U.S. Department of Energy

Livermore Site Office, Livermore, California 94550

Lawrence Livermore National Laboratory

Lawrence Livermore National Security, LLC, Livermore, California 94551

LLNL-AR-486703-DRAFT

Draft Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300

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June 2011

*Weiss Associates, Emeryville, California

Environmental Restoration Department

This work performed under the auspices of the U. S. Department of Energy 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.

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License expires: April 30, 2012
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Approval and Concurrence for the Five-Year Review for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300

Prepared by:

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

Approved:

Claire S. Holtzapple **Date**

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

Five-Year Review Summary Form

Site Identification		
Site name: Lawrence Livermore National Laboratory Site 300, General Services Area Operable Unit		
EPA ID: CA 2890090002		
Region: IX	State: California	City/County: San Joaquin/Alameda
1.0SITE STATUS		
NPL status: Final		
Remediation status: Operating		
Multiple OUs: Yes	Construction completion date: June 2005	
Has the site been put into reuse: No		
2.0REVIEW STATUS		
Reviewing agency: U.S. Department of Energy		
Author name: John Valett		
Author title: Project Hydrogeologist	Author affiliation: Weiss Associates	
Review period: March 2006 to December 2010		
Date(s) of site inspection: July 13, 2005		
Type of review: Statutory		
Review number: 3		
Triggering action: Final Record of Decision for the General Services Area OU		
Triggering action date: February 5, 1997		
Due date: December 14, 2011		

Five-Year Review Summary Form (continued)

Deficiencies:

No deficiencies in the remedy were identified during this evaluation.

Recommendations and Follow-up Actions:

The following recommendations to be carried out by the United States (U.S.) Department of Energy (DOE) were developed during the review process:

1. Drill and install one new extraction well (W-CGSA-2708) to increase hydraulic capture of volatile organic compound (VOCs) and contaminant mass removal in the northern plume area. This new extraction well would be connected to the Central General Services Area (GSA) ground water extraction and treatment system.

No other follow-up actions were identified related to this Five-Year Review. As discussed below, these recommendations do not affect the protectiveness of the remedy.

DOE will: (1) estimate costs and the timeframe necessary to accomplish the new work scope; (2) prioritize new work scope and present these priorities to the regulatory agencies; (3) incorporate the new work scope into upcoming fiscal year budget requests; and (4) develop a schedule for implementing the work.

Protectiveness Statement:

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

The cleanup standards for the GSA OU ground water are drinking water standards. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario upon completion.

The 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. This prohibition is included in the Site-Wide Record of Decision. This prohibition will remain in place until and unless a risk assessment is performed in accordance with current U.S. Environmental Protection Agency (EPA) risk assessment guidance and is agreed by the DOE, the EPA, the California Department of Toxic Substances Control, and the Regional Water Quality Control Board as adequately showing no unacceptable risk for residential or unrestricted land use.

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1. Introduction

The United States (U.S.) Department of Energy (DOE) has conducted a Five-Year Review of the remedial actions implemented at the General Services Area (GSA) operable unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. Environmental cleanup is conducted under the oversight of the U.S. Environmental Protection Agency (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 March 2006 to December 2010. Parties providing analyses in support of the review include:

- U.S. DOE, Livermore Site Operations 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 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).

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

This is the third Five-Year Review for the GSA OU (OU 1). The first and second Five-Year Reviews were completed in 2001 (Ferry et al., 2001) and 2006 (Dibley et al., 2006a), respectively. 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 CERCLA. The triggering action for the first review was the signature date (February 5, 1997) of the Final Record of Decision (ROD) for the GSA OU (DOE, 1997).

Individual Five-Year Reviews are conducted for each OU at Site 300. The Remedial Action Completion Report (Holtzapple, 2008) and Site-Wide ROD (U.S DOE, 2008) are the triggers for the Five-Year Review for OUs 3 and 8, respectively, in accordance with EPA guidance. At the other OUs where construction began prior to the Site-Wide ROD as treatability studies and/or removal actions, DOE and the regulatory agencies agreed to use the completion of the OU-specific Remedial Design report as the trigger for the first Five-Year Review.

The background and description of the GSA OU are presented in Section 3. The following sections include the descriptions and status of the other OUs and areas where environmental restoration activities are occurring at Site 300.

1.1. Building 834 (OU 2)

From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface soil and rock and ground water with volatile organic compounds (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 contaminants of concern (COCs) in surface soil.

Completed remedial activities include excavating VOC-contaminated soil (1983) and installing a surface water drainage diversion 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 ROD (U.S. DOE, 2001) and subsequent 2008 Site-Wide ROD. The Building 834 OU remedy includes monitoring, risk and hazard management, and ground water and soil vapor extraction and treatment. Significant *in situ* bioremediation is occurring in Building 834 ground water and a treatability study focusing on understanding and enhancing this process is currently underway. 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 1,060,000 micrograms per liter (µg/L) in 1993 to a maximum of 180,000 µg/L in January 2010. TBOS/TKEBs in ground water has also been reduced from a historic maximum concentration of 7,300,000 µg/L in 1995 to 140,000 µg/L (January 2010). While nitrate concentrations have decreased from a historic maximum of 749 milligrams per liter (mg/L) in 2000 to 290 mg/L (January 2010), the continued elevated nitrate concentrations indicate an ongoing source of ground water nitrate. It is likely that there are multiple sources of nitrate at Building 834. One possible anthropogenic source is the septic system leach field located in the vicinity of wells W-834-S1. A second probable source is natural soil nitrate. Additional sources could be nitrogenous compounds, like nitric acid or barium nitrate, that might have inadvertently been discharged into the septic system via a test cell floor drain or to the ground during accidental spills and/or pipeline leaks that released TCE to the environment. Anaerobic bacteria in the Building 834 Core and T2 areas reduce nitrate locally by denitrification.

DOE has performed two Five-Year Reviews for the Building 834 OU (Ferry et al., 2002a and Dibley et al., 2007a). The third Five-Year Review is scheduled for 2012.

1.2. Pit 6 Landfill (OU 3)

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. 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 trichloroethene (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 are limited, DOE will continue 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 VOCs in ground water from a historic maximum of 250 µg/L in 1988 to a maximum concentration of 8 µg/L (March 2010). Tritium activities are well below the cleanup standard and continue to decrease towards background levels. Perchlorate is not currently detected in any wells above the cleanup standard. The extent of nitrate at concentrations exceeding the cleanup standard continues to be limited to one well. Installation of the landfill cap mitigated the onsite worker inhalation risk.

The first Five-Year Review for this OU is scheduled for 2012.

1.3. High Explosive (HE) Process Area (OU 4)

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 rinsewater 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 are COCs in surface water at Spring 5. HE compounds are COCs in surface soil. HE compounds and VOCs are COCs in subsurface soil. No further action was selected as the remedy for VOCs and 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 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. The remedial design was completed in 2002. Construction completion for the OU was achieved in September 2007. Six ground water extraction and treatment systems currently operate in the OU.

Ground water remediation efforts have reduced VOC concentrations from a historic maximum of 450 µg/L in 1992 to a maximum of 61 µg/L in March 2010. Research Department Explosive (RDX) in ground water has also been reduced from a maximum historic concentration of 350 µg/L in 1994 to a maximum concentration of 110 µg/L in February 2010. Natural denitrification processes are reducing nitrate concentrations in ground water to background levels. Perchlorate concentrations have decreased from a historic maximum of 50 µg/L in 1998 to 29 µg/L (February 2010). Remediation has also mitigated risk to onsite workers in the HE Process Area OU.

DOE has performed a Five-Year Review for the High Explosives Process Area OU (Dibley et al., 2007b). The second Five-Year Review is scheduled for 2013.

1.4. Building 850/Pit 7 Complex (OU 5)

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

The first Five-Year Review for this OU is scheduled for 2016.

1.4.1. Building 850 Firing Table (OU 5)

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, High-Melting Explosive (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, monitoring, and risk and hazard management. 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 58,400 pCi/L (April 2010). 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 current maximum perchlorate concentration in this OU is 79 µg/L (February 2010) and a treatability study to evaluate *in situ* biodegradation of perchlorate is planned.

1.4.2. Pit 7 Landfill Complex (OU 5)

The Pit 3, 4, 5, and 7 Landfills are collectively designated the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits in the 1950s through the 1980s. The Pit 4 and 7 Landfills were capped in 1992. During years of above-average 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 Complex required additional study; accordingly, 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 Complex was signed in 2007 (U.S. DOE, 2007) that described the selected remedy for the Pit 7 Complex including monitoring, risk and hazard management, MNA, ground water extraction and treatment, and source control. The interim remedial design was completed in 2008. A hydraulic drainage diversion system was constructed in 2008 to control contaminant sources by preventing ground water from rising into the pit waste and underlying contaminated bedrock. 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 255,000 pCi/L (January 2010) 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 120 pCi/L (April 2010). VOC concentrations are currently near or below cleanup standards. Nitrate concentrations in ground water remain relatively stable, while perchlorate concentrations have decreased.

1.5. Building 854 (OU 6)

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, 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 rinsewater lagoon was excavated in 2005 (Holtzapple, 2005). The selected remedy for this OU includes monitoring, risk and hazard management, and ground water and soil vapor extraction and treatment. The interim 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 VOC concentrations from a historic maximum of 2,900 µg/L in 1997 to 97 µg/L (April 2010). Nitrate concentrations have decreased from a historic maximum of 260 mg/L in 2003 to 180 mg/L (June 2010). Perchlorate concentrations in ground water have also decreased from a historic maximum of 27 µg/L in 2003 to 17 µg/L (June 2010). Risks to onsite workers from inhalation of VOC vapors and from exposure to PCBs, dioxins, and furans in surface soil have been mitigated.

A Five-Year Review of remediation in the Building 854 OU was completed in January 2009 (Dibley et al., 2009a). The second Five-Year-Review is scheduled for 2014.

1.6. Building 832 Canyon (OU 7)

Contaminants were released from Buildings 830 and 832 through piping leaks and surface spills during past activities at these buildings. VOCs, nitrate, and perchlorate are COCs in ground water. VOCs are COCs in surface water at Spring 3. VOCs, nitrate, and HMX are COCs in subsurface soil. HMX is also a COC in surface soil. No further action was selected as the remedy for HMX and nitrate in surface and subsurface soil. Ground water and soil vapor extraction and treatment have been conducted since 1999 to reduce contamination in ground water and subsurface soil. The Building 832 Canyon OU remedy includes monitoring, risk and hazard management, MNA for nitrate, and ground water and soil vapor extraction and treatment. The interim remedial design was completed in 2006. Construction completion for the OU was achieved in September 2007. Three ground water extraction and treatment systems and two soil vapor extraction and treatment systems currently operate in the OU.

Remediation has reduced VOC concentrations from a historic maximum of 13,000 µg/L in 1997 to a maximum of 4,200 µg/L (February 2010). Perchlorate concentrations have been reduced from a historic maximum of 27 µg/L in 2003 to a maximum of 17 µg/L (March 2010). Nitrate concentrations in ground water remain fairly stable, and are possibly the result of the ongoing contribution of nitrate from septic systems and natural bedrock sources. However, natural denitrification processes continue to reduce nitrate concentrations to background levels towards the site boundary. Remediation has also mitigated risk to onsite workers in several locations in the Building 832 Canyon OU.

A Five-Year Review of remediation in the Building 832 Canyon OU was completed in 2011 (Helmig et al., 2011). The second Five-Year-Review is scheduled for 2016.

1.7. OU 8

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 interim 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. The first Five-Year Review for this OU is scheduled for 2013. These release sites are summarized below.

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

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 and transported to the Nevada Test Site, for eventual disposal. 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 and nitrate concentrations in ground water are currently near or below cleanup standards or at background levels. 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 selected remedy for this area includes monitoring and risk and hazard management. No further action was selected as the remedy for VOCs in subsurface soil at Building 801.

No Remedial Design documents are required for this area.

1.7.2. Building 833 (OU 8)

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

The selected remedy for Building 833 includes monitoring and risk and hazard management. No Remedial Design document is required for this area. Ground water monitoring at Building 833 has shown a decline in VOC concentrations from a historic maximum of 2,100 µg/L in 1992 to 110 µg/L (February 2010).

1.7.3. Building 845 Firing Table and the Pit 9 Landfill (OU 8)

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 selected remedy for Building 845 and the Pit 9 Landfill includes monitoring and risk and hazard management. No further action was selected as the remedy for uranium and HMX in subsurface soil at Building 845. No Remedial Design documents are required for this area.

1.7.4. Building 851 Firing Table (OU 8)

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, there is no risk to humans or animal populations, or threat to ground water associated with these contaminants in surface and subsurface soil. Uranium-238 was identified as a COC in ground water. However, it poses no risk to human or ecological receptors, and uranium activities are 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 selected remedy for Building 851 includes monitoring and risk and hazard management. 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 is required for this area.

1.7.5. Pit 2 Landfill (OU 8)

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 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 selected remedy for the Pit 2 Landfill includes monitoring and risk and hazard management. Monitoring data indicate that uranium activities remain below the cleanup standard. No Remedial Design document is required for this area.

1.8. Building 812 (OU 9)

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 ground water, and uranium isotopes and selected metals in soil. In 2008, a draft Remedial Investigation/Feasibility Study (RI/FS) describing the results of characterization activities and remedial alternatives for the Building 812 OU was submitted to the regulatory agencies. A DOE task force reviewed the soil washing alternative and determined that it would not be effective at Site 300, therefore a soil washing treatability study will not be performed. DOE is currently evaluating a new remedial strategy for contaminated soil at Building 812. Additional characterization is scheduled to begin in 2011. A new RI/FS will be prepared following the completion of the characterization. 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 tetrachloroethene (PCE), were identified as COCs in ground water. The remediation pathway for Building 865 is currently being negotiated.

2. Site Chronology

The following chronology summarizes important events relevant to environmental restoration in the GSA OU:

1955

- LLNL Site 300 was established as a DOE high-explosives test facility.

1960s/1970s

- Solvents from the craft shops were discharged to dry wells in the Central GSA.
- VOC-contaminated rinsewater was discharged to the ground surface at the Building 879 steam-cleaning/sink facility.
- VOC-contaminated shop debris was disposed in Eastern GSA trenches.

1970s/1980s

- Solvent spills from drum rack occurred.

1982

- Site investigations began in the GSA OU.

1990

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

1991

- Ground water extraction and treatment began in the Eastern GSA as a removal action.

1992

- A Federal Facility Agreement for Site 300 was signed. The parties to the Agreement included DOE, the U.S. EPA, the California DTSC, and the California RWQCB.

1993

- Ground water extraction and treatment began in the Central GSA as a removal action.

1994

- Soil vapor extraction and treatment began in the Central GSA as a removal action.

1994

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

1995

- A Feasibility Study for the GSA OU was issued (Rueth et al., 1995).

1996

- The Proposed Plan for Environmental Cleanup of the GSA OU was issued (U.S. DOE, 1996).
- A point-of-use Memorandum of Understanding was established with the nearby landowners.

1997

- A Record of Decision for the GSA OU was signed.

- Ground water and soil vapor extraction and treatment began as a remedial action.

1998

- The Remedial Design document for the GSA OU was issued (Rueth et al., 1998).

1999

- The Phase I expansion of the Central GSA extraction wellfield was completed.

2001

- The first Five-Year Review for the GSA OU was issued.

2003

- DOE received permission from the RWQCB to include the GSA treatment facility compliance reporting in the semiannual Compliance Monitoring Reports (CMRs).

2005

- The Phase II expansion of the Central GSA extraction wellfield was completed.
- Remedial action construction was completed June 2005.
- The EPA performed the OU construction completion inspection July 13, 2005.

2006

- The second Five-Year Review for the GSA OU was issued.

2007

- Remediation efforts in the Eastern GSA successfully reduced concentrations of VOCs in ground water to below their respective cleanup standards set in the GSA ROD. The Eastern GSA ground water extraction and treatment system was shut off on February 15, 2007 with regulatory approval. As required by the GSA ROD, ground water monitoring is being conducted for 5 years after shutdown to determine if VOC concentrations rise or "rebound" above cleanup standards.
- The Central GSA ground water treatment system (GWTS) began receiving partially treated water from the Building 830-Distal South ground water extraction and treatment system (830-DISS) at the end of the first semester 2007.
- In the Eastern GSA Compliance Feasibility Report submitted to regulatory agencies on July 15, 2007 (Holtzapple, 2007), DOE/LLNL evaluated onsite discharge options that could be implemented if VOC concentrations rebound above cleanup standards requiring that the Eastern GSA extraction and treatment system be restarted.

2008

- The Site-Wide ROD Site 300 was signed. The GSA OU was not included in the Site-Wide ROD because an OU-specific ROD was in place.

2009

- The revised Compliance Monitoring Plan/Contingency Plan for Interim Remedies was issued (Dibley et al., 2009b). Requirements for the GSA OU were included.

3. Background

3.1. Physical Characteristics

3.1.1. Site Description

LLNL Site 300 is a U.S. DOE experimental test facility operated by the Lawrence Livermore National Security (LLNS), Limited Liability Corporation. Site 300 is approximately 11 square miles and located in the Eastern Altamont Hills, 17 miles east of Livermore, California (Figure 1). At Site 300, DOE conducts research, development, and testing associated with high-explosive materials. During previous Site 300 operations, a number of contaminants were released to the environment. These releases occurred primarily from spills, leaking pipes, leaching from unlined landfills and pits, high-explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps).

