U.S. Department of Energy
National Nuclear Security Administration
Livermore Field Office, Livermore, California 94551

Lawrence Livermore National Laboratory
Lawrence Livermore National Security, LLC, Livermore, California 94551

LLNL-AR-682543-DRAFT

Draft Second Five-Year Review Report for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300

Authors:

J. McKaskey*
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L. Ferry
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Contributors:

D. Ardary*
G. Lorega
R. Villarreal*

February 2016

*Weiss Associates, Emeryville, California

Environmental Restoration Department

This work performed under the auspices of the U. S. Department of Energy/National Nuclear Security Administration by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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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.

Victor Madrid **Date**
California Registered Geologist
No. 5051
License expires: April 30, 2016
California Certified Hydrogeologist
No. 378
License expires: April 30, 2016

Approval for the Second Five-Year Review Report for the Building 832 Canyon Operable Unit Lawrence Livermore National Laboratory Site 300

Prepared by:

The United States Department of Energy
Livermore Field Office
Livermore, California

Approved:

____

Claire S. Holtzapple **Date**

Site 300 Remedial Project Manager
U.S. Department of Energy
National Nuclear Security Administration
Livermore Field Office

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name: Lawrence Livermore National Laboratory Site 300, Building 832 Canyon Operable Unit (OU) 7		
EPA ID: CA 2890090002		
Region: IX	State: California	City/County: San Joaquin/Alameda
SITE STATUS		
NPL status: Final		
Multiple OUs: No	Has the site achieved construction completion? Yes. Construction completion date: September 2007	
REVIEW STATUS		
Lead agency: United States (U.S.) Department of Energy (DOE)/National Nuclear Security Administration (NNSA)		
Author name: J. McKaskey		
Author title: Site 300 Project Hydrogeologist	Author affiliation: Weiss Associates Emeryville, California	
Review period: July 2010 to June 2015		
Date(s) of site inspections: October 22 and December 15, 2015		
Type of review: Statutory		
Review number: 2		
Triggering action date: Remedial Design for the Building 832 Canyon OU		
Due date: August 12, 2016 (Final)		

Five-Year Review Summary Form (continued)

<table>
<tr><th colspan="5">ISSUES/RECOMMENDATIONS</th></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">OU(s) without Issues/Recommendations Identified in the Five-Year Review:</td></tr>
<tr><td colspan="5">Not applicable.</td></tr>
<tr><td colspan="5">Issues/Recommendations Identified in the Five-Year Review:</td></tr>
<tr><td rowspan="3">OU(s):
Building 832 Canyon OU (7)</td><td colspan="4">Issue Category: No Issue</td></tr>
<tr><td colspan="4">Issue: Although no deficiencies or issues were identified with the Building 832 Canyon OU remedy, the following recommendations were developed to improve performance monitoring and demonstrate that the extraction wellfields are adequately capturing the highest contaminant of concern (COC) concentrations in addition to monitoring the leading edge of the plumes in the Tnsc$_{1a/b}$ and Upper Tnbs$_1$ hydrostratigraphic units (HSUs).</td></tr>
<tr><td colspan="4">Recommendation #1: Combining the Tnsc$_{1a}$ and Tnsc$_{1b}$ HSUs into one Tnsc$_{1a/b}$ HSU provides a more comprehensive assessment of ground water flow directions and spatial distribution of COC in the Building 832 Canyon OU, but also highlights areas where some additional ground water monitoring wells are needed. To address these needs, DOE/NNSA recommend installing a total of four new wells, one Upper Tnbs$_1$ HSU monitor well and three Tnsc$_{1a/b}$ monitor wells:
• The lateral extent of the Upper Tnbs$_1$ volatile organic compound (VOC) plume needs to be delineated south of the Building 832-SRC area. DOE/NNSA recommends installing one additional Upper Tnbs$_1$ monitor well between W-832-2906 and W-832-09 within the extent of saturation of the Upper Tnbs$_1$.
• To better delineate the lateral extent of saturation and distribution of high VOC concentrations southeast of the Building 832-source area in the Tnsc$_{1a/b}$ HSU, DOE/NNSA recommends installing a ground water monitor well along Route 1 south of Building 831.
• To better delineate the VOC plume in the Tnsc$_{1a/b}$ HSU, DOE/NNSA recommend installing two ground water monitor wells downgradient of the Building 830-source area; one monitor well located near Building 882 and the other located near Buildings 814 and 819 along Route 3.</td></tr>
<tr><td>Affect Current Protectiveness</td><td>Affect Future Protectiveness</td><td>Implementing Party</td><td>Oversight Party</td><td>Milestone Date</td></tr>
<tr><td>No</td><td>No</td><td>DOE</td><td>EPA/State</td><td>September 30, 2019*
* Milestone is contingent upon receiving adequate funding to drill in 2019.</td></tr>
</table>

Five-Year Review Summary Form (continued)

PROTECTIVENESS STATEMENT		
OU: The Building 832 Canyon OU (7)	**Protectiveness Determination:** Protective	**Addendum Due Date:** NA

Protectiveness Statement: The remedy at the Building 832 Canyon OU is protective of human health and the environment for the site's industrial land use. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of land use controls, the Health and Safety Plan, and the Contingency Plan.

The remedy protects human health because:

1. Ground water monitoring of volatile organic compounds (VOCs), perchlorate, and nitrate in Building 832 Canyon OU ground water will provide an early indication of changes in the concentrations and/or extent of these constituents that could impact human health or the environment. As indicated in the revised Compliance Monitoring Plan and Contingency Plan (Dibley et al., 2009b), if ground water contaminant concentrations (i.e. VOCs, perchlorate, and/or nitrate concentrations) in the Building 832 Canyon OU increase in a consistent and significant manner for reasons not attributable to remediation efforts (e.g., cyclic pumping), or natural aquifer or laboratory variables, DOE will notify the regulatory agencies and modifications to the remedial action will be considered as necessary to protect human health.
2. Ground water extraction and treatment continues to reduce VOC, perchlorate, and nitrate mass and concentrations in the Building 832 Canyon OU ground water towards cleanup standards, and prevent offsite plume migration.
3. Soil vapor extraction in the Building 832 and 830 source areas continues to reduce VOC mass and concentrations towards cleanup standards, preventing further contaminant releases through source control, and mitigating risk to human health and ecological receptors.
4. Monitored natural attenuation (MNA) has been effective in reducing nitrate concentrations in the Building 832 Canyon OU ground water towards the cleanup standard. Institutional controls described in Section 4.5.1.1 are in place to prevent exposure to nitrate in ground water at concentrations above cleanup standards.
5. No new contaminant releases have been identified for the Building 832 Canyon OU, and continued detection monitoring will provide an indication of any future releases.
6. Ground water monitoring will provide an early indication of migration of contaminants towards the site boundary.
7. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of land use/institutional controls, the Health and Safety Plan, and the Contingency Plan.

Five-Year Review Summary Form (continued)

PROTECTIVENESS STATEMENT (continued)		
OU: The Building 832 Canyon OU (7)	**Protectiveness Determination:** Protective	**Addendum Due Date:** NA

The cleanup standards for Building 832 Canyon OU ground water are Maximum Contaminant Levels (MCLs). Because MCL-based standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario.

The 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 cleanup standards, a land use control prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. The Site 300 Federal Facility Agreement (FFA) prohibits DOE from transferring lands with unmitigated contamination that could cause potential harm unless it complies with the requirements of Section 120(h) of CERCLA, 42 U.S.C. 9620(h) and requirements for notification and protection of the integrity of the remedy set forth in Section 28 of the FFA. 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 (CCR) Division 4.5, Chapter 39, Section 67391.1 as specified in the Site 300 Site-Wide Record of Decision (ROD), and will implement deed restrictions per CERCLA 120(h). These land use controls will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and the DOE/NNSA, U.S. EPA, Department of Toxic Substances Control (DTSC), and Regional Water Quality Control Board (RWQCB) agree that it adequately shows that no unacceptable risk is present for residential or unrestricted land use.

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1. Introduction

The United States (U.S.) Department of Energy/National Nuclear Security Administration (DOE/NNSA) has conducted a five-year review of the remedial actions implemented at the Building 832 Canyon Operable Unit (OU) 7 at Lawrence Livermore National Laboratory (LLNL) Site 300. (OU 7 is hereafter referred to as the Building 832 Canyon OU.) Environmental cleanup is conducted under the oversight of the U.S. Environmental Protection Agency (U.S. EPA), the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) – Central Valley Region. DOE is the lead agency for environmental restoration at LLNL. The review documented in this report was conducted from July 1, 2010 to June 30, 2015. Parties providing analyses in support of the review include:

- DOE/NNSA, Livermore Field Office.
- LLNL, Environmental Restoration Department (ERD).
- Weiss Associates.

The purpose of a five-year review is to evaluate the implementation and performance of a remedy to determine whether the remedy is currently protective and will continue to be protective of human health and the environment. The five-year review report presents the methods, findings, and conclusions of the review. In addition, the five-year review identifies issues or deficiencies in the selected remedy, if any, and presents recommendations to address them. The format and content of this document is consistent with guidance issued by DOE (U.S. DOE, 2002) and the U.S. EPA (U.S. EPA, 2001).

DOE is preparing this five-year review for the Building 832 Canyon OU pursuant to Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment Reauthorization Act (SARA), which requires that remedial actions resulting in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a five-year review. The National Contingency Plan 40 Code of Federal Regulations Section 300.430(f)(4)(ii) 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, Federal agencies are responsible for ensuring that five-year reviews are conducted at sites where five-year reviews are required or appropriate.

LLNL Site 300 is a DOE/NNSA experimental test facility currently operated by the Lawrence Livermore National Security (LLNS), Limited Liability Corporation. It is located in the Eastern Altamont Hills 17 miles east of Livermore, California (Figure 1). At Site 300, DOE/NNSA conducts research development, and testing associated with high explosive materials. Historic Site 300 operations involved the release of a number of contaminants to the environment. Nine Operable Units (OUs) have been designated at LLNL Site 300 based on the nature and extent of contamination to effectively manage site cleanup (Figure 2):

- General Services Area (GSA) (OU 1) including the Central and Eastern GSA.
- Building 834 (OU 2).
- Pit 6 Landfill (OU 3).

- High Explosives (HE) Process Area (OU 4) including Building 815, the HE Lagoons, and the HE Burn Pit.
- Building 850/Pit 7 Complex (OU 5).
- Building 854 (OU 6).
- Building 832 Canyon (OU 7) including Buildings 830 and 832.
- Site-Wide (OU 8) including Buildings 801, 833, 845, and 851 and the Pit 2, 8, and 9 Landfills.
- Building 812 (OU 9).

Five-year reviews are currently conducted individually for each OU at Site 300, except for OUs 3 and 8. The Remedial Design Report for the Building 832 Canyon OU (Madrid et al., 2006) completed in February 2006 was the trigger for the start of the first five-year review period for the Building 832 Canyon OU, in accordance with U.S. EPA guidance (U.S. EPA, 2001). At the other OUs where construction began prior to the Site-Wide Record of Decision (ROD) as treatability studies and/or removal actions, DOE and the regulatory agencies agreed to use the completion of the OU-specific Remedial Design report as the trigger for start of the first five-year review period.

This is the Second Five-Year Review for the Building 832 Canyon OU. This review is considered a statutory review because: (1) contamination will remain onsite upon completion of the remedial action, (2) the Record of Decision was signed after October 17, 1986 (the effective date of the SARA), and (3) the remedial action was selected under the CERCLA.

The first Five-Year Review for the Building 832 Canyon OU was completed in August 2011 (Helmig et al., 2011). No deficiencies that affect the protectiveness of the remedy for the Building 832 Canyon OU were identified in that review.

Section 1.1 through 1.9 include the descriptions and status of the other OUs and areas where environmental restoration activities are occurring at Site 300. Section 2 presents the chronology of significant environmental restoration events at the Building 832 Canyon OU. Section 3 presents background and description for the Building 832 Canyon OU. Section 4 discusses remedial actions selected and implemented in the Building 832 Canyon OU, and progress towards meeting remedial action objectives and cleanup standards. Section 5 discusses remediation progress since the last (2011) Five-Year Review for the Building 832 Canyon OU. Sections 6 and 7 provide a discussion of the five-year review process and the technical assessment of the remedy function and protectiveness, respectively. Section 8 presents issues identified during the review process and Section 9 provides recommendations to address those issues. Section 10 summarizes the protectiveness of the remedy for the Building 832 Canyon OU.

1.1. General Services Area

The GSA OU has been separated into the Central GSA and the Eastern GSA based on differences in hydrogeology and the distribution of environmental contaminants. DOE has performed three Five-Year Reviews for the GSA OU (Ferry et al., 2001a; Dibley et al., 2006; and Valett et al., 2011). The Third Five-Year Review for the GSA determined that additional offsite land use controls are necessary for long-term protectiveness due to the presence of contamination in offsite ground water. The Fourth Five-Year Review is scheduled for 2016.

1.1.1. Central GSA

Chlorinated solvents, mainly trichloroethene (TCE), were used as degreasing agents in craft shops in the Central GSA. Rinse water from these degreasing operations was disposed of in dry wells that were gravel-filled holes about 3 to 4 feet (ft) deep and two ft in diameter. As a result, subsurface soil and ground water was contaminated with volatile organic compounds (VOCs). There are no contaminants of concern (COCs) in surface soil in the central GSA. The Central GSA dry wells were used until 1982. In 1983 and 1984, these dry wells were decommissioned and excavated.

Ground water cleanup began in the Central GSA in 1992 and soil vapor extraction started in 1994 as removal actions. In 1997, a Final ROD for the GSA OU (U.S. DOE, 1997) was signed and ground water and soil vapor extraction and treatment continued as a remedial action. The selected remedy for the Central GSA includes monitoring, risk and hazard management including land use controls, and ground water and soil vapor extraction and treatment. The remedial design was completed in 1998 and construction completion for the OU was achieved in September 2005.

Operation of the ground water and soil vapor extraction and treatment systems to remove VOCs from the subsurface is ongoing. Remediation has reduced maximum VOC concentrations in ground water from a historic maximum of 272,000 micrograms per liter (µg/L) (March 1992) to a 2014 maximum of 364 µg/L (April 2014) and has mitigated the risk to onsite workers from inhalation of VOCs inside Building 875.

1.1.2. Eastern GSA

The sources of contamination in the Eastern GSA are debris burial trenches that received craft shop debris that contained solvent residue. Leaching of solvents from the debris resulted in the release of VOCs to ground water.

Ground water cleanup began in the Eastern GSA in 1991 as a removal action. In 1997, a Final ROD for the GSA OU was signed and ground water extraction and treatment continued as a remedial action. The remedial design was completed in 1998 and construction completion for the OU was achieved in September 2005. A ground water extraction and treatment system operated from 1991 to 2007 to remove VOCs from ground water.

By 2005, VOC concentrations in both onsite and offsite ground water in the Eastern GSA area had been reduced to below the drinking water Maximum Contaminant Level (MCL) cleanup standards. In February 2007, the ground water extraction and treatment system was shut down with regulatory concurrence. DOE/NNSA continued to monitor ground water for five years, during which time VOC concentrations remained below the cleanup standards, indicating that ground water cleanup had been successfully completed in the Eastern GSA. A Draft Close-out Report for the Eastern GSA was submitted to the regulatory agencies in December 2012 (Dibley and Ferry, 2012a). At the regulatory agencies request, additional characterization activities were conducted in 2014 to determine if polychlorinated biphenyls (PCBs,) semi-volatile organic compounds, and polycyclic aromatic hydrocarbons are present in subsurface soil in the Eastern GSA debris burial trench area. Per regulatory agreement, the results of these characterization activities will be presented in a Technical Memorandum in early 2016.

1.2. Building 834 (OU2)

From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface soil and rock and ground water with VOCs and silicone oils (tetrabutyl orthosilicate/tetrakis (2-ethylbutyl) silane [TBOS/TKEBs]). Nitrate in ground water results from septic system effluent but may also have natural sources. There are no COCs in surface soil.

Completed remedial activities include excavating VOC-contaminated soil (1983) and installing a surface water drainage system to prevent rainwater infiltration in the contaminant source area (1998). Ground water and soil vapor extraction and treatment began in 1986 as treatability studies. An area-specific Interim ROD for the Building 834 OU (U.S. DOE, 1995) was superseded by the Interim Site-Wide ROD (U.S. DOE, 2001) and subsequent 2008 Site-Wide ROD (U.S. DOE, 2008). The Building 834 OU remedy includes monitoring, risk and hazard management including land use controls, and ground water and soil vapor extraction and treatment. Significant *in situ* bioremediation is occurring in Building 834 ground water and a treatability study was conducted that focused on understanding and enhancing this process. The remedial design was completed in 2002 and construction completion for the OU was achieved in September 2005.

Remediation has reduced VOC concentrations in ground water from a historic maximum of 1,100,000 µg/L (March 1988, W-834-D5) to a 2014 maximum of 180,000 µg/L (February 2014, W-834-A1). TBOS/TKEBs in ground water have also been reduced from a historic maximum concentration of 7,300,000 µg/L in 1995 to a most recent maximum of 91 µg/L (August 2014). While nitrate concentrations have decreased from a historic maximum of 749 milligrams per liter (mg/L) in 2000 to a 2014 maximum of 300 mg/L (February 2014, W-834-M1), the elevated nitrate concentrations continue to indicate an ongoing source of ground water nitrate. Sources of nitrate at Building 834 include the septic system leach field located in the vicinity of wells W-834-S1, and naturally occurring nitrate in soil. Nitrogenous compounds, like nitric acid or barium nitrate, might also have inadvertently been discharged into the septic system via a test cell floor drain. Anaerobic bacteria in the Building 834 Core and T2 areas reduce nitrate locally by denitrification.

DOE has performed three Five-Year Reviews for the Building 834 OU (Ferry et al., 2002a, Dibley et al., 2007a, and Valett et al., 2012). No deficiencies that affect the protectiveness of the remedy for the Building 834 OU were identified in the last (Third) Five-Year Review in 2012. The next (Fourth) Five-Year Review Report is scheduled for 2017.

1.3. Pit 6 Landfill (OU3)

From 1964 to 1973, approximately 1,900 cubic yards (yd^3) of waste from LLNL Livermore Site and Lawrence Berkeley Laboratory were buried in nine unlined trenches and animal pits at the Pit 6 Landfill. Infiltrating rainwater leached contaminants from pit waste resulting in tritium, VOC, and perchlorate contamination in ground water. Nitrate contamination in ground water results from septic system effluent. No COCs were identified in surface or subsurface soil.

In 1971, DOE excavated portions of the waste contaminated with depleted uranium. From 1973 to 1997, no waste was placed in the Pit 6 Landfill. In 1997, a landfill cap was installed as a CERCLA removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of decreasing VOC concentrations in ground water, the presence of TCE degradation products, and the short half-life of tritium (12.3 years), the selected remedy for

VOCs and tritium at the Pit 6 Landfill is monitored natural attenuation (MNA). Because ground water monitoring data for perchlorate and nitrate were limited, DOE/NNSA continued to monitor ground water to determine if and when an active remedy for these contaminants might be necessary. The remedy also includes risk and hazard management. Construction completion was achieved in October 2002. No remedial design document was required for this area.

The extent of contamination at the Pit 6 Landfill is limited and continues to decrease with concentrations/activities near and below cleanup standards. Natural attenuation has reduced total VOCs in ground water from a historic maximum of 250 µg/L in 1988 to a 2014 maximum of 5.2 µg/L (January 2014), consisting entirely of TCE. Tritium activities are well below the cleanup standard and continue to decrease towards background levels. Perchlorate has not been detected in any wells above the 4 µg/L reporting limit since 2011. The extent of nitrate at concentrations exceeding the cleanup standard continues to be limited to one well located near a septic system. Installation of the landfill cap mitigated the onsite worker inhalation risk. There is no evidence of new contaminant releases from the Pit 6 Landfill indicated by the ground water detection monitoring data.

DOE has performed one five-year review for this OU in 2013 (Buscheck et al., 2013). In the 2013 Five-Year Review, the regulatory agencies agreed to remove 1,2-dichloroethane, cis- and trans-1,2-dichloroethene (DCE), tetrachloroethene (PCE), 1,1,1 trichloroethane, and perchlorate as COCs in Pit 6 Landfill OU ground water because concentrations of these COCs had decreased to and have remained below their cleanup standard and/or reporting limit in all Pit 6 wells for at least 4 years and up to 21 years.

1.4. High Explosives (HE) Process Area (OU4)

From 1958 to 1986, surface spills at the drum storage and dispensing area for the former Building 815 steam plant resulted in the release of VOCs to ground water, subsurface soil, and bedrock. HE compounds, nitrate, and perchlorate detected in ground water are attributed to wastewater discharges to former unlined rinse water lagoons that occurred from the 1950s to 1985. VOCs, nitrate, and perchlorate have also been identified as COCs in ground water near the former HE Burn Pits. VOCs have been identified as COCs in surface water at Spring 5. HE compounds are the COCs in surface soil. HE compounds and VOCs are the COCs in subsurface soil. No further action was selected as the remedy for VOCs and High-Melting Explosive (HMX) in surface and subsurface soil.

The HE Open Burn Facility was capped under the Resource Conservation and Recovery Act (RCRA) in 1998. In 1999, DOE implemented a CERCLA removal action to extract ground water at the site boundary and prevent offsite TCE migration. The HE Process Area remedy selected in the Site-Wide ROD includes: (1) ground water extraction and treatment for VOCs, HE compounds, and perchlorate, and (2) MNA for nitrate (except at Building 829 where nitrate is extracted and treated), (3) monitoring, and (4) risk and hazard management including land use controls. The remedial design was completed in 2002. Construction completion for the OU was achieved in September 2007. Five ground water extraction and treatment systems currently operate in the OU. In 2013, use of the 829-Source ground water treatment system was discontinued due to intermittent flow and very low production. Ground water extracted from the Building 829 source area is stored and transported to the 815-Source facility for treatment.

Ground water remediation efforts have reduced total VOC concentrations from a historic maximum of 1,013 µg/L in 1993 to a 2014 maximum of 40 µg/L (March 2014). Perchlorate concentrations have decreased from a historic maximum of 50 µg/L in 1998 to a 2014 maximum of 29 µg/L (July 2014). Research Department Explosive (RDX) in ground water has been reduced from a maximum historic concentration of 350 µg/L in 1988 to a 2014 maximum of 87 µg/L (March 2014). Natural denitrification processes are reducing nitrate concentrations in ground water to background levels. Remediation has also mitigated risk to onsite workers in the HE Process Area OU.

DOE has performed two Five-Year Reviews for the High Explosives Process Area OU (Dibley et al., 2007b and Helmig et al., 2012). The Second Five-Year Review for the High Explosives Process Area determined that additional offsite land use controls are necessary for long-term protectiveness due to the presence of contamination in offsite ground water. The next (Third) Five-Year Review Report is scheduled for 2017.

1.5. Building 850/Pit 7 Landfill Complex (OU5)

This OU has been divided into two areas for cleanup purposes: (1) the Building 850 Firing Table area, and (2) the Pit 7 Landfill Complex.

A Remedial Action Completion Report for the Building 850/Pit 7 Landfill Complex OU was completed in 2011 (Dibley et al., 2011b). The First Five-Year Review Report for this OU is scheduled for completion in 2016.

1.5.1. Building 850 Firing Table

High-explosives experiments were conducted at the Building 850 Firing Table from 1958 to 2008. Tritium was used in some of these experiments, primarily between 1963 and 1978. As a result of the destruction and dispersal of test assembly debris during detonations, surface soil was contaminated with metals, polychlorinated biphenyls (PCBs), dioxins, furans, HMX, and depleted uranium. Leaching from firing table debris has resulted in tritium and depleted uranium contamination in subsurface soil and ground water. Nitrate and perchlorate are also COCs in ground water. Tritium is the only COC in surface water (Well 8 Spring).

Gravel was removed from the firing table in 1988 and placed in the Pit 7 Landfill. PCB-contaminated shrapnel and debris were removed from the area around the firing table in 1998. The Building 850 remedy consists of MNA of tritium in ground water, monitoring, and risk and hazard management including land use controls. A remedial design was completed in 2004. The remedial design included the excavation and off-site disposal of contaminated surface soil and sand pile. This remedy was not implemented due to a large increase in transportation and offsite disposal costs. DOE and the regulatory agencies agreed to perform remediation of contaminated surface soil as a non-time critical removal action. An Engineering Evaluation/Cost Analysis (Dibley et al., 2008a) and Action Memorandum (Dibley et al., 2008b) were completed in 2008. A removal action was completed in 2010 for the excavation and solidification of PCB-, dioxin-, and furan-contaminated soil and sand pile. Metals, HMX, and uranium in surface soil at Building 850 do not pose a risk to human health or threat to ground water, therefore a no further action remedy was selected. However, these constituents in surface soil were removed during the soil excavation/solidification removal action.

Natural attenuation has reduced tritium activities from a historic maximum of 566,000 picocuries per liter (pCi/L) in 1985 to a 2014 maximum of 25,100 pCi/L (April, well NC7-70). Uranium activities are below the cleanup standard and are within the range of natural background levels. The extent of nitrate with concentrations above cleanup standards is limited and does not pose a threat to human health or the environment. The maximum perchlorate concentration in 2014 was 44 µg/L (March and August, well NC7-61). A treatability study to evaluate *in situ* biodegradation of perchlorate is in progress.

In the November 20, 2014 Remedial Project Manager's (RPM) Meeting, DOE/LLNL presented a summary and review of the Building 850 source area site conceptual model and site characterization data for perchlorate. One of the objectives of the presentation was to identify and discuss any outstanding perchlorate characterization issues or data gaps that the regulatory agencies might have before proceeding with the Focused Remedial Investigation/Feasibility Study (RI/FS) for perchlorate at Building 850. The regulatory agencies agreed that characterization was adequate to proceed with the Focused RI/FS for perchlorate in ground water at Building 850 with the exception of the need for additional characterization of perchlorate in soil and ground water directly beneath the firing table. The U.S. EPA, California DTSC, and the RWQCB requested additional subsurface soil and ground water sampling directly beneath the firing table to determine if a significant source of perchlorate was present in the vadose zone that would pose a continued threat to ground water. Although HE compounds were not identified as COCs in the 2008 Site-Wide ROD, RDX and HMX were more recently detected in Building 850 ground water and were evaluated as part of the recent (First) Five-Year Review process for the Building 850 area. DOE recommended sampling of subsurface soil and ground water samples from boreholes drilled in the Building 850 Firing Table for HE compound analysis.

A Final Work Plan for the sampling of subsurface soil and ground water for perchlorate and HE compound analysis at the Building 850 Firing Table for perchlorate analysis was submitted to the regulatory agencies in September 2015. This sampling effort was completed in the fall of 2015. The results of this subsurface soil sampling effort were presented to the regulators at the December 1, 2015 RPM meeting. The regulators agreed that the characterization of perchlorate (and HE compounds) at the Building 850 Firing Table was complete, and that DOE could proceed with preparing the Focused RI/FS for perchlorate.

1.5.2. Pit 7 Landfill

The Pit 3, 4, 5, and 7 Landfills collectively comprise the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits between 1958 and 1988. The Pit 4 and 7 Landfills were capped in 1992. The cap also covers about 30% of Pit 3. During years of above-normal rainfall (i.e., 1997-1998 El Niño event), ground water rose into the bottom of the landfills and the underlying contaminated bedrock. This resulted in the release of tritium, uranium, VOCs, perchlorate, and nitrate to ground water. There are no COCs in surface water or surface soil. Tritium and depleted uranium are COCs in subsurface soil.

DOE and the regulatory agencies agreed that the Pit 7 Landfill Complex required additional study. As a result, this area was not included in the 2001 Interim ROD and an area-specific Remedial Investigation/Feasibility Study (Taffet et al., 2005) was completed. An Amendment to the Interim ROD for the Pit 7 Landfill Complex was signed in 2007 (U.S. DOE, 2007) that described the selected remedy for the Pit 7 Landfill Complex including monitoring, risk and hazard management including land use controls, MNA, ground water extraction and treatment, and source control. The interim remedial design was completed in 2008. Construction of a drainage diversion system, designed to divert recharge away from the pits and minimize water table rises during intense rainfall events, was completed in 2008. Also, a ground water extraction and treatment system was constructed in 2009-2010 to treat uranium, nitrate, perchlorate, and VOCs in ground water.

Natural attenuation has reduced tritium activities in ground water from a historic maximum of 2,660,000 pCi/L in 1998 to a 2014 maximum of 182,000 pCi/L (October, well NC7-25), and has mitigated risk to onsite workers from inhalation of tritium vapors. Uranium activities have also decreased from a historic maximum of 781 pCi/L in 1998 to a 2014 maximum of 109 pCi/L (April, W-Pit7-2703). VOC concentrations are currently near or below cleanup standards. Nitrate concentrations in ground water remain relatively stable, from a historic maximum of 90 mg/L in 2011 (well NC7-63) to a 2014 maximum of 66 mg/L (May, well NC7-47). Perchlorate concentrations have decreased from a historic maximum of 40 µg/L in 2009 (W-Pit7-2306) to a 2014 maximum of 14 µg/L (April, W-Pit7-2305).

1.6. Building 854 (OU6)

TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid, primarily between 1967 and 1984. Nitrate and perchlorate are also COCs in ground water. HE compounds (HMX), PCBs, dioxins, furans, tritium, and metals were identified as COCs in surface soil. No further action was selected as the remedy for metals, HMX, and tritium in surface soil.

In 1983, TCE-contaminated soil was excavated at the northeast corner of Building 854F. Ground water extraction and treatment has been conducted since 1999 to reduce VOC, nitrate, and perchlorate concentrations in ground water. PCB-, dioxin-, and furan-contaminated soil in the Building 855 former rinse water lagoon was excavated in 2005 (Holtzapple, 2005). The remedy selected for this OU in the Site-Wide ROD includes monitoring, risk and hazard management including land use controls, and ground water and soil vapor extraction and treatment. The remedial design was completed in 2003. Construction completion for the OU was achieved in September 2007. Three ground water extraction and treatment systems and one soil vapor extraction and treatment system currently operate in the OU.

Ground water remediation has reduced total VOC concentrations from a historic maximum of 2,900 µg/L in 1997 to a 2014 maximum of 92 µg/L (February). Nitrate concentrations have decreased from a historic maximum of 260 mg/L in 2003 to a 2014 maximum of 130 mg/L (May). Perchlorate concentrations in ground water have also decreased from 27 µg/L in 2003 to a 2014 maximum of 15 µg/L (May). Risks to onsite workers from inhalation of VOC vapors and from exposure to PCBs, dioxins, and furans in surface soil have been mitigated.

DOE has performed two Five-Year Reviews for the Building 854 OU in 2009 and 2014 (Dibley et al., 2009a and Valett et al., 2014). No deficiencies that affect the protectiveness of the remedy for the Building 854 OU were identified in the last (Second) Five-Year Review in 2014. The next (Third) Five-Year Review Report is scheduled for 2019.

1.7. Site-Wide (OU8)

Operable Unit 8 includes the contaminant release sites that have a monitoring-only remedy: the Building 801 Dry Well and Pit 8 Landfill, Building 833, Building 845 and Pit 9 Landfill, the Building 851 Firing Table, and the Pit 2 Landfill. OU 8 release sites have a monitoring-only remedy because either: (1) contaminants in surface and subsurface soil/bedrock do not pose a risk to humans or plant and animal populations or a threat to ground water, (2) there is no ground water contamination, (3) contaminant concentrations in ground water do not exceed cleanup standards, and/or (4) the extent of contamination in ground water is limited. These release sites are summarized below.

DOE has performed one Five-Year Review for this OU in 2013 (Buscheck et al., 2013). No deficiencies that affect the protectiveness of the remedy for the Site-Wide OU were identified in the last (First) Five-Year Review in 2013. In the 2013 Five-Year Review, the regulatory agencies agreed to remove cis-1,2-DCE as a ground water COC at Building 833 because: (1) cis-1,2-DCE has only been detected in one well (W-833-12) and cis-1,2-DCE concentrations in this well decreased to and have remained below the 0.5 µg/L reporting limit since April 1993; and (2) cis-1,2-DCE has never been detected above the 0.5 µg/L reporting limit in any other area well, including well W-833-30, screened in the deeper $Tnbs_1$ HSU.

1.7.1. Building 801 Dry Well and the Pit 8 Landfill (OU8)

The Building 801 Firing Table was used for explosives testing and operations resulting in contamination of adjacent soil with metals and uranium. Use of this firing table was discontinued in 1998, and the firing table gravel and some underlying soil were removed. Waste fluid was discharged to a dry well (sump) located adjacent to Building 801D from the late 1950s to 1984. The dry well was decommissioned and filled with concrete in 1984. VOCs, perchlorate and nitrate are COCs in ground water due to the past releases from the Building 801 Dry Well. VOC concentrations in ground water are currently near or below cleanup standards. Nitrate concentrations in ground water currently exceed the cleanup standard in two wells. Perchlorate is not currently detected in ground water. VOCs are COCs in subsurface soil, but do not pose a risk to human health. The adjacent Pit 8 Landfill received debris from the Building 801 Firing Table until 1974, when it was covered with compacted soil. There is no evidence of contaminant releases from the landfill.

The remedy selected for this area in the Site-Wide ROD includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy for VOCs in subsurface soil at Building 801.

No remedial design documents were required for this area.

1.7.2. Building 833 (OU8)

TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinse water disposal, resulting in TCE-contamination of subsurface soil and shallow perched ground water. No contamination has been detected in the deeper regional aquifer. No COCs were identified in surface soil at Building 833.

The selected remedy for Building 833 includes monitoring and risk and hazard management including land use controls. No remedial design document was required for this area. Ground water monitoring at Building 833 has shown a decline in total VOC concentrations from a historic maximum of 2,100 µg/L in 1992 to a 2014 maximum of 110 µg/L.

1.7.3. Building 845 Firing Table and the Pit 9 Landfill (OU8)

The Building 845 Firing Table was used from 1958 until 1963 to conduct explosives experiments. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and HMX but no unacceptable risk to human or ecological receptors or threat to ground water was identified. No contaminants have been detected in surface soil or in ground water at the Building 845 Firing Table. Debris generated at the Building 845 Firing Table was buried in the Pit 9 Landfill. There has been no evidence of contaminant releases from the Pit 9 Landfill.

The remedy selected for Building 845 and the Pit 9 Landfill in the Site-Wide ROD includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy for uranium and HMX in subsurface soil at Building 845. No remedial design document was required for this area.

1.7.4. Building 851 Firing Table (OU8)

The Building 851 Firing Table has been used for high-explosives research since 1962. VOCs and uranium-238 were identified as COCs in subsurface soil, and RDX, uranium-238, and metals as surface soil COCs. However, no risk to humans or animal populations, or threat to ground water associated with these contaminants in surface and subsurface soil was identified in the baseline risk assessment. Uranium-238 was identified as a COC in ground water. However, it poses no risk to human or ecological receptors, and uranium activities remain well below cleanup standards and within the range of background levels.

In 1988, the firing table gravel was removed and disposed in Pit 7. Gravel has been replaced periodically since then. The remedy selected for Building 851 in the Site-Wide ROD includes monitoring and risk and hazard management including land use controls. No further action was selected as the remedy for VOCs and uranium in surface and subsurface soil, and for RDX and metal in surface soil at Building 851. No remedial design document was required for this area.

In 2014, DOE/NNSA identified the need for additional investigation of uranium-238 in surface soil at the Building 851 Firing Table to determine if the results of the baseline risk assessment are still valid, given the ongoing use of the firing table after the remedial investigation was completed.

1.7.5. Pit 2 Landfill (OU8)

The Pit 2 Landfill was used from 1956 until 1960 to dispose of firing table debris from Buildings 801 and 802. Ground water data indicate a discharge of potable water conducted from 1996 to 2005 to support a red-legged frog habitat located upgradient from the landfill may have leached depleted uranium from the buried waste. The frogs were relocated and the water discharge was discontinued, thereby removing the leaching mechanism. No contaminants were identified in surface or subsurface soil at the Pit 2 Landfill. No risk to human or ecological receptors has been identified at the Pit 2 Landfill.

The remedy selected for the Pit 2 Landfill in the Site-Wide ROD includes monitoring and risk and hazard management including land use controls. Monitoring data indicate that uranium activities remain below the cleanup standard. There is no evidence of new contaminant releases from the Pit 2 Landfill indicated by the ground water detection monitoring data. No remedial design document was required for this area.

1.8. Building 812 (OU9)

The Building 812 Complex was built in the late 1950s-early 1960s and was used to conduct explosives tests and diagnostics until 2008. A Characterization Summary Report for this area was completed in 2005 (Ferry and Holtzapple, 2005). The Building 812 Complex was designated as OU 9 in March 2007 based on characterization results that indicated the presence of uranium, VOCs, HE compounds, nitrate, and perchlorate in environmental media. In 2008, a draft RI/FS describing the results of characterization activities and remedial alternatives for the

Building 812 OU (Taffet et al., 2008) was submitted to the regulatory agencies and a DOE task force. The DOE task force recommended additional characterization be performed at the OU and the regulatory agencies agreed. Additional characterization began in 2011 and is ongoing. A Final Work Plan for the sampling of surface soil in the Building 812 Firing Table area for PCB and HE compound analysis was submitted to the regulatory agencies on September 1, 2015. This sampling effort was completed in the fall of 2015. A revised RI/FS report will be prepared once the regulatory agencies concur that characterization is complete at the Building 812 OU. A Proposed Plan will subsequently present the alternatives and a preferred remedy for public comment. A remedy will then be selected in an Amendment to the Site-Wide ROD.

1.9. Building 865/Advanced Test Accelerator

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. In 2006, a Characterization Summary Report for this area was submitted to the regulatory agencies (Ferry and Holtzapple, 2006). Freon 113, Freon 11, and PCE were identified as COCs in ground water. However, concentrations of Freon 11 and Freon 113 are well below their MCLs; and PCE is only detected in one well at a concentration slightly above its 5 µg/L MCL (6.6 µg/L in well W-865-2004 in January 2014). In July of 2014, DOE/NNSA agreed to conduct additional characterization at Building 865 to add to the degree of certainty that residual contamination is not present in some areas where soil was previously characterized and/or excavated. A Final Work Plan for the sampling of subsurface soil at the Oil Conditioning System, Storm Drain Outfall, and former Surface Impoundment locations for VOCs and semivolatile organic compounds (SVOCs) analysis was submitted to the regulatory agencies in August 2015. This sampling effort was completed in the fall of 2015. An RI/FS report will be prepared once the regulatory agencies concur that characterization is complete in the Building 865 area. A Proposed Plan will subsequently present the alternatives and a preferred remedy for public comment. A remedy will then be selected in an Amendment to the Site-Wide ROD.

2. Site Chronology

A chronology of important environmental restoration events at the Building 832 Canyon OU is summarized below.

<u>1950s–1960s</u>

- The Building 830 and 832 Complexes were used to test the stability of weapon components under various environmental conditions.

<u>1985</u>

- Testing at the Building 830 and 832 Complexes was discontinued.

<u>1990</u>

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

<u>1992</u>

- A Federal Facility Agreement for Site 300 was signed.

<u>1996</u>

- The Building 832 Canyon Study Area Fact Sheet (Ziagos and Sutherland, 1996) was issued. This Fact Sheet summarized the historical operations, use, and chemical releases in the OU, as well as plans for additional investigations.

<u>1997</u>

- The Building 832 Canyon Operable Unit Characterization Summary letter report was issued (Ziagos and Ko, 1997).

<u>1999</u>

- The Site-Wide Feasibility Study (Ferry et al., 1999) for Site 300 was issued that included the Building 832 Canyon OU.
- The Building 832-Source (832-SRC) ground water and soil vapor extraction and treatment facility began operating.

<u>2000</u>

- The Building 830-Proximal North (830-PRXN) ground water extraction and treatment facility began operating.
- The Building 830-Distal South (830-DISS) ground water extraction and treatment facility began operating.

<u>2001</u>

- An Interim Site-Wide ROD for Site 300 was signed (U.S. DOE, 2001). The Interim Site-Wide ROD specified no further action for: (1) HMX in surface soil and nitrate in subsurface soil and bedrock at Building 830, and (2) HMX and nitrate in soil and bedrock at Building 832. Soil vapor and ground water extraction and treatment, ground water monitoring, and administrative controls (i.e., risk and hazard management) were also selected as components of the remedy for the Building 832 Canyon OU.
- 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.

<u>2002</u>

- The Compliance Monitoring Plan/Contingency Plan for Interim Remedies was issued (Ferry et al., 2002b).

<u>2003</u>

- The Building 830-Source (830-SRC) ground water and soil vapor extraction and treatment facility began operating.

<u>2004</u>

- A risk evaluation performed for the 2004 Annual Compliance Monitoring Report (Dibley et al., 2005) indicated no further onsite worker risk from the inhalation of VOCs volatilizing from the subsurface into outdoor air in the vicinity of Building 830 and indoor air inside Building 832F.

<u>2005</u>

- The Building 832-Source ground water extraction wellfield was expanded into the downgradient portion of the contaminant plumes.

- Building 832F was decontaminated and demolished.

2006

- The Building 832 Canyon Interim Remedial Design Report was submitted to the regulatory agencies (Madrid, et al., 2006).
- Use of 830-PRXN treatment facility was discontinued. Additional extraction wells were connected to 830-SRC treatment facility and the 830-PRXN treatment unit was removed.

2007

- Modifications were performed on the 830-DISS to remove the bioreactor and granular activated carbon (GAC) components. A pipeline was built to convey VOC-bearing water from the 830-DISS extraction wells to the Central GSA ground water treatment system for removal of the VOCs.
- Construction of the interim remedy was completed.

2008

- The EPA performed the OU construction completion inspection.
- The Site-Wide ROD with selected remedies and cleanup standards for Site 300, including the Building 832 Canyon OU, was signed (U.S. DOE, 2008). The remedy for the Building 832 Canyon OU did not change between the 2002 and 2008 Site-Wide ROD, with the exception that: (1) ground water cleanup standards were added in the 2008 Site-Wide ROD, and (2) the remedy for nitrate in ground water changed from extraction and treatment to monitored natural attenuation.

2009

- The revised Compliance Monitoring Plan/Contingency Plan for Interim Remedies was issued (Dibley et al., 2009b).
- Two 830-SRC ground water extraction wells were converted to monitor wells due to lack of water.

2010

- Modifications were performed on the 830-SRC treatment facility to allow extracted ground water from high-flow extraction wells with perchlorate concentrations below the 4 µg/L reporting limit to bypass the ion-exchange treatment columns. These modifications decreased backpressure, allowing the extraction well pumps to operate more effectively, thereby improving the long-term performance of the treatment facility.
- One new guard well, W-830-2610, was installed in the $Tnsc_{1a}$ HSU near the site boundary.

2011

- As recommended in the 2011 (First) Five-Year Review (Helmig et al., 2011), a downgradient $Tnsc_{1a}$ well, W-830-2701, was installed to increase hydraulic capture in the $Tnsc_{1a}$ HSU downgradient of extraction well W 830-2214. The decision whether to connect it as an extraction well to the 830-SRC treatment facility was to be made after hydraulic testing is conducted in 2013.

2012

- A new monitor well, W-830-2806, was installed southwest of the Building 830 source area and on the other side of Building 832 Canyon in the $Tnsc_{1a}$ HSU to better delineate VOCs in the $Tnsc_{1a}$ HSU southwest of the Building 830 source area to fulfill a recommendation from the Building 832 Canyon OU Five-Year Review report.

2013

- After conducting the step-drawdown hydraulic test on downgradient $Tnsc_{1a}$ well, W-830-2701, the decision was made to connect this well to the 830-SRC ground water extraction and treatment facility in 2014.
- A new Upper $Tnbs_1$ monitor well, W-832-2906, was installed downgradient of the Building 832 source area and to the north of extraction well W-830-57 to determine the extent of TCE in the Upper $Tnbs_1$ HSU upgradient of the Building 830 source area.

2014

- Two new wells, W-832-3019 and W-832-3020, were drilled near the Building 832 source area and completed in the $Tnsc_{1a}$ HSU to fulfill recommendations from the 2011 Building 832 Canyon OU Five-Year Review report. Well W-832-3019 is planned as a dual extraction well to be connected to the 832-SRC treatment facility in 2016. Well W-832-3020 was installed near existing $Tnsc_{1b}$ extraction well W-832-11 that has gone dry due to a decline in the water table under drought conditions. Both wells will function as extraction wells and will be connected to the 832-SRC ground water extraction and treatment facility.
- The Building 830-SRC ground water and soil vapor extraction and treatment facilities underwent construction to upgrade both systems, and to connect $Tnsc_{1a}$ HSU extraction well W-830-2701, installed in 2011, to the treatment system. All new piping, media vessels, and electronic controls were installed to improve long-term operational efficiencies.
- Four new shallow ground water monitor wells (W-832-3015, W-832-3016, W-832-3017 and W-832-3018) were hand-augered into the Building 832 Canyon alluvial portion of the Qal/WBR. These wells were installed to replace W-832-SC1, W-832-SC2 and W-832-SC3 that had become non-functional due to continuous build up of silt in these shallow wells.

2015

- Two new wells (W-830-3101 and W-832-3103) were installed as potential injection wells screened in the Upper and Lower $Tnbs_1$ HSUs and W-832-3103, is a ground water monitor well screened in the Upper $Tnbs_1$ HSU.
- One new guard well, W-830-3103, was installed downgradient of the Building 832 source area to verify and delineate the extent of VOC contamination in the Upper $Tnbs_1$ HSU. This guard well was installed to fulfill a recommendation from the 2011 Building 832 Canyon OU Five-Year Review report.

3. Background

3.1. Physical Characteristics

3.1.1. Site Description

The Building 832 Canyon OU is located in a 2-mile-long, southeast-oriented canyon in the southeastern part of Site 300 (Figure 1). This 400-acre canyon is an ephemeral drainage that conveys surface runoff and shallow ground water into Corral Hollow Creek during heavy rainfall events. Starting in the late 1950s and early 1960s, facilities in the Building 830 and 832 areas were used to test the stability of weapon components under various environmental conditions. Testing at the Building 830 and 832 facilities was discontinued in 1985.

The Building 830 Complex is a single building containing three test cells where experiments involving explosives chemicals and weapon components were conducted. When experiments ceased in 1985, the Building 830 Complex was used mainly for electrical equipment storage. The complex was returned to institutional control several years ago and is no longer in use.

The Building 832 Complex consists of eight buildings (Buildings 832 A-F and Buildings 831 and 838) where experiments were conducted. Since testing ceased in 1985, the Building 832 Complex has been used for storage of HE compounds, records storage and office space. HE is stored at Buildings 832B and D and in HE magazines 832-1 and 832-2. Building 832F was decontaminated and demolished in 2005.

The Building 832 Canyon OU includes the release sites at Buildings 830 and 832 and any associated contamination released to environmental media. The OU boundary is defined by the current extent of VOCs in ground water. As shown on Figure 1, the OU boundary is currently approximately 4,000 ft long and extends from the tributary canyon that contains the Building 832 Complex to the site boundary. The Building 830 Complex is located about midway between the Building 832 Complex and the site boundary. Three ground water extraction and treatment systems (GWTSs) and two soil vapor extraction and treatment systems (SVTSs) are currently in place and operating to remediate VOC and perchlorate in ground water: Building 832-Source (832-SRC), Building 830-Source (830-SRC), and Building 830-Distal South (830-DISS). The 832-SRC and 830-SRC facilities extract and treat ground water and soil vapor, while the 830-DISS facility extracts and treats ground water only. Ground water is monitored for VOCs, nitrate, and perchlorate in seventy-five ground water monitor wells to evaluate the progress of remediation. The locations of existing monitor, extraction and water-supply wells and treatment facilities are shown on Figure 3.

3.1.2. Hydrogeologic Setting

This section describes the general hydrogeologic setting for the Building 832 Canyon OU including the unsaturated zone, and the hydrostratigraphic units (HSUs) underlying the area, and surface water. An HSU is a water-bearing zone that exhibits similar hydraulic and geochemical properties within a particular stratigraphic unit.

A conceptual hydrostratigraphic column for the southeastern portion of Site 300 including the Building 832 Canyon area is shown on Figure 4. Hydrogeologic cross-sections showing the static water levels and vertical distribution of total VOCs in the Qal/WBR, $Tnbs_2$, $Tnsc_{1b}$ $Tnsc_{1b}$ and Upper $Tnbs_1$ HSUs in the Building 832 Canyon OU during first semester 2015 are shown on Figures 5, 6, and 7.

3.1.2.1. Unsaturated (Vadose) Zone

A seasonally variable unsaturated zone exists in the Building 832 Canyon OU. The unsaturated zone is composed of quaternary alluvial sand and gravel, small areas of overlapping colluvium, and the underlying weathered Neroly bedrock. The streambed within the canyon and the tributary surface water drainages are generally dry in the summer months and during periods of drought. A 20-to 30-ft thick sandstone ($Tnsc_{1b}$) within the $Tnsc_1$ claystone/siltstone is variably saturated beneath the Building 832 and 830 source areas, as seen in hydrogeologic cross-sections on Figures 5, 6, and 7.

3.1.2.2. Saturated Zone

The HSUs in the Building 832 Canyon OU are described below.

Qal/WBR HSU

The Quaternary alluvium/colluvium/weathered bedrock (Qal/WBR) HSU is an unconfined and highly transmissive water-bearing zone consisting of alluvial sands and gravels and the underlying weathered Neroly bedrock within the canyon and tributary surface water drainages. In addition to the natural alluvial material, the Building 832 and Building 830 tributary canyons contain up to several feet of artificial fill underneath building foundations. This artificial fill is a heterogeneous mixture of sand, gravel, and native soil. It is generally of low permeability and is difficult to distinguish from the underlying natural alluvium and bedrock. The Qal/WBR HSU typically contains ground water only after significant rainfall events and is highly responsive to seasonal rainfall. This response is typical of shallow alluvial water-bearing zones at Site 300 that transmit ground water following intense rainfall events, but are generally dry during summer months and during extended drought periods. When saturated conditions exist, ground water in the Qal/WBR HSU flows in the down-canyon direction (generally south-southeast) where it eventually discharges into the Quaternary alluvium of Corral Hollow Creek. Due to the intersection of the $Tnsc_{1b}$ HSU water table with the canyon bottom, discharge from the $Tnsc_{1b}$ HSU may also contribute to flow the Qal/WBR HSU near Spring 3, where the $Tnsc_{1b}$ HSU intersects the canyon bottom south of monitor well W-830-25. A ground water elevation map for the Qal/WBR HSU is presented as Figure 8.

Tertiary Neroly Upper Blue Sandstone ($Tnbs_2$) HSU

The Tertiary Neroly Upper Blue Sandstone $Tnbs_2$ HSU consists primarily of Neroly Formation sandstones with lesser amounts of interbedded siltstones and claystones. This aquifer is the main contaminated aquifer in the HE Process Area OU. A portion of this aquifer also exists beneath the southern end of Building 832 Canyon where it merges with Corral Hollow Creek between the General Services Area (GSA) and the HE Process Area OUs. This part of the $Tnbs_2$ aquifer, which contains low concentrations of VOC (TCE) at the leading edge of the OU4 plume, is being captured and remediated by the 830-DISS extraction wellfield.

Tertiary Neroly Upper Siltstone/Claystone ($Tnsc_1$) HSUs

Stratigraphic and hydrostratigraphic analysis of the Tertiary Neroly Upper Siltstone/Claystone $Tnsc_1$ interval at the Building 832 Canyon OU is challenging for a variety of reasons, including complex stratigraphy and structure, limited geophysical log data, lithologic heterogeneity and variable fracturing, changing hydrologic conditions, and limited data acquisition at the 832 and 830 source area extraction wellfields. The data acquisition limitations have been largely addressed through upgrades at the 830-SRC treatment facility and similar ongoing upgrades at the 832-SRC treatment facility.

The $Tnsc_1$ is a 70 to 100 ft-thick stratigraphic interval comprised primarily of interbedded siltstone and claystone with some minor sandstone intervals. Due to the predominance of fine-grained lithologies in the $Tnsc_1$, this interval serves as a confining layer that hydraulically separates the two main sandstone aquifers at Site 300: the overlying $Tnbs_2$ aquifer from the underlying $Tnbs_1$ aquifer. Many wells screened in the $Tnsc_1$ stratigraphic zone are low yield and do not sustain continuous pumping, especially wells located in the Building 832 and 830 source areas. These low yield wells are screened in fine-grained, low permeability geologic materials. Additionally these zones received limited recharge, especially during recent drought conditions. Because of the fine-grained nature of this stratigraphic zone, significant ground water flow is primarily associated with fracture and rubble zones. These zones have been identified during drilling operations when significant amounts of water enter the borehole and confirmed using geophysical methods such as optical televiewer (OTV) and caliper logs. The occurrence of such fractures is spatially variable and unpredictable.

