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Lawrence Livermore National Security, LLC, Livermore, California 94551

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Annual 2022 Compliance Monitoring Report

Lawrence Livermore National Laboratory Site 300

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Attachment 1 Analytical results for routine monitoring during 2022.

Acknowledgements

Many people in the field and in the office support the Lawrence Livermore National Laboratory Site 300 Environmental Restoration Project. The dedication and diverse skills of all these individuals have contributed to the ongoing success of the Environmental Restoration Department activities. The authors and editors wish to collectively thank all the contributing people and companies.

1. Introduction

This compliance monitoring report (CMR) summarizes the monitoring and remediation activities performed from January through December 2022 at Lawrence Livermore National Laboratory (LLNL) Site 300 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This report was prepared by the LLNL Environmental Restoration Department (ERD) and is submitted in compliance with the *Compliance Monitoring Plan /Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300* (CMP/CP) (Dibley et al. 2009a) and *Addendum to the Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300* (CMP/CP Addendum) (MacQueen et al. 2013).

The previous CMR, *First Semester 2022 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300* (First Semester 2022 CMR) (Buscheck et al. 2022), summarizes monitoring and remediation performed at Site 300 from January through June 2022. As noted in this document, personnel availability significantly increased in 2022 as conditions surrounding the COVID-19 pandemic improved. However, there were instances when sufficient personnel were not available to complete all required groundwater sampling and analysis for the year, as outlined in the CMP sampling and analysis requirements. Section 2 includes a discussion of common causes of deviations from the required CMP sampling and analysis during the reporting period. Regardless, the vast majority of CMP monitoring requirements were met in 2022.

Table Summ-1 presents the volumes of groundwater and soil vapor treated, and the estimated masses removed, by each treatment facility operating at Site 300. During 2022, approximately 7.1 million gallons (gal) of groundwater and 69 million cubic feet (cf) of soil vapor were treated at Site 300, removing approximately 5.2 kilograms (kg) of volatile organic compounds (VOCs), 75 grams (g) of perchlorate, 1,091 kg of nitrate, 86 g of Research Department Explosive (RDX), 0.047 g of tetrabutyl orthosilicate (TBOS)/tetrakis [2-ethylbutyl) silane] (TKEBS), and 2.8 g of uranium.

As presented in Table Summ-2, approximately 486 million gal of groundwater and over 1.49 billion cf of soil vapor have been treated since remediation activities began in 1991, removing approximately 648 kg of VOCs, 2 kg of perchlorate, 24,532 kg of nitrate, 3.1 kg of RDX, 9.5 kg of TBOS/TKEBS, and 0.11 kg of uranium.

1.1. Report Organization

The primary elements of this report are organized within the following major sections:

- **Section 2–Site 300 Monitoring Program**: Fundamental and detailed discussions of Site 300 monitoring results and remedy progress and performance, organized by operable unit (OU). The OUs are introduced in Section 2 and are the geographic areas of Site 300 where particular programmatic activities occurred or continue to occur.
- **Section 3–Detection, Monitoring, Inspection, and Maintenance Program**: Detection monitoring results and inspection and maintenance summaries for the Pit 1, 2, 3, 4, 5, 6, 7, 8, and 9 landfills in OUs 3, 5, and 8 and inspection and maintenance results for the Pit 7

Complex drainage diversion system (DDS) and the Building 850 corrective action management unit (CAMU) in OU 5.

- **Section 4–Risk and Hazard Management Program**: Discussion of the Site 300 environmental restoration risk and hazard management program, which addresses human health and ecological risks and hazards.
- **Section 5–Data Management Program**: Summary of the Site 300 environmental restoration data management program, including modifications to existing procedures and new procedures.
- **Section 6–References**: Documents and communications cited in this report.
- **Section 7–Acronyms and Abbreviations**: A defined list of all acronyms and abbreviations used in this report.

2. Site 300 Monitoring Program

The monitoring results for the Site 300 remediation systems, groundwater monitoring network, and surface water sampling and analyses are discussed by OU, in their respective sections:

- **Section 2.1**: General Services Area (GSA) (OU 1).
- **Section 2.2**: Building 834 (OU 2)
- **Section 2.3**: Pit 6 Landfill (OU 3).
- **Section 2.4**: High Explosives Process Area (HEPA) (OU 4).
- **Section 2.5**: Building 850/Pit 7 Complex (OU 5).
- **Section 2.6**: Building 854 (OU 6).
- **Section 2.7**: Building 832 Canyon (OU 7).
- **Section 2.8**: Site-wide (Building 833, Building 801/Pit 8, Building 845/Pit 9, and Building 851) (OU8).

Figure 2-1 presents the locations of these OUs.

The discussions for each OU are accompanied by three types of figures:

- Base maps with locations of key facilities, including monitor, extraction, and water-supply wells; treatment facilities; and, if applicable, area boundaries within an OU.
- Potentiometric surface contour maps that show groundwater elevations.
- Isoconcentration contour maps and post-only maps that show individual concentrations of contaminants of concern (COCs), including VOCs, and water elevations and approximate flow directions.

All COC and groundwater elevation maps were constructed using the quarterly sampling data set that contained the most complete geographic coverage for a particular semester. The concentrations of most compounds in water are reported in micrograms per liter (µg/L) with the exception of nitrate, which is reported in milligrams per liter (mg/L) as NO_3, and tritium and total uranium, which are reported in units of picoCuries per liter (pCi/L).

Isoconcentration contour maps and post-only maps for primary COCs in groundwater were constructed using 2022 second semester data while those for secondary COCs were constructed using data from the first semester of 2022. However, for collocated wells, the highest concentration of a given COC was used for contouring, which, in rare instances, may cause the maximum concentrations reported in Sections 2.1 through 2.8 to disagree with values posted on the contour maps. This disagreement may be expected when the sample with the maximum current-year concentration was collected during a different semester from the one used to construct the map (i.e., second or first semester) or if the maximum current-year concentration sample was collected during the same semester but a different quarter.

Total VOC (TVOC) isoconcentration maps were constructed by contouring the sum of the concentrations of the following VOCs:

- Trichloroethene (TCE).
- Tetrachloroethene (PCE).
- *Cis*-1,2-dichloroethene (*cis*-1,2-DCE).
- *Trans*-1,2-dichloroethene (*trans*-1,2-DCE).
- Carbon tetrachloride (CTET).
- Chloroform (CFORM).
- 1,1-dichloroethane (1,1-DCA).
- 1,2-dichloroethane (1,2-DCA).
- 1,1-dichloroethene (1,1-DCE).
- 1,1,1-trichloroethane (1,1,1-TCA).
- Trichlorofluoromethane (Freon 11).
- 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113).
- 1,1,2-trichloroethane (1,1,2-TCA).
- Vinyl chloride.

While the individual VOCs that comprise the TVOC concentrations are also posted on the maps, the concentrations discussed in Sections 2.1 through 2.8 refer to the sum total of the VOCs unless otherwise specified.

Both COC and groundwater elevation contour maps also depict hydraulic capture and injection zones for extraction and injection wells that were active when the groundwater elevations were measured. Hydraulic capture zones are derived primarily from equipotentials and extents of saturation on the groundwater elevation contour maps. Consequently, these capture zones may differ from those presented in the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (SWRESR) (Ferry et al. 2006), which were estimated using computer models such as WinFlow© or the Finite Element subsurface FLOW system (FEFLOW©). As a general rule, capture zones in this CMR were extended to two upgradient groundwater elevation contours. Where a few observation wells were located nearby, a Thiem solution for steady-state radial flow in the vicinity of a pumping well was used to control the groundwater elevation contours.

