U.S. Department of Energy
Livermore Site Office, Livermore, California 94550

Lawrence Livermore National Laboratory
University of California, Livermore, California 94550

UCRL-AR-226628

Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300

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March 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.

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Approval and Concurrence for the Five-Year Review for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300

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3-07/ERD B834 5-Yr Review:VRD:gl

Five-Year Review Summary Form

Site Identification		
Site name: Lawrence Livermore National Laboratory Site 300, Building 834 Operable Unit		
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: December 2004	
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: May 2005 to October 2006		
Date(s) of site inspection: July 13, 2005		
Type of review: Statutory		
Review number: 2		
Triggering action: Five-Year Review for the Building 834 OU		
Triggering action date: February 11, 2002		
Due date: February 7, 2007		

Five-Year Review Summary Form
(continued)

Deficiencies:

No deficiencies in the overall approach specified in the interim remedy for the Building 834 operable unit (OU) were identified during the evaluation.

Recommendations and Follow-up Actions:

Ground water and soil vapor extraction and treatment continue to make progress toward reducing contaminant concentrations and mass in the vadose zone and ground water. The U.S. Department of Energy and Lawrence Livermore National Laboratory (DOE/LLNL) have implemented all the actions required in the Interim Site-Wide Record of Decision, the Remedial Design Work Plan for the Interim Remedies, and the Interim Remedial Design document for the Building 834 OU.

DOE/LLNL will sample and analyze all monitor wells in the Building 834 OU for perchlorate and report the results in the 2007 Annual Site-Wide Compliance Monitoring Report for Site 300. Based on the results of the analysis, specific wells may continue to be monitored for perchlorate in ground water.

In addition, DOE/LLNL will continue to evaluate other remedial technologies, such as *in situ* bioremediation, that could shorten cleanup time, especially those that will facilitate remediation of the low-permeability sediments. However, even if these technologies are implemented, it may not be possible to fully remediate volatile organic compounds in the low-permeability sediments.

Because some VOCs may remain at the Building 834 OU following the achievement of the proposed 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 codified 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 7.2, and ARARs related to ground water cleanup will be established in the Final Site-Wide ROD scheduled for 2008.

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

Protectiveness Statement:

The remedy at the Building 834 OU is expected to be protective of human health and the environment upon completion (i.e., when clean-up levels 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 Building 834 OU ground water are drinking water standards. 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 codified 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 U.S. EPA, the DTSC, and the RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use.

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1. Introduction

The United States Department of Energy (DOE) has conducted a Five-Year Review of the remedial actions implemented at the Building 834 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 May 2005 through October 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 (DOE, 2000) and the U.S. Environmental Protection Agency (EPA) (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 (NCP) 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 second Five-Year Review for the Building 834 OU (OU 2). The first Five-Year Review was completed in 2002 (Ferry, 2002a). 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 Superfund Amendment Reauthorization Act), and (3) the remedial action was selected under the Comprehensive Response, Compensation, and Liability Act (CERCLA). Since cleanup was initiated at this OU as a treatability study, the triggering action for the first review was the September 26, 1995 signature date of the Interim Record of Decision (ROD) for the Building 834 OU (DOE, 1995).

Five-year reviews are conducted individually for the other OUs at Site 300 and will be performed five years after the completion of the final Remedial Design Reports (OUs 1, 2, and 4 through 7) or Final Site-Wide ROD, when no remedial design is necessary (OUs 3 and 8).

The background and description of the Building 834 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 (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 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 (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. 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.

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 trichloroethylene (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.

High Explosives Process Area OU (OU 4) – Surface spills from 1958 to 1986 resulted in the release of VOCs at the former Building 815 steam plant. High explosive compounds, nitrate, and perchlorate are present in the subsurface and are attributed to wastewater discharges to former unlined rinsewater lagoons. The High Explosives Burn Pits were capped in 1998. In 1999, DOE implemented a removal action to perform ground water extraction at the site boundary to prevent the TCE plume from migrating offsite. The selected interim remedy for this OU includes continued ground water extraction and treatment. The remedial design for the OU includes the operation of six ground water 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 2007.

Building 850 Firing Table (OU 5) – High explosives 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, high-explosive compounds, and depleted uranium. Leaching from firing table debris has resulted 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 (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. 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 high-explosive 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 high-explosive 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 high-explosives contamination in soil and ground water. 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 significant releases of contamination have occurred to the environment as a result of activities in this area. DOE has proposed No Further Action for the Sandia Test Site area.

2. Site Chronology

A chronology of important environmental restoration events at the Building 834 OU is summarized below.

Late 1950s

- Experiments involving the thermal-cycling (i.e., repeated heating and cooling) of weapon components started at the Building 834 Complex.

1962–1978

- During the course of these experiments, VOCs, primarily TCE, were released through spills and piping leaks. TCE was used as the primary heat-transfer fluid during these experiments and was sometimes mixed with tetrabutylorthosilicate (TBOS) and tetra-kis-2-ethylbutyl silane (TKEBS) to prevent degradation of pump seals and gaskets.

1982–1983

- DOE/LLNL excavated approximately 100 cubic yards of TCE-contaminated soil resulting from spills and piping leaks.
- Site investigations began at Building 834.

1986

- Ground water and soil vapor extraction began as treatability studies.

1989

- Ground water and soil vapor extraction treatability studies ended and construction of a full-scale facility began at Building 834.

1990

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

1991

- DOE/LLNL conducted a treatability test using an electron accelerator to treat VOCs in extracted vapor. This technology was later screened out in the Site-Wide Feasibility Study (Ferry et al., 1999) due to the production of undesirable byproducts, including phosgene.

1992

- A Federal Facility Agreement for Site 300 was signed. The parties to the Agreement included DOE, EPA, the California Department of Toxic Substances Control (DTSC), and California Regional Water Quality Control Board (RWQCB).
- DOE/LLNL conducted an evaluation of a technology to treat extracted soil vapor using ultraviolet light and hydrogen peroxide. This technology was later screened out in the Site-Wide Feasibility Study due to the high energy and operation costs.

- An electrical soil heating (Joule heating) pilot test was performed. This technology was later screened out in the Site-Wide Feasibility Study due to limited applicability at Building 834.

<u>1993</u>

- The heat-exchange system was dismantled in 1993–1994.

<u>1994</u>

- The Site-Wide Remedial Investigation report for Site 300 (Webster-Scholten et al., 1994) was issued.
- A Feasibility Study for the Building 834 OU was issued.

<u>1995</u>

- An Interim ROD for the Building 834 OU was signed. Ground water extraction began as an interim remedial action. DOE also agreed to test innovative cleanup technologies at Building 834.

<u>1998</u>

- Soil vapor extraction began as an interim remedial action.
- DOE/LLNL began treatability studies to evaluate the role of intrinsic *in situ* biodegradation in reducing TCE mass and concentration. This process was found to be important in removing TCE from the subsurface and measures to maximize biodegradation are being incorporated into the cleanup.
- A surfactant "push-pull" treatability test was performed. This technology was subsequently screened out in the Site-Wide Feasibility Study due to difficulty in ensuring complete capture of mobilized contaminants and resulting risk of enhanced migration.
- A laboratory-scale treatability test was performed using soil from Building 834 to test the capability of potassium permanganate injection to destroy VOCs *in situ*. These tests indicated potential problems with injection and distribution of the potassium permanganate. Therefore, this technology was subsequently screened out in the Site-Wide Feasibility Study.
- Surface water drainage was diverted to prevent infiltration of precipitation in the Building 834 contaminant source area.

<u>1999</u>

- The Site-Wide Feasibility Study for Site 300 was issued that included the Building 834 OU.

<u>2000</u>

- Additional extraction well configuration testing was conducted at Building 834 to optimize interim remedial action performance.

<u>2001</u>

- An Interim Site-Wide ROD for Site 300 was signed that superceded the 1995 Interim ROD for the Building 834 OU. The Interim Site-Wide ROD specified continued ground water and soil vapor extraction, administrative controls (e.g., risk and hazard management), and monitoring as the components of the selected interim remedy for the Building 834 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 (Ferry et al., 2001b) was issued that contained the strategic approach and schedule to implement the remedies in the Interim Site-Wide ROD.
- DOE/LLNL performed treatability studies at the Building 834 OU that indicated that the existing air-sparging ground water treatment system could be replaced by an aqueous-phase granular activated carbon (GAC) system.

<u>2002</u>

- The Interim Remedial Design document for the Building 834 OU was issued.
- Submitted the Compliance Monitoring Plan/Contingency Plan for the Interim Remedies (Ferry et al., 2002b).
- The first 5-Year Review for the Building 834 OU was submitted.

<u>2004</u>

- Building 834 buildout and upgrade of the ground water and soil vapor extraction and treatment systems were completed.
- Construction completion was achieved.

<u>2005</u>

- A ground water tracer test and microcosm study was conducted to evaluate the feasibility of accelerating ground water cleanup through *in situ* bioremediation.

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 Building 834 Complex is located on an isolated hilltop in the southeast portion of Site 300 (Figure 1). Facilities at the Building 834 Complex have been in use since the late 1950s for thermal-cycling experiments conducted on weapon components. These experiments were performed in four main buildings surrounded by a ring of eight smaller test cells (Figure 2). Aboveground pipes carried TCE-based heat-exchange fluid from storage tanks at the main buildings to the test cells. From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface with TCE and the silicone oils TBOS and TKEBS at eight release points. Nitrate associated with septic-system effluent is also present in ground water.

The Building 834 OU is informally divided into three areas: the core, leachfield (septic system), and distal areas (Figure 2). The core area generally refers to the vicinity of the buildings and test cells in the center of the Building 834 Complex where the majority of contaminant releases occurred. The septic system leachfield area is located immediately southwest of the core area. The distal area refers to the area downgradient (south) of the core and leachfield areas. The T2 area, located near well W-834-T2 on Figure 2, is within the distal area.

3.1.2. Hydrogeologic Setting

The vadose zone and primary hydrostratigraphic units (HSUs) in the Building 834 area are described below, from shallowest to deepest. A composite hydrostratigraphic column for the southeast corner portion of Site 300 that includes the Building 834 area is shown on Figure 3.

3.1.2.1. Vadose (Unsaturated) Zone

The vadose zone consists of unconsolidated to highly cemented gravel, sand, silt, and clay sediments beneath the Building 834 Complex that are unsaturated to a depth of approximately 30 feet (ft) below ground surface (bgs).

3.1.2.2. Saturated Zone

The three HSUs have been identified in the Building 834 area:

Perched Water-Bearing Zone (Tpsg HSU) – This unit consists of variably saturated, discontinuous perched water-bearing zone in Tertiary sand and gravel lenses (defined as the Tpsg HSU) below the vadose zone. The saturated thickness of the perched zone is up to 8 ft. Ground water in the perched Tpsg HSU generally flows toward the south. Figure 4 shows potentiometric surface elevation contours and ground water flow direction in the Tpsg HSU. Perched ground water in this HSU is not laterally continuous except for short periods of time following heavy rainfall events. The lateral extent of the perched zone is limited by the steep slopes to the north, east, and west of the Building 834 Complex.

Perching Horizon (Tps-$Tnsc_2$ HSU) – Downward ground water and contaminant movement from the perched zone is inhibited by the underlying low-permeability Tps-$Tnsc_2$ clay and claystone HSU perching horizon. The thickness of the perching horizon ranges from 10 to 40 ft.

Regional Aquifer ($Tnbs_1$ HSU) – Approximately 280 ft of unsaturated, interbedded claystone ($Tnsc_1$) and sandstone ($Tnbs_2$ and Upper $Tnbs_1$) lie below the Tps perching horizon. A laterally-extensive regional aquifer (Lower $Tnbs_1$ HSU) occurs at a depth of about 340 ft bgs.

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 Building 834 OU since the Interim Site-Wide ROD and none are anticipated. The Building 834 Complex is still used for thermal cycling experiments and is accessible only to DOE/LLNL workers. Building 834D, where an unacceptable risk for VOC inhalation was identified, is still used only for storage and building occupancy restrictions remain in place as discussed in Section 4.4.

Current offsite land use near the OU includes agriculture, private residences, and an ecological preserve. 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 land adjacent to the OU.

Ground water underlying the Building 834 Complex is present in a shallow, perched HSU and is not used for water-supply due to extremely low well yields, limited extent of saturation, and naturally poor water quality. At Site 300, the regional aquifer ($Tnbs_1$ HSU) is a source of water for drinking, processing of explosives, and fire suppression. Offsite, the regional aquifer supplies water for domestic and agricultural uses. There are no onsite or private offsite water-supply wells in use near the OU.

There are no environmentally-sensitive areas on Site 300 property within the Building 834 OU. However, the American badger (a California Department of Fish and Game species of special concern) and the big tarplant (an annual plant on the California Native Plant Society's List 1B) do occur in the area. The California Department of Fish and Game operates an ecological preserve east of the OU along Corral Hollow Creek, but contaminant releases from the OU are not anticipated to affect the preserve.

3.3. History of Contamination

The Building 834 facilities have been used since the 1950s for experiments involving the thermal cycling of weapon components. From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface with VOCs, primarily TCE and cis-1,2 dichloroethylene (cis-1,2-DCE), and silicone oils (TBOS and TKEBS). DOE estimates that approximately 550 gallons of TCE were released, either directly to the ground surface and/or to floor drains leading to a nearby septic system leach field. It is likely that a significant fraction of the total amount of TCE released volatilized without infiltrating into the subsurface. Elevated nitrate concentrations in ground water result from a combination of septic system effluent and natural sources. The amount of silicone oil and nitrate released has not been determined. Diesel, benzene, toluene, and ethylbenzene have been detected sporadically in ground water in the core area. The source of these contaminants is an underground fuel storage tank that was excavated in 1994 and closed with the concurrence of the State of California regulatory agencies; no further action is required.