Historically, the $Tnsc_1$ stratigraphic zone was sub-divided into three HSUs, the $Tnsc_{1c}$, $Tnsc_{1b}$, and the $Tnsc_{1a}$ based on stratigraphic and hydraulic properties. These HSUs are briefly described in the following sections. Based on detailed ongoing hydrogeologic analysis that began five years ago, DOE/LLNL proposes a slight modification to the historical Building 832 Canyon OU HSU interpretation that includes a comprehensive integration of ground water elevation data, hydraulic response, and spatial and temporal COC trends that is discussed below.

$Tnsc_{1c}$ HSU

The $Tnsc_{1c}$ is a 20-ft thick, fine-grained stratigraphic interval located at the top of the $Tnsc_1$ that has never yielded any measureable ground water to a borehole during drilling operations. It is characterized by low electrical resistivity and high natural gamma on geophysical logs. There are currently no ground water monitor or extraction wells completed in the $Tnsc_{1c}$. The $Tnsc_{1c}$ serves primarily as a confining unit. This HSU will remain unchanged as data collected to date continue to support this interpretation.

$Tnsc_{1b}$ HSU

The $Tnsc_{1b}$ HSU is a 20-to 30-ft thick, fine to medium-grained sandstone that occurs in the middle of the $Tnsc_1$ stratigraphic zone that has yielded variable amount of ground water. It is characterized by an increase in electrical resistivity associated with the fine-grained, variably cemented sandstone. Depth to ground water in this HSU ranges from 15 to over 100 ft below ground surface (ft bgs). Ground water generally flows to the south-southeast. A potentiometric surface contour map for the $Tnsc_{1b}$ HSU is presented as Figure 9. Although this zone is widespread, its hydraulic properties vary spatially due to depth, proximity to recharge areas and presence of fractures. For example, $Tnsc_{1b}$ extraction wells in the Buildings 830 and 832 source areas exhibit such low yield that they cannot sustain continuous flow, while other wells screened in this HSU sustain long-term flow under natural artesian pressure at a rate of a few gallons per minute (gpm). The low-yield wells are generally located near the limit of saturation and extraction rates are limited by the available recharge from tributary canyons.

$Tnsc_{1a}$ HSU

The $Tnsc_{1a}$ HSU is a 20- to 30-ft thick, fine-grained siltstone/claystone that occurs near the base of the $Tnsc_1$ siltstone/claystone. Although the $Tnsc_{1a}$ HSU is laterally continuous over the southeast part of Site 300, its hydraulic properties are spatially variable due to the presence of fractures and rubble zones. For example, $Tnsc_{1a}$ extraction well W-832-25 (located south of the Building 832 source area) exhibits such low yield that it cannot sustain continuous flow, while other wells screened in this HSU (e.g. extraction well W-830-2701) can sustain long-term flow at rates exceeding 3 gpm. Due to the limited characterization data available for this HSU, post-only ground water elevation and COC maps have been historically presented as shown on Figure 10.

Proposal to combine $Tnsc_{1a}$ and $Tnsc_{1b}$ HSUs into a single HSU ($Tnsc_{1a/b}$)

During initial soil and ground water investigations in Building 832 Canyon, the $Tnsc_{1b}$ was identified as the only contaminated water-bearing zone within the $Tnsc_1$ bedrock stratigraphic interval. Hydrogeologic analysis during this five-year review period has resulted in an improved understanding of the hydraulic communication and the spatial distribution of COCs within the $Tnsc_1$ stratigraphic zone.

As a result of this ongoing hydrogeologic analysis, it was recognized that the $Tnsc_{1a}$ is a significant and widespread ground water-bearing zone that contains VOCs (primarily TCE), and that this zone is capable of sustaining ground water pumping, especially where it is fractured. This analysis has demonstrated that wells screened in the $Tnsc_{1a}$ and $Tnsc_{1b}$ HSUs exhibit a common response to hydraulic stresses (see Appendix C). Additionally, many wells in the Building 832-SRC area that were formerly interpreted as screened in the $Tnsc_{1b}$ HSU have been reinterpreted as $Tnsc_{1a}$ completions; other wells were reinterpreted as screened across this stratigraphic interface. Thus, all previous depictions of $Tnsc_{1b}$ COC and ground water data (e.g. previous Compliance Monitoring Report maps, Five-Year Review report maps) were based on data derived from both $Tnsc_{1b}$ and $Tnsc_{1a}$ wells.

Additional evidence of common response to hydraulic stresses between the $Tnsc_{1a}$ and $Tnsc_{1b}$ HSUs was observed in data collected from $Tnsc_{1a}$ monitor well W-830-2311, which was monitored using a ground water elevation level transducer. This well clearly responded to changes in hydraulic stresses during shutdown and startup of the Building 830-DISS GWTS. When the 830-DISS GWTS $Tnsc_{1b}$ artesian extraction wellfield (W-830-51, W-830-52, and W 830-53) was shut down for freeze protection in December 2014, ground water elevations in $Tnsc_{1a}$ well W-830-2311 exhibited a reversal from declining to rising ground water levels. This recovery trend continued until April 2015, at which point ground water elevation quickly decreased, coinciding with the startup of the 830- DISS $Tnsc_{1b}$ extraction wells. The response of $Tnsc_{1a}$ well W-830-2311 to the $Tnsc_{1b}$ artesian extraction wells supports the interpretation that there is a hydraulic connection between $Tnsc_{1a}$ and $Tnsc_{1b}$ HSUs and provides additional support for the combination of the HSUs.

The preponderance of data reviewed as part of this hydrogeologic analysis, primarily hydraulic response and spatial distribution of COCs, support the merging of these two stratigraphic zones into a single HSU. This interpretation is presented in hydrogeologic cross-sections (Figures 5, 6, and 7) and in the combined $Tnsc_{1a/b}$ HSU ground water elevation and total VOC maps that will be discussed further in Section 6.4.1.1. Therefore, DOE/LLNL propose that ground water elevation and COC data from the $Tnsc_{1a}$ and $Tnsc_{1b}$ wells will be integrated and presented as a single HSU in all future documents (e.g. five-year reviews, and compliance monitoring reports).

Tertiary Neroly Lower Blue Sandstone ($Tnbs_1$) HSUs

The Tertiary Neroly lower blue sandstone ($Tnbs_1$) consists primarily of Neroly Formation sandstones with lesser amounts of interbedded siltstones and claystones present throughout the Building 832 Canyon OU. There are two distinct aquifers within the $Tnbs_1$ stratigraphic unit; (1) the Upper $Tnbs_1$ HSU, and (2) the Lower $Tnbs_1$ HSU. These two aquifers are hydraulically separated by a 10-ft thick, low-permeability aquitard known as the claystone marker bed. Depending on location, ground water occurs under unconfined to confined and flowing artesian conditions in both the Upper and Lower $Tnbs_1$ HSUs. In some wells, the artesian head is 10 to 15 ft above the ground surface. The saturated thickness of the Upper $Tnbs_1$ HSU ranges from 0 to 60 ft, and depth to ground water in the Upper $Tnbs_1$ HSU ranges from 60 to 280 ft bgs in Building 832 Canyon. The full saturated-thickness of the Lower $Tnbs_1$ HSU is unknown because this unit has never been fully penetrated beneath Building 832 Canyon. The depth to ground water in the Lower $Tnbs_1$ HSU ranges from approximately 100 to 350 ft bgs beneath the Building 832 Canyon and the adjacent HE Process Area where the Lower $Tnbs_1$ serves as the main water-supply aquifer for Site 300 (Well 20). Ground water in the Upper $Tnbs_1$ HSU generally flows to the southeast (Figure 11). Only the Upper $Tnbs_1$ HSU is contaminated in the Building 832 Canyon OU. This contamination consists of VOCs, primarily TCE, beneath Building 832 Canyon and downgradient from the Building 832 and 830 source areas as shown on Figure 16.

The Upper and Lower $Tnbs_1$ HSUs are recharged in the upper reaches of Building 832 Canyon northwest of the Building 832 source area. Some of the ground water from the $Tnbs_1$ HSUs ultimately discharges into the Corral Hollow Creek alluvium in the Central GSA where these bedrock zones subcrop beneath the alluvium. Compared to the Qal/WBR HSU, the $Tnbs_1$ HSU exhibits lower magnitude, delayed responses to rainfall events. Water levels in wells completed within the Lower $Tnbs_1$ HSU at Site 300 have been rising since the start of the 1998 El Niňo rainfall.

3.1.2.3. Surface Water

Short-term surface water flows occur in the Building 832 Canyon OU drainages during or after significant rainfall events. Minor amounts of surface water are also present that discharges at Spring 3 near the southern end of the canyon (Figure 2). Discharge rates from this spring are too low to measure. However, it is sufficient to moisten the soil and support phreatic vegetation in the vicinity of the spring even during low rainfall years and under drought conditions. A vertical standpipe has been installed within the spring area from which samples can be collected.

Surface water at Spring 3 likely originates from where Neroly bedrock ground water from the $Tnsc_{1b}$ HSU discharges as base flow into the Qal/WBR HSU in Building 832 Canyon (Figure 4). Spring 4 is located on the west canyon wall of Building 832 Canyon south of Building 832. Ground water from the Tps HSU feeds this spring. Due to the location of the spring on the canyon wall, surface water does not collect in Spring 4. However, flow can be sufficient to moisten the soil and support some phreatic vegetation in the vicinity of the spring.

3.2. Land and Resource Use

Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. Less than 5 percent of the Site 300 7,000-acre property is developed. Land use at Site 300, including the Building 832 Canyon OU area, which extends to the southeastern site boundary, is designated as restricted access, federal government industrial (experimental test) use. There have been no changes in land, building, or ground water use in the Building 832 Canyon OU during the five-year review period or since the Site-Wide ROD was signed in 2008, and other than the changes in onsite water-supply uses documented below, none are anticipated.

The Building 832 OU is accessible only to DOE/LLNL workers. Buildings located near the 832 source area are used for high explosives storage, records storage, and office space. Buildings located near the Building 830 source area are no longer used.

Site 300 was originally selected as a DOE experimental test site because of the sparsely populated surrounding area. On the basis of residential population, the average density around the perimeter of Site 300 is less than one person per square mile. Land use adjacent to the site boundary closest to the Building 832 Canyon OU consists of private rangeland: Gallo and Connolly Ranches located south of Site 300, Fireworks America, a private firm operating a fireworks storage facility adjacent to the eastern border of Site 300, and the Carnegie State Vehicular Recreation Area, located southwest of Site 300. There is no known planned modification or proposed development of the offsite rangeland closest to (north and west of) the OU. The nearest major population center (Tracy, California) is 8.5 miles to the northeast. There are plans to develop the land parcel east of Site 300 for residential housing, but thus far the development plans have been delayed by city restricted growth initiatives. As part of this development plan, a minimum buffer zone/open space of 1 to 1.5 miles is planned between residential development and the Site 300 boundary. The developer has informed DOE/LLNL that ground water would not be used as the water-supply for this development.

Several offsite private water-supply wells near the southern boundary of the Building 832 Canyon OU and Site 300 supply water for domestic and agricultural uses to neighboring ranches. Currently, onsite water-supply Well 20 and backup water-supply Well 18 (Figure 3) are the water-supply sources for Site 300, although bottled water is the primary source for onsite drinking water. Site 300 plans to transition to the Hetch Hetchy water-supply in the near future. After Site 300 begins using the Hetch-Hetchy reservoir as its primary water-supply, Well 20 will become a backup water-supply well and Well 18 will no longer be used. Eventually, Well 18 will be sealed and abandoned. Following this transition to Hetch Hetchy water, the decrease in onsite water-supply well pumping may result in increases in ground water levels in the $Tnsc_1$ and $Tnbs_1$ HSUs. Some wells located near the Site 300 boundary may also become flowing artesian. The increased regional water levels could have some positive impacts on Building 832 Canyon OU remediation. Higher ground water levels in the $Tnsc_{1b}$ HSU may increase extraction well flow and mass removal rates. Lower pumping rates at water-supply wells 18 and 20 may decrease the potential for downgradient migration of contaminants. Surface water in onsite springs is not used for water supply or other human uses at Site 300. The springs provide wetland habitat for wildlife.

Site 300 has unique environmental qualities, largely because livestock have not grazed on it for over 50 years and it contains several habitat types and numerous special status species (e.g., threatened and endangered species, species of special concern, migratory birds, and rare plants). Introduced annual grasslands cover the majority of the Building 832 Canyon OU, with limited areas of coastal sage scrub scattered throughout the OU (Jones and Stokes, 2002; Dibley et al., 2014). Wetlands are found in association with Springs 3 and 4. Wildlife within the OU is typical of California grasslands, and includes a variety of small mammals (such as deer mice, ground squirrels, rabbits and skunks), reptiles (such as western fence lizards and rattlesnakes), large mammals such as coyotes and mule deer, passerine birds (such as scrub jays, crows, wrens and towhees) and raptors (such as red-tailed hawks and golden eagles). Amphibians such as frogs and salamanders have been found in areas that can sustain ponded water. A list of vertebrate and rare invertebrate species known to occur at Site 300 can be found in LLNL (Table 4.2-2 in Dibley et al., 2014).

The only special-status plant species known to occur within the boundaries of the Building 832 Canyon OU is the big tarplant (*Blepharizonia plumosa*). The big tarplant is an extremely rare late-season flowering plant with a California Rare Plant Rant (CRPR) of 1B (California Native Plant Society, 2015), and is found throughout Site 300. Plants with a CRPR of 1B are considered rare and endangered throughout their range. In the Building 832 Canyon OU, the plant occurs in the canyon from Spring 3 north to the upper reaches of the canyon, east of Building 830 and adjacent to Building 832 (see Figure 4.2-4 in Dibley et al., 2014). As observed throughout Site 300, while the locations of the various populations are relatively stable, the size of the populations can greatly fluctuate from year to year. Such variations are common in annual plant populations, depending on environmental conditions. Four additional special status species occur at Site 300 outside of the Building 832 Canyon OU. The federally endangered large-flowered fiddleneck (*Amsinckia grandiflora*), occurs to the west within the Building 854 OU. Three special-status plant species (all with a CRPR of 1B), the diamond-petaled California poppy (*Eschscholzia rhombipetala*), the round-leaved filaree (*California macrophylla*) and the adobe navarretia (*Navarretia nigelliformis* ssp. *radians*) occur in the far northern and western portions of Site 300.

Two special-status amphibians may occur within the Building 832 Canyon OU boundary, the California red-legged frog (*Rana aurora draytonii*) and the California tiger salamander (*Spea Hammondii*). Both are federally threatened, and the California tiger salamander is also state threatened. Although no breeding pools for these species occur within the Building 832 Canyon OU, the wetlands associated with Springs 3 and 4 may provide aquatic habitat for both species. The entire OU resides within the upland dispersal and critical habitat for the California red-legged frog, and the majority of the OU resides within the 1,100 meter buffer zone for California tiger salamander breeding pools occurring within the General Services Area OU (Dibley et al., 2014). The species has also been observed at breeding pools located to the west of the High Explosives Process Area OU.

Several special status bird species may occur within the Building 832 Canyon OU. Special status raptor species known to breed or regularly occur at Site 300 that may also occur within the Building 832 Canyon OU include the golden eagle (*Aquila chrysaetos*), white-tailed kite (*Elanus leucurus*) and the short-eared owl (*Asio flammeus*) (Dibley et al. 2014). Although no raptors have been observed to breed in the OU, they may use the Building 832 Canyon OU grasslands for foraging. While several additional special status bird species have been observed throughout Site 300, most have occurred within the northern portion of the site. The loggerhead shrike (*Lanius ludovicianus*), a California Species of Special Concern and a federal Bird of Conservation Concern, has been recorded nesting within the OU.

Three special-status mammal species may occur within the Building 832 Canyon OU. Although not directly observed with the OU, the American badger (*Taxidea taxus*), a California Species of Special Concern, has been observed throughout Site 300 (Dibley et al., 2014). Calls of the pallid bat (*Antrozous pallidus*) and western red bat (*Lasiurus blossevillii*), both California Species of Special Concern, were detected south of the OU within the General Services Area OU. While the Building 832 Canyon OU represents potential habitat for the state- and federally- endangered San Joaquin kit fox (*Vulpes macrotis mutica*), none have ever been observed at Site 300, despite numerous surveys.

3.3. History of Contamination

TCE was used as a heat-exchange fluid as part of testing activities at Buildings 830 and 832. TCE and other VOCs were released to soil, bedrock, and ground water as a result of piping leaks and surface spills. Rinsewater containing HE compounds was disposed via floor drains in Building 832 leading to a surface discharge outside the building. As a result, HMX has been detected in soil and bedrock. However, no HE compounds have been detected in ground water. Nitrate in ground water in the OU is believed to be the result of a combination of HE-related testing, some septic system releases, and natural sources. Although rinsewater containing HE compounds was likely discharged to a small disposal lagoon near Building 830, no HE compounds have been detected in any media in this area. However, the HE compounds released may have degraded and migrated downward as nitrogenous compounds. The source of perchlorate in Building 832 Canyon OU ground water is not known, but it is suspected that it was a component of HE test assemblies.

3.4. Initial Response

DOE/LLNL began environmental investigations in the Building 832 Canyon OU in the early 1980s to identify contaminant source areas and to characterize the extent of contamination in soil, bedrock, ground water and surface water. These characterization efforts included records searches and interviews; the drilling of 82 boreholes and the installation of 65 ground water monitor wells, 10 ground water extraction wells, four dual-phase (soil vapor and ground water) extraction wells and three passive flowing artesian extraction wells (Figure 3). Seven inactive extraction wells are also connected to the 832-SRC treatment facility, but these wells have not been used since 2003 due to lack of water. During 2009, two 830-SRC extraction wells (W-830-1929 and W-830-2213) were converted to monitor wells due to dry conditions, and between 2010 and 2015, seven additional monitor wells, three additional extraction wells, and two potential injection wells were installed in the Building 832 Canyon OU.

The geologic and chemical data from these wells and boreholes have been used to characterize the site hydrogeology and to monitor temporal and spatial changes in saturation and dissolved contaminants. Site characterization also included surface soil sampling, hydraulic testing, evaluating observed water level responses to rainfall events, geologic mapping, ground water transport modeling, geologic and hydrogeologic characterization, soil vapor flux chamber measurements, soil vapor surveys, soil vapor extraction testing, and risk assessment.

As summarized in Section 2, remediation activities at the Building 832 Canyon OU conducted prior to the Interim Site-Wide ROD (U.S. DOE, 2001) included extraction and treatment of contaminated ground water at the Building 832 source area, immediately downgradient of the Building 830 source area, and near the Site 300 boundary.

3.5. Contaminants of Concern

Contaminants of concern (COCs) in environmental media at Building 832 Canyon OU were determined based on: (1) an unacceptable human health cancer risk (greater than 10^{-6}) or noncancer hazard (Hazard Index [HI] greater than 1), (2) an unacceptable hazard (HI greater than 1) to ecological receptors, (3) the potential for soil contaminants to impact ground water at concentrations above MCLs, and/or (4) the presence of ground water contaminants at concentrations above the MCL.

COCs have been identified for impacted environmental media in the Building 832 Canyon OU area:

- Surface soil (0 to 6 inches): HMX.
- Subsurface soil and bedrock: VOCs, HMX, and nitrate.
- Surface water (Spring 3): VOCs and nitrate.
- Ground water: VOCs (primarily TCE, but also including PCE, cis-1,2 DCE, and chloroform), nitrate, and perchlorate.

Baseline human health risks and hazards for Building 832 Canyon were estimated and presented in the Site-Wide Remedial Investigation (SWRI) (Webster-Scholten, 1994) using industrial adult onsite exposure and offsite residential exposure scenarios. The adult onsite exposure scenario estimated health risk where an adult is assumed to work in the immediate vicinity of worst-case contamination 8 hours a day, 5 days per week, for 25 years. This exposure scenario further assumed that workers would not dig into subsurface soil; excavation will be prevented through institutional/land use controls.

VOCs, primarily TCE (a human carcinogen), are present in subsurface soil and rock, in surface water at Spring 3, and in ground water. An unacceptable baseline excess cancer risk (greater than 10^{-6}) was calculated for VOCs in the following environmental media in the Building 832 Canyon OU:

- Inhalation risk of 3×10^{-6} for onsite workers inside Building 830.
- Inhalation risk of 1×10^{-5} for onsite workers outside of Building 830.
- Inhalation risk of 3×10^{-6} for onsite workers inside Building 832.
- Inhalation risk of 7×10^{-5} for onsite workers in ambient air in the vicinity of Spring 3.

The HE compound HMX is a human carcinogen present in surface soil and subsurface soil and rock in the Building 832 Canyon. No unacceptable risk or hazard associated with HMX in surface soil or subsurface soil/rock in the Building 832 Canyon OU has been identified.

Elevated nitrate is present in ground water as a result of a combination of natural and anthropogenic sources in the Building 832 Canyon OU. In addition to natural soil nitrate and septic system discharges, discharge of rinsewater containing nitrogenous HE-compounds to the ground surface occurred at Building 832 and possibly at small disposal lagoons or dry wells located near Building 830. Nitrate can cause non-carcinogenic health effects if ingested at elevated levels. No human health risk has been associated with nitrate in subsurface soil/rock or ground water in the Building 832 Canyon OU.

In the Building 832 Canyon OU, VOCs, perchlorate, and nitrate contamination are present in ground water in the Qal/WBR $Tnsc_{1b}$ and $Tnsc_{1a}$ HSUs. Ground water in the Upper $Tnbs_1$ HSU is primarily contaminated with VOCs, although perchlorate above 6 µg/L cleanup standard has been detected in the past.

MCLs were selected as the cleanup standards for COCs in ground water in the Building 832 Canyon OU in the Site-Wide ROD. Therefore, ground water cleanup is designed to achieve MCLs rather than by carcinogenic or noncarcinogenic hazard estimates. Ground water in the Building 832 Canyon OU is not currently used as drinking water and institutional controls will prohibit such use until cleanup standards are achieved.

During the Building 832 Canyon OU 2016 Five-Year Review reporting period, no data has been collected that would change these conclusions.

3.6. Summary of Basis for Taking Action

The response actions selected in the Site-Wide ROD (U.S. DOE, 2008) were necessary to protect human health or the environment from actual or threatened releases of hazardous substances from the Building 832 Canyon OU. The baseline risk assessment evaluated potential present and future human health and ecological risks associated with environmental contamination in this OU using the assumption that no cleanup or remediation activities would take place. The risk assessment provided the basis for implementing a remedial action and identified the exposure pathways that that need to be addressed. Selection of the cleanup actions was based in part on the extent to which they could reduce human and ecological risks.

Remedial actions were initiated in the Building 832 Canyon OU to address:

- An unacceptable human health risk associated with onsite worker inhalation exposure to VOCs volatilizing from subsurface soil into indoor air inside Building 830 and outdoor air in the vicinity of Building 830 and Building 832A.
- An unacceptable human health risk associated with onsite worker inhalation exposure to VOCs volatilizing from surface water in the vicinity of Spring 3.
- VOCs, nitrate, and perchlorate present in ground water at concentrations exceeding cleanup standards.

4. Remedial Actions

4.1. Remedial Action Objectives

Remedial Action Objectives (RAOs) are included in the Site-wide ROD. The RAOs applicable to the Building 832 Canyon OU selected remedies are:

<u>For Human Health Protection:</u>

- Restore ground water containing VOC, nitrate, and perchlorate concentrations above cleanup standards.
- Prevent human ingestion of ground water containing VOC, nitrate, and perchlorate concentrations (single carcinogen) above cleanup standards.
- Prevent human inhalation of VOCs volatilizing from subsurface soil to air that pose an excess cancer risk greater than 10^{-6} or HI greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of 10^{-4}, or a cumulative HI (all noncarcinogens) greater than 1.

- Prevent human inhalation of VOCs volatilizing from surface water to air that pose an excess cancer risk greater than 10^{-6} or HI greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of 10^{-4}, or a cumulative HI (all noncarcinogens) greater than 1.
- Prevent human exposure to contaminants in media of concern that pose a cumulative excess cancer risk (all carcinogens) greater than 10^{-4} and/or a cumulative HI greater than 1 (all noncarcinogens).

For Environmental Protection:

- Restore water quality to ground water cleanup standards within a reasonable timeframe and to prevent plume migration to the extent technically and economically practicable. Maintain existing water quality that complies with ground water cleanup standards to the extent technically and economically practicable. This will apply to both individual and multiple constituents that have additive toxicology or carcinogenic effects.
- Ensure ecological receptors important at the individual level of ecological organization (listed threatened or endangered, State of California species of special concern) do not reside in areas where relevant hazard indices exceed 1.
- Ensure existing contaminant conditions do not change so as to threaten wildlife populations and vegetation communities.

An RAO for human health protection/applicable or relevant and appropriate requirements (ARARs) compliance for ingestion of surface waters (i.e., water from Site 300 springs) was not developed because there is not a complete exposure pathway for ingestion of surface waters for humans at Site 300. Humans do not drink water from Site 300 springs. In addition, the springs in which contaminants are detected do not produce a sufficient quantity of water to be used as a water supply (more than 200 gallons per day).

4.2. Remedy Selection

In the 2001 Interim Site-Wide ROD (U.S. DOE, 2001), an interim remedy for the Building 832 Canyon 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 remedy for the Building 832 Canyon OU consisted of:

1. No Further Action for HE compounds in surface soil and nitrate in subsurface soil/bedrock at Building 830, and for HE compounds in subsurface soil/rock at Building 832.
2. Monitoring ground water to evaluate the effectiveness of the remedy in achieving cleanup standards, and to ensure there is no impact to downgradient water-supply wells.
3. Risk and hazard management to prevent onsite worker exposure to VOCs volatilizing from subsurface soil into indoor air at Building 830 and from surface water at Spring 3 until risk and hazard is mitigated through active remediation. Annual risk re-evaluation indicates that the inhalation risk for VOCs volatilizing from subsurface soil into outdoor air near Building 830 and to indoor air at Building 832F has been mitigated through remediation. Therefore, risk and hazard management for this exposure pathway is no longer necessary. These risk re-evaluation results are documented in the 2006 Annual

Compliance Monitoring Report for LLNL Site 300 (Dibley et al., 2007c). Institutional/land use controls will be implemented to prevent human exposure to contamination and to protect the integrity of the remedy.

4. Extracting and treating VOCs in soil vapor and ground water, and perchlorate, and nitrate in ground water to mitigate unacceptable VOC inhalation risk for onsite workers, prevent further impacts to ground water and offsite plume migration, and reduce contaminant concentrations in soil and ground water to cleanup standards.
5. MNA of nitrate in ground water.

4.3. Remedy Implementation

Remedial action monitoring requirements are contained in the Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at LLNL Site 300 (Dibley et al., 2009b).

A risk and hazard management program, including institutional and land use controls, has been implemented at Building 832 Canyon OU. The land use/institutional controls for the Building 832 Canyon OU are described in Section 4.5 and Table 2.

The results of remedial action ground water, and surface water monitoring, remediation progress, and the status of institutional control implementation for the Building 832 Canyon OU are reported in the ERD semiannual and annual Compliance Monitoring Reports.

Three GWTSs and two SVTS are currently being operated in the Building 832 Canyon OU: Building 832-Source (832-SRC), Building 830-Source (830-SRC), and Building 830-Distal South (830-DISS). The 832-SRC and 830-SRC facilities extract and treat both ground water and soil vapor, while the 830-DISS facility extracts and treats ground water only.

A map of Building 832 Canyon OU showing the location of monitor and extraction wells and treatment facilities is presented on Figure 3. The location of the former treatment facility 830-PRXN, which was decommissioned and removed in 2006, is also shown on Figure 3. Photographs of the treatment facilities are included in Appendix A,

The implementation history of each extraction treatment system is summarized below:

832-SRC GWTS and SVTS

The 832-SRC GWTS removes VOCs and perchlorate from ground water and the SVTS removes VOCs from soil vapor. The GWTS and SVTS began operation in September and October 1999, respectively. Initially, ground water was extracted from nine dual extraction wells (W-832-12, -13, -14, -15, -16, -17, -18, -20, and -22) at a combined total flow rate that initially ranged from 30 to 300 gallons per day (gpd). The total flow eventually dropped to 5 to 50 gpd due to lowering of the water table by dewatering and lack of rainfall. In early 2005, it was observed that nearly all the ground water yield was attributable to Qal/WBR-$Tnsc_{1b}$ HSU extraction wells W-832-12 and W-832-15. Therefore, the source area extraction wellfield was reduced to these two wells operating with vacuum enhancement and a combined flow rate ranging from 60 to 220 gpd. The increase in flow rate in these two wells may be a result of differing hydrologic conditions or the vacuum enhancement. Although no ground water is currently being extracted from wells W-832-13, -14, -16, -17, -18, -20, and -22, these wells are sampled whenever ground water is present.

In late 2005, the extraction wellfield was expanded to include three additional $Tnsc_{1b}$ HSU downgradient wells (W-832-01, W-832-10, and W-832-11). As a result, the combined flow rate increased to about 1,300 gpd, and VOC concentrations in 832-SRC facility influent increased four-fold. $Tnsc_{1a}$ well W-832-25 was connected to 832-SRC in July 2006. In 2014, two new wells, dual extraction well W-832-3019 and ground water extraction well W-832-3020, were drilled near the Building 832 source area and completed in the $Tnsc_{1a}$ HSU. Well W-832-3020 was installed near existing $Tnsc_{1b}$ extraction well W-832-11, which has gone dry due to a decline in the water table under drought conditions. Both of these wells will function as extraction wells but will continue to serve as monitor wells until they are connected to the 832-SRC ground water extraction and treatment facility as part of the upcoming facility upgrades at that location. Currently, ground water is extracted from wells W-832-01, W-832-10, W-832-12, W-832-15 and W-832-25 at an approximate combined flow rate of 0.1 to 1 gpm. Soil vapor is extracted from wells W-832-12 and W-832-15 at an approximate combined flow rate of approximately 3 to 5 standard cubic feet per minute (scfm). The current GWTS configuration includes a Cuno filter for particulate filtration, two columns with ion-exchange resin connected in series to remove perchlorate, and three aqueous-phase GAC units (also connected in series) to remove VOCs. Nitrate-bearing treated effluent is then discharged via a misting tower over the landscape for uptake and utilization of the nitrate by indigenous grasses. A positive displacement rotary lobe blower is used to create a vacuum at selected wellheads through a system of piping manifolds. The contaminated vapors are treated using three vapor-phase GAC units connected in series. Treated soil vapors are then discharged to the atmosphere under a permit from the San Joaquin Valley Unified Air Pollution Control District.

830-SRC GWTS and SVTS

The 830-SRC GWTS removes VOCs and perchlorate from ground water and the SVTS removes VOCs from soil vapor. The GWTS and SVTS began operation in February and May 2003, respectively. Ground water was extracted from three wells at a total flow rate ranging from 5 to 100 gpd. These wells included one Qal/WBR-$Tnsc_1$ well W-830-1807, and two $Tnsc_{1b}$ wells W-830-19 and W-830-59. The 830-SRC extraction wellfield was expanded in 2006 to include seven additional GWTS extraction wells: $Tnsc_{1b}$ wells W-830-49, W-830-1829, W-830-2213; $Tnsc_{1a}$ well W-830-2214; and Upper $Tnbs_1$ wells W-830-57, W-830-60, and W-830-2215. The expansion well testing began in 2006. The tests were completed and the expanded wellfield was in full operation during the first semester 2007. During the second semester 2009, wells W-830-1829 and W-830-2213 were converted back to monitor wells due to lack of water. In early 2010, extracted ground water from higher flow extraction wells W-830-2215, W-830-60, and W-830-57 that did not contain perchlorate at concentrations above the 4 µg/L reporting limit was routed around the 830-SRC ion-exchange canisters. This bypass improved the capability of the 830-SRC facility to extract and treat ground water by decreasing backpressure and is expected to increase ground water flow and mass removal rates from the 830-SRC Upper $Tnbs_1$ extraction wells. Ground water extracted from low-flow $Tnsc_{1a}$ well W-830-2214 still contains perchlorate above the discharge limit; this well does not bypass the perchlorate treatment system. In 2011, and as recommended in the 2011 Five-Year Review (Helmig et al., 2011), a downgradient $Tnsc_{1a}$ extraction well, W-830-2701, was installed to increase hydraulic capture in the $Tnsc_{1a}$ HSU downgradient of extraction well W-830-2214. In 2014 and 2015, both GWTS and SVTS were upgraded to replace aging system components and improve operational efficiencies, and to connect extraction well W-830-2701. All new piping, media vessels, and electronic controls were installed to improve long-term operational efficiencies. The upgraded systems become operational again in September 2015. As modified, the 830-SRC GWTS is currently extracting ground water at a combined flow rate of approximately 5 to 12 gpm. The GWTS configuration includes a Cuno filter for particulate filtration, two columns with ion-exchange resin connected in series to remove perchlorate, and three in series aqueous-phase GAC units to remove VOCs in series. Nitrate-bearing treated effluent is then discharged via a misting tower over the landscape for uptake and utilization of the nitrate by indigenous grasses. The 830-SRC soil vapor extraction wellfield was also expanded to include well $Tnsc_{1b}$ W-830-49 in 2006. Soil vapor is extracted from Qal/WBR-$Tnsc_{1b}$ well W-830-1807 and $Tnsc_{1b}$ well W-830-49 using a liquid ring vacuum pump at a current combined flow rate of approximately 18 to 34 scfm. The contaminated vapors are treated using three vapor-phase GAC units connected in series. Treated soil vapors are then discharged to the atmosphere under a permit from the San Joaquin Valley Unified Air Pollution Control District.

830-DISS GWTS

The 830-DISS GWTS began operation in July 2000 and removes VOCs, perchlorate, and nitrate from ground water. Approximately 1 to 2 gpm of ground water is passively extracted from three flowing artesian $Tnsc_{1b}$ wells (W-830-51, W-830-52, and W-830-53). The GWTS configuration consisted of a Cuno filter for particulate filtration, two aqueous-phase GAC units in series to remove VOCs, two in-series columns with ion-exchange resin to remove perchlorate, and three bioreactor units for nitrate reduction. These units were open-container wetland bioreactors containing microorganisms that use nitrate during cellular respiration. Acetic acid was added to the process stream as a carbon source. Treatment system effluent was discharged via a storm drain that discharges to the Corral Hollow alluvium. At the request of the RWQCB, the facility was modified during the first semester 2007 to cease discharge of treated water to a surface water drainage way. The modification included the addition of a fourth well, W-830-2216, to the extraction wellfield. The GWTS is now extracting ground water passively from flowing artesian wells W-830-51, W-830-52, and W-830-53 passively under natural artesian pressure, and actively from well W-830-2216 at a combined flow rate of approximately 2 to 36 gpm. Typically, W-830-52 and W-830-53 do not contribute a significant volume of ground water to the treatment facility except immediately after extended shut down periods when water levels are able to recover. Currently, extracted ground water from the four extraction wells flows through ion-exchange canisters to remove perchlorate at the 830-DISS location. The water is piped to the Central GSA GWTS for VOC removal. Nitrate-bearing treated effluent is then discharged via a misting tower over the landscape for uptake and utilization of the nitrate by indigenous grasses.

830-PRXN

A fourth GWTS, Building 830-PRXN operated in the OU from October 2000 until April 2006. Ground water was extracted from extraction well W-830-57 using a solar-powered ground water treatment unit at approximately 300 gallons per day. The ground water was treated using three aqueous-phase GAC units connected in series to remove VOCs. The effluent was discharged to the shallow subsurface via a French drain in a disposal trench. The 830-PRXN extraction well, W-830-57 was connected to 830-SRC as part of the 830-SRC expansion performed in 2006.

4.4. System Operations/Operation and Maintenance

The remedy for the Building 832 Canyon OU operated as designed during this five-year review period and no significant operational or cost issues were identified. All required documentation is in place, and the inspection, operation, and maintenance procedures for the Building 832 Canyon ground water and soil vapor treatment systems are consistent with established procedures and protocols. Inspection, operation, and maintenance activities and any operational or compliance issues identified during this five-year review period for the Building 832 Canyon OU remedies are discussed below.

The remedy components for the Building 832 Canyon OU that require long-term inspection, operation, and maintenance include:

- Three GWTSs (832-SRC, 830-SRC, and 830-DISS) to remove VOCs and perchlorate from ground water.
- Two SVTSs (832-SRC and 830-SRC) to remove VOCs from soil vapor.
- A ground water and soil vapor monitoring network to evaluate the effectiveness of cleanup.

The inspection, operation, and maintenance (O&M) procedures for the Building 832 Canyon treatment systems are contained in the following documents:

- Health and Safety Plan and Quality Assurance/Quality Control Plan for the O&M of the Building 832 Canyon Treatment Facilities, contained within the Interim Remedial Design report (Madrid, et. al., 2006).
- Operations and Maintenance Manual for Miniature Treatment Units, Ground Water Treatment Units, and Solar Treatment Units, Volume 13 (Martins, 2006).
- Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation (LLNL, 2004).
- Integration Work Sheet Safety Procedure #11341: Ground Water and Soil Vapor Treatment Facility Operations at Site 300.
- Integration Work Sheet Safety Procedure #11314: ERD Site 300 Ion-Exchange Resin Replacement (if resin is used at the facility).
- Integration Work Sheet Safety Procedure #11313: ERD Site 300 Off-Road Driving Training.
- Integration Work Sheet Safety Procedure #11343: ERD Routine Ground Water Sampling & Water Level Monitoring at Site 300.
- Integration Work Sheet Safety Procedure #14984: ERD Routine Electronic Operations at Site 300.
- Integration Work Sheet Safety Procedure #11339: ERD Site 300 Hydraulic Pump Operation.
- Integration Work Sheet Safety Procedure #11346: Spent Aqueous and Vapor-phase Granular Activated Carbon (GAC) Replacement at Site 300.
- Building 832 Canyon and Building 854 OU Substantive Requirements and the Monitoring and Reporting Program issued by the California RWQCB.

- Site-Wide Compliance Monitoring Plan/Contingency Plan for Interim Remedies at LLNL Site 300 (Ferry et al., 2002b) until superseded by the Site-Wide Compliance Monitoring Plan/Contingency Plan for Remedies at LLNL Site 300 (Dibley et al., 2009b).
- LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (Goodrich and Lorega, 2012).

The applicable inspection, operation, and maintenance activities for the GWTS, SVTS and monitoring network are discussed in Section 4.4.1 below.

Monitoring and optimizing the performance and efficiency of these extraction and treatment systems comprises a large portion of the O&M activities. Extracted ground water and soil vapor is sampled throughout the treatment process to ensure compliance with discharge requirements. Treatment system parameters such as pressure and flow are routinely recorded to anticipate potential mechanical problems and monitor system performance.

The major O&M activities for the Building 832 Canyon treatment systems include:

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

More specific maintenance details for the Building 832 Canyon treatment systems during this five-year review period are documented in the semiannual and annual Compliance Monitoring Reports; however, the main activities are summarized below:

830-SRC GWTS and SVTS

- Influent pipeline to treatment facility was separated into two different pipelines in June 2010. One pipeline containing ground water from non-perchlorate bearing extraction wells was separated from extraction wells containing perchlorate, so that non-perchlorate bearing water would bypass the ion-exchange system to reduce back pressure on the system. After the ion-exchange resin units, the pipelines were joined to a single line for the remainder of treatment.
- Spent ion-exchange resin was replaced with new resin in August 2010 and March 2013.
- Spent aqueous-phase GAC was replaced with new GAC in October 2010, August 2011, April and October 2012, and November 2013.
- The GWTS and SVTS were shut down to prevent damage from freezing temperatures during the winter months of 2010, 2011, 2012, 2013, and 2014.
- A failed transformer caused a power outage to the GWTS system in March 2011. The SVTS was already shut down since December 2010 to replace the condensate drum. After performing maintenance and replacing the power pole, transformer, blown fuses, input module, interlock and pump for the misting tower tank, and approximately 2,000 ft of rodent-damaged wiring, both systems were restarted at the end of May 2011.
- The GWTS and SVTS were shut down due to electrical issues at the end of June 2011. The power supply was replaced and the systems were restarted at the end of July 2011.
- Misting of the GWTS effluent was switched from the north misting tower to the south misting tower location in April 2012.

- Discharge of treated effluent was switched to the north misting tower location in October 2012.
- A site power outage in October 2012 caused the GWTS and SVTS to shut down. The systems were restarted, however, the SVTS would not restart due to a failed blower. A new blower was purchased and installed in January 2013.
- The southern effluent misting tower was rebuilt to facilitate alternating misting of the treatment facility effluent between towers in July 2013.
- Both the GWTS and the SVTS were shut down in August 2014 for a system upgrade and remained offline for the rest of 2014 and through first semester 2015.

832-SRC GWTS and SVTS

- The GWTS and SVTS were shut down to prevent damage from freezing temperatures during the winter months of 2010, 2012, and 2013. During the winter of 2011, the system remained operational, except for a one-week period, utilizing only two of the extraction wells. All expansion wells were shut down for freeze protection.
- A new condensate knockout drum was installed in March 2011.
- Spent aqueous-phase GAC was replaced with new GAC in July 2011.
- Spent ion-exchange resin was replaced with new resin in July 2012 and March 2014.
- The GWTS was taken offline in October 2014 due to a leak in the treated effluent line to the misting towers. Due to needed maintenance issues, the GWTS remained offline for the remainder of 2014. The SVTS was also secured in October 2014 and remained offline for the rest of 2014.
- The GWTS and the SVTS were restarted in May 2015 after replacing the effluent discharge line, followed by conducting a pipeline flush and testing process to ensure residual VOCs in the glue used on the replacement polyvinyl chloride effluent discharge piping were not released to the discharge point (misting towers) upon restart.

830-DISS GWTS

- Extraction well W 830-2216 was shut down during the winter months of 2010 and 2013 to prevent damage from freezing temperatures. The system continued to operate by extracting water from the flowing artesian wells.
- Water from extraction well W 830-2216 plumbed through ion-exchange resin in August 2010 after finding trace levels of perchlorate just below the reporting limit of 4.0 µg/L.
- Spent nitrate ion-exchange resin was replaced with new resin in September 2011, August 2012, and February 2013.
- The GWTS was shut down in November 2011 and was restarted in February 2012 due to discharge issues at the Central GSA GWTS.
- The GWTS was shut down intermittently between December 2012 and June 2013 due to Central GSA GWTS shutdowns.
- The GWTS was shut down to prevent damage from freezing temperatures during the winter months of 2013 and 2014. The GWTS was restarted in May 2014, after the new misting towers of the Central GSA GWTS were brought online.
- The GWTS was restarted after freeze protection in April 2015. However, the GWTS was shut down from April 10 to April 22 to investigate a detection of perchlorate in the

effluent (4.0 µg/L, April 8, 2015). The cause of the perchlorate detection was a faulty valve- allowing partial bypass of the ion-exchange resin. Once this faulty valve was replaced, effluent samples were in compliance with the discharge permit.

- The GWTS was shut down in May 2015 due to the shut down of the central GSA GWTS.

The budgeted and actual environmental restoration costs for the Building 832 Canyon OU are tracked closely and are generally within the allocated budget, except when extra costs were incurred to address unanticipated problems or regulatory requests. Table 2 presents the actual costs for the last five fiscal years, 2011 through 2015.

4.5. Institutional and Land Use Controls

Land use controls are restrictions or controls that are implemented to protect human health and the environment, such as restricting access or limiting activities at a contaminated site.

Types of land use controls include:

- Institutional controls.
- Engineered controls.
- Physical barriers.

The U.S. EPA (2010) defines institutional controls as non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a response action. Institutional controls are typically designed to work by limiting land or resource use or by providing information that helps modify or guide human behavior at a site. Institutional controls are a subset of land use controls. Institutional controls are divided into four categories:

1. Proprietary controls.
2. Governmental controls.
3. Enforcement and permit tools.
4. Information devices.

Proprietary controls are generally created pursuant to state law to prohibit activities that may compromise the effectiveness of a remedial action or restrict activities or future resource use that may result in unacceptable risk to human health or the environment, such as easements and covenants. Governmental controls impose restrictions on land use or resource use, using the authority of a government entity. Federal landholding agencies, such as DOE, possess the authority to enforce institutional controls on their property. At active federal facilities, such as LLNL Site 300, land use restrictions may be addressed in master plans, facility construction review processes, and digging permit systems. Enforcement and permit tools are legal tools, such as Federal Facility Agreement (FFAs) that limit certain site activities or require the performance of specific activities. Information devices provide information or notifications to local communities that residual or contained contamination remains onsite.

Land use controls also include engineering controls and physical barriers, such as fences and security guards, as means to protect human health by reducing or eliminating the hazard and/or the potential for exposure to contamination.

In this document, the term "land use controls" is used to encompass institutional controls, engineered controls, and physical barriers.

Land use controls are necessary to prevent human receptor exposure to contaminants in soil, and to ground water currently above the MCLs. Land use controls are more effective if they are layered or implemented in series with each other. Layering can involve using different types of land use controls at the same time to enhance the protectiveness of the remedy. DOE/LLNL has implemented multiple layers of protection to prevent human receptor exposure to contaminants in soil, and in ground water currently above the MCLs.

The land use controls and requirements described herein are only applicable to the Building 832 Canyon OU and associated contaminated environmental media that are being addressed through the CERCLA process. As required by the Site 300 Compliance Monitoring Plan, the land use controls are reviewed annually using the Institutional Controls Monitoring Checklist. The land use/institutional controls checklist was reviewed and approved by the regulatory agencies and was presented in the 2009 Compliance Monitoring Plan. The annual checklists are included in the Annual Compliance Monitoring Reports.

Land use controls agreed to in the Site-Wide ROD (DOE, 2008) for the Building 832 Canyon OU are described in Table 1, which presents descriptions of: (1) the land use control objective and duration, (2) the risk necessitating these controls, and (3) the specific land use controls and implementation mechanisms used to prevent exposure to contamination at the Building 832 Canyon OU. Figure 12 shows the specific areas of the Building 832 Canyon OU where the land use controls have been maintained or implemented.

The land use control objectives and the risk necessitating these controls, the specific land use controls and implementation mechanisms used to prevent exposure to contamination at the Building 832 Canyon OU by objective, and the status of the land use controls are summarized below.

4.5.1. Land Use Controls

Land use control objectives were established for the Building 832 Canyon OU in the Site-Wide ROD (U.S. DOE, 2008) to reduce risk and prevent exposure to contaminated environmental media. The risk drivers, associated land use control objectives, and the land use controls to meet these objectives are described in Sections 4.5.1.1 through 4.5.1.5 below. These sections are organized by the land use control objectives identified for the Building 832 Canyon OU. However, to avoid repetition, the governmental institutional and land use controls - Dig Permit Process, Work Induction Board Process, and Physical Barriers that apply to the Building 832 Canyon OU are described in a single section below, and are then referenced in the subsequent subsections where these controls are implemented.

DOE/LLNL has implemented multiple layers of protection (governmental institutional and land use controls) to prevent or control:

1. Water-supply use or consumption of onsite contaminated ground water in the Building 832 Canyon OU until ground water cleanup standards are met.
2. Excavation activities to prevent onsite worker exposure to VOCs in subsurface soil at Buildings 832 and 830 until it can be verified that subsurface soil does not pose an exposure risk to onsite workers.
3. Building occupancy restriction to prevent onsite site worker inhalation exposure to VOCs inside Building 830 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.

4. Land use restriction/institutional controls in the vicinity of Spring 3 to prevent onsite site worker inhalation exposure to VOCs at Spring 3 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.
5. Transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.

The multiple layers of protection are accomplished at the Building 832 Canyon OU by restricting access or limiting activities through the following governmental institutional and land use controls:

- Dig Permit Process.
- Work Induction Board Process
- Physical Barriers

Detailed descriptions of these controls are provided below and are referenced in the subsequent Sections 4.5.1.1 through 4.5.1.5, where the land use controls are being discussed.

Dig Permit Process: A soil excavation permit approved by the LLNL Facilities and Infrastructure Documentation and Permits Group is required prior to any excavation or well installation work onsite. As part of the soil excavation permit process, a preconstruction site evaluation is required and as soon as it is determined that soil or debris are to be disturbed at a project site, the Responsible Individual/project manager is required to notify the LLNL Environment, Safety and Health (ES&H) Team Environmental Analyst (EA) to initiate a preconstruction site evaluation. To document the request, a Site Evaluation Request Form is filled out and given to the LLNL ES&H Team EA with a description of the project attached, including project location, and excavation footprint and depth. The LLNL ES&H Team EA evaluated the proposed project location to determine whether sampling of the project location is required.

The evaluation includes:

- Review of LLNL ERD historical source investigation.
- Review of Environmental Functional Area site evaluation documents.
- Review of current and past operations, and pre-existing soil analytical data.
- Visual inspection to evaluate the project site for possible contamination.

If this evaluation indicates there will be unacceptable environmental consequences such as use or exposure to contaminated ground water or contaminated soil, the dig permit will not be issued until and unless the plan of work is amended to resolve such consequences. If no such consequences are apparent, the EA will determine whether soil sampling of the project location is required. If sampling of the project location is required, the LLNL ES&H Team EA and ES&H technician prepare and implement the sampling plan. The LLNL ES&H Team EA evaluates the results and, if a potential for contaminant exposure is identified, recommends methods to ensure that the original sampling adequately defined the hazards and that the necessary controls are identified and implemented prior to the start of work. These controls are identified through conditions to the soil excavation permit and are implemented by the Responsible Individual/project manager. The LLNL ES&H Team, including the ES&H Team EA, representatives from health and safety disciplines, and LLNL Waste Management will also work with the Responsible Individual/project manager proposing the project to determine if the work plans can be modified to avoid areas of contamination or to relocate the well to ensure ground water contaminants would not be drawn into the well.

During excavation or soil or debris disturbing activities such as well drilling, a Controlled Area (approximately 50 ft radius exclusion zone) is established with regulated access. If potentially contaminated soil or debris is unexpectedly discovered during excavation or soil or debris disturbing activities, the Responsible Individual/project manager is required under LLNL internal procedures to stop work and immediately notify the LNLL ES&H Team EA and the ERD so that the material can be evaluated. Samples are gathered to properly classify the soils and/or debris. After evaluating the results, the proper method of handling any contaminated material is implemented.

Work Induction Board: All proposed excavation or onsite well drilling activities are submitted to and must be cleared through the LLNL Work Induction Board. Additionally, workers do not occupy or plan to occupy Building 830 in the near future. Any significant changes in activities or proposed area usage at Building 830 are also submitted to and must be cleared by the LLNL Work Induction Board. The Work Induction Board meets weekly to review new proposed work at Site 300 to ensure that work is conducted in conformance with the appropriate controls and includes the special concerns for work at Site 300 (i.e., environmental contamination). If excavation activities or any significant changes in activities are proposed for the Building 832 and/or 830 areas, the Work Induction Board coordinates with the ERD and the ES&H Team EA to determine if the proposed excavation activity is located in an area where there is a potential for exposure to VOCs in subsurface soil. If installation of new water-supply wells is being proposed, ERD will ensure that new water-supply wells are not located in areas of ground water contamination. If a potential for contaminant exposure is identified, Environmental Health and Safety personnel ensures that hazards are adequately evaluated and necessary controls identified and implemented prior to the start of work.

Signage: Building 830 is not currently occupied; the building was returned to institutional control several years ago and is no longer in use. Warning signs are maintained prohibiting full time occupancy without notification and authorization by LLNL Site 300 Management. Any significant changes in activities conducted in Building 830 must be cleared through the LLNL Work Induction Board.

The risk drivers, associated land use control objectives, and the land use controls to meet the objectives are described in Sections 4.5.1.1 through 4.5.1.5 below.

4.5.1.1. Prevent Onsite Water-supply Use/Consumption of Contaminated Ground Water in the Building 832 Canyon OU: Governmental Institutional Controls

Risk Driver – VOCs, perchlorate, and nitrate concentrations in ground water onsite exceed cleanup standards.

Land Use Control Objective:

- Prevent onsite water-supply use/consumption of contaminated ground water until ground water cleanup standards are met.

Land Use Controls:

- Dig Permit Process
- Work Induction Board Process

Five-Year Review Status: During this five-year review period, there were no dig permit applications to drill and install new onsite water-supply wells within areas of onsite ground water contamination in the Building 832 Canyon OU. Contamination in the Building 832 Canyon is limited to onsite ground water. Therefore, land use controls are not needed to prevent offsite water-supply use/consumption of contaminated ground water.

4.5.1.2. Control Excavation Activities to Prevent Onsite Worker Exposure to Contaminants in Subsurface Soil at Buildings 832 and 830: Government Institutional Controls

Risk Driver – Potential exposure to VOCs at depth in subsurface soil in the Buildings 830 and 832 areas.

Land Use Control Objective:

- Control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil until it can be verified that subsurface soil does not pose an exposure risk to onsite workers. The areas at Buildings 830 and 832 for which excavation controls are in place are shown on Figure 12 by dashed lines in the Buildings 830 and 832 source areas.