In accordance with the requirements of the CMP/CP, hydraulic capture and injection zones are displayed on groundwater potentiometric surface contour maps and primary and secondary COC isoconcentration contour maps for all OUs where active groundwater remediation was occurring in 2021 (i.e., OU 1, OU 2, OU 4, OU 5, OU 6, and OU 7), with the exception of OU 5. Although treatment was active in OU 5 during 2022, capture zones are not depicted on its contour maps because the calculated zones are the same or smaller in size than the well symbols depicted on the maps.

Several Site 300 OUs have a soil vapor treatment system (SVTS) associated with a dedicated, nearby groundwater treatment system (GWTS). The condensate that accumulates in these SVE systems is automatically conveyed and treated at the corresponding adjacent GWTS. DOE/LLNL has contingency plans for treating condensate at a compatible GWTS if an adjacent GWTS is idle due to freeze protection or for other reasons. Because the Building 833 sub-slab depressurization system (SSDS) does not have a corresponding GWTS in its area, the condensate it generates is collected and treated at the Building 815-Source (815-SRC) GWTS.

This CMR contains the following tables that present the results of the 2022 monitoring and remediation at Site 300:

- **Table 2.1**: Details on wells and boreholes that were installed or decommissioned in 2022.
- **Tables 2.2 and 2.3**: Monthly volumes of groundwater and soil vapor extracted and contaminant masses removed, respectively, between July and December 2022.
- **Table 2.4**: Summary of concentrations and activity concentrations of COCs in groundwater extraction and treatment system influent and effluent between July and December 2022.
- **Table 2.5**: List of treatment facility operations and maintenance (O&M) issues and other notable events that occurred in 2022.

In addition to figures and tables, this CMR includes the following appendices and attachment that support the main report:

- **Appendix A**: Treatment facility pH measurements collected during the second semester of 2022.
- **Appendix B**: Treatment facility sampling and analysis plans for the first semester of 2023.
- **Appendix C**: Sampling and analysis plans for groundwater and surface water monitoring at Site 300 for all of 2022.
- **Appendix D**: Tables of all groundwater elevation data for 2022.
- **Appendix E**: Table summarizing current land use controls for the Site 300 OUs, maps of land use controls for each OU or subarea, and the completed institutional control monitoring checklist for 2022.
- **Appendix F**: Summary of 2022 vapor intrusion (VI) indoor air sampling activities, data analysis, and resulting results and reporting for Site 300 buildings.
- **Appendix G**: Summary of environmental restoration program quality assurance activities conducted in 2022.
- **Appendix H**: Time-series graphs of individual groundwater elevations and associated projected landfill bottom elevations for key wells adjacent to landfill Pits 3 and 5 in the Pit 7 Complex of OU5 and daily rainfall totals for October 2021- December 2022.
- **Attachment 1:** Three tables tabulating surface water and groundwater, soil vapor, and indoor air analytical data, respectively, for samples collected during 2022.

The tables in Appendix C contain explanations for any individual deviations from the OU sampling plans. While DOE/LLNL plans sampling events on a quarterly basis and the sampling coordinator makes every effort to schedule sampling events when each location is anticipated to be accessible, many scenarios can prevent samplers from accessing a well or surface water location at any time during the sampling period.

Access issues can be grouped into the following four main categories:

- **Operational restrictions**: Site 300 operates multiple programmatic facilities that perform unique experiments. Explosives, radiation beam, and other "muster" events and corresponding areas are often activated around these facilities during experiments, limiting access to sampling locations. The duration and size of the muster events and areas vary depending on each experiment. The sampling coordinator incorporates the best available knowledge into the sampling schedule, but the muster schedule can be very dynamic.
- **Wildlife and sensitive habitat restrictions:** Site 300 is home to multiple rare, endangered, and threatened species. Access to areas where these populations exist is controlled by wildlife biologists who ensure that applicable federal and state regulations are enforced. Access to certain locations is often restricted by the presence of wildlife whose behavior and travel patterns are not predictable.
- **Terrain and weather-related restrictions:** The topography of Site 300 consists of a series of steep hills and canyons. Elevation ranges from approximately 500 feet (ft) above mean sea level (amsl) in its southeast corner to approximately 1,750 ft amsl in the northwestern area. Sampling locations are typically accessed via dirt roads that quickly become unsafe or unnavigable for travel during and after significant rainfall events. Significant repairs may be required, and access to sampling locations can be restricted for extended periods of time. Overgrown vegetation may also temporarily restrict access to springs.
- **Equipment malfunctions:** DOE/LLNL uses a tracking system to monitor the operational status of each monitoring and extraction well and its equipment (e.g., dedicated submersible pump). When a piece of sampling equipment becomes inoperable, it is entered into the WellTrack system, which prioritizes and tracks the status of its repair or replacement. The sampling coordinator schedules well sampling as soon as the repair or replacement is completed.

Although these access issues may arise, samplers make repeated attempts to access sampling locations until the end of a given sampling period without compromising their safety.

2.1. General Services Area (OU1)

The GSA OU consists of the Eastern GSA (EGSA) and Central GSA (CGSA) areas.

2.1.1. Eastern General Services Area

The source of contamination in the EGSA was abandoned burial trenches that received craft shop debris. Solvents in this debris were leached, resulting in the release of VOCs to groundwater.

Between 1991 and 2007, a GWTS using three wells located downgradient of the trenches, W-26R-03, W-25N-01, and W-25N-24, extracted contaminated groundwater at a combined average flow rate of 45 gal per minute (gpm) for VOC removal. These remediation efforts successfully reduced concentrations of TCE and other VOCs in groundwater to below their respective maximum contaminant level (MCL) cleanup standards, as established in the GSA record of decision (ROD) (DOE 1997). Consequently, the EGSA GWTS was shut off on February 15, 2007, with approval from the U.S. Environmental Protection Agency (EPA), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Toxic Substances Control (DTSC).

As required by the GSA ROD, groundwater monitoring was conducted for five years after the treatment facility was shut down to determine if VOC concentrations increased or "rebounded" above MCL cleanup standards. The monitoring results indicated that VOC concentrations had remained below MCL cleanup standards during the post-shutdown monitoring period. These monitoring results were presented at the remedial project managers (RPM) meeting held on February 24, 2012, during which the regulatory agencies agreed that cleanup of the EGSA was complete, monitoring and reporting could cease, and close-out documentation could be submitted. The final close-out document, *Close Out Report for Eastern General Services Area Subarea of Operable Unit 1 at Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2017), was submitted to the regulatory agencies on June 26, 2017.

2.1.2. Central General Services Area

At the CGSA, chlorinated solvents, primarily TCE, were historically used as degreasing agents in craft shops such as at Building 875. Rinse water from the degreasing operations was disposed of in dry wells, which were typically gravel-filled borings approximately 3 to 4 ft deep and 2 ft in diameter. These dry wells were used until 1982 and then decommissioned and excavated between 1983 and 1984.

The CGSA GWTS has been operating since 1993, removing VOCs from the Building 875 dry well release site in the CGSA. Groundwater cleanup began in 1993 using four extraction wells completed in the $Qt\text{-}Tnsc_1$ HSU. A Phase I wellfield expansion occurred in 1999 and included the addition of three $Qt\text{-}Tnsc_1$ HSU groundwater 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 Buildings 872 and 873 dry well VOC-release sites, respectively. Extraction well W-7O was installed hydraulically downgradient from the Building 875 dry well release area. In 2005, the Phase II wellfield expansion was initiated to include the addition of two $Qal\text{-}Tnbs_1$ HSU groundwater extraction wells, W-7R and W-7P, that increase hydraulic capture of the downgradient VOC plume. These extraction wells were installed farther downgradient from the Building 875 dry well release area, and well W-7P was also installed immediately downgradient of the CGSA debris burial trench.