3.4. Initial Response

DOE/LLNL began environmental investigations in the Building 834 area in 1983. Since then, 117 boreholes have been drilled in the Building 834 OU; 82 of these boreholes were completed as ground water monitor or extraction wells (Figure 2). Eleven wells have since been abandoned due to long well screens that were placed across two HSUs. The geologic and chemical data from these wells and boreholes are used to characterize the site hydrogeology and to monitor temporal and spatial changes in saturation and dissolved contaminants. Site characterization also included soil vapor surveys, test pits, hydraulic testing, and geophysical surveys.

As summarized in Section 2, remediation activities at the Building 834 OU conducted prior to the 2001 Interim Site-Wide ROD included soil excavation, numerous treatability studies, soil vapor and ground water extraction, and diverting surface water drainage from contaminant source areas.

3.5. Contaminants of Concern

Three COCs have been identified in ground water in the Building 834 OU: (1) VOCs, (2) TBOS/TKEBs, and (3) nitrate. VOCs have also been identified as COCs in subsurface soil/rock. Historical and current concentrations of these COCs are discussed in Section 7.5. No COCs were identified in surface soil or surface water.

The predominant contaminant in the vadose zone and ground water is TCE, a suspected human carcinogen. Due to the high concentrations detected, TCE is suspected to be present as a discontinuous, diminishing dense non-aqueous phase liquid (DNAPL) residual source in the subsurface. The baseline human health risk assessment estimated a maximum excess cancer risk of 1×10^{-3} to onsite workers, assuming continuous inhalation of VOC vapors volatilizing from the subsurface and migrating into indoor air at Building 834D over a 30-year period. The baseline risk assessment also identified a human cancer risk of 6×10^{-4} for onsite workers continuously inhaling VOC vapors volatilizing from the vadose zone into outdoor air in the vicinity of Building 834D over a 30-year period.

The baseline ecological risk assessment for the Building 834 OU identified a hazard index greater than one for inhalation of VOCs in burrow air and for cadmium in surface soil for ground squirrels and the San Joaquin kit fox.

Significant concentrations of cis-1,2-DCE and low concentrations of vinyl chloride and ethane have been detected in ground water. The presence of these breakdown products is primarily the result of the *in situ* biodegradation of TCE. PCE has also been detected in ground water samples.

Silicone oils (TBOS and TKEBS) occur as a light non-aqueous phase liquid (LNAPL) floating on perched ground water. Silicone oils are relatively non-toxic, and no health risks have been identified for these compounds.

Elevated nitrate concentrations in ground water results from a combination of natural and anthropogenic sources including septic system effluent. Nitrate can cause non-carcinogenic health effects if ingested at elevated concentrations.

The ground water COCs are present in two shallow HSUs: the Tpsg HSU perched water-bearing gravel zone and the underlying Tps-$Tnsc_2$ HSU clay perching horizon. The Tpsg perched HSU is highly contaminated with VOCs and TBOS/TKEBS beneath the core area. Discontinuous VOC plumes extend into distal areas in this HSU. Nitrate is present in the Tpsg HSU in the vicinity of the septic tank leach field. Some VOC contamination is also present in the Tps-$Tnsc_2$ HSU clay perching horizon. COCs have not been detected in the unsaturated portion of the $Tnbs_1$ sandstone or in ground water in the lower $Tnbs_1$ regional aquifer.

3.6. Summary of Basis for Taking Action

Remedial actions were initiated in the Building 834 OU to address unacceptable human health risks associated with onsite worker inhalation exposure to TCE volatilizing from the subsurface soil to indoor air within Building 834D. The remedial actions were also initiated to restore the beneficial uses of ground water in this area. The remedial action objectives for the Building 834 OU cleanup are discussed in Section 4.1.

4. Interim Remedial Actions

4.1. Interim Remedy Selection

The remedy selected for the Building 834 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.

Protection of the Environment:

- Restore water quality, at a minimum, to water quality numeric limits that are protective of beneficial uses (i.e., MCLs) 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. However, there are currently no hazard indices greater than 1 at the Building 834 OU.

- 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 and compliance with applicable or relevant and appropriate requirements (ARARs) for surface waters (i.e., spring water) because there are no springs or other surface water in the Building 834 OU.

In the Interim Site-Wide ROD, the remedy for the Building 834 OU was selected based on its ability to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, and protect human health and the environment. The selected interim remedy for the Building 834 OU consists of:

1. Monitoring soil vapor and ground water to evaluate the effectiveness of the remedial action in reaching remediation goals, plus post-remediation monitoring.
2. Risk and hazard management, including institutional/land use controls, to prevent contaminant exposure to humans and impacts to ecological receptors.
3. Extraction and treatment of ground water and soil vapor to mitigate risk and hazards posed by VOCs in the subsurface soil and protect and restore beneficial uses of ground water.

4.2. Interim Remedy Implementation

Ground water and soil vapor extraction and treatment systems have been operating in the Building 834 OU since 1986; first as treatability studies and later as interim remedial actions. The location of ground water and soil vapor extraction wells and treatment systems are shown in Figure 2. Full-scale ground water extraction and treatment began in the Building 834 core (source) area in 1995 to reduce VOC concentrations and mass in ground water. Full-scale soil vapor extraction and treatment began in 1998 to reduce VOC concentrations and mass in the vadose zone. In the source area, ground water extraction is used to dewater the Tpsg HSU, creating a larger volume of soil available to extract VOCs in soil vapor. Typically, soil vapor extraction is more effective in removing VOCs than ground water extraction. In addition, the negative pressure (i.e., vacuum) created in the well casing during soil vapor extraction enhances the yield of ground water from this low permeability HSU.

Due to the very low ground water yield from individual extraction wells (less than 0.1 gallons per minute [gpm]), the ground water treatment system has been operated in batch mode. The original treatment process utilized an oil-water separator to remove the floating silicon oils (TBOS/TKEBS) followed by air sparging to remove VOCs from ground water. The VOC-laden vapors were removed using vapor-phase GAC. Treated ground water was then discharged via a misting system. The soil vapor extraction system utilizes vapor-phase GAC for VOC removal. Treated vapors are discharged to the atmosphere under an air permit from the San Joaquin Valley Unified Air Pollution Control District.

In 2004, modifications were made to improve the performance of both the ground water treatment system and the extraction wellfield at the Building 834 OU. In 2004, the following modifications were made to the ground water treatment system:

- Replacement of the oil-water separator with floating hydrocarbon adsorption devices (pigs) placed in the influent ground water storage tank to remove any floating product that is extracted.
- Conversion from air sparging with vapor-phase GAC treatment to the use of aqueous-phase GAC to remove VOCs from ground water.
- Installation of monitoring equipment to measure the volume of ground water and soil vapor extracted from each well.

The core area extraction wellfield was also modified, reducing the number of extraction wells from 16 to nine wells. This modification was based on individual well performance data collected during a series of zone-of-influence tests conducted on core area extraction wells. Test data indicated seven extraction wells were not contributing significantly to mass removal. These seven wells were converted to performance monitoring wells and the remaining nine core area extraction wells extract both ground water and soil vapor.

In 2004, the ground water and soil vapor extraction wellfield was expanded to the VOC plume in the leachfield area to accelerate ground water cleanup. The average ground water extraction rate for the expanded extraction wellfield is approximately 4,000 gallons per month. Three additional extraction wells are located in the T2 area. Pumping of the T2 area ground water and soil vapor extraction wells is being delayed to conduct studies to evaluate the potential of utilizing *in situ* bioremediation in this area.

4.3. System Operations/Operation and Maintenance

In general, the Building 834 OU ground water and soil vapor extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during this evaluation. 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 Building 834 Treatment Facilities, contained within the Interim Remedial Design document (Gregory et al., 2002).
- Building 834 Treatment Facility Operations and Maintenance Manual (LLNL, in progress).
- Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation (LLNL, 2004).
- Building 834 Substantive Requirements and the Monitoring and Reporting Program issued by the California RWQCB.
- Building 834 Permit to Operate issued by the San Joaquin Valley Unified Air Pollution Control District.
- Site-Wide Compliance Monitoring 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 O&M activities. Ground water treatment system effluent is monitored to ensure compliance with discharge requirements. Vapor effluent from the soil vapor treatment system is monitored to ensure compliance with air permit discharge limits. 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 Building 834 ground water and soil vapor treatment systems include:

- Maintaining the particulate filters, blower, and compressor.
- Maintaining the misting towers used to discharge treated ground water.
- Protecting the unit from freezing in cold weather.
- Replacing spent GAC.
- Routinely inspecting and maintaining extraction well pumps, pipelines, the soil vapor extraction blower, and temperature and air flow sensors.
- Ensuring the temperature within the vapor-phase GAC units remains within the optimal range.
- Collecting condensate from vapor extraction lines and vapor-phase GAC units to maximize GAC adsorption capacity.

The treatment systems have consistently operated in compliance with all permits and regulatory requirements.

The budgeted and actual environmental restoration costs for the Building 834 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 Building 834 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 Building 834 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 a description 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

Building 834 OU. Figure 5 shows the specific areas of the Building 834 OU where the institutional/land use controls will be implemented and maintained.

Monitoring and inspection of the Building 834 OU will 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 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 U.S. 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 Building 834 OU and associated contaminated environmental media that are being addressed through the CERCLA process. DOE will implement, maintain, and enforce these institutional/land use controls at the Building 834 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 5 showing the specific areas of the Building 834 OU where the institutional/land use controls will be implemented and maintained, will be entered into the Final Site-Wide Record of Decision.

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. Department of Energy, 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 Building 834 OU.

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

5. Progress Since Last Review

This section describes the Protectiveness Statement and recommendations and follow-up actions from the 2002 Building 834 OU Five-Year Review. It also describes the status of the actions recommended in this previous review.

5.1. Protectiveness Statement from Last Review

The 2002 Building 834 OU Five-Year Review indicated that the remedy for the OU was protective of human health and the environment. The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water.

No deficiencies in the remedy were identified during the previous Five-Year Review conducted in 2002.

5.2. Recommendations and Follow-up Actions from the 2002 Five-Year Review

The following recommendations were developed during the Five-Year Review process in 2002:

1 Modify the ground water and soil vapor extraction wellfield configurations to optimize contaminant mass removal and prevent stagnant zones from forming.

2 Operate the core area extraction wells cyclically to maximize *in situ* biodegradation of TCE.

3 DOE should continue to evaluate other remedial technologies that could shorten cleanup time, especially those that will facilitate remediation of the low-permeability sediments.

4 Due to the limited amount of recharge, installing additional ground water extraction wells may not result in a significant increase in contaminant mass removal or a decrease in cleanup time. Any additional ground water extraction wells should be installed only in areas where the wells will yield significant quantities of ground water. Soil vapor extraction appears to be a much more efficient mass removal technology given the nature of the subsurface materials at Building 834.

No other follow-up actions were identified related to this Five-Year Review.

5.3. Results of Implemented Actions

The status of actions taken in response to the recommendations listed in Section 5.2 are as follows:

1. The core area extraction well field has been reconfigured to improve performance monitoring while maintaining complete hydraulic and pneumatic capture. During 2003, an extensive extraction well field optimization study was performed. Data collected during soil vapor extraction zone-of-influence tests resulted in a reduction in the total number of core area extraction wells from 16 to 9 wells. The new well field configuration maintained adequate VOC mass removal while increasing performance monitoring. Increases in mass removal were achieved through the addition of extraction wells outside the core area as described in item 4, below.

2. Intentional cyclic operation of the core area extraction wells did not occur during the last five years due to the realization that incomplete biodegradation of TCE to cis-1,2-DCE provided only minimal mass reduction. Greater mass removal was achieved through continued normal operations. However, *in situ* biodegradation of TCE did occur within the core area whenever the soil vapor extraction system was shut down for extended time periods. During these shut downs, anaerobic reductive dechlorination resulted in the conversion of TCE to cis-1,2-DCE. More complete biodegradation resulting in larger mass reduction may be achieved in the future depending on the outcome of the T2 area bioremediation testing discussed below.
3. The feasibility of *in situ* enhanced bioremediation is currently being tested in the Building 834 T2 area. The first phase of testing, conducted in 2005, consisted of a tracer test that demonstrated that an *in situ* technology involving fluid injection is feasible to treat contaminants in the Tpsg HSU. The next phase began in late 2006 and includes injection of a carbon source (lactate) followed by injection of a consortium of anaerobic bacteria (bioaugmentation with KB-1). Innovative technologies that enhance the permeability of low-yield formations (i.e., soil fracturing) are under consideration for future testing.
4. During 2004, three leachfield area ground water monitoring wells were converted to dual-phase extraction wells in order to target VOC concentrations in the leachfield area and increase overall VOC mass removal. These wells are located in areas with high VOC concentrations. The three leachfield wells account for approximately one third of the total ground water volume removed at the Building 834 OU.
5. In 2005, three ground water monitor wells in the distal T2 area were converted to dual-phase extraction wells. Pumping from these new extraction wells has not yet commenced due to potential interference with the *in situ* enhanced bioremediation treatability test currently underway in this area.

5.4. Status of Other Prior Issues

There are no other prior issues.