Land Use Controls:

- Dig Permit Process
- Work Induction Board Process

Five-Year Review Status: During this five-year review period, there were two dig permit applications for excavation or construction activities within the Building 832 or 830 source areas for which excavation/construction activities are controlled (Figure 12). These included dig permits for: (1) the installation of extraction well W-832-3019 in 2014 in the Building 832 source area, and (2) the installation of an injection well W-830-3102 in 2015 in the Building 830 source area. During the drilling of these wells, health and safety procedures were in place to prevent the drilling team from exposure to VOCs in subsurface soil. These procedures included regular monitoring of the well boreholes, drill cuttings, and the work area with an organic vapor analyzer during drilling. If VOCs are detected above background levels, the ES&H team is contacted to determine the need for additional personal protective equipment. However, this was not necessary during the drilling of W-832-3019 and W-830-3102 as VOCs were not detected above background during drilling monitoring. While other dig permits applications were submitted for activities in Building 832 Canyon OU during the five-year review period, none of these included activities within the Building 832 or 830 source areas for which excavation/construction activities are controlled.

4.5.1.3. Maintain Building Occupancy Restriction to Prevent Onsite Work Exposure to VOCs inside Building 830: Physical Barriers and Government Institutional Controls

Risk Driver: The baseline risk assessment identified a risk of 3×10^{-6} for onsite workers from inhalation of VOCs volatilizing from subsurface soil into ambient air inside Building 830. The annual risk re-evaluation conducted in 2014 indicated that the risk to onsite workers inside Building 830 remains above 10^{-6}.

Land Use Control Objective: Maintain building occupancy restriction to prevent onsite site worker inhalation exposure to VOCs inside Building 830 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.

Land Use Controls:

- Physical Barrier: Signage
- Work Induction Board Process

Five-Year Review Status: During this five-year review period: (1) Building 830 remained unoccupied, (2) warning signs were maintained which prohibit full time occupancy without notification and authorization by LLNL Site 300 Management, and (3) no new activities were proposed for Building 830. DOE conducts annual risk re-evaluations for VOC inhalation risk at Building 830 to determine when the inhalation risk has been mitigated. The risk re-evaluation results are reported in the Annual Site-Wide Compliance Monitoring Reports.

4.5.1.4. Maintain Land Use Restrictions to Prevent Onsite Work Exposure to VOCs Volatilizing from Surface Water from Spring 3: Government Institutional Controls

Risk Driver: The baseline risk assessment identified a risk of 7×10^{-5} for onsite workers from inhalation of VOCs volatilizing from Spring 3 into outdoor air.

Land Use Control Objective: Maintain land use restriction/institutional controls in the vicinity of Spring 3 to prevent onsite site worker inhalation exposure to VOCs at Spring 3 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.

Land Use Control:

- Work Induction Board Process.

Five-Year Review Status: The risk and hazard management evaluation for Spring 3 was completed in 2009 (Dibley et al., 2010a). The estimated risk remained below 10^{-6} and the HI remained below 1 for two consecutive years. No unacceptable risk or hazard to onsite workers exists at Spring 3. Therefore, institutional controls are no longer needed to prevent exposure.

In addition, workers do not occupy or plan to occupy the Spring 3 area in the near future. Current activities in the vicinity of the Spring 3 are restricted to semi-annual spring sampling, when water is present in the spring. The time spent sampling is well below the exposure scenario for which the unacceptable exposure risk was originally calculated in the baseline risk assessment, which assumed a worker would spend 8 hours a day, five days a week for 25 years working at the Spring 3.

4.5.1.5. Prohibit Transfer of Lands with Unmitigated Contamination: Proprietary Controls

Risk Driver: Potential exposure to contaminated environmental media.

Land Use Control Objective: Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.

Land Use Controls: Land use controls have been implemented to prohibit the transfer of Site 300 property or portions thereof with unmitigated contamination that could cause potential harm under residential or unrestricted land use, as required in the Site 300 Site-Wide ROD. The land use control and implementation status is described in more detail below.

Five-Year Review Proprietary Controls Implementation Status: The Site 300 Site-Wide ROD requires the implementation of land use controls to prohibit the residential or unrestricted land use of Site 300 property or portions thereof with unmitigated contamination that could cause potential harm to human health.

To prevent the potential exposure to contaminated waste and/or environmental media in the event of the transfer of Site 300 property, the Site 300 FFA prohibits DOE from transferring lands with unmitigated contamination that could cause potential harm unless it complies with the requirements of Section 120(h) of CERCLA, 42 U.S.C. 9620 (h) and requirements for notification and protection of the integrity of the remedy set forth in Section 28 of the FFA. The Site 300 FFA has not been modified during this five-year review period, and its provisions remain as originally stated.

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 (CCR) Division 4.5, Chapter 39, Section 67391.1 as specified in the Site 300 Site-Wide ROD, and will implement deed restrictions per CERCLA 120(h). No change in ownership of Site 300 will take effect without provision for continued maintenance of any contaminant system, treatment system, monitoring system, or other response action(s) installed or implemented.

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 the DOE, U.S. EPA, DTSC, and RWQCB agree that it adequately shows that no unacceptable risk for residential or unrestricted land use is present.

LLNL Site 300 remains an active DOE facility, and DOE has not proposed any plans to transfer any Site 300 land for residential, unrestricted, or non- DOE industrial land use during the five-year review period. Therefore, it has not been necessary to execute a land use covenant or deed restrictions. These institutional controls will be implemented if and when the property or a portion thereof is transferred in accordance with the requirements of the Site 300 Site-Wide ROD, Title 22 CCR Division 4.5, Chapter 39, Section 67391.1, and CERCLA 120(h).

4.5.2. Summary of the Status of Building 832 Canyon OU Land Use Controls

The review of the land use controls for the Building 832 Canyon OU for this five-year review period determined that these controls are effective for preventing exposure to contaminated media. DOE will implement, maintain, and enforce the land use controls for the Building 832 Canyon OU for as long as necessary to keep the selected remedy protective of human health and the environment.

5. Progress Since Last Review

This section describes the Protectiveness Statement and recommendations and follow-up actions from the previous Building 832 Canyon OU five-year review completed in 2011. It also describes the status of the actions recommended in this previous review.

5.1. Protectiveness Statement from Last Review

The 2011 Building 832 Canyon OU Five-Year Review indicated that the remedy for the OU is 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 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 timeframe 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 2011 Five-Year Review.

5.2. Recommendations and Follow-up Actions from the 2011 Five-Year Review

The following recommendations and follow-up actions were developed during the Five-Year Review process in 2011:

1. Drill and install one new extraction well (W-830-2701) to increase hydraulic capture and prevent migration of COCs in the $Tnsc_{1a}$ HSU. This new extraction well would be connected to the 830-SRC facility where extracted ground water would be treated.
2. Drill and install one new dual extraction well (W-832-2702) to increase hydraulic capture of COCs in the $Tnsc_{1b}$ HSU and contaminant mass removal in the Building 832 source area, and prevent contaminant migration in this HSU. This new extraction well would be connected to the 832-SRC facility where extracted ground water and soil vapor would be treated.
3. Drill and install two $Tnsc_{1a}$ HSU monitor wells (W-832-3102 and W-830-2803) to better delineate the VOC plume in the $Tnsc_{1a}$ HSU west and southwest of the Building 830 source area, respectively.
4. Drill and install one $Tnsc_{1a}$ HSU monitor well (W-832-3001) to better delineate the extent of VOC contamination in this HSU downgradient of the Building 832 source area. This proposed monitor well W-832-3001 may be converted to an extraction well if ground water yields and total VOC concentrations are sufficient.
5. Drill and install one monitor well (W-832-2901) in the Upper $Tnbs_1$ HSU downgradient of the Building 832 source area. This well will be used as an Upper $Tnbs_1$ HSU guard well to verify that no contaminants from the Building 832 source area have reached this HSU.
6. Due to contamination by surface runoff, abandon $Tnsc_{1b}$ HSU monitor well W-832-05. Monitor well W-832-06, which is screened across the $Tnsc_{1b}$ and $Tnsc_{1a}$ HSUs, should also be abandoned because data collected from this well may not be fully representational of VOC concentrations in the $Tnsc_{1a}$ HSU near the Building 832 source area, and could act as a conduit allowing the downgradient migration of contaminants from the $Tnsc_{1b}$ HSU into the $Tnsc_{1a}$ HSU. After abandonment, replace wells with new monitor wells in the $Tnsc_{1b}$ and $Tnsc_{1a}$ HSUs. The locations of the replacement wells are to be determined, but will likely be located near the 832-SRC or 830-SRC treatment facilities.

No other follow-up actions were identified related to the 2011 Five-Year Review.

5.3. Results of Implemented Actions

The status of actions taken in response to the 2011 Five-Year Review recommendations listed in Section 5.2 above are as follows:

1. The recommended extraction well W-830-2701 was installed in 2011 to increase hydraulic capture and prevent migration of COCs in the $Tnsc_{1a}$ HSU in the distal parts of the VOC plume downgradient of the Building 830 source area. The well is completed in the $Tnsc_{1a}$ HSU and screened between 70 and 90 ft bgs. A hydraulic test completed in 2013 determined that the well was capable of producing up to 7 gpm. As part of the

GWTS and SVTS upgrade in 2014-2015, the extraction well was connected to the 830-SRC GWTS in 2015. Since extraction wellfield startup in August 2015, extraction well W-830-2701 has operated between 2.5 and 4 gpm.

2. The recommended dual extraction well, identified as W-832-2702 in the 2011 Five-Year Review report, was installed in 2014 as W-830-3019 east of Building 832 to increase hydraulic capture of COCs in the $Tnsc_{1b}$ HSU, increase contaminant mass removal in the Building 832 source area, and prevent contaminant migration in this HSU. The total VOC concentrations at this location are elevated, with 1,600 µg/L TCE and 0.61 µg/L cis-1,2-DCE detected in baseline samples collected in August 2015. Dual extraction well W-832-3019 will be integrated into the 832-SRC GWTS and SVTS as part of the ongoing 832-SRC facility upgrade scheduled in 2016 and will serve as a monitor well until then.
3. The recommended $Tnsc_{1a}$ HSU monitor well, identified as W-832-2901 in the 2011 Five-Year Review report, was installed in 2012 as W-830-2806 to better delineate the VOC plume in the $Tnsc_{1a}$ HSU southwest of the Building 830 source area. This monitor well is completed between 233 and 238 ft bgs. VOCs have not been detected in ground water from W-830-2806 above their respective reporting limits. Therefore, well W-830-2806 has delineated the extent of VOC plume in the $Tnsc_{1a}$ HSU southwest of Building 830-SRC area.

   The recommended $Tnsc_{1a}$ HSU monitor well to better delineate the VOC plume in the $Tnsc_{1a}$ HSU west of the Building 830 source area, identified as W-832-3102 in the 2011 Five-Year Review report, is scheduled for installation in fiscal year (FY) 2017 and will be located near monitor well W-832-3103.
4. The recommended $Tnsc_{1a}$ HSU monitor well, identified as W-830-3001 in the 2011 Five-Year Review report, was installed in 2014 as W-832-3020 for the purpose of better delineating VOC concentrations south of the Building 832-SRC area and possible conversion to an extraction well. Results from the August 2015 baseline sampling of this well indicated a total VOC concentration of 135 µg/L, with TCE, trichlorofluoromethane, and cis-1,2-DCE concentrations of 130 µg/L, 1 µg/L, and 3.5 µg/L, respectively. As part of ongoing 832-SRC GWTS facility upgrades scheduled in 2016, this well will be converted to an extraction well replacing W-832-11. Well W-832-11 will be converted for use as a monitor well.
5. The recommended Upper $Tnbs_1$ HSU guard well, identified as W-832-2901 in the 2011 Five-Year Review report, was installed in 2015 as W-832-3103 to confirm the extent of VOCs southwest and downgradient of the Building 832-SRC area. Baseline results for this well did not indicate any COC concentrations above their respective reporting limits.
6. Monitor wells W-832-3209 and W-832-3210, replacing wells W-832-05 and W-832-06, respectively are scheduled to be installed in 2016. The decommissioning of both wells W-832-05 and W-832-06 will be scheduled after the new monitor wells are installed.

5.4. Status of Other Prior Issues

There are no other prior issues.

6. Five-Year Review Process

6.1. Notification of Review/Community Involvement

This Five-Year Review report will be placed in the Administrative Record file and the Information Repositories located in the LLNL Discovery Center in Livermore, California and in the Tracy Public Library in Tracy, California. Notice of its initiation and completion will be placed in two publications: *The Tracy Press* and *San Joaquin Herald*. The initial notice was published in *The Tracy Press* and *San Joaquin Herald* on DATE. Completed documents can also be accessed electronically at LLNL's Environmental Restoration Department electronic library web page at *http://www-erd/library/* or the Environmental Community Relations web page at *http://www-envirinfo.llnl.gov*.

The draft, draft final and final five-year review is also submitted to the community action group Tri-Valley Communities Against a Radioactive Environment for review.

6.2. Identification of Five-Year Review Team Members

The Five-Year Review of the Building 832 Canyon OU at LLNL Site 300 was led by Claire Holtzapple, Site 300 Remedial Project Manager for the DOE/NNSA-Livermore Field Office. The following team members assisted in the review:

- Leslie Ferry, Program Leader, LLNS.
- Vic Madrid, Hydrogeology Team Leader, LLNS.
- Todd Trammell, Treatment Facility Operator, LLNS.
- Larry Griffith, Treatment Facility Operator, LLNS.
- Jonathan McKaskey, Hydrogeologist, Weiss Associates.
- Ricky Villarreal, Hydrogeologist, Weiss Associates.
- Anja Verce, Environmental Engineer, Weiss Associates.

6.3. Document Review

This Five-Year Review included examination of the following relevant project documents and site data:

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300 (Webster-Scholten, 1994).
- Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300 (Ferry et al., 1999).
- Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300 (U.S. DOE, 2001).
- Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300 (U.S. DOE, 2008).
- Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300 (Ferry et al., 2001b).
- Remedial Design for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300 (Madrid, et. al., 2006).

- Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300 (Ferry et al., 2006a).
- Semi-annual and Annual Site-Wide Compliance Monitoring Reports that include evaluations of remediation progress in the Building 832 Canyon OU (Dibley et al., 2010b, 2011a, 2011c, 2012b, 2012c, 2013a, and 2013b, 2014, and Ferry and Buscheck (ed.) 2014a, 2014b, and 2015).
- First Five-Year Review Report for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300 (Helmig et al., 2011).

These documents are available on-line at *www-erd.llnl.gov/library/index.html#reports.s300*.

6.4. Building 832 Canyon OU Data Review and Evaluation

The progress of ground water remediation in the Building 832 Canyon OU was evaluated by:

- Comparing 2015 ground water COC concentrations and spatial distribution (Figures 7 through 14) to 2010 concentrations and distribution.
- Comparing temporal changes in COC extent and concentration.
- Reviewing extraction well performance.
- Reviewing VOC soil vapor mass removal data for the 832-SRC and 830-SRC soil vapor extraction and treatment facilities.
- Reviewing ground water COC mass removal data for the 832-SRC, 830-SRC, and 830-DISS ground water treatment facilities.

The results of this evaluation for VOCs in the vadose zone and ground water COCs in the Building 832 Canyon OU during this five-year review period are discussed in the following subsections: contaminant concentrations and distribution (Section 6.4.1), contaminant remediation, mass removal, and capture zone analysis (Section 6.4.2.), and risk mitigation progress (Section 6.4.3).

6.4.1. OU Contaminant Concentrations and Distribution

As defined in the Compliance Monitoring Plan and Contingency Plans for Site 300, in the Building 832 Canyon OU, VOCs are the primary COC in soil vapor and ground water and perchlorate and nitrate are secondary COCs (Ferry et al., 2002b and Dibley et al., 2009b). VOCs have been identified within the Qal/WBR, $Tnsc_{1a/b}$, and Upper $Tnbs_1$ HSUs. VOCs have historically been detected in one well in the Lower $Tnbs_1$ HSU, however concentrations have been below the 0.5 μg/L reporting limit since August 2009. A comparison of VOC concentrations and distribution of total VOCs in these HSUs in 2010 and 2014 are shown on Figures 13-16. Perchlorate is present in the Qal/WBR and $Tnsc_{1a/1b}$ HSUs. A comparison of perchlorate concentrations and distribution in these HSUs in 2010 and 2014 are shown on Figures 17-19. Nitrate has been identified within the Qal/WBR, $Tnsc_{1a/1b}$, and Upper $Tnbs_1$ HSUs. The concentrations and distribution of nitrate in these HSUs are shown on Figures 20–22. VOC, perchlorate, and nitrate concentrations in the $Tnsc_{1a/1b}$ HSU are separate figures (as the $Tnsc_{1a}$ and $Tnsc_{1b}$) as the consolidation of these HSUs into one HSU ($Tnsc_{1a/1b}$) was done after the figures were completed.

VOC, perchlorate, and nitrate concentrations and distribution in ground water are discussed by HSU in Section 6.4.1.1, 6.4.1.2, and 6.4.1.3. In addition, although HE compounds were not identified as a ground water COC in the Building 832 Canyon OU, the results of ground water monitoring for HE compounds are discussed in Section 6.4.1.4 as they were identified as a surface soil COC.

6.4.1.1. VOC Concentrations, Distribution, and Remediation

VOCs detected in Building 832 area ground water consist primarily of TCE. During first semester 2015, VOCs other than TCE present above the reporting limits were cis-1,2-DCE, chloroform, 1,1,2-trichloroethane, Freon 11, chloroethane, chloromethane, and methylene chloride. Of these VOCs, only TCE was detected at concentrations above its 5 µg/L MCL cleanup standard.

During first semester 2015, VOCs present above the reporting limits in Building 830 area ground water were PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and chloroform. Of these VOCs, only TCE was detected at concentrations above its MCL cleanup standard of 5 µg/L.

VOCs detected in Building 830 distal area ground water consist primarily of TCE, but a detection of cis-1,2-DCE was also present in one well. Of these VOCs detected, only TCE was found at concentrations above its MCL cleanup standard of 5 µg/L.

VOC concentrations and distribution are discussed by HSU below.

Qal/WBR HSU

Since remediation began in 2000 in the Building 830 source area, total VOC concentrations in Qal/WBR HSU ground water near 830-SRC have decreased by two orders of magnitude from a historic maximum of 10,000 µg/L in 2003 (well SVI-830-035) to a first semester 2015 maximum of 480 µg/L in the same well (entirely TCE, February).

Since remediation began in 1999 in the Building 832 source area, ground water total VOC concentrations in wells screened in the Qal/WBR HSU have decreased from a historic maximum of 1,800 µg/L in 1998 (well W-832-18) to a first semester 2015 maximum of 100 µg/L in monitor well W-832-23 (February). Well W-832-23 is screened in the Qal/WBR and $Tnsc_{1b}$ HSUs. Since 1999, total VOC concentrations in this well have fluctuated seasonally over a broad range of concentrations from 23 to 690 µg/L, with a stable to slightly decreasing long-term trend. Total VOC concentrations in soil vapor are also declining in the Building 832 source area. Total VOC concentrations detected in soil vapor in well W-832-15 have decreased from a historic maximum concentration of 1.8 $ppm_{v/v}$ in 2001 to a first semester 2015 maximum of 0.036 $ppm_{v/v}$ (June). Neither W-832-15 nor W-832-12 have contained VOC concentrations in excess of 0.44 $ppm_{v/v}$ since 2011.

During this five-year review period, total VOC concentrations in ground water samples taken from Qal/WBR HSU guard wells W-35B-01 and W-880-02, both located south of the Building 832 Canyon OU near the Site 300 southern boundary, were near or below the 0.5 µg/L reporting limit. Since 2011, none of the 16 samples collected from guard well W-35B-01 contained VOC concentrations above the 0.5 µg/L reporting limit. During the same time period, only four of ten samples collected from guard well W-880-02 contained VOC concentrations above their respective reporting limits, with a total maximum of 0.61 µg/L in November 2011.

$Tnbs_2$ HSU

Well W-830-2216 extracts ground water from the $Tnbs_2$ HSU. COCs in this well are likely due to a combination of sources located in the HE Process Area and Building 832 Canyon OUs.

Since extraction began in 2007, total VOC concentrations in W-830-2216 have consistently declined from a historic maximum of 20 µg/L (2007) to a first semester 2015 maximum of 3.8 µg/L (April). TCE was the only VOC detected in extraction well W-830-2216 and nearby monitor well W-830-13 during first semester 2015. Total VOC concentrations in monitor well W-830-13 have decreased from a historic maximum of 26 µg/L in September 2006 to a minimum of 3.3 µg/L in August 2015. Although there was a slight increase in TCE concentrations in this well between 2010 and 2012, TCE concentrations have remained consistently below the 5 µg/L MCL cleanup standard since 2012, indicating that extraction well W-830-2216 is capturing the higher concentrations of VOCs in the plume. The extracted ground water is treated at the 830-DISS and central GSA treatment facilities.

While these $Tnbs_2$ wells are located within the technical boundary of the Building 832 Canyon OU, the performance of these wells is discussed in more detail in five-year reviews of the HE Process Area OU. The boundary of HE Process Area OU overlaps in this area so that performance remedy of the entire $Tnbs_2$ HSU can be evaluated as one piece, rather than being split between two OUs.

$Tnsc_{1b}$ HSU

As discussed above in Section 3.1.2.2, significant refinements have been made to the HSU analysis in the $Tnsc_1$ stratigraphic interval in the Building 832 Canyon OU that will be presented in future ground water elevation and contaminant isoconcentration maps. In this section, the $Tnsc_{1b}$ and $Tnsc_{1a}$ HSUs are discussed separately. However, new ground water elevation and total VOC plume maps are provided where the $Tnsc_{1b}$ and $Tnsc_{1a}$ HSUs are combined on Figures 30 through 32 which show a revised extent of saturation and distribution of total VOCs from previous ground water elevation and total VOC maps (Figures 9 and 14), particularly in the Building 832 source area.

Overall, the total VOC concentrations in wells completed in the $Tnsc_{1b}$ HSU have continued to decrease since the start of remediation through 2015. The plume geometry remains relatively unchanged from 2010 to first semester 2015, except for slight differences in extent of saturation related to long-term climatic conditions.

In the Building 832-SRC area, wells are drying out due to prolonged drought conditions. Wells in the immediate vicinity of Building 832 that still contain sufficient ground water for sampling have stable to decreasing VOC concentrations except for well W-832-23. In this well, VOC concentrations exhibited an increasing trend from 25 µg/L in March 2010 to 510 µg/L in August 2014, and then decreased to 100 µg/L in February 2015. To better characterize the extent of VOC contamination and remediate any residual VOCs in the Building 832 source area, a dual extraction well (W-832-3019) was installed near W-832-23 as recommended in the first five-year review (Helmig, et al., 2011). W-832-3019 was installed in 2014 and is discussed in more detail in the $Tnsc_{1a}$ section below because it was drilled and screened somewhat deeper than W-832-23 to the base of the $Tnsc_{1a}$ zone. Wells W-832-23 and W-832-3019 are located in the highest total VOC concentrations in the Building 832 source area.

Since remediation began in 2000 in the Building 830 source area, total VOC concentrations in ground water in the $Tnsc_{1b}$ HSU have decreased from a historic maximum of 13,000 µg/L in extraction well W-830-49 in 2003, to a first semester 2015 maximum of 1,800 µg/L in monitor well W-830-1829 (February). Concentration trends in the other 830-SRC extraction wells (W-830-49, and W-830-59) exhibit similar significant decreases during the five-year review reporting period. For example, total VOC concentrations in extraction well W-830-19 have decreased from a high of 4,200 µg/L in January 2010 to 2,100 µg/L in September 2015 (Figure 28). All other 830-SRC area extraction or monitor wells, completed in the $Tnsc_{1b}$ HSU, have shown stable or decreasing total VOC concentrations trends since 2010. For example, performance monitor well W-830-2213, located just downgradient from the Building 830 source area, has exhibited an order-of-magnitude decrease in total VOC concentration during this five-year reporting period from 611 µg/L in August 2010 to 57 µg/L in March 2015.

Since remediation began in the 830-DISS area in 1999, total VOC concentrations in $Tnsc_{1b}$ HSU artesian wells W-830-51, W-830-52 and W-830-53, have decreased from a historic maximum of 170 µg/L in 2002 (extraction well W-830-51) to a 2015 maximum of 18 µg/L in the same well (April). As shown on Figure 14, total VOC concentrations remain below 0.5 µg/L in monitor well W-830-1831 since its installation in 2002 and located downgradient of the Building 830 source area, and have only been detected twice in the parent samples of monitor well W-830-16 (installed in 1996) at 0.94 µg/L and 0.54 µg/L in April and November 2004, respectively. However, no VOCs were detected above the 0.5 µg/L reporting limit in duplicate samples collected on the same day. All other 830-DISS area monitor wells completed in the $Tnsc_{1b}$ HSU show stable to decreasing total VOC concentrations trends since 2010.

Farther south along the Building 832 Canyon, the leading edge of the $Tnsc_{1b}$ VOC plume continues to be contained within the Site 300 boundary based on total VOC concentrations below their respective reporting limits in guard wells W-880-03, W-830-1730, and W-4C.

$Tnsc_{1a}$ HSU

Since recognition and remediation of the $Tnsc_{1a}$ HSU began in early 2007, total VOC concentrations in ground water at both Building 830 and 832 source areas have generally decreased from the historic maximum of 1,700 µg/L in 1998 (monitor well W-830-27). However, in a baseline sample at new extraction well W-830-3019, total VOCs were detected at 1,500 µg/L (April). Plans are in place to connect well W-830-3019 to the 832-SRC GWTS and SVTS as a dual extraction well in the near future. Total VOCs measured in other wells during this five-year review period were relatively stable compared to the previous five-year review period.

As indicated above, to better characterize the vertical extent of VOC contamination in the Building 832 source area, and the VOC concentration trends in monitor well W-832-23, a dual extraction well, W-832-3019, was installed less than 15 ft away from well W-832-23. W-832-3019 was drilled to a deeper depth than W-832-23 and completed in the $Tnsc_{1a}$ HSU. In a final well development baseline sample collected in April 2015 and in a later routine sample in August 2015, total VOC concentrations in the Building 832 source area were detected at concentrations of 1,500 µg/L and 1,600 µg/L, respectively (Figure 31), the highest concentration in the Building 832 source area. These results illustrate that concentrations can vary significantly over short distances due to the heterogeneous nature of the hydrogeology in typical Site 300 VOC source areas. The samples from W-832-3019 are not shown as part of the $Tnsc_{1a}$ total VOC 2014 Annual data presented on Figure 15. However, the April, 2015 result is included in the combined $Tnsc_{1a/b}$ map presented on Figure 31 which included 2015 data. W-832-3019 is a proposed dual extraction well that will be connected to the 832-SRC GWTS and SVTS as part of 832-SRC upgrades. Until that time, it will serve as a monitor well.

A significant difference in extent of saturation and VOC distribution exists when comparing the $Tnsc_{1b}$ VOC plume on Figure 14 with the combined $Tnsc_{1a/b}$ VOC map presented on Figure 31, especially in the area between the Building 832 and 830 source areas. This is the first time that VOC concentrations from the $Tnsc_{1a}$ and $Tnsc_{1b}$ have been contoured together as one HSU, the $Tnsc_{1a/b}$. To further constrain the extent of high VOC concentrations southeast of the Building 832 source area, DOE/NNSA recommends installing a ground water monitor well along Route 1, south of Building 831 (Figure 32). Additionally, the extent of saturation and distribution of VOCs downgradient of the Building 830 source area has increased when comparing these two interpretations. To further constrain the extent of VOC concentrations southwest of the Building 830 source area, DOE/NNSA recommends installing two ground water monitor wells as presented on Figure 32.

Upper $Tnbs_1$ HSU

Since remediation began in the Upper $Tnbs_1$ HSU, total VOC concentrations in ground water have decreased from a historic maximum of 100 µg/L in 1998 (monitor well W-830-28) to a first semester 2015 maximum of 23 µg/L in performance monitor well W-830-18 (February). Total VOC concentrations in well W-830-18 have increased since pumping of extraction well W-830-2215 began in 2006. This increasing trend in W-830-18 is an indication that the plume is being captured by the extraction well. In Upper $Tnbs_1$ guard wells W-830-15 and W-832-2112, VOCs have not detected above their respective reporting limits since they were installed in 1995 and 2005, respectively.

The interpretation of the spatial distribution of VOC contamination in the upgradient portion of the Upper $Tnbs_1$ HSU has changed during this five-year review period due to analytical results from a new monitor well, W-832-2906, located between the Building 830 and 832 source areas. Monitor well W-832-2906 was installed in 2013 to delineate the extent of VOC contamination between 830-SRC and 832-SRC areas. Since installation, total VOC concentrations have ranged from 5 to 12 µg/L indicating a contribution of VOCs from 832-SRC area. Additionally, drilling data for W-832-09 (installed in 1994) indicated ground water was encountered while drilling through the Upper $Tnbs_1$ HSU and a sample from 80 ft depth yielded 5 µg/L VOCs, all TCE. The 2014 total VOC contours on Figure 16 conservatively reflect the presence of VOCs in the Upper $Tnbs_1$ in both W-832-2906 and W-832-09, indicating the presence of VOCs upgradient from the 830-SRC area. The refined extent of VOCs in this area, taking into account the Upper $Tnbs_1$ total VOC concentrations at both W-832-2906 and W-832-09, was initially presented in the Upper $Tnbs_1$ total VOC map in the 2014 annual Compliance Monitoring Report. As shown in this map, there is some uncertainty regarding the distribution of VOCs upgradient between W 832-2906 and the Building 832 source area. To address this uncertainty in VOC distribution in this area, DOE/NNSA recommend installing an Upper $Tnbs_1$ ground water monitor well located between W-832-09 and W-832-2906 along Route 2 as shown on Figure 32.

Lower $Tnbs_1$ HSU

During this five-year review period, VOCs have not been detected above their respective reporting limits in any wells screened within the Lower $Tnbs_1$ HSU. Historically, the only Lower $Tnbs_1$ HSU well in which VOCs have been detected in Building 832 Canyon OU is W-830-29, with a historic maximum of 1.8 µg/L in June 1999. However, VOCs have not been detected in this well above their respective reporting limits since August 2009. No other Lower $Tnbs_1$ HSU wells in the 832 Canyon OU have detected any VOCs.

6.4.1.2. Perchlorate Concentrations, Distribution, and Remediation

In the Building 832 Canyon OU, perchlorate has historically been detected in the Qal/WBR, $Tnsc_{1b}$, $Tnsc_{1a}$, and Upper $Tnbs_1$ HSUs.

During second semester 2014, perchlorate was initially detected above the reporting limit of 4 µg/L in one ground water sample collected from Upper $Tnbs_1$ guard well W-830-15 (86 µg/L, August) and one sample from $Tnsc_{1b}$ guard well W-880-03 (7.3 µg/L, August). The results for these samples were reviewed and determined to be analytical laboratory errors, likely due to "matrix interference," which is a common problem with perchlorate analyses. During first semester 2015, samples from well W-830-15 did not contain perchlorate concentrations above the 4 µg/L reporting limit (March).

Qal/WBR HSU

Perchlorate concentrations in the Qal/WBR HSU have decreased in the Building 830 and 832 source areas from a historic maximum of 51 µg/L in monitor well W-830-34 in 1998, to a first semester 2015 maximum of 9.5 µg/L in monitor well W-832-13 (February). During the five-year review reporting period, perchlorate was not detected in this HSU above the 4 µg/L reporting limit in the 830-SRC area, 830-DISS area, or in Qal/WBR HSU guard wells W-35B-01 and W-880-02. Several wells that have previously contained perchlorate do not contain sufficient ground water for sampling due to prolonged drought conditions and a declining water table to beneath the well screens (e.g. W-832-18, SVI-830-032, W-832-21). These wells are monitored for presence of water and will be sampled when sufficient water is available.

$Tnbs_2$ HSU

Perchlorate detections in the Building 832 Canyon OU $Tnbs_2$ HSU have all been below the 4 µg/L reporting limit, except for one detection in extraction well W-830-2216 (4.2 µg/L, 2007) and two detections in nearby monitor well W-830-13 (4.1 µg/L, 2004; 4.7 µg/L, 2006). The source of perchlorate contamination in these Building 832 Canyon area wells is the $Tnbs_2$ perchlorate plume in the HE Process Area.

$Tnsc_{1b}$ HSU

In the Buildings 830 and 832 source areas, perchlorate concentrations in the $Tnsc_{1b}$ HSU continue a relatively stable to decreasing trend. During first semester 2015, the maximum perchlorate concentration detected in the $Tnsc_{1b}$ HSU was 9.6 µg/L in well W-832-13 (February), slightly above the 6 µg/L MCL cleanup standard. Perchlorate has never been detected above the reporting limit in $Tnsc_{1b}$ HSU guard wells W-830-1730 and W-4C, including first semester 2015.

In the Building 830 distal area, perchlorate concentrations have remained steady to decreasing except in well W-830-51, where perchlorate concentrations have increased from below the reporting limit of 4 µg/L to 5.9 µg/L in August 2015, still below the well's historic maximum of 8.2 µg/L (April 2005).

$Tnsc_{1a}$ HSU

Since remediation of the $Tnsc_{1a}$ HSU began in early 2007, perchlorate concentrations in ground water at both the Buildings 830 and 832 source areas have generally remained stable or decreased. However, a baseline sample from new Building 832 source area well W-830-3019 yielded perchlorate at 18 µg/L (April 2015), a historic maximum for $Tnsc_{1a}$ wells in the Building 832 Canyon OU. DOE/LLNL plan to connect W-830-3019 as a dual extraction well to the 832-SRC GWTS and SVTS in the near future, which will include perchlorate treatment.

In the 830-DISS area, perchlorate concentrations in $Tnsc_{1a}$ well W-830-2311 remain low, ranging from below the 4 µg/L reporting limit to 4.9 µg/L (March 2015).

Upper $Tnbs_1$ HSU

Since 2005, perchlorate detections in the Upper $Tnbs_1$ HSU have all been below the 4 µg/L reporting limit, except for analytical laboratory errors as discussed above.

Lower $Tnbs_1$ HSU

Perchlorate has never been detected in the Lower $Tnbs_1$ HSU above the 4 µg/L reporting limit, including first semester 2015.

6.4.1.3. Nitrate Concentrations, Distribution, and Remediation

During this five-year review period, nitrate concentrations in ground water remained high in the vicinity of the Buildings 832 and 830 source areas, and low or below the 0.5 mg/L reporting limit in the downgradient, deeper parts of all Building 832 Canyon HSUs. All nitrate concentrations discussed in this report refer to nitrate in mg/L as NO_3.Concentration trends in the various HSUs are discussed below. Spatial and temporal nitrate concentration trends in all HSUs in the 832 Canyon OU continue to support the interpretation that nitrate is naturally attenuating in the ground water.

Qal/WBR HSU

During first semester 2015, nitrate in Qal/WBR HSU ground water ranged from 120 mg/L in Building 830 source area monitor well W-830-34 (February), and 140 mg/L in Building 832 source area monitor well W-832-13 (February), with nitrate concentrations generally decreasing downgradient. Nitrate concentrations remain the below the 0.5 mg/L reporting limit in guard wells located near the site boundary.

$Tnbs_2$ HSU

During the five-year review period, nitrate concentrations have remained stable in $Tnbs_2$ HSU wells, except for W-830-13, where nitrate concentrations continued to decrease from a historic maximum of 79 mg/L in 2004 (February) to 13 mg/L in March 2014, the last sample collected from this well.

$Tnsc_{1b}$ HSU

During the five-year review period, ground water nitrate concentrations in the $Tnsc_{1b}$ HSU remained high but stable (between 20 and 140 mg/L) in the vicinity of the Buildings 832 and 830 source areas and continue to exhibit a significant decreasing trend toward the Site 300 boundary where the ground water is under confined hydraulic conditions. During the five-year review period, nitrate concentrations in the downgradient $Tnsc_{1b}$ guard wells were all below the 0.5 mg/L reporting limit.

$Tnsc_{1a}$ HSU

Although nitrate concentrations remain high in the $Tnsc_{1a}$ HSU, they have decreased from a historic maximum of 160 mg/L in 2002 (monitor well W-830-27) to first semester 2015 maxima of 110 mg/L in the 830-SRC area (monitor well W-830-27, February), and 102 mg/L in the 832-SRC area (extraction well W-832-3019, February). The $Tnsc_{1a}$ nitrate levels near the Site 300 boundary are not known because the only monitor well installed in this HSU (W-830-2610) was damaged due to problems encountered during drilling and well installation.

Upper Tnbs$_1$ HSU

Historically, the highest nitrate concentration in the Upper Tnbs$_1$ HSU in the Building 832 Canyon OU was 21 mg/L in 1997 (monitor well W-830-28). The first semester 2015 maximum for the Buildings 830 and 832 areas was 8.8 mg/L (well W-830-28), significantly below its 45 mg/L MCL cleanup standard. During first semester 2015, nitrate was not detected in guard wells W-830-15 or W-832-2112 above the reporting limit of 0.5 mg/L. The very low nitrate concentrations in the downgradient areas and the absence of detectable nitrate in the southern site boundary guard wells are consistent with the interpretation that nitrate is naturally attenuating *in situ* in the Upper Tnbs$_1$ HSU.

Lower Tnbs$_1$ HSU

To date, nitrate has rarely been detected above the reporting limit in the Lower Tnbs$_1$ HSU in Building 832 Canyon OU. For example, well W-830-29 detected nitrate at 18 mg/L in 2003 (February). This was a single occurrence bracketed by multiple results below the reporting limit and could likely be attributed to matrix interference or laboratory error. Any nitrate detected in this HSU in the vicinity of 832 Canyon has been low or not detected above the 0.5 mg/L reporting limit.

6.4.1.4. HE Compound Concentrations and Distribution

As discussed in Section 6.4.1, HE compounds were not identified as a ground water COC in the Building 832 Canyon OU. However, ground water monitoring for HE compounds in ground water is conducted as they were identified as a surface soil COC.

HE compounds have never been detected in ground water above reporting limits in the Building 832 Canyon OU.

6.4.2. Contaminant Remediation and Mass Removal

Significant progress has been made towards remediating the vadose zone and ground water in the Building 832 Canyon OU. Ground water and soil vapor remediation was initiated in 1999 and all planned treatment facilities (832-SRC, 830-SRC, and 830-DISS [ground water only]) are in place and operating.

The performance of the 832-SRC and 830-SRC soil vapor extraction and treatment systems in remediating VOC contamination and reducing VOC mass in the vadose zone during the five-year review period is discussed in Section 6.4.2.1. The performance of the 832-SRC, 830-SRC, and 832-DISS ground water extraction and treatment systems in in reducing VOC and perchlorate concentrations and mass in ground water, and the effectiveness of MNA in reducing nitrate concentrations during the five-year review period are discussed in Section 6.4.2.2.

6.4.2.1. Vadose Zone Remediation Progress

Vadose zone remediation in the form of dual soil vapor/ground water extraction and treatment has been ongoing at the Building 832 and 830 source areas since 1999 and 2003, respectively. The remediation strategy in these low-yield, high-VOC source area extraction wells is to maintain a vacuum in the well while simultaneously lowering the water table by pumping. This dual extraction approach is the most effective way to lower the water table and expose VOC-contaminated soil and bedrock to soil vapor extraction while enhancing ground water yield. To date, an order of magnitude more VOC mass has been removed in the vapor phase than in the dissolved phase using dual extraction at 830-SRC and 832-SRC treatment facilities. Time-series plots of the cumulative total VOC mass removed from soil vapor by the 832-Source and 830-Source soil vapor extraction and treatment systems are shown on Figure 25.

During this five-year review period, the 832-SRC SVTS extracted and treated soil vapor from two dual extraction wells (W-832-12 and W-832-15). During this time, the 832-SRC SVTS extracted and treated 7.15 million cubic feet (ft^3) of soil vapor, and removed 250 grams (g) of VOCs from soil vapor. The TCE concentrations in soil vapor extraction wells W-832-12 and W-832-15 and monthly vapor flow in the 832-SRC soil vapor extraction and treatment system influent are shown on Figure 23. Total VOC soil vapor concentrations in wells W-832-12 and W-832-15 have declined from a historic maxima of 1.1 $ppm_{v/v}$ (November 2008) and 1.8 $ppm_{v/v}$ (September 2001), respectively, to concentrations consistently below 0.5 $ppm_{v/v}$ during the entire five-year review reporting period. Over time, the mass of VOCs removed by the 832-SRC SVTS has declined mainly due to decreasing VOC concentrations in the subsurface. In 2014, a new $Tnsc_{1a/b}$ HSU well W-832-2019 was drilled near the Building 832 source area. Well W-832-2019 is planned as a dual extraction well to be connected to the 832-SRC SVTS in 2016 to increase VOC mass removal in the $Tnsc_{1a/b}$ HSU. Replacing aging components as part of the upgrade process for the 832-SRC SVTS will also increase mass removal by increasing operational efficiency.

During the five-year review period, the 830-SRC SVTS extracted and treated soil vapor from two dual extraction wells (W-830-49 and W-830-1807). During this time, the 830-SRC SVTS extracted and treated 40 million ft^3 of soil vapor, and removed 4,900 g of VOCs from soil vapor. The TCE concentrations in soil vapor extraction wells W-830-49 and W-830-1807 and monthly vapor flow in the 830-SRC soil vapor extraction and treatment system influent are shown on Figure 24. Total VOC soil vapor concentrations in well W-830-1807 declined from a historic maximum of 35 $ppm_{v/v}$ (January 2004) to at or below 1 $ppm_{v/v}$ during the five-year review reporting period except for once instance. While VOC concentrations in soil vapor at W-830-49 have significantly decreased from a historic maximum of 259 $ppm_{v/v}$ (April 2007), during the current five-year review reporting period concentrations have varied between 0 and 14 $ppm_{v/v}$. Over time, the mass of VOCs removed by the 830-SRC SVTS has declined due to both decreasing VOC concentrations in the subsurface and decreased efficiency of aging SVTS components, which have been repaired or upgraded during the recent facility upgrade.

6.4.2.2. Ground Water Remediation Progress

Ground water remediation has been ongoing at the Building 832 and 830 source areas since 1999 and 2003, respectively, and at the distal portion of the Building 830 VOC and perchlorate plumes since 2000 to: (1) reduce VOC and perchlorate concentrations to meet cleanup standards; (2) control contaminant sources at Buildings 832 and 830; and (3) prevent offsite plume migration. All planned treatment facilities (832-SRC, 830-SRC, and 830-DISS) are in place and operating. Significant progress has been made towards remediating ground water in the Building 832 Canyon OU.

However, ground water remediation efforts continue to be constrained by:

- Steep topography that limits the availability of accessible locations for additional extraction and monitor well.
- Low yields due to fine-grained geologic materials and limited recharge.

- The need to balance site boundary pumping and upgradient source area pumping to avoid pulling contaminants farther downgradient.

In the five-year review period, 325,441 gallons of ground water were extracted from wells W-832-10, -11, 12, -15, and -25 at a combined flow rate of 0.035 gallons per minute (gpm), and treated at the 832-SRC facility. However, by 2014, well W-832-10 produced negligible amounts of water and W-832-11 produced no water. Ground water yields from 832-SRC extraction wells decreased significantly during the five-year period. For example, the volume of water extracted at 832-SRC decreased from 100,800 in gallons extracted in the 2011 to 24,519 gallons extracted in 2014. The low/decreased yields are due to a combination of geologic materials of low hydraulic conductivity, dewatering by ground water extraction, and limited recharge as a result of drought conditions during the review period. However, the volume of soil vapor extracted increased from 1,192,000 ft^3 in 2011 to 1,804,000 ft^3 in 2014, presumably as a result of a greater volume of vadose zone exposed due to declining water levels. The TCE concentrations in ground water extraction wells W-832-01, -10, -11, -12, -15 and W-832-25 and monthly flow in the 832-SRC ground water extraction and treatment system influent are shown on Figure 27. During the five-year review period, the 832-SRC GWTS removed approximately 115 grams (g) of VOCs, 9.6 g of perchlorate, and 150 kilograms (kg) of nitrate from ground water. Time-series plots of the cumulative total VOC and perchlorate mass removed from ground water by the 832-SRC ground water extraction and treatment system are shown on Figures 25 and 26, respectively.

In the five-year review period, 8,500,342 gallons of ground water were extracted from wells W-830-19, -49, 57, -59, -60, -1807, -2214, and -2215 at a combined flow rate of 6 to 11 gpm and treated at the 830-SRC facility. Similar to the 832-SRC facility, ground water yields from 830-SRC extraction wells have significantly decreased due to low conductivity geologic materials, dewatering by ground water extraction, and limited recharge. For example, the volume of water extracted at 830-SRC decreased from 56,850 gallons extracted in the second semester of 2010 to 6,641 gallons extracted in the first semester of 2015. The TCE concentrations in ground water extraction wells W-830-19, -49, -59, - -1807, and W-830-2214 and monthly flow in the 830-SRC ground water extraction and treatment system influent are shown on Figure 28. Upgrades to the 830-SRC GWTS and SVTS were completed in 2015 that included replacement of and improvements to aging facility components to increase operational efficiency and ensure long-term effectiveness. These upgrades also included improvements to the data collection capabilities at the 830-SRC GWTS that will make it possible to better evaluate mass removal trends and long-term performance of this system in the future. During the five-year review period, the 830-SRC GWTS removed approximately 6,000 g of VOCs, 18.5 g of perchlorate, and 700 kg of nitrate from ground water. The 830-SRC treatment facility exhibits the highest cumulative total VOC mass removed due to the high VOC concentrations and flow rates at this facility relative to 832-SRC and 830-DISS treatment facilities. Time-series plots of the cumulative total VOC and perchlorate mass removed from ground water by the 830-Source ground water extraction and treatment system are shown on Figures 25 and 26, respectively.

In the five-year review period, 4,910,816 gallons of ground water were extracted from wells W-830-51, -52, 53, and -2216 at a combined flow rate of approximately 1 to 2 gpm, and treated at the 830-DISS facility. The TCE concentrations in ground water extraction wells W-830-51, -52, and W-830-2216 and monthly flow in the 830-DISS ground water extraction and treatment system influent are shown on Figure 29. During the five-year review period, the 830-DISS GWTS removed approximately 6,400 g of VOCs, 45 g of perchlorate, and 1,600 kg of nitrate from ground water. Time-series plots of the cumulative total VOC and perchlorate mass removed from ground water by the 830-DISS ground water extraction and treatment system are shown on Figures 25 and 26, respectively.

Hydraulic capture zones are not shown for the Qal/WBR HSU because there are not enough ground water elevation data points to contour these data due to the limited extent of saturation. The hydraulic capture zones in the $Tnsc_{1b}$ stratigraphic portion of the $Tnsc_{1a/1b}$ HSU are shown on Figures 9 and 14. Hydraulic capture is difficult to assess in the Building 832 source area as ground water yields from many of the $Tnsc_{1b}$ HSU extraction wells in this area are low and cannot maintain continuous pumping. Hydraulic capture zones for the $Tnsc_{1a}$ HSU extraction wells W-832-25 and W-830-2214 are not shown on Figure 15, but are expected to be similar to $Tnsc_{1b}$ HSU extraction wells W-832-10 and W-830-1830, respectively. $Tnsc_{1a}$ HSU extraction wells W-832-25 and W-830-2214 have low yields and are located in areas with limited recharge. Extraction well hydraulic capture in the $Tnsc_{1a/1b}$ HSU, while generally effective at removing and reducing high VOC source area concentrations, continues to be constrained at the Building 832 and 830 source areas by low yields and limited recharge. Both the 832-SRC and 830-SRC facilities use dual extraction to enhance ground water yield and expand hydraulic influence. As shown on Figure 14, the 832-SRC, 830-SRC, and 830-DISS extraction well hydraulic capture zones target the zones with the highest VOC concentrations in the $Tnsc_{1a/1b}$ HSU. Nevertheless, due to low yields and limited recharge, the zones of hydraulic influence for many $Tnsc_{1a/1b}$ HSU extraction wells are limited. The steep topography present in the Building 832 Canyon also limits the locations where new extraction wells can be safely installed. Near the 830-DISS treatment facility, hydraulic capture associated with passive extraction captures the leading edge of the VOC plume. This is demonstrated by a decreasing VOC trend in downgradient well W-830-56 and the absence of VOCs in guard wells W-830-1730 and W-880-03. In the area near the 830-DISS treatment facility, the area of hydraulic capture is adequate and no additional extraction or monitor wells are planned for this area in the $Tnsc_{1a/1b}$ HSU. The hydraulic capture zones in the Upper $Tnbs_1$ HSU are shown on Figures 11 and 16. As shown on Figure 16, the 830-SRC Upper $Tnbs_1$ extraction wells adequately capture the VOC plume. The hydraulic capture zones shown on this figure are estimated based on pumping water levels from extraction wells and nearby performance monitor wells.

During the last five years, DOE/LLNL have continued to expand the 832-SRC and 830-SRC extraction wellfields to increase hydraulic capture and prevent the migration of contaminants vertically into deeper HSUs and laterally towards the site boundary. At the 832-SRC treatment facility, two new wells (W-832-3019 and W-832-3020) were installed as potential dual extraction wells to be connected to the facility in 2016. These wells are currently undergoing evaluation to determine the feasibility of using the wells for dual extraction. At the 830-SRC treatment facility, one new ground water extraction well (W-830-2701) was connected to the extraction wellfield. In addition, seven new ground water monitor wells were installed in the Building 832 Canyon OU during the five-year review period to monitor contaminants and remediation effectiveness. These include one new $Tnsc_{1a/b}$ HSU monitor well (W-830-2806), two new Upper $Tnbs_1$ HSU monitor wells (W-832-2906 and W-832-3103), and four new Qal/WBR HSU wells (W-832-3015, W-832-3016, W-832-3017, and W-832-3018), installed in the shallow alluvium in the Building 832 Canyon streambed (Figure 3). Two new $Tnbs_1$ HSU wells (W-830-3101 and W-830-3102) were drilled and installed as potential effluent injection wells for treated effluent from the 830-SRC GWTS. These wells are being tested and are scheduled for hookup to the 830-SRC GWTS in 2016. DOE/LLNL plan to drill additional injection wells for the 830-SRC and 830-DISS GWTS treated effluent in 2017 and 2018, respectively. Once installed and connected to the GWTSs, these injection wells will replace the misting towers for discharge of treated effluent from the Building 832 Canyon treatment facilities. The change from misting towers to injection wells are planned to minimize impacts to special status species, and to fully utilize the MNA remedy for nitrate in ground water.

DOE/LLNL will continue to evaluate the extent of hydraulic capture and the progress of each extraction wellfield toward achieving ground water RAOs, especially in light of anticipated changes in hydraulic gradients associated with the shutdown of Site 300 water-supply Well 20. The transition from Wells 18 and 20 is an ongoing process and the overall schedule and post-transition plans are still being developed. It is not possible to predict the effects of this change in operating conditions on the hydraulic capture and progress of each extraction wellfield, in advance. However, some increase in regional water levels in the $Tnsc_{1a/1b}$ and $Tnbs_1$ HSUs is expected, particularly near the site boundary where some wells are expected to become artesian. If performance data indicate that the extraction wellfields are not performing as expected, wellfield optimization will be conducted.

As part of the ongoing facility assessment and upgrade process, upgrades to data collection capabilities at the 832-SRC, 830-SRC, and 830-DISS GWTSs will make it possible to better evaluate mass removal trends and long-term performance of these systems in the future. These upgrades were completed at the 830-SRC facility in 2015, and are scheduled at the 832-SRC and 830-DISS GWTSs in 2016 and 2017, respectively.

Overall, COC concentrations continue to decrease as a result of remediation efforts in Building 832 Canyon OU. For example, VOC concentrations have decreased from a historic maximum of 30,000 µg/L in 1997 to a first semester 2015 maximum of 1,800 µg/L. Perchlorate concentrations have decreased from a historic maximum of 51 µg/L in 1998 to a first semester 2015 maximum of 9.6 µg/L. The MNA remedy for nitrate Building 832 Canyon OU ground water continues to be effective and protective of human health and the environment, and to make progress toward meeting cleanup standards. Decreasing nitrate concentration trends in confined portions of the $Tnsc_{1a/b}$ HSU indicate that natural attenuation continues to reduce nitrate concentrations and that the MNA remedy is protective. In the Qal/WBR HSU, adequate anoxic conditions for microbial degradation of nitrate are likely not present; however, as discussed below, nitrate concentrations have continued to decline in all source areas and nitrate concentrations have not been detected near the site boundary in ground water above the MCL cleanup standard. In the Upper $Tnbs_1$ HSU, nitrate concentrations are not present in ground water above the MCL cleanup standard. Reductions in VOC, perchlorate, and nitrate concentrations and plume configurations during the five-year review period are discussed in more detail in Sections 6.4.1.1, 6.4.1.2, and 6.4.1.3, respectively.