The CGSA GWTS was taken offline between December 2016 and October 2019 for planned system and wellfield upgrades. The GWTS configuration currently consists of particulate filtration, air stripping to remove VOCs from extracted water, and granular activated carbon (GAC) to treat vapor effluent from the air stripper. Treated groundwater is then discharged to the surrounding natural vegetation using misting towers. For most of the first semester of 2022, the facility was offline due to freeze protection, mechanical issues, and power outages but was operated from June through November 10, 2022, when it was secured again for freeze protection.

The CGSA GWTS also treats groundwater from two additional sources:

- **830-Distal South (830-DISS) GWTS**: Located in the Building 832 Canyon OU, this facility was offline for most of 2022 due to freeze protection and mechanical issues.
- **CGSA-North groundwater extraction system (GWES)**: The CGSA-North GWTS was approved for conversion to a GWES on October 17, 2017 (Buscheck and Loll 2017).

In 1994, the CGSA SVTS began removing VOCs from soil vapor at a location adjacent to the contaminant source at the Building 875 dry well. Similar to the GWTS, the SVTS was offline for system upgrades between December 2016 and September 2018. The SVTS configuration currently consists of a water knockout chamber, a rotary vane blower, and four 140 pound vapor-phase GAC vessels arranged in series. Treated vapors are discharged to the atmosphere under a permit from the San Joaquin Valley Air Pollution Control District (SJVAPCD).

The SVE wellfield now consists of six wells, W-7I, W-875-07, W-875-08, W-875-09, W-875-11, and W-875-15, with an estimated combined total flow rate of approximately 25 standard cubic ft per minute (scfm). When the CGSA GWTS is operating, simultaneous groundwater extraction in the vicinity lowers the elevation of the water table and maximizes the volume of unsaturated soil influenced by vapor extraction. The CGSA SVTS was online for most of 2022.

Figure 2.1-1 is a map of the CGSA showing the locations of monitor and extraction wells and treatment facilities.

2.1.3. Groundwater and Soil-Vapor Extraction and Treatment System Operations and Monitoring

2.1.3.1. Compliance Summary

Due to winter freeze protection, equipment issues, and power outages, the Central GSA GWTS was offline for most of the first semester of 2022 until mid-April. It was operational from June until November 10, when it was again secured for winter freeze protection, and it operated in compliance with the RWQCB substantive requirements for wastewater discharge. Meanwhile, the CGSA SVTS operated in compliance with the SJVAPCD air permit for the entire reporting period. The CGSA-North GWES has no compliance monitoring requirements.

Appendix B contains the sampling and analysis plan for the first semester of 2023 for the CGSA treatment facilities. The plan for this reporting period complies with the monitoring requirements established in the CMP/CP, and no modifications were made to it.

As discussed in Section 2.1.2, the CGSA-North is now a GWES; therefore, only the associated extraction well, W-CGSA-2708, is sampled for chemical analyses to track contaminant mass removal.

2.1.3.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the CGSA:

- **Table 2.2**: Monthly volumes of groundwater and soil vapor extracted and discharged by treatment facilities in the CGSA for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater and soil vapor mass removed at the treatment facilities for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at the treatment facilities in 2022.

- **Table Summ-1**: The total volume of groundwater extracted and treated and total contaminant mass removed from this OU during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater treated and discharged and total contaminant mass removed from this OU.
- **Appendix A**: pH measurements. Because the CGSA-North GWES does not treat groundwater, effluent samples and pH measurements were not collected at this facility.

During the second semester of 2022, the CGSA GWTS extracted approximately 517,300 gal of groundwater while the CGSA SVE extracted 6,914,000 cf of soil vapor.

The CGSA-North GWES operated as expected during the second semester of 2022 and extracted approximately 3,000 gal of groundwater. Due to extremely low yield from its single extraction well, W-CGSA-2708, this system must be shut down and drained when there is any threat of freezing temperatures to prevent freeze damage and potential spills of untreated water. It is also routinely shut down to allow water levels in the extraction well to recover for quarterly compliance sample collection.

2.1.3.3. GSA Treatment Facility and Extraction Wellfield Modifications

The CGSA GWTS and SVTS were recently upgraded; consequently, modifications were not needed in 2022.

2.1.4. Groundwater Monitoring

Appendix C contains the 2022 groundwater and surface water sampling and analysis plan for the CGSA. This appendix also explains deviations from the plan and includes the sampling and analysis plan for the three EGSA offsite water-supply wells and three EGSA wells retained for CMP/CP monitoring downgradient of the CGSA.

During the reporting period, groundwater monitoring was conducted in accordance with CMP/CP monitoring requirements, except for eight required analyses for eight different wells. These analyses were not performed because the wells were dry or had insufficient water for sample collection.

Attachment 1 and Appendix D tabulate the analytical results and groundwater elevation measurements, respectively, reported during 2022. Figure 2.1-2 is a groundwater potentiometric surface map of the Qt-$Tnsc_1$ and Qal-$Tnbs_1$ hydrostratigraphic units (HSUs) within the CGSA.

2.1.5. Remediation Progress Analysis

This section is organized into three subsections: analysis of contaminant distribution and concentration trends, remediation optimization evaluation, and performance issues.

2.1.5.1. Contaminant Concentrations and Distribution

At the CGSA, VOCs are the only COCs in groundwater and soil vapor, with TCE comprising approximately 90 percent of the total VOCs (TVOCs). Other VOC COCs include PCE; *cis*-1,2-DCE; *trans*-1,2-DCE; 1,1-DCA; 1,1-DCE; 1,1,1-TCA; 1,1,2-TCA; Freon 11; Freon 113; benzene; bromodichloromethane; CFORM; and vinyl chloride. These VOCs have been detected in the Qt-$Tnsc_1$ HSU in the western part of CGSA, the Qal-$Tnbs_1$ HSU in the eastern part, and the underlying Upper and Lower $Tnbs_1$ HSUs.

The following general trends of VOC concentrations were observed in the CGSA during 2022:

- TVOC concentrations in groundwater decreased from a 1992 historical maximum of 272,000 µg/L, detected in a bailed sample collected during the drilling of dual extraction well W-875-07, to a 2022 maximum of 475 µg/L in the same well in July.
- TVOC concentrations in soil vapor decreased from a 1999 historical maximum of 603 parts per million on a volume per volume basis ($ppm_{v/v}$) in dual extraction well W-875-07 to a 2022 maximum of 0.639 $ppm_{v/v}$ in dual extraction well W-875-09 in October.

Figure 2.1-3 is a TVOC isoconcentration contour and individual VOC concentration map for the $Qt\text{-}Tnsc_1$ and $Qal\text{-}Tnbs_1$ HSUs, created using data from the second semester of 2022. Because this map is representative of contaminant concentrations during a particular semester, the maximum concentrations shown may not match the maximum concentrations described in the following sections.

2.1.5.1.1. Dry Well Pad Area

The center of mass of the VOC plume in the CGSA $Qt\text{-}Tnsc_1$ and $Qal\text{-}Tnbs_1$ HSUs is located in the Building 875 dry well pad area, where the highest TVOC and TCE concentrations continue to occur in the $Qt\text{-}Tnsc_1$ HSU. During the reporting period, all wells in this area were sampled as scheduled, except for dual extraction wells W-875-09, W-875-10, and W-875-15, which were dry and could not be sampled during the fourth quarter of 2022.