6. Five-Year Review Process

The Five-Year Review of the Building 834 OU at LLNL Site 300 was led by Claire Holtzapple, Site 300 Remedial Project Manager for the DOE/NNSA-Livermore Site Office. The following team members assisted in the review:

- Valerie Dibley, Deputy Project Leader, LLNL
- Vic Madrid, Environmental Scientist, LLNL
- John Valett, Geologist, 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 Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300.
- Five-Year Review Report for the Building 834 Operable Unit 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 Building 834 OU (Dibley et al., 2004a; 2004b; 2005a; 2005b; 2006b; and 2006c).

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

A notice informing the public that this Five-Year Review was in progress was placed in the Tracy Press on February 7, 2007. 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.

7. Five-Year Review Findings

7.1. Interviews and Site Inspection

Interviews or a site inspection are not required for sites with an ongoing presence. "Ongoing presence" means that either the U.S. EPA, the State, or another agency is the lead agency for the site and that the lead agency is involved in and knowledgeable of site activities, issues, concerns, and status. Specifically, there should be regular activity at the site, evidenced by continuing response work that is overseen by the continued presence of the lead agency or regular inspections by the lead agency.

Because the cleanup at the Building 834 OU falls within the definition of "ongoing presence" neither interviews nor a site inspection were required. However, the EPA conducted a Remedial Action Construction Completion inspection on July 13, 2005. All remedial components were determined to be operational and functional.

7.2. 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.

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

There have been no changes in land, building, or ground water use in the Building 834 OU since the Interim Site-Wide ROD. The Building 834 Complex is still used for thermal cycling experiments and is accessible only to DOE/LLNL workers. Building 834D, where an unacceptable risk for VOC inhalation was identified, is still used only for storage and building occupancy restrictions remain in place as discussed in Table 2. Ground water underlying the Building 834 Complex is present in a shallow, perched HSU and is not used for water-supply.

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

There have been no changes in exposure pathways, toxicity, and other contaminant characteristics in the Building 834 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 (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.

7.5. Data Review and Evaluation

7.5.1 Vadose Zone Remediation Progress

The effectiveness of the selected interim remedy to remediate VOCs in the vadose zone sources was evaluated by:

1. Reviewing VOC concentrations trends in soil vapor over time and mass removal data.
2. Reviewing dissolved-phase ground water VOC mass removal data.
3. Assessing VOC concentration rebound in ground water following the 2002 to 2004 rebound test.

Prior to the startup of the Building 834 soil vapor extraction (SVE) system in 1998, the highest, pre-remediation TCE concentrations measured in soil vapor in the core area ranged from 2,000 parts per million on a volume per volume basis ($ppm_{v/v}$) to 3,000 $ppm_{v/v}$. Since full-scale soil vapor extraction began in 1998, TCE concentrations in soil vapor in the core area decreased to a maximum of 11 $ppm_{v/v}$ in the first semester of 2005. In 2004, SVE was initiated from three new dual-phase extraction wells located in the leachfield area. Prior to SVE startup, TCE concentrations in soil vapor from these wells ranged from 250 $ppm_{v/v}$ to 750 $ppm_{v/v}$. By August 2005, TCE concentrations in soil vapor samples from the leachfield wells had decreased from 200 $ppm_{v/v}$ to 20 $ppm_{v/v}$.

The original mass of VOCs estimated to have been present in the vadose zone was 602 kilograms (kg) to 1,118 kg. In 1982 and 1983, DOE/LLNL excavated approximately 100 cubic yards of TCE-contaminated soil at five locations within the Building 834 core area where heat-exchange fluid had been spilled or released from leaking pipes. The excavated soil contained approximately 96 kg of VOCs, representing 9% to 16% of the estimated pre-remediation mass of VOCs in the vadose zone. DOE/LLNL have not identified any other areas at the Building 834 Complex where excavation would be a cost-effective remedial technology.

Approximately 208 kg of VOCs have been removed by SVE since the remedial action began in 1998. An estimated additional 201 kg of VOCs were removed during earlier treatability testing. The total mass of VOC removed through soil vapor extraction represents 37% to 68% of the original mass. Although the SVE wells in the leachfield area have only operated for a limited period of time, analytical data indicate significant VOC mass is being removed; accounting for approximately 90% (50 kg) of the VOC mass removed using SVE in 2004.

Measuring the rebound of VOC concentrations in soil vapor following a shutdown period is one of the best indicators of remediation progress. The extent of concentration rebound is indicative of the magnitude of the remaining VOC source in the vadose zone. VOC concentrations were measured in soil vapor samples from core area wells while the treatment system was shut down from June 12, 2002 to September 20, 2004 as a Defense Program experiment was being conducted in the area and measurements continued during treatment system modifications. Prior to SVE system shutdown, the maximum VOC soil vapor concentration detected in SVE wells in the core area was 38 $ppm_{v/v}$. The maximum rebound VOC concentration detected in soil vapor in the year following SVE system shutdown was 75 $ppm_{v/v}$. Significant rebound of VOC concentrations in soil vapor was not detected during this time period, indicating that remediation efforts have been successful in reducing the VOC source in the vadose zone.

In summary, vadose zone remediation efforts are progressing as expected. VOC soil vapor concentrations in individual extraction wells in the core and leachfield areas and in treatment facility influent are decreasing. Rebound testing indicates that the VOC vadose zone source strength within the influence of the core area extraction well field has significantly decreased. The expansion of the dual-phase extraction wellfield to the leachfield area has significantly increased vapor-phase VOC mass removal at this OU. COC data do not indicate any new or increased impacts to ground water as a result of leaching of contaminants from the vadose zone to ground water.

7.5.2. Ground Water Remediation Progress

Ground water data were evaluated to assess the effectiveness of extraction and treatment to remediate VOCs, TBOS/TKEBS, and nitrate in ground water in the Building 834 OU. Remediation progress was evaluated by:

1. Comparing pre-remediation dissolved-phase COC concentrations and spatial distribution in ground water to first semester 2005 data.
2. Reviewing COC concentration trends in ground water over time.
3. Assessing VOC concentration rebound in ground water following the 2002 to 2004 rebound test.
4. Reviewing dissolved-phase ground water VOC mass removal data.
5. Evaluating extraction well field capture zones.

The results of this evaluation for VOCs, TBOS/TKEBs, and nitrate in ground water are discussed below.

Volatile organic compounds in ground water – A comparison of the distribution of total VOCs in perched ground water in the Tpsg HSU before full-scale ground water extraction and treatment began in 1995 and in the first semester of 2005 is shown in Figure 6. While the overall extent of VOCs detected in ground water has not changed significantly, the highest concentrations have decreased by several orders of magnitude during the last 10 years in the vicinity of the core area extraction wellfield as shown by the total VOC time-series plot of well W-834-D3 in Figure 8. In addition, the 2005 VOC plume map shows that the extent of VOCs with concentrations greater than 10,000 micrograms per liter (μg/L) has decreased significantly compared to the pre-remediation extent, especially in the core area. In the leachfield and distal areas, the extent of VOCs in ground water has not changed significantly because ground water remediation in these areas did not begin until late 2004. The extent of VOCs in ground water in the leachfield and distal areas is expected to decrease in the next few years as a result of ground water extraction from the expanded wellfield. A hydrogeologic cross-section showing the vertical distribution of total VOCs in the Building 834 OU HSUs is shown in Figure 7.

VOC concentration trends in ground water over time are another important indicator of ground water remediation progress. As shown in Figures 8 and 9, VOC concentrations in ground water in the core and leachfield areas have decreased significantly from their maximum historical levels. The maximum historical VOC concentration in the perched Tpsg HSU in the core area has declined from 1,060,000 μg/L in 1993 (pre-remediation) to 32,000 μg/L in the first semester of 2005. This concentration decrease is due primarily to dual-phase extraction and treatment, and to a much lesser extent to intrinsic bioremediation. Remediation efforts in the core area have not significantly reduced VOC concentrations in ground water in the low-permeability sediments of the Tps-Tnsc$_2$ HSU clay perching horizon. VOCs in the Tps-Tnsc$_2$ clay will likely act as a long-term source for diffusive flux into the overlying Tpsg HSU, significantly extending ground water cleanup time. As shown in Figure 10, VOC concentrations in ground water in the distal (T2) area have remained relatively stable because no active remediation has yet taken place in this area. While the extraction wellfield was expanded to the distal area in 2004, pumping from these wells has not yet been initiated while the *in situ* enhanced bioremediation study is being conducted. VOC concentrations remain below method detection limits (0.5 μg/L) in the $Tnbs_1$ regional aquifer.

Measuring the rebound of VOC concentrations in ground water following a shutdown period is one of the best indicators of remediation progress. The extent of concentration rebound is indicative of the magnitude of the remaining VOC source. VOC concentrations were measured in ground water samples from core area wells while the treatment system was shutdown for modifications in 2002 to 2003. Significant rebound of VOC concentrations was not detected during this time period, indicating that remediation efforts have been successful in reducing the VOC source.

Ground water remediation progress was also evaluated by estimating the reduction in VOC mass achieved through remediation. Estimates of dissolved phase VOC mass prior to the start of ground water remediation in 1995 ranged from 65 kg to 120 kg. As shown in Figure 11, approximately 34 kg of VOCs have been removed from the ground water. An estimated additional 6 kg of VOCs were removed during pre-1995 short-term treatability testing. The total mass of ground water VOCs removed ranges from 30% to 60% of the original mass. Future dissolved phase mass removal rates depend on several factors including: (1) variations in seasonal recharge and saturated thickness, (2) extraction well field configuration, (3) dissolution from residual DNAPL sources, and (4) the rate of VOC diffusive flux from low permeability Tps clay.

Conservative estimates of ground water capture by the core, leachfield, and distal (T2) area extraction well fields are presented in Figure 12. As shown in Figure 12, the core area extraction wellfield capture zones extend to the saturated limits of the perched zone to the north, west, and east of the core area. The significant decreases in VOC concentrations observed in leachfield well W-834-S1 since the mid-1980s, is likely due in part to the effective hydraulic capture by the upgradient core area wellfield. The recently added leachfield and distal area extraction wells are designed to achieve complete capture of the VOC plumes in those areas. The capture plots shown in Figure 12 show the estimated extent of capture after 5 years of pumping and for steady-state conditions.

The capture zones presented in Figure 12 were generated using the WinFlow analytical element model discussed in Section B-3.3 of Appendix B of the Site-Wide Remediation Evaluation Summary Report to predict long-term capture zones based on current and planned extraction flow rates. The capture zones predicted by the WinFlow model are conservative because: (1) the basic model parameters used for each model are selected conservatively (i.e., maximum aquifer thickness, hydraulic conductivity, and hydraulic gradient values), and (2) the WinFlow model assumes an infinite extent of saturation, while the extent of saturation in the Tpsg and $Tps\text{-}Tnsc_2$ HSUs is limited.

Once the extraction wellfield in the Building 834 distal plume area has 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 and performance monitoring wells. DOE/LLNL expects that the capture zones at Building 834 OU will extend to the entire extent of saturation, including the area south of the distal area and the area between wells W-834-S1 and W-834-S13. For example, capture in the core area has already influenced the entire extent of saturation due to higher flow rates enhanced by soil vapor extraction and the limited extent of saturation.

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.

TBOS/TKEBs in ground water – Although TBOS/TKEBS concentrations have significantly decreased, these compounds continue to be detected at high concentrations in some wells in the core area. The highest historical concentration of these compounds dissolved in ground water was 7,300,000 μg/L (1995). The maximum concentration detected in first quarter 2005 was 22,000 μg/L. Time-series plots of TBOS concentrations in ground water in well W-834-D3 and treatment facility influent are shown in Figure 13. The wells with the historical concentrations of TBOS vary from one sampling event to the next, likely due to varying amounts of free-phase TBOS in the sample. The silicone oil contamination in the subsurface is contained within the lateral and vertical distribution of the VOC plume. Therefore, the extraction wellfield for VOC cleanup will be used to remediate TBOS/TKEBS in ground water. Since 1995, approximately 10 kg of silicone oils have been extracted.

Nitrate in ground water – Elevated levels of nitrate occur in the ground water throughout the Building 834 OU with concentrations ranging from less than 0.44 milligrams per liter (mg/L) to 329 mg/L during the first semester of 2005. The highest historical concentration of nitrate in ground water (750 mg/L) was detected near the septic system leachfield in 2000. Generally lower concentrations of nitrate occur in the core area. The low nitrate levels in this area are related to denitrification associated with intrinsic *in situ* biodegradation. Although both natural (soil) and anthropogenic (septic) sources contribute to the nitrate in the perched ground water, the septic source is likely to be the most significant. Nitrate concentrations remain below detection limits in ground water from the deep $Tnbs_1$ HSU guard wells. Since 1995, approximately 67 kg of nitrate has been extracted from ground water.

Toluene and xylenes in ground water – Although not identified as COCs in the Interim Site-Wide ROD, benzene, toluene, ethylbenzene, and xylene (BTEX) compounds and diesel continue to be monitored at the request of the regulatory agencies. Samples from only two wells contained BTEX compounds and diesel in the first semester of 2005. Toluene and xylene compounds were detected at concentrations well below their State and Federal MCLs. Benzene concentrations (1.2 μg/L) were below the Federal MCL (5 μg/L) but slightly above the State MCL (1 μg/L).

7.5.3. Risk Mitigation Remediation Progress

This section summarizes the results the annual risk re-evaluations conducted for the Building 834 OU to assess the progress of the remediation effort in mitigating VOC inhalation risk to onsite workers in indoor and outdoor air at Building 834D. The risks from Building 834 COCs were summarized in Section 3.5 and described in more detail in the Interim ROD.