Declining water levels due to drought conditions continue to impact the amount of ground water available for extraction and treatment, particularly in the Building 832 source area. No other new issues were identified during this reporting period that could impact the long-term performance of the cleanup remedy for the Building 832 Canyon OU. The remedy continues to make progress toward cleanup and to be protective of human health and of the environment.

6.4.3. OU Risk Mitigation Progress

The baseline risk assessment was presented in the Site-Wide Remedial Investigation (Webster-Scholten et al., 1994) and updated in the Site-Wide Feasibility Study (Ferry et al., 1999). A baseline excess cancer risk was calculated for onsite workers of 1×10^{-5} for the inhalation of VOCs that volatilize from the subsurface soil into outdoor air in the vicinity of Building 830 and 3 × 10^{-6} for the inhalation of VOCs that volatilize from the subsurface soil into Building 832F indoor air. The remediation in the Building 832 Canyon OU mitigated these risks prior to the implementation of the Compliance Monitoring Plan annual risk evaluations that began in 2003. The risk evaluations performed for the 2003 and 2004 Annual Compliance Monitoring Reports (Dibley et al., 2004 and 2005) indicated there were no longer onsite worker risks from the inhalation of VOCs volatilizing from the subsurface into outdoor air at Building 830 or into Building 832F indoor air.

A baseline excess cancer risk for onsite workers of 3 × 10^{-6} was calculated for the inhalation of VOCs that volatilize from the subsurface soil into the indoor air of Buildings 830. The annual risk evaluations indicate that the VOC inhalation risk inside Building 830 remains above 10^{-6} and the HI remains above 1. Therefore, the Risk and Hazard Management Program, including institutional controls, will continue in this area until the risk evaluations indicate the risk and HI are below 10^{-6} and 1, respectively, for two consecutive years.

A baseline excess cancer risk for onsite workers of 7 × 10^{-3} was calculated for the inhalation of VOCs that volatilize from surface water into outdoor air in the vicinity of Spring 3. The risk evaluations performed for the 2008 and 2009 Annual Compliance Monitoring Reports (Dibley et al., 2009c and 2010a) indicated there was no longer an unacceptable risk at Spring 3. No newly or previously unidentified unacceptable ecological risk or hazard has been identified in the baseline ecological assessment or subsequent ecological reviews.

6.5. Interviews and Site Inspection

DOE/NNSA and LLNL meet approximately monthly with the EPA, RWQCB, and DTSC RPMs and quarterly with a community action group at Technical Assistance Grant Meetings to discuss remediation activities, issues, and cleanup status and progress.

On December 4. 2015, DOE/NNSA submitted interview forms to the EPA, RWQCB, and DTSC requesting regulatory input on the Building 832 Canyon OU by January 8, 2016.

There is a continuous presence of ERD staff at Site 300 that routinely inspect the monitoring wellfield during sampling activities. The treatment facility operator regularly inspects the Building 832 Canyon OU extraction wellfield and GWTS and SVTS to identify system components needing repair or replacement to ensure the effective and compliant operation of the systems. Additional details of routine inspections of remedy components are discussed in Section 4.4.

LLNL conducts self-assessment inspections and DOE/NNSA conducts inspections of remediation activities at Site 300. The RWQCB RPM performs site inspections twice a year, and the U.S. EPA and DTSC RPMs request periodic site inspections. The U.S. EPA performed the construction completion inspection for the Building 832 Canyon OU treatment facilities on February 6, 2008. LLNL ERD conducted a preliminary Five-Year Inspection on October 22, 2015, and DOE/NNSA, LLNL ERD, EPA, and the RWQCB performed a formal Five-Year Review Inspection on December 15, 2015. The Five-Year Review Inspection Checklist Photographs and completed Inspection Checklist for Building 832 Canyon OU are included in Appendix A as Appendix A1 and Appendix A2, respectively.

Operational issues and resulting corrective actions identified during routine inspections associated with the Building 832 Canyon GWTS and SVTS, and the OU monitoring wellfields are: (1) described in the semiannual Site 300 Compliance Monitoring Reports that are issued semi-annually by the LLNL ERD and (2) discussed and presented in the RPM Project Updates that are issued prior to and discussed with the regulators at the monthly RPM meetings. The contents of the Project Updates are incorporated into the RPM meeting minutes distributed following the meetings.

7. Technical Assessment

The protectiveness of the remedy was assessed by determining if:

1. The 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 remedy into question.

7.1. Remedy Function

The remedy was determined to be functioning as intended at the time of the decision documents because:

- No early indicators of potential remedy failure were identified.
- Costs have generally been within budget, except when extra costs were incurred to address unanticipated problems, work scope, or regulatory requests.
- The remedies for the Building 832 Canyon OU are functioning as intended by effectively removing VOC, perchlorate, and nitrate mass from the subsurface, by effectively reducing these COC concentrations towards cleanup standards, by preventing further contaminant releases through source control, and by mitigating risk to human health and ecological receptors.
- MNA has been effective in reducing nitrate activities in the Building 832 Canyon OU ground water towards the cleanup standard.
- The GWTS and SVTS in the Building 832 Canyon OU are performing as designed and will continue to be operated and maintained to reduce the concentrations of VOCs, perchlorate, and nitrate in ground water and VOCs in soil vapor. While DOE/LLNL continue to evaluate opportunities to optimize the efficiency and effectiveness of the GWTS and SVTS to improve operations and expedite cleanup, optimization of the treatment systems in the Building 832 Canyon OU is limited by the steep topography that limits the availability of accessible locations for additional extraction and monitor well, the low yields due to fine-grained geologic materials and limited recharge, and the need to balance site boundary pumping and upgradient source area pumping to avoid pulling contaminants farther downgradient.
- No early indicators of potential interim remedy failure were identified.
- Institutional controls are in place. No current or planned changes in land use at the site suggest that they are not or would not be effective.

Overall, analytical data indicate that the RAOs of the remedies in the Building 832 Canyon OU will be met including: (1) ongoing MNA of nitrate to ensure that concentrations and extents are stable-to-decreasing, (2) continued mitigation of the risk from VOCs in soil at Building 830 by conducting soil vapor extraction in the Building 830 source area, (3) ongoing removal of contaminant mass in ground water from downgradient of Buildings 830 and 832 source areas, (4) preventing offsite migration of ground water contaminants, and (5) ensuring that listed threatened or endangered, State of California species of special concern do not reside in areas where relevant hazard indices exceed 1.

7.2. Changes to Exposure Assumptions, Toxicity Data, Cleanup Levels, and Remedial Action Objectives

The assumptions used in the decision-making process were determined to still be valid because:

- There have been no significant changes in risk assessment methodologies or calculations that could call the protectiveness of the remedy into question.
- There have been no changes in exposure pathways that could call the protectiveness of the remedy into question.
- No new or previously unidentified unacceptable risk or hazard to human health have been identified.
- There have been no changes in land, building, or water use.
- No new contaminant sources have been identified.
- No remedy byproducts have been identified.
- Changes in location-, chemical-, or action-specific ARARs or to-be-considered requirements:
    - The State of California established a 6 µg/L MCL for perchlorate on October 18, 2007. This action-specific ARAR and ARARs related to ground water cleanup were included in the 2008 Site-Wide ROD.
    - The U.S. EPA National Pollution Discharge Elimination System (NPDES) Pesticide Rule changed in 2011. However, there are no discharges to the ground surface or NPDES permit required as part of the Building 832 Canyon OU remedies.
- The review found that the remedy is making progress toward meeting the RAOs.

7.3. Other Information

No additional information was identified that would call the protectiveness of the remedy into question:

- The Health and Safety Plan and Site-Wide Contingency Plan are in place, sufficient to control risks, and properly implemented.
- No unanticipated events (i.e., natural disasters) occurred that would call the protectiveness of the remedy into question.
- No additional information has been identified that would call the protectiveness of the interim remedy into question.

As part of the five-year review process, new technologies that could accelerate or achieve cleanup in a more cost-effective manner are evaluated. In the Building 832 Canyon, in the future, DOE/NNSA will evaluate site-specific data and consider the potential effectiveness of *in situ* bioremediation for source area remediation. Due to the documented assimilative capacity of the $Tnsc_{1a/b}$ HSU for natural attenuation of nitrate via *in situ* denitrification, the assimilative capacity of the same HSU will be evaluated for perchlorate reduction.

8. Issues

No deficiencies or issues were identified with the remedy selected to address VOCs, perchlorate, or nitrate in ground water. However, recommendations are presented to optimize the operation and maintenance of the Building 832 Canyon OU wellfields in Section 9.

9. Recommendations and Follow-up Actions

DOE/NNSA developed recommendations/follow-up actions for the Building 832 Canyon OU during the review process. These recommendations/follow-up actions are presented below.

Although no deficiencies or issues were identified with the Building 832 Canyon OU remedy, the following recommendations were developed to improve performance monitoring and demonstrate that the extraction wellfields are adequately capturing the highest COC concentrations in addition to monitoring the leading edge of the plumes in the $Tnsc_{1a/b}$ and Upper $Tnbs_1$ HSUs. As discussed in Section 3.1.2.2, combining the $Tnsc_{1a}$ and $Tnsc_{1b}$ HSUs into one ($Tnsc_{1a/b}$ HSU) provides a more comprehensive assessment of ground water flow directions and spatial distribution of COC in the Building 832 Canyon OU, but also highlights areas where some additional ground water monitoring are needed. To address these needs, DOE/NNSA recommend a total of four new wells (one Upper $Tnbs_1$ HSU monitor well and three $Tnsc_{1a/b}$ monitor wells). All new wells recommended below are shown on Figure 32.

1. The following new wells are recommended to be installed in the Upper $Tnbs_1$ and $Tnsc_{1a/b}$ HSUs:
   - To constrain the extent of the Upper $Tnbs_1$ VOC plume south of the Building 832-SRC area, DOE/NNSA recommends installing one Upper $Tnbs_1$ monitor well between W-832-2906 and W-832-09 within the extent of saturation of the Upper $Tnbs_1$.
   - To better delineate the extent of saturation and distribution of high VOC concentrations southeast of the Building 832 source area in the $Tnsc_{1a/b}$ HSU, DOE/NNSA recommends installing a ground water monitor well along Route 1 south of Building 831.
   - To better delineate the VOC plume in the $Tnsc_{1a/b}$ HSU, DOE/NNSA recommends installing two ground water monitor wells downgradient of the Building 830 source area. As shown on Figure 32, one monitor well would be located near Building 882 and the other located near Buildings 814 and 819 along Route 3.

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

10. Protectiveness Statement

The remedy at the Building 832 Canyon OU is protective of human health and the environment for the site's industrial land use. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of land use controls, the Health and Safety Plan, and the Contingency Plan.

The remedy protects human health because:

1. Ground water monitoring of VOCs, perchlorate, and nitrate in Building 832 Canyon OU ground water will provide an early indication of changes in the concentrations and/or extent of these constituents that could impact human health or the environment. As indicated in the revised Compliance Monitoring Plan and Contingency Plan (Dibley et al., 2009b), if ground water contaminant concentrations (i.e. VOCs, perchlorate, and/or nitrate concentrations) in the Building 832 Canyon OU increase in a consistent and significant manner for reasons not attributable to remediation efforts (e.g., cyclic pumping), or natural aquifer or laboratory variables, DOE will notify the regulatory agencies and modifications to the remedial action will be considered as necessary to protect human health.
2. Ground water extraction and treatment continues to reduce VOC, perchlorate, and nitrate mass and concentrations in the Building 832 Canyon OU ground water towards cleanup standards, and prevent offsite plume migration.
3. Soil vapor extraction in the Building 832 and 830 source areas continues to reduce VOC mass and concentrations towards cleanup standards, preventing further contaminant releases through source control, and mitigating risk to human health and ecological receptors.
4. MNA has been effective in reducing nitrate concentrations in the Building 832 Canyon OU ground water towards the cleanup standard. Institutional controls described in Section 4.5.1.1 are in place to prevent exposure to nitrate in ground water at concentrations above cleanup standards.
5. No new contaminant releases have been identified for the Building 832 Canyon OU, and continued detection monitoring will provide an indication of any future releases.
6. Ground water monitoring will provide an early indication of migration of contaminants towards the site boundary.
7. Exposure pathways that could result in unacceptable risk to onsite workers are being controlled by the implementation of land use/institutional controls, the Health and Safety Plan, and the Contingency Plan.

The cleanup standards for Building 832 Canyon OU ground water are Maximum Contaminant Levels (MCLs). Because MCL-based standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario.

The 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 cleanup standards, a land use control prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. The Site 300 FFA prohibits DOE from transferring lands with unmitigated contamination that could cause potential harm unless it complies with the requirements of Section 120(h) of CERCLA, 42 U.S.C. 9620(h) and requirements for notification and protection of the integrity of the remedy set forth in Section 28 of the FFA. 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 CCR Division 4.5, Chapter 39, Section 67391.1 as specified in the

Site 300 Site-Wide ROD, and will implement deed restrictions per CERCLA 120(h). These land use controls will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and the DOE/NNSA, U.S. EPA, DTSC, and RWQCB agree that it adequately shows that no unacceptable risk is present for residential or unrestricted land use.

11. Next Review

The next statutory review will be conducted within five years of the signature date of this report (2021).

12. References

Buscheck, M., J. Valett, M. Taffet, V. Dibley, V. Madrid, L. Ferry (2013), *First Five-Year Review Report for Operable Units 3 and 8 at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-579495).

Dibley, V., R. Blake, T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, M. Taffet, J. Valett (2004), *First Semester 2004 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-04).

Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, M. Taffet, and J. Valett (2005), *2004 Annual Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-04).

Dibley, V., J. Valett, L. Ferry (2006), *Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-220827).

Dibley, V., J. Valett, S. Gregory, and V. Madrid (2007a), *Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-226628).

Dibley, V., V. Madrid, and M. Denton (2007b), *Five-Year Review Report for the High Explosive Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-232231).

Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, D. Mason, P. McKereghan, M. Taffet, J. Valett (2007c), *2006 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-06).

Dibley, V., L. Ferry, M. Taffet, G. Carli, and E. Friedrich (2008a), *Engineering Evaluation/Cost Analysis for PCB-, Dioxin, and Furan-contaminated Soil at the Building 850 Firing Table, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-233862).

Dibley, V., L. Ferry, M. Taffet (2008b), *Action Memorandum for the Removal Action at the Building 850 Firing Table, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-403206).

Dibley, V., J. Valett, and M. Buscheck (2009a), *Five-Year Review Report for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-404822).

Dibley, V., L. Ferry, S. Gregory, L. Hall, V. Madrid, L. Martello, E.N. Shiroma, M. Taffet, K.S. Wells (2009b), *Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-411239).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2009c), *2008 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-08).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2010a), *2009 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-09).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2010b), *First Semester 2010 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-10).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2011a), *2010 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-10).

Dibley, V. L. Ferry, M. Taffet, Z. Demir, V. Madrid, K. Moffitt, R. Ruiz, (2011b), *Remedial Action Completion Report for the Building 850/Pit 7 Complex Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-432791).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2011c), *First Semester 2011 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-11).

Dibley V., and L. Ferry (2012a), *(Draft) Final Close Out Report for the Eastern General Services Area Subarea of Operable Unit 1 at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-607015-DRAFT).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2012b), *2011 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-11).

Dibley, V., L. Ferry, and M. Buscheck, Ed. (2012c), *First Semester 2012 Compliance Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-12).

Dibley, V., L. Ferry, M. Buscheck, Ed. (2013a), *2012 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-12).

Dibley, V., L. Ferry, and M. Buscheck, Ed. (2013b), *First Semester 2013 Compliance Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-13).

Dibley, V., L. Ferry, and M. Buscheck, Ed. (2014), *2013 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-13).

Ferry, L., R. Ferry, W. Isherwood, R. Woodward, T. Carlsen, Z. Demir, R. Qadir, and M. Dresen (1999), *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore Calif. (UCRL-AR-132609).

Ferry, R., W. Daily, L. Ferry, G. Aarons, V. Madrid, J. Valett, Z. Demir (2001a), *Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-14104).

Ferry, R., M. Dresen, L. Ferry, W. Isherwood, and J. Ziagos (2001b), *Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-138470).

Ferry, R., L. Ferry, S. Gregory, V. Madrid, J. Valett, (2002a), *Five-Year Review Report for the Building 834 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-144744).

Ferry, R., L. Ferry, M. Dresen, and T. Carlsen (2002b), *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-147570).

Ferry L., and C. Holtzapple (2005), *Characterization Summary Report for the Building 812 Study Area at Lawrence Livermore National Laboratory Site 300*, U.S. Department of Energy and Lawrence Livermore National Laboratory, Livermore Calif., 21 pp. plus attachments.

Ferry L., and C. Holtzapple (2006), *Characterization Summary Report for the Building 865 Study Area at Lawrence Livermore National Laboratory Site 300*, U.S. Department of Energy and Lawrence Livermore National Laboratory, Livermore Calif., 31 pp. plus attachments.

Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, M. Denton (2006a), *Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-220391).

Ferry, L., and M. Buscheck (ed). (2014a), *First Semester 2014 Compliance Report for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-14.)

Ferry, L., and M. Buscheck (ed). (2014b), *2014 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206319-14.)

Ferry, L., and M. Buscheck (ed). (2015), *First Semester 2015 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-206769-15.)

Goodrich, R., and G. Lorega (Eds.) (2012), *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)*, Lawrence Livermore National Laboratory Livermore, Calif. (UCRL-AM-109115 Rev. 14).

Helmig, A., V. Dibley, V. Madrid, and J. Valett (2011), *Five-Year Review Report for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-470073).

Helmig, A., V. Dibley, V. Madrid, J. Valett, and L. Ferry (2012), *Second Five-Year Review Report for the High Explosive Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-553611).

Holtzapple, C. (2005), *Excavation of polychlorinated biphenyl-contaminated soil at the Building 855 lagoon at Lawrence Livermore National Laboratory (LLNL) Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (letter report).

Jones and Stokes (2002), Special status Plant Species Surveys and Vegetation Mapping at Lawrence Livermore National Laboratory, prepared for Lawrence Livermore National Laboratory, Livermore, Calif. (September 2002).

LLNL (2004), *Operations and Maintenance Manual, Volume 1: Treatment Facility Quality Assurance and Documentation*, Lawrence Livermore National Laboratory, Livermore, Calif.

Madrid, V., J. Valett, M. Denton, Z. Demir, M. Dresen, and W. Daily (2006), Interim Remedial Design for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-214990).

Martins, S. (2006), *Operations and Maintenance Manual, Volume 13: Miniature Treatment Units (MTUs), Ground Water Treatment Units (GTUs), and Solar Treatment Units (STUs)*, Lawrence Livermore National Laboratory, Livermore, Calif.

Taffet, M.J., L. Ferry, V. Madrid, T. Carlsen, Z. Demir, J. Valett, M. Dresen, W. Daily, S. Coleman, V. Dibley (2005), *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-202492).

Taffet, M.J., V. Dibley, T. Carlsen, V. Madrid, Z. Demir, B. Daily, and L. Ferry (2008), *Draft Building 812 Remedial Investigation/Feasibility Study Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-404981-DRAFT).

U.S. DOE (1995), *Interim Record of Decision for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-119791).

U.S. DOE (1997), *Final Record of Decision for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-124061).

U.S. DOE (2001), *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-138470).

U.S. DOE (2002), *Draft Department of Energy CERCLA Five-Year Review Guidance*, U.S. Department of Energy, Washington, D.C.

U.S. DOE (2007), *Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-222569).

U.S. DOE (2008), *Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-236665).

U.S. EPA (2001), *Comprehensive Five-Year Review Guidance*, U.S. Environmental Protection Agency (EPA 540-R-01-007), OSWER Directive 9355.7-03B-P.

U.S. EPA (2010), *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites*, U.S. Environmental Protection Agency (EPA 540-R-09-001), OSWER Directive 9355.0-89.

Valett, J., V. Dibley, V. Madrid, L. Ferry (2011), Five-Year Review Report for the General Services Area Operable Unit, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-486703).

Valett, J., V. Dibley, V. Madrid, L. Ferry (2012), Draft Five-Year Review Report for the Building 834 Operable Unit, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-499272).

Valett, J., V. Dibley, M. Taffet, M. Buscheck, and L. Ferry (2014), *Second Five-Year Review Report for the Building 854 Operable Unit at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (LLNL-AR-638895).

Webster-Scholten C.P., Ed. (1994), *Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MI-141567).

Ziagos, J., and D. Sutherland (1996), *Building 832 Canyon Fact Sheet*, *Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif.

Ziagos, J., and P. Ko (1997) *Characterization Summary Report for the Building 832 Canyon Operable Unit*, *National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (Letter report).

13. Acronyms and Abbreviations

aMSL	Above mean sea level
api	American Petroleum Institute Units
ARARs	Applicable or relevant and appropriate requirements
ATA	Advanced Test Accelerator
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMB	Claystone marker bed
COC	Contaminant of concern
CRPR	California Rare Plant Rant
DCE	Dichloroethene or Dichloroethylene
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EA	Environmental Analyst
EPA	Environmental Protection Agency
ERD	Environmental Restoration Department
ES&H	Environmental Safety & Health
FFA	Federal Facilities Agreement
ft	Feet
ft^3	Cubic feet
FY	Fiscal year
g	Gram
GAC	Granular activated carbon
gpd	Gallons per day
gpm	Gallons per minute
GSA	General Services Area
GWTS	Ground water treatment system
HE	High explosives
HI	Hazard Index
HMX	High-Melting Explosive
HSU	Hydrostratigraphic unit
IW	Insufficient water
kg	Kilogram
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security, LLC
MCL	Maximum contaminant level
mg/L	Milligrams per liter
MNA	Monitored natural attenuation
MSL	Mean sea level
ND	Not detected (analytes)
NM	Not measured

NNSA	National Nuclear Security Administration
NPDES	National Pollution Discharge Elimination System
NS	Not sampled (typically a well)
O&M	Operations and maintenance
ohm-m	Ohm-meters
OU	Operable unit
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethene or Tetrachloroethylene
pCi/L	PicoCuries per liter
$ppm_{v/v}$	Parts per million volume for volume
Qal	Quaternary alluvium
Qal/WBR	Quaternary alluvium/weathered bedrock
RA	Restricted access
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDX	Research Department explosive
REVAL	Remediation evaluation (ERD)
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPMs	Remedial Project Managers
RSL	Regional Screening Level
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendment Reauthorization Act
scfm	Standard cubic feet per minute
SRC	Source
SWRI	Site-Wide Remedial Investigation
SVOCs	Semivolatile organic compounds
SVTS	Soil vapor extraction and treatment system
TBOS/TKEBS	Tetrabutyl orthosilicate/ Tetrakis (2-ethylbutyl) silane
TCE	Trichloroethylene
TFRT	Treatment Facility Real Time
Tmss	Miocene Cierbo Formation—lower siltstone/claystone member
$Tnbs_0$	Neroly silty Sandstone
$Tnbs_1$	Tertiary Neroly Lower Blue Sandstone
$Tnsc_0$	Tertiary Neroly Formation—lower siltstone/claystone member
$Tnsc_{1a}$	Tertiary Neroly Formation—lower member of the upper siltstone/claystone
$Tnsc_{1b}$	Tertiary Neroly Formation—middle member of the upper siltstone/claystone
$Tnsc_{1c}$	Tertiary Neroly Formation—upper member of the upper siltstone/claystone
Tps	Tertiary Pliocene nonmarine sediments
Tpsg	Tertiary Pliocene sand and gravel
UC	Unsafe conditions
U.S.	United States

VOCs	Volatile organic compounds
WBR	Weathered bedrock
yd^3	Cubic yards
µg/L	Micrograms per liter
830-DISS	Building 830-Distal South ground water extraction and treatment facility
830-PRXN	Building 830-Proximal North ground water extraction and treatment facility
832-SRC	Building 832-Source ground water and soil vapor extraction and treatment facility

Figures

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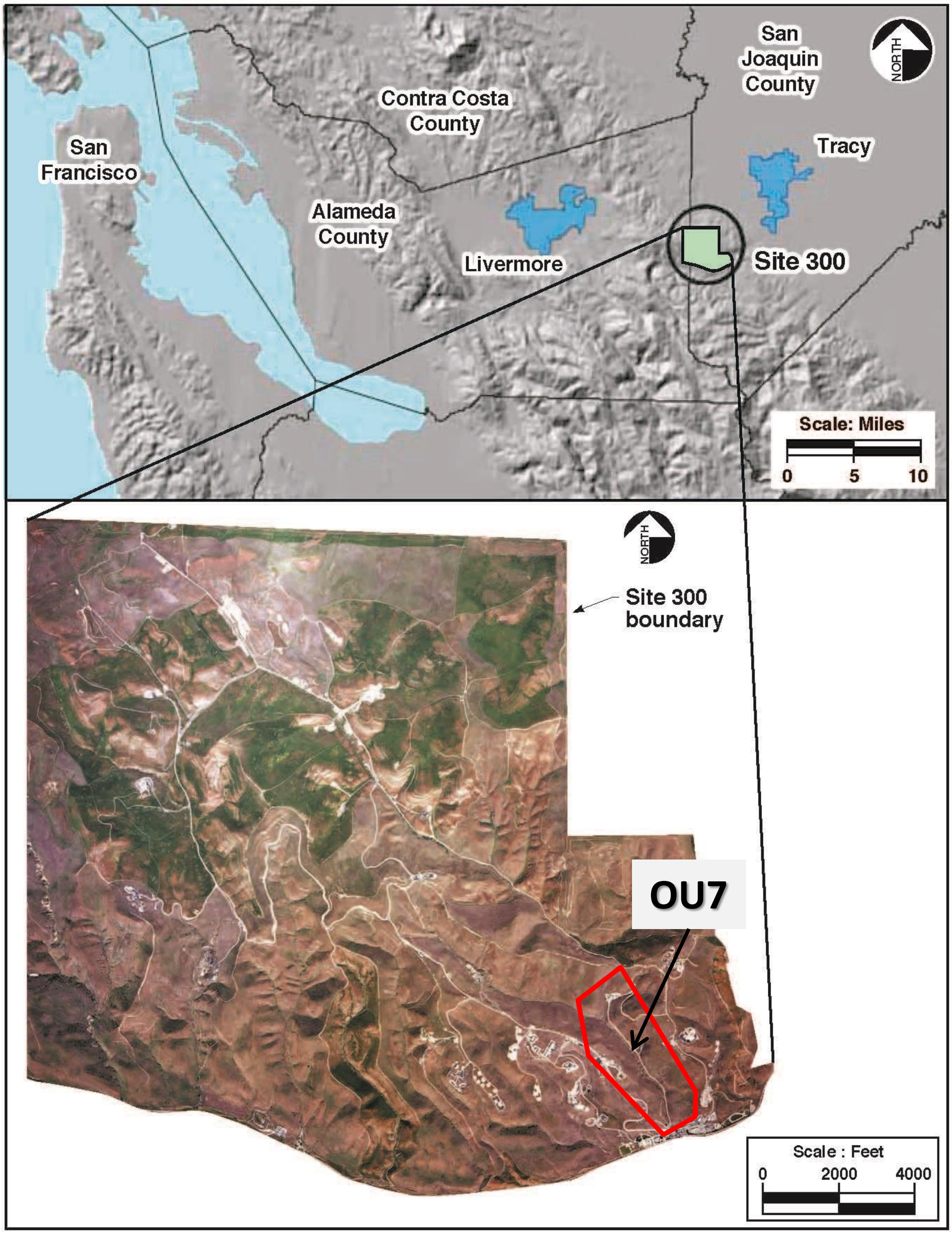


Figure 1. Location of LLNL Site 300.

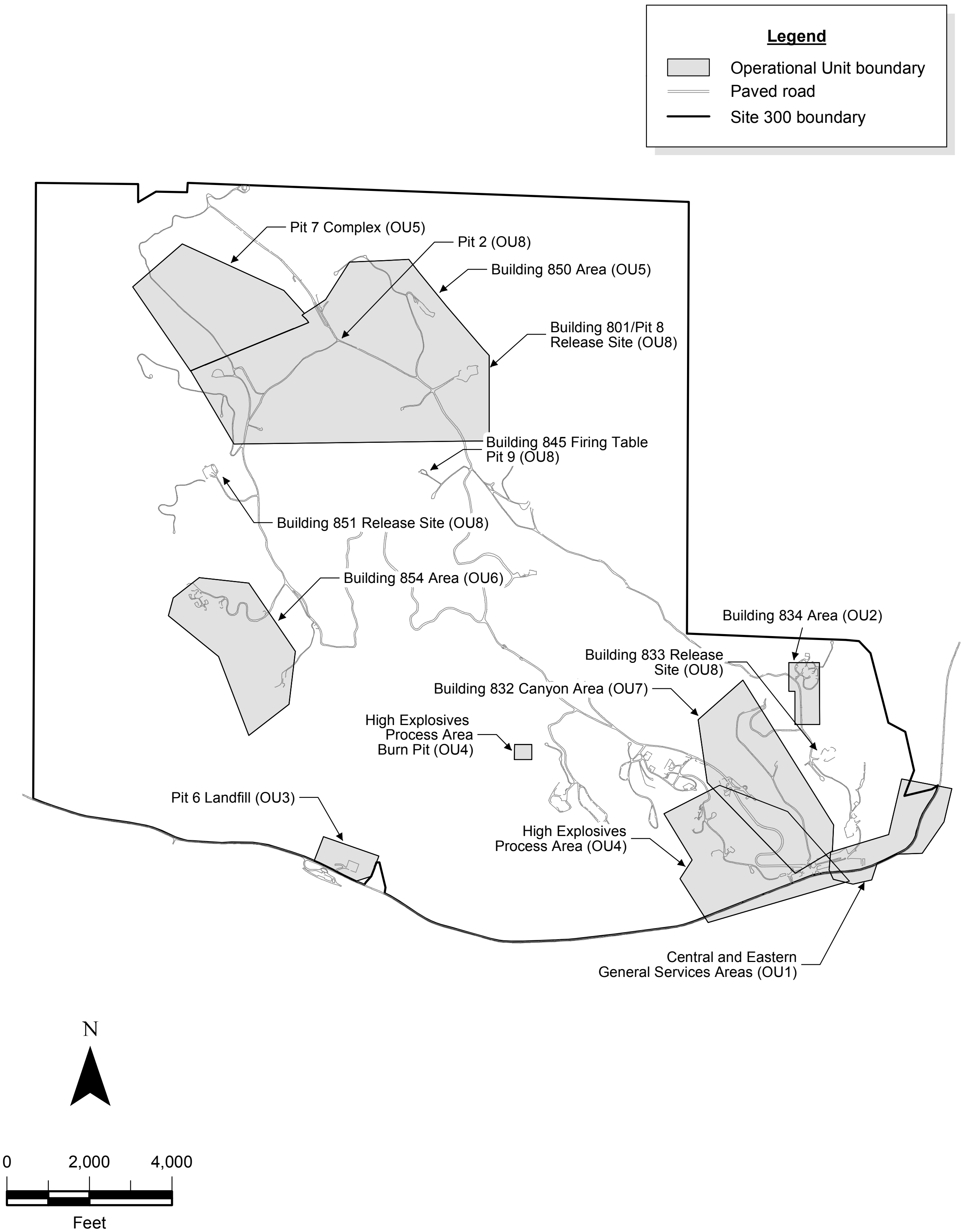


Figure 2. Site 300 map showing Operable Unit locations.

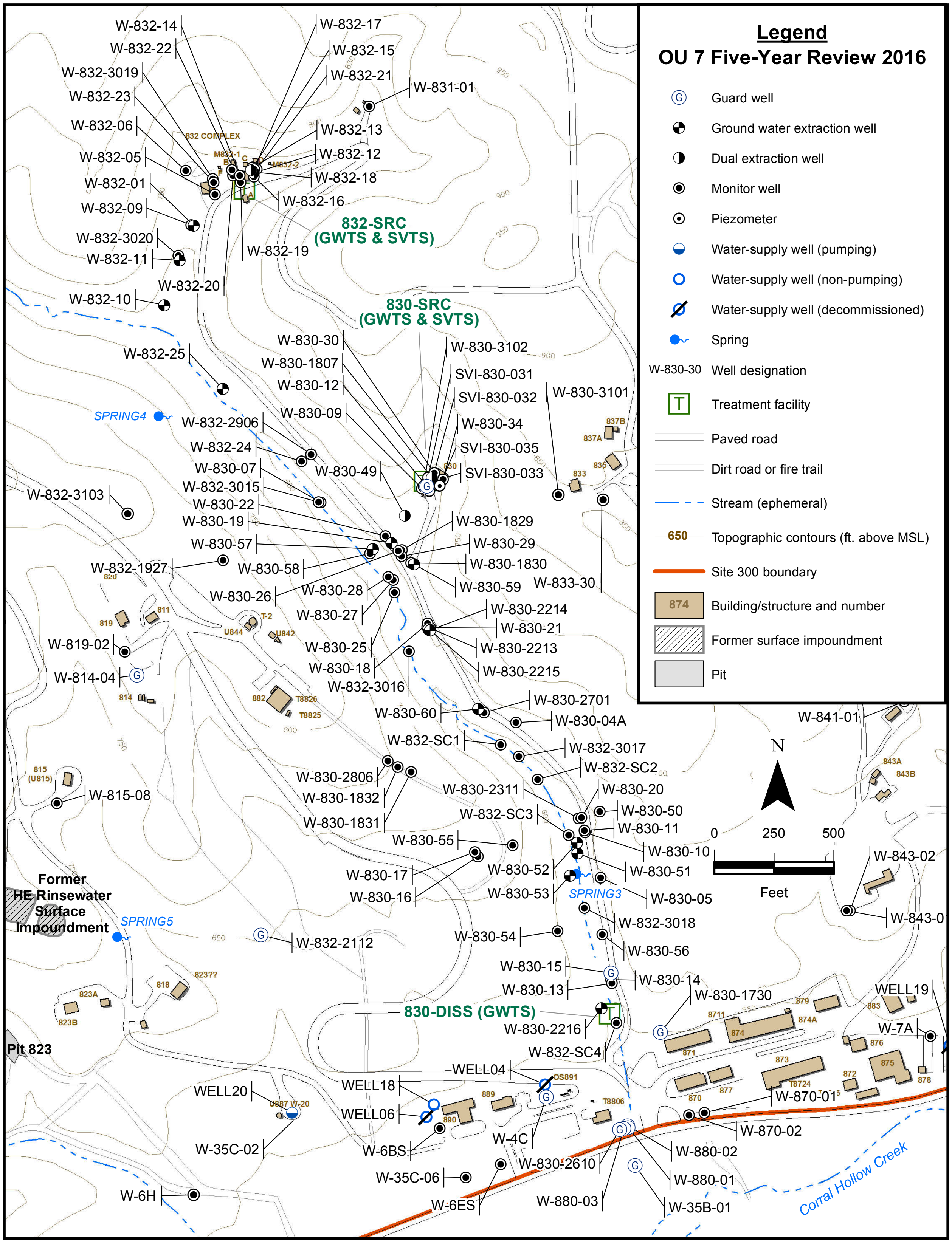


Figure 3. Building 832 Canyon area site map showing monitor and extraction wells, springs, treatment facilities, and other remediation features.

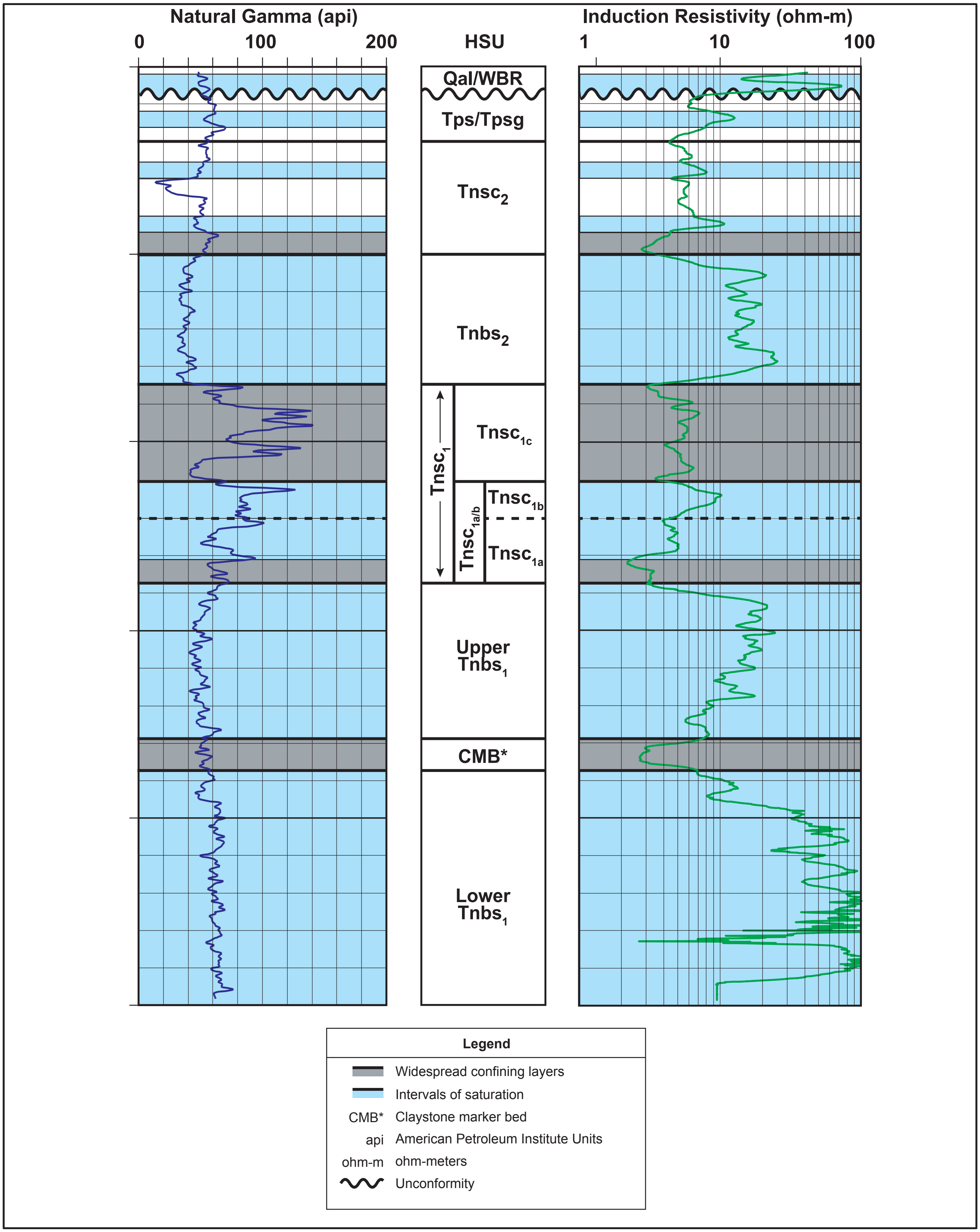


Figure 4. Typical geophysical log showing hydrostratigraphic units and widespread confining layers.

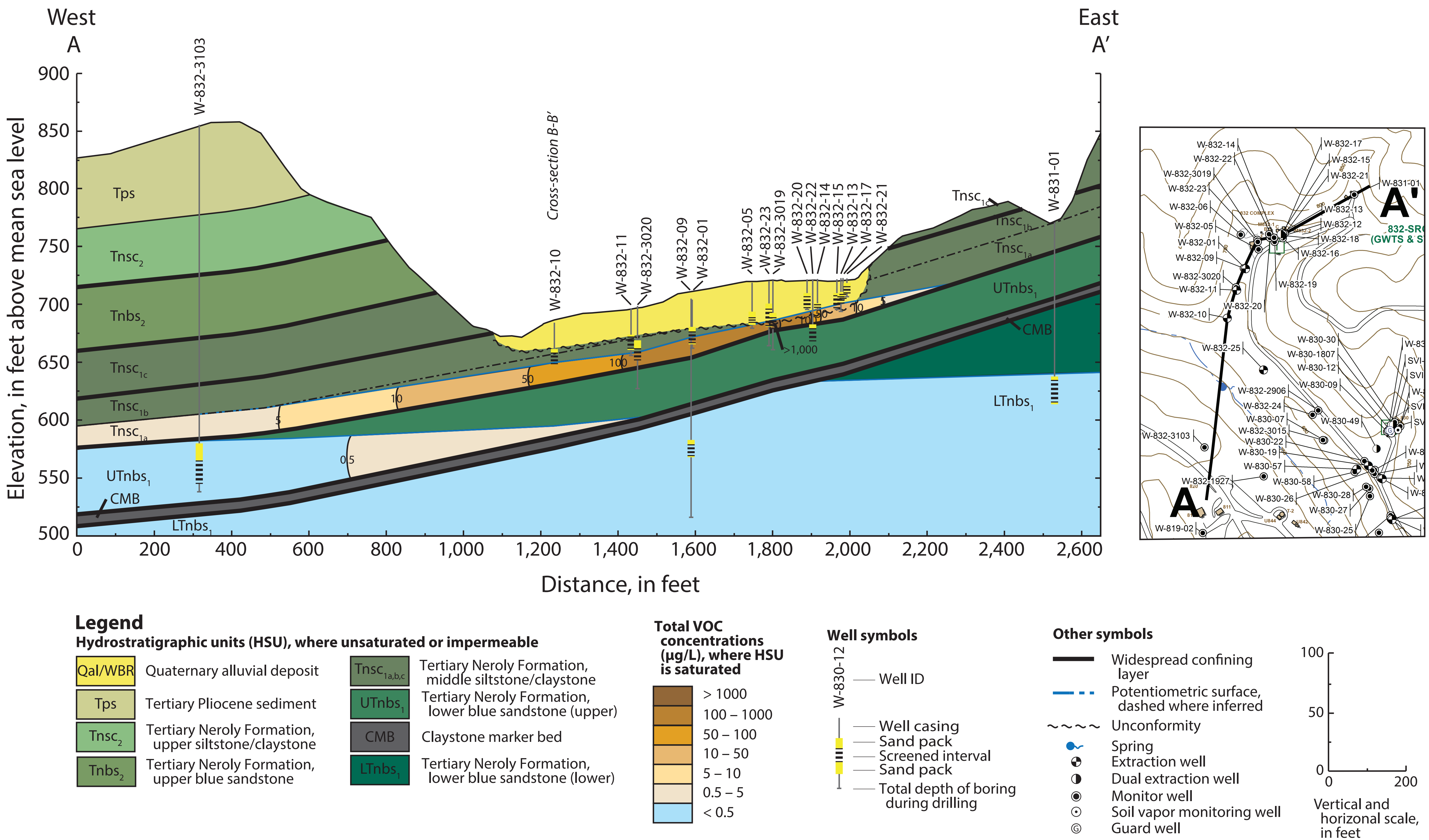


Figure 5. West to east hydrogeologic cross-section A-A' showing distribution of dissolved total volatile organic compounds (VOCs) in saturated hydrostratigraphic units. View looking north.

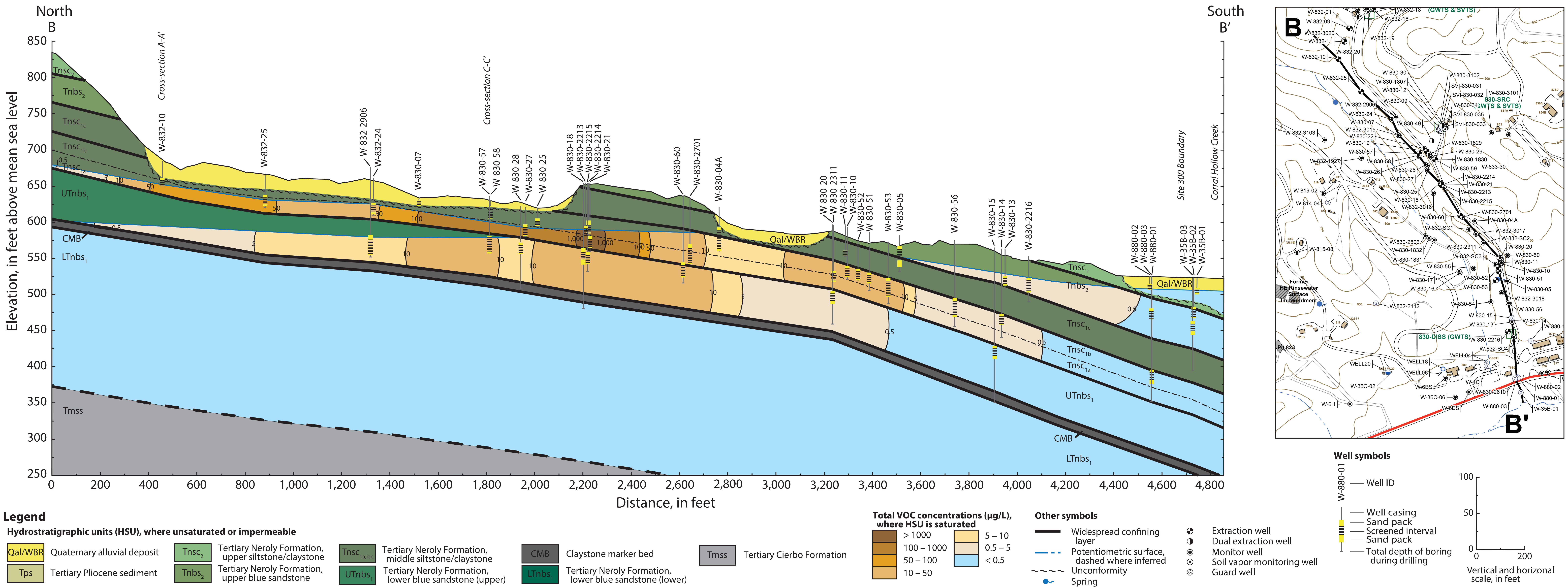


Figure 6. North to south hydrogeologic cross-section B-B' showing distribution of dissolved total volatile organic compounds (VOCs) in saturated hydrostratigraphic units. View looking east.

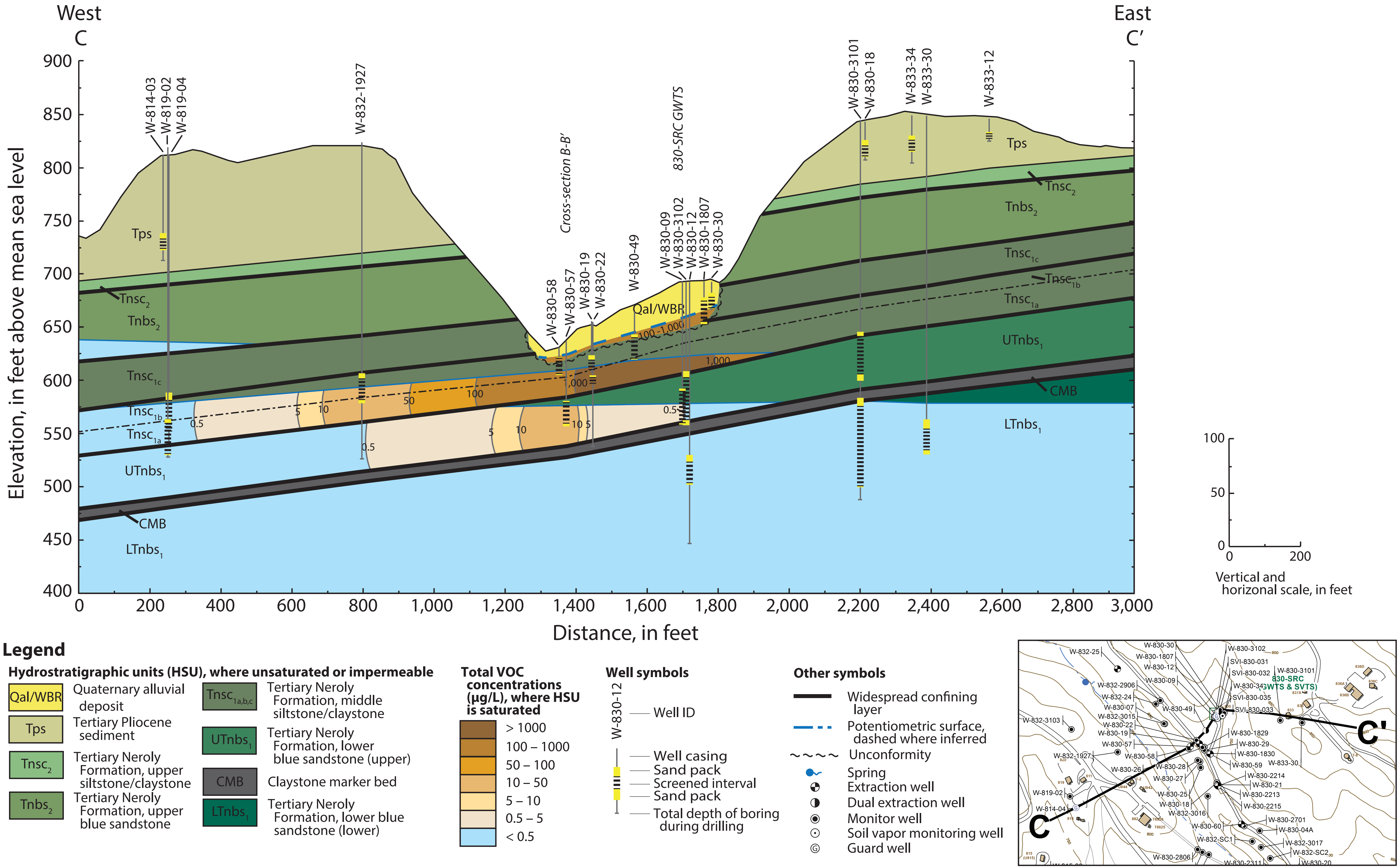


Figure 7. West to east hydrogeologic cross-section C-C' showing distribution of dissolved total volatile organic compounds (VOCs) in saturated hydrostratigraphic units. View looking north.

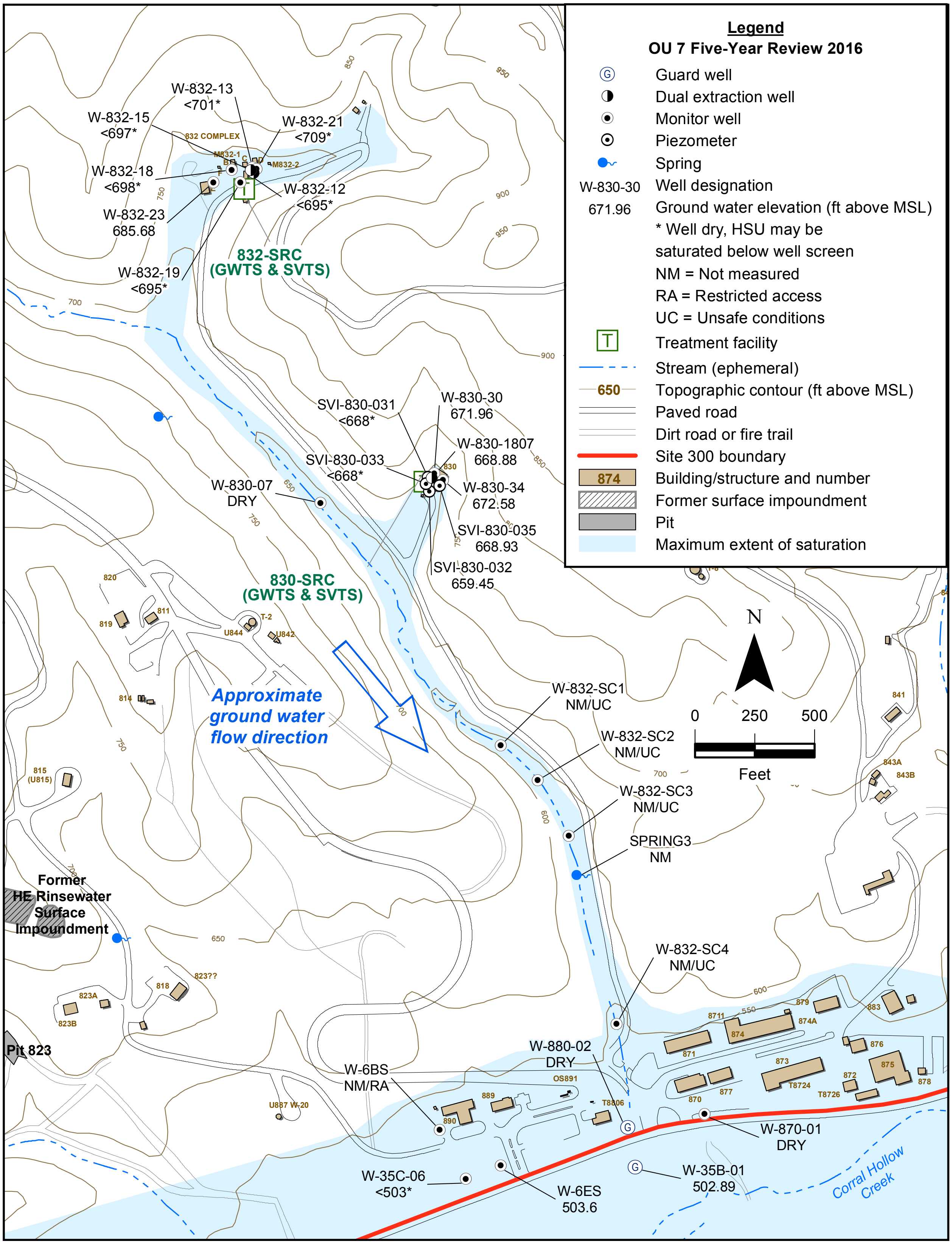


Figure 8. Building 832 Canyon OU ground water elevations (2014) and flow direction for the Qal/WBR hydrostatigraphic unit.