TCE is the major VOC detected in the Building 875 dry well area. Other VOCs typically detected in this area have included PCE; *cis*-1,2-DCE; *trans*-1,2-DCE; 1,1-DCE; 1,1-DCA; and 1,2-dichloroethane (1,2-DCA). Of these VOCs, only TCE, PCE, and *cis*-1,2-DCE have generally been present at concentrations that significantly exceed their MCL cleanup standards while 1,2-DCA has been detected at or near its MCL cleanup standard of 0.5 µg/L.

The following trends show that, overall, VOC concentrations in groundwater continue to decrease in the dry well pad area:

- **TCE**: Decreased from a 1993 historical maximum of 240,000 µg/L in dual extraction well W-875-07 to a 2022 maximum of 420 µg/L in the same well in July.
- **PCE**: Decreased from a 1993 historical maximum of 25,000 µg/L in well W-875-07 to a 2022 maximum of 43 µg/L in the same well in July.
- ***cis*-1,2-DCE**: Decreased from a 1993 historical maximum of 16,000 µg/L in dual extraction well W-7I to a 2022 maximum of 68 µg/L in dual extraction well W-875-08 in October.
- **1,1-DCA**: Decreased from a 1993 historical maximum of 38 µg/L in well W-7I to below the 0.5 µg/L laboratory reporting limit, in all area wells.
- **1,1-DCE**: Decreased from a 1993 historical maximum of 860 µg/L in well W-7I to a 2022 maximum of 4.5 µg/L in well W-875-07 in July and well W-875-08 in October.

In 2022, TCE soil vapor concentrations in wells W-875-07, W-875-08, W-875-09, W-875-11, and W-875-15 ranged between 0.0094 and 0.56 $ppm_{v/v}$ (51 and 3,000 $\mu g/m^3$), with the highest concentration occurring in dual extraction well W-875-09 in October. These concentrations have decreased significantly from the historical maximum TCE concentration of 530 $ppm_{v/v}$ (2,800,000 µg/m^3) detected in extraction well W-875-07 in 1994.

2.1.5.1.2. Outside the Dry Well Pad Area

Outside the Building 875 dry well pad area, several wells monitor the Qt-$Tnsc_1$, Qal-$Tnbs_1$, Upper $Tnbs_1$, and Lower $Tnbs_1$ HSUs. The overall spatial distribution of VOCs in groundwater downgradient of this source area did not change significantly during 2022.

Qt-$Tnsc_1$ and the Qal-$Tnbs_1$ HSUs

Among the monitor wells located outside the dry well pad area and screened in the Qt-$Tnsc_1$ and the Qal-$Tnbs_1$ HSUs, the historical maximum TVOC concentration of 920 µg/L was detected in 1994 in monitor well W-7O, which is screened in the Qt-$Tnsc_1$ HSU. The 2022 maximum of 110 µg/L was detected in the same well in April and included 100 µg/L of TCE and other VOCs including PCE; *cis*-1,2-DCE; 1,1-DCE; trans-1,2-DCE; and Freon 11. Of these VOCs, only TCE is typically present above its MCL cleanup standard of 5 µg/L, although, in well W-7O, PCE was also detected slightly above its 5 µg/L MCL cleanup standard at 5.5 µg/L and 7.4 µg/L in February and April, respectively.

In the area of the CGSA-North GWES, TVOC concentrations in well W-889-01 declined from 8.2 µg/L in November 2021 to 1.77 µg/L in November 2022. In well W-876-01, TVOCs declined from 4.6 µg/L in October 2021 to 1.5 µg/L in November 2022. Similarly, in well W-CGSA-2708, TVOCs declined from 4 µg/L in October 2021 to 3.1 µg/L in October 2022. Owing to these data from the second semester of 2022, a 5 µg/L TVOC contour is no longer present in this area on the map in Figure 2.1-3. Groundwater extraction and VOC mass removal rates at the CGSA-North GWES were nearly identical between 2022 and 2021.

Upper $Tnbs_1$ HSU

Five monitor wells, W-7A, W-7B, W-7C, W-7E, and W-7N, are screened in the Upper $Tnbs_1$ HSU. In these wells, VOCs have not been detected above their reporting limits since 2012, including in 2022.

Lower $Tnbs_1$ HSU

Five monitor wells, W-873-01, W-7G, W-7K, W-7L, and W-7M, are screened in the deeper Lower $Tnbs_1$ HSU. The historical maximum TVOC concentration in this HSU was detected in 1989 in well W-7G at 47 µg/L, comprised mostly of TCE. During 2022, no VOCs were detected above reporting limits in these wells.

A vinyl chloride concentration of 0.54 µg/L was detected in a sample taken from well W-7G in December 2019. Two years earlier, in December 2017, 13.8 µg/L of TVOCs, comprised of 11 µg/L of TCE and 2.8 µg/L of *cis*-1,2-DCE, were detected in well W-873-01. Except for the one-time detection in 2017, VOCs have never been detected above their reporting limits in this well since its installation in 1988, including in 2022. Wells W-873-01 and W-7G will continue to be monitored closely. Except for once in December 2017, VOCs have not exceeded their respective reporting limits in the Lower $Tnbs_1$ HSU wells in the CGSA since 2001.

2.1.5.1.3. South of the Site 300 Boundary

South of the Site 300 boundary, 17 wells monitor the Qt-$Tnsc_1$, Upper $Tnbs_1$, and Lower $Tnbs_1$ HSUs.

Qt-Tnsc$_1$ HSU

During 2022, VOCs were detected above individual compound reporting limits in the following three Qt-Tnsc$_1$ HSU offsite monitor wells:

- **W-35A-01**: 28 µg/L in June, comprised of 27 µg/L of TCE and 1.1 µg/L of PCE, and 1.6 µg/L in November, comprised entirely of TCE.
- **W-35A-10**: 10.9 µg/L in June, comprised of 6.9 µg/L of TCE and 4.0 µg/L of Freon 11, and 10.8 µg/L in November, comprised of 6.4 µg/L of TCE and 4.4 µg/L of Freon 11.
- **W-35A-09**: 1.49 µg/L in June, comprised of 0.91 µg/L of Freon 11 and 0.58 µg/L of TCE, and 1.78 µg/L in November, comprised of 0.96 µg/L of Freon 11 and 0.82 µg/L of TCE.

The 1991 historical maximum TVOC concentration observed south of the Site 300 boundary in this HSU was 545 µg/L in well W-35A-01, comprised of 510 µg/L of TCE, 32 µg/L of PCE, and 3 µg/L of 1,1-DCE. During 2022, no VOCs were detected above their respective reporting limits in any other Qt-Tnsc$_1$ HSU wells located south of the Site 300 boundary.

Upper Tnbs$_1$ HSU

During 2022, VOCs were not detected in the three monitor wells, W-35A-05, W-35A-12, and W-35A-13, screened in the Upper Tnbs$_1$ HSU, south of the Site 300 boundary. VOCs were last detected in this HSU in 2006 when 0.59 µg/L of TCE was observed in well W-35A-13.

Lower Tnbs$_1$ HSU

Five Lower Tnbs$_1$ HSU wells are located south of the Site 300 boundary.

In December 2021, a monthly groundwater sample collected from water-supply well CDF1 yielded low concentrations of vinyl chloride, with 0.69 µg/L in the duplicate sample and 0.52 µg/L in the routine sample. Because vinyl chloride had never been detected above the 0.5 µg/L reporting limit in this well dating back to 1987, it was resampled in early January 2022, with the routine and duplicate samples being analyzed by two different laboratories. Vinyl chloride did not exceed the laboratory reporting limit of 0.5 µg/L in either sample.

In 2022, low concentrations of vinyl chloride were detected in monthly groundwater samples collected from well CDF1 during the following months:

- **February**: 0.59 µg/L in a duplicate sample (the routine sample did not exceed 0.5 µg/L).
- **June**: 1.8 µg/L in a duplicate sample (the routine sample did not exceed 0.5 µg/L).
- **July**: 2.8 µg/L in a duplicate sample and 1.8 µg/L in a routine sample.
- **August**: 1.1 µg/L in a duplicate sample and 0.53 µg/L in a routine sample.