The risks associated with VOCs in subsurface soil at Building 834D were re-evaluated in 2003, 2004 and 2005 as part of the Risk and Hazard Management Program. Soil vapor extraction at Building 834 has contributed to reducing the human health risk due to inhalation of

VOC vapors outside Building 834D to a level that is no longer of concern (less than 10^{-6}). Although Building 834D indoor air continues to present an unacceptable risk (greater than 10^{-6}) to onsite workers, the risk evaluations conducted in 2003, 2004, and 2005 indicate both risk and hazard are being reduced. Building 834D continues to be used only for storage and institutional controls are in place to prevent human exposure.

The results of the ecological survey program conducted in 2004 and reported in the First Semester 2004 Compliance Monitoring Report (Dibley, 2004b) indicated that burrow air did not contain VOCs at concentrations that would result in a hazard index or quotient greater than 1.

In addition, surface soil sampling and analysis for cadmium conducted in 2003 indicated that the ecological hazard associated with cadmium in surface soil at Building 834 identified in the baseline ecological assessment ((Webster-Scholten 1994) was no longer present. The baseline ecological hazard was based on a detection of cadmium in one surface soil sample. In 2003, 24 additional surface soil samples were conducted at Building 834. All cadmium concentrations in these surface soil samples were below the detection limit, including samples collected near the location where cadmium had previously been detected. Therefore cadmium was deleted from the list of ecological COCs and will no longer be evaluated and reported. Details of the 2003 soil sampling and cadmium analysis were presented in the 2003 Annual Compliance Monitoring Report (Dibley, 2004a).

7.5.4. New Sources, Releases, or Contaminants

Ground water and soil vapor data indicate there are no new sources, releases, or contaminants in the Building 834 OU.

In 1999 through 2001, ground water samples were collected for perchlorate analysis to determine if this constituent was present in Building 834 ground water. Perchlorate was detected in ground water samples collected from two wells in the Building 834 OU at concentrations above the method detection limit of 4 μg/L. In 2005, perchlorate was detected in ground water samples collected from four newly installed wells at concentrations ranging from 4.7 to 28 μg/L. However, perchlorate was not detected in a verification sample that was immediately collected from one of these wells. Samples from all monitor wells in the Building 834 OU will be reanalyzed for perchlorate, and the results will be reported in the 2007 Annual Site-Wide Compliance Monitoring Report for Site 300. Based on the results of the analyses, specific wells may continue to be monitored for perchlorate in ground water.

In 2004, n-butyl-benzenesulfonamide was identified in Building 834 ground water monitor wells. Following an evaluation of possible sources of the n-butyl-benzenesulfonamide, it was determined that the compound was leaching from the nylon tubing used with the ground water extraction pumps. The tubing was replaced to correct the problem.

7.5.5. New Technology Assessment

As discussed in Section 2, several innovative technologies have been tested in the Building 834 OU to determine if they were more effective in VOC cleanup than the pump-and-treat technology. The technologies included electron acceleration, ultraviolet light/peroxidation, electrical soil heating, surfactant "push-pull", and potassium-permanganate injection. These innovative technologies were screened out in the Interim Site-Wide Feasibility Study based on cost, effectiveness, and/or the creation of additional problems such as toxic byproducts.

The feasibility of implementing an *in situ* enhanced bioremediation technology is currently being tested in the T2 distal area. The first phase of the enhanced bioremediation study that consisted of a tracer test and microcosm study, has been completed. The tracer test was performed to determine: (1) the reagent injection rate, (2) the transit time for the injected reagent, and (3) to identify the presence of any preferential flow paths. The tracer test results will be used to determine whether injection of a fluid reagent, such as lactate or ethanol, is feasible. The microcosm study was conducted to evaluate if indigenous bacteria are capable of completely degrading TCE or if the natural bacterial population needs to be augmented with non-indigenous bacteria that have this capability. Preliminary microcosm test results indicate that indigenous bacteria readily degrade TCE to cis-1,2-DCE but are limited in their ability to complete the reaction to the non-toxic end product ethane. However, the preliminary microcosm test results indicate that with bioaugmentation and introduction of a carbon source, the degradation reaction is completed. If the final results of the tracer test and microcosm study indicate that injection of a reactive material will accelerate ground water cleanup, a field test will be considered. The results of this study will be used to determine whether to implement enhanced bioremediation to provide more efficient, cost effective cleanup of the Building 834 OU, and possibly at other Site 300 OUs.

Other innovative technologies that enhance the permeability of low-yield formations and therefore potentially increase contaminant mass removal are also being considered for future application. The ability to control the fracturing and breaching of the integrity of the perching horizon is a major concern in applying these types of technologies.

8. Technical Assessment

The protectiveness of the 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 evaluation determined that the interim remedy for the Building 834 OU is protective, based on the following:

- There have been no 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 Building 834 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 and soil vapor extraction are reducing contaminant concentrations in the subsurface. The maximum VOC concentrations in ground water in the perched Tpsg HSU have decreased by approximately two orders of magnitude, although high concentrations remain in the upper part of the underlying low-permeability Tps clay perching horizon. The ground water and soil vapor extraction wellfield has been expanded to remove contaminant mass and decrease COC concentrations in the distal plumes. DOE/LLNL have removed approximately 545 kg of VOCs from the subsurface, representing 44 to 81% of the mass of total VOCs that were present prior to remediation. Of the total mass removed from the subsurface, 75% has been through soil vapor extraction, 18% through excavation, and 7% through ground water extraction. These data indicate that soil vapor extraction is much more effective than ground water extraction in removing contaminants from the subsurface. Mass removal rates are declining for both ground water and soil vapor in the core area as significant amounts of VOC mass have already been removed from the more permeable Tpsg sediments. However, VOCs continue to diffuse slowly from lower permeability Tps clay perching horizon.
- 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.
- No new sources, releases, or contaminants have been identified in the Building 834 OU.
- There have been no changes in risk assessment methodologies that could 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.

9. Deficiencies

No deficiencies in the overall approach specified in the interim remedy for the Building 834 OU were identified during the evaluation. However, the length of time necessary to achieve ground water cleanup standards using pump and treat technologies may be long due to: (1) low well yields resulting from the recharge-limited nature of the Tpsg HSU, (2) VOCs that will likely continue to diffuse from the low permeability Tps clay into perched ground water in the overlying Tpsg HSU, and (3) the limited ability of pump and treat technology to remove VOCs from low-permeability sediments in the Tps HSU.

Experimental treatment technologies, such as bioremediation or hydraulic fracturing, are being evaluated to determine if these technologies can improve the long-term performance of the selected remedy.

10. Recommendations and Follow-Up Actions

Ground water and soil vapor extraction and treatment continue to make progress toward reducing contaminant concentrations and mass in the vadose zone and ground water. DOE/LLNL have implemented 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 Building 834 OU.

DOE/LLNL will sample and analyze all monitor wells in the Building 834 OU for perchlorate and report the results in the 2007 Annual Site-Wide Compliance Monitoring Report for Site 300. Based on the results of the analysis, specific wells may continue to be monitored for perchlorate in ground water.

In addition, DOE/LLNL will continue to evaluate other remedial technologies, such as *in situ* bioremediation, that could shorten cleanup time, especially those that will facilitate remediation of the low-permeability sediments. However, even if these technologies are implemented, it may not be possible to fully remediate VOCs in the low-permeability sediments.

Because some VOCs may remain at the Building 834 OU following the achievement of the proposed 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 codified 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 7.2, and ARARs related to ground water cleanup will be established in the Final Site-Wide ROD scheduled for 2008.

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

11. Protectiveness Statement

The remedy at the Building 834 OU is expected to be protective of human health and the environment upon completion (i.e., when clean-up levels 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 Building 834 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 codified 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 U.S. EPA, the DTSC, and the RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use.

12. 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
BTEX	Benzene, toluene, ethylbenzene, xylenes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Contaminant of concern
DCE	Dichloroethylene
DNAPL	Dense non-aqueous phase liquid
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EPA	Environmental Protection Agency
ft	Feet
GAC	Granular activated carbon
gpm	Gallons per minute
HSU	Hydrostratigraphic unit
kg	Kilogram
LLNL	Lawrence Livermore National Laboratory
LNAPL	Light non-aqueous phase liquid
MCL	Maximum contaminant level
mg/L	Milligrams per liter
O&M	Operation and maintenance
OU	Operable unit
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethylene
$ppm_{v/v}$	Parts per million on a volume per volume basis
RAOs	Remedial Action Objectives
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SVE	Soil vapor extraction
TBOS	Tetrabutylorthosilicate
TCE	Trichloroethylene
TKEBS	Tetra-kis-2-ethylbutyl silane
$Tnbs_1$	Tertiary Neroly Lower Blue Sandstone
$Tnbs_2$	Tertiary Neroly Upper Blue Sandstone
$Tnsc_1$	Tertiary Neroly Lower Siltstone/Claystone
$Tnsc_2$	Tertiary Neroly Upper Siltstone/Claystone

Tps	Tertiary Pliocene nonmarine sediments
Tpsg	Tertiary Pliocene sand and gravel
VOCs	Volatile organic compounds
μg/L	Micrograms per liter

Figures

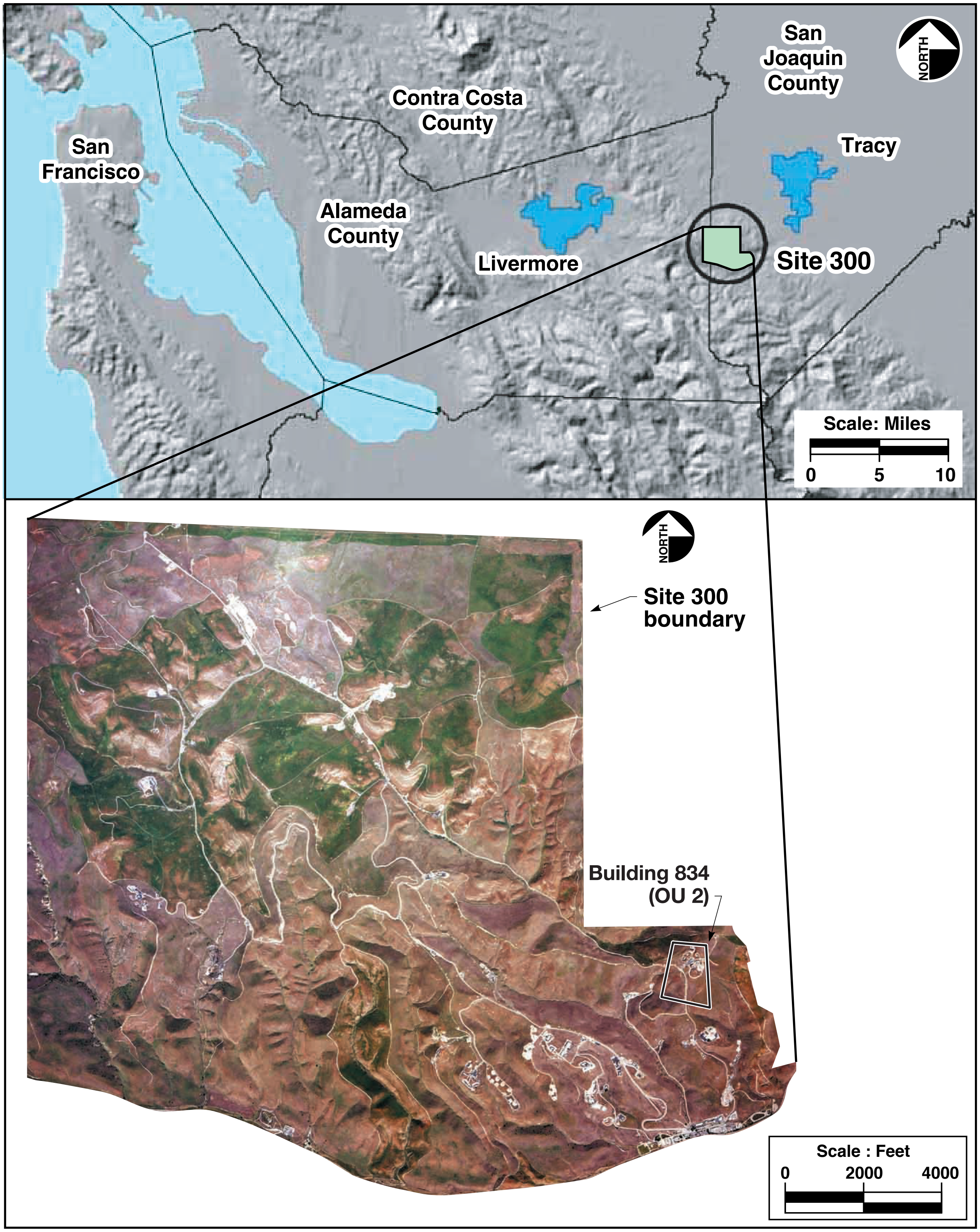

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Figure 1. Location of LLNL Site 300.