The GSA OU is approximately 72 acres, located in the southeast corner of Site 300 (Figure 1). Within the GSA are a number of craft shops, storage buildings, and offices that support the research being conducted at Site 300. The GSA has been separated into the Central GSA and the Eastern GSA based on differences in hydrogeology and the distribution of environmental contaminants. The majority of structures are located in the Central GSA. The Eastern GSA contains a sewage treatment and adjacent overflow ponds. The offsite area adjacent to the GSA is sparsely populated and used for agriculture. The nearest major population center (Tracy, California) is 8.5 miles to the northeast.

There are no environmentally sensitive areas on Site 300 property within the GSA OU. However, the California Department of Fish and Game maintains an ecological preserve immediately northeast of the GSA along Corral Hollow Creek. Administrative controls are in place to minimize any potential detrimental impacts on the preserve from the GSA cleanup, including managing of ground water treatment system discharges to prevent surface water from reaching the preserve during the summer months.

The GSA OU includes the release sites in the Central and Eastern GSA and any associated contamination released to environmental media. The OU boundary is defined by the current extent of VOCs in ground water. As shown in Figure 1, the OU boundary is currently approximately 2,000 ft long by 1,000 ft wide. One ground water and one soil vapor extraction and treatment systems are currently operating to remediate VOC in Central GSA ground water. The Eastern GSA ground water extraction and treatment system is still in place, but was shut down in February 2007 when VOC concentrations were reduced to below ground water cleanup standards. Post-shutdown monitoring is underway to determine if VOC concentrations in Eastern GSA ground water rebound above cleanup standards. Ground water is monitored for VOCs in 104 wells to evaluate the progress of VOC remediation in the GSA OU. The locations of existing monitor, extraction and water-supply wells, and treatment facilities for the Central and Eastern GSA are shown on Figures 2 and 3, respectively.

3.1.2. Hydrogeologic Setting

This section describes the general hydrogeologic setting for the GSA OU including the unsaturated zone and the hydrostratigraphic units (HSUs) underlying the area. A southwest-northeast oriented hydrogeologic cross-section through the GSA is presented in Figure 4.

3.1.2.1. Vadose (Unsaturated) Zone

The vadose zone in the western portion of the Central GSA is comprised of the unsaturated portion of the Quaternary alluvial terrace (Qt) silty clay, sand, and gravel deposits, and the underlying Tertiary Neroly Upper Blue Sandstone ($Tnbs_2$). These deposits are unsaturated to a depth of approximately 10 to 20 feet (ft) below ground surface (bgs). The vadose zone is contaminated with VOCs in the vicinity of the Building 875 former dry wells.

In the eastern portion of the Central GSA (near the sewage treatment pond) and the Eastern GSA, the vadose zone is comprised of the unsaturated portion of the Quaternary alluvial (Qal) silty clay, sand, and gravel deposits and the underlying Tertiary Neroly Lower Blue Sandstone ($Tnbs_1$). In the Eastern GSA, these deposits are unsaturated to a depth of approximately 10 to 15 ft bgs. There is no significant contamination present in unsaturated Qal and $Tnbs_1$ units in the Eastern GSA.

3.1.2.2. Saturated Zone

An HSU consists of one or more stratigraphic intervals that comprise a water-bearing zone exhibiting similar hydraulic and geochemical properties. There are three primary HSUs beneath the GSA OU: two shallow HSUs and one deeper HSU. The shallow HSUs are:

- Quaternary terrace deposits (Qt)-Tertiary Neroly Middle Siltstone/Claystone ($Tnsc_1$) HSU, a water-bearing zone in the western portion of the Central GSA that consists of Qt deposits and the portions of the underlying Neroly $Tnbs_2$ and $Tnsc_1$ bedrock units that are in direct hydraulic communication with the Qt.
- Quaternary alluvial (Qal)-$Tnbs_1$ HSU, a water-bearing zone within the eastern portion of the Central GSA and throughout the Eastern GSA, that consists of Qal deposits and the portion of the underlying Neroly $Tnbs_1$ bedrock unit that is in direct hydraulic communication with the Qal.

The deeper HSU is:

- $Tnbs_1$ HSU, that consists of the regional Neroly $Tnbs_1$ bedrock aquifer in the Central and Eastern GSA.

In the western portion of the Central GSA, the Qt-$Tnsc_1$ HSU includes saturated Qt deposits, and the $Tnbs_2$ sandstone and $Tnsc_1$ siltstone/claystone bedrock units beneath the Qt. The $Tnbs_2$ is permeable sandstone that contains unconfined to confined ground water. The $Tnsc_1$ siltstone/claystone is generally low permeability with variable saturation, and acts as an aquitard between the Qt/$Tnbsc_1$ HSU and the deeper $Tnbs_1$ regional aquifer. The depth to ground water in the Qt-$Tnsc_1$ HSU is 10 to 20 ft bgs, and ground water flows toward the south and east at a velocity of 0.05 to 0.10 feet per day (ft/day).

In the eastern portion of the Central GSA (near the sewage treatment pond) and throughout the Eastern GSA, the Qt deposits and the $Tnbs_2$ and $Tnsc_1$ bedrock units are not present. Qal deposits directly overlie the $Tnbs_1$ bedrock. The Qal-$Tnbs_1$ HSU consists of the saturated part of the Qal and the immediate underlying $Tnbs_1$ bedrock. In the Eastern GSA, the hydraulic conductivity of the alluvium is significantly greater than in the Qt in the western part of the Central GSA. The depth to ground water in Qal-$Tnbs_1$ HSU is 10 to 15 ft bgs. Ground water in the Qal flows toward the east and north along the Corral Hollow Creek drainage at a velocity of

0.5 to 3 ft/day. In this area there is generally a natural upward hydraulic gradient such that ground water in the $Tnbs_1$ discharges into the overlying Qal deposits.

The $Tnbs_1$ HSU underlies and is hydraulically separated from the Qt-$Tnsc_1$ HSU by the $Tnsc_1$ siltstone/claystone confining layer in the western portion of the Central GSA. As shown in Figure 4, the Qt, $Tnbs_2$, and $Tnsc_1$ stratigraphic units pinch out toward the eastern part of the Central GSA, and the $Tnbs_1$ HSU directly underlies the Qt deposits in the eastern part of the Central GSA and the Eastern GSA. The $Tnbs_1$ regional aquifer is separated into upper and lower units by a ten-foot thick claystone marker bed that exists throughout the southeast corner of Site 300. Depth to ground water in the $Tnbs_1$ HSU in the southeast corner of Site 300 varies from 12 to 100 ft bgs and ground water flows to the south-southeast. Ground water velocity in the $Tnbs_1$ regional aquifer is approximately 0.3 ft/day.

A potentiometric surface elevation contour map for the Qt-$Tnsc_1$ and Qal-$Tnbs_1$ HSUs in the Central GSA is presented as Figure 5. A potentiometric surface elevation contour map for the Qal-$Tnbs_1$ HSU in the Eastern GSA is presented as Figure 6. Wells screened in deeper $Tnbs_1$ bedrock HSU are not shown on Figures 5 and 6. VOCs have historically not been detected in the $Tnbs_1$ HSU, or have only been sporadically detected at trace concentrations.

3.2. Land and Resource Use

Prior to DOE establishing Site 300 as remote testing facility in 1955, the area was used for cattle grazing. Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. Less than five percent of Site 300's 7000-acre property-area is developed. Craft shops, storage buildings, and offices in the Central GSA are still used to support the research conducted at Site 300. Land in the Eastern GSA is undeveloped and is not used for LLNL programmatic activities. There are no active onsite water-supply wells in the GSA. Two former onsite water-supply wells in the Central GSA were sealed and abandoned in 1988 and 1990 due to the detection of TCE in samples from these wells.

There are no planned modifications or proposed development of the offsite land adjacent to the GSA. Current offsite land use near the GSA includes cattle grazing, private residences, and an ecological preserve. Several private water-supply wells located south of the Eastern GSA area, are in use for domestic and agricultural uses (Figure 9). These offsite wells are monitored regularly and no contamination from the GSA has been detected in these wells since 2001. The VOC detection in 2001 was due to suspected laboratory contamination.

3.3. History of Contamination

The eight confirmed contaminant release sites in the GSA are shown on Figure 7 and listed below:

1. The Building 879 Steam-Cleaning/Sink facility.
2. Former dry well 875-S1.
3. Former dry well 875-S2.
4. A decommissioned solvent drum rack and underground solvent retention tank.
5. Former dry well 872-S.
6. Former dry well 873-S.

7. A former debris burial trench west of the sewage treatment pond in the Central GSA.
8. Several former debris burial trenches north of the sewage treatment overflow pond in the Eastern GSA.

Solvents containing VOCs were commonly used as degreasing agents in craft shops in the Central GSA. Rinse water from these operations was disposed in dry wells. Typically, the dry wells in the Central GSA were gravel-filled pits 3 to 4 feet deep and 2 feet wide. The dry wells were used until 1982 and all were excavated in 1983 and 1984.

In the Eastern GSA, various types of debris were disposed of in debris burial trenches during the 1960s and 1970s. Some of this debris was contaminated with small quantities of VOCs. Trenching of the debris burial area, interviews with former and present employees, and examination of aerial photographs indicate that the trenches contain primarily metal, ceramic, and glass debris from the craft shops.

3.4. Initial Response

DOE began environmental investigations in the GSA in 1982. Since then, over 100 monitor wells have been installed to characterize the vertical and horizontal extent of contamination throughout the GSA and to measure ground water elevations. Other site characterization methods included soil sampling, soil vapor surveys, hydraulic testing, colloidal borescope investigations, and geophysical surveys. Test pits were also used to determine the extent of burial trenches and contamination in the Eastern GSA.

Pre-ROD remediation activities at the GSA included:

- Excavating and backfilling all dry wells.
- Sealing and abandoning impacted or threatened water-supply wells.
- Removal Actions to begin ground water and soil vapor extraction and treatment initiated in the Eastern GSA and Central GSA in 1991 and 1993, respectively.

3.5. Contaminants of Concern

The primary COC found in ground water and soil at the GSA is TCE, comprising approximately 90% of the total VOCs. TCE is a suspected human carcinogen. Other contaminants of concern identified in the GSA include PCE, cis-1,2-dichloroethene (DCE), 1,1-DCE, 1,1,1-trichloroethane (TCA), benzene, bromodichloromethane, and chloroform, .

The baseline human health risk assessment conducted in 1991 for Central GSA estimated a maximum excess carcinogenic risk of 7×10^{-2} if ground water from a hypothetical water-supply well located at the site boundary near the Building 875 dry wells were to be ingested over a 70-yr period (risk values below 10^{-6} are considered protective). The corresponding noncarcinogenic hazard index was 560 (hazard indices below 1 are considered protective). The baseline risk assessment also estimated an excess cancer risk to onsite workers from TCE vapors migrating into Building 875 of 1×10^{-5}. As discussed in Section 7.5.1.2, soil vapor extraction has contributed to reducing the excess cancer risk due to inhalation of VOC vapors migrating into Building 875 from 1×10^{-5} prior to remediation to 9.5×10^{-7} in 2000 (U.S. DOE, 2000). Inhalation risk within Building 875 is no longer of concern. The 1991 baseline human health risk assessment for Eastern GSA estimated an excess carcinogenic risk of 5×10^{-5} for ingesting

ground water from a hypothetical water-supply well located at the site boundary near the debris burial trench. The risk associated with potential use of contaminated ground water at two offsite wells (CDF-1 and SR-1) was approximately 10^{-5}. No unacceptable risk or hazard was associated with potential exposure to VOCs in surface or subsurface soil.

In the Central GSA, the highest pre-remediation concentration of TCE in soil was 360 milligrams per kilogram (mg/kg), detected below the Building 875 dry wells. In general, the highest concentrations of VOC contaminants in ground water have been detected near the dry wells. Total VOC concentrations in ground water in the Qt-$Tnsc_1$ and Qal-$Tnbs_1$ HSUs are shown on Figure 8, based on data from second semester 2010. The pre-remediation concentration of total VOCs in ground water was approximately 272,000 µg/L. The 2010 maximum total VOC concentration was 2,000 µg/L (W-7I, June 2010). VOCs remain below reporting limits in the Central GSA guard wells.

In the Eastern GSA, very low concentrations of VOCs (maximum of 0.017 mg/kg) were detected in the vadose zone beneath the debris trenches. In general, the highest concentrations of VOC contaminants in ground water were detected in the vicinity of the debris burial trench. Total VOC concentrations in ground water in the Qal-$Tnbs_1$ HSU are shown on Figure 9, based on data from the second semester 2010. The highest pre-remediation concentration of total VOCs detected in shallow ground water near the debris burial trench was approximately 74 µg/L. The 2010 maximum total VOC concentration was 5.1 µg/L (4.6 µg/L of TCE and 0.5 µg/L of PCE) in W-26R-04 (June 2010). Prior to the start of remediation, the plume of TCE in ground water exceeding the Maximum Contaminant Level (MCL) of 5 µg/L extended approximately 4,200 ft offsite. Since then, as described in Section 4.2.2 and 7.5.2, TCE concentrations have been reduced to below the 5 µg/L cleanup standard in all onsite and offsite Eastern GSA wells and the portion of the plume exceeding 5 µg/L has been eliminated. Historically, trace concentrations of VOCs have been sporadically detected in the Eastern GSA guard wells; however, only one TCE detection has been observed since 1994 (0.54 µg/L in W-25N-07 in 2006).

3.6. Summary of Basis for Taking Action

Remedial actions were initiated in the GSA OU to address unacceptable human health risks associated with subsurface contamination at the GSA OU including: (1) potential ingestion of ground water containing VOCs at concentrations exceeding drinking water MCLs, and (2) potential onsite worker inhalation exposure to TCE volatilizing from the subsurface soil to indoor air within Building 875. The remedial action objectives for the GSA cleanup are discussed in Section 4.1.

4. Remedial Actions

4.1. Remedy Selection

The remedy selected for the GSA OU is intended to achieve the following Remedial Action Objectives:

For Protection of Human Health:

- Prevent human ingestion of the ground water containing VOC concentrations (single carcinogen) above the State and Federal drinking water MCLs, a cumulative excess cancer risk (all carcinogens) greater than 10^{-6}, and a cumulative hazard index (all noncarcinogens) greater than 1.
- Prevent human inhalation of VOCs in vapor in concentrations above those that pose an excess cancer risk of 10^{-6}.

For Protection of the Environment:

- Restore water quality, at a minimum, to water quality objectives that are protective of beneficial uses (i.e., MCLs).

The cleanup standard for ground water in the GSA OU is to reduce VOC concentrations to MCLs in all impacted ground water. VOCs in the vadose (unsaturated) zone will be remediated to the extent technically and economically feasible to minimize further degradation of the ground water by contaminants in the vadose zone. The vadose zone cleanup will be completed when it is demonstrated that: (1) VOCs remaining in the vadose zone no longer cause concentrations in the leachate to exceed the ground water cleanup standards (established as a soil vapor concentration of 0.36 parts per million on a volume-to-volume basis [$ppm_{v/v}$]) based on an interpretation of soil vapor data using an appropriate vadose zone model, and (2) VOCs have been removed to the extent technically and economically feasible to meet the ground water cleanup levels sooner, more cost-effectively, and more reliably (U.S. DOE, 1997). Another cleanup standard is to mitigate the excess cancer risk from inhalation of indoor air within Building 875 caused by VOCs migrating into the building from the subsurface. This objective has been met as described in Section 3.5.

The remedy for the GSA was selected to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, and protect human health and the environment both onsite and offsite. In the remedial design phase, DOE considered hydrogeologic factors, contaminant characteristics, available remedial technologies, and effective performance monitoring techniques. The selected remedy for the GSA consists of:

1) Monitoring ground water and soil vapor to evaluate the effectiveness of the remedy in achieving cleanup standards, and to ensure there is no impact to downgradient water-supply wells.
2) Risk and hazard management to prevent onsite worker exposure to VOCs volatilizing from subsurface soil into indoor air at Building 875 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 indoor air in Building 875 has been mitigated through remediation. Therefore, risk and hazard management for this exposure pathway is no longer necessary. The risk re-evaluation results are documented in the "Building 875 Inhalation Risk Mitigation Evaluation at the Central GSA at Lawrence Livermore National Laboratory Site 300" (U.S. DOE, 2000). Institutional/land use controls will be implemented to prevent human exposure to contamination and to protect the integrity of the remedy.
3) Extracting and treating VOCs in soil vapor and ground water in the Central GSA 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.

4) Extracting and treating VOCs in ground water in the Eastern GSA to mitigate to reduce VOC concentrations in ground water to cleanup standards. VOC concentrations in Eastern GSA ground water have been below cleanup standards since February 2007.

4.2. Remedy Implementation

Sections 4.2.1 and 4.2.2 present a summary of the actions DOE has taken to implement the selected remedy in the GSA OU, and also describe any significant modifications to the remedy since the Final ROD and Remedial Design documents for the GSA OU. Information on the performance of the remedy and the current concentrations and distribution of contamination is included in Section 7.5.

4.2.1. Central GSA Remedy Implementation

The Central GSA remediation system consists of ground water and soil vapor extraction and treatment as described in Sections 4.2.1.1 and 4.2.2.2. A map of the Central GSA showing the locations of monitoring, extraction, water-supply wells, and treatment facilities is presented as Figure 2.