All monthly routine and duplicate samples collected from well CDF1 in 2022 were sent to two different laboratories, and samples collected in January, March, April, May, September, October, November, and December did not yield vinyl chloride at or above the 0.5 µg/L reporting limit. Based on these results, the detections in February, June, July, and August appear to be anomalous.

Including in 2022, vinyl chloride has never been detected above the laboratory reporting limit in any other well located south of the Site 300 boundary. Well CDF1 will continue to be monitored monthly for vinyl chloride and other VOCs.

VOCs were not detected above their reporting limits in the remaining four Lower $Tnbs_1$ CGSA wells located south of the Site 300 boundary. Except for the low vinyl chloride concentrations reported in well CDF1 in 2022, VOCs have not been reported in this HSU since January 2014, when 0.81 µg/L of CFORM was detected in CDF1.

2.1.5.2. Remediation Optimization Evaluation

During 2022, the CGSA GWTS extracted 517,309 gal of groundwater and removed 94 g of VOC mass, representing a 216 percent increase in gallons extracted and 241 percent increase in VOC mass removed compared to 2021. These increases in 2022 are primarily due to the resolution of maintenance issues at the treatment facilities and an increase in groundwater extraction time. Concurrently, the CGSA SVTS extracted approximately 12.9 million cf of soil vapor and removed 157 g of VOC mass in 2022. The volume of soil vapor extracted during this reporting period was nearly identical to the volume extracted in 2021 while the VOC mass removed from vapor was 85 percent of the mass removed in 2021. In 2022, a total of 3,107 gal of groundwater were extracted at the CGSA-North GWES and 0.0024 g of VOC mass was removed, with both totals nearly identical to those in 2021.

In 2022, static water levels measured in GSA groundwater wells were slightly higher than those measured in 2021 as a result of the 2022 water year rainfall total at Site 300, which was approximately 70 percent higher than the 2021 total. Water levels in wells predominantly screened in the Qal (alluvial channel fill), Qt (terrace alluvium), and weathered bedrock were approximately 0.5 ft higher than those observed in 2021. Water levels in wells primarily screened in bedrock (Upper $Tnbs_1$, Lower $Tnbs_1$, and $Tnsc_1$ HSUs) were approximately 1.25 ft higher than those observed in 2021.

Groundwater extraction at the CGSA GWTS continues to capture groundwater with the highest VOC concentrations. Remediation efforts have reduced TVOC concentrations in CGSA groundwater from a 1992 historical maximum of 272,000 µg/L in a bailed groundwater sample that was collected during the drilling of well W-875-07 to a 2022 maximum of 475 µg/L in the same well in July. At the eastern edge of the VOC plume, concentrations continue to decrease and remain below MCL cleanup standards in monitor wells W-26R-06 and W-26R-11.

Groundwater remediation also continues to reduce VOC concentrations in two key off-site performance monitor wells, W-35A-01 and W-35A-10, located within 50 and 100 ft of the southern Site 300 boundary, respectively. In well W-35A-01, TVOC concentrations have decreased from a 1991 historical maximum of 545 µg/L to 1.6 µg/L in November 2022 while TCE has similarly declined from a 1991 historical maximum of 510 µg/L to 1.6 µg/L in November 2022. Analysis of recent data from operating extraction wells shows that well W-35A-01 may be within the hydraulic capture zone of CGSA extraction well W-875-08.

Although well W-35A-10 is likely not within the hydraulic capture zone of the CGSA extraction wellfield, TVOC concentrations continue to exhibit a long-term decreasing trend due to hydraulic capture of VOCs upgradient of this well. In well W-35A-10, TVOC concentrations decreased from a 1994 historical maximum of 86 µg/L to 10.8 µg/L in November 2022, TCE concentrations decreased from a 1994 historical maximum of 40 µg/L to 6.4 µg/L in November 2022, and Freon 11 concentrations have decreased from a 1994 historical maximum of 46 µg/L to 4.4 µg/L in November

2022. TCE was the only compound detected slightly above its MCL cleanup standard in well W-35A-10 during 2022.

2.1.5.3. Remedy Performance Issues

The CGSA GWTS and SVTS, and CGSA-North GWES operated for the majority of the second semester of 2022, and no new issues affected the performance of the cleanup remedy for the GSA OU. The extent of VOCs in excess of MCL cleanup standards did not change, and concentrations decreased overall from those detected in 2021. The remedy continues to be effective and protective of human health and the environment and is making progress toward cleanup.

2.2. Building 834 (OU 2)

Since the 1950s, the Building 834 area has been used to test the stability of weapons and weapon components under various environmental conditions. Past spills and piping leaks in this OU have resulted in soil and groundwater contaminated with VOCs and TBOS/TKEBS, which are silicate oils that are co-contaminants with TCE. A combination of natural sources and septic system leachate are the likely cause of nitrate concentrations in Building 834 groundwater that exceed the MCL cleanup standard of 45 mg/L. In addition, diesel was released to the subsurface by an underground diesel storage tank that was eventually excavated and removed in 1994.

The Building 834 OU is informally divided into three areas:

- **The core area**: Generally refers to the vicinity of the buildings and test cells in the center of the Building 834 area where most of the contaminant releases occurred.
- **Leachfield (septic system) area**: Located immediately southwest of the core area.
- **Distal (T2) area**: The area downgradient (south) of the core and leachfield areas.

Figure 2.2-1 is a map of the Building 834 OU showing the locations of monitor and extraction wells and the treatment facilities.

Located in the core area, the Building 834 GWTS and SVTS began operation in 1995 and 1998, respectively. The GWTS removes VOCs, nitrate, and TBOS/TKEBS from groundwater extracted primarily from the Tpsg HSU. In contrast, the SVTS removes VOCs from soil vapor. Due to low groundwater yields of less than 0.1 gpm from the individual extraction wells, the GWTS and SVTS have been operated simultaneously in batch mode. While the GWTS can be operated alone, the SVTS typically has been operated with concurrent groundwater extraction. If not, the water table may not be sufficiently lowered beneath the screen in each dual extraction well prior to vapor pumping, and the rising groundwater can cover the well screens and hamper vapor flow into the wells. However, the SVTS was successfully operated without concurrent groundwater extraction for most of this reporting period in order to mitigate potential VI into nearby buildings.

The current extraction wellfield consists of 13 dual extraction wells, 12 of which extract from the Tpsg HSU and one well, W-834-2001, which extracts from the deeper Tps-$Tnsc_2$ HSU. Nine extraction wells, W-834-B2, W-834-B3, W-834-D4, W-834-D6, W-834-D7, W-834-D12, W-834-D13, W-834-J1, and W-834-2001, are located within the core area and four wells, W-834-S1, W-834-S12A, W-834-S13, and W-834-2113, are located within the leachfield area. Groundwater is extracted on a cyclic basis because the wells cannot sustain continuous pumping.

During the first semester of 2022, extraction was limited. The GWTS did not operate throughout the winter freeze-protection period and, due to issues with the misting tower and other equipment, remained offline until early June, after which it operated for 14 days. In mid-June to early July, the facility was secured once more due to equipment issues; since then, the facility operated mostly uninterrupted through November 9, when it was secured for winter freeze protection. Meanwhile, the SVTS operated for most of the year and extracted soil vapor at a combined flow rate of approximately 85 scfm.