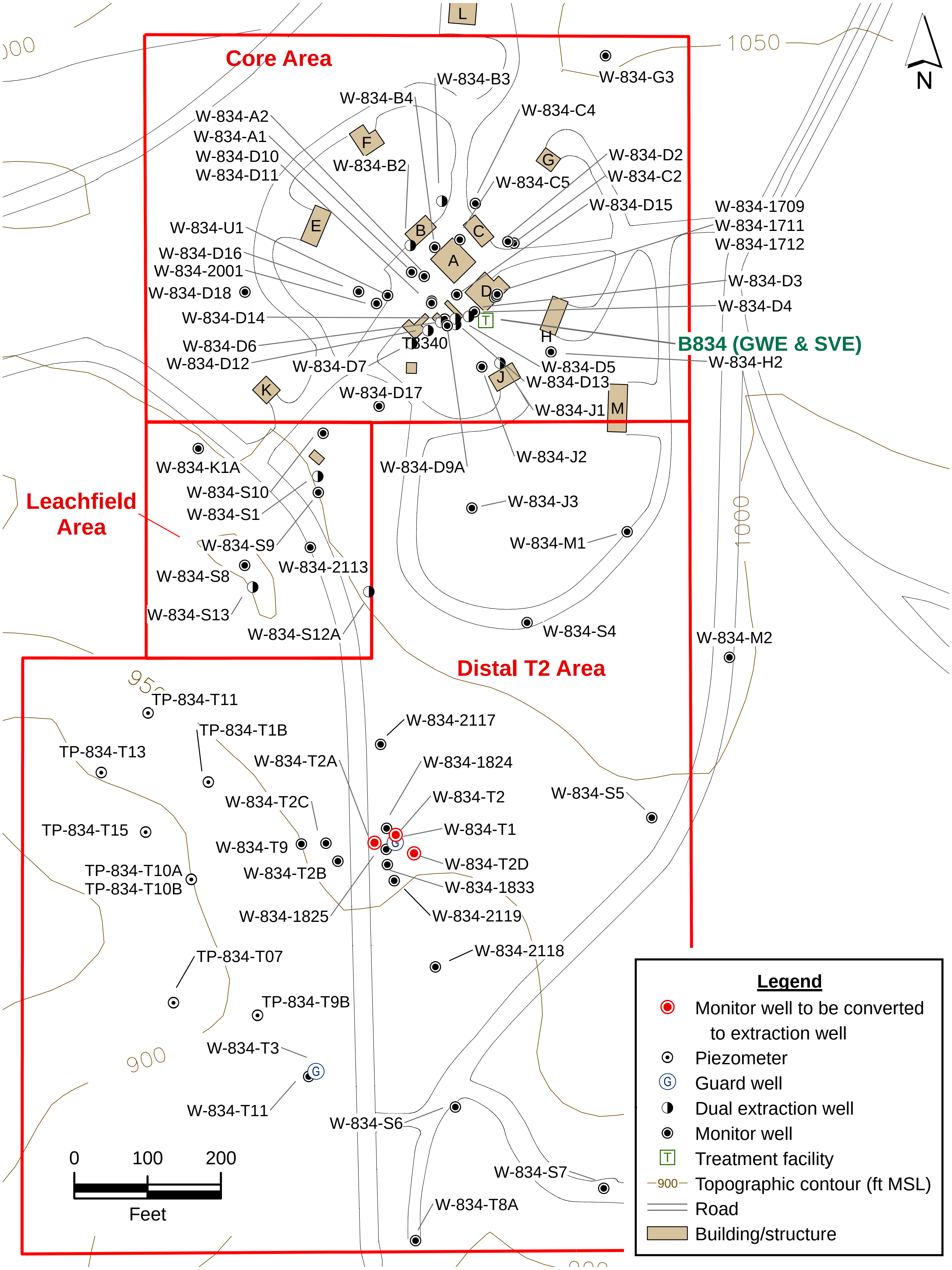
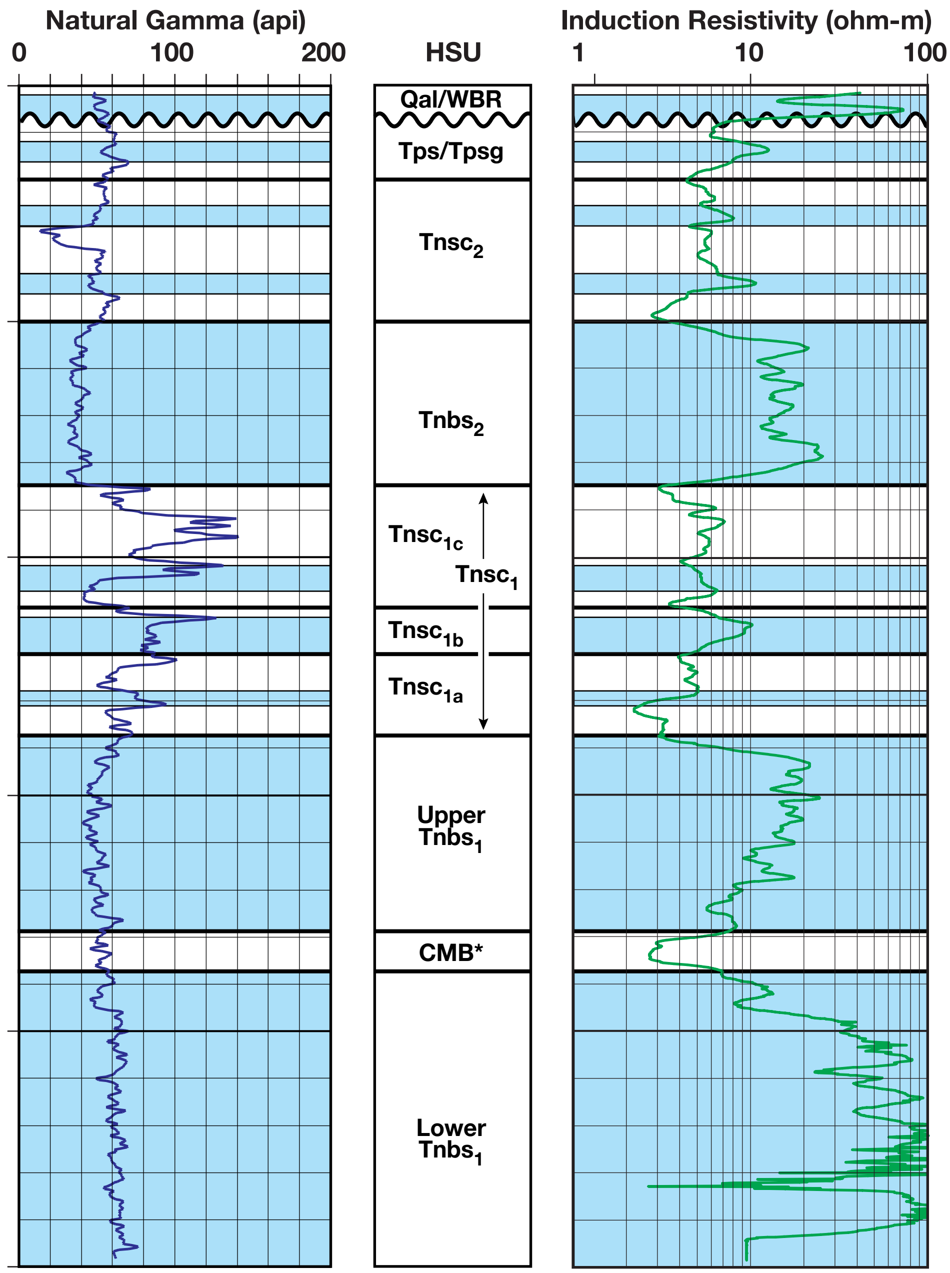


Figure 2. Building 834 Operable Unit site map showing piezometers and monitoring, extraction, and guard wells and the treatment facilities.



Legend

	Intervals of saturation
CMB*	Claystone maker bed
api	American Petroleum Institute Units
ohm-m	ohm-meters
	Unconformity

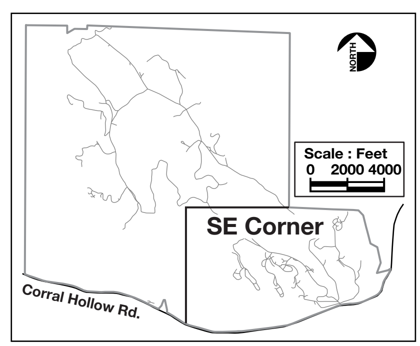


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Figure 3. Composite hydrostratigraphic column for the Southeast Corner of Site 300 showing saturated hydrostratigraphic units (HSUs).

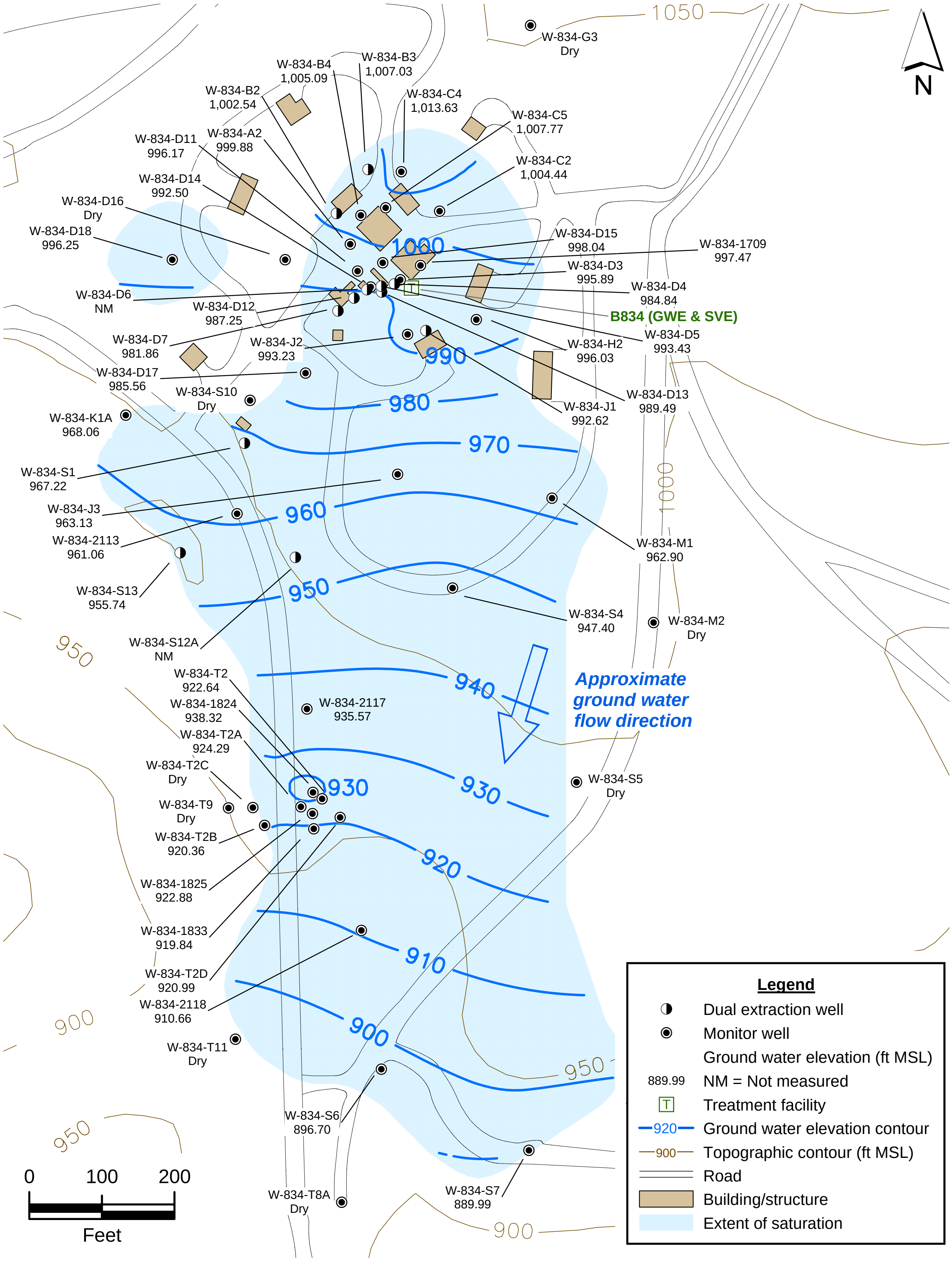

Figure 4. Building 834 Operable Unit potentiometric surface and ground water flow direction in the Tpsg perched water-bearing zone (1st Semester 2005).