4.2.1.1. Central GSA Ground Water Remedy Implementation

Ground water cleanup began in the Building 875 dry well release area at Central GSA in 1993 using four extraction wells completed in the Qt-$Tnsc_1$ HSU. The ROD and Remedial Design documents included plans to evaluate expansion of the ground water extraction wellfield to include other contaminant sources and the downgradient extent of the VOC plume in the Qal-$Tnbs_1$ HSU. VOCs have historically not been detected in the deeper $Tnbs_1$ HSU, or have only been sporadically detected at trace concentrations, and no active remediation is occurring in this HSU. Since ground water remediation began, two wellfield expansions have occurred:

- Phase I wellfield expansion occurred in 1999 and included the addition of three Qt-$Tnsc_1$ HSU extraction wells to increase VOC mass removal and hydraulic capture of the plume. Extraction wells W-872-02 and W-873-07 were installed at the Building 872 and Building 873 dry well VOC release sites, respectively. Extraction well W-7O was installed hydraulically downgradient from the Building 875 dry well release area.
- Phase II wellfield expansion occurred in 2005 and included the addition of two Qal-$Tnbs_1$ HSU extraction wells to increase hydraulic capture of the downgradient VOC plume. Extraction wells W-7R and W-7P were installed further downgradient from the Building 875 dry well release area. Well W-7P is pumped at low flow rates to minimize drawing contamination downward into the $Tnbs_1$ bedrock HSU.

Contaminated ground water is currently extracted from eight wells (W-7I, W-875-07, W-875-08, W-873-07, W-872-02, W-7O, W-7P, and W-7R) at an approximate combined flow rate of approximately 4 to 5 gallons per minute (gpm). The Central GSA GWTS began receiving partially treated water from the 830-DISS facility at the end of the first semester 2007, increasing the flow rate to approximately 7 to 9 gpm.

The current GWTS configuration includes particulate filtration, air stripping to remove VOCs from extracted water, and granular activated carbon (GAC) to treat vapor effluent from

the air stripper. Treated ground water is discharged to the surrounding natural vegetation using misting towers. Treated vapors are discharged to the atmosphere under a permit from the San Joaquin Valley Unified Air Pollution Control District.

4.2.1.2. Central GSA Vadose Zone Remedy Implementation

In July 1994, DOE began soil vapor extraction at the Building 875 dry well VOC source area as a removal action. The soil vapor extraction wellfield and treatment system described in the GSA ROD and Remedial Design documents is fully implemented. Simultaneous ground water extraction in the vicinity lowers the elevation of the ground water surface and maximizes the volume of unsaturated soil influenced by vapor extraction. Soil vapor has historically been extracted from three to seven extraction wells, with others used as vapor inlet wells. In late 2007, Venturi™ flow meters were installed on each well. All seven extraction wells have been operating simultaneously since late 2007.

The current soil vapor treatment system (SVTS) consists of a water knockout chamber, a rotary vane blower, and four 140-pound (lb) vapor-phase GAC columns arranged in series. Treated vapors are discharged to the atmosphere under a permit from the San Joaquin Valley Unified Air Pollution Control District.

4.2.2. Eastern GSA Remedy Implementation

A GWTS operated in the Eastern GSA from 1991 to 2007 to remove VOCs from ground water. A map of the Eastern GSA showing the locations of monitoring, extraction, water-supply wells, and the treatment facility is presented as Figure 3. VOC-contaminated ground water was extracted from three wells (W-26R-03, W-25N01, and W-25N-24), located downgradient from the debris burial trenches, at a combined flow rate of 45 gpm. The extracted ground water was treated in three 1,000-lb granular activated carbon units that removed VOCs through adsorption. The treated effluent water was discharged to nearby Corral Hollow Creek.

Remediation efforts in the Eastern GSA have successfully reduced concentrations of TCE and other VOCs in ground water to below their respective cleanup standards set in the GSA ROD. The Eastern GSA ground water extraction and treatment system was shut off on February 15, 2007 with the regulatory approval. As required by the GSA ROD, ground water monitoring is being conducted for 5 years after shutdown to determine if VOC concentrations rise or "rebound" above cleanup standards. With one exception described in subsection 7.5.2 below, VOC (TCE) concentrations remain below their cleanup standards after four years and three months following shutdown of the treatment facility. If TCE concentrations remain below the cleanup standard (5 µg/L) until February 15, 2012, the post-shutdown monitoring will be complete. At that time, with concurrence of the regulatory agencies that cleanup is complete, DOE will initiate decommissioning of the Eastern GSA treatment facility and abandonment Eastern GSA wells.

4.3. System Operations/Operation and Maintenance

The GSA extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during this Five-Year Review. All required documentation is in place, and treatment system operations and maintenance (O&M) activities are consistent with established procedures and protocols.

O&M procedures are contained in the following documents:

- Health and Safety Plan, Quality Assurance/Quality Control Plan, Compliance Monitoring Plan, and Contingency Plan for the GSA OU, contained within the Remedial Design document.
- 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 #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.
- GSA Compliance Monitoring Plan and Contingency Plan included in Appendices F and G of the GSA Remedial Design (Rueth et al., 1998), until incorporated into and superseded by the Site-Wide Compliance Monitoring Plan/Contingency Plan for Remedies at LLNL Site 300 (Dibley, et al., 2009).
- LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (Goodrich and Lorega, 2009).
- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities (Daily, 2004).
- Eastern GSA Treatment Facility Operations Checklist (LLNL, 1999).
- Central GSA: Substantive Requirements and the Monitoring and Reporting Program issued by the California RWQCB and the Permit to Operate issued by the San Joaquin Valley Unified Air Pollution Control District.
- Eastern GSA: Substantive Requirements and the Monitoring and Reporting Program issued by the RWQCB.

Monitoring and optimizing the performance and efficiency of the extraction and treatment systems comprises a large portion of the O&M activities. Extracted ground water 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 GSA 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.
- Routinely inspecting and maintaining extraction well pumps, pipelines, and flow meters.
- Maintaining air stripper.
- Injecting anti-scaling compounds.
- Maintaining remote computer access and data collection capabilities.

The budgeted and actual costs associated with the management, investigation, testing, modeling, design, construction, and O&M of the environmental remediation activities within the GSA are tracked closely. The GSA OU has consistently operated well below the estimated annual operating costs presented in the ROD. Table 1 presents the actual costs for the last five fiscal years (2006 through 2010).

4.4. Institutional Controls

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

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

Table 2 presents descriptions of: (1) the institutional/land use control objective and duration, (2) the risk necessitating land use controls, and (3) the specific institutional/land use controls and implementation mechanisms used to prevent exposure to contamination at the GSA OU. Figure 10 shows the specific areas of the GSA OU where the institutional/land use controls have been maintained or implemented.

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

Institutional/land use controls are included in the Risk and Hazard Management Program contained in the Site-Wide Compliance Monitoring Plan. Any new or modified institutional/land use controls resulting from the Five-Year Review process will be incorporated in the Risk and Hazard Management Program contained in the Site-Wide Compliance Monitoring Plan. In addition, DOE will work with LLNL Site 300 Management to incorporate these institutional/land use controls into the Site 300 Integrated Strategic Plan or other appropriate institutional planning documents.

The land use controls and requirements described herein are only applicable to the GSA OU and associated contaminated environmental media that are being addressed through the

CERCLA process. DOE will continue to maintain and enforce these institutional/land use controls at the GSA OU for as long as necessary to protect human health and the environment.

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

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

5. Progress Since Last Review

This section describes the Protectiveness Statement and recommendations and follow-up actions from the second GSA Five-Year Review performed in 2006. It also describes the status of the actions recommended in this previous review.

5.1. Protectiveness Statement from Last Review

The 2006 GSA Five-Year Review determined that the remedy for the GSA OU was protective of human health and the environment. The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water.

No deficiencies in the remedy were identified during the 2006 Five-Year Review.

5.2. Recommendations and Follow-up Actions from the 2006 Five-Year Review

The following recommendations were included in the 2006 Five-Year Review.

1. Because cleanup standards (MCLs) have been achieved in Eastern GSA ground water, DOE/LLNL proposes to shut off the GWTS and monitor ground water to determine if VOC concentrations rebound above cleanup standards after extraction ceases. Ground water in the Eastern GSA will be monitored for a period of five years following shutdown of the ground water extraction and treatment system.
2. If VOC concentrations in ground water increase above cleanup standards, re-initiation of remediation efforts will be discussed with the EPA, DTSC, and RWQCB. The ground water system will be restarted and operated until cleanup standards are achieved, unless DOE and the regulatory agencies agree otherwise. Several pumping cycle iterations may be required to achieve the cleanup standards.

3. Further optimization of Central GSA wells W-872-02 and W-873-07 operations should be considered. This may include repositioning the pumps in these wells and/or changing the pumps in order to increase ground water yield, capture, and contaminant mass removal.
4. VOC concentrations in Central GSA well W-889-01 (in the northern plume area) should be closely monitored. If concentrations increase, this well should be considered for conversion to an extraction well.
5. Optimization of the Central GSA SVTS system should continue. Further optimization should include additional rebound testing to evaluate source magnitude, periodic reconfiguration of extraction versus inlet wells to optimize mass removal, and installation of individual vapor flow meters to more accurately track flow and mass removal from individual wells.
6. Because some VOCs may remain at the Central GSA following the achievement of subsurface soil cleanup standards for VOCs, a land use control will be added that prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use. This prohibition will be entered into the administrative record for the GSA ROD through a letter to the file. This letter to the file will also reference the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document into which this prohibition will be incorporated.
7. The changes in location-, chemical-, or action-specific requirements identified in Section 7.2 will be entered into the administrative record for the GSA ROD through a letter to the file.

No other follow-up actions were identified in the 2006 Five-Year Review.

5.3. Results of Implemented Actions

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

1. The Eastern GSA ground water extraction and treatment system was shut off on February 15, 2007 with regulatory approval. As required by the GSA ROD, ground water monitoring is being conducted for five years after shutdown (until February 15, 2012) to determine if VOC concentrations rise or "rebound" above cleanup standards.
2. As a result of 16 years of extraction and treatment at the Eastern GSA, TCE concentrations in ground water have remained below the 5 µg/L cleanup standard in all wells since 2007 when the facility was shut down, with the exception of one detection above 5 µg/L during the first semester of 2009 (6.9 µg/L in well W-26R-01 in May 2009). As described in section 7.5.2, well W-26R-01 and nearby well W-26R-04 were re-sampled for VOCs in June 2009. TCE concentrations did not exceed 5 µg/L in any of the re-samples, and the regulatory agencies agreed that monitoring of Eastern GSA wells could continue as described in the post-shutdown monitoring plan.
3. Optimization of wells W-872-02 and W-873-07 was initiated in early 2011 and is ongoing. Optimization includes repositioning pumps to increase yield and dissolved phase mass removal.

4. Total VOC concentrations in well W-889-01 have remained relatively stable since 2006, ranging from 24 to 38 µg/L. An extraction well will be installed in the vicinity of well W-889-01 in 2011. This extraction well will be connected to the Central GSA treatment facility as part of the evaluation and upgrade scheduled in 2012.
5. As a result of 17 years of soil vapor extraction, TCE vapor concentrations at Central GSA have declined from 529 to 15 $ppm_{v/v}$. Individual vapor flow meters were installed in the Central GSA vapor extraction wells from August 1st to November 7th 2007 to evaluate individual well performance. Soil vapor rebound was evaluated while the Central GSA SVTS was shut down during this time period. TCE vapor concentrations ranged from < 0.2 to 0.5 $ppm_{v/v}$ prior to shutdown to 1.7 to 26 $ppm_{v/v}$ at the end of the shutdown period, thereby showing modest rebound. Since late 2007, soil vapor has been extracted simultaneously using all seven vapor extraction wells. Extraction from all seven wells has also increased soil vapor mass removal.
6. A Memorandum documenting the formal incorporation of a land use control that prohibits the transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use was placed in the Administrative File on May 24, 2011. This Memorandum also references the LLNL Site 300 Integrated Strategic Plan into which this prohibition will be incorporated.
7. A Memorandum documenting the changes that have been made to location-, chemical-, or action-specific requirements since the Final ROD for the GSA OU was signed in 1997 was placed in the Administrative File on May 24, 2011.

5.4. Status of Other Prior Issues

There are no other prior issues.

6. Five-Year Review Process

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

- Leslie Ferry, Program Leader, LLNL.
- Valerie Dibley, Deputy Program Leader, LLNL.
- Vic Madrid, Hydrogeologic Team Leader, LLNL.
- John Valett, Hydrogeologist, Weiss Associates.

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

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300.
- Final Feasibility Study for the General Services Area at Lawrence Livermore National Laboratory Site 300.
- Final Record of Decision for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300.

- Remedial Design Document for the General Services Area Treatment Facilities, Lawrence Livermore National Laboratory Site 300.
- Building 875 Inhalation Risk Mitigation Evaluation at the Central GSA at Lawrence Livermore National Laboratory Site 300.
- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities.
- First Five-Year Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300.
- Second Five-Year Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300.
- Semi-annual Site-Wide CMRs that include evaluations of remediation progress in the Central GSA (Dibley et al., 2006b, 2007c, 2007d, 2008c, 2009c, 2009d, 2010a, 2010b and 2011; LLNL 2008).

This Five-Year Review evaluates subsurface contaminant concentration and remediation system performance data collected through calendar year 2010.

The completed 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 o*n X and X, respectively. Note: the dates of the public notices will be filled in once the draft document and the final document are completed and the notices are sent to the newspapers.

7. Five-Year Review Findings

7.1. Interviews and Site Inspection

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

There is a continuous presence of Site 300 Environmental Restoration Program staff at Site 300 that inspect: (1) the extraction wellfield and treatment facilities weekly, and (2) the monitoring wellfield during sampling activities. The Site 300 Environmental Restoration Program conducts self-assessment inspections of facilities and DOE conducts quarterly inspections of remediation activities at Site 300. The RWQCB RPM performs site inspections twice a year, and EPA and DTSC RPMs perform periodic site inspections

Operational issues and resulting corrective actions identified during routine inspections associated with the GSA treatment systems and extraction wellfields are: (1) described in detail in the semi-annual Site 300 CMRs, and (2) discussed and presented in the monthly RPM Project Updates. The contents of the Project Updates are incorporated into the RPM meeting minutes that are distributed following the meetings.

The EPA performed their construction completion inspection on July 13, 2005. EPA inspected the GSA treatment systems and interviewed LLNL staff. There were no major issues identified. DOE did not receive the final report.

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

The following changes have been made to location-, chemical-, or action-specific requirements since the Final ROD for the GSA OU was signed in 1997:

- The National Toxics Rule (NTR) was last amended on November 9, 1999. The NTR, is an applicable or relevant and appropriate requirements (ARAR) for the discharge to Corral Hollow Creek of treated ground water from the remediation system in the Eastern GSA. However, the Eastern GSA surface water discharge was eliminated before 2010, therefore there is no impact on the protectiveness of the remedy.
- The Federal MCL for total trihalomethanes (TTHM) was changed from 100 µg/L to 80 µg/L in 2002. No TTHMs were detected in GSA ground water in 2010. Therefore, there is no impact on the protectiveness of the remedy related to the reduction in the TTHM MCL. This change to the cleanup standard was entered into the administrative record for the GSA ROD through a letter to the file.
- The California Toxics Rule (CTR) was adopted on May 18, 2000 and amended on February 13, 2001. The CTR is an ARAR for the discharge to Corral Hollow Creek of treated ground water from the remediation system in the Eastern GSA. However, the Eastern GSA surface water discharge was eliminated before 2010, therefore there is no impact on the protectiveness of the remedy.
- The State Implementation Policy (SIP) was adopted in March 2000 and modified on February 24, 2005. It contains policies and procedures for implementation of the NTR and the CTR and is also an ARAR for the discharge to Corral Hollow Creek of treated ground water from the remediation system in the Eastern GSA. However, the Eastern GSA surface water discharge was eliminated before 2010, therefore there is no impact on the protectiveness of the remedy.
- The California Code and Regulations, Title 22, Section 67391.1 was adopted April 19, 2003. It contains requirements for imposing legal limitations on future site uses and activities through a land use covenant. There is no impact on the protectiveness of the remedy related to the new requirement for a land use covenant at the time of property transfer.

The following changes have been made to location-, chemical-, or action-specific requirements since the 2006 Five-Year Review:

- The State of California established an MCL (6 µg/l) for perchlorate on October 18, 2007. Perchlorate is not a COC for the GSA OU therefore there is no impact on the protectiveness of the remedy.
- The EPA National Pollution Discharge Elimination System (NPDES) Pesticide Rule changed in 2011, however, no Site 300 treatment systems currently discharge to the ground surface or fall under an NPDES permit; therefore, there is no impact on the protectiveness of the remedy.

There have been no changes in cleanup standards since the 1997 GSA ROD.

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

There have been no significant changes in land or ground water use in the GSA OU since the 2006 Five-Year Review. The OU is still accessible only to DOE/LLNL workers. Buildings continue to be used as craft shops, storage buildings, and offices. Ground water underlying the OU is not used for human consumption. Hetch Hetchy water is expected to become the primary water supply at Site 300, and Well 20 will become a backup water supply to be used for fire control, explosives processing, and dust suppression. Well 18 is currently on stand-by status but will eventually be abandoned. The transition from Wells 18 and 20 is an ongoing process and the overall schedule and post-transition plans are still being developed. Wells 18 and 20 are located near the southern site boundary, southwest of the GSA OU. No effects to the GSA OU have been identified or are anticipated.