The current GWTS configuration uses hydrocarbon adsorption devices to remove floating TBOS/TKEBS silicate oil and diesel fuel (if present), followed by aqueous-phase GAC to remove VOCs, dissolved-phase TBOS/TKEBS, and diesel fuel from groundwater. Nitrate-bearing treated effluent is then discharged via a misting tower onto the landscape for indigenous grasses to utilize. The current SVTS configuration employs vapor-phase GAC for VOC removal, and treated vapors are discharged to the atmosphere in compliance with an air permit issued by the SJVAPCD.

Since 2005, a long-term enhanced *in situ* bioremediation treatability test has been conducted at the distal T2 area. Summarized in Section 2.2.3.3, this long-term testing has included biostimulation to transform groundwater from oxidizing to reducing conditions and bioaugmentation with KB-1™, a natural non-pathogenic microbial consortium capable of complete dechlorination of TCE to ethene.

2.2.1. Groundwater and Soil Vapor Extraction and Treatment System Operations and Monitoring

2.2.1.1. Compliance Summary

Appendix B contains the treatment facility sampling and analysis plan for the Building 834 OU for the first semester of 2023. The plan for this reporting period complies with monitoring requirements established in the CMP/CP, and no modifications were made to it.

2.2.1.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the Building 834 OU:

- **Table 2.2**: Monthly volumes of groundwater and soil vapor extracted and discharged by treatment facilities in this OU for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater and soil vapor mass removal from this OU for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at the Building 834 GWTS and SVTS in 2022.
- **Table Summ-1**: The total volume of groundwater extracted and treated and total contaminant mass removed from this OU during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater treated and discharged and total contaminant mass removed from this OU.
- **Appendix A**: pH measurements.

During the second semester, the Building 834 GWTS operated for 2,935 hours and extracted 31,253 gal of groundwater while the Building 834 SVTS operated for 3,655 hours and extracted 25,615,000 cf of soil vapor.

2.2.1.3. Treatment Facility and Extraction Wellfield Modifications

No modifications were made to the Building 834 treatment facilities during this reporting period.

2.2.2. Groundwater Monitoring

Appendix C contains the 2022 groundwater and surface water sampling and analysis plan for the Building 834 area. This appendix also explains any deviations from this plan.

Attachment 1 and Appendix D tabulate the analytical results and groundwater elevation measurements, respectively, that were reported during 2022. Figure 2.2-2 is the second semester groundwater potentiometric surface map for the $Tnbs_2$ HSU in the Building 834 OU.

During the second semester of 2022, groundwater monitoring was conducted in accordance with the CMP/CP monitoring requirements, except for 26 required analyses for 26 different wells, which were not performed because the wells were dry or had insufficient water for sample collection.

2.2.3. Remediation Progress Analysis

This section is organized into four subsections: Analysis of contaminant distribution and concentration trends, remediation optimization evaluation, treatability study, and remedy performance issues.

2.2.3.1. Contaminant Concentrations and Distribution

At the Building 834 OU, VOCs, primarily TCE but also PCE; *cis*-1,2-DCE; 1,1,1-TCA; and CFORM, are the primary COCs detected in groundwater. TBOS/TKEBS and nitrate are the secondary COCs. These constituents have been identified in two shallow HSUs: the Tpsg gravel perched water-bearing zone and the underlying Tps-$Tnsc_2$ perching horizon.

The following subsections discuss concentrations and distributions of VOCs, TBOS/TKEBS, nitrate, and other contaminants found in the OU. These discussions are supported by the following figures:

- **Figure 2.2-3**: Individual VOC, TBOS/TKEBS, and nitrate concentrations for the Tps-$Tnsc_2$ HSU from the second semester of 2022.
- **Figure 2.2-4**: Total VOC isoconcentration contours and individual VOC concentrations for the Tpsg HSU from the second semester of 2022.
- **Figure 2.2-5**: TBOS/TKEBS concentrations for the Tpsg HSU from the first semester of 2022.
- **Figure 2.2-6**: Nitrate concentrations for the Tpsg HSU from the first semester of 2022.

Because each map is representative of contaminant concentrations during a particular semester, the maximum concentrations shown on the map may not match the maximum concentrations described in the following sections.

2.2.3.1.1. VOCs Concentrations and Distribution

Although the overall extent of VOCs in Building 834 OU groundwater and soil vapor have not significantly changed, maximum concentrations have decreased by several orders of magnitude since remediation began in the mid-1990s. The most significant changes in the extent of VOC-contaminated groundwater, especially beneath the core area, have resulted from changes in the extent of saturation. Slightly above-average rainfall and recharge during the 2018–2019 winter season were followed by below-average rainfall and less recharge during the 2019–2020, 2020–2021, and 2021–2022 winter seasons, which have slightly reduced the areal extent of saturation and VOCs, mostly in the core area.

VOCs detected in groundwater in the Building 834 area consist primarily of TCE and *cis*-1,2-DCE. Other VOCs, including PCE; 1,1,1-TCA; CFORM; vinyl chloride; 1,1-DCE; 1,1,2-TCA; *trans*-1,2-DCE; Freon 11; Freon 113; and CTET; ethane and ethene, have also been detected albeit at much lower concentrations in recent years. Since 2004 and including in 2022, 1,1,1-TCA has not been observed above its typical reporting limit of 0.5 µg/L in any Building 834 OU wells.

Core Area

The Building 834 core area continues to exhibit high VOC concentrations in groundwater and soil vapor within the Tpsg and Tps-$Tnsc_2$ HSUs.

Tpsg HSU

A total of 27 wells (19 monitor wells and eight dual extraction wells) are screened in the Tpsg HSU in the core area. Significant progress has been made in removing VOC mass from extracted groundwater and vapor, and as a result, this HSU has exhibited decreasing VOC concentration trends since treatment began in 1995. While the spatial extent of VOCs has decreased over time, the highest concentrations continue to occur near core area wells W-834-C5, W-834-D3, W-834-D4, W-834-D5, W-834-D6, W-834-D7, W-834-D13, and W-834-D14.

The following general trends in primary COC VOCs were observed in Tpsg HSU groundwater:

- **TVOC**: Decreased from a 1988 historical maximum concentration of 1,100,000 µg/L in well W-834-D5 to a 2022 maximum of 18,000 µg/L in well W-834-C5 in January.
- **TCE**: Decreased from a 1988 historical maximum concentration of 1,100,000 µg/L in well W-834-D5 to a 2022 maximum of 7,300 µg/L in well W-834-D7 in October.
- ***cis*-1,2-DCE**: Decreased from a 1990 historical maximum concentration of 540,000 µg/L in well W-834-D4 to a 2022 maximum of 12,000 µg/L in well W-834-C5 in January.
- **PCE**: Decreased from a 1993 historical maximum PCE concentration of 10,000 µg/L in well W-834-D3 to a 2022 maximum of 47 µg/L in well W-834-D7 in October.
- **1,1,1-TCA**: Decreased from a 1991 historical maximum concentration of 33,000 µg/L in well W-834-J1 to below the typical laboratory reporting limit range of 0.5 to 2.5 µg/L in all core area Tpsg HSU wells during 2022.
- **CFORM**: Decreased from a 2009 historical maximum concentration of 44 µg/L in well W-834-1709 to a 2022 maximum of 1.3 µg/L in well W-834-D15 in March.

In the core area, *cis*-1,2-DCE, vinyl chloride, and ethene are microbial dechlorination products of TCE that appear to be present in portions of the Tpsg HSU that contain TBOS/TKEBS, which are silicate oils that support the long-term dechlorination of TCE. TBOS/TKEBS can slowly hydrolyze abiotically to butanol and ethylbutanol, respectively, and ferment biotically to butyrate and ethylbutyrate, respectively. During fermentation of these alcohols, hydrogen is produced, providing electrons for microbial dechlorinators. Butyrate is an excellent slow-fermenting substrate, producing the hydrogen needed for dehalogenation (Vancheeswaran 1998; Yu and Semprini 2002).