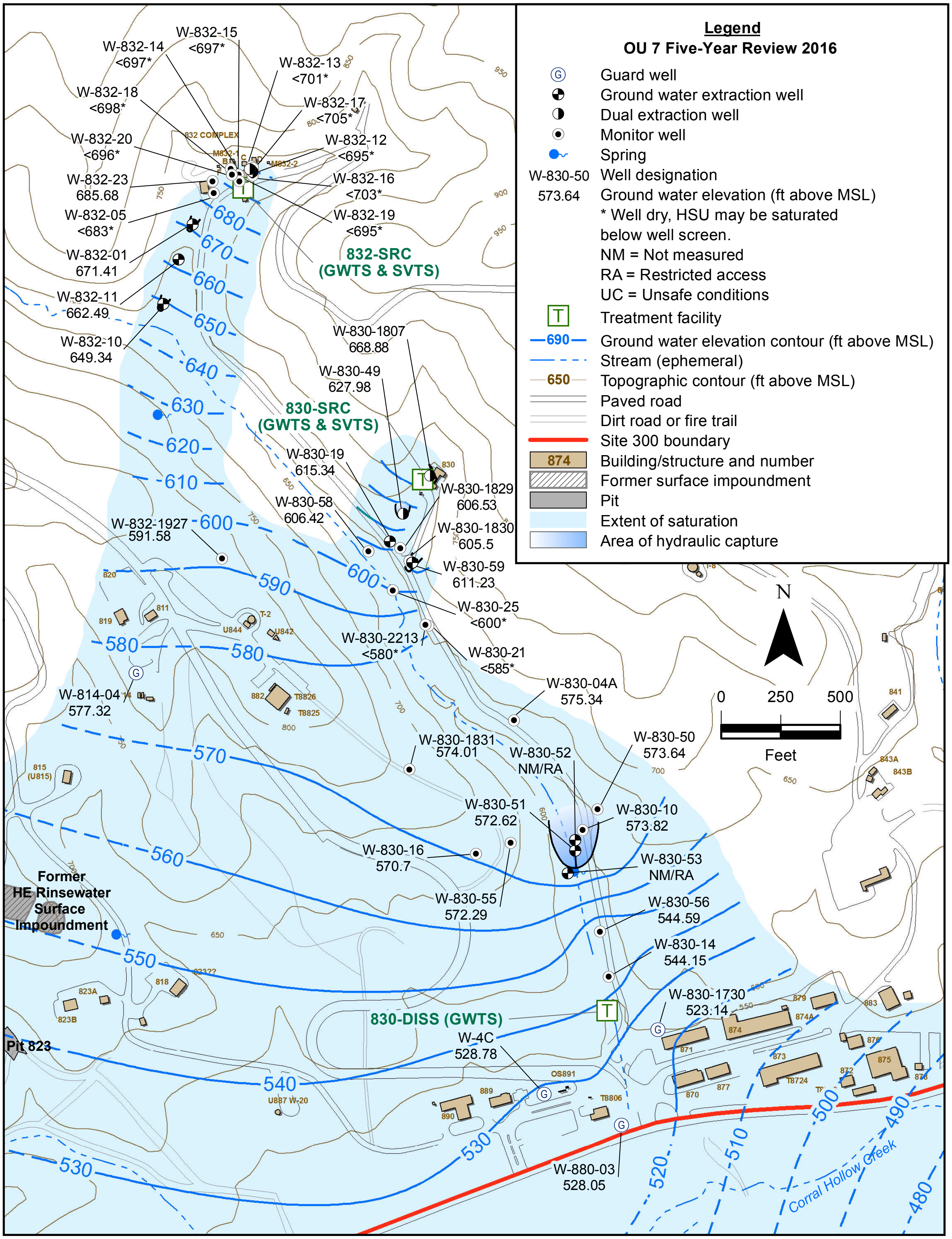


Figure 9. Building 832 Canyon OU potentiometric surface map (2014) for the Tnsc$_{1b}$ hydrostratigraphic unit, including hydraulic capture zones.

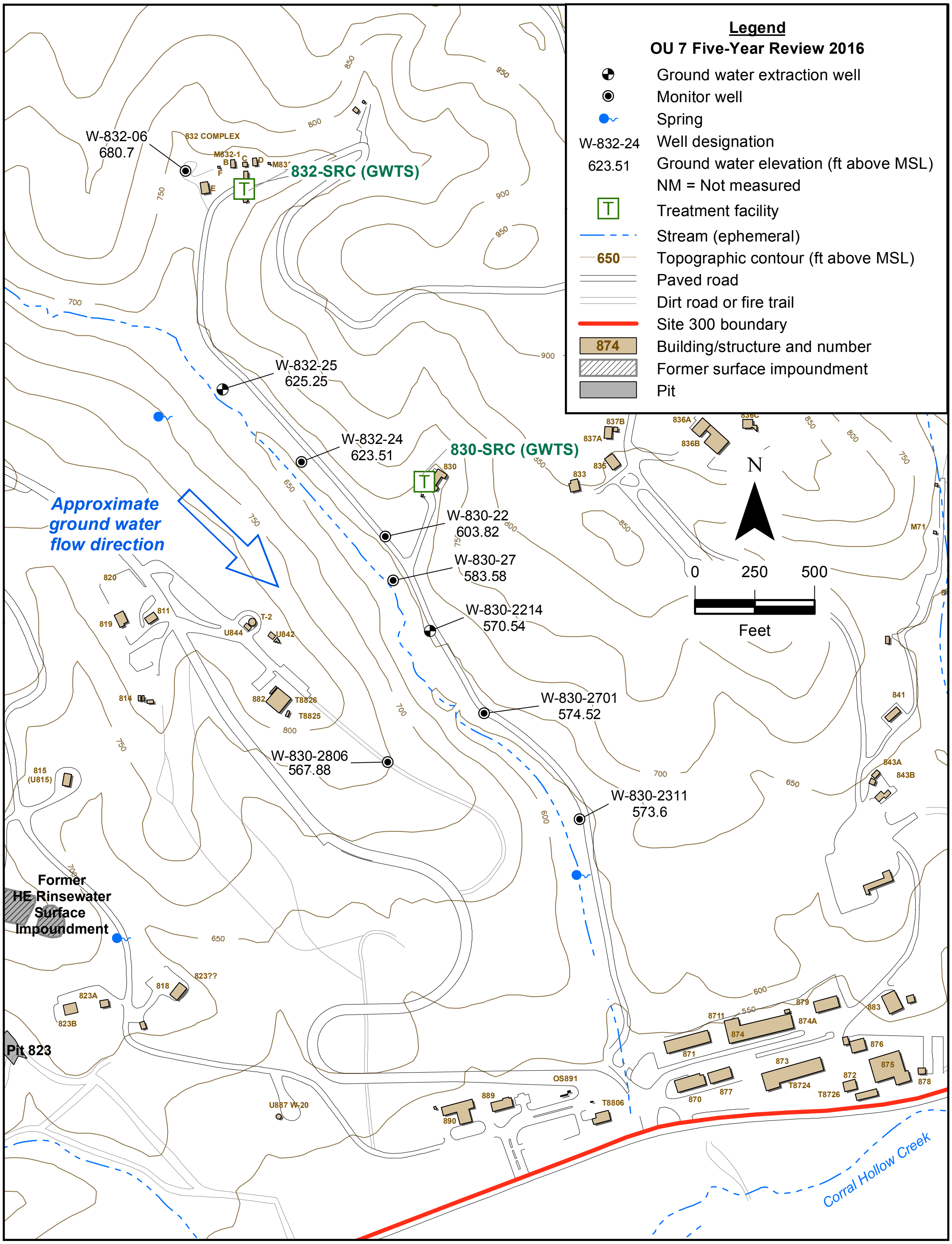


Figure 10. Building 832 Canyon OU ground water elevations and flow direction (2014) for the Tnsc$_{1a}$ hydrostratigraphic unit.

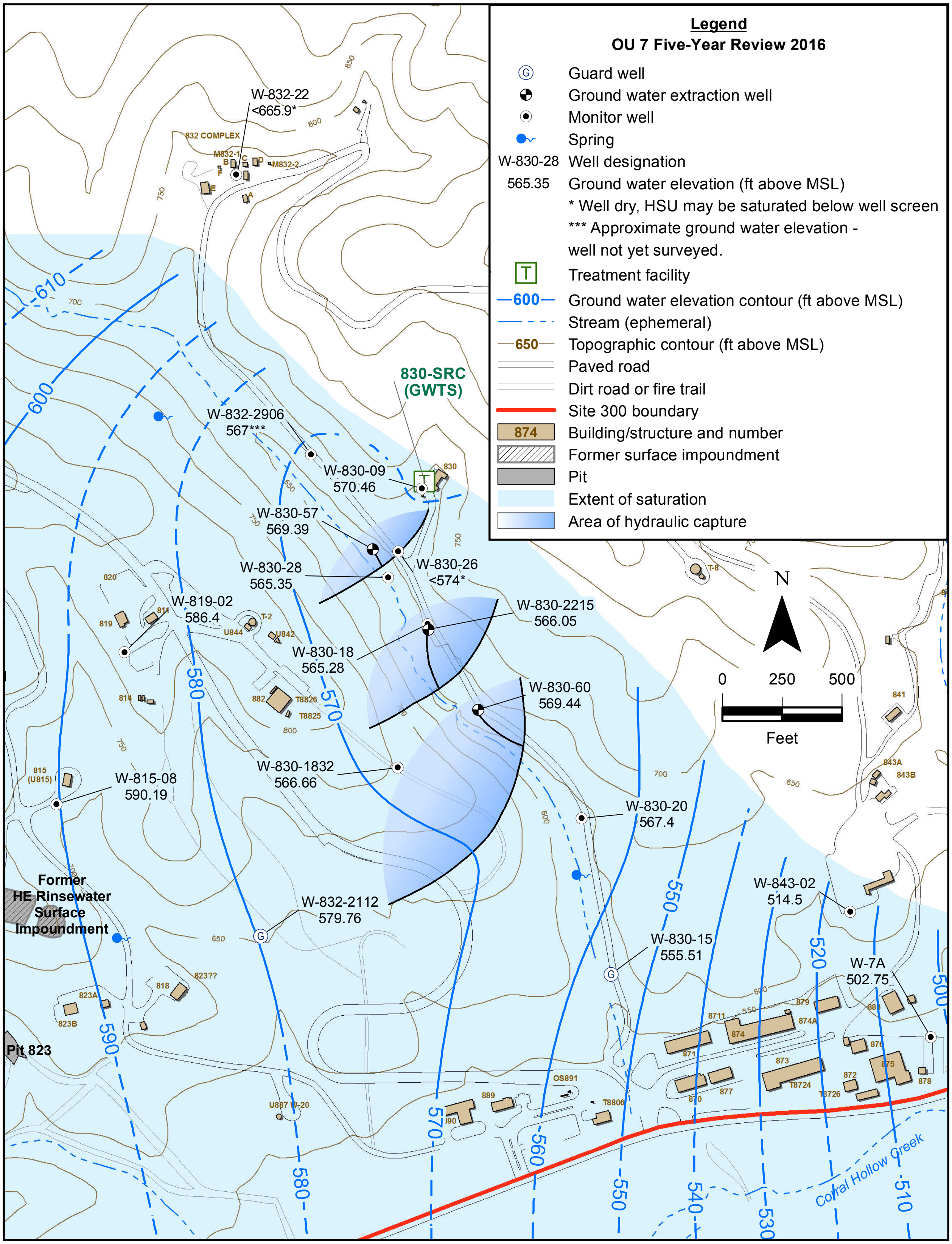


Figure 11. Building 832 Canyon OU potentiometric surface map (2014) for the Upper Tnbs$_1$ hydrostratographic unit, including hydraulic capture zones.

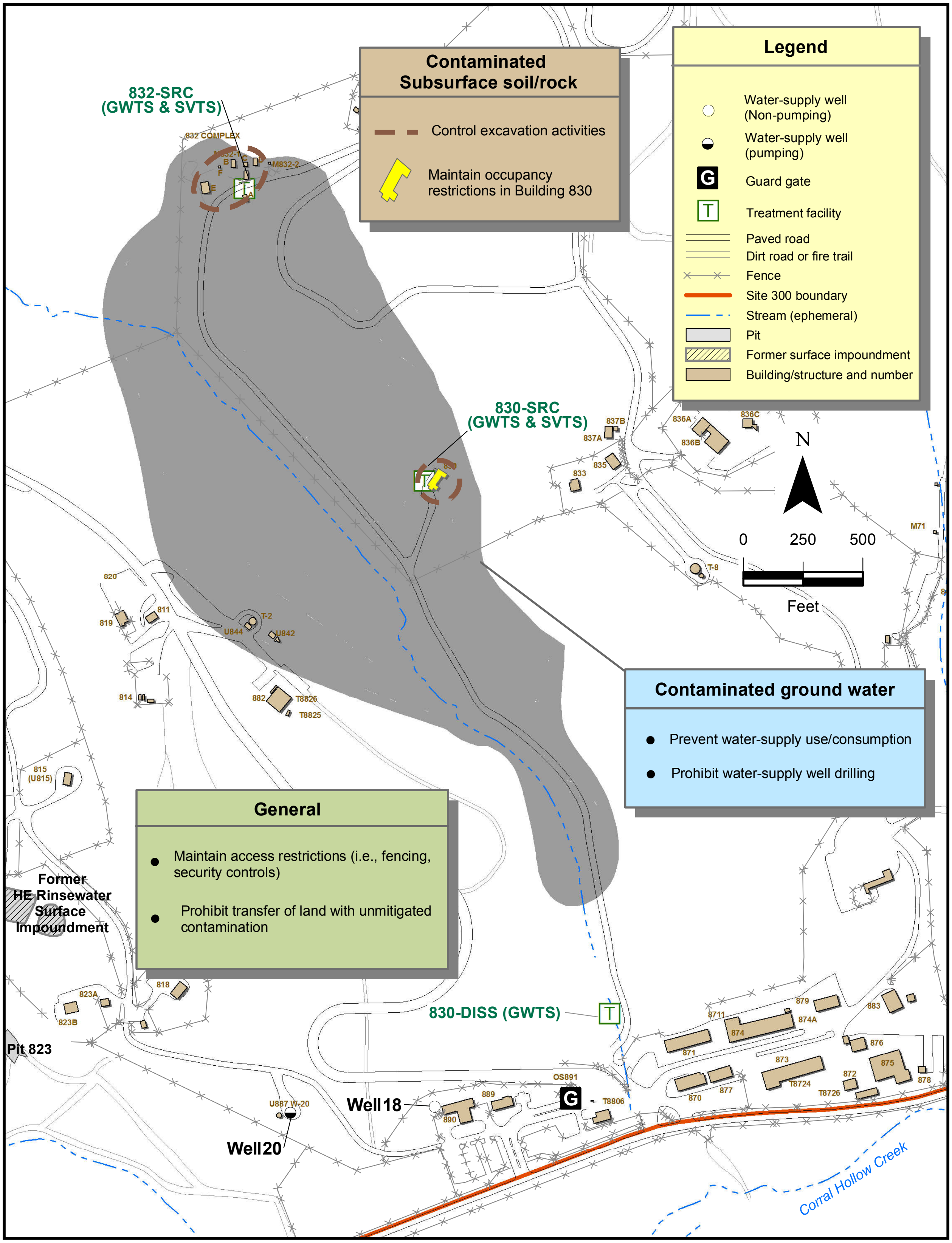


Figure 12. Building 832 Canyon OU land use controls.

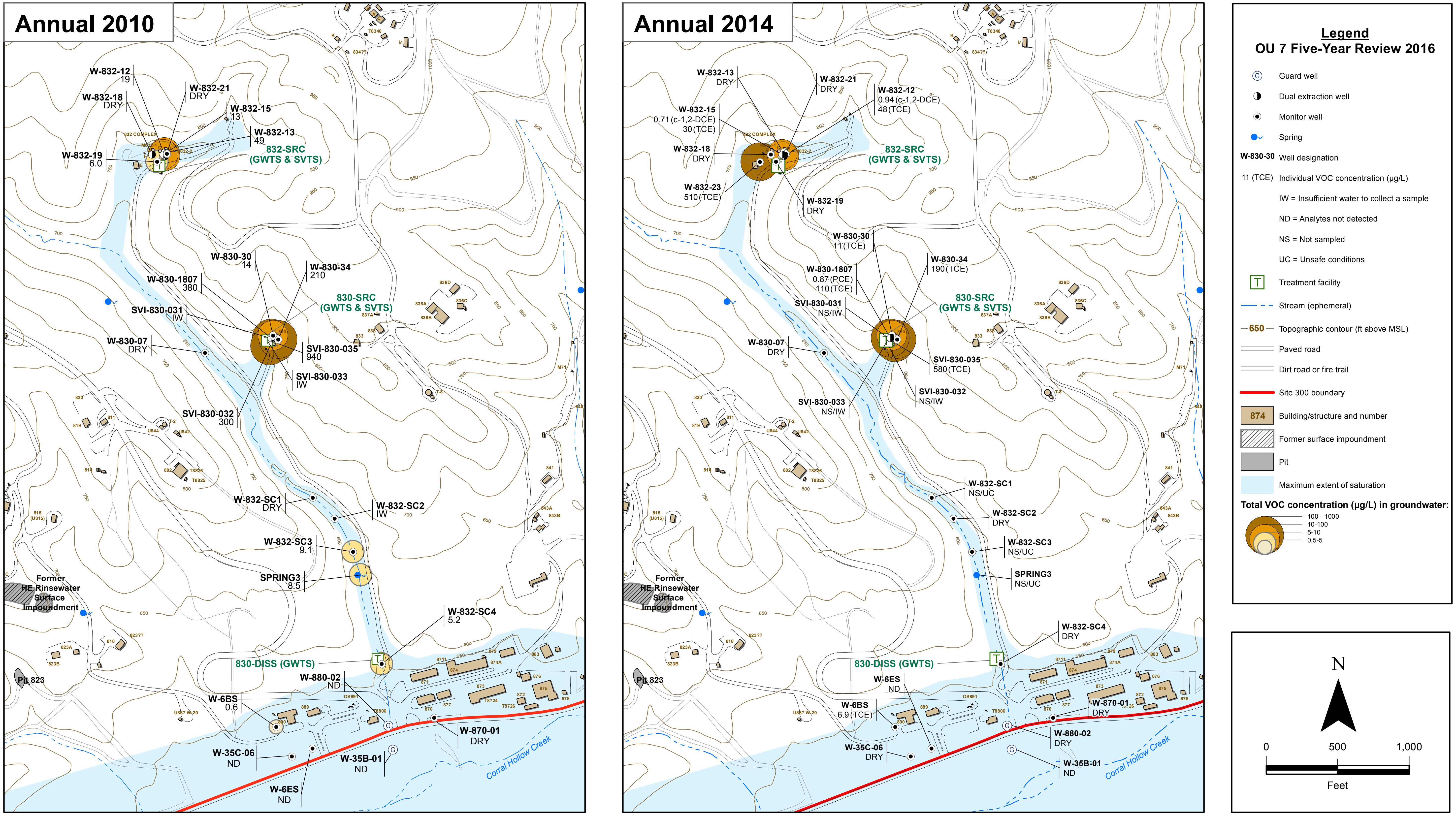


Figure 13. Building 832 Canyon OU maps (2010 and 2014) showing total VOC concentrations for the Qal/WBR hydrostratigraphic unit.

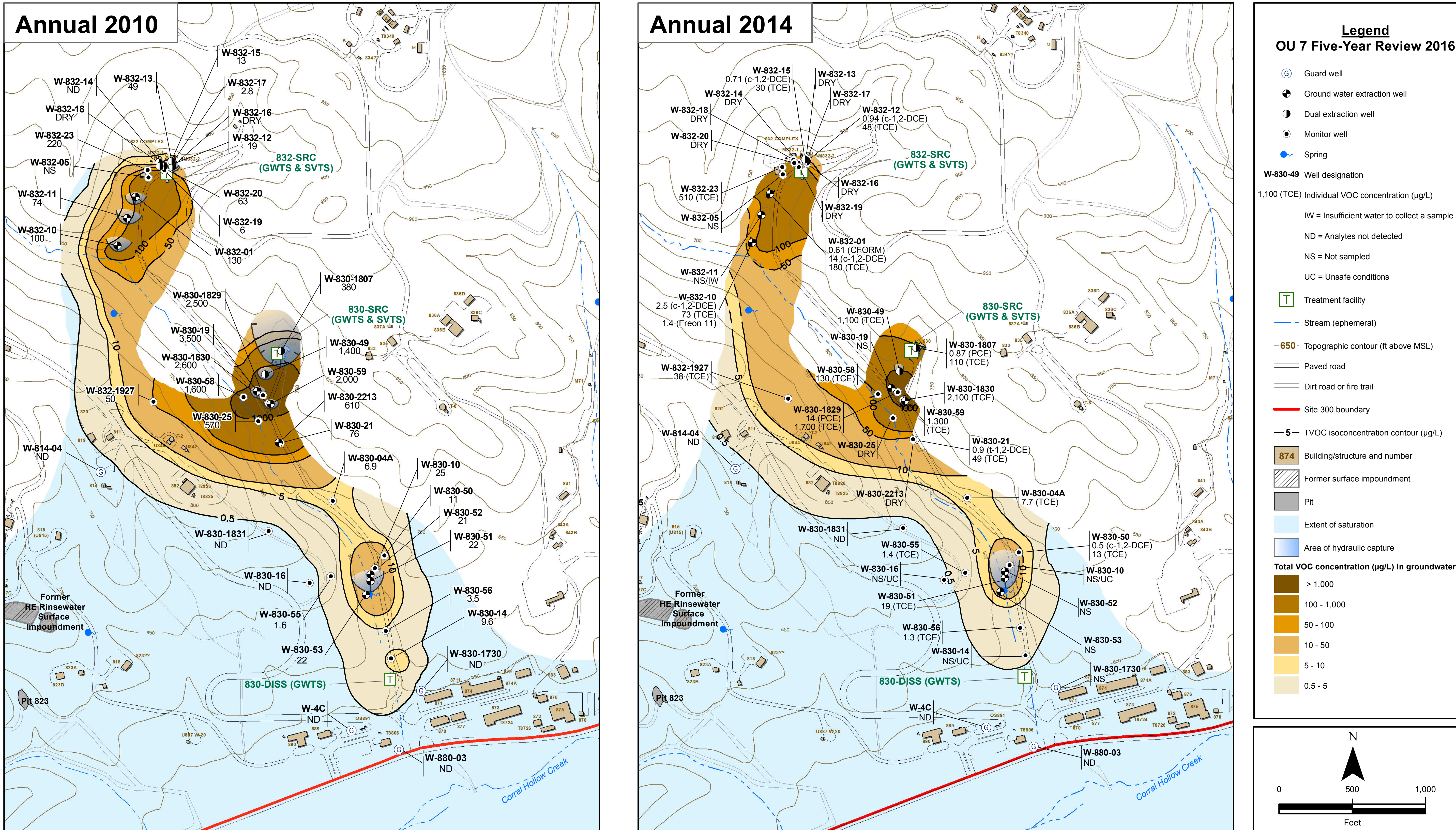


Figure 14. Building 832 Canyon OU total VOC isoconcentration contour maps (2010 and 2014) for the Tnsc$_{1b}$ hydrostratigraphic unit.

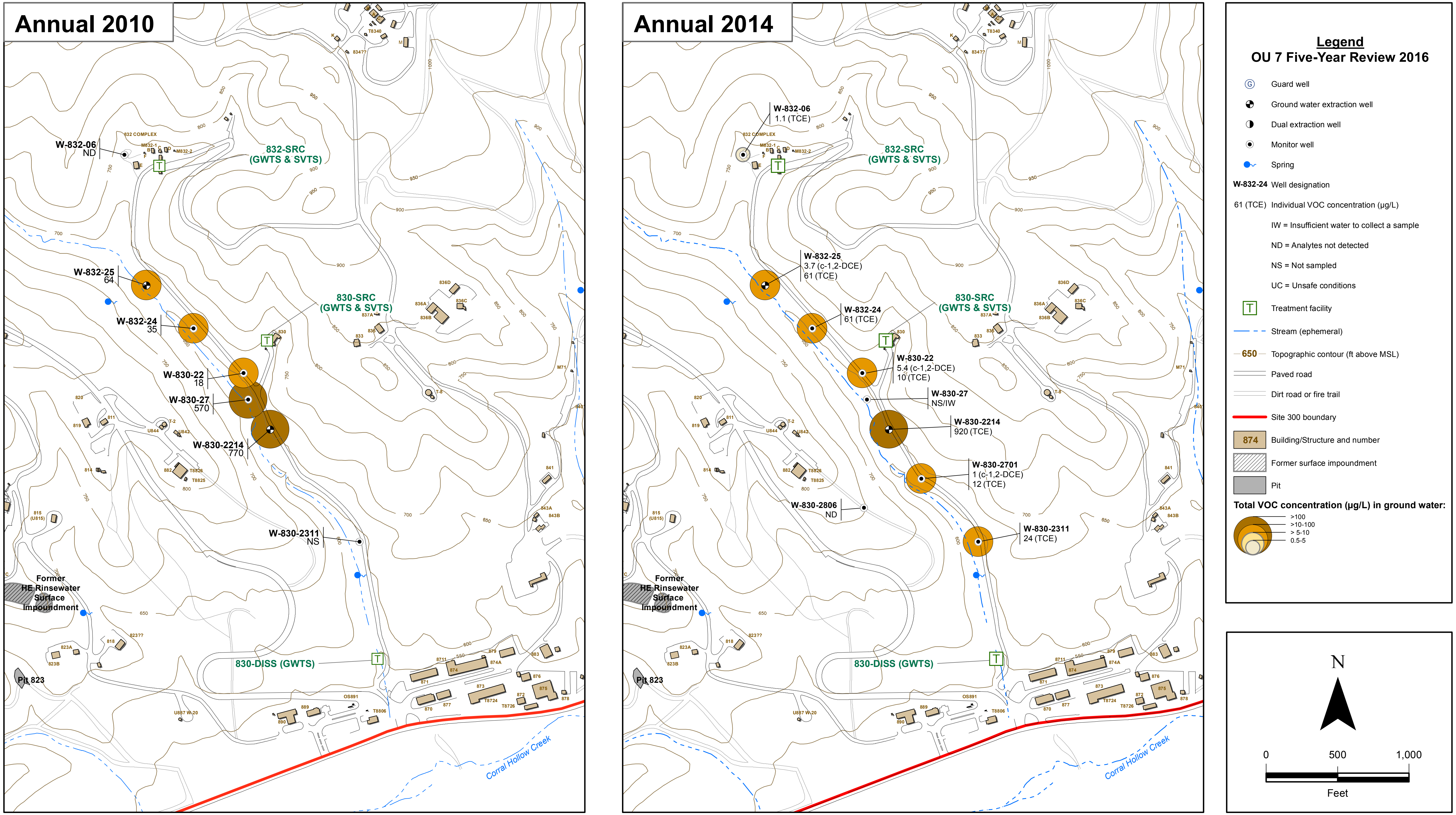


Figure 15. Building 832 Canyon OU maps (2010 and 2014 showing total VOC concentrations for the $Tnsc_{1a}$ hydrostratigraphic unit.

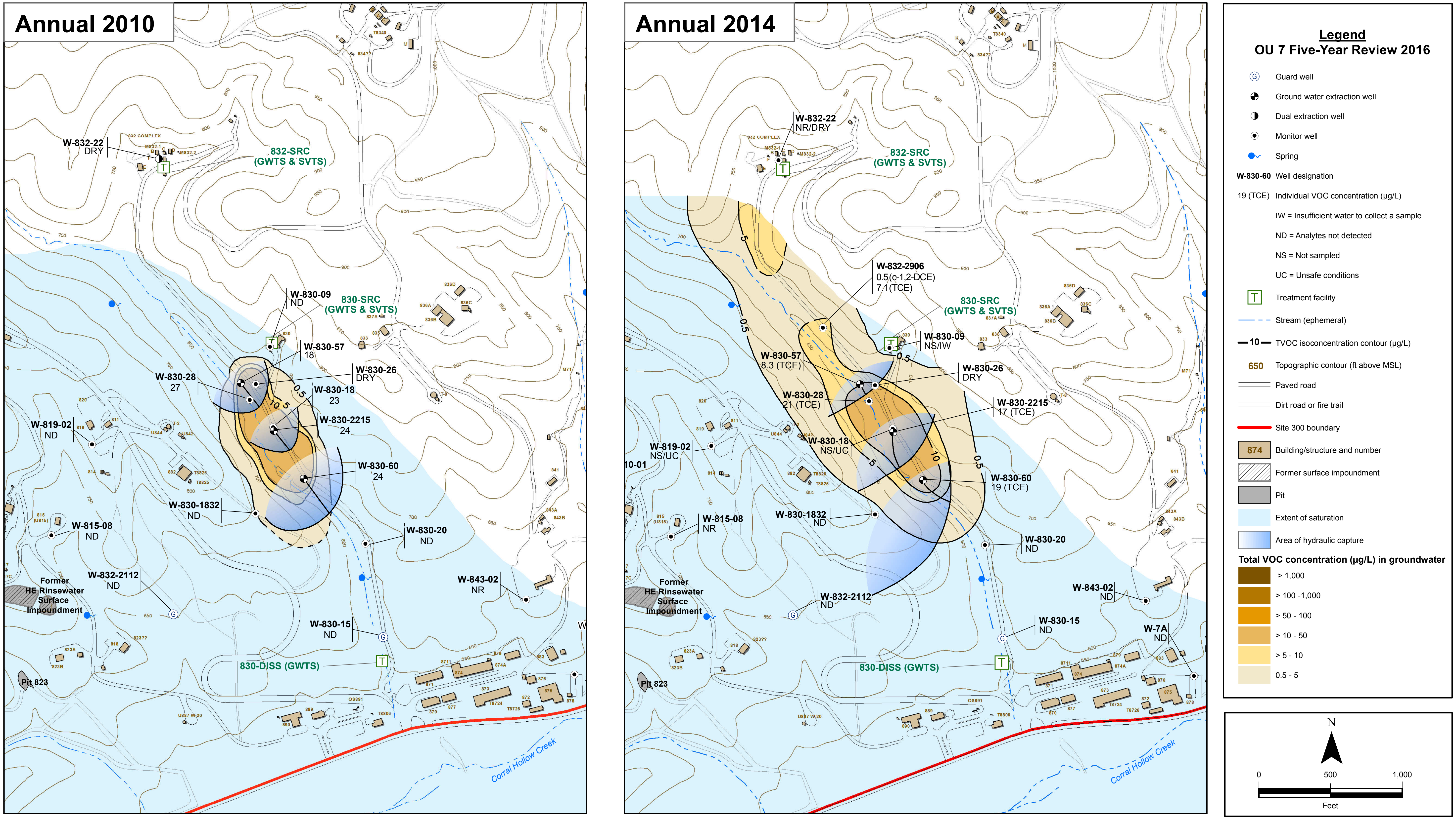


Figure 16. Building 832 Canyon OU total VOC isoconcentration contour maps (2010 and 2014) for the Upper Tnbs$_1$ hydrostratigraphic unit.

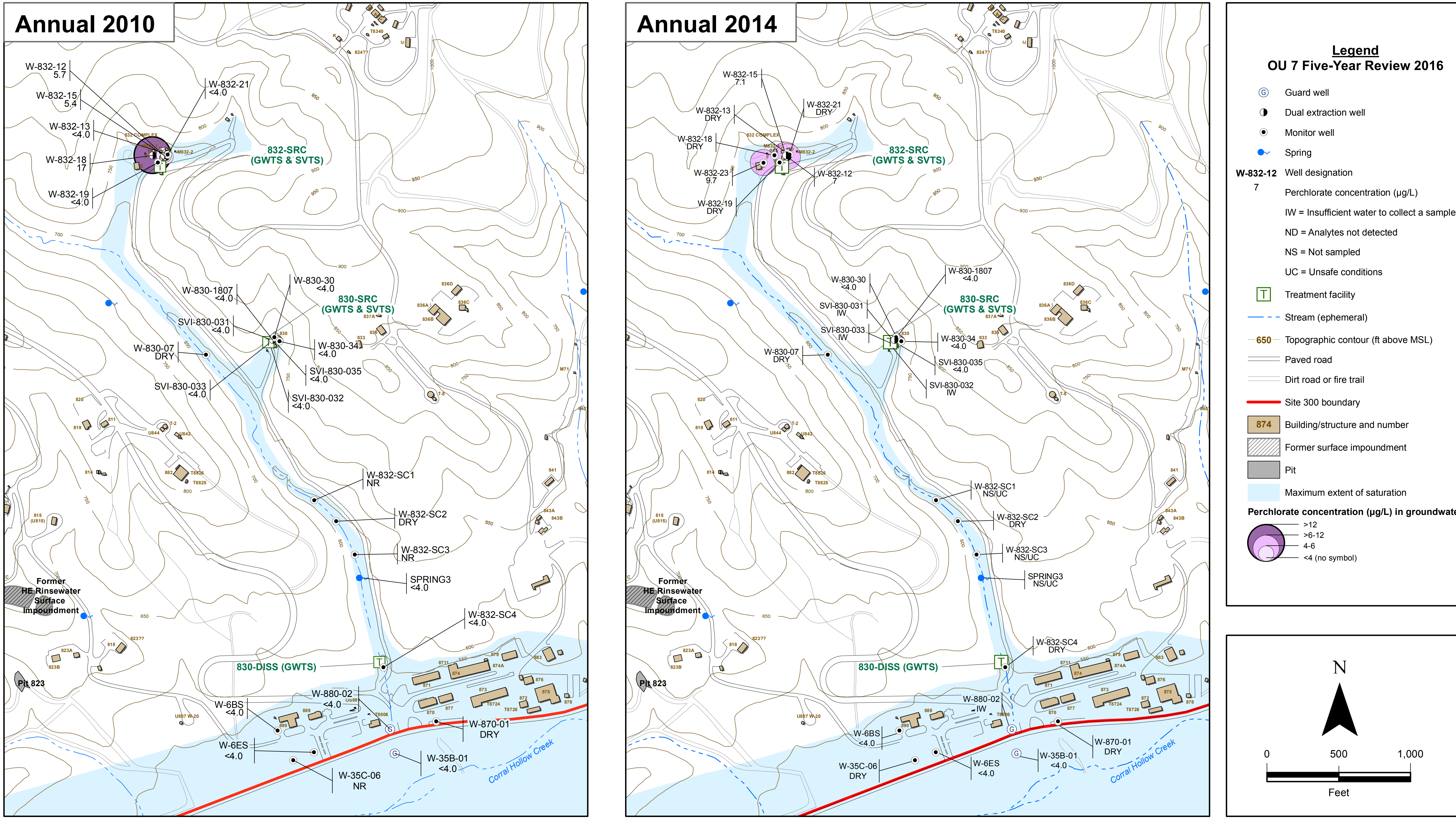


Figure 17. Building 832 Canyon OU maps (2010 and 2014) showing perchlorate concentrations for the Qal/WBR hydrostratigraphic unit.

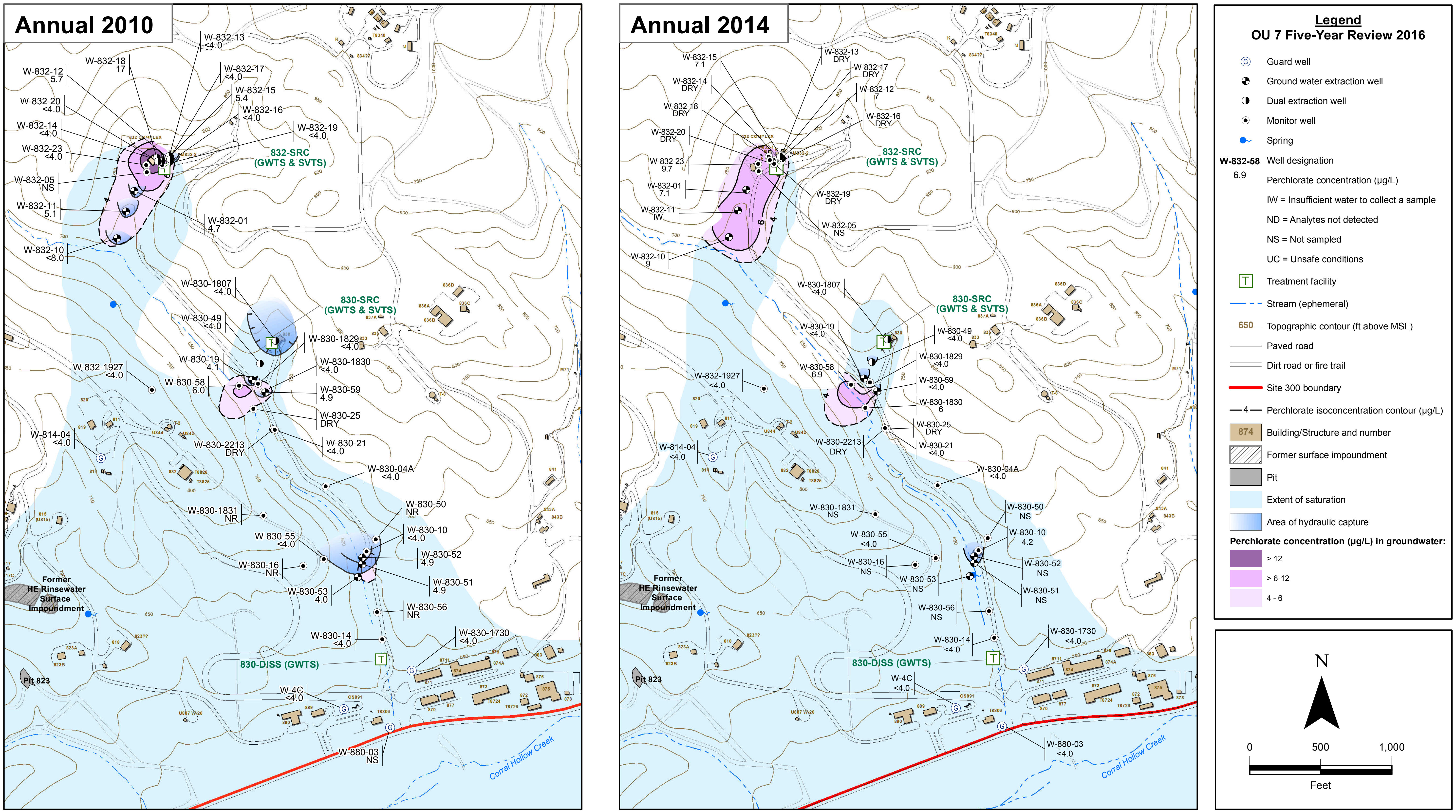


Figure 18. Building 832 Canyon OU perchlorate isoconcentration contour maps (2010 and 2014) for the $Tnsc_{1b}$ hydrostratigraphic unit.

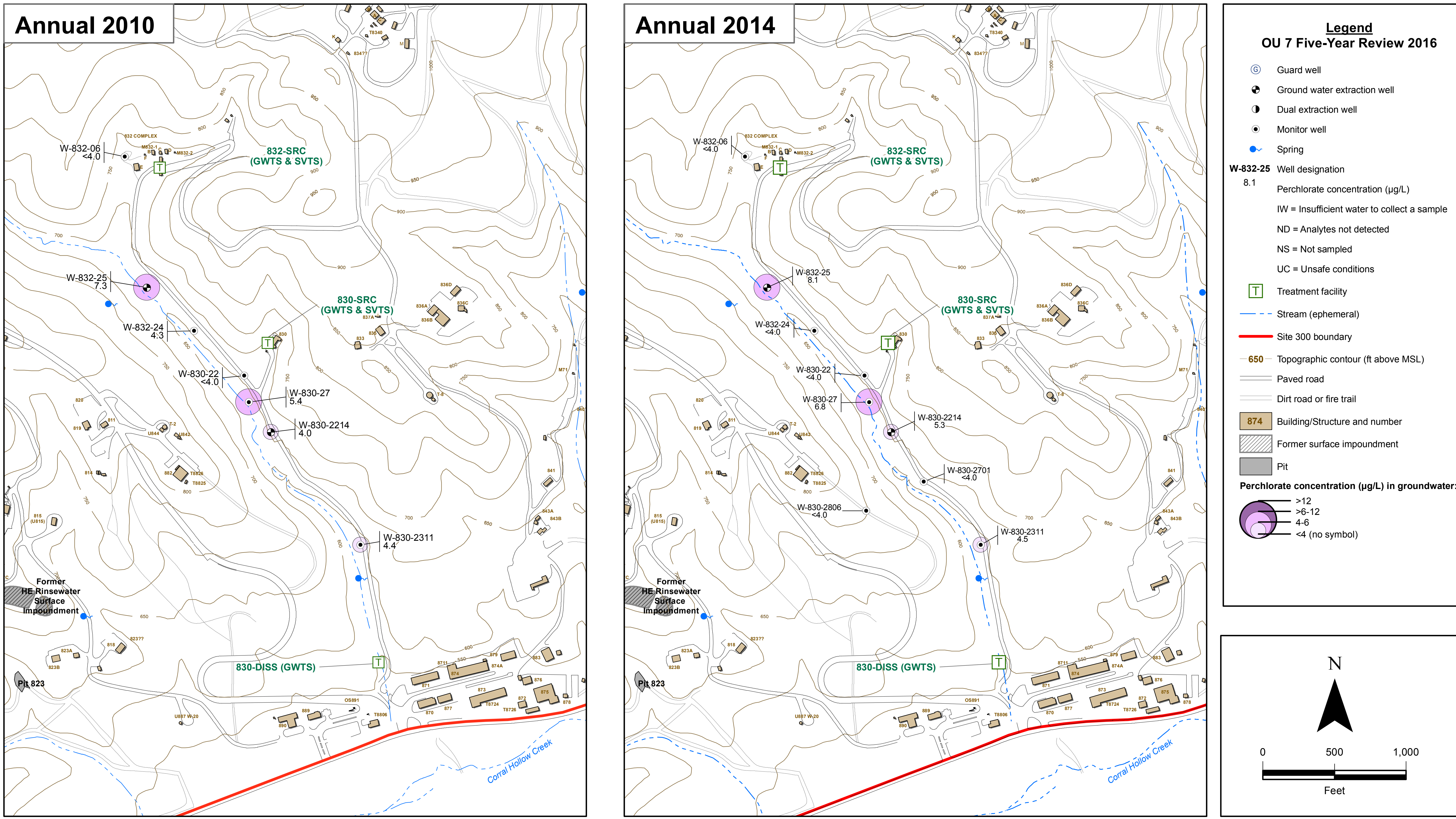


Figure 19. Building 832 Canyon OU maps (2010 and 2014) showing perchlorate concentrations for the Tnsc$_{1a}$ hydrostratigraphic unit.

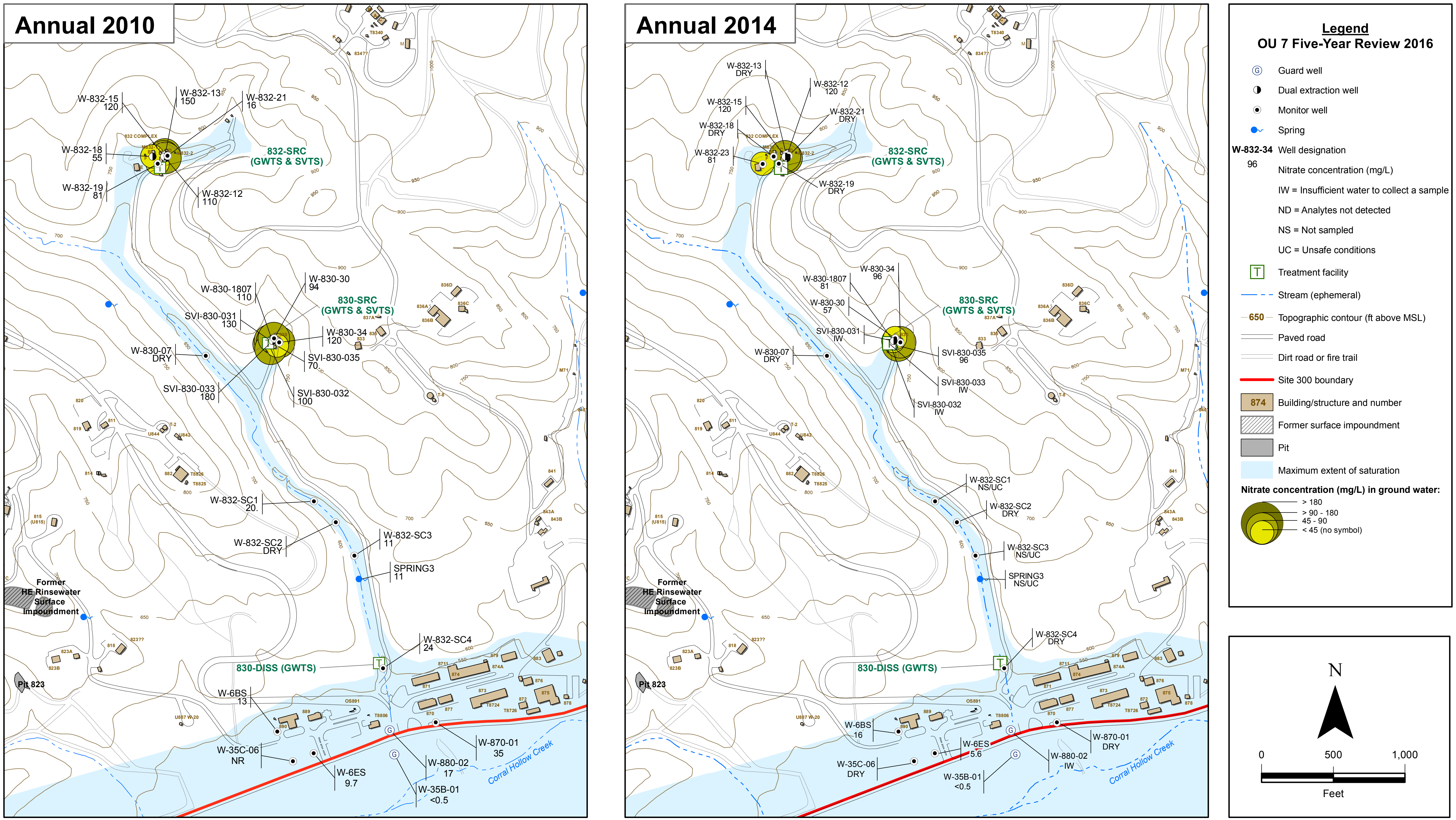


Figure 20. Building 832 Canyon OU maps (2010 and 2014) showing nitrate concentrations for the Qal/WBR hydrostratigraphic unit.

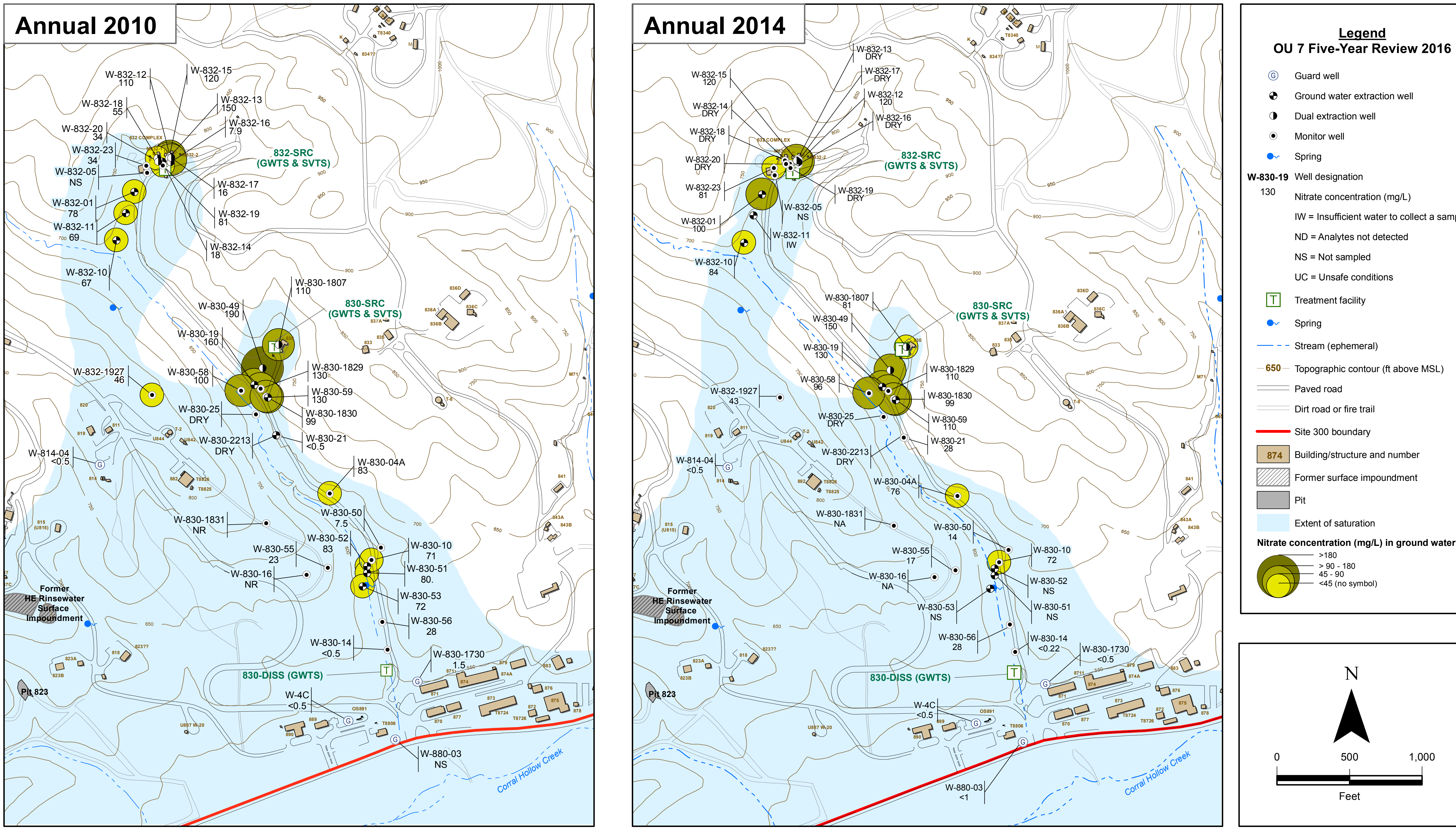


Figure 21. Building 832 Canyon OU maps (2010 and 2014) showing nitrate concentrations for the Tnsc$_{1b}$ hydrostratigraphic unit.