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

There have been no changes in exposure pathways, toxicity, and other contaminant characteristics in the GSA OU since the GSA ROD was signed in 1997.

7.5. Data Review and Evaluation

7.5.1. Central GSA Remediation Progress

7.5.1.1. Central GSA Ground Water Remediation Progress

Significant progress has been made towards remediating ground water in the Central GSA area since ground water extraction and treatment was initiated in 1993. Ongoing performance of the Central GSA ground water remediation system is evaluated using multiple data sets including:

- Comparing historic maximum ground water VOC concentrations and plume extent to current concentrations and extent,
- Reviewing temporal VOC trends in individual wells and dissolved-phase VOC mass removal, and
- Evaluating extraction wellfield capture zones.

These performance indicators are summarized and documented in the annual CMR reports.

Ground water remediation has been ongoing at the Central GSA since 1993. Prior to remediation, the historic maximum total VOC concentration in Central GSA ground water was approximately 272,000 µg/L (well W-875-07, 1992), compared to the 2010 maximum (June) of 2,000 µg/L (dry well pad area well W-7I). The maximum total VOC concentration shown on Figure 8 (second semester of 2010) is 630 µg/L in well W-875-07. The hydraulic capture zones presented in Figure 8 were prepared using data from the second semester 2010. A capture zone is not shown for extraction well W-872-02 on Figure 8 because this well has either been off or had very minimal ground water extraction occurring since the capture zone depiction began in the CMRs in 2007. These capture zones show that extraction wells generally capture the area of highest concentrations in the VOC plume, including the highest concentrations in the dry well pad area. Optimization (pump re-positioning and/or replacement) of extraction wells W-872-02,

W-873-03, W-7O and W-7R are ongoing to further increase drawdown and contaminant mass removal.

To evaluate remediation progress, Figure 11 shows a comparison of the spatial distribution of VOCs in Central GSA ground water between 2005 and 2010. Although the overall extent of total VOCs in ground water with concentration above the 0.5 µg/L reporting limit has not changed significantly, the area of highest concentration has been reduced. The area with VOC concentrations greater than 50 µg/L has been significantly reduced and the area with VOC concentrations greater than 100 µg/L is constrained to the immediate vicinity of the dry well pad.

Long-term VOC trends in Central GSA ground water extraction wells, as well as the monthly volume of ground water treated at the Central GSA treatment facility, are presented on Figure 12 (a and b). This figure depicts total VOC concentration axes on log scale to better differentiate trends between wells. Figures 12a and 12b show VOC trends for the dry well pad area extraction wells, and the other (non-pad area) extraction wells, respectively. The extraction wells generally exhibit decreasing VOC concentration trends. The TCE concentration in offsite well W-35A-10 has remained generally stable during the last five years. Optimization of extraction wells in this area (W-870-02 and W-873-07) was initiated in early 2011 to increase yield and dissolved-phase mass removal.

Figure 13 shows VOC trends for monitoring wells in the northern plume area. These wells, including W-889-01, have generally shown stable trends over the past five years. As shown on Figure 8, one new extraction well (W-CGSA-2708) is proposed for completion in the immediate vicinity of W-889-01 to increase capture of VOCs and contaminant mass removal in the northern plume area.

As shown on Figure 14, the Central GSA ground water extraction and treatment system removed 25.36 kilograms (kg) of VOCs by the end of 2010. Modeling performed in the Remedial Design (Rueth, et al, 1998) estimated that approximately 8 kg of TCE would be removed by ground water extraction by 2010. The actual mass removed by 2010 is approximately three times the estimated mass removed, indicating that the source term in the model may have been underestimated. This underestimation may be due to uncertainties in the source term, as discussed in the Remedial Design.

7.5.1.2.Central GSA Vadose Zone Remediation Progress

Ongoing performance of the Central GSA soil vapor extraction system is evaluated by reviewing temporal trends in soil vapor extraction well concentrations during both active extraction and non-active rebound periods.

Vadose zone remediation has been ongoing at the Building 875 dry well contaminant source area since July 1994. Simultaneous ground water extraction in the vicinity lowers the elevation of the ground water surface and maximizes the volume of unsaturated soil influenced by vapor extraction. Soil vapor has historically been extracted from three to seven extraction wells, with others used as vapor inlet wells. All seven extraction wells have been operating simultaneously since late 2007. The system operated from 1994 to 2003 at an average monthly flow volume of 520,000 cubic feet. As shown on Figure 15, monthly facility flow volumes were more closely tracked after 2003. Figure 15 also shows TCE vapor concentrations in individual extraction wells have decreased from a start-up maximum of 529 $ppm_{v/v}$ to a current (second semester 2010) maximum of 15 $ppm_{v/v}$. During periods of facility shutdown, TCE vapor concentrations in

the extraction wells have generally rebounded from low concentrations just prior to shutdown, however the magnitude of this rebound has generally decreased over time. During a three month long rebound test in late 2007, TCE vapor concentrations showed modest rebound ranging from <0.2 to 0.5 $ppm_{v/v}$ prior to shutdown to 1.7 to 26 $ppm_{v/v}$ at the end of the shutdown period. The continued decline in rebound vapor concentrations is an indication of significant source area remediation progress.

TCE soil vapor concentrations in the facility influent have decreased over time from a maximum of 417 $ppm_{v/v}$ in January 1995 (six months after start-up) to below 0.2 $ppm_{v/v}$ in late 2005. Between late 2005 and late 2007, influent concentrations varied from 0.4 to 1.1 $ppm_{v/v}$. Influent sampling stopped in late 2007 after the individual well Venturi™ flow meters were installed.

As shown on Figure 14, the vapor extraction and treatment system has removed 74.72 kg of VOCs as of the end of 2010. Modeling performed in the Remedial Design estimated that approximately 35 kg of TCE would be removed by soil vapor extraction by 2010. The actual mass removed by 2010 is approximately twice the estimated mass removed, indicating that the source term in the model may have been underestimated. This underestimation may be due to uncertainties in the source term, as discussed in the Remedial Design.

Future optimization of the Central GSA vapor treatment system will include pneumatic communication and additional rebound testing, and periodic reconfiguration of extraction and air inlet wells.

7.5.2. Eastern GSA Remediation Progress

DOE began ground water remediation at the Eastern GSA in 1991 as a removal action and continued as a remedial action after the 1997 GSA ROD. As of the second semester 2005, and shown on Figure 16, remediation efforts in the Eastern GSA reduced concentrations of TCE in ground water from a historic maximum of 74 µg/L to below analytical reporting limits (0.5 µg/L) in the majority of wells and to below the 5 µg/L cleanup standard in all wells, including the three extraction wells (Figure 16a), the monitoring wells in the vicinity of the debris burial pit (Figure 16b), and wells downgradient of the debris burial pit (Figure 16c). Figure 16a also shows the monthly volume of treated ground water at the Eastern GSA facility. Figure 17 is a set of time-series maps showing changes in the extent and concentrations of TCE in ground water in the Eastern GSA from 1990 through 2010. As of the second semester 2005, the portion of the plume exceeding cleanup standards has been eliminated.

The Eastern GSA ground water extraction and treatment system was shut off on February 15, 2007 with regulatory approval. As required by the GSA ROD, ground water monitoring is being conducted for 5 years after shutdown (to February 15, 2012) to determine if VOC concentrations rise or "rebound" above cleanup standards. Additionally, in the Eastern GSA Compliance Feasibility Report submitted to regulatory agencies on July 15, 2007, DOE/LLNL evaluated onsite discharge options that could be implemented if VOC concentrations rebounded above cleanup standards requiring that the Eastern GSA extraction and treatment system be restarted (Holtzapple, 2007). Since February 2007, TCE concentrations in ground water have remained below the 5 µg/L cleanup standard in all wells, with the exception of one detection above 5 µg/L during the first semester of 2009 (6.9 µg/L in well W-26R-01 in May 2009). Well W-26R-01 and nearby well W-26R-04 were re-sampled for VOCs in June 2009. During the re-sample event, four ground water samples were collected from each well;

two collected after low flow purging and two after purging three casing volumes. For each purge method, the two samples were submitted to different analytical laboratories. TCE concentrations did not exceed 5 µg/L in any of the eight ground water samples collected during the June re-sampling event. The regulatory agencies agreed that monitoring of Eastern GSA wells could continue as described in the post-shutdown monitoring plan. If TCE concentrations remain below the cleanup standard (5 µg/L) in all wells to February 15, 2012, DOE will initiate conversations with the regulators to decommission the Eastern GSA treatment facility and abandon Eastern GSA wells.

As shown on Figure 14, the Eastern GSA ground water extraction and treatment system had removed 7.56 kg of VOCs as of February 2007.

7.5.3. Risk Mitigation Remediation Progress

The baseline human health risk assessment conducted in 1991 estimated a maximum excess carcinogenic risk of 7×10^{-2} if ground water from a hypothetical water-supply well located at the site boundary near the Building 875 dry wells were to be ingested over a 70-yr period. The corresponding noncarcinogenic hazard index was 560. As described in Section 7.5, the VOC concentrations in the Central GSA ground water have been reduced from a pre-remediation concentration of total VOCs in ground water of 272,000 μg/L to 630 μg/L, as of the second semester 2010. Although this risk has been reduced through remediation, TCE concentrations remain above cleanup standards in Central GSA ground water.

The baseline risk assessment also estimated an excess cancer risk to onsite workers from TCE vapors migrating into Building 875 of 1×10^{-5}. As described in Section 3.5, soil vapor extraction has contributed to reducing the excess cancer risk due to inhalation of VOC vapors migrating into Building 875 from 1×10^{-5} prior to remediation to 9.5×10^{-7} in 2000. Inhalation risk within Building 875 is no longer of concern.

The 1991 baseline human health risk assessment estimated an excess carcinogenic risk of 5×10^{-5} for ingesting ground water from a hypothetical water-supply well located at the site boundary near the Eastern GSA debris burial trench. As described in Section 7.5, the VOC concentrations in Eastern GSA ground water have been reduced to below cleanup standards. There were no VOCs detected above cleanup standards in ground water offsite at the site boundary near the debris burial trench.

The risk associated with potential use of contaminated ground water at two offsite wells (CDF-1 and SR-1) was approximately 10^{-5}. As described in Section 7.5, the VOC concentrations in Eastern GSA ground water have been reduced to below cleanup standards. There were no VOCs detected in ground water samples from CDF1 in 2010.

No unacceptable risk or hazard was associated with potential exposure to VOCs in surface soil.

The baseline ecological assessment, conducted to evaluate the potential for adverse impact to plants and animals from long-term exposure to contaminants in the GSA OU, determined that VOCs do not pose ecological risk in this area. This determination was based on estimates of potential hazard from exposure to contaminants that were calculated for mammal and aquatic species that could potentially inhabit this area, as well as biological surveys conducted to determine which species actually inhabit or migrate through the GSA. No information was identified during this review to question the ecological protectiveness of the remedy.

7.5.4. New Sources, Releases, or Contaminants

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

7.5.5. New Technology Assessment

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

8. 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.

This Five-Year Review determined that the remedy for the GSA OU was protective based on the following:

- Ground water and dual-phase extraction and treatment are effectively reducing contaminant concentrations and mass in the subsurface. In the Central GSA, the current maximum VOC concentrations in both ground water and soil vapor have decreased by over two orders of magnitude. Soil vapor extraction at the Building 875 release site has contributed to reducing the human health risk due to inhalation of TCE vapors within nearby Building 875 to a level that is not of concern. VOCs remain below reporting limits in the Central GSA guard wells.
- Ground water remediation in the Eastern GSA has successfully reduced concentrations of TCE and other VOCs to below cleanup standards. Therefore, DOE/LLNL shut off the ground water extraction and treatment system in February 2007 and continues to monitor ground water to determine if VOC concentrations rise or "rebound" above cleanup standards. Historically, trace concentrations of VOCs have been sporadically detected in the Eastern GSA guard wells; however, only one TCE detection has been observed since 1994 (0.54 µg/L in W-25N-07 in 2006).
- Ground water and vapor treatment systems are performing as designed and will continue to be operated and optimized. Optimization may include installing new extraction wells, adding higher capacity pumps to maximize yield and to increase hydraulic capture, and adding additional effluent discharge technologies, including injection wells and misting towers, where appropriate.
- System operation procedures are consistent with requirements.
- Costs have generally been within budget, except when extra costs were incurred to address unanticipated problems or regulatory requests.
- No early indicators of potential interim remedy failure were identified.
- All required institutional controls are in place and no current or planned changes in land use at the site suggest that they are not or would not be effective.

- The Health and Safety Plan and Site-Wide Contingency Plan are in place, sufficient to control risks, and properly implemented.
- There have been no changes in location-, chemical-, or action-specific requirements that change the protectiveness of the remedy, nor have there been changes in exposure pathways, toxicity, and other contaminant characteristics.
- There have been no changes in risk assessment methodologies that could call the protectiveness of the remedy into question.
- No new contaminants, source areas, or remedy by-products have been found in the GSA OU since the previous Five-Year Review.
- No additional information has been identified that would call the protectiveness of the remedy into question.

9. Deficiencies

No deficiencies were identified during the Five-Year Review process.

10. Recommendations and Follow-Up Actions

The following recommendations to be carried out by the United States (U.S.) Department of Energy (DOE) were developed during the review process:

1. Drill and install one new extraction well (W-CGSA-2708) to increase hydraulic capture of volatile organic compound (VOCs) and contaminant mass removal in the northern plume area. This new extraction well would be connected to the Central General Services Area (GSA) ground water extraction and treatment system.

No other follow-up actions were identified related to this Five-Year Review. As discussed below, these recommendations do not affect the protectiveness of the remedy.

DOE will: (1) estimate costs and the timeframe necessary to accomplish the new work scope; (2) prioritize new work scope and present these priorities to the regulatory agencies; (3) incorporate the new work scope into upcoming fiscal year budget requests; and (4) develop a schedule for implementing the work.

11. Protectiveness Statement

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

The cleanup standards for GSA OU ground water are drinking water standards. Because drinking water standards do not differentiate between industrial and residential use, the ground water cleanup remedy will be protective under any land use scenario upon completion.

The 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. This prohibition was entered into the administrative record for the GSA through a letter to the file. This prohibition will remain in place until and unless a risk assessment is performed in accordance with current U.S. EPA risk assessment guidance and is agreed by the DOE, the EPA, the DTSC, and RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use.

12. Next Review

The next statutory review will be conducted within five years of the issuance date of this Five-Year Review report.

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14. Acronyms and Abbreviations

830-DISS	Building 830-Distal South ground water extraction and treatment system
ARARs	Applicable or relevant and appropriate requirements
ATA	Advanced Test Accelerator
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMR	Compliance Monitoring Reports
COCs	Contaminants of concern
CTR	California Toxics Rule
DCE	Dichloroethene
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EPA	Environmental Protection Agency
ERD	Environmental Restoration Department
ft	Feet
ft/day	Feet per day
GAC	Granular activated carbon
gpm	Gallons per minute
GSA	General Services Area
GWTS	Ground water extraction and treatment system
HE	High explosives
HMX	High-Melting Explosive
HSU	Hydrostratigraphic unit
kg	Kilogram
lb	Pound
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilograms
mg/L	Milligrams per liter
MNA	Monitored natural attenuation
NPDES	National Pollution Discharge Elimination System
NTR	National Toxics Rule
O&M	Operation and maintenance
OU	Operable unit
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethene
pCi/L	picoCuries per liter

$ppm_{v/v}$	Parts per million on a volume-to-volume basis
Qal	Quaternary alluvium
Qt	Quaternary alluvial terrace
RCRA	Resource Conservation and Recovery Act
RDX	Research Department explosive
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPMs	Remedial Project Managers
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendment Reauthorization Act
SIP	State Implementation Policy
SVTS	Soil vapor extraction and treat system
TBOS/TKEBS	Tetrabutyl orthosilicate/ Tetrakis (2-ethylbutyl) silane
TCA	Trichloroethane
TCE	Trichloroethene
$Tnbs_1$	Tertiary Neroly Lower Blue Sandstone
$Tnbs_2$	Tertiary Neroly Upper Blue Sandstone
$Tnsc_1$	Tertiary Neroly Middle siltstone/claystone
TTHM	Total Trihalomethanes
U.S.	United States
VOCs	Volatile organic compounds
yd^3	Cubic yards
µg/L	Micrograms per liter