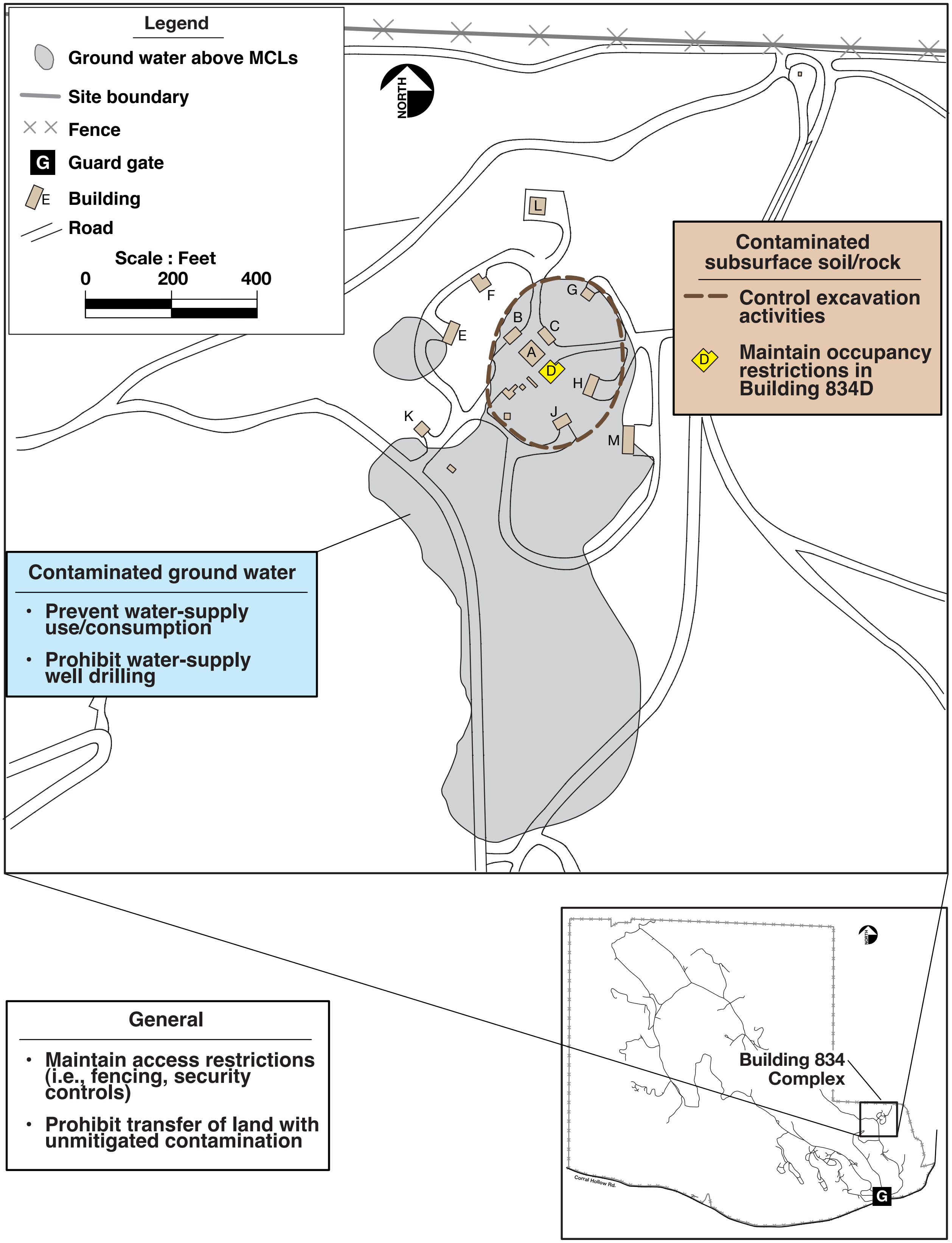

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Figure 5. Building 834 OU institutional/land use controls.

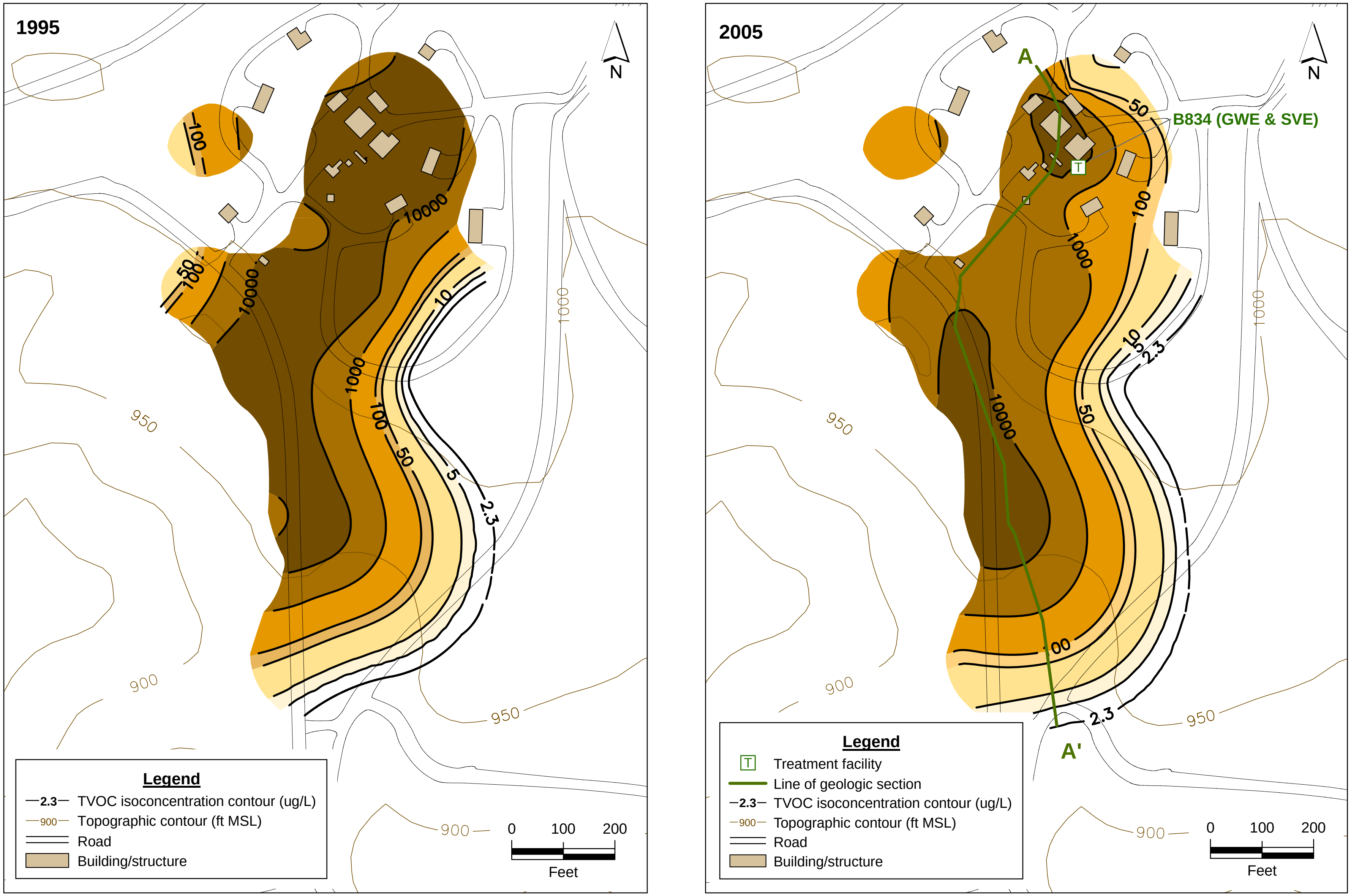


Figure 6. Comparison of the distribution of total VOCs in the Building 834 Tpsg perched water-bearing zone in 1995 and 1st Semester 2005.

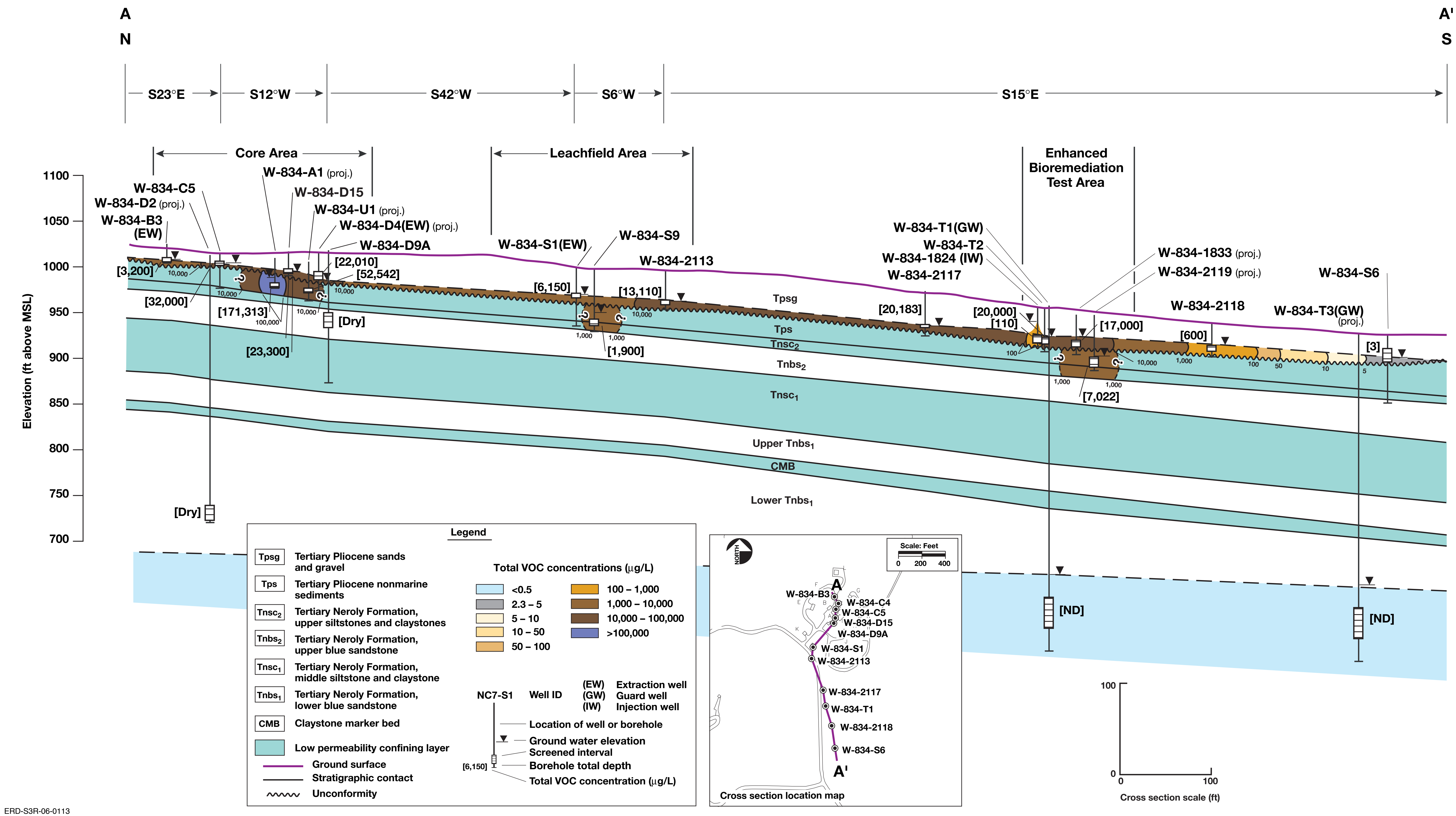
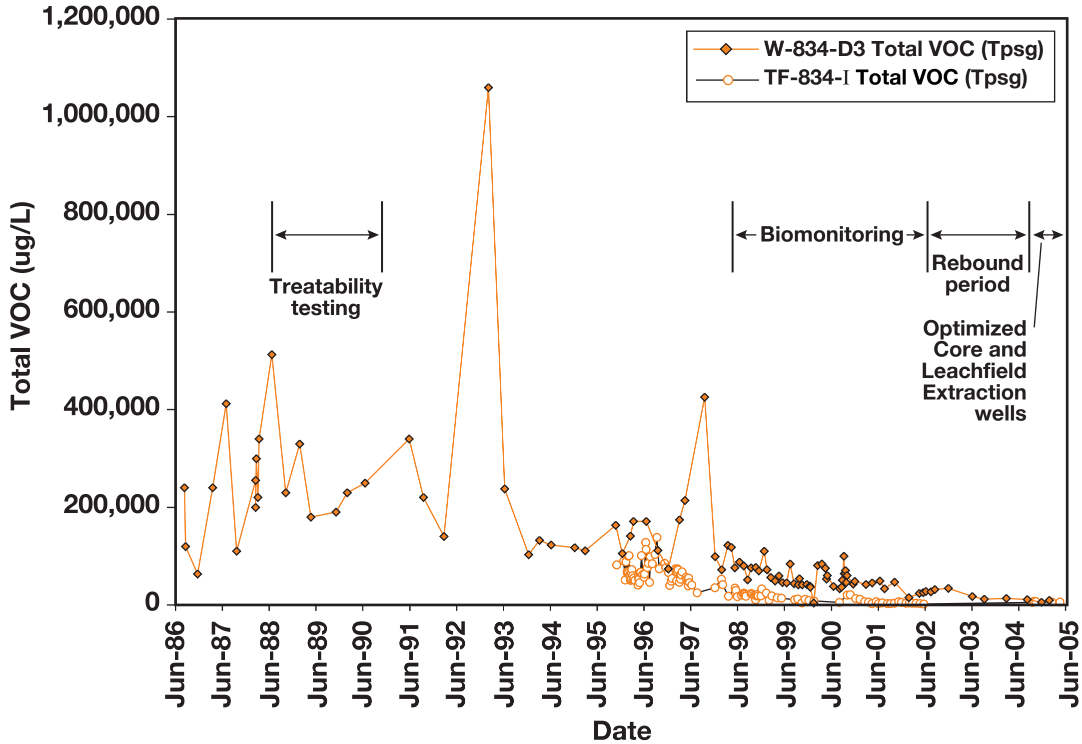


Figure 7. Building 834 Hydrogeologic Cross-section A-A'.