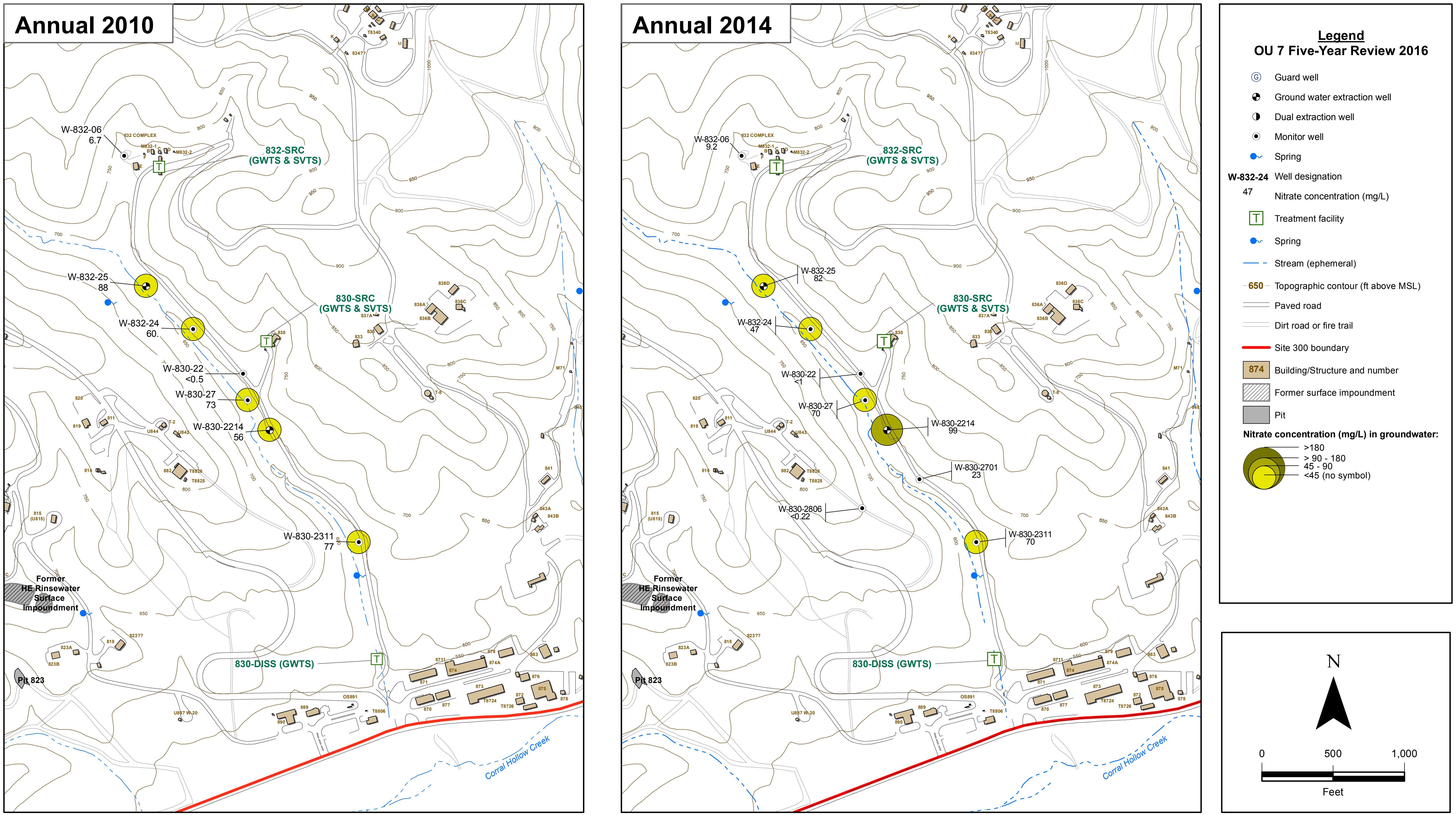


Figure 22. Building 832 Canyon OU maps (2010 and 2014) showing nitrate concentrations for the $Tnsc_{1a}$ hydrostratigraphic unit.

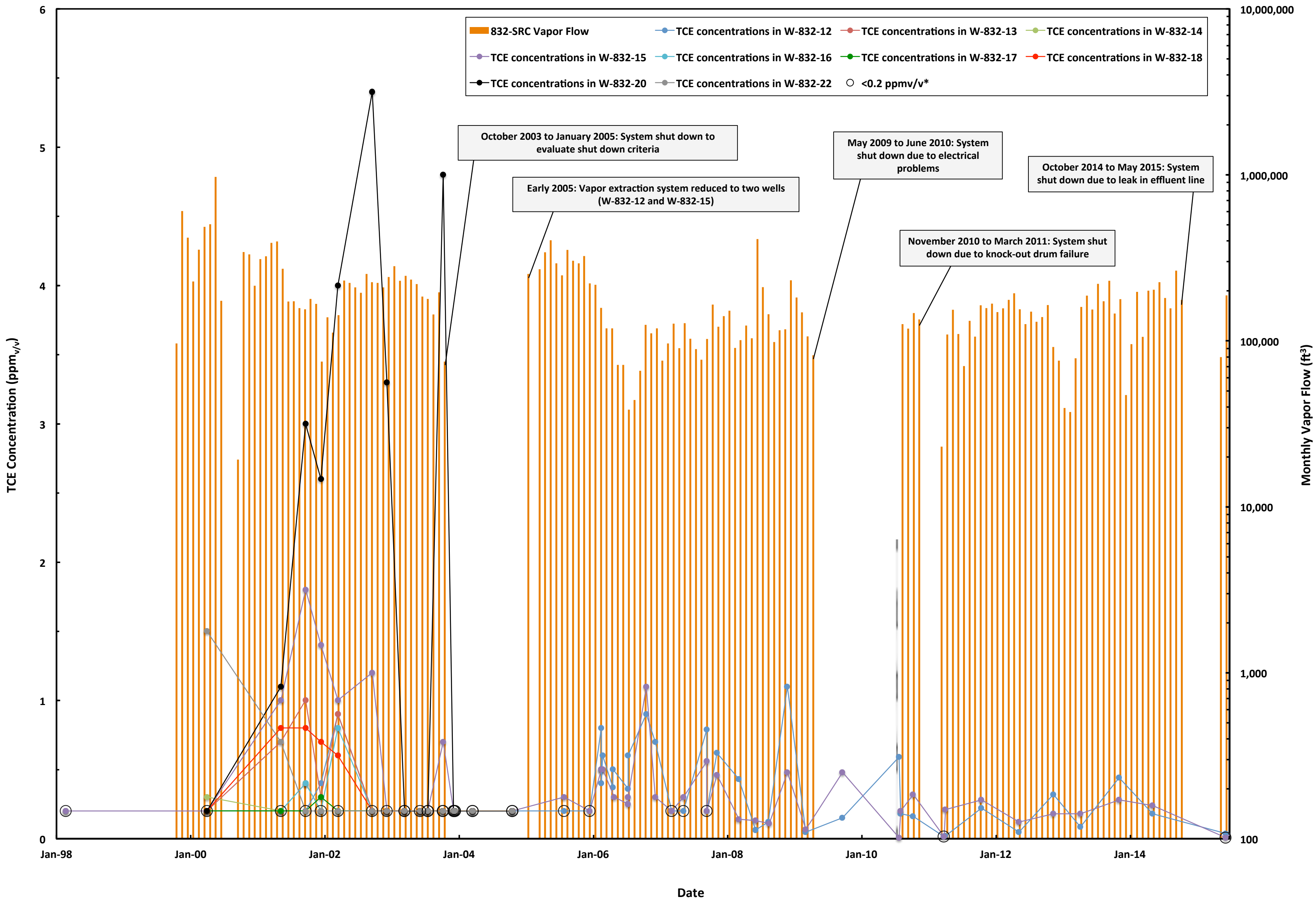


Figure 23. 832-SRC soil vapor extraction and treatment system: extraction well trichloroethene (TCE) vapor and monthly facility flow. <0.2 $ppm_{V/V}$*: TCE concentrations are below the analytical detection limit of 0.2 $ppm_{V/V}$. The detection limit for samples collected in March 2011 and June 2015 were 0.014 $ppm_{V/V}$ and 0.0063 $ppm_{V/V}$, respectively.

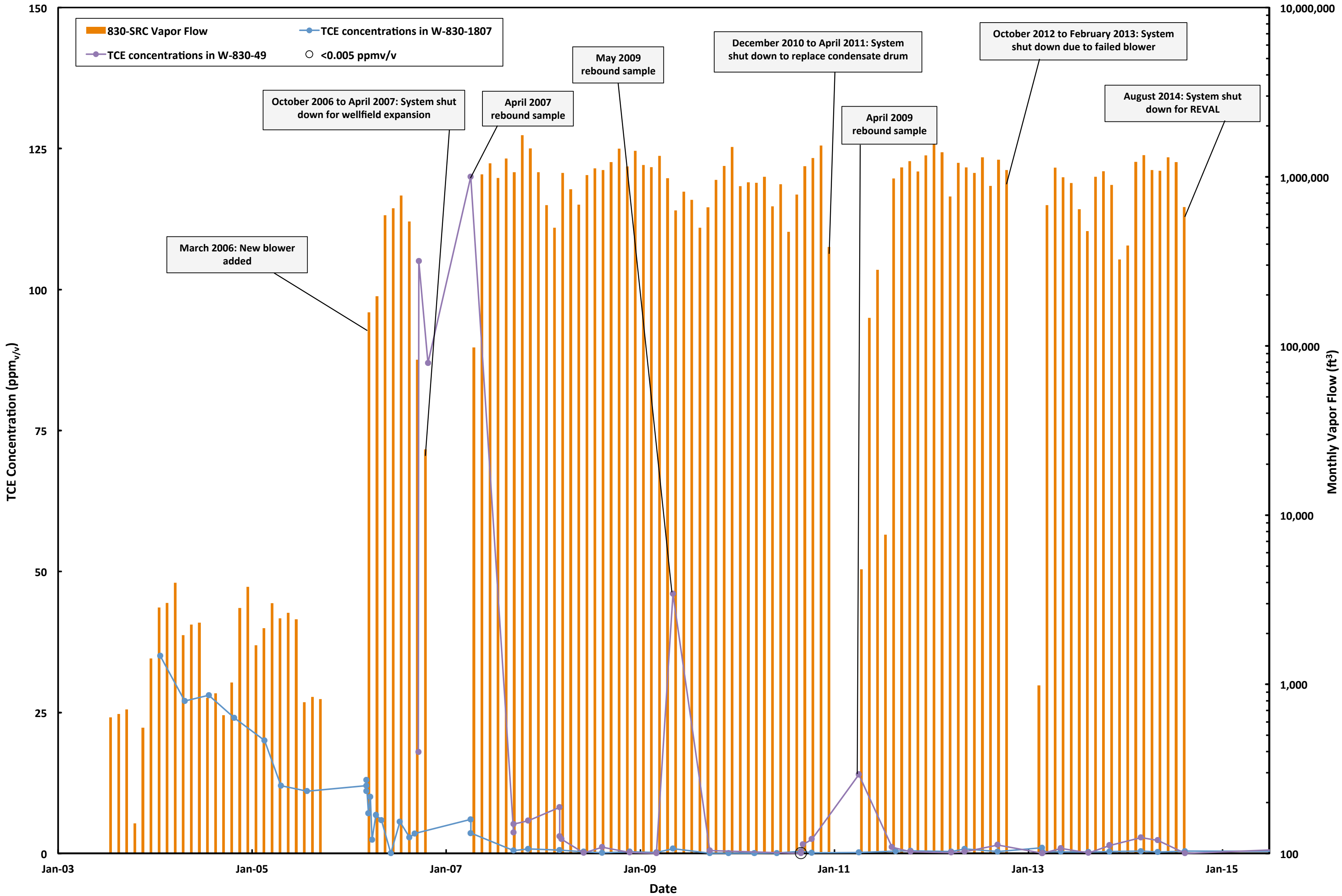


Figure 24. 830-SRC soil vapor extraction and treatment system: extraction well trichloroethene (TCE) vapor and monthly facility flow. <0.005 $ppm_{V/V}$: TCE concentrations are below the analytical detection limit of 0.005 $ppm_{V/V}$. REVAL: Remediation evaluation (ERD).

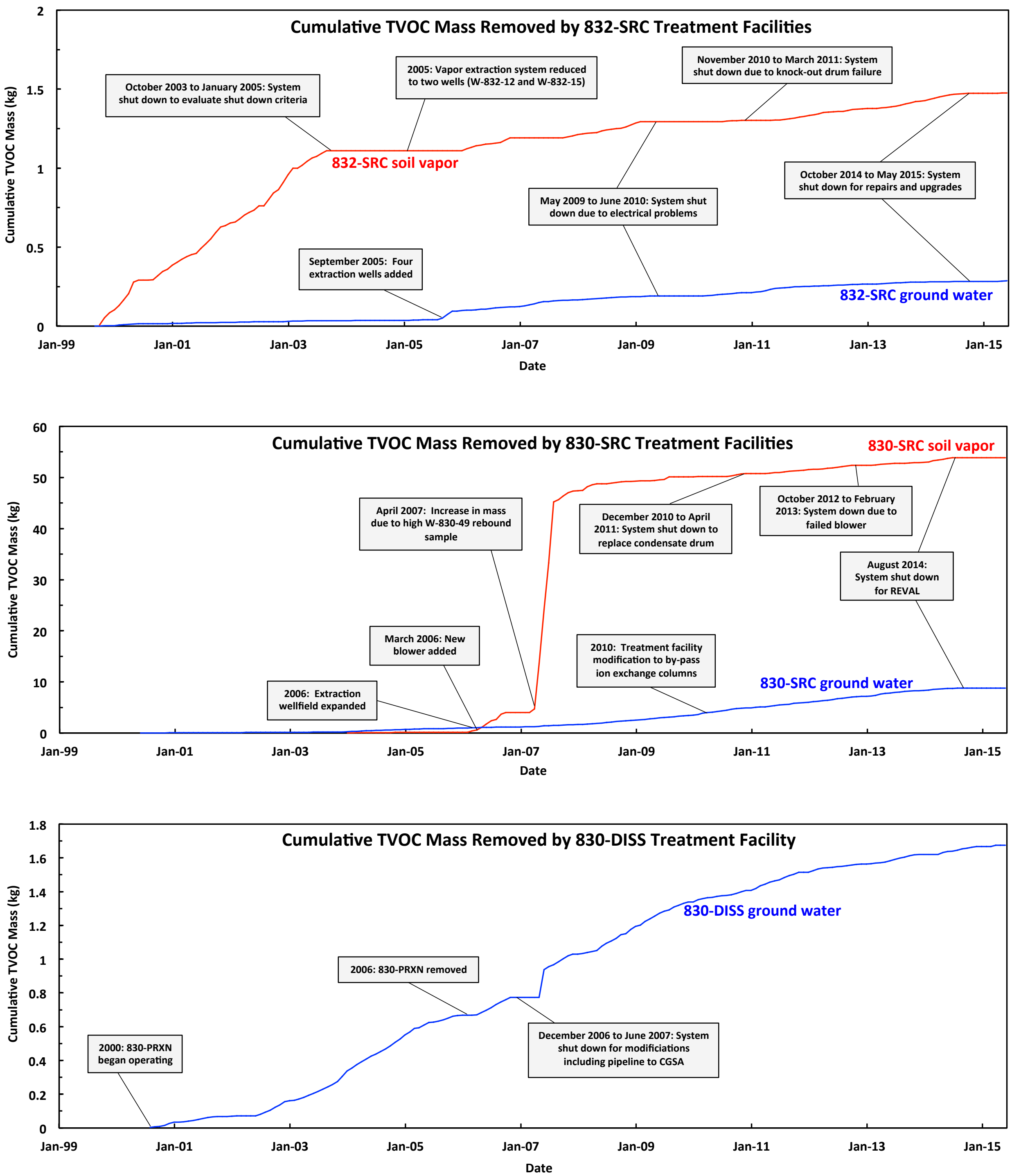


Figure 25. Time-series plots of cumulative total VOC mass removed from Building 832 Canyon OU Treatment Facilities.

REVAL: Remediation evaluation (ERD).

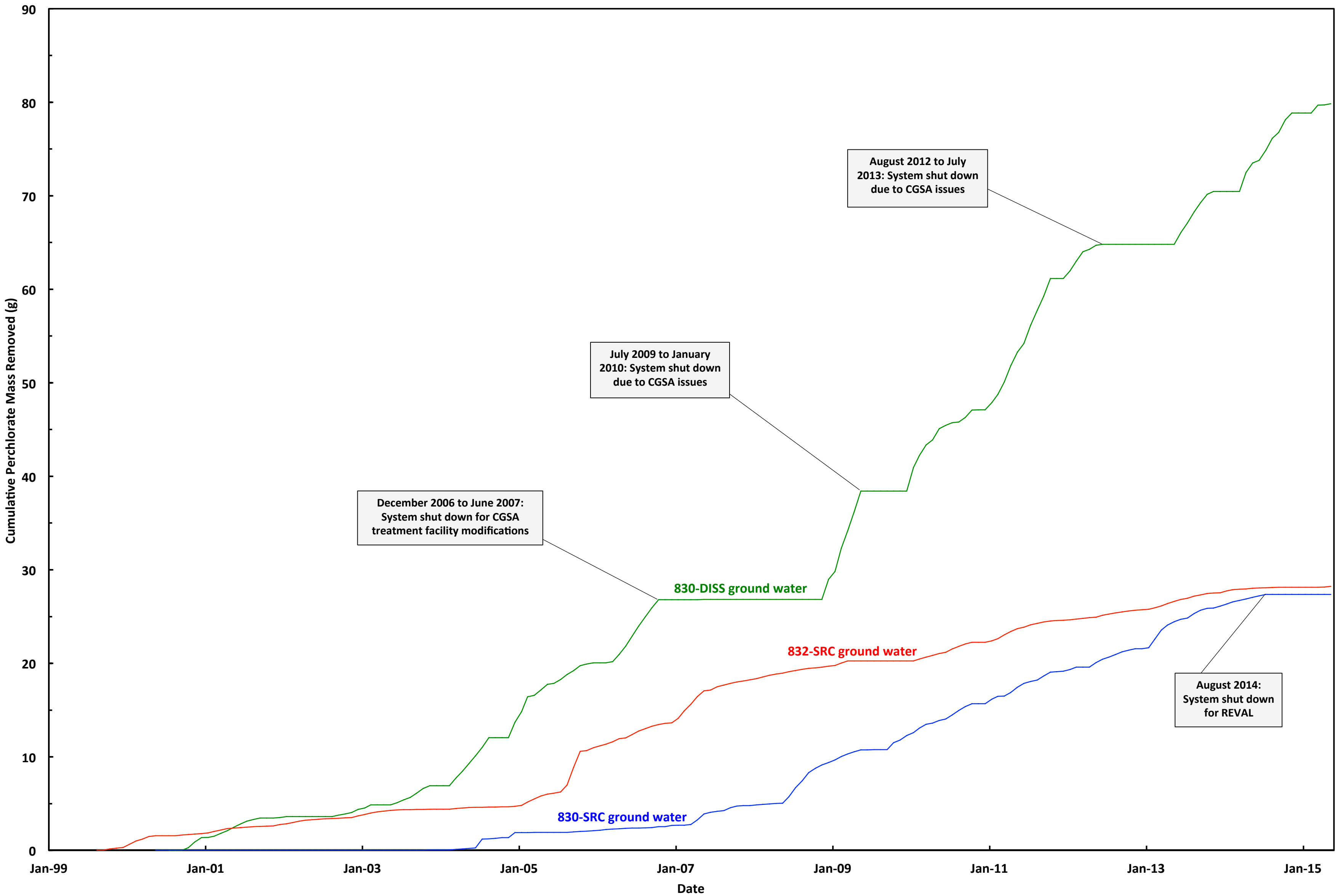


Figure 26. Time-series plot of cumulative perchlorate mass removed from Building 832 Canyon OU Treatment Facilities.

REVAL: Remediation evaluation (ERD).

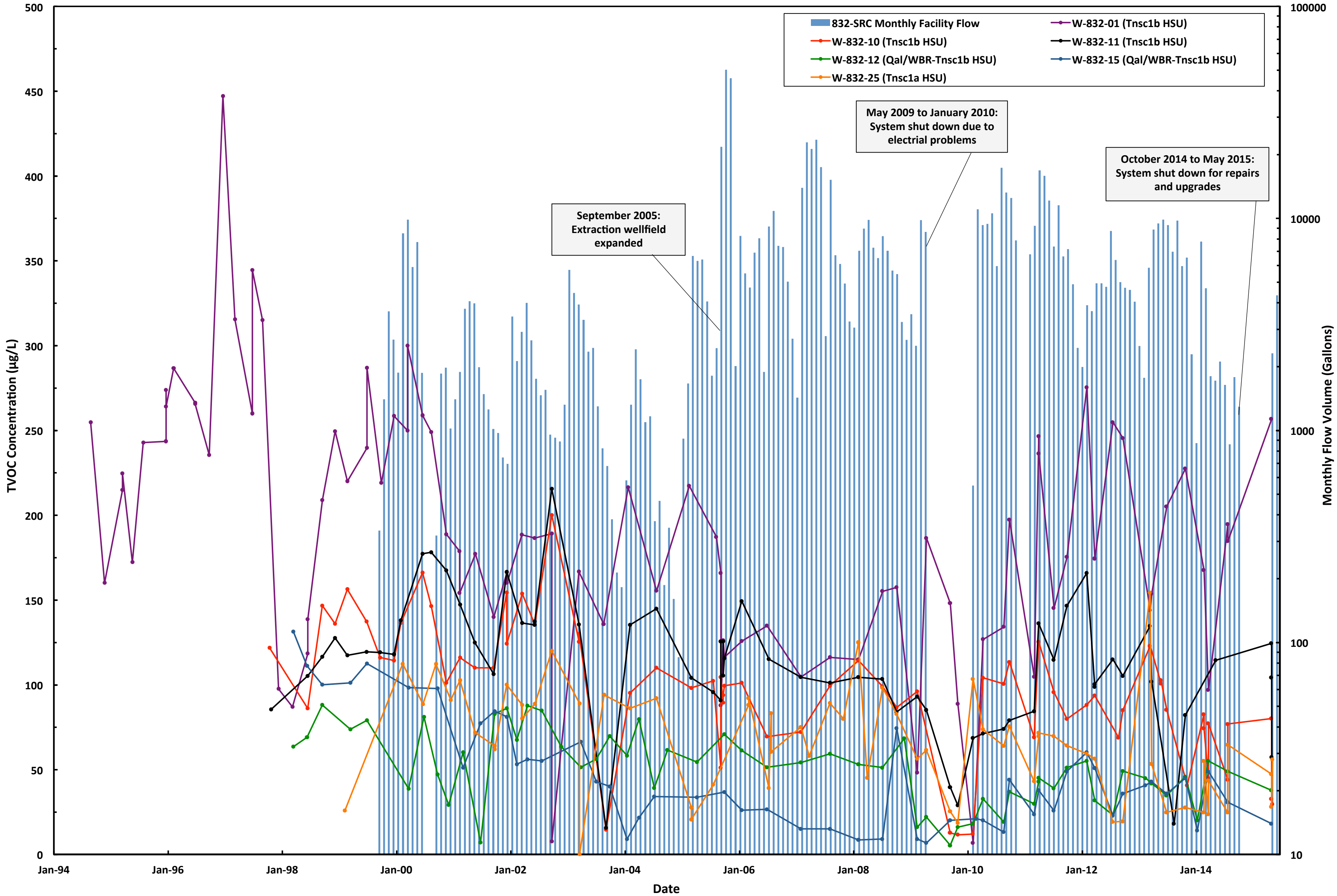
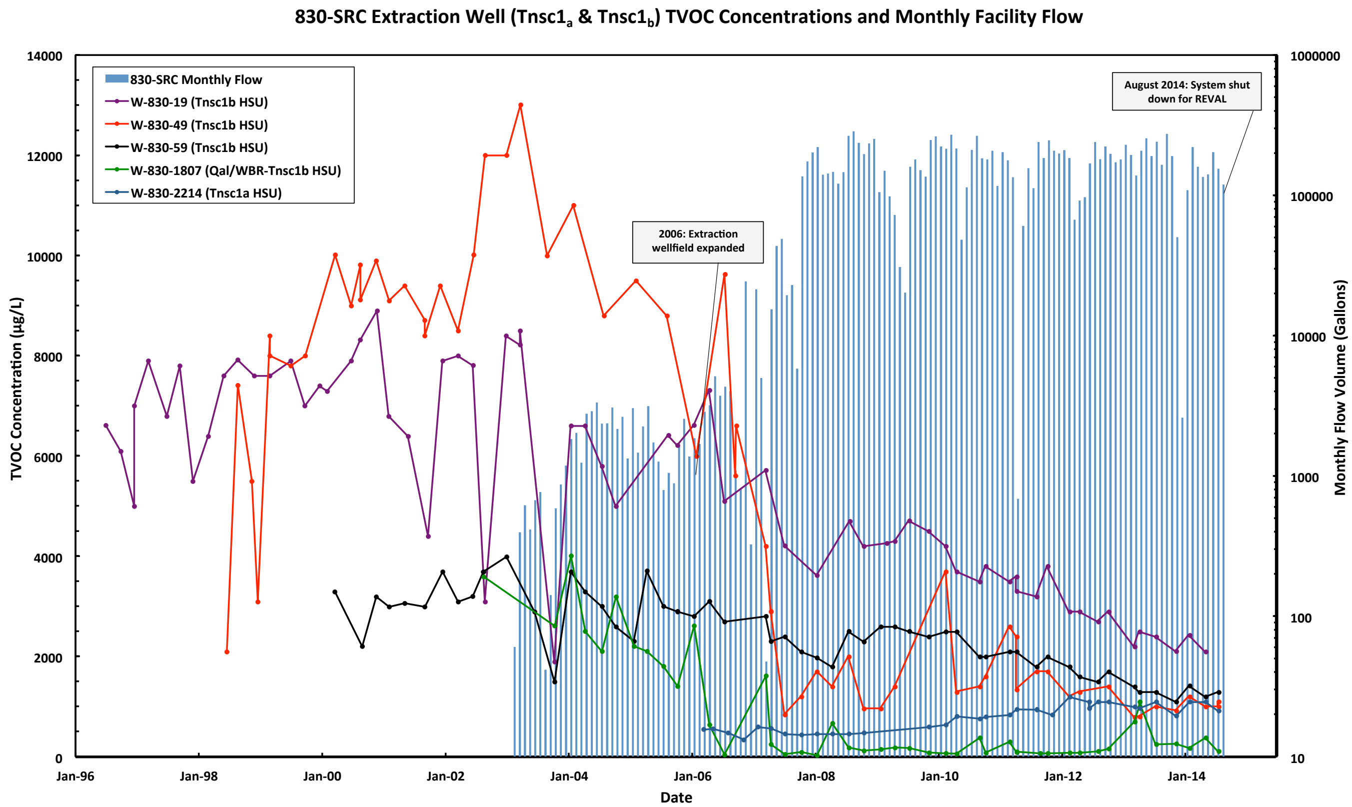


Figure 27. 832-SRC GWTS: extraction well total VOC concentrations and monthly facility flow.



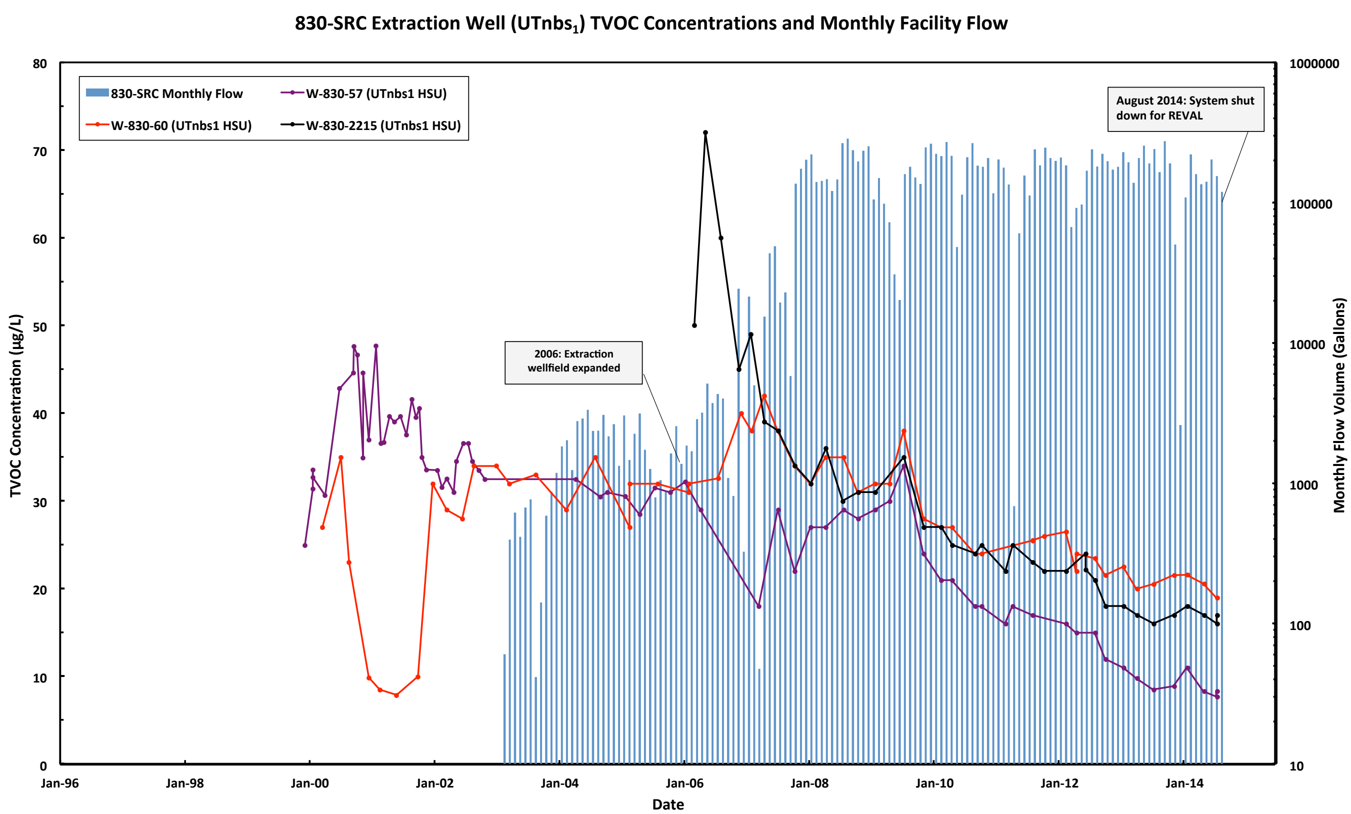


Figure 28. 830-SRC GWTS: extraction well total VOC concentrations and monthly facility flow. REVAL: Remediation evaluation (ERD).

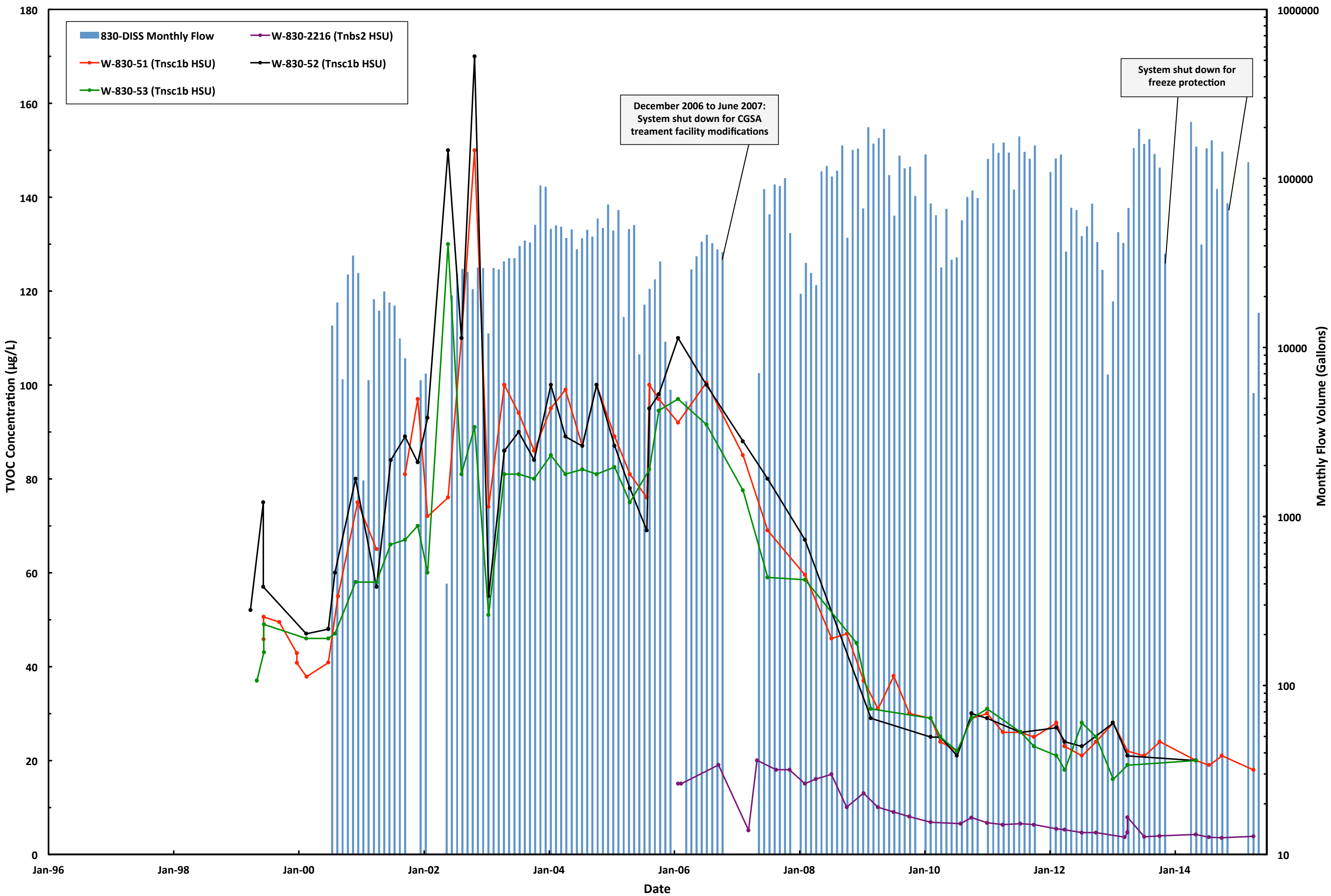


Figure 29. 830-DISS GWTS: extraction well total VOC concentrations and monthly facility flow.

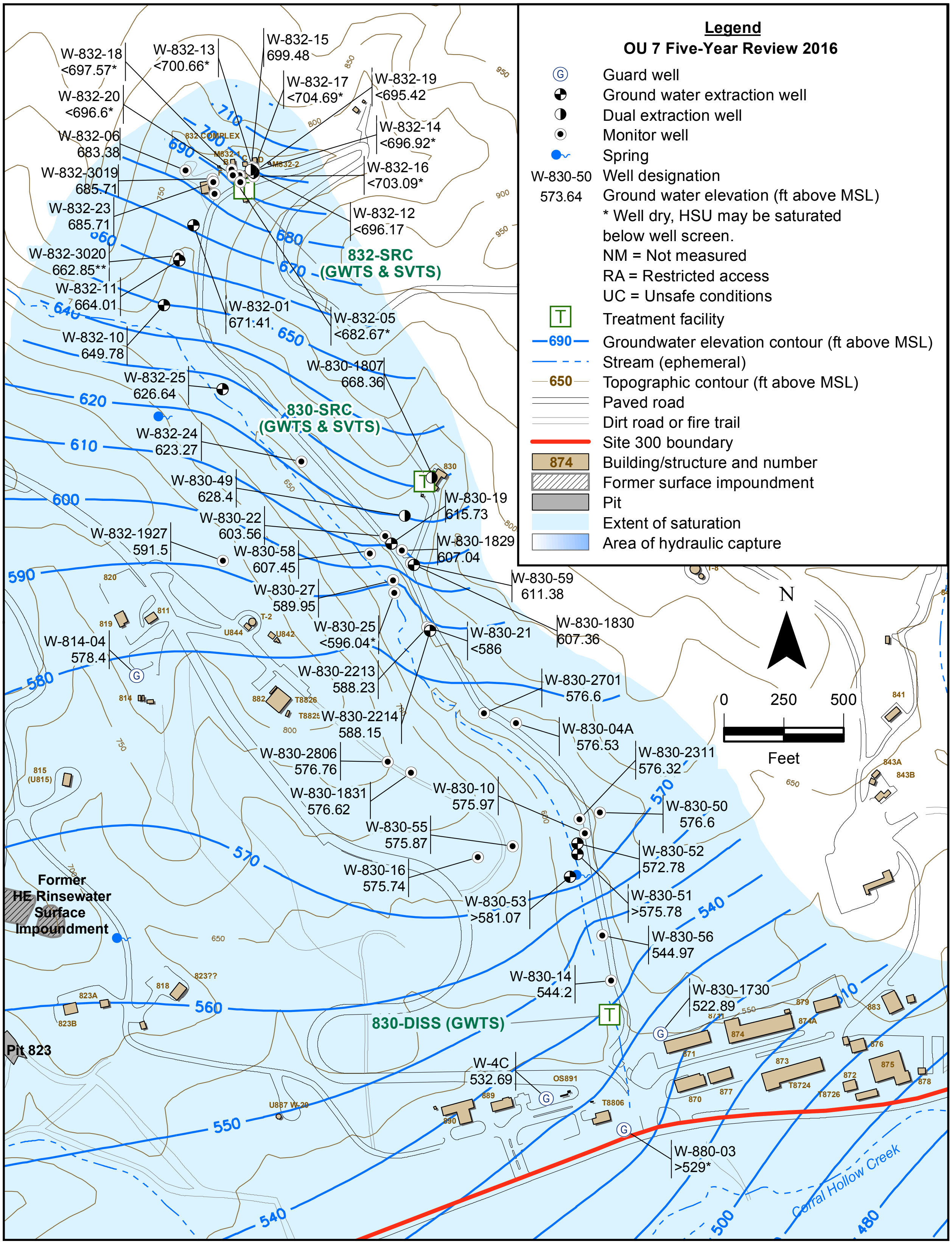


Figure 30. Building 832 Canyon OU potentiometric surface map (2015) for the Tnsc$_{1a/b}$ hydrostratigraphic unit.

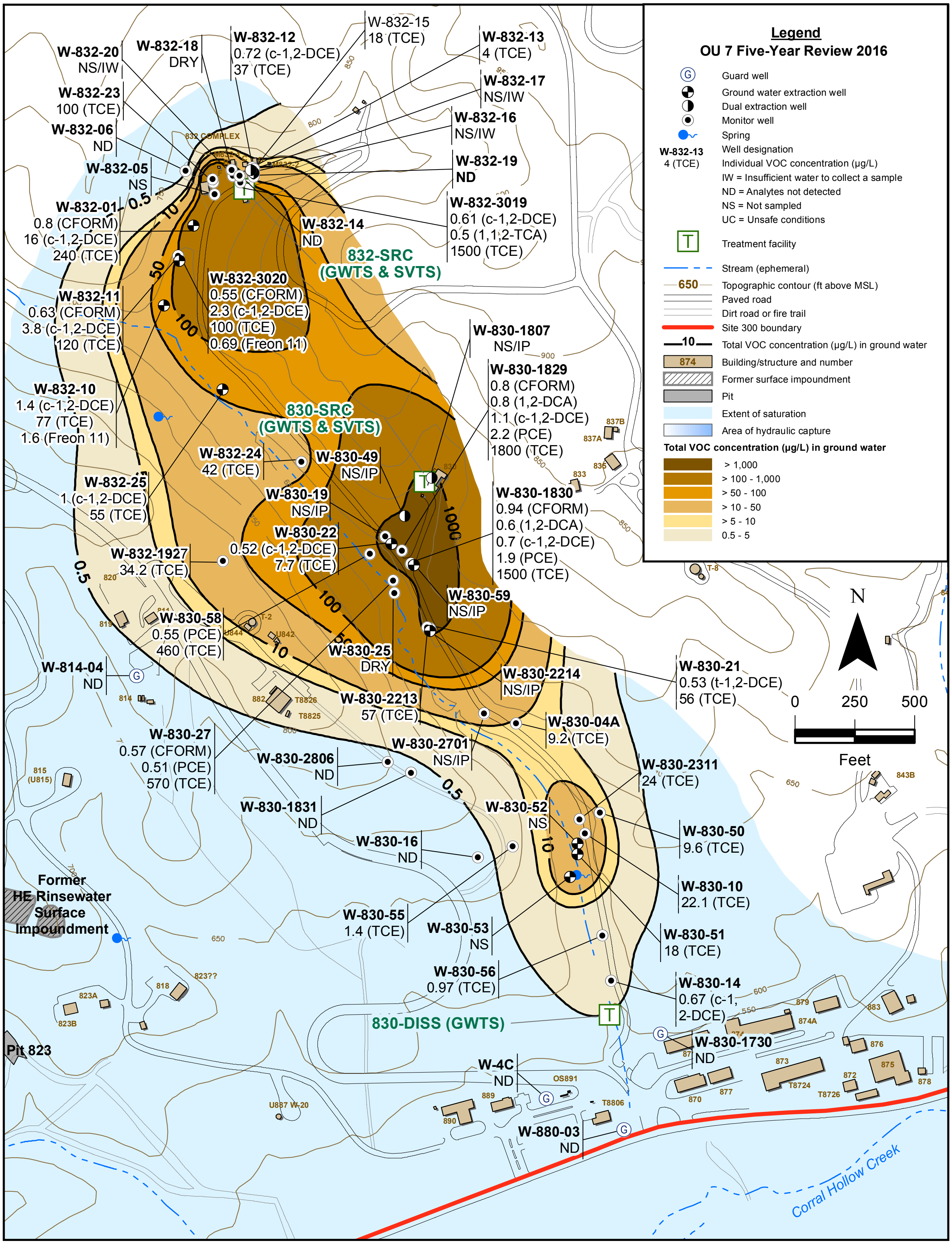


Figure 31. Building 832 Canyon OU total VOC isoconcentration contour map (2015) for the $Tnsc_{1a/b}$ hydrostratigraphic unit.

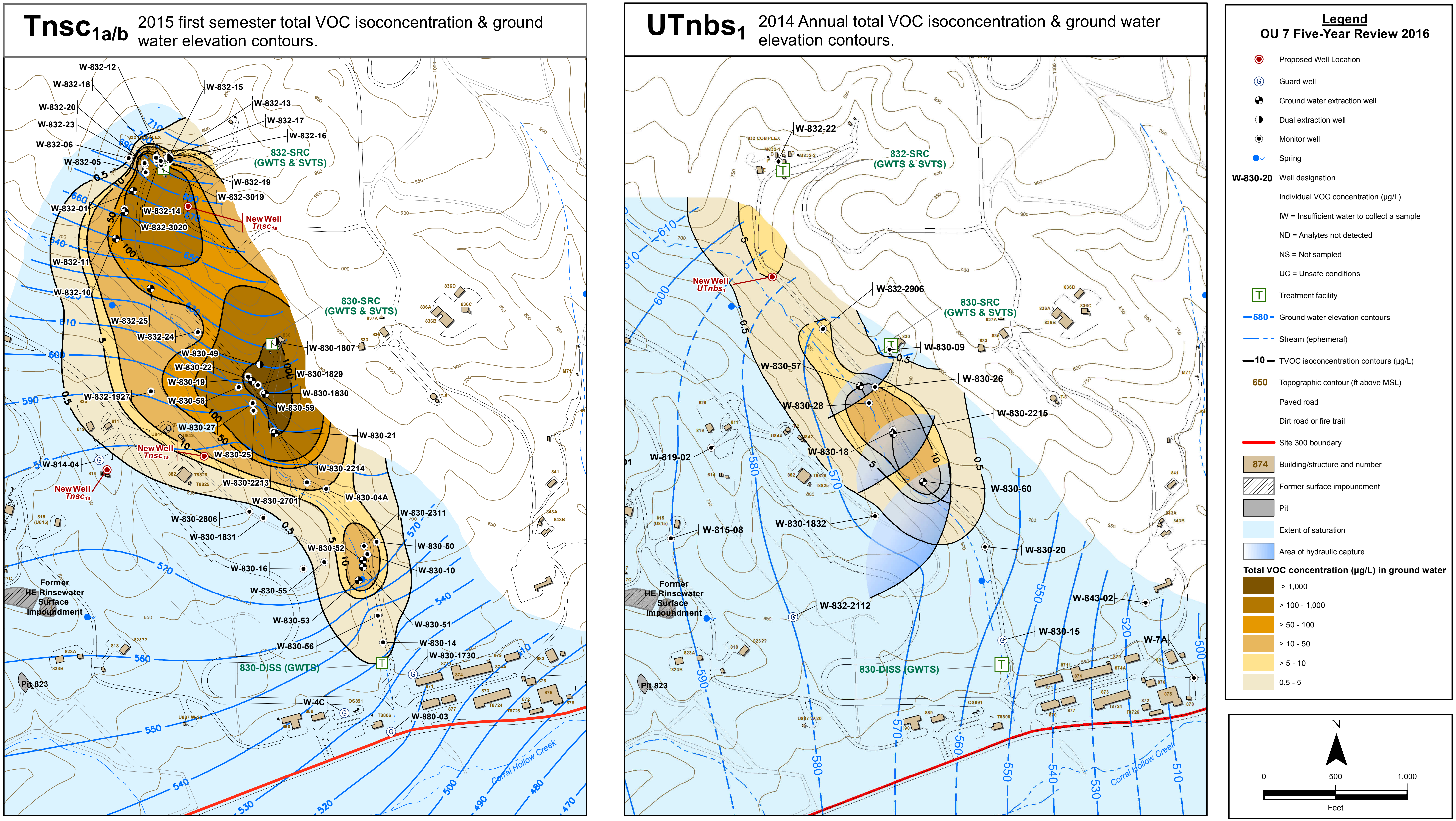


Figure 32. Area map depicting locations of wells recommended in the Building 832 Canyon OU Second Five-Year Review.

Tables

List of Tables

Table 1. Description of Land Use Controls (institutional and engineered) for the Building 832 Canyon 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 onsite water-supply use/consumption of contaminated ground water until ground water cleanup standards are met.	Volatile organic compounds (VOCs), perchlorate, and nitrate concentrations in ground water onsite exceed drinking water standards.	U.S. DOE/LLNL has implemented multiple layers of protection (land use controls) to prevent the water-supply use or consumption of onsite contaminated ground water in the Building 832 Canyon Operable Unit (OU) area until ground water cleanup standards are met. The land use controls include the Dig Permit Process and the Work Induction Board Process. A LLNL Dig Permit is required to drill and install any new onsite wells at Site 300. This permit process includes an evaluation of the proposed well location by the LLNL Environment, Safety and Health (ES&H) Team, including the Environmental Analyst (EA), and representatives of the LLNL Waste Management and the LLNL Work Induction Board to determine if the proposed new water-supply well is located in an area of ground water contamination. If it is determined that the proposed onsite water-supply well location is in a ground water contamination area, the ES&H Team, the works with the LLNL entity proposing the well installation and the LLNL Environmental Restoration Department (ERD) to relocate the well to ensure ground water contaminants would not be drawn into the well. There are no existing or planned water-supply wells in the Building 832 Canyon OU area. Contamination is limited to onsite ground water; therefore, land use controls are not needed to prevent offsite water-supply use/consumption of contaminated ground water.
Control excavation activities to prevent onsite worker exposure to contaminants in subsurface soil until it can be verified that subsurface soil does not pose an exposure risk to onsite workers.	Potential exposure to VOCs at depth in subsurface soil at the Buildings 830 and 832.	Land use controls have been implemented to control excavation activities to prevent onsite worker exposure to VOCs in subsurface soil at Buildings 830 and 832 until it can be verified that concentrations do not pose an exposure risk to onsite workers. The land use controls include the Dig Permit Process and the Work Induction Board Process. A LLNL Dig Permit is required to conduct any ground disturbing activities at Site 300, including activities that involve the excavation of soil and/or rock. This permit process includes an evaluation of the proposed location for the ground disturbing/excavation activity by the LLNL EA to determine if it is located in an area of soil/rock contamination. The EA works with the LLNL entity proposing the excavation activity to determine if the work plans can be modified to move these activities outside of areas of contamination.

Table 1. Description of Land Use Controls (institutional and engineered) for the Building 832 Canyon OU. (Continued)

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Control excavation in subsurface soils *(continued)*.	Potential exposure to VOCs at depth in subsurface soil at the Buildings 830 and 832 *(continued)*.	If the work plans cannot be modified to move excavation activities outside areas of subsurface soil contaminations, LLNL ES&H personnel evaluate the potential hazards and identify the necessary controls to be implemented for the activity. All proposed excavation activities are also submitted to and must be cleared through the LLNL Work Induction Board. The Work Induction Board meets weekly to review new proposed work at Site 300 to ensure that work is conducted in conformance with the appropriate controls and includes the special concerns for work at Site 300 (i.e., environmental contamination). If excavation activities are proposed for the Buildings 830 and 832 area, the Work Induction Board coordinates with the LLNL ERD and the EA to determine if the proposed excavation activity is located in an area where there is a potential for exposure to VOCs in subsurface soil. If a potential for contaminant exposure is identified, LLNL ES&H personnel ensures that hazards are adequately evaluated and necessary controls identified and implemented prior to the start of work.
Maintain building occupancy restriction to prevent onsite site worker inhalation exposure to VOCs inside Building 830 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	Baseline risk assessment identified a risk of 3 x 10^{-6} for onsite workers from inhalation of VOCs volatilizing from subsurface soil into ambient air inside Building 830. Annual risk re-evaluation conducted in 2014 indicated the risk to onsite workers inside Building 830 remains above 10^{-6}.	Building occupancy restriction implemented at Building 830 to prevent onsite site worker inhalation exposure to VOCs until annual risk re-evaluation indicates that the risk is less than 10^{-6} include physical barriers such as signage and the Work Induction Board Process. Building 830 is not currently occupied; the building was returned to institutional control several years ago and is no longer in use. Warning signs are maintained prohibiting full time occupancy without notification and authorization by LLNL Site 300 Management. Any significant changes in activities conducted in Building 830 must be cleared through the LLNL Work Induction Board. During this five year review period, no new activities were proposed for Building 830. U.S. DOE conducts annual risk re-evaluations for VOC inhalation risk at Building 830 to determine when the inhalation risk has been mitigated. The risk re-evaluation results are reported in the Annual Site Wide Compliance Monitoring Reports.

Table 1. Description of Land Use Controls (institutional and engineered) for the Building 832 Canyon OU. (Continued)

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Maintain land use restriction/institutional controls in the vicinity of Spring 3 to prevent onsite site worker inhalation exposure to VOCs at Spring 3 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	Baseline risk assessment identified a risk of 7 x 10^{-5} for onsite workers from inhalation of VOCs volatilizing from Spring 3 into outdoor air.	Implementation of land use restriction/institutional controls in the vicinity of Spring 3 to prevent onsite site worker inhalation exposure to VOCs until annual risk re-evaluation indicates the risk is less than 10^{-6} include the Work Induction Board Process. However, the risk and hazard management evaluation for Spring 3, completed in 2009 (Dibley et al., 2010a), indicated the estimated risk remained below 10^{-6} and the hazard index remained below 1 for two consecutive years. No unacceptable risk or hazard to onsite workers exists at Spring 3. Therefore, institutional controls are no longer needed to prevent exposure. In addition, workers do not occupy or plan to occupy the Spring 3 area in the near future. Current activities in the vicinity of the Spring 3 are restricted to semi-annual spring sampling when water is present in the spring. The time spent sampling is well below the exposure scenario for which the unacceptable exposure risk was calculated, assuming a worker would spend 8 hours a day, 5 days a week for 25 years working at the Spring 3.
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.	Potential exposure to contaminated environmental media.	The Site 300 ROD requires the implementation of land use controls to prohibit the residential or unrestricted land use of Site 300 property or portions thereof with unmitigated contamination that could cause potential harm to human health. To prevent the potential exposure to contaminated waste and/or environmental media in the event of the transfer of Site 300 property, the Site 300 Federal Facility Agreement (FFA) prohibits U.S. DOE from transferring lands with unmitigated contamination that could cause potential harm unless it complies with the requirements of Section 120(h) of CERCLA, 42 U.S.C. 9620 (h) and requirements for notification and protection of the integrity of the remedy set forth in Section 28 of the FFA. The Site 300 FFA has not been modified during this five-year review period, and its provisions remain as originally stated. 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 (CCR), Division 4.5, Chapter 39, Section 67391.1 as specified in the Site 300 ROD, and will implement deed restrictions per CERCLA 120(h). No change in ownership of Site 300 will take effect without provision for continued maintenance of any contaminant system, treatment system, monitoring system, or other response action(s) installed or implemented.

Table 1. Description of Land Use Controls (institutional and engineered) for the Building 832 Canyon OU. (Continued)

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Land transfer prohibition *(continued)*.	Potential exposure to contaminated environmental media *(continued)*.	Development at Site 300 will be restricted to industrial land usage. These restrictions will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and is agreed by the U.S. DOE, the U.S. EPA, DTSC, and the RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use. LLNL Site 300 remains an active U.S. DOE facility, and U.S. DOE has not proposed any plans to transfer any Site 300 land for residential, unrestricted, or non-U.S. DOE industrial land use during the five-year review period. Therefore, it has not been necessary to execute a land use covenant or deed restrictions. These institutional controls will be implemented if and when the property or a portion thereof is transferred in accordance with the requirements of the Site 300 ROD, Title 22 CCR Division 4.5, Chapter 39, Section 67391.1, and CERCLA 120(h).

Notes:

CCR = California Code of Regulations.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
EA = Environmental Analyst.
ES&H = Environment, Safety and Health.
U.S. DOE = United States Department of Energy.
DTSC = California Department of Toxic Substances Control.
U.S. EPA = United States Environmental Protection Agency.
ERD = Environmental Restoration Department.
FFA = Federal Facility Agreement.
LLNL = Lawrence Livermore National Laboratory.
OU = Operable Unit.
ROD = Record of Decision.
RWQCB = California Regional Water Quality Control Board.
VOCs = Volatile Organic Compounds.