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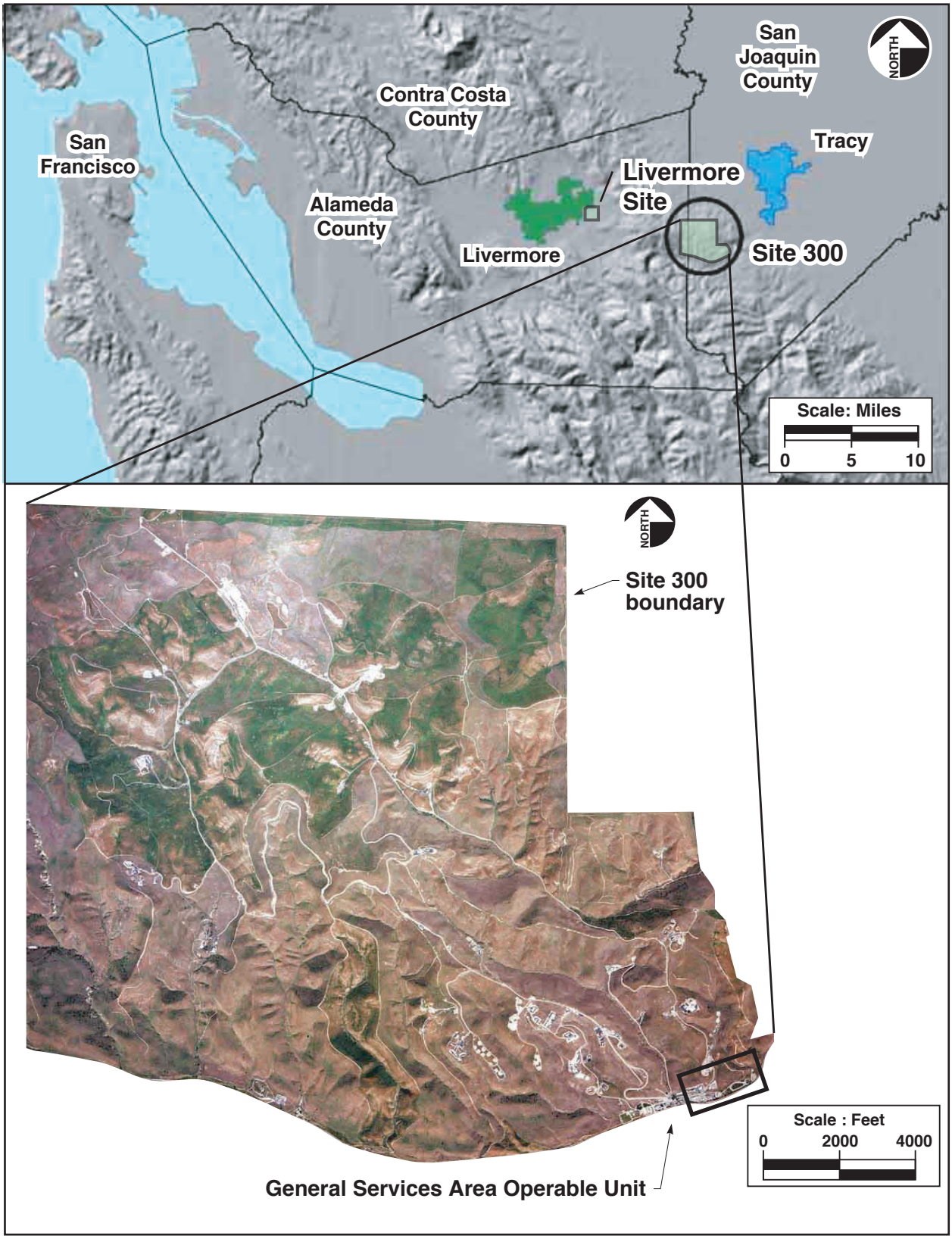

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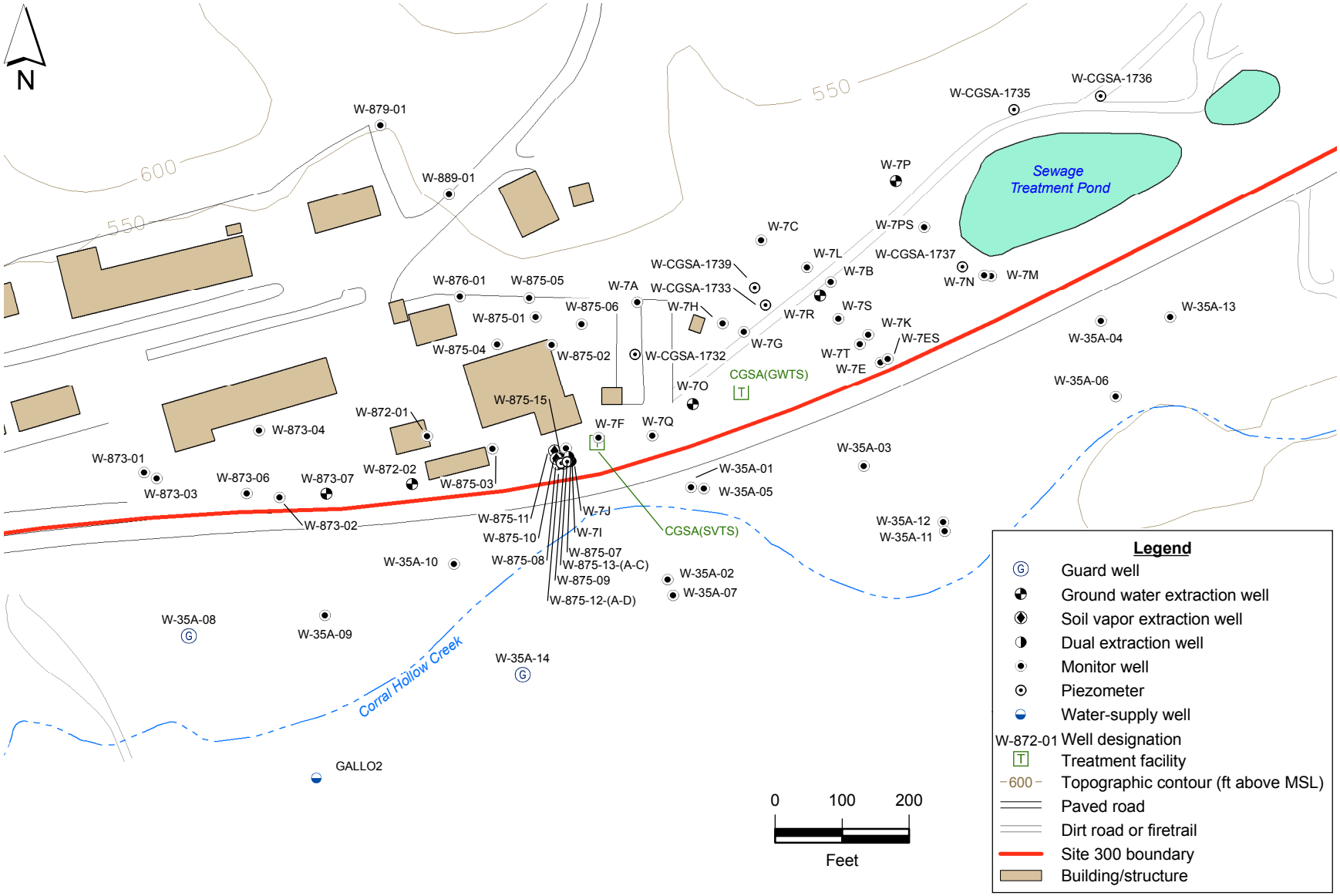

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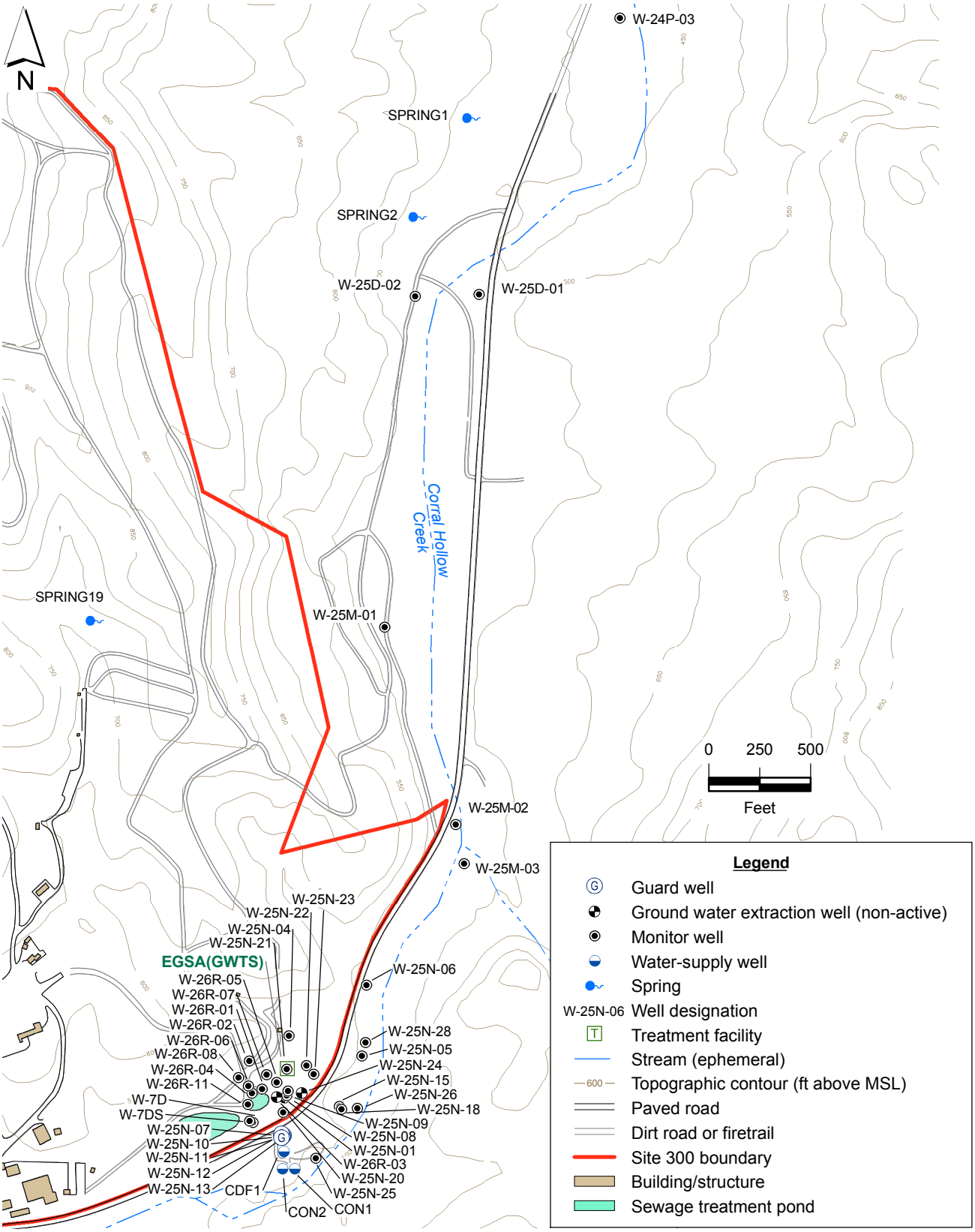

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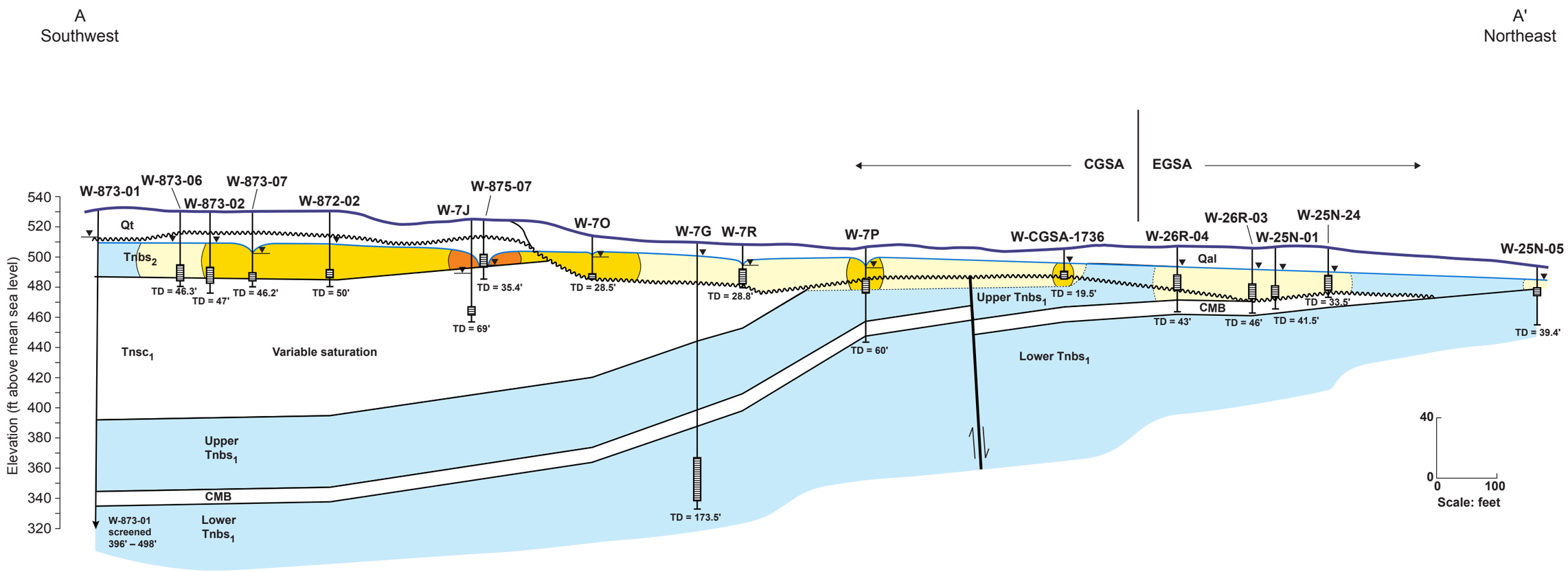