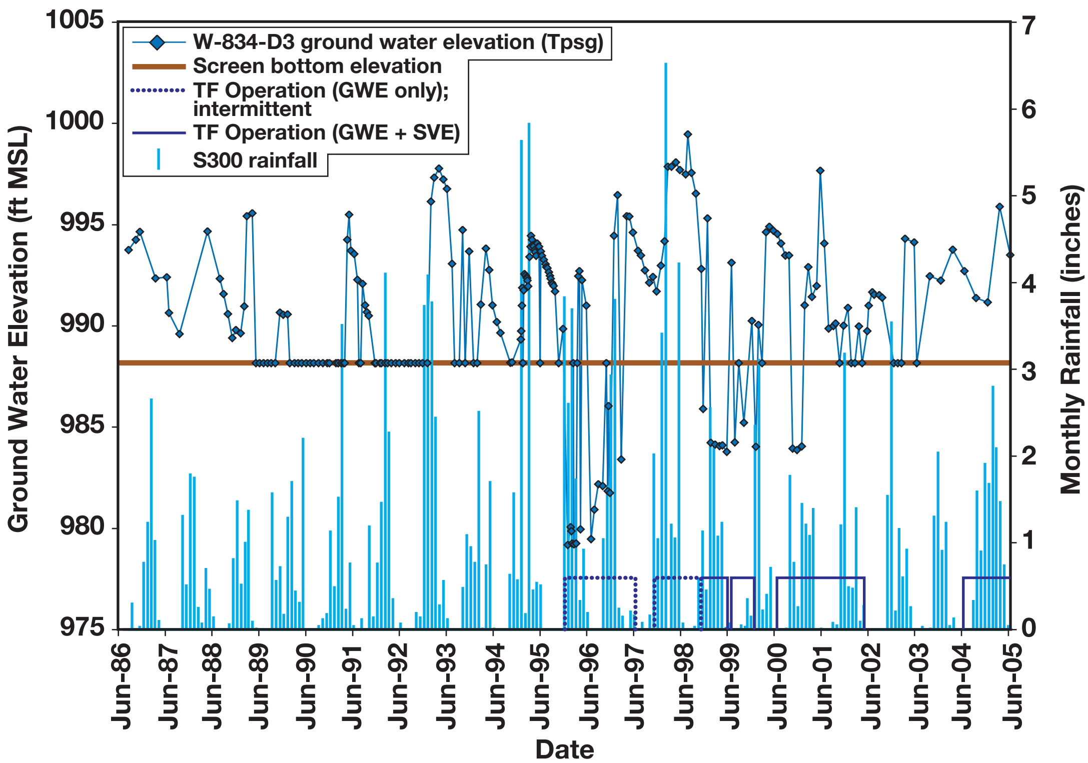


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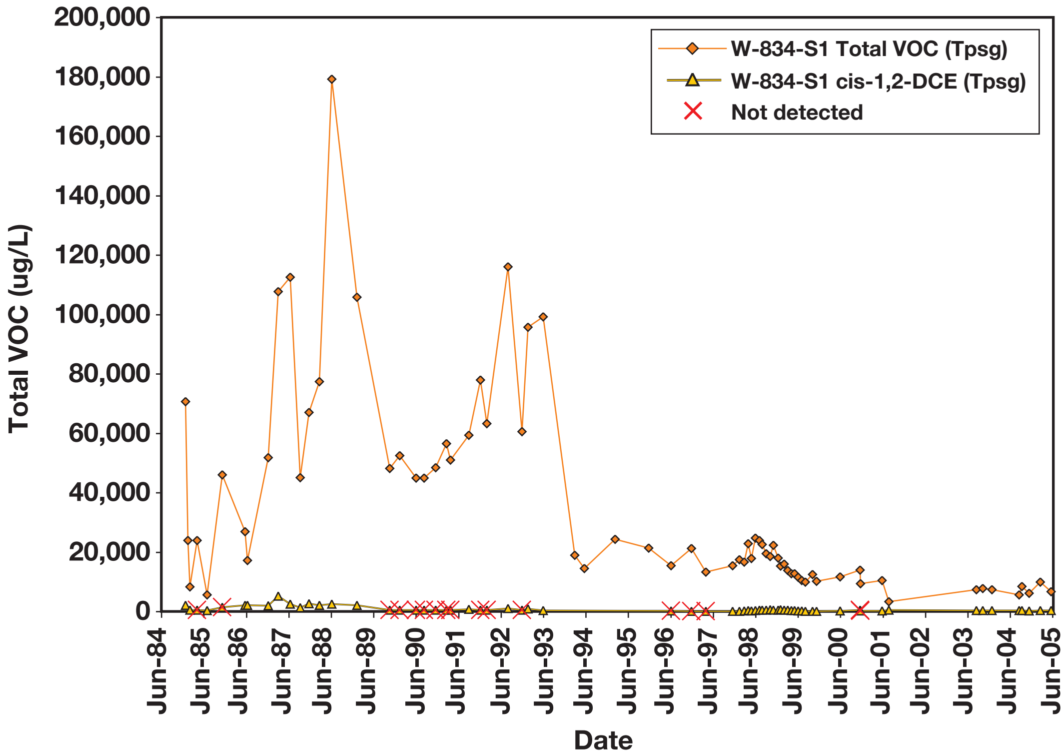
Figure 8. Time-series plots of total VOCs in ground water and hydrograph at the Building 834 core area.



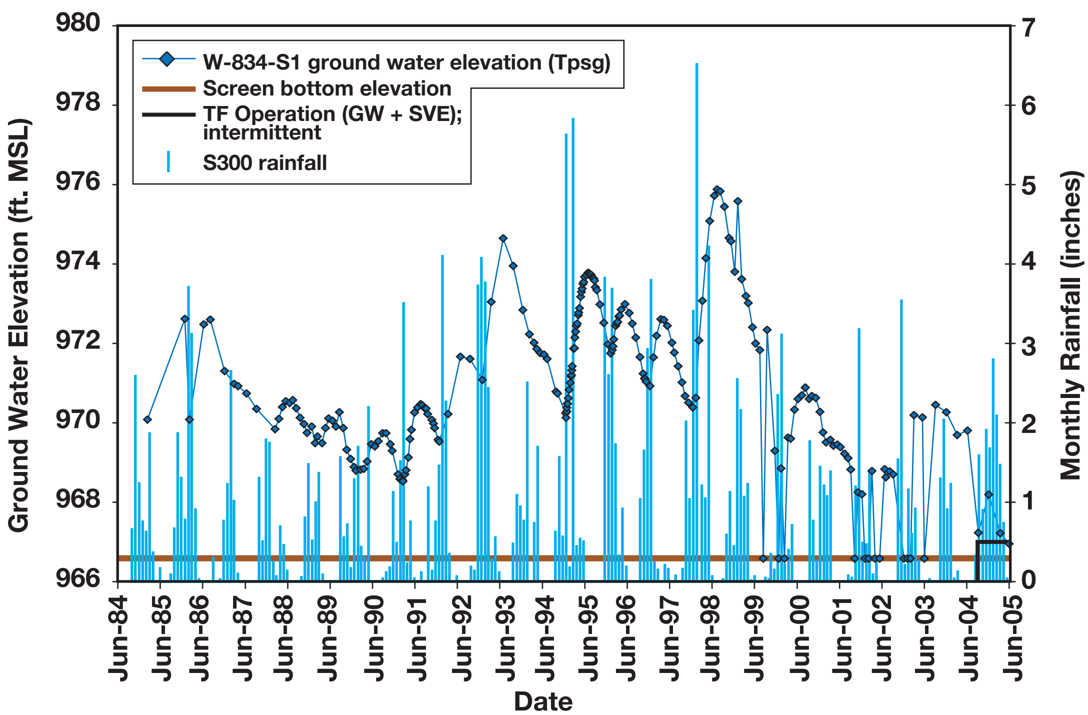


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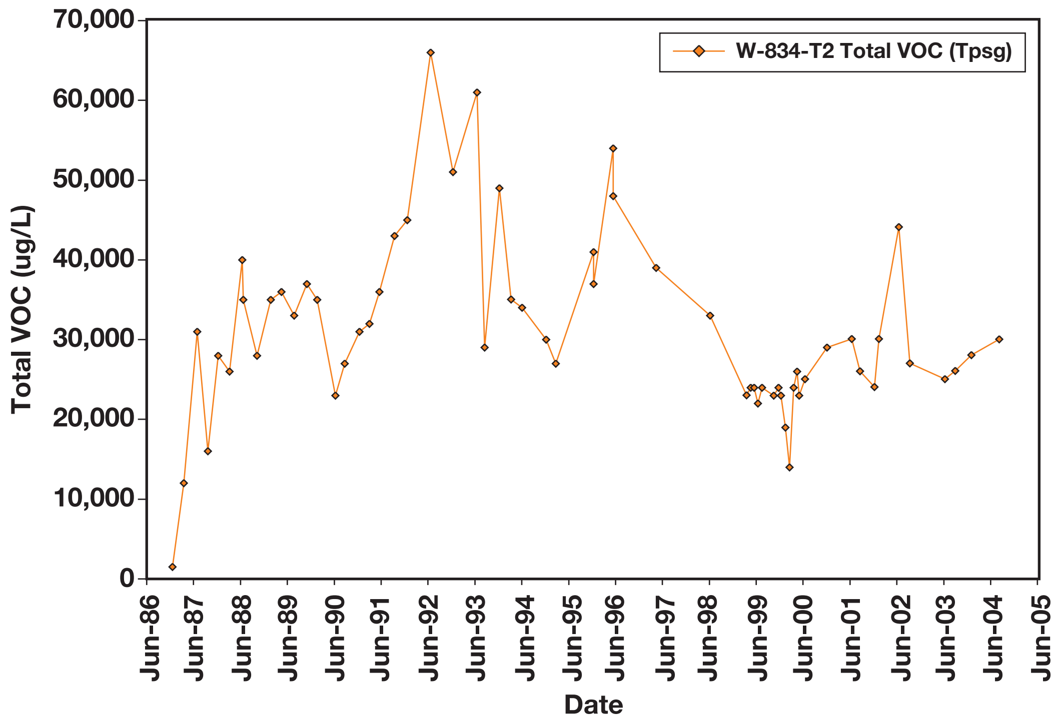
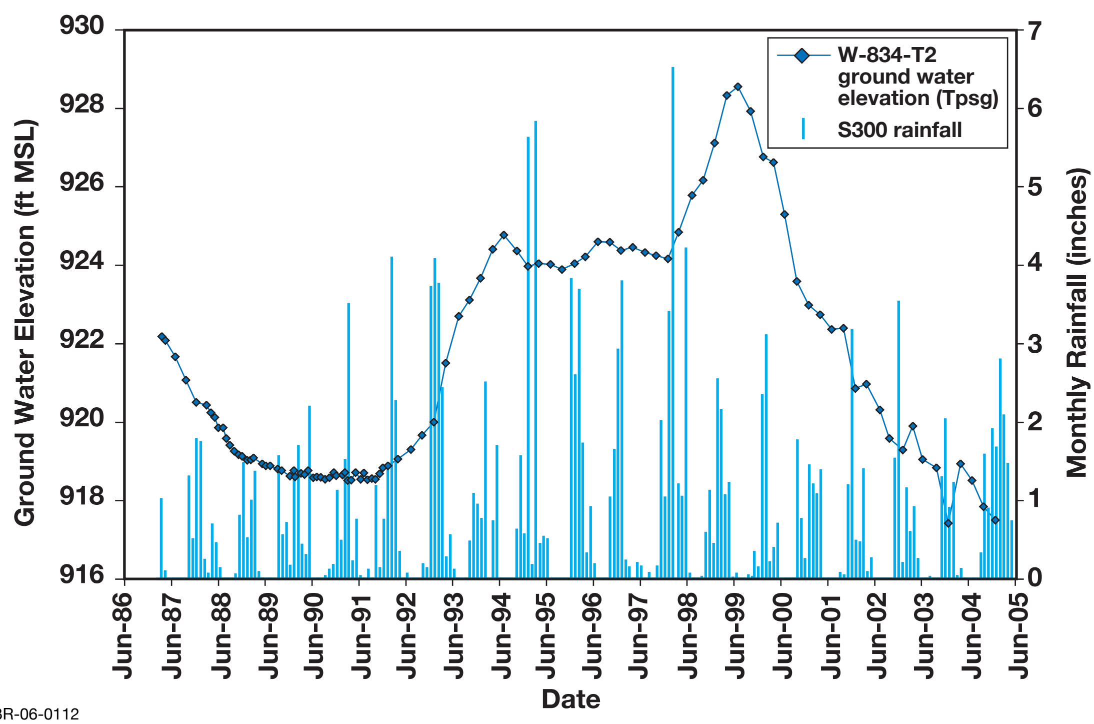
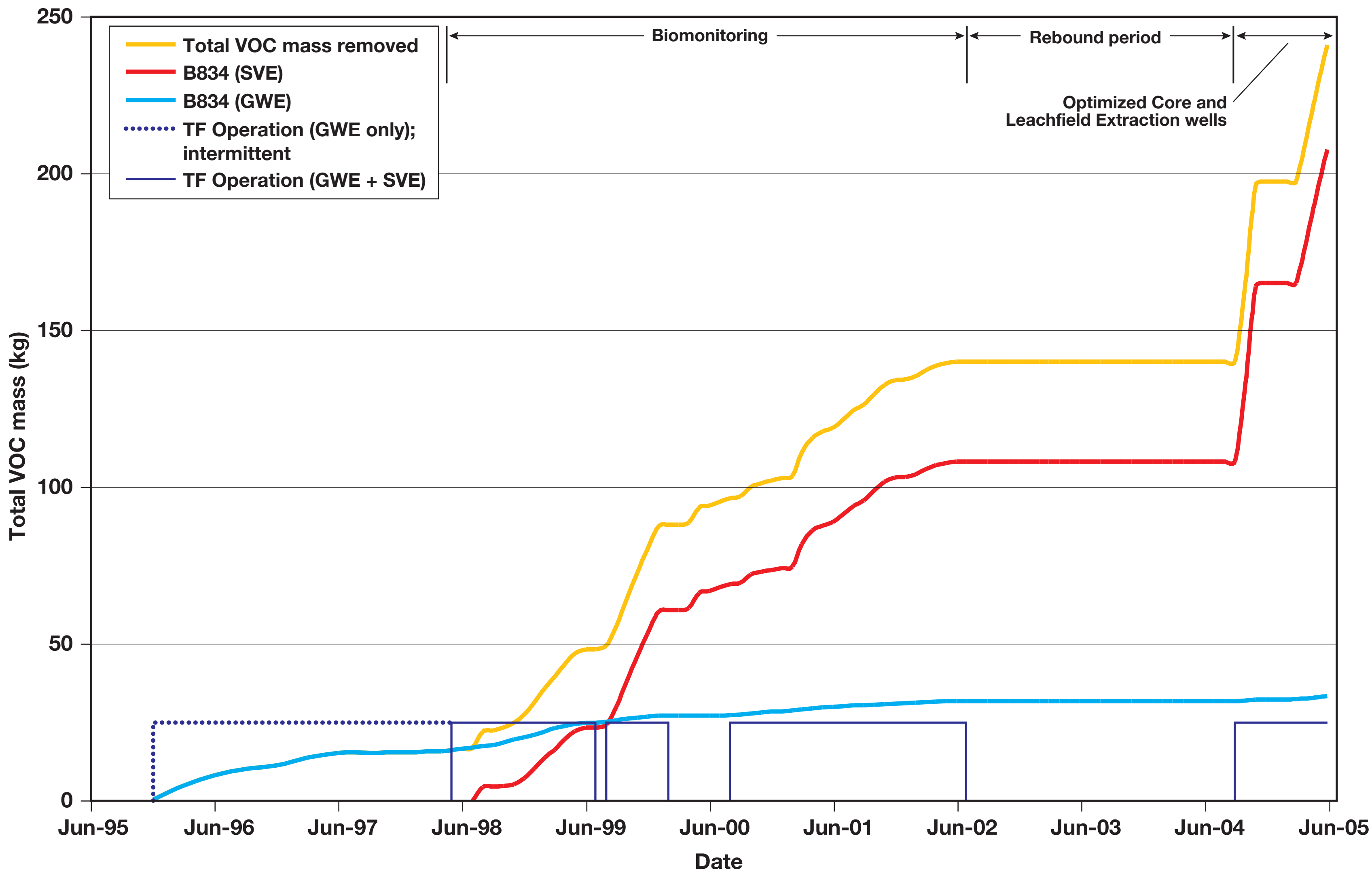
Figure 9. Time-series plots of total VOCs and cis-1,2-DCE in ground water and hydrograph at the Building 834 leachfield area.