Table 2. Actual annual costs for the Building 832 Canyon Operable Unit for fiscal years 2011 through 2015.

Fiscal Year	Annual Budget	Actual Annual Cost	Cost Variance	Cost Variance Explanation
2011	$908,492	$971,052	$62,560	The FY 2011 costs were slightly over budget due to a well installation costing more than planned and unanticipated maintenance conducted at the Buildings 830-Source and 832-Source treatment facilities.
2012	$859,047	$858,527	$520	The FY 2012 was on budget (within +/-5% tolerance limits).
2013	$912,582	$840,703	$71,879	The FY 2013 costs were slightly over budget due to treatment facility upgrades being conducted on FY 2012 carryover. The upgrades were delayed until FY 2013 due to FY 2012 funding not being finalized until late in the fiscal year.
2014	$1,907,517.88	$1,707,923	$199,595	The FY 2014 costs were over budget due to treatment facility upgrades being conducted on FY 2013 carryover. The upgrades were delayed until FY 2014 due to FY 2013 funding not being finalized until late in the fiscal year.
2015	$1,521,466	$1,540,801	$19,334	The FY 2015 was on budget (within +/-5% tolerance limits).

Notes:

FY = Fiscal year.

O&M = Operations and maintenance.

Appendix A

Appendix A1

Building 832 Canyon OU
Five-Year Review Inspection Checklist Photographs

Building 832 Canyon OU
Five-Year Review Inspection Checklist Photographs

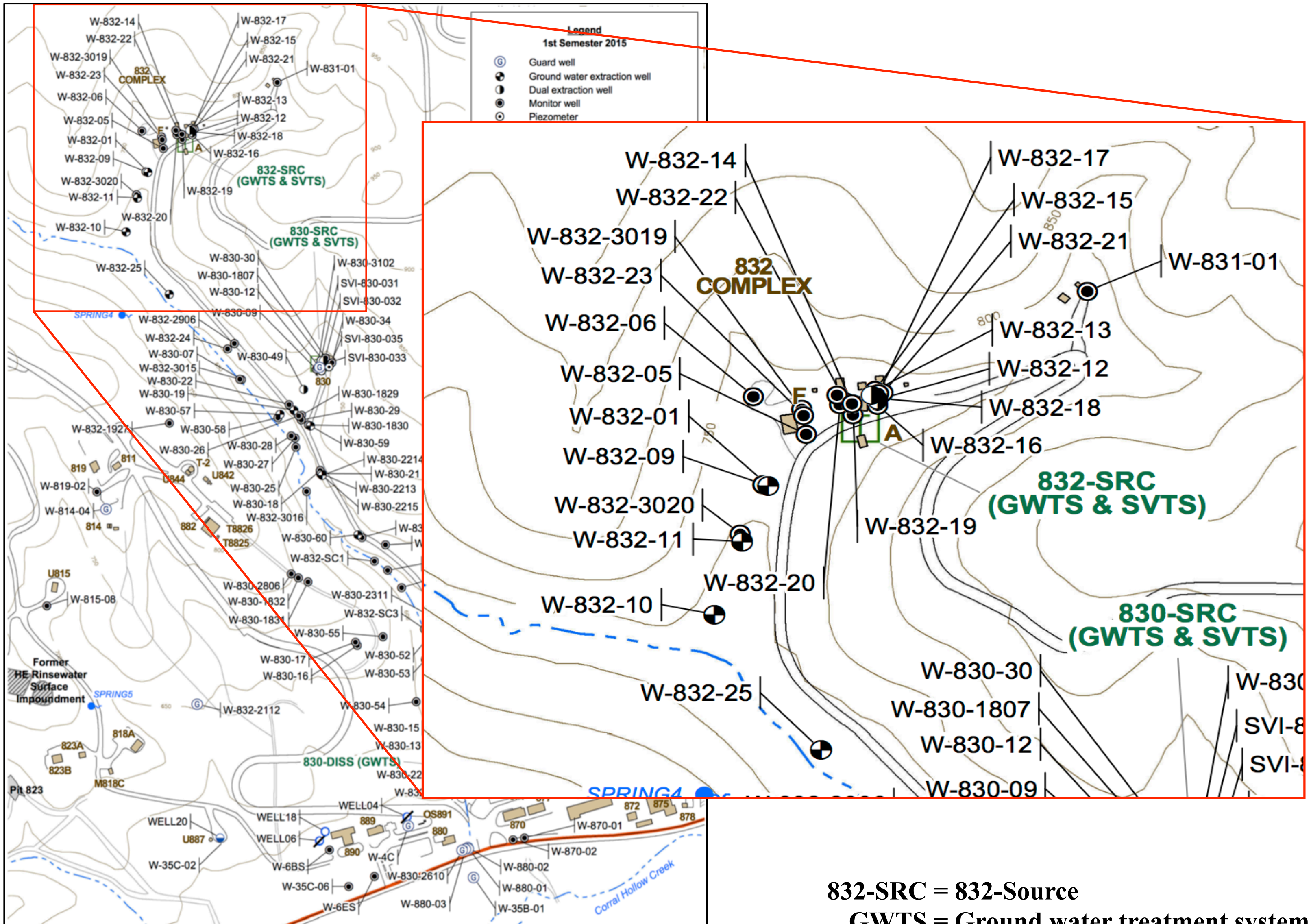
1. **Building 832-Source ground water and soil vapor extraction and treatment systems, misting tower, and other system components**

2. **Building 830-Source ground water and soil vapor extraction and treatment systems, misting tower, and other system components**

3. **Building 830-Distal South ground water extraction and treatment system**

Photographs of the Building 832-Source ground water and soil vapor extraction and treatment systems, misting tower, and other system components

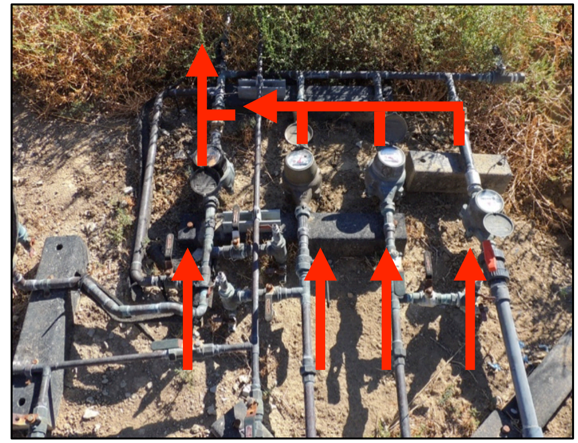
Building 832-Source extraction and monitor wellfield



832-SRC = 832-Source
GWTS = Ground water treatment system
SVTS = Soil vapor treatment system

Building 832-Source (SRC) Ground Water Treatment System (GWTS)

(a) Example of current wellhead configuration for well with air-actuated pump (W-832-01 shown).



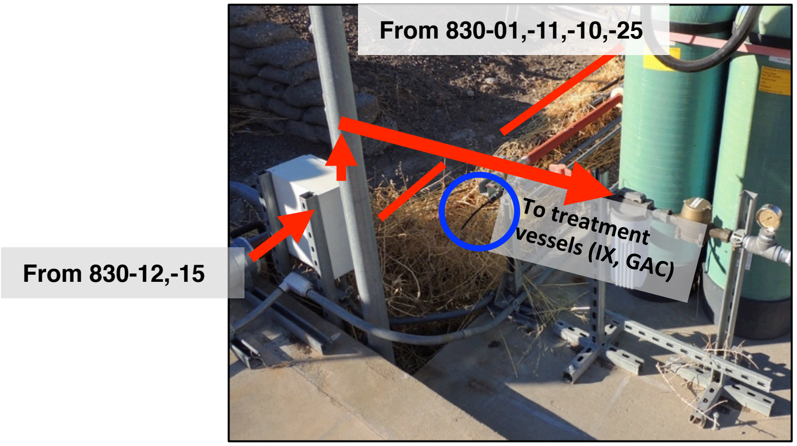
(b) Granular activated carbon vessels for volatile organic compound treatment in ground water (flow direction indicated with arrows).

(c) Piping from manifold through culvert underneath road (flow direction indicated with arrow).

(d) Piping exiting culvert and directed towards 832-SRC GWTS (flow direction indicated with arrows).

Building 830-SRC ground water treatment system influent manifolds and granulated activated carbon and ion-exchange vessels.

Building 832-Source (SRC) Ground Water Treatment System (GWTS)



(a) Manifold (hidden) combining flow into 832-SRC GWTS (flow direction indicated by arrows, & sample port circled).

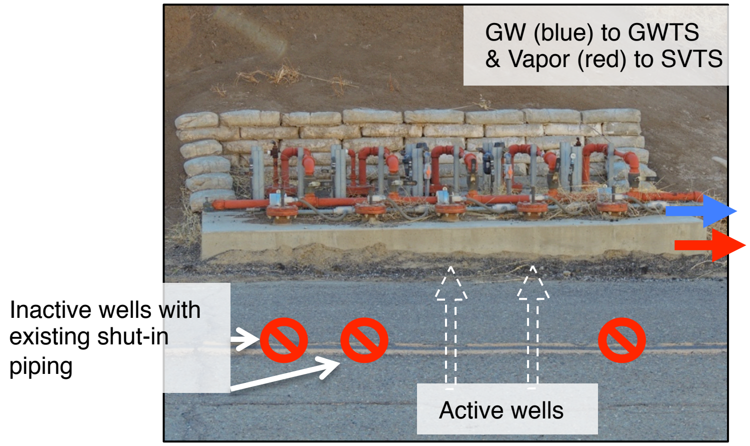
(b) Ion-exchange resin vessels for perchlorate treatment (flow direction indicated by arrows).

(c) Granular activated carbon vessels for ground water treatment of volatile organic compounds and batch tank for periodic discharge of treated effluent to misting tower.

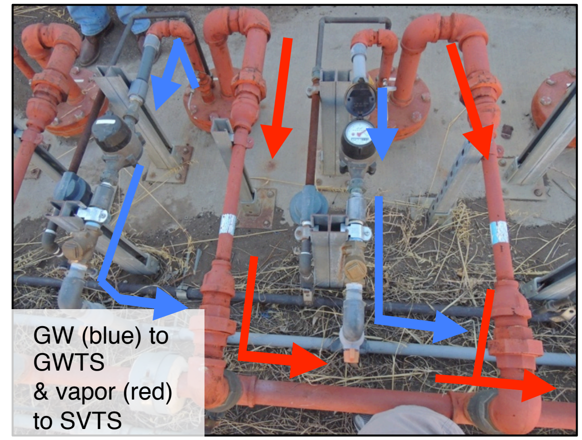
(d) Building 832-SRC GWTS air-compressor driving ground water extraction wells.

Building 832-SRC ground water treatment system treatment media vessels and air-compressor for ground water extraction pumps.

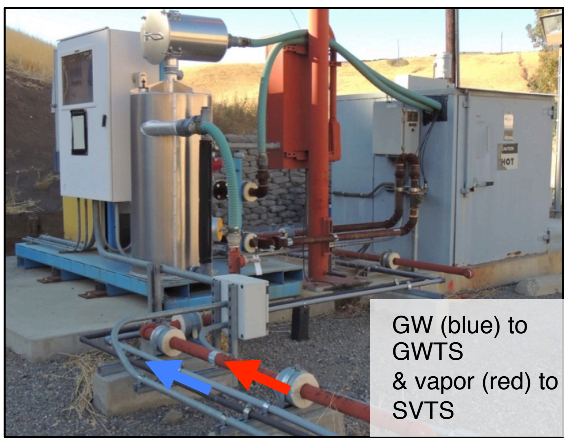
Building 832-Source (SRC) Ground Water Treatment System (GWTS) and Soil Vapor Treatment System (SVTS)



(a) Piping is run under parking area and road to manifold setup (flow direction indicated with arrows). Note the two currently active well connections.



(b) Ground water currently sampled at manifold, soil vapor at wellhead (not pictured).



(c) Knock-out canister(left) to reduce condensation in vapor & vapor-phase GAC to treat VOCs, in unheated enclosure(right).

(d) Discharge of treated vapor via permitted vapor stack.

Building 832-SRC ground water treatment system influent manifolds and granulated activated carbon and ion-exchange vessels.

Building 832-Source (SRC) Ground Water Treatment System (GWTS)

(a) Building 832-SRC misting tower, view from west.

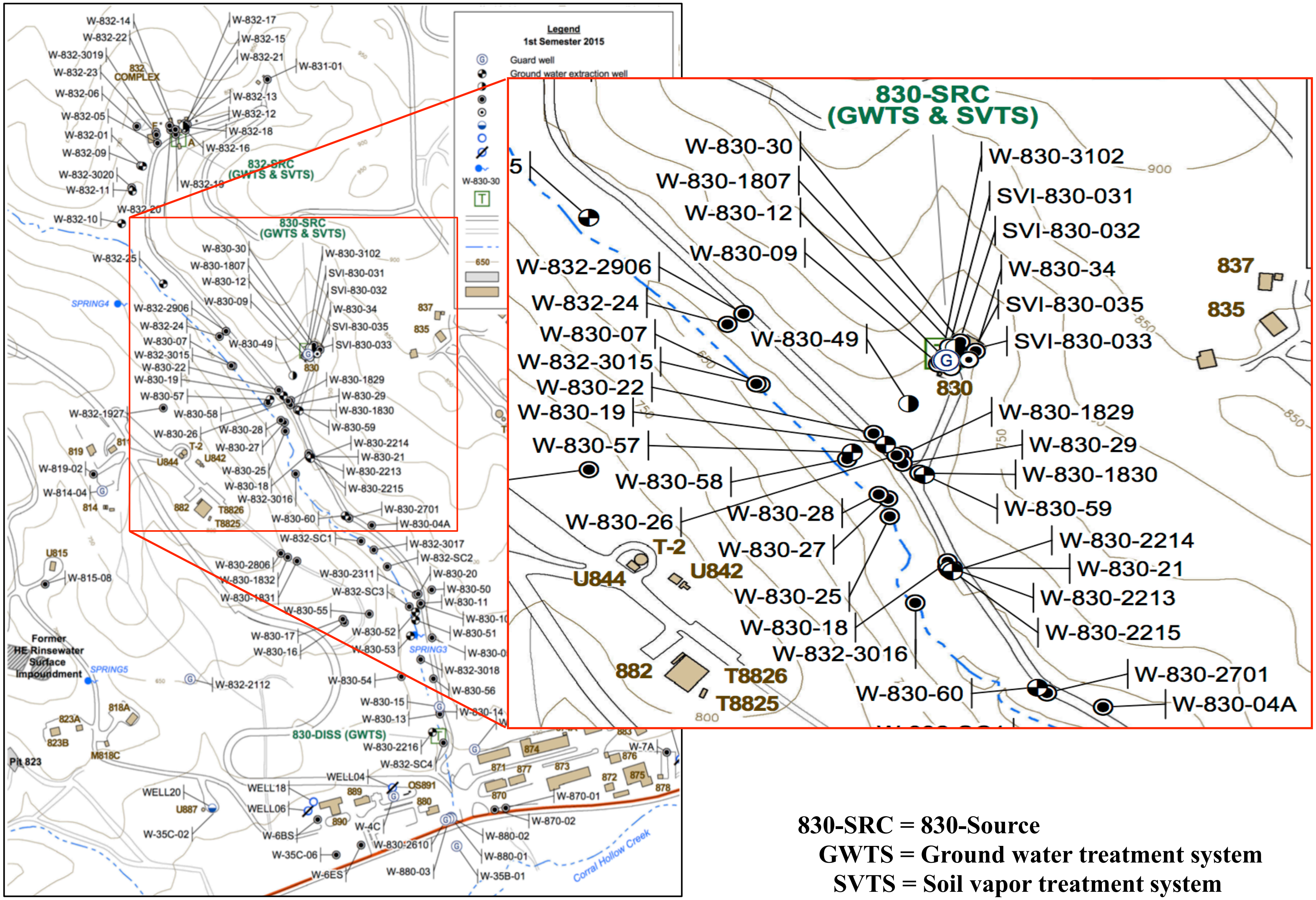
(b) Retaining structure behind Building 832-SRC soil vapor treatment system not vertical; often over-topped with sediment. (Improvements planned.)

(c) New dual extraction well W-832-3019 installed in 2014.

Building 832-SRC GWTS misting tower, new wells, and soil retaining structure.

Photographs of the Building 830-Source ground water and soil vapor extraction and treatment systems, misting tower, and other system components

Building 830-Source extraction and monitor wellfield



830-SRC = 830-Source

GWTS = Ground water treatment system

SVTS = Soil vapor treatment system

Building 830-Source (SRC) Ground Water Treatment System (GWTS)

(a) Example of ground water-only extraction wellhead completion with flow meter (W-830-57 shown).

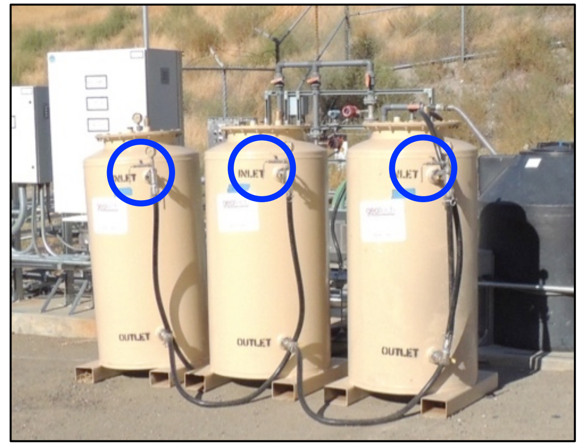
(b) Example of a monitor well outfitted with real-time data collection equipment (W-830-59 shown).

(c) Extraction well piping is raised on unistruts along road, in double-contained in culvert under road, and on unistruts up hill to Building 830-SRC GWTS (flow indicated by arrows).

Building 832-SRC ground water treatment system wellhead configurations and piping to treatment facility.

Building 830-Source (SRC) Ground Water Treatment System (GWTS)

(a) Influent is two streams on basis of treatment: ion-exchange resin and granular activated carbon (GAC) vs. GAC only (sample ports circled and flow direction through filters indicated with arrows).



(b) GAC vessels for volatile organic compound treatment in ground water and sample ports (circled).

(c) Ion-exchange vessels secured to unistrut.

(d) An ion-exchange vessel sample ports (circled).

Building 830-SRC ground water treatment system influent manifolds and granulated activated carbon (GAC) and ion-exchange vessels.

Building 830-Source (SRC) Ground Water Treatment System (GWTS)

(a) Building 830-SRC GWTS north misting tower (view from north).

(b) Building 830-SRC GWTS north misting tower (view from east).

(c) Building 830-SRC GWTS south misting tower (view from north).

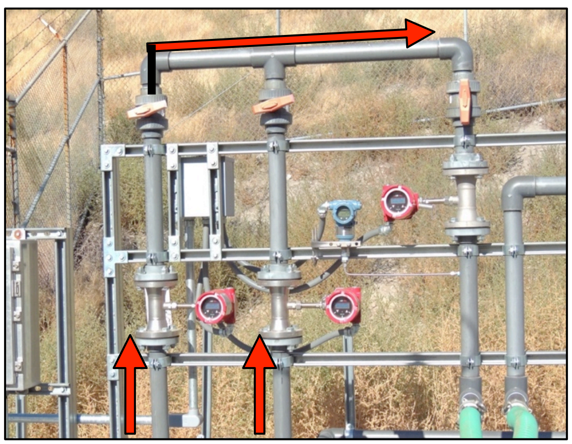
(d) Injection testing of potential injection well W-830-3101, east of the 830-SRC GWTS south misting tower.

Building 832-SRC ground water treatment system effluent misting towers and one location of possible future reinjection of effluent.

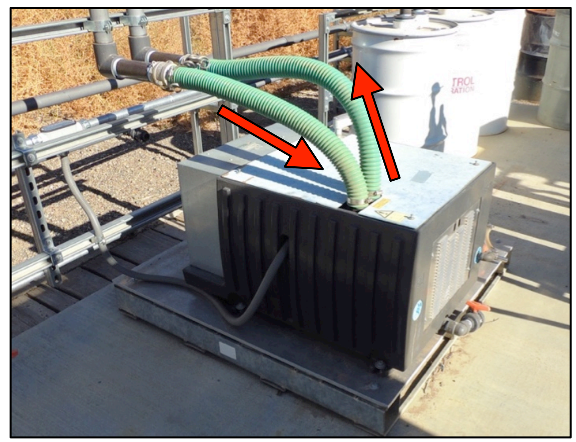
Building 830-Source (SRC) Soil Vapor Treatment System (SVTS)

(a) Example of dual extraction wellhead standardized design (ground water sampling port circled; W-830-1807 shown).

(b) Example of vapor sampling location at W-830-1807 (circled).



(c) Vapor flow mass flow meters and manifolds (arrows indicate flow direction).



(d) Liquid ring vacuum pump blower for vapor extraction, between manifold and vapor-phase granular activated carbon.

Building 830-SRC soil vapor treatment system wellhead configuration, sampling location, flow manifolds, and vacuum source for vapor extraction.

Building 830-Source (SRC) Soil Vapor Treatment System

(a) Vapor-phase granular activated carbon vessels (vapor flow direction indicated by arrows).

(b) Vapor-phase granular activated carbon vessels and intermediate sample ports (circled).

(c) Permitted treated vapor discharge stack (indicated with arrow).

(d) Site Inspection with regulators on December 15, 2015.

Building 830-SRC soil vapor treatment system.

Building 830-Source (SRC) Ground Water Treatment System (GWTS)

(a) Well W-830-3101, a new potential injection well installed in 2015 (well W-833-18 in background).

(b) One of four shallow alluvial stream-bed Qal/WBR monitoring wells installed by hand-augering in 2014 (W-832-3017 shown).

(c) Well W-830-3102, a new potential injection well installed in 2015, shown with purge-water tank used during final well-development.

Selected photos of new wells installed in Building 832 Canyon OU since previous five-year review.

Building 830-Source (SRC) Ground Water and Soil Vapor Treatment System

(a) Before: Dual-extraction well with analog flow meters and vacuum gauges and cluttered piping.

(b) After: Dual-extraction well with digital flow meter and vacuum gauges, level transducer, simplified piping, and real-time data.

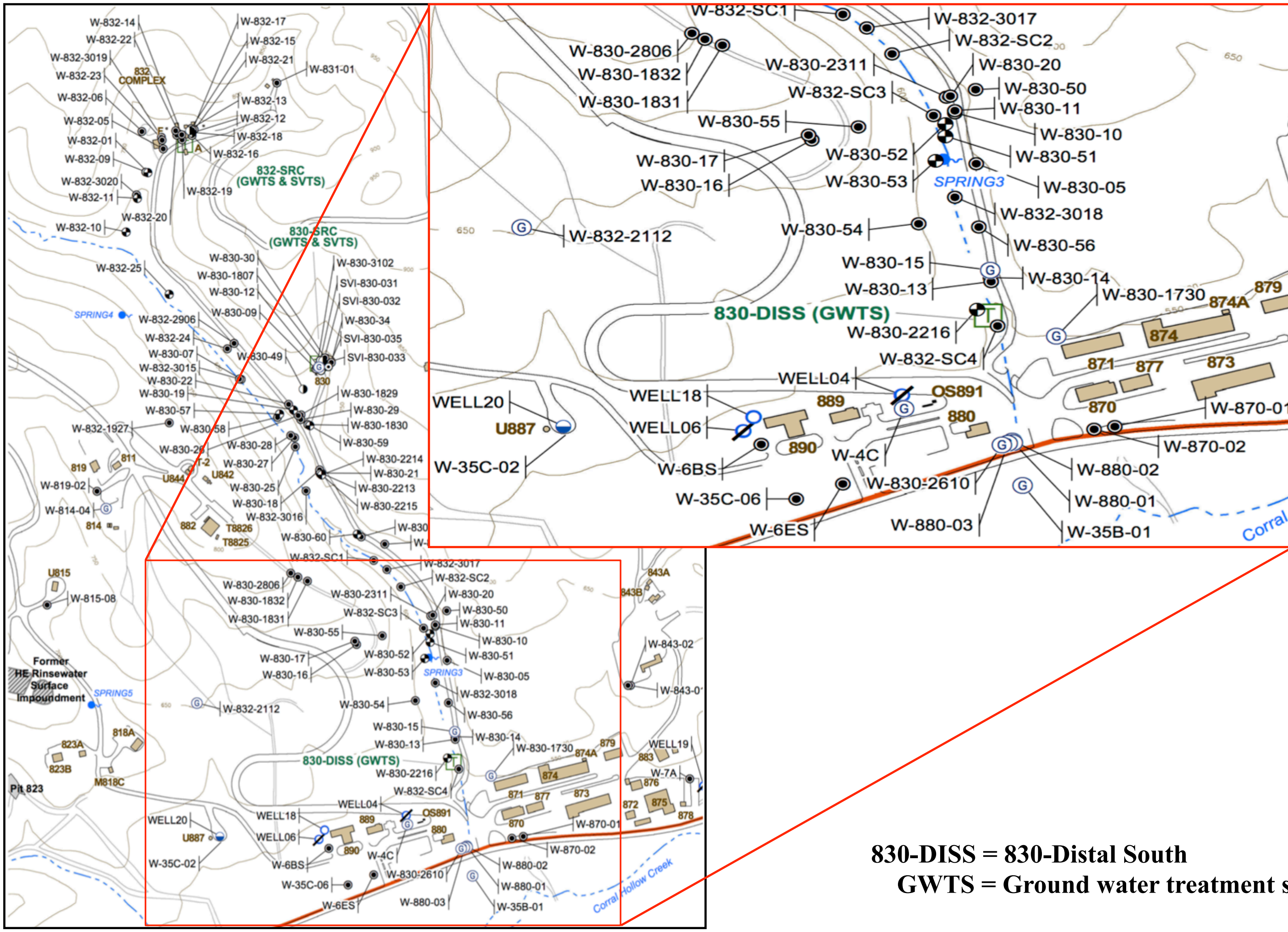
(c) Before: Extraction well with analog flow totalizer only.

(d) After: Extraction well with digital flow meters, totalizers, water level transducers, & real-time data.

Building 830-SRC ground water and soil vapor treatment system extraction wellheads before and after system upgrades.

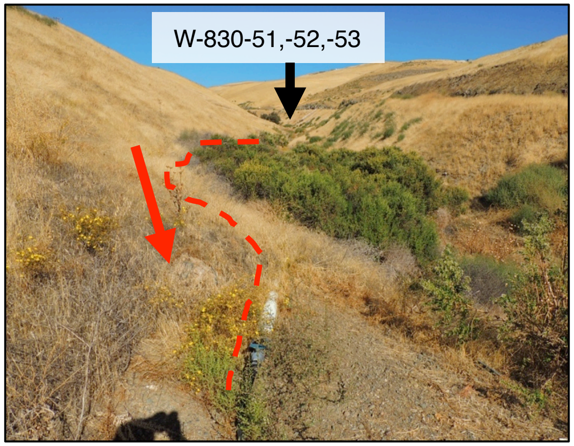
Photographs of the Building 830-Distal South ground water extraction and treatment system

Building 830-Distal extraction and monitor wellfield



830-DISS = 830-Distal South
GWTS = Ground water treatment system

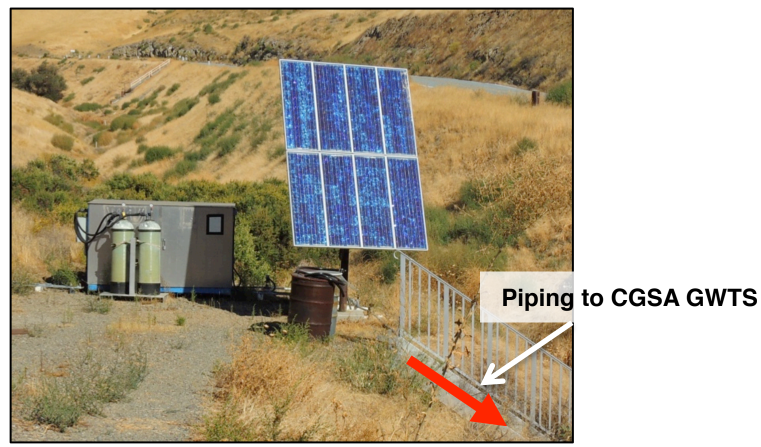
Building 830-Distal South (DISS) Ground Water Treatment System (GWTS)



(a) 830-DISS wellfield viewing from 830-DISS GWTS, looking north (pipeline path indicated with dashed red line, flow direction with red arrow.)

(b) Influent from W-830-51, -52, -53 are treated at 830-DISS for perchlorate removal, after which VOC-bearing water from W-830-2216 is added to pipeline. All water is then treated at the Central GSA GWTS for VOCs.

(c) 830-DISS GWTS enclosure for flow manifolds and batteries and two ion-exchange columns for perchlorate removal.



(d) Building 830-DISS GWTS with ion-exchange resin vessels, battery enclosure to power W-830-2216, and a solar panel array to charge batteries.

Building 830-DISS ground water extraction and treatment system.

Appendix A2
Building 832 Canyon Operable Unit
Five-Year Review Site Inspection Checklist
Lawrence Livermore National Laboratory (LLNL) Site 300

I. SITE INFORMATION

Site Name: Building 832 Canyon Operable Unit (OU), LLNL Site 300

Date of inspection: October 22, 2015

Location and Region: Corral Hollow Road, San Joaquin/Alameda County, California

EPA Region: 9

EPA ID: CA 2890090002

Agency Leading the Five-Year Review: U.S. Department of Energy (DOE) – National Nuclear Security Administration (NNSA) Livermore Field Office (LFO)

Weather/Temperature: The climate of Site 300 is semiarid and windy with wide temperature variations.

Remedy Includes:

- Monitoring to evaluate the effectiveness of the remedial action in achieving cleanup standards.
- Risk and hazard management (including institutional and administrative controls) to prevent onsite workers exposure to volatile organic compounds (VOCs) volatilizing from subsurface soil and impacts to onsite workers until risk and hazard is mitigated through active remediation.
- Extracting and treating VOCs, perchlorate, and nitrate in ground water and soil vapor to mitigate unacceptable VOC inhalation risk for onsite workers, prevent further impacts to ground water and offsite plume migration, and reduce contaminant concentrations in ground water to cleanup standards.
- Monitoring Natural Attenuation (MNA) of nitrate in ground water.
- Monitoring of contaminants of concern in ground water to evaluate the effectiveness of the remedial action in achieving cleanup standards.
- Risk and hazard management:
  - Maintain institutional/land use controls for the Building 832 Canyon OU specified in the in Table 2 of the Five-Year Review.

Site Map: See Figures 2 and 3 in the Building 832 Canyon OU Five-Year Review.

II. INTERVIEWS

1. O&M Site Manager

Lawrence Livermore National Security (LLNS), LLC (M&O Contractor to DOE): Leslie Ferry, Site 300 Environmental Restoration (ER) Program Leader.

Remarks: As there is a full-time presence of the DOE-LFO Remedial Project Manager (RPM) and the LLNS Site 300 ER Program Leader, Site 300 ER Field Operations Manager, and the Building 832 Canyon OU treatment facility operators at the site, the oversight, inspections, evaluations, and discussions of the Building 832 Canyon OU remedy are ongoing. Remedy performance, facility operations, and any related issues are managed in real-time in collaboration with the Field Operations Manager, the facility operator, and full-time staff from the Site 300 ER Field Operations, Hydrogeology, Engineering, Water Quality Sampling, and Analysis Teams. As such, there was no single "interview" of DOE or LLNS O&M Managers or interview results that can be referenced. The information contained within this inspection checklist is a compilation of this and other DOE-LFO RPM routine inspections, evaluations, and discussions with the LLNS Site 300 ER Program Leader and staff regarding the Building 832 Canyon OU remedy and treatment facilities. In addition, DOE/LLNS presents and discusses any treatment facility operations and maintenance (O&M) or other remedy related issues with the regulatory agencies on an ongoing basis via monthly regulatory RPM project updates and meetings, and in the semi-annual and annual compliance monitoring reports.

2. O&M Staff

Lawrence Livermore National Security (LLNS), LLC (M&O Contractor to DOE):

Name	Function
Steve Orloff	Site 300 ER Field Operations Manager (LLNS)
Todd Trammell	Operator - Building 832-Source and 830-Source ground water and soil vapor extraction and treatment systems (LLNS)
Larry Griffith	Operator – Building 830-Distal South ground water extraction and treatment system (LLNS)
Jonathan McKaskey	Site 300 ER Hydrogeologist (Weiss Associates – LLNS Subcontractor)
Eric Walter	Site 300 ER Sampling Coordinator (LLNS)
Jon Ulrech	Site 300 ER Sampling Technician (LLNS)

Remarks: As there is a full-time presence of the DOE-LFO RPM, LLNS Site 300 ER Program Leader, Site 300 ER Field Operations Manager, and Building 832 Canyon OU treatment facility operator at the site, the oversight, inspections, evaluations, and discussions of the Building 832 Canyon OU remedy are ongoing. Facility operations and any related issues are managed in real-time by the entities listed above in collaboration with full-time staff from the Site 300 ER Field Operations, Hydrogeology, Engineering, Water Quality Sampling and Analysis Teams. As such, there was no single "interview" of O&M staff or interview results that can be referenced. The information contained within this inspection checksheet is a compilation of this and other DOE-LFO RPM routine inspections, evaluations, and discussions regarding the Building 832 Canyon OU remedy and treatment facilities.

3. Local Regulatory Authorities and Response Agencies (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Not applicable.

4. Federal and State Regulatory Authorities and Response Agencies (i.e., U.S. Environmental Protection Agency [EPA], California Department of Toxic Substances Control [DTSC], Regional Water Quality Control Board-Central Valley Region [RWQCB]). Fill in all that apply.

Remarks: Input from the U.S. EPA, DTSC, and RWQCB are provided in Attachment A2-1.

III. ON-SITE DOCUMENTS & RECORDS VERIFIED

1. O&M Documents

O&M manual:	Readily available and up-to-date
As-built drawings:	Readily available and up-to-date
Maintenance logs:	Readily available and up-to-date

Remarks: As-built drawings for the Building 832 Canyon OU treatment facilities are maintained in the LLNL Environmental Restoration Department files. The Building 832 Canyon OU treatment facilities consist of the Building 832-Source, Building 830-Source, and Building 830-Distal South. The Building 832 Canyon OU treatment facilities maintenance activities are recorded in a facility-specific logbook maintained by the facility operator. Inspections, operation, and maintenance of the Building 832 Canyon OU ground water extraction and treatment systems are performed under the lead of the treatment facility operator, with as-needed maintenance assistance from mechanical and electrical/electronics technicians and engineers. Treatment facility inspection, operation, and routine maintenance procedures are documented in the LLNL Site 300 Operations and Maintenance Manual. The ground water monitor well network for the Building 832 Canyon OU is routinely inspected during semi-annual sampling activities. Maintenance activities for the monitoring network included pump replacements, repairing damaged wiring, and general wellhead maintenance on an as-needed basis. LLNL maintains a database (known as "Well Track") that tracks both the history and current status of well maintenance, including wells currently in need of maintenance. Operation and maintenance activities associated with the Building 832 Canyon OU ground water monitor wells are recorded and maintained in the well logbooks maintained by the Sampling Technicians.

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2. Site-Specific Health & Safety Plan

Site-Specific Health & Safety Plan:	Readily available and up-to-date
Contingency plan/emergency response plan:	Readily available and up-to-date

Remarks: Site-specific health and safety information for Environmental Restoration activities is contained in the "Site Safety Plan for LLNL CERCLA Investigations at Site 300." Activity-specific hazards and controls are contained in the LLNL Environmental Restoration Integration Work Sheets. Activities conducted at LLNL Site 300 are also conducted in accordance with the LLNL Environment, Safety, and Health Plan.

The contingency plan, including contingency actions in the event of natural disasters or other emergencies, for the Building 832 Canyon OU remedial action is included in the "Compliance Monitoring Plan and Contingency Plan for the Environmental Restoration at LLNL Site 300."

Emergency responses are also contained in 1) Volume II, Part 22 of the LLNL Environment, Safety, and Health Plan, and 2) the Self-Help Plans.

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3. O&M and OSHA Training Records

O&M and OSHA Training Records	Readily available and up-to-date

Remarks: Operation and maintenance activities associated with the Building 832 Canyon OU ground water and soil vapor extraction and treatment systems are recorded and maintained in the facility-specific logbooks maintained by the facility operators. In addition, O&M activities are discussed in monthly Project Updates submitted to the regulatory RPMs, at regular RPM meetings, and in the semi-annual and annual Site-Wide Compliance Monitoring Reports.

OSHA HAZWOPER training for LLNS ER Department staff is up-to-date. Training Records for LLNS ER Department staff are maintained electronically in the LLNL Laboratory Training Records and Information (LTRAIN) System.

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4. Permits and Service Agreements

Air discharge permit:	Readily available and up-to-date
Effluent discharge permit:	Not applicable*
Waste Disposal:	Readily available and up-to-date
Other service agreements:	Readily available and up-to-date

Remarks:
Air discharge permit: The air permits to operate Building 832-Source and Building 830-Source soil vapor treatment systems issued by the San Joaquin Valley Air Pollution Control District (SJVAPCD) are maintained at the Building 830-Source and 832-Source treatment facilities, and in files at Building 543. The 830-Distal South facility does not treat soil vapor, therefore there is not air permit associated with this facility.

***Effluent discharge:** Effluent discharge limits are contained in the Substantive Requirements for Waste Discharge issued by the Regional Water Quality Control Board (RWQCB)-Central Valley Region and in the Site-Wide Record of Decision (ROD) for LLNL Site 300. The RWQCB Substantive Requirements and Site-Wide ROD are maintained in the administrative record at LLNL; the Site-Wide ROD is also available on-line at *www-erd.llnl.gov/library/index.html.*

Waste Disposal: Spent treatment media is stored at a permitted onsite storage facility (EPA ID No CA2890090002) by the LLNL Radioactive and Hazardous Waste Department prior to shipment offsite to a permitted disposal facility.

Other Service Agreements: The LLNL Maintenance and Utility Department (MUSD) performs annual compressor maintenance and semi-annual blower maintenance for the Building 830-Source and 832-Source treatment facilities.

Other permits: None.

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5. Gas Generation Records

Gas Generation Records:	Not applicable

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6. Settlement Monument Records

Settlement Monument Records: Not applicable

7. Ground water Monitoring Records

Ground water Monitoring Records: Readily available and up-to-date

Remarks: Ground water monitoring records for the Building 832 Canyon OU are maintained in the LLNL ER Department's Taurus Environmental Information Management System (TEIMS) database. The ground water compliance monitoring results are presented in the semi-annual and annual Site-Wide Compliance Monitoring Reports that are sent to the U.S. EPA, the RWQCB, and the California Department of Toxic Substances Control (DTSC), and are available on-line at *www-erd.llnl.gov/library/index.html.*

8. Leachate Extraction Records:

Leachate Extraction Records: Not applicable

9. Discharge Compliance Records

Air: Readily available and up-to-date
Water: Readily available and up-to-date

Remarks:
Air: Air discharge monitoring results for the Building 832-Source and Building 830-Source soil vapor treatment system are recorded weekly in the treatment facility logbooks. The SJVAPCD conducts annual inspections to ensure compliance with the air permit discharge requirements. The air permit compliance status is also reported in the RPM Project Updates.

Water (effluent): The Building 832 Canyon OU ground water extraction and treatment systems effluent discharge compliance records are maintained in the LLNL ER Department's TEIMS data base, and are presented in the semi-annual and annual Site-Wide Compliance Monitoring Reports that are sent to the U.S. EPA, the RWQCB, and DTSC, and are available on-line at *www-erd.llnl.gov/library/index.html.*

10. Daily Access/Security Logs

Daily Access/Security Logs: Readily available and up-to-date

Remarks: The entire perimeter of Site 300 is enclosed by a 4-ft-high, barbed-wire fence. In addition, the area in which the Building 832-Source and 830-Source treatment facilities are located are enclosed by a secondary 8-ft-high chain link security fence topped with barbed wire. Warning signs are placed around the perimeter of Site 300 on the barbed wire fence indicating that the site is U.S. government property, an explosives test facility, and that trespassing is forbidden by law. Site 300 is a restricted access facility with a single point of entry secured by a guarded gate manned 24-hours; only personnel with appropriate clearance and identification are granted entry. The Building 832 Canyon OU is entirely surrounded by Site 300 property and does not extend to the site boundary. The OU is accessible only to DOE/LLNL workers. Full-time LLNL workers are housed at Building 832E. Occasional workers in this area include high explosive (HE) and other supply delivery personnel; environmental restoration staff conducting monitoring, characterization, and remediation activities; LLNL Maintenance Department personnel, and janitorial service staff for Building 832 E.

IV. O&M COSTS

1. O&M Organization

Contractor for Federal Facility: The Environmental Restoration Department of Lawrence Livermore National Security, LLC; the M&O contractor for the U.S. DOE at LLNL.

2. O&M Cost Records

O&M Cost Records: Readily available and up-to-date
Funding mechanism in place

Remarks: The actual annual costs for the Building 832 Canyon OU during the review period (2010-2015) are presented in Table 1 of the Five-Year Review. LLNS Environmental Restoration Department provides monthly reports to the DOE-LFO RPM on Building 832 Canyon OU restoration planned and actual costs with explanations/justifications of any cost variances.

3. Unanticipated or Unusually High O&M Costs During the Review Period

Describe costs and reasons: No unanticipated or unusually high O&M costs were incurred during the review period. As described in Table 1 of the Building 832 Canyon Five-Year Review, costs for the Building 832 Canyon OU were on or slightly over budget for the review period due to higher than expected well installation and facility maintenance costs.

V. ACCESS AND INSTITUTIONAL CONTROLS — Applicable

A. Fencing

1. Fencing Damaged

Fencing damaged location:	Fencing in good condition
Gate secured:	Yes

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing to prevent unauthorized access. See Daily Access/Security Logs above.

B. Other Access Restrictions

2. Signs and Other Security Measures

Signs and Other Security Measures In Place — Yes

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing and has a full-time security force to prevent unauthorized access to the site. See Daily Access/Security Logs above. In addition, personnel accessing the Building 832 and 830 areas are required to have Q-clearances to pass through an additional security checkpoint and must sign in and out at Building 832E. At Building 830, signs are in place prohibiting full-time building occupancy without contacting LLNL Environmental Health and Safety for a building evaluation.

C. Institutional Controls (ICs)

1. Implementation and Enforcement

Site conditions imply ICs not properly implemented:	No
Site conditions imply ICs not being fully enforced:	No

Type of monitoring (e.g., self-reporting, drive by):	Physical inspection
Frequency:	Physical ICs are inspected annually. ICs are reviewed annually for adequacy and protectiveness.

Responsible party/agency:	U.S DOE
Contact Name:	Claire Holtzapple
Title:	DOE-LFO Site 300 Environmental Restoration RPM
Phone No.:	925/422-0670

IC Inspection Date: 10/22/15

Reporting is up-to-date:	Yes
Reports are verified by the lead agency:	Yes
Specific requirements in deed or decision document have been met:	Yes
Violations have been reported:	Not Applicable
Other problems or suggestions:	None

Remarks: Refer to Section 4.5 (Institutional Controls) of the Building 832 Canyon OU Five-Year Review for further details on institutional controls in the Building 832 Canyon OU.

2. Adequacy

ICs are adequate: Yes

Remarks: Refer to Section 4.5 (Institutional Controls) of the Building 832 Canyon Five-Year Review for further details on institutional controls in the Building 832 Canyon OU.

D. General

1. Vandalism/trespassing

Vandalism/trespassing: No vandalism evident

Remarks: LLNL Site 300 is a restricted access facility that is surrounded by fencing and has a full-time security force to prevent unauthorized access to the site.

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2. Land Use Changes Onsite

Land Use Changes Onsite: None

Remarks: There have been no changes in land, building, or ground water use in the Building 832 Canyon OU since the Site-Wide Record of Decision and none are anticipated. The Building 830 Complex is a single building containing three test cells where experiments involving explosives chemicals and weapon components were conducted. When experiments ceased in 1985, the Building 830 Complex was used mainly for electrical equipment storage. The complex was returned to institutional control several years ago and is no longer in use. The Building 832 Complex consists of eight buildings (Buildings 832 A-F and Buildings 831 and 838) where experiments were conducted. Since testing ceased in 1985, the Building 832 Complex has been used for storage of high explosive (HE) compounds, records storage and office space. HE is stored at Buildings 832B and D and in HE magazines 832-1 and 832-2. Building 832F was decontaminated and demolished in 2005.

At Site 300, ground water is used for a variety of needs including cooling towers, HE processing, and fire suppression. Bottled water is the primary source of onsite drinking water, however potable ground water from onsite water-supply Well 20, located in the High Explosives Process Area OU, is available as necessary for potable supply. Well 18, also located in the southeast part of the High Explosives Process Area OU is used as a backup water-supply well. Site 300 is currently scheduled to transition to Hetch Hetchy water as its primary onsite water supply. See the Section 3.2 (Land and Resource Use) of this Five-Year Review for additional details.

3. Land Use Changes Offsite

Land Use Changes Offsite: Not applicable

Remarks: Land use adjacent to the site boundary closest to the Building 832 Canyon OU consists of private rangeland. There is no known planned modification or proposed development of the offsite rangeland closest to (south of) the OU. The nearest major population center (Tracy, California) is 8.5 miles to the northeast. While there is offsite development proposed east and north of Site 300 (the Tracy Hills Development), this development does not border the Building 832 Canyon OU. See Section (3.2) (Land and Resource Use) of this Five-Year Review for additional details.

VI. GENERAL SITE CONDITIONS

A. Roads

1. Roads Damaged

Roads damaged location: Roads adequate

Remarks: The Building 832 Canyon OU treatment facilities and wells are accessed by roads maintained by the LLNL Site 300 management.

B. Other Site Conditions

Remarks: Buildings and other facilities in the Building 832 Canyon OU are maintained in good condition by the LLNL Site 300 management. Any concerns are outlined below.

There are two soil-retaining structures located immediately behind the 832-SRC treatment facility: a wall made from cemented-together bags of concrete and a short wooden wall with vertical support posts. Both structures periodically allow sediment to overtop the structures and one structure appears to be leaning. Photos of these structures are included in Appendix A. Although this does not pose a safety risk, DOE/LLNL are currently evaluating options to shore up or replace these structures.

VII. LANDFILL COVERS — Not applicable

VIII. VERTICAL BARRIER WALLS — Not applicable

IX. GROUND WATER/SURFACE WATER REMEDIES — Applicable

A. Groundwater Extraction Wells, Pumps, and Pipelines — Applicable

1. Pumps, Wellhead Plumbing, and Electrical

Building 832-Source:

Good condition: Yes

All required wells properly operating: Yes

Remarks: The extraction wells are inspected weekly, are in good condition, and are operating properly. In addition, the Building 832-Source facility, including extraction wellfield equipment, is scheduled to undergo assessment and implementation of any necessary upgrades to ensure long-term operational efficiency in 2016. As part of this work, two new wells are scheduled to be connected to the 832-Source treatment facility: dual-extraction well W-832-3019 and ground water extraction-well W-832-3020.

Building 830-Source:

Good condition: Yes
All required wells properly operating: Yes*

Remarks: The extraction wells are inspected weekly, are in good condition, and are operating properly. The Building 830-Source facility, including extraction wellfield equipment, was upgraded in 2015 to ensure long-term operational efficiency.

* At the time of this inspection, extraction wells W-830-2214 ($Tnsc_{1a}$) and W-830-2215 (Upper $Tnbs_1$) were not operational due to an ongoing evaluation of a black substance detected on the pump in nearby monitor well W-830-18 (Upper $Tnbs_1$). Bailed water samples were collected from well W-830-18 and analyzed for halogenated VOCs, semivolatile organic compounds, polychlorinated biphenyls, drinking water metals, general minerals, and oil and grease. The analytical results indicate that the water in the well has not been affected by the black substance observed on the pump. Pumping resumed in W-830-2214 on November 2, 2015 as it was determined that because there is no hydraulic communication between the different HSUs in which the wells are screened, the substance in monitor well W-830-18 would not be affected by pumping at W-830-2214. Extraction well W-830-2215 remains offline pending the scheduled redevelopment of monitor well W-830-18 in order to avoid any possible formation damage that could occur by pumping the nearby Upper $Tnbs_1$ extraction well (W-830-2215)..

Building 830-Distal:

Good condition: Yes
All required wells properly operating: Yes*

Remarks: The ground water extraction wells are inspected weekly, are in good condition, and are operating properly.

* At the time of this inspection, the Building 830-Distal extraction wells (W-830-51, W-830-52, W-830-53, and W-832-2216) were not operational as the facility was shut down due to the Central GSA treatment facility being offline for misting tower repairs. When operational, ground water is extracted from W-830-51, W-830-52, and W-830-53 using artesian pressure and from W-830-2216 by submersible pump. Artesian pressure, supplemented by ground water extraction pump pressure from

W-830-2216, is used to gravity flow extracted ground water to the Central GSA treatment facility. The pump in W-830-2216 is in reasonably good condition; artesian wells W-830-51, W-830-52, and W-830-53 do not contain pumps.

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2. Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances

Building 832-Source:
Good condition: Yes

Remarks: All extraction system pipelines and valves are inspected weekly and are in good condition. The Building 832-Source facility, including extraction system pipelines and valves, is scheduled to undergo assessment and implementation of any necessary upgrades to ensure long-term operational efficiency in 2016.

Building 830-Source:
Good condition: Yes

Remarks: All extraction system pipelines and valves are inspected weekly and are in good condition. The Building 830-Source extraction wellfield pipelines were replaced in 2015 as part of the facility upgrade to ensure long-term operational efficiency.

Building 830-Distal South:
Good condition: Yes

Remarks: The pipelines from artesian extraction wells W-830-51, W-830-52, and W-830-53 extending from the wells to the 830-Distal South treatment facility and the pipelines extending from the treatment facility to the drainage culvert are not well supported. Corrective measures will be evaluated. It should be noted that, due to topographical constraints, these pipelines are located in the Building 832 Canyon surface water drainage. Significant issues may need to be resolved with the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to implement improvements to these pipelines given their location. The Building 830-Distal South facility, including extraction system pipelines and valves, is scheduled to undergo assessment and implementation of any necessary upgrades to ensure long-term operational efficiency in 2017.

3. Spare Parts and Equipment

Readily available: Yes
Good condition: Yes

Remarks: Spare parts for routine equipment maintenance are readily available and in good condition.

B. Surface Water Collection Structures, Pumps, and Pipelines Not applicable

C. Treatment System Applicable

1. Treatment Train (check components that apply)

Metals removal:	Not applicable
Air Stripping:	Not applicable
Oil/Water separation:	Not applicable
Bioremediation:	Not applicable
Carbon adsorbers:	Yes*
Ion exchange resin:	Yes
Filters: Cuno particulate/Shelco bag filters:	Yes**
Additive (e.g., chelation agent, flocculent):	No
Good condition:	Yes
Sampling ports properly marked and functional:	Yes
Sampling/maintenance log displayed and up-to-date:	Yes
Equipment properly identified:	Yes
Quantity of ground water treated annually:	
832-Source:	650,088 gallons[a]
830-Source	1,700,068 gallons[a]
830-Distal South:	982,163 gallons[a]
Quantity of surface water treated annually:	Not applicable
Quantity of soil vapor treated annually:	
832-Source:	1,430 cubic feet[a]
830-Source:	8,013 cubic feet[a]

a- Quantities based on an average of the annual totals from July 2010-June 2015.
***- See remarks below.**

Remarks: Refer to Section 4.4 (System Operations/Operations and Maintenance of the Building 832 Canyon OU Five-Year Review) for further details about the Building 832 Canyon OU ground water extraction and treatment systems operations and maintenance. Photographs of the Building 832-Source and Building 830-Source ground water and soil vapor extraction and treatment systems, and the Building 830-Distal South ground water extraction and treatment system are included in Appendix A.

* The granular activated carbon (carbon adsorbers) for the Building 832-Source and 830-Source treatment facilities are part of these facilities' treatment trains. At the Building 830-Distal South treatment facility, perchlorate is removed from extracted ground water using ion-exchange resin at the facility. VOC-bearing

ground water is then piped to the Central GSA treatment facility for removal of VOCs by air stripping.

** Sediment is removed from extracted ground water by Cuno filters for the Building 830-Source and –Distal South facilities, and by 2 Shelco bag filters at the Building 832-Source facilities.

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2. Electrical Enclosures and Panels (properly rated and functional)

Good condition: Yes

Remarks: The electrical control panel and enclosure are in good condition, properly rated, and functional.