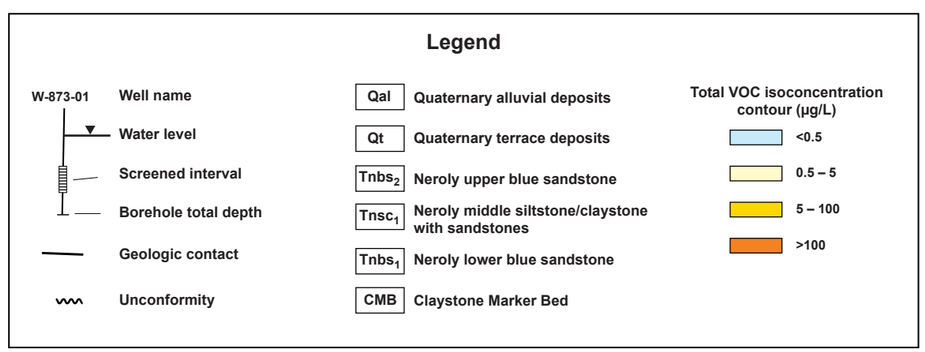

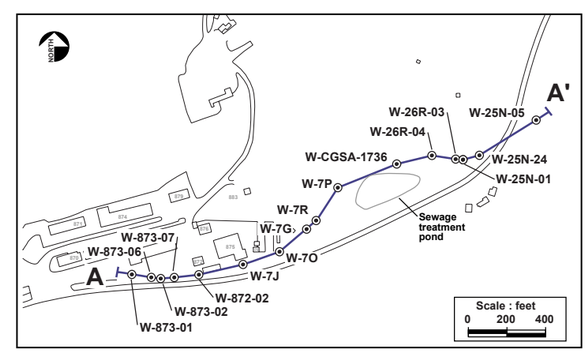

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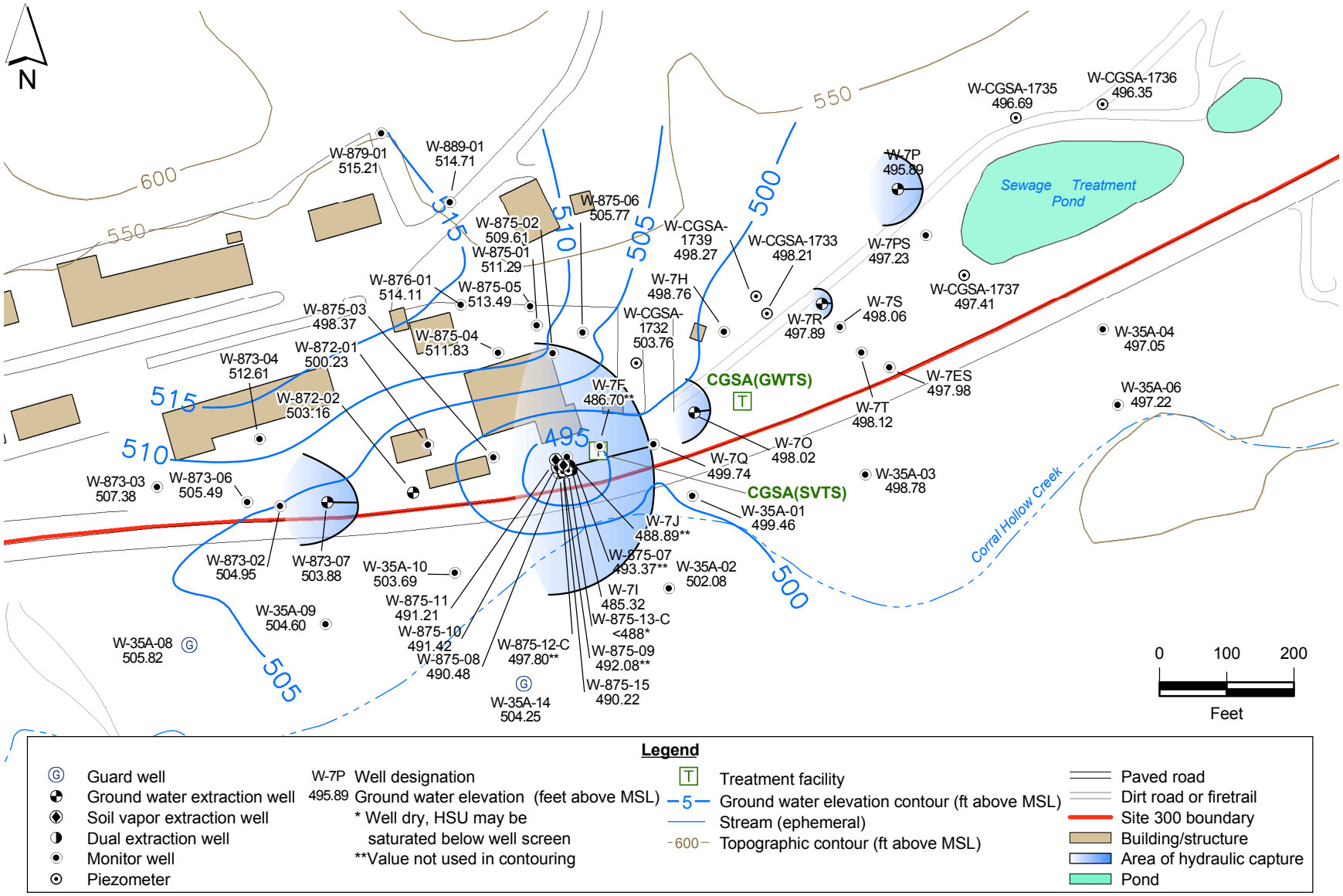
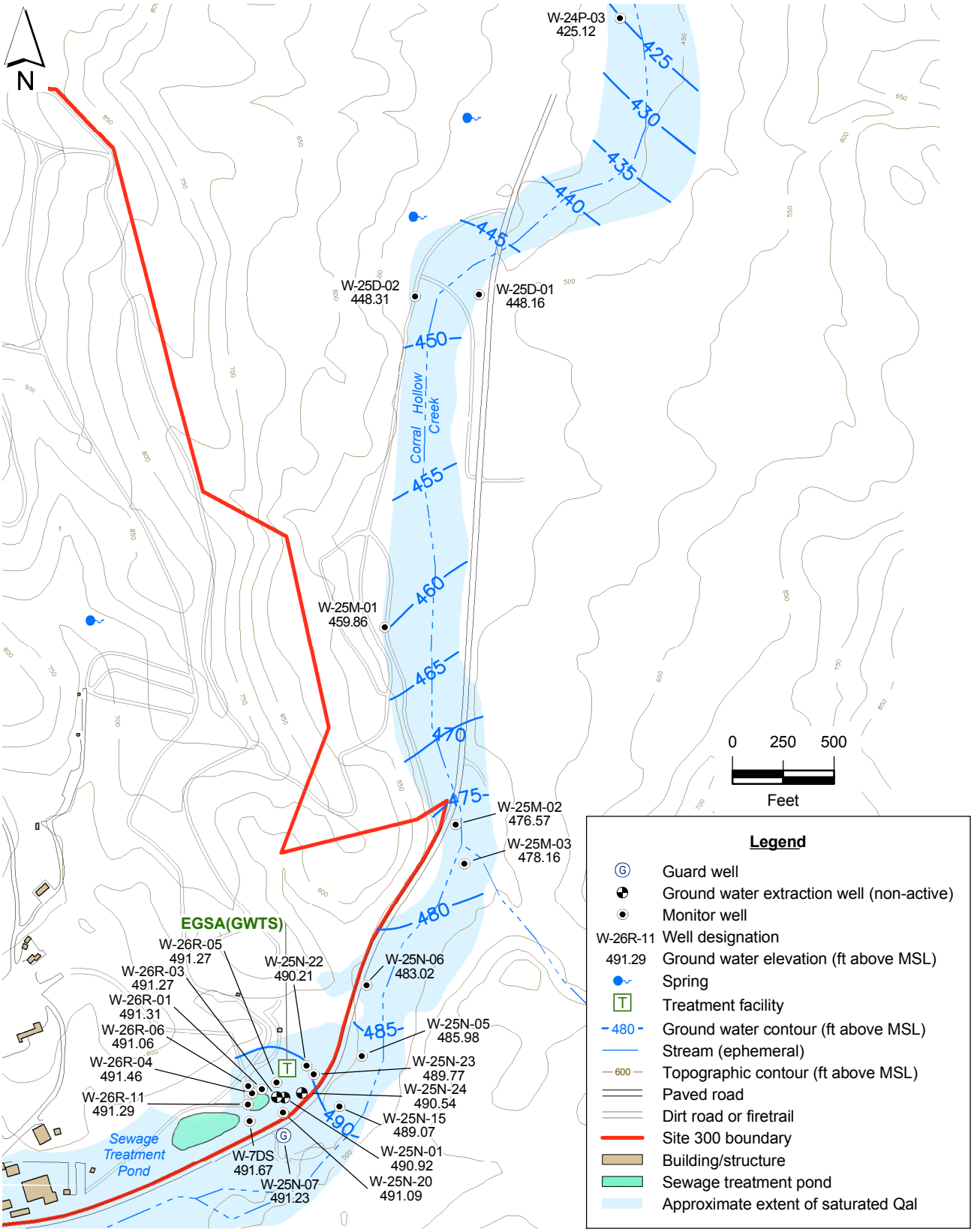


Legend

Ⓖ Guard well	W-7P Well designation	T Treatment facility	Paved road
Ground water extraction well	495.89 Ground water elevation (feet above MSL)	5 Ground water elevation contour (ft above MSL)	Dirt road or firetrail
Soil vapor extraction well	* Well dry, HSU may be saturated below well screen	Stream (ephemeral)	Site 300 boundary
Dual extraction well	**Value not used in contouring	600 Topographic contour (ft above MSL)	Building/structure
Monitor well			Area of hydraulic capture
Piezometer			Pond

Figure 5. Central General Services Area Operable Unit ground water potentiometric surface map for the Qt-Tnsc$_1$ and Qal-Tnbs$_1$ hydrostratigraphic units including hydraulic capture zones.



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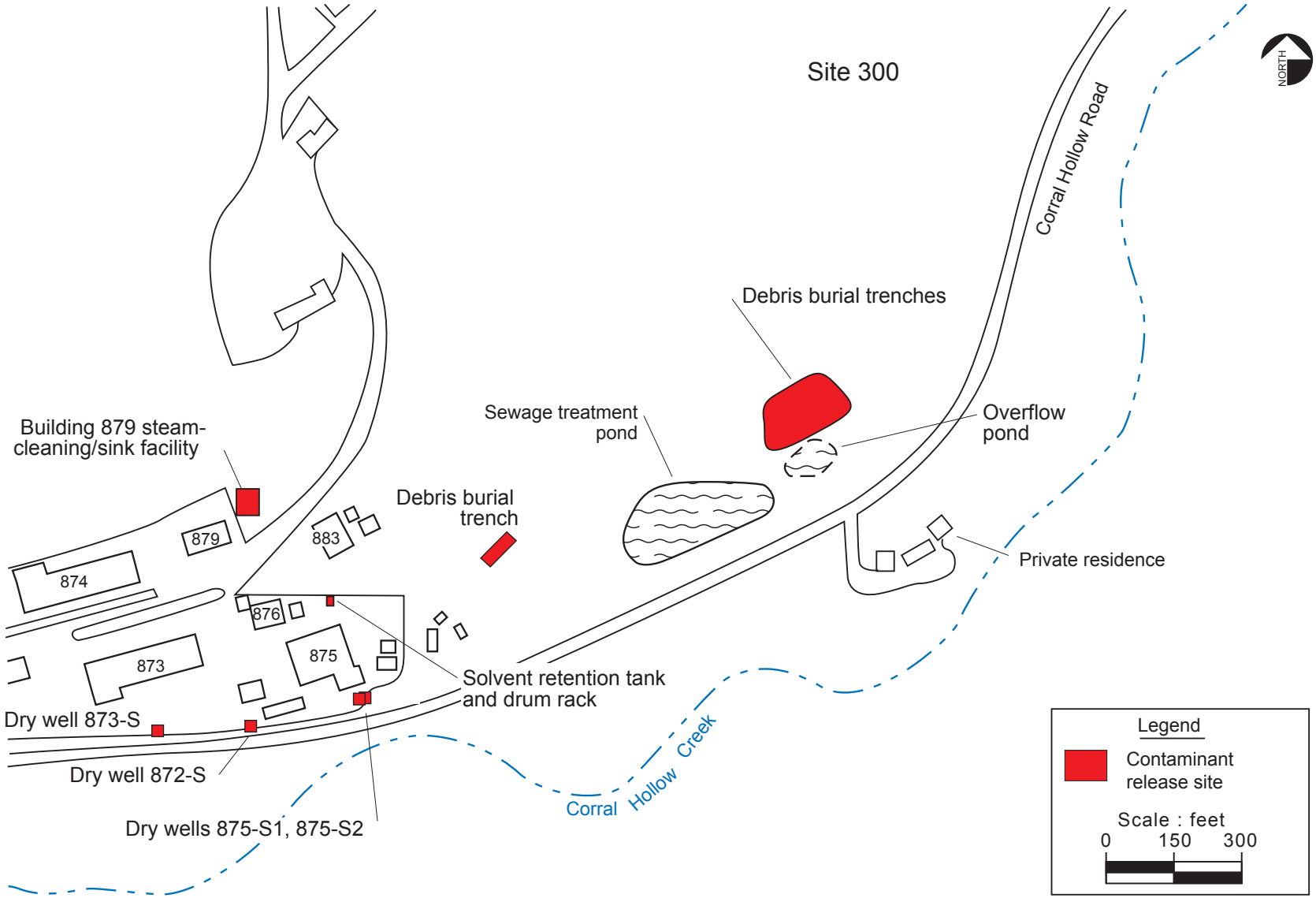

Figure 7. Contaminant release sites in the General Services Area.

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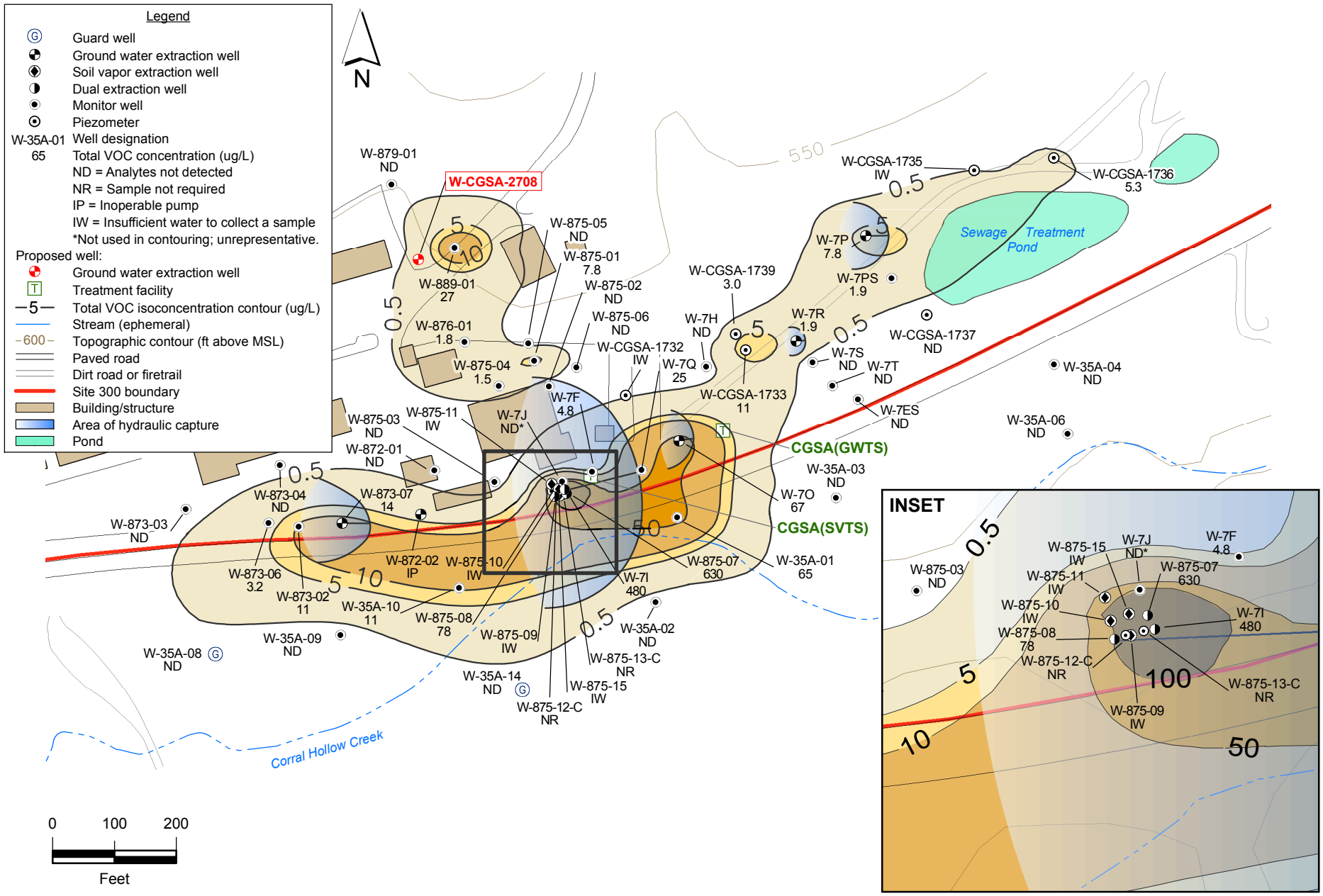

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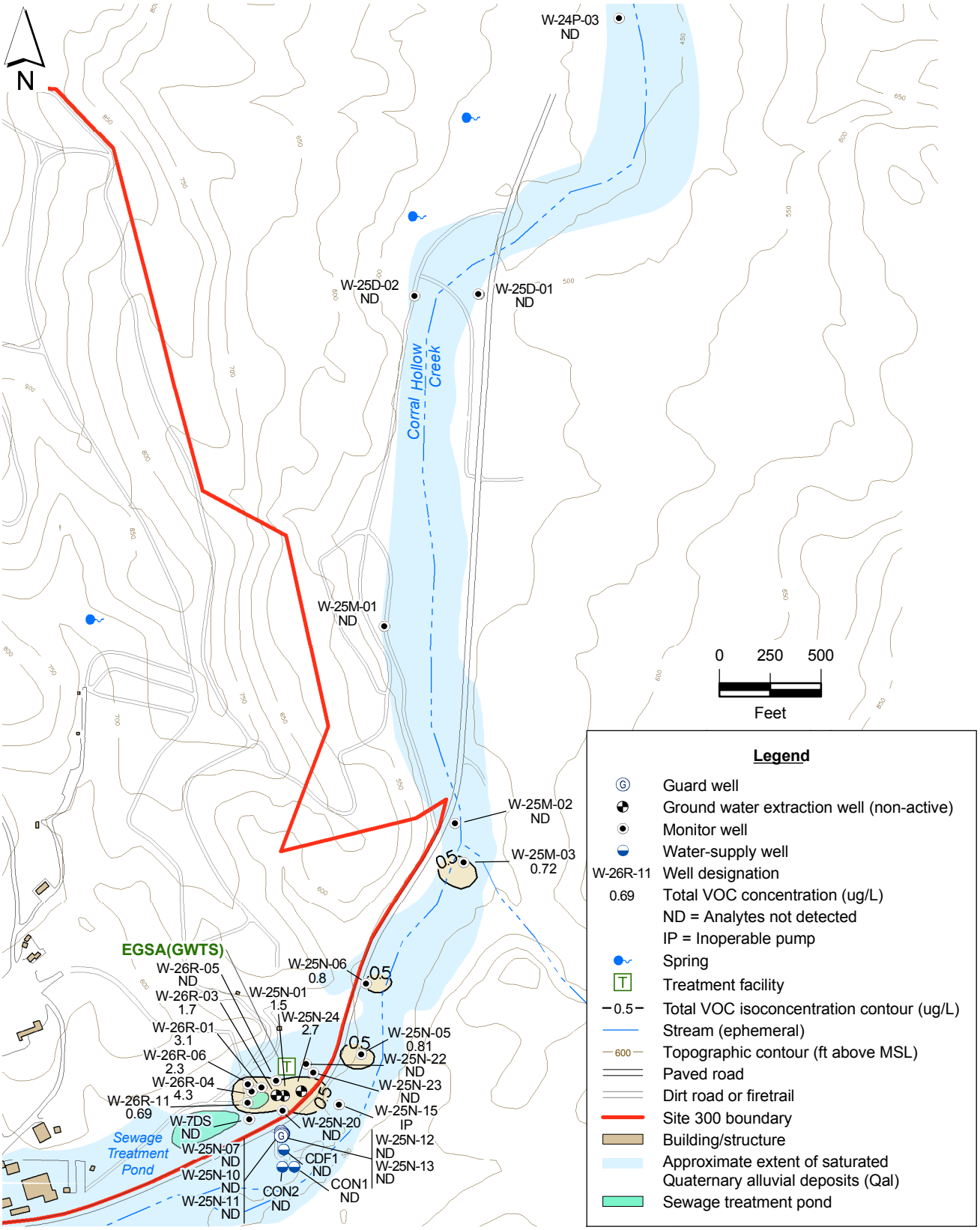