ERD-S3R-06-0112

Figure 10. Time-series plots of total VOCs in ground water and hydrograph at the Building 834 distal (T2) area.



ERD-S3R-06-0109

Figure 11. Time-series plots of cumulative mass of total VOCs removed by ground water extraction (GWE) and soil vapor extraction (SVE) from the Building 834 OU.

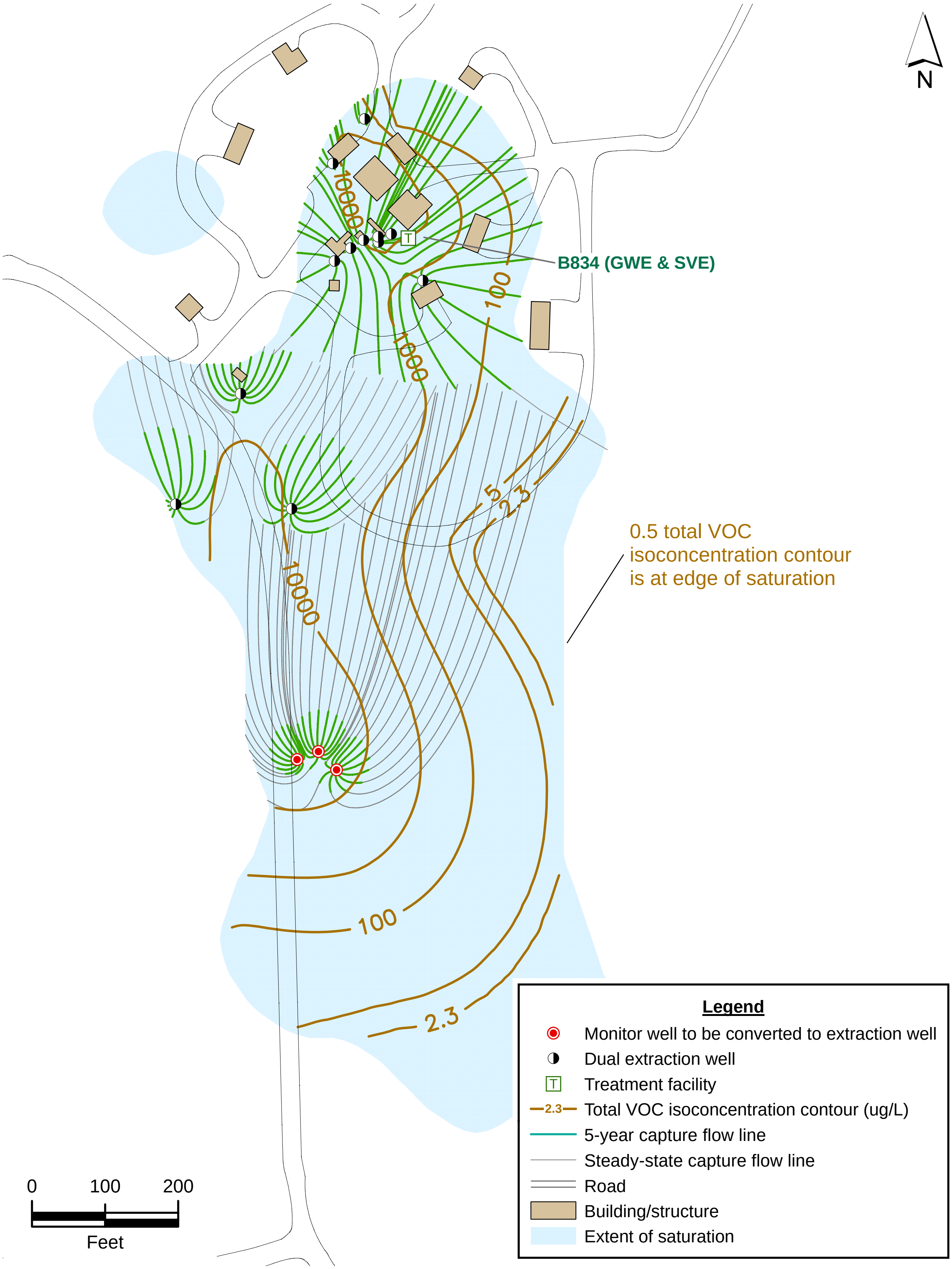
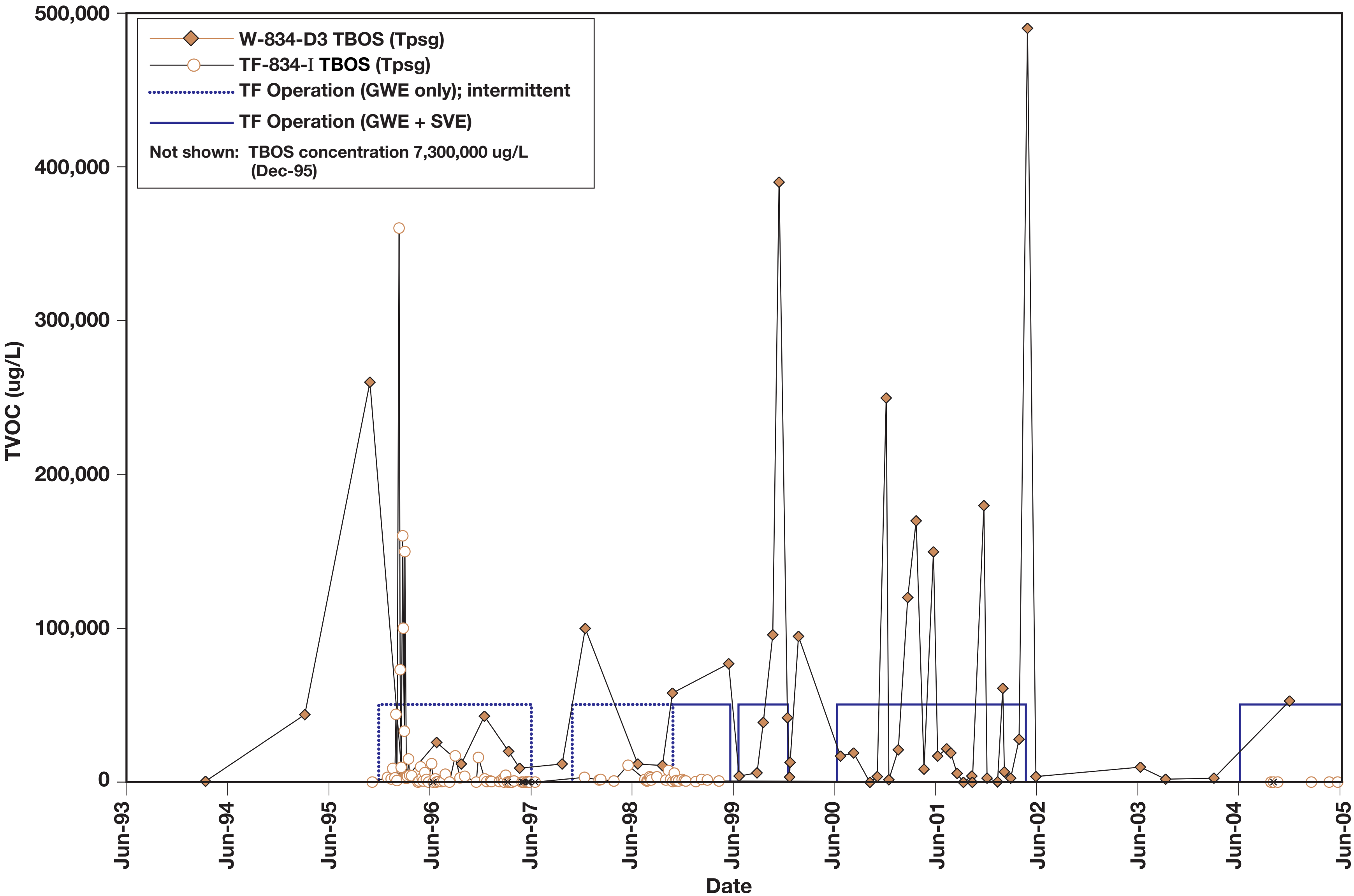


Figure 12. Capture zone analysis results for the designed remedial extraction wellfield at the Building 834 Operable Unit.



ERD-S3R-06-0114

Figure 13. Time-series plots of TBOS in ground water at the Building 834 core area.

Tables

Table 1. Actual annual costs for the Building 834 Operable Unit for fiscal years 2002 through 2006.

Fiscal Year	Annual Budget	Actual Annual Cost
2002	$1,087,177	$466,031
2003	$790,571	$533,663
2004	$929,162	$979,481
2005	$693,569	$659,349
2006	$507,920	$400,283

Table 2. Description of institutional/land use controls for the Building 834 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 and nitrate concentrations in ground water exceeding drinking water standards.	There are no existing or planned water-supply wells in the Building 834 OU. Any proposed well drilling activities would be submitted to the Site 300 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. Contamination is limited to onsite ground water and modeling indicates the plumes will not migrate offsite. 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 VOCs in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers.	Potential exposure to VOCs at depth in subsurface soil at the Building 834 Complex[a].	All proposed excavation activities must be cleared through the Site 300 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 Hazards Control Department ensures that hazards are adequately evaluated and necessary controls are 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 building occupancy restriction to prevent onsite worker inhalation exposure to VOCs inside Building 834D until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	A pre-remediation risk of 1×10^{-3} was identified for onsite workers from potential inhalation of VOCs volatilizing from subsurface soil into ambient air inside Building 834D.	Building 834D is not currently occupied. Warning signs are in place and will be maintained prohibiting full time occupancy without notification and authorization by LLNL Site 300 Management. Any significant changes in activities conducted in Building 834D must be cleared through the Site 300 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 building usage. If a potential for contaminant exposure is identified as a result of the changes in building use, the LLNL Hazards Control Department will be notified and any necessary engineered control requirements to prevent exposure will be determined. If full-time building occupancy is proposed, engineering controls will be implemented to prevent onsite worker exposure that could migrate from the subsurface into the building until the inhalation risk was mitigated through remediation. This building occupancy restriction will be incorporated into the LLNL Site 300 Integrated Strategic

Table 2. Description of institutional/land use controls for the Building 834 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
		Plan or other appropriate institutional planning documents. DOE will conduct annual risk re-evaluations to determine when the VOC inhalation risk inside Building 834D has been mitigated. The risk re-evaluation results will be reported in the Annual Site-Wide Compliance Monitoring Reports. The baseline risk assessment also identified a pre-remediation risk of 6×10^{-4} for onsite workers continuously inhaling VOC vapors volatilizing from the vadose zone into outdoor air in the vicinity of Building 834D over a 30-year period. However this risk has been successfully mitigated through ground water and soil vapor extraction and treatment, therefore institutional/land use controls are no longer needed to prevent onsite worker exposure to VOCs in outdoor air.
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.[b]	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 by the DOE, the U.S. EPA, DTSC, and the RWQCB agree the results show 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 documents.

Notes:

DOE = U.S. Department of Energy
DTSC = California Department of Toxic Substances Control
EPA = U.S. Environmental Protection Agency
LLNL = Lawrence Livermore National Laboratory
RWQCB = California Regional Water Quality Control Board
VOCs = Volatile organic compounds

[a] **Risk for onsite worker exposure to VOCs at depth in subsurface soil could not be re-calculated as there are no new subsurface soil data. Land use controls based on the potential exposure to VOCs in subsurface soil during ground-breaking construction activities conservatively assume that the VOCs in subsurface soil may pose a risk to human health.**

[b] **This prohibition will be codified in the Final Record of Decision.**

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