Reductive dechlorination is occurring in this area, as indicated by the occurrence of vinyl chloride at the following wells:

- **Core area extraction well W-834-B3**: 53 µg/L in November.
- **Core area extraction well W-834-D5**: 37 µg/L in January and 0.53 µg/L in August.
- **Core area extraction well W-834-D3**: 8.0 µg/L in March.
- **Core area monitor well W-834-1709**: 0.67 µg/L in January and 3.7 µg/L in September.
- **Core area monitor well W-834-C5**: 1.6 µg/L in January.
- **Core area monitor well W-834-D13**: 1.3 µg/L in October.

While many bacteria species are capable of reductively dechlorinating TCE to *cis*-1,2-DCE, so far, only certain strains of *Dehalococcoides mccartyi (Dhc)* have been found capable of dechlorinating *cis*-1,2-DCE to vinyl chloride and vinyl chloride to innocuous ethene and ethane (Pérez-de-Mora et al. 2018). During 2022, the above wells were not sampled for light hydrocarbons (i.e., the dissolved gases ethene, ethane, methane) and volatile fatty acids. However, the most recent sampling for these analytes, conducted in September 2017, yielded ethene concentrations as high as 99 µg/L in monitor well W-834-D3, with lesser concentrations of ethene ranging from less than the 0.1 µg/L reporting limit to 1.1 µg/L in the remaining core area wells. An oxidation/reduction potential (ORP) measurement of -27 millivolts (mV) taken in September 2022 in monitor well W-834-1709 indicated reducing subsurface conditions were still present, although less so than what has been observed in previous years.

Historically, these data have suggested that complete reductive dechlorination is still occurring in portions of the core area, supported by the presence of TBOS/TKEBS as an electron donor. In general, wells that contained TBOS/TKEBS exhibited the highest concentrations of *cis*-1,2-DCE and vinyl chloride, which accumulate under anaerobic conditions when the SVE system is not operational, such as during periods of winter freeze-protection shutdown. Concentrations of *cis*-1,2-DCE and vinyl chloride decline once the SVE system is restarted and the subsurface becomes more oxygenated in the summer. During the most recent 2021–2022 winter freeze-protection period, groundwater extraction was suspended while SVE continued.

While not a COC, in 2022, 1,1-DCE was detected above the reporting limit in nine core area Tpsg HSU wells: W-834-B3, W-834-B4, W-834-C5, W-834-D4, W-834-D5, W-834-D7, W-834-D13, W-834-D15, and W-834-1709. Only well W-834-C5 yielded 1,1-DCE in excess of the 6 µg/L MCL cleanup standard, with a concentration of 59 µg/L in January. The compound *trans*-1,2-DCE was detected above the reporting limit in three core area Tpsg HSU wells, W-834-D3, W-834-D4, and W-834-D13. Only well W-834-D3 yielded *trans*-1,2-DCE in excess of the 10 µg/L MCL cleanup standard, with a concentration of 28 µg/L in September. Another sample from the well collected in March yielded 1.2 µg/L. The historical maximum concentration of *trans*-1,2-DCE in this well is 200 µg/L in 1999.

Other VOCs in the core area Tpsg HSU wells, including 1,1-DCA; 1,2-DCA; 1,1,2-TCA; Freon 11; Freon 113; and CTET, either did not exceed reporting limits or were below their MCL cleanup standards.

During the reporting period, TCE soil vapor concentrations in core area SVE wells ranged from 0.013 to 3.7 $ppm_{v/v}$ (70 and 20,000 µg/m^3), representing a three-order-of-magnitude decrease from the 1989 (i.e., pre-remediation) maximum TCE concentration of 3,200 $ppm_{v/v}$ (17,000,000 µg/m^3) at extraction well W-834-D4. Well W-834-D4 is located approximately 10 ft from former extraction well W-834-D5, which yielded the historical maximum groundwater VOC concentration in the Tpsg HSU in 1988. The highest TCE soil vapor concentration of 3.7 $ppm_{v/v}$ (20,000 µg/m^3) was detected in extraction well W-834-B2 on July 19, 2022, a result representative of pumping conditions.

Tps-$Tnsc_2$ HSU

Seven wells (six monitor wells and one dual extraction wells) are screened in the Tps-$Tnsc_2$ HSU in the core area. Underlying the Tpsg HSU, the Tps-$Tnsc_2$ HSU continues to contain the highest VOC concentrations in groundwater in the Building 834 OU and at Site 300. Progress has been made in removing COC mass in both the aqueous and vapor phases and the spatial extent of VOCs has decreased over time. However, the highest concentrations continue to occur near core area wells W-834-2001, W-834-A1, and W-834-U1.

The following general trends in primary COC VOCs were observed Tps-$Tnsc_2$ HSU groundwater:

- **TVOC**: Decreased from a 2012 historical maximum concentration of 298,000 µg/L in well W-834-A1 to a 2022 maximum of 167,000 µg/L in the same well in September.
- **TCE**: Decreased from a 2012 historical maximum concentration of 298,000 µg/L in well W-834-A1 to a 2022 maximum of 160,000 µg/L in the same well in September.
- ***cis*-1,2-DCE**: Decreased from a 2000 historical maximum of 36,000 µg/L in well W-834-D8 to a 2022 maximum of 7,200 µg/L in well W-834-A1 in January.
- **PCE**: Decreased from a 2001 historical maximum PCE concentration of 7,900 µg/L in well W-834-A1 to a 2022 maximum of 660 µg/L in the same well in September.
- **1,1,1-TCA**: Decreased from a 2000 historical maximum concentration of 28 µg/L in well W-834-A1 to below the typical laboratory reporting limit range of 0.5 to 2.5 µg/L in all core area Tps-$Tnsc_2$ HSU wells during 2022.
- **CFORM**: Decreased from a 2000 historical maximum concentration of 42 µg/L in wells W-834-A1 and W-834-U1 to a 2022 maximum of 17 µg/L in well W-834-A1 in January.

Additionally, while not a COC, the compound 1,1-DCE was detected above the 6 µg/L MCL cleanup standard in one core area Tps-$Tnsc_2$ HSU well, W-834-A1, at 56 µg/L in January. Concentrations of other VOCs in Tps-$Tnsc_2$ HSU wells, including *trans*-1,2-DCE; 1,1-DCA; 1,2-DCA; 1,1,2-TCA; Freon 11; Freon 113; and CTET, were either below their respective reporting limits or MCL cleanup standards during 2022.

During the reporting period, the highest TCE soil vapor concentration from the only core area Tps-$Tnsc_2$ HSU SVE well, W-834-2001, was 0.842 $ppm_{v/v}$ (4,500 µg/m^3), in a sample collected on July 19, 2022, under pumping conditions. The historical maximum TCE vapor concentration in this well is

30 $ppm_{v/v}$ (160,000 µg/m^3) in April 2011; this concentration is representative of rebound conditions following a prolonged period of treatment facility shutdown, as higher vapor concentrations may be observed after an extended rebound period.

Leachfield Area

Tpsg HSU

Six wells (two monitor wells and four dual extraction wells) are screened in the Tpsg HSU in the leachfield area. Since treatment began in 1995, this HSU has exhibited decreasing VOC concentration trends, and progress has been made in removing COC mass in both the aqueous and vapor phases.