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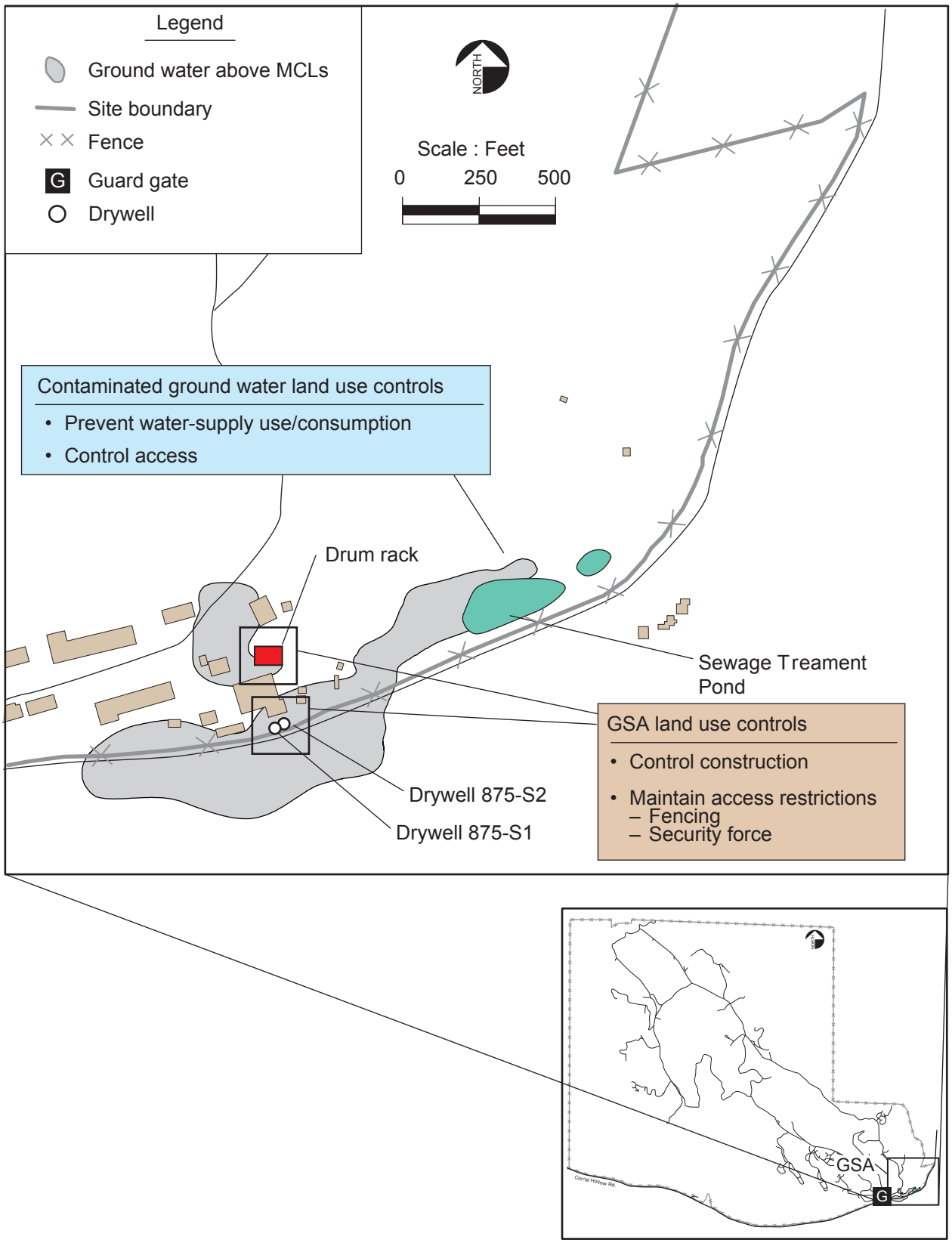

Figure 10. General Services Area (GSA) institutional/land use controls.

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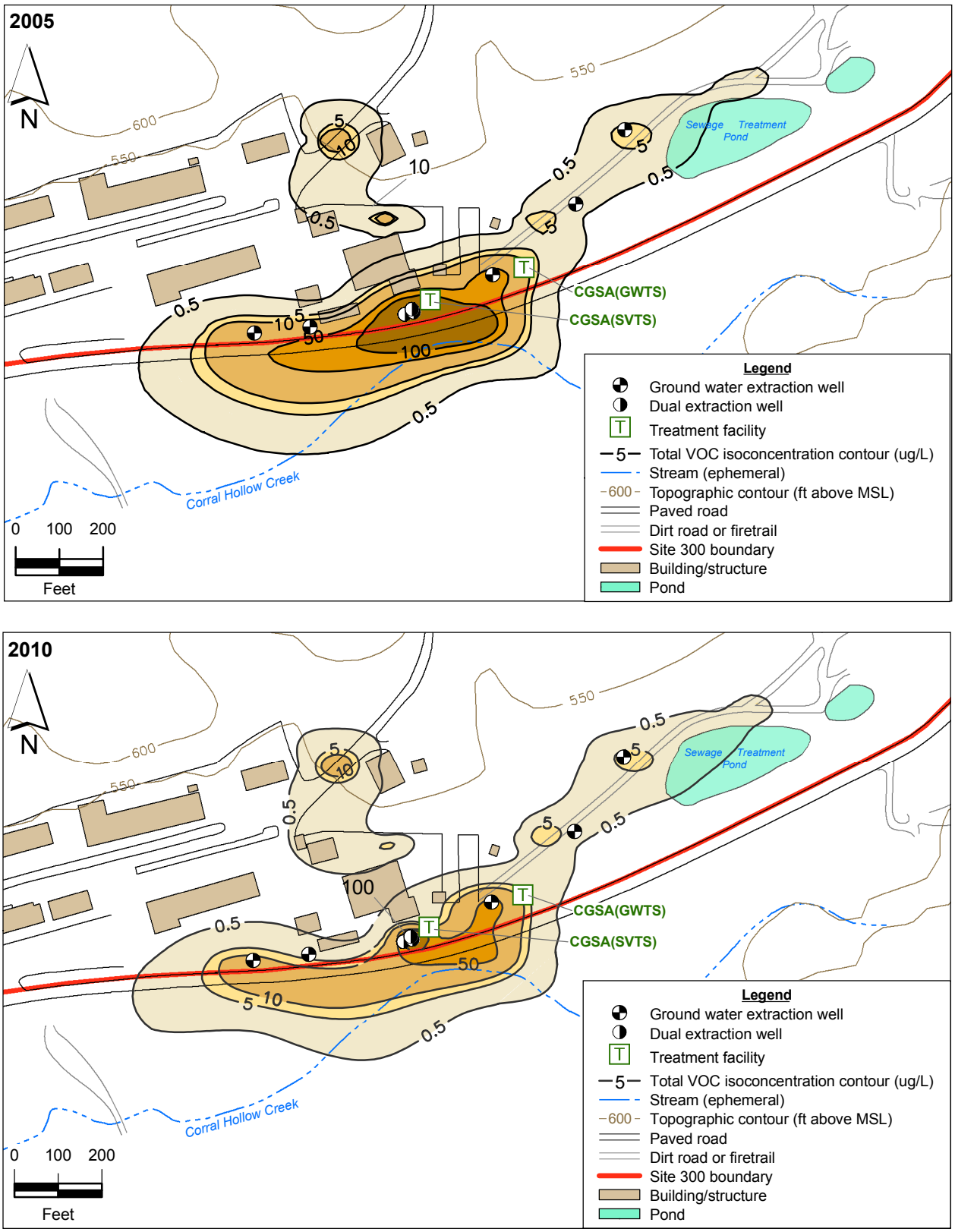

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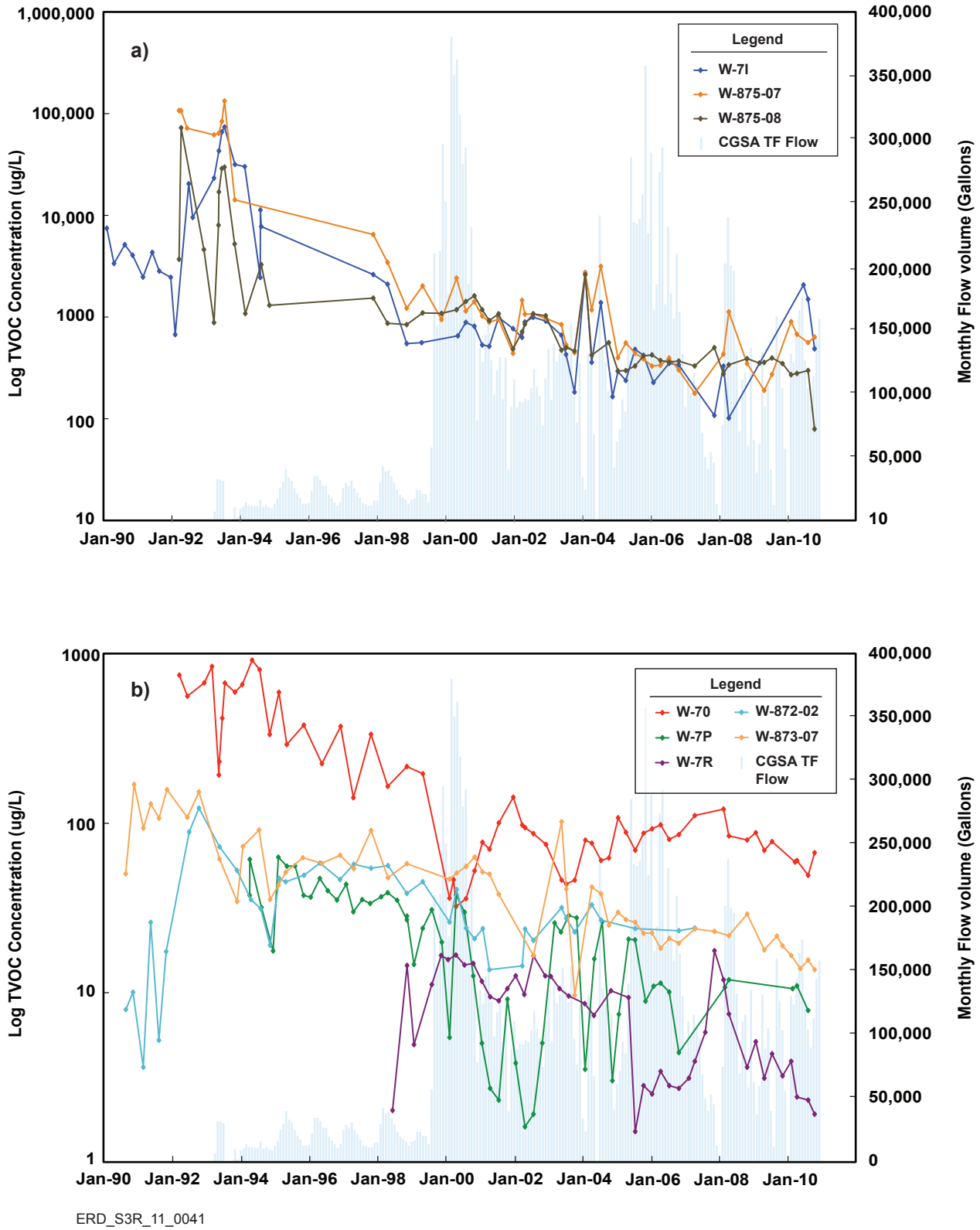

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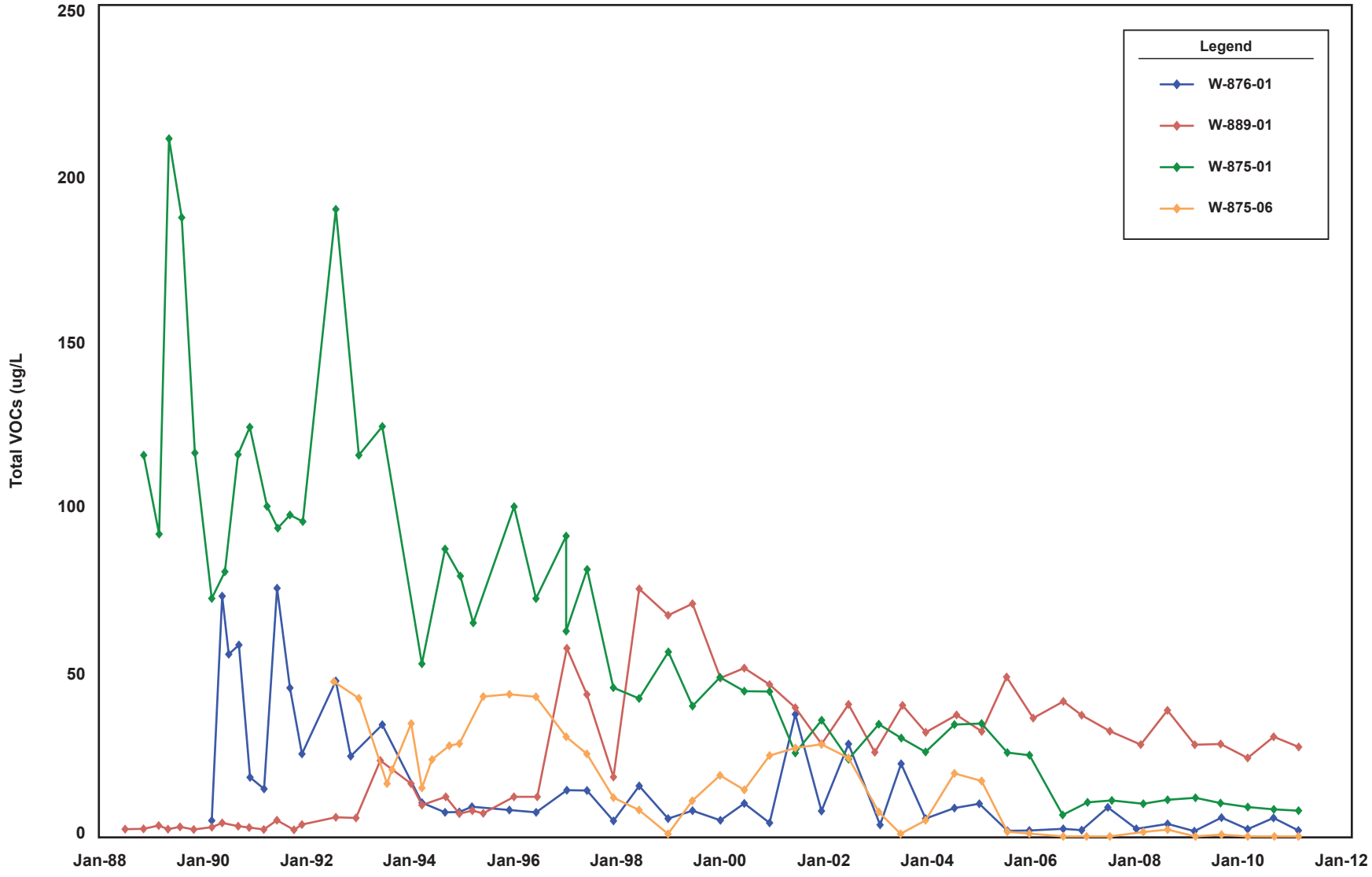

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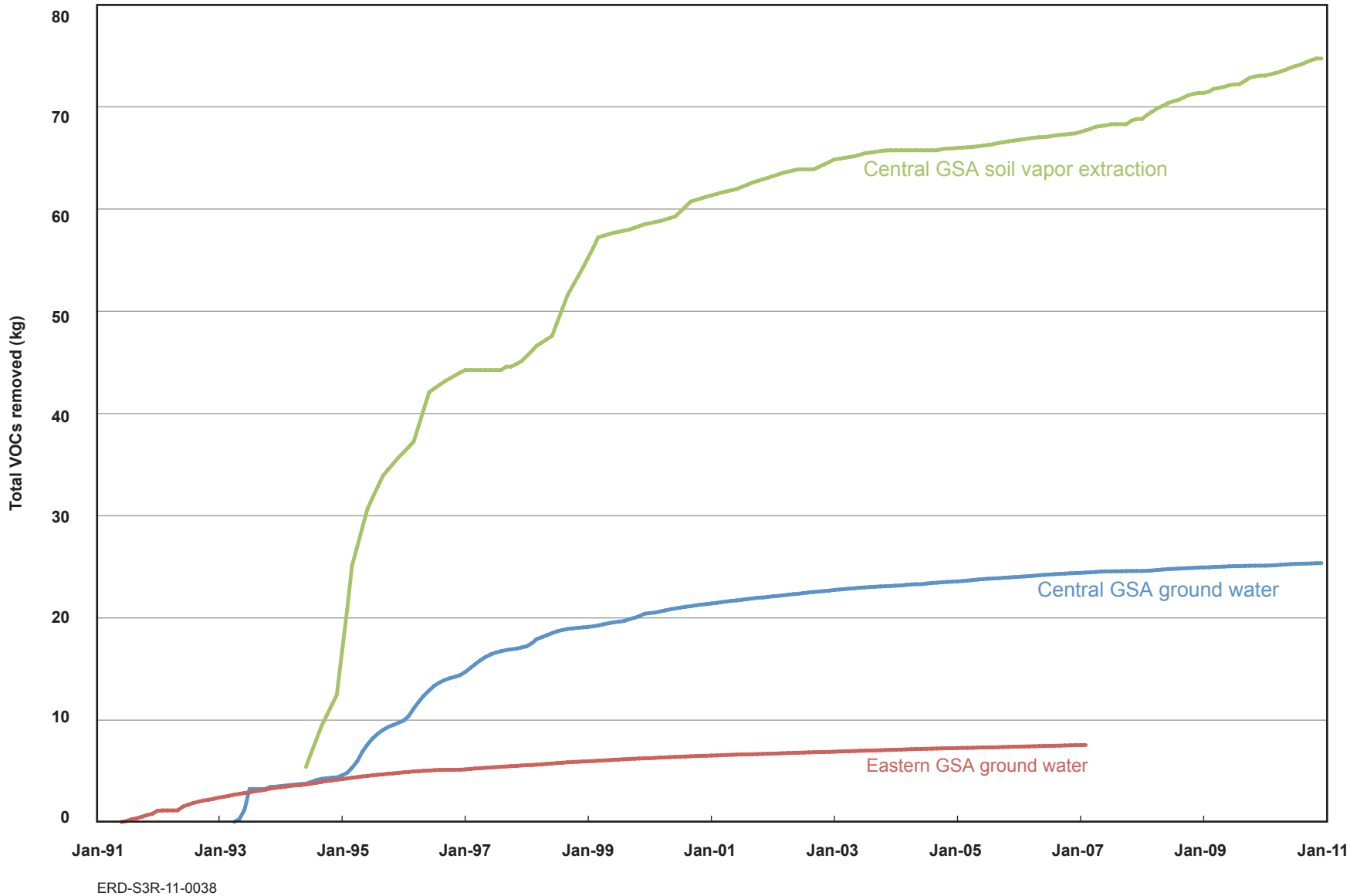
Figure 13. Time-series graphs of total volatile organic compound (VOC) in ground water for wells in the Central General Services Area northern plume area.