3. Tanks, Vaults, Storage Vessels

Good condition: Yes
Proper secondary containment Not applicable

Remarks: A 200-gallon tank is located adjacent to the Building 832-Source treatment media containers and is used to store treated ground water prior to misting of the facility effluent. A 300-gallon tank is located adjacent to the Building 830-Source treatment media containers and is used to store treated ground water prior to misting of the facility effluent. Secondary containment is not necessary for the effluent storage tank as they are used to store treated ground water. There is also a small condensate tank for the 830-Source liquid ring pump that is drained twice weekly. The treatment media and facility effluent tanks are in good condition, properly rated, and functional. Photographs of the treatment media vessels and effluent storage tanks are included in Appendix A.

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4. Discharge Structure and Appurtenances

Ground Water Treatment System Effluent Discharge Structures:

Good condition (832-Source): Yes
Good condition (830-Source): No
Good condition (830-Distal South at the Central GSA) Yes*

Remarks: The treated ground water effluent from Building 832 Canyon OU ground water treatment systems is currently discharged via misting towers as follows:

Treatment System	Discharge Method
832-Source	Misting tower (1)
830-Source	Misting towers (2)
830-Distal South	Misting towers (at the Central GSA) (4)

Photographs of ground water treatment facility effluent misting tower structures are included in Appendix A.

The misting tower for treated effluent from the Building 832-Source treatment facility is in good condition and operating as intended. DOE/LLNL plan to convert the effluent discharge method for the Buildings 832-Source ground water treatment system from misting to injection. The drilling and hookup of a new injection well for the 832-Source facility is currently scheduled for fiscal year 2017.

A section of the pipeline from the Building 830-Source treatment facility to the south effluent misting towers is not in good condition (i.e. not well supported). Currently at times, there is insufficient pressure to optimally discharge form the 830-Source north misting tower. As a temporary solution, LLNL engineers are evaluating the pump configuration for transfer from the 830-Source ground water treatment system batch tank to the misting towers to ensure consistently optimal discharge of ground water at the north misting tower. Two new wells were drilled in 2015 for the injection of treated effluent from 830-Source facility: W-830-3101 and W-830-3102. Injection testing of these two wells, and a third existing well, W-833-30, has been completed and the preliminary design of pipelines from the 830-Source ground water treatment system to the injection wells is currently underway. Once the pipelines to the injection wells are constructed, DOE/LLNL currently plan to discontinue use of the misting towers for discharge of treated effluent from the 830-Source ground water treatment system.

After treatment to remove perchlorate, ground water from the 830-Distal South system is treated for VOCs at Central GSA ground water treatment system using an air stripper and vapor-phase granular activated carbon. The resulting treated ground water is discharged via misting towers at Central GSA area and the treated vapor is discharged via vapor stack. The Central GSA misting towers used to discharge treated ground water from the Central GSA and 830-Distal South treatment systems are generally in good shape. However, LLNL engineers are currently working with the misting tower motor vendor to resolve issues with early motor burnout. DOE/LLNL plan to convert the effluent discharge method for the Buildings 830-Distal ground water treatment system from misting to injection. The drilling and hookup of two new injection wells for the 830-Distal facility is currently scheduled for fiscal year 2018.

Soil Vapor Treatment System Effluent Discharge Structures:

Good condition: Yes

Remarks: The treated air effluent from the Building 832-Source soil vapor treatment system is currently discharged via 14-foot high, 6-inch diameter vapor stack. The treated air effluent from the Building 830-Source soil vapor treatment system is currently discharged via 7 ft 7 inch-foot high, 4-inch diameter vapor stack. Photographs of Building 832-Source and 830-Source soil vapor treatment facility effluent discharge stacks are included in Appendix A. Soil vapor is not extracted or treated by the 830-Distal South facility. However, VOCs in ground water from the 830-Distal South facility are treated by air stripping at the Central GSA treatment facility. The treated air effluent is discharged at the Central GSA facility via a 6-foot high, 6-inch diameter stack.

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5. Treatment Buildings Not applicable

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6. Monitoring Wells:

Properly secured/locked: Yes
Functioning: Yes
Routinely sampled: Yes
Good condition: Yes
All required wells located: Yes
Needs maintenance: No

Remarks: The current Building 832 Canyon OU wellfield consists of: 15 ground water extraction wells, 4 dual-extraction wells (soil vapor and ground water), and 75 ground water monitor wells. During first semester 2015, ground water monitoring was conducted in accordance with the Compliance Monitoring Plan monitoring requirements with the following exceptions:

- A total of 12 analyses in four different wells (W-830-13, W-830-17, W-830-29 and W-832-09) were not performed because of an inoperable pump. The pumps in wells W-830-13, W-830-29 and W-832-09 have been repaired or replaced. Efforts to remove and replace the pump in W-830-17 have not been successful as the pump is stuck in the well. DOE/LLNL are evaluating options to remove and replace the pump.
- A total of 47 analyses in 16 different wells and two different springs were not performed because the wells or springs were dry or contained insufficient water for sample collection.
- A total of 11 analyses in three different artesian wells were not performed because the connected facilities were not operating and these wells were not equipped with ground water pumps. Since then, wellheads at W-830-52 and W-830-53 were

modified to accommodate grab-sampling and recommendations in the Building 832 Canyon OU Second Five-Year Review include additional modifications, including ground water pumps for sampling.

- A total of six analyses in two different wells and one spring were not performed due to restricted access of unsafe conditions at the sampling locations.
- A total of 23 analyses in six different wells were not performed because the associated treatment facilities were turned off for freeze protection.
- A total of 42 analyses from ten different wells were not performed because the facility was undergoing engineering upgrades and the wells had not had their groundwater pumps re-installed yet. These upgrades have since been completed, but W-830-18 is now offline for the reasons discussed previously in Section IX:A:1 of this inspection checklist.

Although under artesian pressure, extraction wells W-830-52 and W-830-53 do not always flow at the surface as does W-830-51. Recent improvements to well completion have added the ability to check water levels at these locations when not flowing at the surface, and allowed for temporary pencil-bailer grab samples. However, these pencil bailer samples may not be fully representative of groundwater in these wells. As a longer-term solution, DOE/LLNL are evaluating options to install sampling and/or extraction pumps at these artesian locations.

As mentioned in Section IX.A.1, extraction well W-830-2215 is currently not being operated and performance monitor well W-830-18 is not being sampled pending the scheduled redevelopment of W-830-18 due to a black substance that was observed on the pump in this well.

D. Monitoring Data

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1. Monitoring Data

Is routinely submitted on time:	Yes
Is of acceptable quality:	Yes

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2. Monitoring data suggests:

Ground water plume is effectively contained:	Yes
Contaminant concentrations are declining:	Yes

Remarks: Refer to Section 6.4 (Building 832 Canyon OU Data Review and Evaluation) of the Building 832 Canyon OU Five-Year Review for further details on the progress of the remedial action at the Building 832 Canyon OU.

E. Monitored Natural Attenuation (MNA)

1. Monitoring Wells (natural attenuation remedy)

Properly secured/locked:	Yes
Functioning:	Yes
Routinely sampled:	Yes*
Good condition:	Yes
All required wells located:	Yes
Needs maintenance:	No

Remarks: MNA is the remedy for nitrate in Building 832 Canyon OU ground water. Samples are collected annually to monitor the effectiveness of natural attenuation in reducing nitrate concentrations to meet cleanup standards. Sample results and MNA remediation progress is reported in the Compliance Monitoring Reports and Section 6.4.1.3 (Nitrate Concentrations, Distribution, and Remediation) and Section 6.4.2.1. (Ground Water Remediation Progress) of the five-year review for further details on the progress of MNA in the Building 832 Canyon OU.

*In 2014 and 2015, nitrate was not sampled in extraction wells W-854-51, W-854-52, and W-854-03 due to the shut down of the 832-Distal South and/or Central GSA ground water treatment systems and these wells were not equipped with ground water pumps. Since then, wellheads at W-830-52 and W-830-53 were modified to accommodate grab sampling. Recent improvement to wellhead completions at W-854-52 and W-854-53 will allow for future sampling at these locations using pencil bailer grab sampling when the treatment facilities are not operating. Additionally, DOE/LLNL are evaluating options to install sampling and/or extraction pumps in these artesian wells.

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy:

Soil vapor is extracted from two wells at Building 832 and an additional two wells at Building 830. The extracted soil vapor is treated using granular activated carbon. The inspections of the soil vapor systems at Buildings 832 and 830 is included in the checklist for the ground water extraction and treatment system in Section IX above.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.). Describe issues and observations relating to whether the remedy is effective and functioning as designed.

The remedy selected for the Building 832 Canyon OU is intended to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, reduce contaminant concentrations in ground water to cleanup standards, and mitigate VOC inhalation risk to onsite workers. Refer to Section 4.1 of the Five-Year Review for further details on the remedial action objectives.

The remedy at the Building 832 Canyon OU is effective, functioning as designed, and is protective of human health and the environment for the site's industrial land use. Refer to Section 7 (Technical Assessment) and Section 10 (Protectiveness Statement) of the Building 832 Canyon OU Five-Year Review for further details regarding the remedy effectiveness, functionality, and protectiveness.

No deficiencies in or issues with the remedy for the Building 832 Canyon OU were identified during this evaluation. Refer to Section 8 (Issues) and Section 9 (Recommendations and Follow-up Actions) of the Building 832 Canyon OU Five-Year Review for further details regarding deficiency conclusions and recommendations for follow-up actions developed as part of the review process.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

There were no issues or observations related to the implementation and scope of operation and maintenance procedures for the Building 832 Canyon OU ground water extraction and treatment facilities.

However, during the inspection, the inspection team recommended opportunities for improvement that would increase the operational efficiency and/or reduce maintenance for ground water and soil vapor treatment systems in Building 832 Canyon OU (See Section D).

C. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

There were no issues or observations that suggest that the protectiveness of the remedy at the Building 832 Canyon OU may be compromised in the future. DOE's long-term plans include periodic assessments and upgrades to the Building 832 Canyon OU ground water extraction and treatment systems to ensure the effectiveness and protectiveness of the remedy.

D. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

The inspection team recommended opportunities for improvement that would increase the operational efficiency and reduce maintenance for ground water and soil vapor treatment systems in Building 832 Canyon OU. These recommendations are outlined below by treatment facility area.

832-Source

The Building 832-Source facility operator recommended moving the above-ground piping from the southern valley extraction wells (W-832-25, W-832-10, W-832-01, and W-832-3020) from the fence line down the hill up to a path along side the road to make facilitate access for regular checks and maintenance. This would shorten any down-time related to pipeline upgrades in the future and allow for more thorough leak checking.

830-Source

The Building 830-Source facility operator recommended installing a higher-powered liquid ring vacuum pump for the soil vapor treatment system to decrease maintenance costs at this location, and to change the layout of the condensation purge system. This would allow the soil vapor treatment system to operate more consistently, ultimately removing more soil vapor volume and VOC mass from the subsurface.

The facility operator also recommended that the effluent line between the 830-Source ground water treatment system and misting towers be secured better to facilitate access for regular checks and maintenance. This would shorten any down-time related to pipeline upgrades in the future and allow for more thorough leak checking.

830-Distal South

The Building 830-Distal South facility operator recommended improvements in the placement of the above-ground piping from artesian extraction wells W-830-51 and W 830-52 to the facility to improve access for regular checks and maintenance. The same recommendation was made for the section of discharge line extending from the 830-Distal South ground water treatment system to the culvert where the polyvinyl chloride (PVC) piping is routed under Route 2 towards Building 870. This will shorten any down-time related to pipeline upgrades in the future and allow for more thorough leak checking.

Refer to Section 9 (Recommendations and Follow-up Actions) of the Five-Year Review for further details regarding recommendations for optimization of the Building 832 Canyon OU extraction and treatment systems developed as part of the review process.

Attachment A2-1

Interview Records

INTERVIEW RECORD LLNL Site 300 Building 832 Canyon Operable Unit Five Year Review				
Site Name: Operable Unit 7, Building 832 Canyon			**EPA ID No.: CA2890090002**	
Subject: 2nd Five-Year Review			**Time:**	**Date:**
Type: Telephone Visit x Other **Location of Visit:** Not applicable			Incoming x Outgoing	
Contact Made By:				
Name: Claire Holtzapple	**Title:** Site 300 Remedial Project Manager		**Organization:** DOE/NNSA-Livermore Field Office	
Individual Contacted:				
Name: Jacinto Soto	**Title:** Remedial Project Manager		**Organization:** Department of Toxic Substances Control	
Telephone No: 510/540-3842 **E-Mail Address:** JSoto@dtsc.ca.gov		**Street Address:** 700 Heinz Avenue, Suite 200 **City, State, Zip:** Berkeley, CA 94710-2721		

Please provide responses to the following questions. For those questions you do not feel you have an answer for, it is acceptable to respond "I don't have an opinion" or "I don't wish to comment."

General Questions

1. **How long have you worked or been associated with the Building 832 Canyon Operable Unit (OU)? What is your current role as it relates to the Building 832 Canyon OU?**

DTSC Input: I have been working on the project for 10 years as the Remedial Project Manager for the Department of Toxics Substances Control, Berkeley Office.

2. **Do you have access to information on the remedies in place at the Building 832 Canyon OU; and do you access that information (e.g., at the LLNL Information Repositories, Administrative Record File, or at Remedial Project Manager's Meeting [RPM] meetings)?**

DTSC Input: Yes, I access the information through RPM meetings, submissions by LLNL, through DTSC files and Envirostor.

3. **To the best of your knowledge, have there been any violations of the land use controls at the Building 832 Canyon OU), that required a response from your office? If so, please provide details of the events and results of the responses.**

DTSC Input: No.

4. **Have there been routine communication or activities (site visits, inspections, reporting activities, etc.) conducted by your office regarding the site? If so please give purpose and results.**

DTSC Input: Yes; DTSC reviews semi-annual compliance monitoring and updated reports

5. **What is your single greatest concern regarding the ongoing performance of the Building 832 Canyon OU?**

DTSC Input: Length of time that is taking to clean up the onsite groundwater and subsurface soil.

Remedy Protectiveness Questions

6. **Are you aware of any community concerns regarding the protectiveness of the remedies at the Building 832 Canyon OU? If so, please provide details.**

DTSC Input: No; however, Tri-Valley CAREs (Communities Against a Radioactive Environment) often complains about DOE not communicating enough to the surrounding community about all the investigation and cleanup activities going on site.

7. **Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at the Building 832 Canyon OU? If so, please provide details.**

DTSC Input: No

8. **Do you have any comments on the remedies for the Building 832 Canyon OU related to future effectiveness or optimization of operations?**

DTSC Input: Because VOC concentrations above residential levels will most likely remain in subsurface soil at the conclusion of the cleanup process, a land use covenant/control needs to be in place to make sure that the site is used for commercial/industrial purpose only.

Operation and Maintenance Questions

9. **Have there been unexpected operation and maintenance (O&M) difficulties or costs for implementation and maintenance of the land use controls, maintaining and sampling the monitoring well network, and the implementation of the vapor intrusion evaluation and monitoring program for the Building 832 Canyon OU?**

DTSC Input: No.

10. Do the monitoring data show any trends that contaminant levels are increasing or decreasing? Have any new or emerging contaminants of concern (COC) been identified? If so, have they impacted the effectiveness of the remedies?

DTSC Input: Monitoring data to date show that contaminant levels in groundwater and soil vapor have declined since remediation started in 1999. No new contaminants of concern have been identified.

11. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedy implemented at the Building 832 Canyon OU?

DTSC Input: Additional wells needed to be drilled and installed to increase hydraulic capture and better delineate the VOC plume due to declining water levels.

INTERVIEW RECORD LLNL Site 300 Building 832 Canyon Operable Unit Five Year Review				
Site Name: Operable Unit 7, Building 832 Canyon			**EPA ID No.: CA2890090002**	
Subject: 2nd Five-Year Review			**Time:** 0930	**Date: 12/15/15**
Type: Telephone x Visit Other **Location of Visit:** B832, B830 and B830Distal			Incoming x Outgoing	
Contact Made By:				
Name: Claire Holtzapple	**Title:** Site 300 Remedial Project Manager		**Organization:** DOE/NNSA-Livermore Field Office	
Individual Contacted:				
Name: Andy Bain	**Title:** Remedial Project Manager		**Organization:** U.S. EPA	
Telephone No: 415/972-3167 **E-Mail Address:** Bain.Andrew@epa.gov		**Street Address:** SFD-8-2, 75 Hawthorne Street **City, State, Zip:** San Francisco, CA 94105-6114		

Please provide responses to the following questions. For those questions you do not feel you have an answer for, it is acceptable to respond "I don't have an opinion" or "I don't wish to comment."

General Questions

1. **How long have you worked or been associated with the Building 832 Canyon Operable Unit (OU)? What is your current role as it relates to the Building 832 Canyon OU?**

EPA Input: 3.5 years. EPA RPM – Federal Facility NPL oversight.

2. **Do you have access to information on the remedies in place at the Building 832 Canyon OU; and do you access that information (e.g., at the LLNL Information Repositories, Administrative Record File, or at Remedial Project Manager's Meeting [RPM] meetings)?**

EPA Input: Yes. However, the LLNL Administrative Record File (online) is incomplete. We often rely on DTSC to post information to their EnviroStor web site.

DOE/LLNL Clarification Note*:* The onsite LLNL Site 300 Library is not the Administrative Record File for the Site 300 Environmental Restoration Program, but rather is intended as a repository of major documents associated with the cleanup program to facilitate public access.

3. **To the best of your knowledge, have there been any violations of the land use controls at the Building 832 Canyon OU), that required a response from your office? If so, please provide details of the events and results of the responses.**

EPA Input: No.

4. **Have there been routine communication or activities (site visits, inspections, reporting activities, etc.) conducted by your office regarding the site? If so please give purpose and results.**

EPA Input: Yes. Although this was RPM Bain's first visit, RPM Setian and Consultant Brasaemle participated in previous inspections, including the RA completion.

5. **What is your single greatest concern regarding the ongoing performance of the Building 832 Canyon OU?**

EPA Input: Potential VI pathway in occupied structures.

Remedy Protectiveness Questions

6. **Are you aware of any community concerns regarding the protectiveness of the remedies at the Building 832 Canyon OU? If so, please provide details.**

EPA Input: No. General concern is related to offsite plume migration, which doesn't apply to the B832 Canyon.

7. **Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at the Building 832 Canyon OU? If so, please provide details.**

EPA Input: No?

8. **Do you have any comments on the remedies for the Building 832 Canyon OU related to future effectiveness or optimization of operations?**

EPA Input: EPA supports the optimization ideas discussed, including reinjection and weatherizing the pipelines. EPA supports the Treatability Studies involving T2 EISB and Perchlorate ISCO as possible

Operation and Maintenance Questions

9. **Have there been unexpected operation and maintenance (O&M) difficulties or costs for implementation and maintenance of the land use controls, maintaining and sampling the monitoring well network, and the implementation of the vapor intrusion evaluation and monitoring program for the Building 832 Canyon OU?**

EPA Input: Conversion of misting towers to reinjection, due to biological concerns. Weatherizing copper pipe at B832.

10. Do the monitoring data show any trends that contaminant levels are increasing or decreasing? Have any new or emerging contaminants of concern (COC) been identified? If so, have they impacted the effectiveness of the remedies?

EPA Input: Decreasing. Perchlorate in the B830 TF.

<u>**DOE/LLNL Clarification Note**</u>***:*** Although EPA is correct that perchlorate is present in ground water at the Building 830-Source treatment facility, it was identified as a contaminant of concern in the Site-Wide Record of Decision, and remedy was selected and implemented to reduce perchlorate concentrations in ground water to meet cleanup standards. Therefore, it would not be considered as a new or emerging contaminant, and remediation measures are in place to address perchlorate in ground water in the Building 832 Canyon OU.

11. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedy implemented at the Building 832 Canyon OU?

EPA Input: Drought. To be seen, how the wet year impacts the systems.

INTERVIEW RECORD

LLNL Site 300 Building 832 Canyon Operable Unit Five Year Review

Site Name: Operable Unit 7, Building 832 Canyon			**EPA ID No.: CA2890090002**	
Subject: 2nd Five-Year Review			**Time:** 09:30AM	**Date:** 12/15/2015
Type: Telephone x Visit Other **Location of Visit:** Bldg. 832-Source, Bldg. 830-Source, and Building 830-Distal			Incoming x Outgoing	
Contact Made By:				
Name: Claire Holtzapple	**Title:** Site 300 Remedial Project Manager		**Organization:** DOE/NNSA-Livermore Field Office	
Individual Contacted:				
Name: Aimee Phiri	**Title:** Remedial Project Manager		**Organization:** RWQCB-Central Valley Region	
Telephone No: 916/464-4746 **E-Mail Address:** aimee.phiri@waterboards.ca.gov		**Street Address:** 11020 Sun Center Dr. #200 **City, State, Zip:** Rancho Cordova, CA 95670-6114		

Please provide responses to the following questions. For those questions you do not feel you have an answer for, it is acceptable to respond "I don't have an opinion" or "I don't wish to comment."

General Questions

1. **How long have you worked or been associated with the Building 832 Canyon Operable Unit (OU)? What is your current role as it relates to the Building 832 Canyon OU?**

RWQCB Input: About 3.5 years. Remedial Project Manager with the Central Valley Regional Water Quality Control Board (CVRWQCB).

2. **Do you have access to information on the remedies in place at the Building 832 Canyon OU; and do you access that information (e.g., at the LLNL Information Repositories, Administrative Record File, or at Remedial Project Manager's Meeting [RPM] meetings)?**

RWQCB Input: Yes.

3. **To the best of your knowledge, have there been any violations of the land use controls at the Building 832 Canyon OU), that required a response from your office? If so, please provide details of the events and results of the responses.**

RWQCB Input: No.

4. **Have there been routine communication or activities (site visits, inspections, reporting activities, etc.) conducted by your office regarding the site? If so please give purpose and results.**

RWQCB Input: Yes. CVRWQCB staff have visited the site during scheduled semi-annual site inspections conducted for the Site 300 facilities. No issues requiring immediate action were identified.

5. **What is your single greatest concern regarding the ongoing performance of the Building 832 Canyon OU?**

RWQCB Input: The effects (if any), of the prolonged drought followed by an onset of prolonged wet weather.

Remedy Protectiveness Questions

6. **Are you aware of any community concerns regarding the protectiveness of the remedies at the Building 832 Canyon OU? If so, please provide details.**

RWQCB Input: No.

7. **Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at the Building 832 Canyon OU? If so, please provide details.**

RWQCB Input: Based on this site visit, no.

8. **Do you have any comments on the remedies for the Building 832 Canyon OU related to future effectiveness or optimization of operations?**

RWQCB Input: The CVRWQCB concurs with the facility upgrades planned to improve operational effectiveness and the expanded extraction wellfields at Building 830-Source and the Building 832-Source to increase hydraulic capture.

Operation and Maintenance Questions

9. **Have there been unexpected operation and maintenance (O&M) difficulties or costs for implementation and maintenance of the land use controls, maintaining and sampling the monitoring well network, and the implementation of the**

vapor intrusion evaluation and monitoring program for the Building 832 Canyon OU?

RWQCB Input: Treatment systems shut down for extended time periods due to needed upgrades, budget issues, pump repairs, and freeze protection. Based on discussions held during the site visit, vapor intrusion evaluation and monitoring are not conducted at the Building 832 Canyon OU because there are no occupied structures.

DOE/LLNL Clarification Note*:* Vapor intrusion (re-)evaluation is conducted annually for buildings in the Building 832 Canyon OU wherever an unacceptable risk ($>10^{-6}$ cancer risk or Hazard Index>1) was identified in the baseline risk assessment, regardless of whether the building is occupied. The results of the annual risk re-evaluation are reported in the Annual Compliance Monitoring Reports. For example, an unacceptable risk was identified associated with the onsite worker exposure to volatile organic compounds (VOCs) volatilizing from subsurface soil into indoor air inside Building 830 and outdoor air in the vicinity of Building 830 and Building 832A. As discussed in Section 6.4.3 of the Five-Year Review, a baseline excess cancer risk was calculated for onsite workers of 1×10^{-5} for the inhalation of VOCs that volatilize from the subsurface soil into outdoor air in the vicinity of Building 830 and 3×10^{-6} for the inhalation of VOCs that volatilize from the subsurface soil into Building 832F indoor air. The risk evaluations performed for the 2003 and 2004 Annual Compliance Monitoring Reports (Dibley et al., 2004 and 2005) indicated there were no longer onsite worker risks from the inhalation of VOCs volatilizing from the subsurface into outdoor air at Building 830 or into Building 832F indoor air. The annual risk re-evaluation conducted in 2014 indicated that the risk to onsite workers inside Building 830 remains above 10^{-6}, although this building is not currently occupied. Section 4.5.1.3 of the Five-Year Review discusses land use/institutional controls in place to prevent onsite site worker inhalation exposure to VOCs inside Building 830 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.

10. Do the monitoring data show any trends that contaminant levels are increasing or decreasing? Have any new or emerging contaminants of concern (COC) been identified? If so, have they impacted the effectiveness of the remedies?

RWQCB Input: Generally, monitoring data indicates that COC concentrations are decreasing or are stable. Perchlorate has been identified in groundwater at the Building 830-Source and Building 832-Source. It does not appear that perchlorate has impacted the effectiveness of the remedies at the site in the short-term; long-term effects are yet to be seen depending on how concentrations and mobility of perchlorate in the subsurface will respond to El Niño conditions.

DOE/LLNL Clarification Note*:* Although the RWQCB is correct that perchlorate is present in ground water at the Building 830-Source and Building 832-Source areas, it was identified as a contaminant of concern in the Site-Wide Record of Decision, and remedy was selected and implemented to reduce perchlorate concentrations in ground water to meet cleanup standards. Therefore, it would not be considered as a new or emerging contaminant, and remediation measures are in place to address perchlorate in ground water in the Building 832 Canyon OU.

11. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedy implemented at the Building 832 Canyon OU?

RWQCB Input: Declining water levels and low yields due to drought conditions limit the volume of groundwater that can be extracted and treated, thereby, reducing and slowing down contaminant mass removal.

Appendix B

Responses to Regulatory Comments

Appendix B

Appendix C

830-Source Ground Water Treatment System Startup

Appendix C

List of Figures

Appendix C

830-Source Ground Water Treatment System Startup

As part of the engineering upgrades to Building 830-Source (SRC) treatment facility in 2015, data collection capabilities at many wells near Building 830-SRC area were upgraded. The treatment facility was secured during construction activities from August 2014 to August 2015, allowing all wells in the area to recover to unstressed, static ground water conditions. As part of the initial startup of the Building 830-SRC ground water treatment system (GWTS), additional transducer data were collected in real time and subsequently evaluated. The objective of this analysis was to evaluate the nature and extent of any hydraulic communication between Upper $Tnbs_1$ wells and other wells completed in the shallower $Tnsc_{1a}$ or $Tnsc_{1b}$ stratigraphic zones. This section summarizes the analysis of the data collected in August 2015 at the 830-SRC GWTS in Building 832 Canyon operable unit (OU).

C-1.1. Startup Procedure and Results

The procedures and results for the 830-SRC startup performed in the $Tnsc_{1a}$, $Tnsc_{1b}$, and Upper $Tnbs_1$ hydrostratigraphic units (HSUs) are described below:

Startup of Upper $Tnbs_1$ Extraction Wells

Startup of Upper $Tnbs_1$ 830-SRC GWTS extraction wells was performed from August 8 through August 13, 2015. As part of the Building 830-SRC treatment facility upgrades, Upper $Tnbs_1$ extraction wells W-830-57, W-830-60, and W-830-2215 and monitor wells W-830-18, and W-830-28 were instrumented to record real-time ground water elevation data to the database. In addition, prior to startup, ground water elevation transducers were installed in Upper $Tnbs_1$ monitor wells W-830-2906 and W-830-09 as shown on Figure C-1 to evaluate hydraulic response to pumping from nearby Upper $Tnbs_1$ extraction wells during startup of Building 830-SRC GWTS. The sequence of the Upper $Tnbs_1$ wells startup was as follows:

- **August 9, 2015:** Pumping at extraction well W-830-60, was initiated, at approximately 4 gallons per minute (gpm).
- **August 10, 2015:** Pumping at extraction well W-830-2215 was initiated, at approximately 4 gpm. Well W-830-60 continued to pump at approximately 4 gpm.
- **August 11, 2015:** Pumping at extraction well W-830-57 was initiated, at approximately 3 gpm. Pumping continued at W-830-60 and W-830-2215 at the rates specified above.

On the afternoon of August 13, 2015, all three extraction wells were shut down to allow hydraulic rebound monitoring back to static conditions in all wells.

Startup of $Tnsc_{1a}$ Extraction Wells

Startup of $Tnsc_{1a}$ 830-SRC GWTS extraction well W-830-2701 was performed from August 26 to August 31, 2015. $Tnsc_{1a}$ extraction wells W-830-2214 and W-830-2701, monitor well W-830-27, and $Tnsc_{1b}$ monitor well W-830-58, were instrumented as part of the

Building 830-SRC upgrade to record real-time ground water elevation data. In addition, prior to startup of Building 830-SRC GWTS, a ground water elevation transducer was installed in $Tnsc_{1a}$ monitor well W-830-2311 to monitor hydraulic response in this well during startup. The sequence of the startup was as follows:

- **August 26, 2015:** Pumping at W-830-2701 was initiated, at approximately 5 gpm.
- **August 30, 2015:** W-830-2701 was shutdown to allow for hydraulic rebound monitoring back to static conditions.

C-1.2. Discussion

Upper $Tnbs_1$ well startup

Hydrographs of the 830-SRC GWTS Upper $Tnbs_1$ well startup are shown in Figures C-2 and C-3. As shown in Figure C-2, when pumping from Upper $Tnbs_1$ extraction well W-830-60 was initiated, drawdown was observed in nearby extraction wells W-830-57 and W-830-2215 and in nearby monitor wells W-830-18 and W-830-28. Upon starting the second Upper $Tnbs_1$ extraction well, W-830-2215, additive drawdown was observed in extraction well W-830-57 and in monitor wells W-830-18 and W-830-28. Additionally, drawdown was observed in monitor wells W-830-09 and W-830-2906 that was previously unobserved when only W-830-60 was operational. Upon starting the third and final Upper $Tnbs_1$ extraction well, W-830-57, reduced drawdown was observed at the other two operational extraction wells and no additional drawdown was observed. Shortly after shutting off all extraction wells, an error occurred in TFRT monitoring activities resulting in a short data gap from August 11 to August 12, 2015 (Figures C-2 and C-3).

The data collected during the 830-SRC Upper $Tnbs_1$ startup reaffirm and support the current interpretation of hydraulic response and communication within the Upper $Tnbs_1$ HSU in the Building 832 Canyon OU. No hydraulic response was observed in any $Tnsc_{1a}$ or $Tnsc_{1b}$ wells during startup monitoring (Figure C-3). The hydraulic responses observed in Upper $Tnbs_1$ wells during startup, and long-term contaminant of concern (COC) temporal and spatial trends and hydrographs, support the current interpretation of 830-SRC capture zones for this HSU are accurate. Additionally, pumping Upper $Tnbs_1$ HSU extraction wells does not hydraulically influence overlying contaminated $Tnsc_1$ zones, indicating that these zones are hydraulically isolated from each other in this area.

$Tnsc_{1a}$ well startup

Hydrographs of the 830-SRC $Tnsc_1$ wells startup are shown in Figures C-4 and C-5. When the first and only $Tnsc_{1a}$ extraction well, W-830-2701 was started, drawdown was observed in downgradient monitor $Tnsc_{1a}$ well W-830-2311 (Figure C-4). However, no response was seen in any other nearby $Tnsc_{1a}$ or $Tnsc_{1b}$ extraction or monitor wells that were actively monitored, including the closest upgradient $Tnsc_{1a}$ well, extraction well W-830-2214, located approximately 400 feet to the north (Figure C-4).

The data obtained during the 830-SRC $Tnsc_{1a}$ well startup provide some additional information regarding the magnitude of hydraulic response within the $Tnsc_{1a}$ and will be used to estimate future capture zones associated with pumping from extraction well W-830-2701.

Cross HSU Evaluation

Hydraulic data collected from different HSUs during both startup periods were evaluated to determine the presence and/or magnitude of any hydraulic response within and between Upper $Tnbs_1$, $Tnsc_{1a}$, and $Tnsc_{1b}$ wells related to pumping from Upper $Tnbs_1$ and $Tnsc_{1a}$ wells. In Figure C-2, hydrographs for $Tnsc_{1a}$ and $Tnsc_{1b}$ wells are plotted relative to hydrographs from Upper $Tnbs_1$ extraction wells. As shown in Figure C-2, ground water elevations in $Tnsc_{1a}$ and $Tnsc_{1b}$ wells did not respond to Upper $Tnbs_1$ pumping. In Figure C-5, hydrographs of Upper $Tnbs_1$ wells are plotted and compared to the hydrograph from the $Tnsc_{1a}$ extraction well W-830-2701. Ground water elevations in the Upper $Tnbs_1$ wells did not respond to pumping in the $Tnsc_{1a}$ well, W-830-2701 (Figure C-5). The various pumping configurations demonstrated during startup of Building 830-SRC GWTS show that there is no hydraulic communication between the $Tnsc_{1a/b}$ HSU and the underlying Upper $Tnbs_1$ HSU in this area.

As part of ongoing operational hydrogeologic analysis and performance monitoring, DOE/LLNL will continue to monitor hydraulic response and COC trends in nearby $Tnsc_{1a}$ and $Tnsc_{1b}$ wells related to pumping from the 830-SRC extraction wellfield and interpret these results in the context of a combined $Tnsc_{1a/b}$ HSU as described in Section 3.1.2.2.

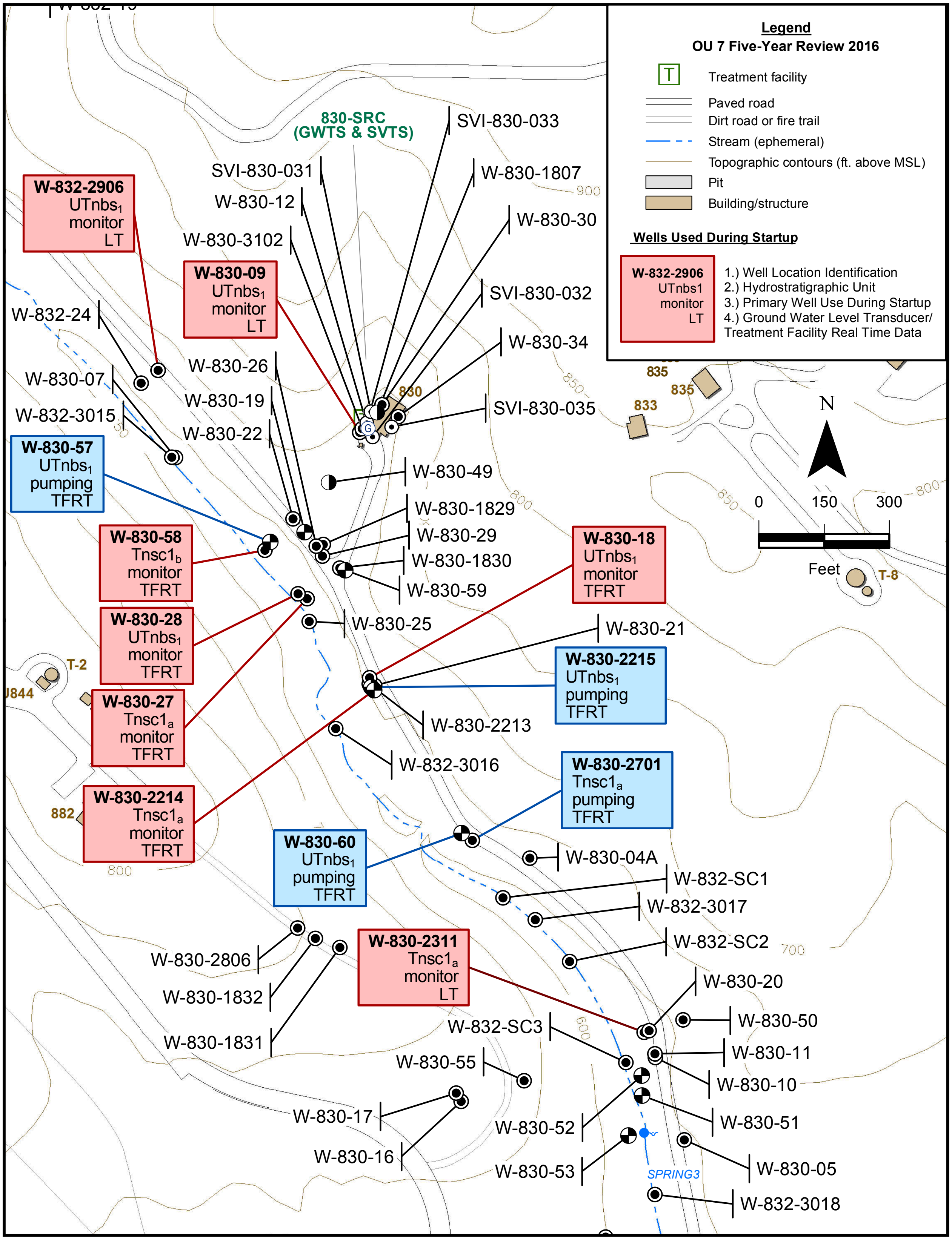

Figure C-1. Area map of Building 832 Canyon OU with locations of extraction and monitor wells used in wellfield startup testing at Building 830-SRC area in August 2015.

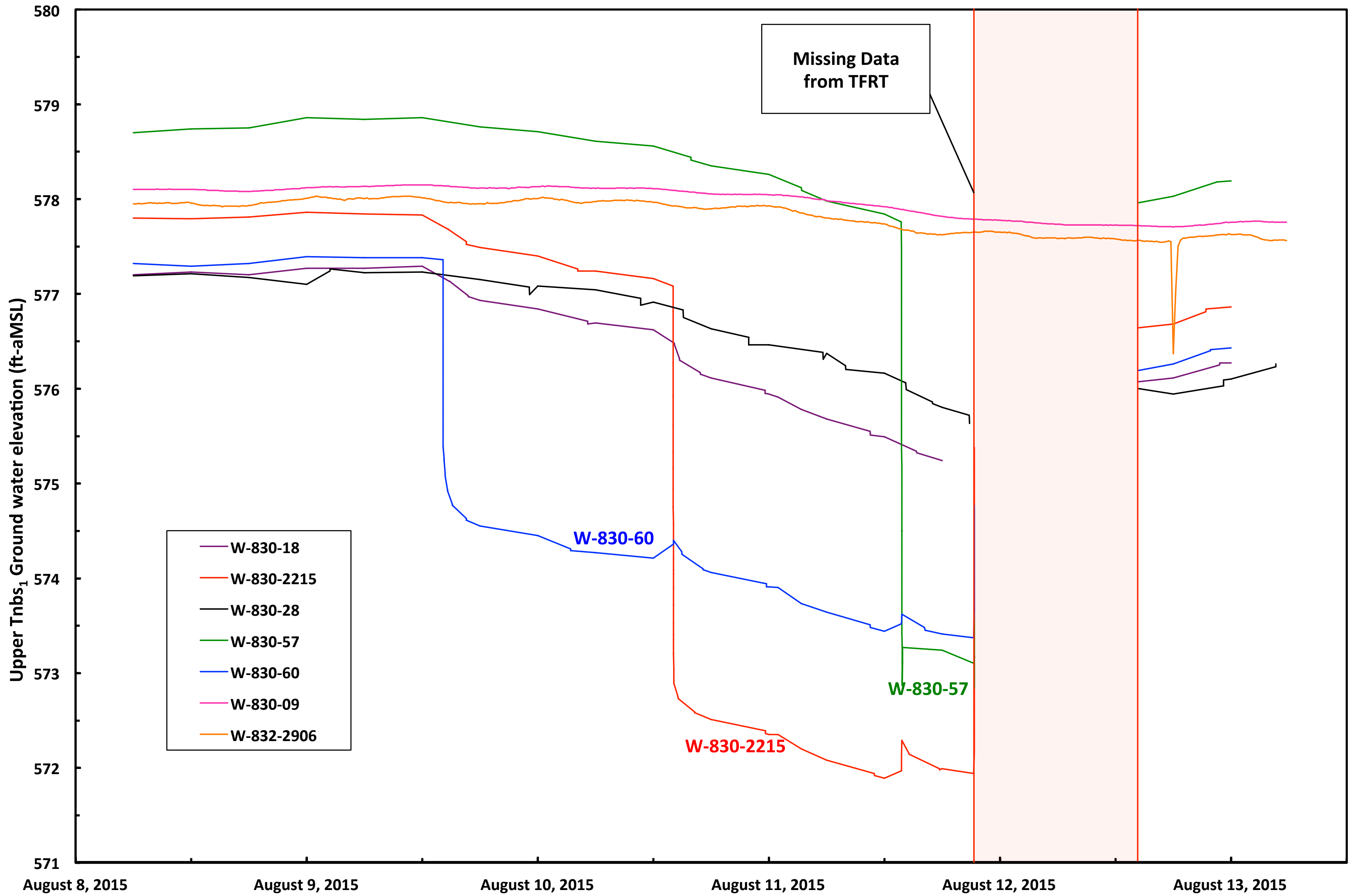

Figure C-2. Building 830-SRC GWTS Upper Tnbs$_1$ HSU startup test hydrographs.

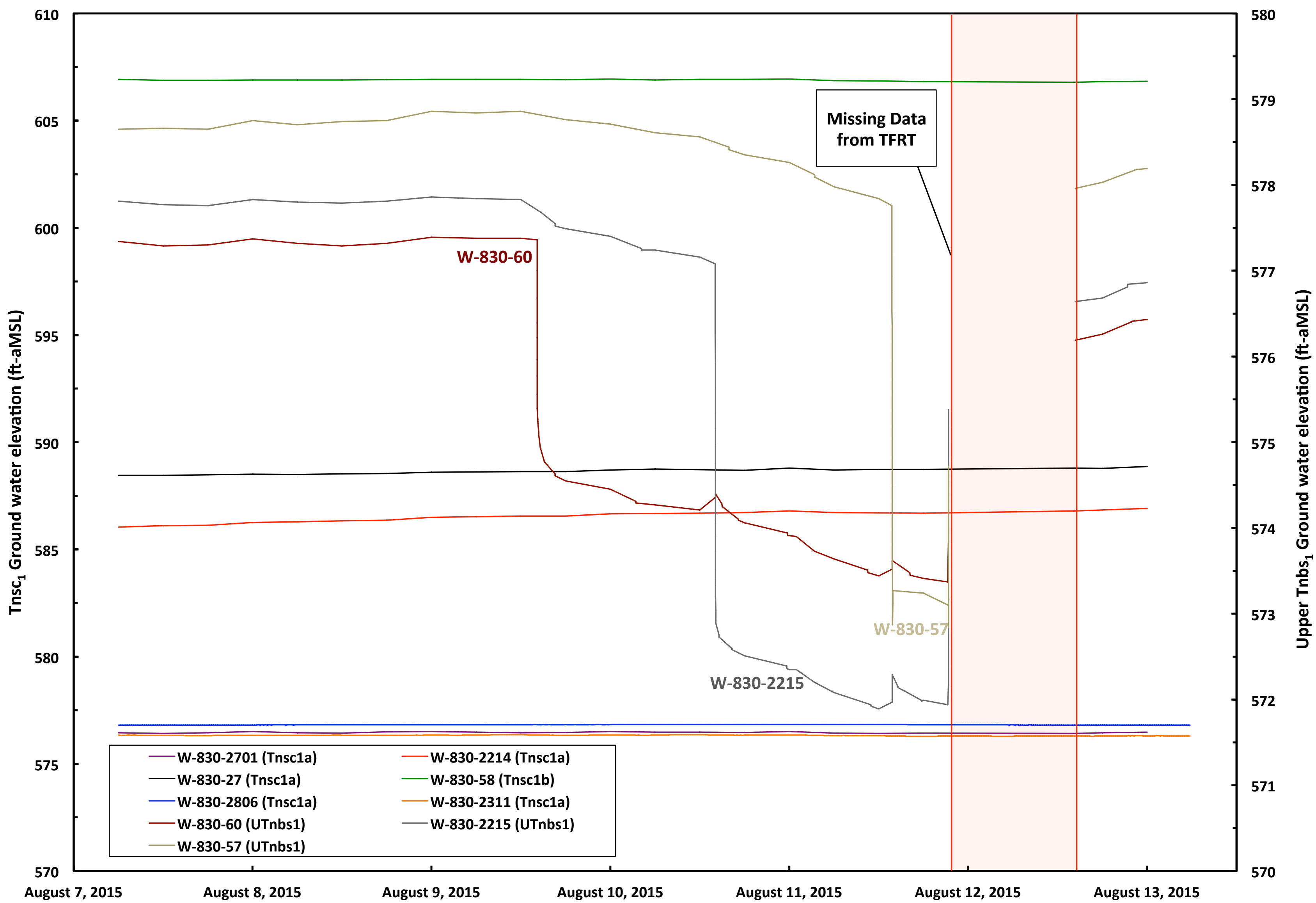

Figure C-3. Hydrographs showing response in $Tnsc_{1a}$ and $Tnsc_{1b}$ HSU to pumping in the Upper $Tnbs_1$ HSU.

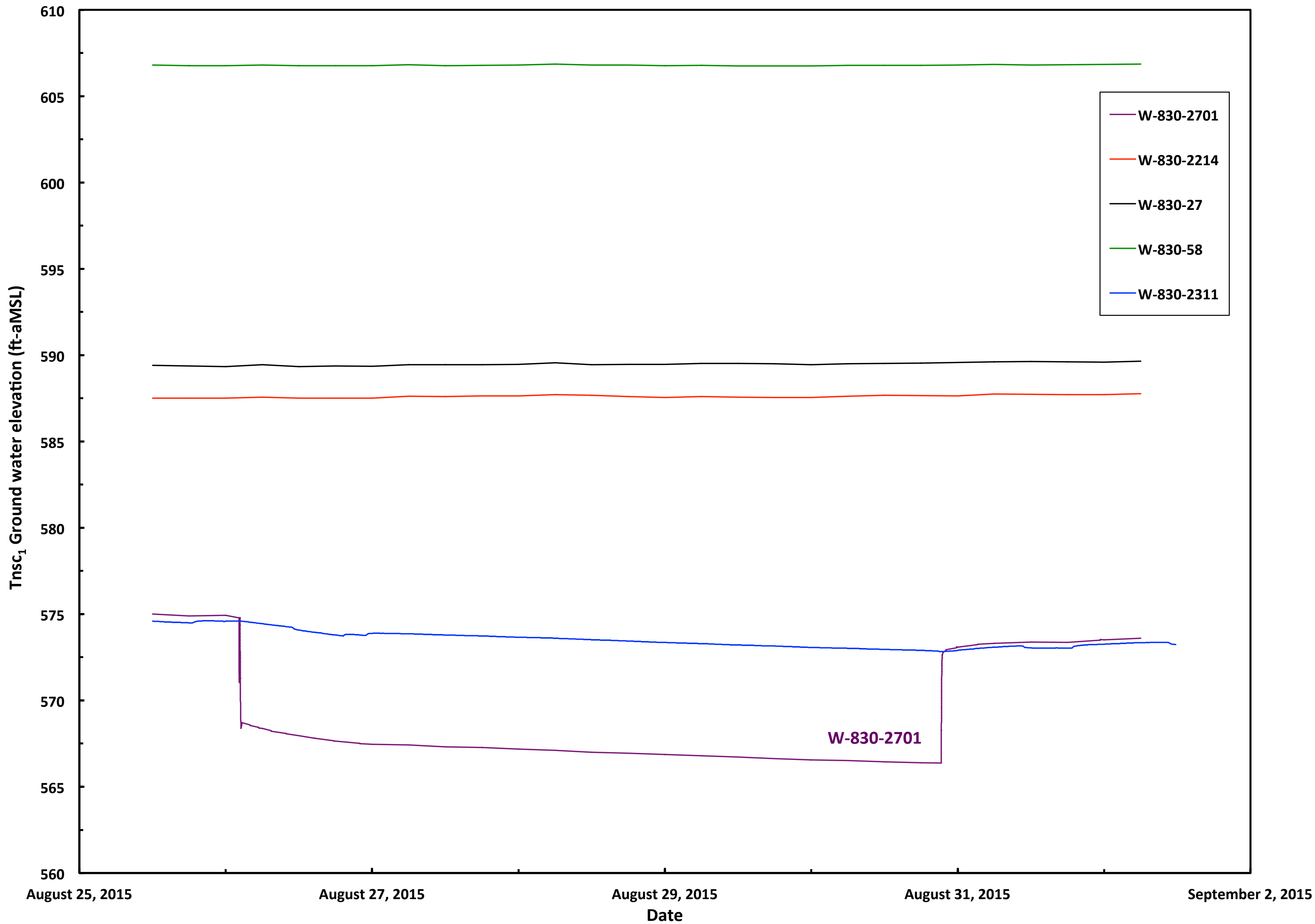

Figure C-4. Building 830-SRC GWTS Tnsc$_{1a}$ HSU startup test hydrographs.

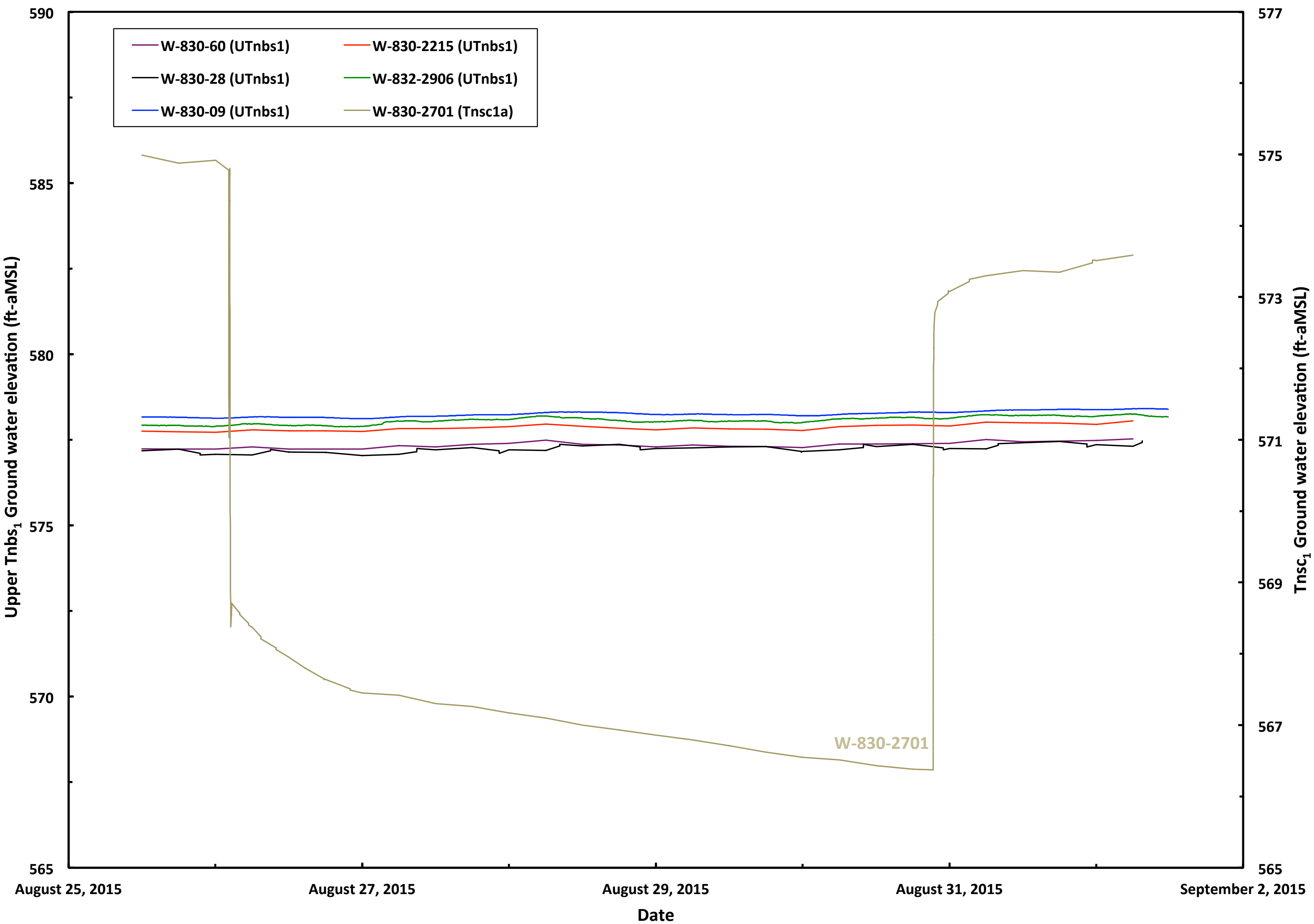

Figure C-5. Hydrographs showing response in the Upper $Tnbs_1$ HSU to pumping in the $Tnsc_{1a}$ HSU.

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