HMX, and RDX at depth in subsurface soil at the HEPA OU[a].	All proposed excavation activities must be cleared through LLNL Work Induction Board and require an excavation permit. The Work Induction Board coordinates with the LLNL Environmental Restoration Division to identify if there is a potential for exposure to contaminants in the proposed construction areas. If a potential for contaminant exposure is identified, the LLNL Site 300 Hazards Control Department ensures that hazards are adequately evaluated and necessary controls identified and implemented prior to the start of work. The Work Induction Board including the LLNL Environmental Analyst will also work with the Program proposing the construction project to determine if the work plans can be modified to move construction activities outside of areas of contamination.
Maintain land use restriction in the vicinity of Building 815 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	Pre-remediation risk of 5×10^{-6} for onsite workers from potential inhalation of VOCs volatilizing from the subsurface soil into outdoor air in the vicinity of Building 815.	This risk has been successfully mitigated since 2004 through ground water extraction and treatment, therefore this institutional/land use control is no longer needed.

Table 2. Description of institutional/land use controls for the High Explosive Process Area (HEPA) Operable Unit (OU). (Continued)

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Maintain land use restriction in the vicinity of Spring 5 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	1 x 10^{-5} risk for onsite workers continuously inhaling VOC vapors volatilizing from Spring 5 into outdoor air over a 25-year period.	The spring has been dry since 2003. There are currently no active facilities located in the vicinity of the Spring 5 and there is no surface water present in the spring. Current activities in the vicinity of the Spring 5 are restricted to semi-annual spring sampling. The time spent sampling is well below the exposure scenario for which the unacceptable exposure risk was calculated, which assumed a worker would spend 8 hours a day, five days a week for 25 years working at Spring 5. DOE will conduct annual risk re-evaluations when water is present in Spring 5 to determine when the inhalation risk has been mitigated. The risk re-evaluation results will be reported in the Annual Site-Wide Compliance Monitoring Reports. Any significant changes in activities conducted in the Spring 5 area must be cleared through LLNL Work Induction Board. The Work Induction Board coordinates with the LLNL Environmental Restoration Division to identify if there is a potential for exposure to contaminants as a result of the proposed area usage. If a potential for contaminant exposure is identified as a result of these changes in activities or area use, the LLNL Site 300 Hazards Control Department is notified and determines any necessary personal protective equipment to prevent exposure.
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.	Potential exposure to contaminated waste and/or environmental media.	The Site 300 Federal Facility Agreement contains provisions that assure that DOE will not transfer lands with unmitigated contamination that could cause potential harm. In the event that the Site 300 property is transferred in the future, DOE will execute a land use covenant at the time of transfer in compliance with Title 22 California Code of Regulations, Division 4.5, Chapter 39, Section 67391.1. Development will be restricted to industrial land usage. These restrictions will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and is agreed by the DOE, the U.S. EPA, DTSC, and the RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use. These restrictions will be incorporated into the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document.

Notes appear on the following page.

Table 2. Description of institutional/land use controls for the High Explosive Process Area (HEPA) Operable Unit (OU). (Continued)

Notes:

DOE = U.S. Department of Energy
DTSC = California Department of Toxic Substances Control
EPA = U.S. Environmental Protection Agency
HEPA = High Explosives Process Area
HMX = High melting explosive
LLNL = Lawrence Livermore National Laboratory
RDX = Research department explosive
RWQCB = California Regional Water Quality Control Board
VOCs = Volatile organic compounds

[a] **Risk for onsite worker exposure to VOCs, RDX, and HMX at depth in subsurface soil during excavation activities was not calculated as this was not considered a long-term exposure scenario. As a result, land use controls based on the potential exposure to VOCs, RDX, and HMX in subsurface soil during excavation conservatively assume that the COCs in subsurface soil may pose a risk to human health.**

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