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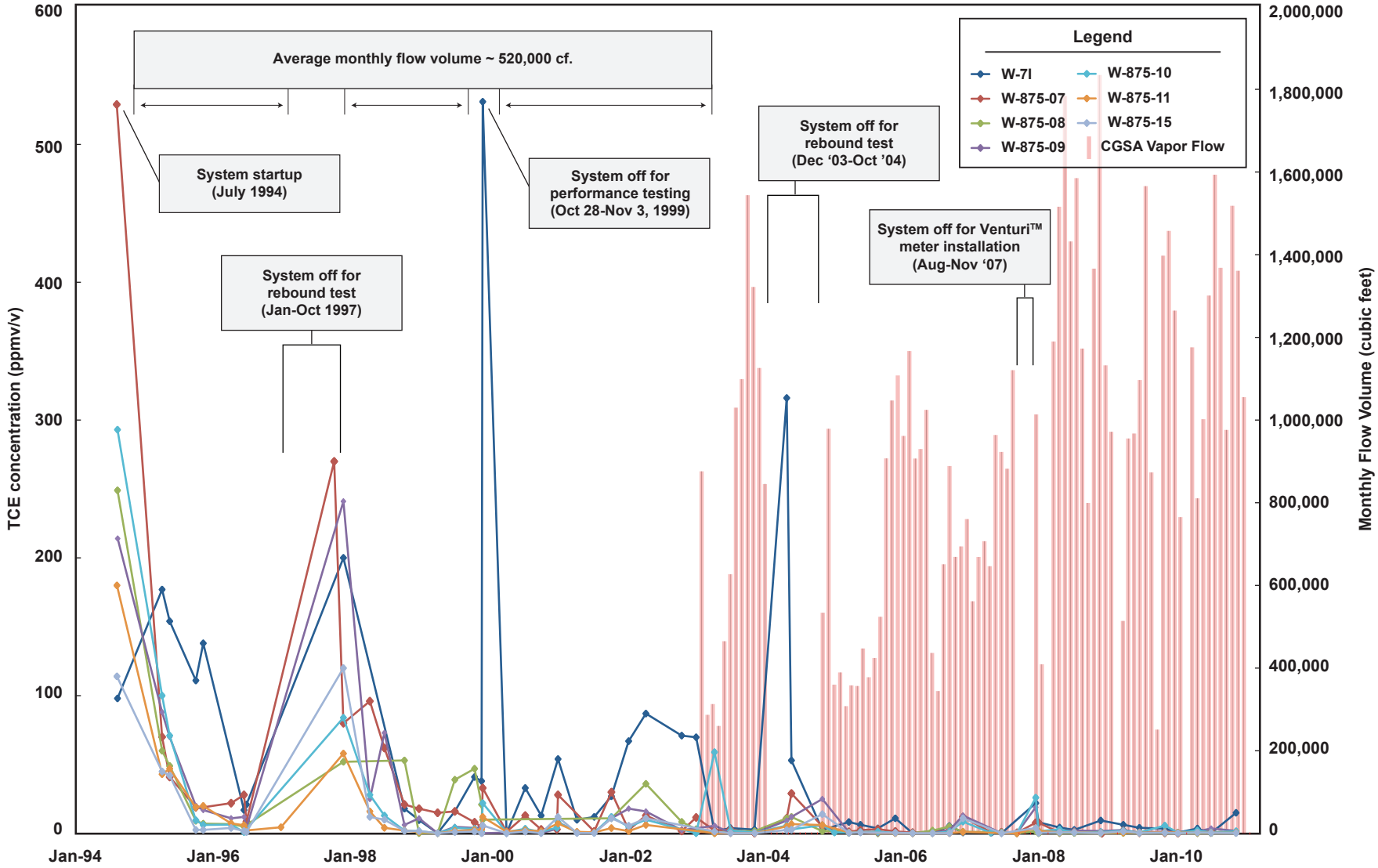

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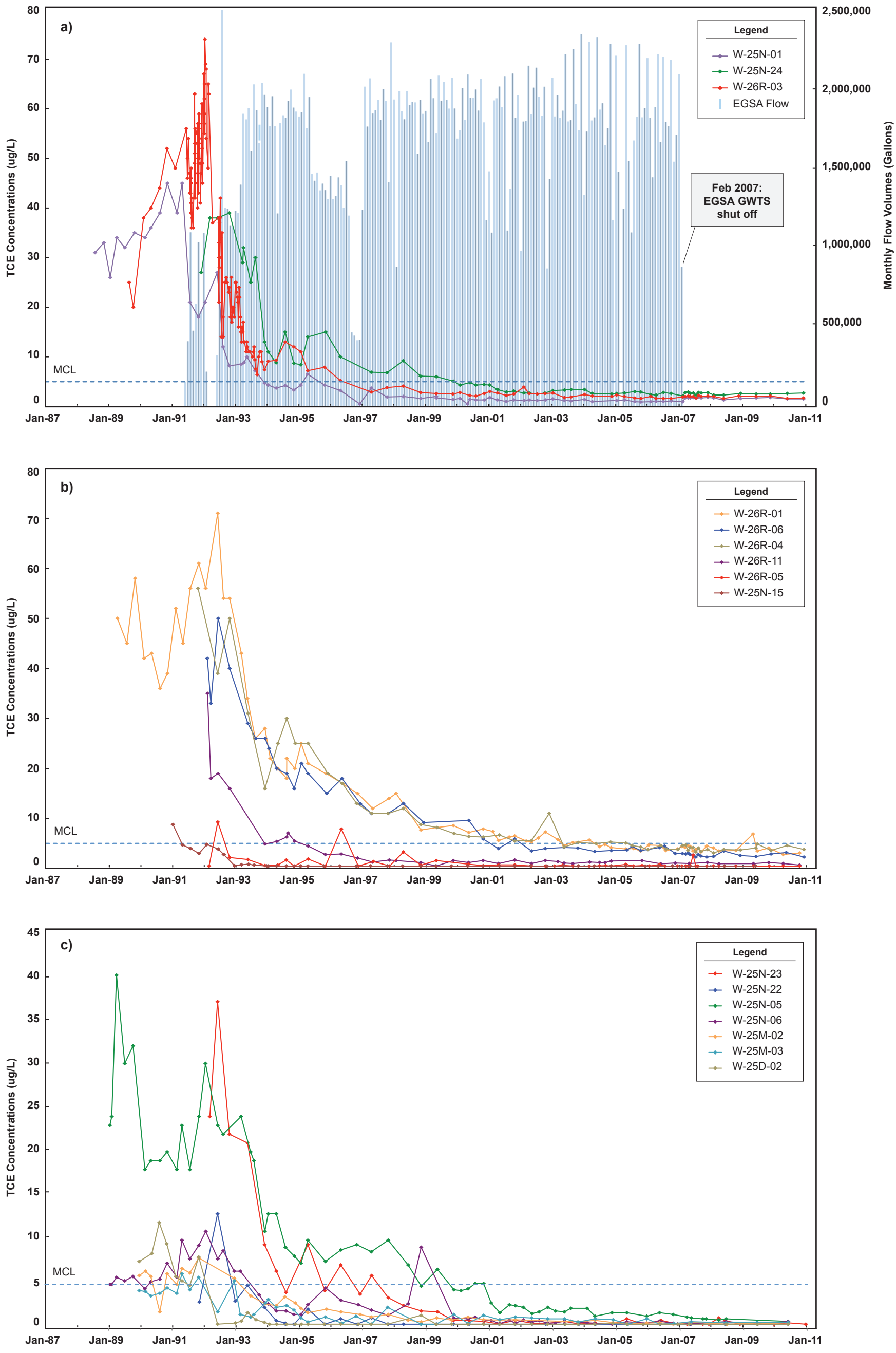

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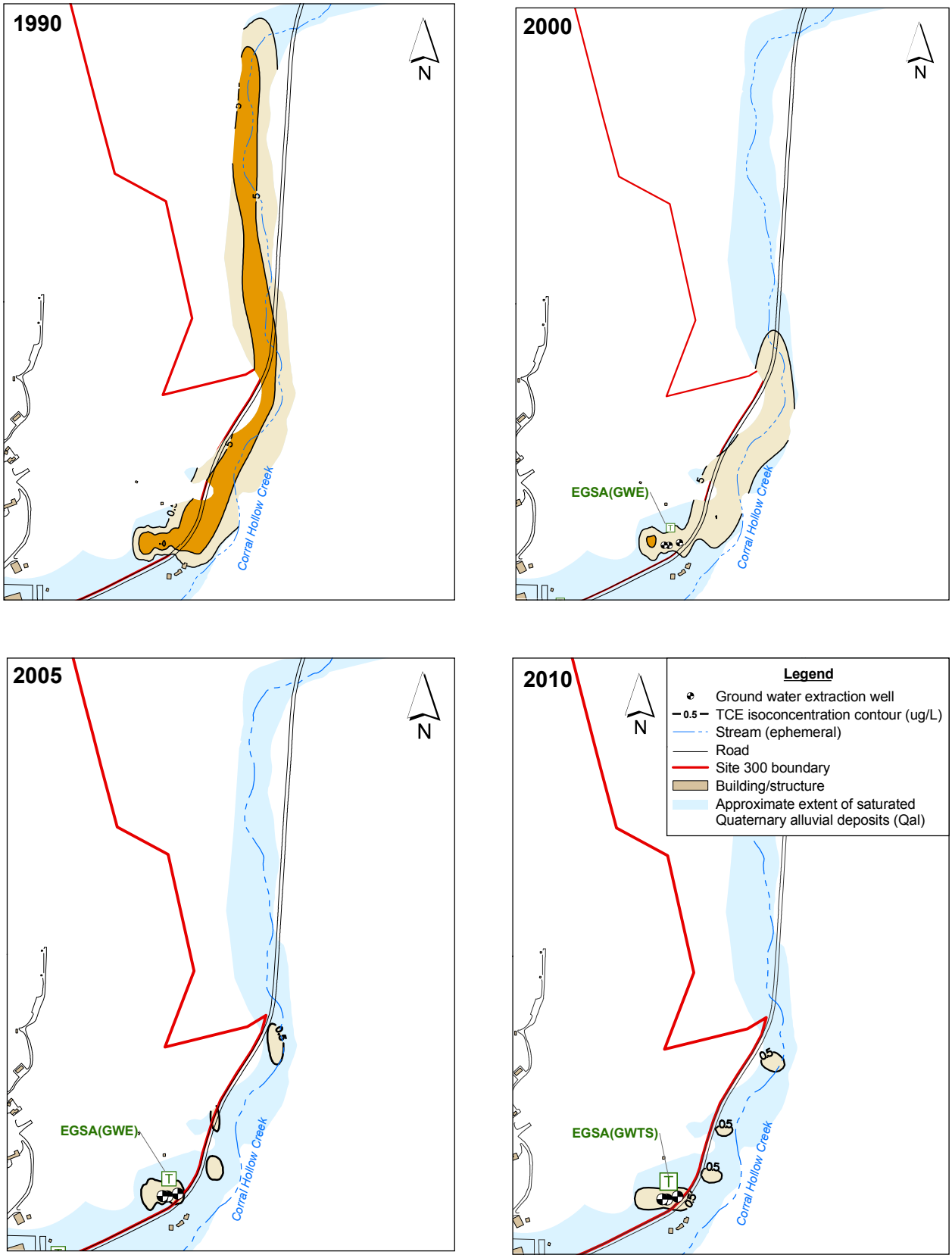

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Table 1. Actual annual costs for the General Services Area Operable Unit for fiscal years 2006 through 2010.

Fiscal Year	Annual Budget	Actual Annual Cost	Cost Variance[a]
2006	$489,635	$401,238	$88,397
2007	$454,886	$415,683	$39,203
2008	$299,251	$283,809	$15,442
2009	$408,091	$347,092	$60,999
2010	$422,778	$326,053	$96,725

Notes:

[a] **The General Services Area was consistently under budget due to lower than expected operations, maintenance, and optimization costs.**

Table 2. Description of institutional/land use controls for the General Services Area Operable Unit.

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Prevent water-supply use/consumption of contaminated ground water until ground water cleanup standards are met.	VOC concentrations in ground water exceeding cleanup standards.	**Central GSA:** There are no existing or planned water-supply wells in the Central GSA Operable Unit. Any proposed well drilling activities would be submitted to the LLNL Work Induction Board, and are reviewed by LLNL Environmental Restoration Department to ensure that new water-supply wells are not located in areas of ground water contamination. Existing offsite downgradient water-supply wells are monitored monthly for contaminants of concern in ground water that could potentially impact the wells. There is a Memorandum of Understanding with the owners of the offsite downgradient water-supply wells that includes point-of-use treatment if VOCs above MCLs are detected in the well. **Eastern GSA:** VOC concentrations in Eastern GSA ground water have been reduced to below ground water cleanup standards (MCLs) through remediation, therefore this institutional/land use control is no longer needed.
Control excavation activities to prevent onsite worker exposure to VOCs in subsurface soil until it can be verified that concentrations do not pose an exposure risk to onsite workers.	Potential exposure to VOCs at depth in subsurface soil at the Building 875 dry well pad[a].	**Central GSA:** All proposed excavation activities must be cleared through the LLNL Work Induction Board and require an excavation permit. The Work Induction Board coordinates with LLNL Environmental Restoration Department to identify if there is a potential for exposure to contaminants in the proposed construction areas. If a potential for contaminant exposure is identified, LLNL Environmental Health & Safety personnel ensures that hazards are adequately evaluated and the necessary controls are identified and implemented prior to the start of work. The Work Induction Board including the LLNL Environmental Analyst will also work with the Program proposing the construction project to determine if the work plans can be modified to move construction activities outside of areas of contamination. Controls for excavation activities will be incorporated into the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning documents. **Eastern GSA:** Institutional/land use controls are not necessary to prevent worker exposure to VOCs in surface and subsurface soil because concentrations are below the U.S. EPA's industrial and residential Preliminary Remediation Goals.

Table 2. Description of institutional/land use controls for the General Services Area Operable Unit (continued).

Institutional/land use control performance objective and duration	Risk necessitating institutional/land use control	Institutional/land use controls and implementation mechanism
Maintain engineering controls to prevent onsite site worker inhalation exposure to VOCs inside Building 875 until annual risk re-evaluation indicates that the risk is less than 10^{-6}.	A pre-remediation risk of 1×10^{-5} was identified for onsite workers from inhalation of VOCs volatilizing from subsurface soil into ambient air inside Building 875 (Central GSA).	**Central GSA:** Engineering controls (heating, ventilating, and air-conditioning system for Building 875) were implemented to prevent onsite worker exposure to VOCs that could migrate from the subsurface into the building until the inhalation risk was mitigated through remediation. The risk has been successfully reduced to less than 10^{-6} through ground water and soil vapor extraction and treatment in the Building 875 area as of 2000 (see Section 3.5), therefore this institutional/land use control is no longer needed. **Eastern GSA:** There is no risk or hazard associated with soil in the Eastern GSA.
Prohibit transfer of lands with unmitigated contamination that could cause potential harm under residential or unrestricted land use.	Potential exposure to contaminated waste and/or environmental media.	The Site 300 Federal Facility Agreement contains provisions that assure DOE will not transfer lands with unmitigated contamination that could cause potential harm. In the event that the Site 300 property is transferred in the future, DOE will execute a land use covenant at the time of transfer in compliance with Title 22 California Code of Regulations, Division 4.5, Chapter 39, Section 67391.1. Development will be restricted to industrial land usage. These restrictions will remain in place until and unless a risk assessment is performed in accordance with then current U.S. EPA risk assessment guidance and is agreed by the DOE, U.S. EPA, DTSC, and RWQCB as adequately showing no unacceptable risk for residential or unrestricted land use. These restrictions will be incorporated into the LLNL Site 300 Integrated Strategic Plan or other appropriate institutional planning document.

Notes:

DOE = United States Department of Energy.
DTSC = California Department of Toxic Substances Control.
GSA = General Services Area.
LLNL = Lawrence Livermore National Laboratory.
MCLs = Maximum Contaminant Levels.
RWQCB = California Regional Water Quality Control Board.
U.S. EPA = United States Environmental Protection Agency.
VOCs = Volatile organic compounds.

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

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