While the spatial extent of contamination has decreased over time, the highest VOC concentrations continue to occur in the vicinity of leachfield area wells W-834-2113, W-834-S1, and W-834-S12A. As shown on Figure 2.2-4, the extent of the 100 µg/L TVOC isoconcentration contour diminished in 2022, notably in the vicinity of extraction well W-834-S13, which experienced a decrease in maximum TVOC detections from 200 µg/L in 2021 to 38 µg/L in 2022. Also, the extent of the 1,000 µg/L TVOC isoconcentration contour surrounding extraction well W-834-2113 shrank slightly due to a decrease in maximum TVOC concentrations in nearby extraction well W-834-S1 (from 980 µg/L in 2021 to 290 µg/L in 2022). Otherwise, no significant changes in VOC concentrations were observed in the leachfield area in 2022 when compared to the 2021 TVOC isoconcentration contours.

The following general trends in primary COC VOCs were observed in Tpsg HSU groundwater:

- **TVOC**: Decreased from a 1988 historical maximum concentration of 179,000 µg/L in well W-834-S1 to a 2022 maximum of 1,460 µg/L in well W-834-2113 in October.
- **TCE**: Decreased from a 1988 historical maximum concentration of 170,000 µg/L in well W-834-S1 to a 2022 maximum of 1,400 µg/L in well W-834-2113 in October.
- ***cis*-1,2-DCE**: Decreased from a 2003 historical maximum concentration of 3,900 µg/L in well W-834-S13 to a 2022 maximum of 250 µg/L in extraction well W-834-2113 in June.
- **PCE**: Decreased from a 1986 historical maximum PCE concentration of 6,300 µg/L in well W-834-S1 to a 2022 maximum of 4.96 µg/L in extraction well W-834-2113 in October.
- **1,1,1-TCA**: Decreased from a 1986 historical maximum concentration of 300 µg/L in well W-834-S1 to below the typical laboratory reporting limit range of 0.5 to 2.5 µg/L in all leachfield area Tpsg HSU wells during 2022.
- **CFORM**: Decreased from a 1989 historical maximum concentration of 950 µg/L in well W-834-S1 to below the typical laboratory reporting limit of 0.5 µg/L in all leachfield area Tpsg HSU wells during 2022.

Except for a 1,1-DCE detection of 0.71 µg/L in June and a 1,1,2-TCA detection of 0.6 µg/L in October at well W-834-2113, other VOCs, including *trans*-1,2-DCE; 1,1-DCA; 1,2-DCA; CTET; vinyl chloride; Freon 11; and Freon 113, did not exceed reporting limits in Tpsg HSU leachfield area wells during this reporting period.

During 2022, TCE soil vapor concentrations ranged from less than 0.005 $ppm_{v/v}$ to 2.4 $ppm_{v/v}$ (27 to 13,000 µg/m^3), significantly lower than the 710 $ppm_{v/v}$ (3,800,000 µg/m^3) maximum pre-remediation concentration measured in 2004 in leachfield area well W-834-S13. The highest TCE soil vapor concentration of 2.4 $ppm_{v/v}$ (13,000 µg/m^3) was detected in extraction well W-834-2113 on February 22, 2022, a result representative of pumping conditions.

Tps-$Tnsc_2$ HSU

In the leachfield area, the Tps-$Tnsc_2$ HSU has continued to exhibit overall declining VOC concentrations since monitoring began in 1989. Monitored by two wells, W-834-S8 and W-834-S9, this HSU exhibits VOC concentrations significantly lower than those observed in the overlying Tpsg HSU or in the core area.

The following general trends in primary COC VOCs were observed in Tps-$Tnsc_2$ HSU groundwater:

- **TVOC**: Decreased from a 1992 historical maximum concentration of 16,000 µg/L in well W-834-S8 to a 2022 maximum of 3,200 µg/L in well W-834-S9 in March.
- **TCE**: Decreased from a 1992 historical maximum concentration of 16,000 µg/L in well W-834-S8 to a 2022 maximum of 3,200 µg/L in well W-834-S9 in March.
- ***cis*-1,2-DCE**: Decreased from a 1991 historical maximum concentration of 130 µg/L in well W-834-S8 to a 2022 maximum of 46 µg/L in the same well in September.
- **PCE**: Decreased from a 1993 historical maximum PCE concentration of 170 µg/L in well W-834-S8 to a 2022 maximum of 21 µg/L in the same well in September.
- **1,1,1-TCA**: Decreased from a 1991 historical maximum concentration of 260 µg/L in well W-834-S8 to below the typical laboratory reporting limit range of 0.5 to 2.5 µg/L in all leachfield area Tps-$Tnsc_2$ HSU wells during 2022.
- **CFORM**: Decreased from a 1993 historical maximum concentration of 6.1 µg/L in well W-834-S8 to a 2022 maximum of 1.7 µg/L in the same well in September.

Similar to results from recent years, concentrations of other VOCs in leachfield area Tps-$Tnsc_2$ HSU wells, including *trans*-1,2-DCE; 1,1-DCE; 1,1-DCA; 1,2-DCA; 1,1,2-TCA; Freon 11; Freon 113; CTET; and vinyl chloride, either did not exceed reporting limits or were below applicable MCL cleanup standards.

Distal Area

Tpsg HSU

A total of 23 monitor wells are screened in the Tpsg HSU of the distal area. Since monitoring began in 1989, this HSU has continued to exhibit decreasing VOC concentrations.

In the T2 area, the Tpsg HSU has been the target of a long-term enhanced *in situ* bioremediation treatability study since 2005, as discussed in Section 2.2.3.4. While TVOC concentrations have been reduced by an order of magnitude since the start of the treatability study, elevated VOC concentrations continue to occur in the vicinity of distal area wells W-834-2117, W-834-T2A, W-834-T2B, W-834-T2D, W-834-1825, and W-834-1833. No significant changes were observed in the distal area of the 2022 TVOC isoconcentration contour map shown in Figure 2.2-4 when compared to that of the 2021 map.

The following general trends in primary COC VOCs were observed in Tpsg HSU groundwater:

- **TVOC**: Decreased from a 1988 historical maximum concentration of 86,000 µg/L in well W-834-T2A to a 2022 maximum of 3,050 µg/L in well W-834-T2D in March.
- **TCE**: Decreased from a 1988 historical maximum concentration of 86,000 µg/L in well W-834-T2A to a 2022 maximum of 3,040 µg/L in well W-834-T2D in March.
- ***cis*-1,2-DCE**: Decreased from a 2008 historical maximum concentration of 6,200 µg/L in well W-834-T2 to a 2022 maximum of 180 µg/L in well W-834-1833 in January.
- **PCE**: Decreased from a 1987 historical maximum PCE concentration of 160 µg/L in well W-834-S6 to a 2022 maximum of 24 µg/L in well W-834-2117 in September.
- **1,1,1-TCA**: Decreased from a 1991 historical maximum concentration of 200 µg/L in well W-834-T2D to below the typical laboratory reporting limit range of 0.5 to 2.5 µg/L in all distal area Tpsg HSU wells during 2022.
- **CFORM**: Decreased from a 1999 historical maximum concentration of 270 µg/L in well W-834-M1 to a 2022 maximum of 1.6 µg/L in well W-834-1833 in January.

Although not a COC, in 2022, vinyl chloride was detected above the reporting limit in two distal area Tpsg HSU wells: 17 µg/L and 74 µg/L in well W-834-T2 in February and September, respectively, and 2.7 µg/L in well W-834-1833 in January. Similarly, 1,1-DCE was detected above the reporting limit in two distal area Tpsg HSU wells: 9 µg/L in well W-834-1833 in January, exceeding the 6 µg/L MCL cleanup standard, and 0.76 µg/L in well W-834-T2D in March.

Freon 113, 1,1-DCA, 1,2-DCA, and CTET were not detected above their respective reporting limits in any distal area wells. Other VOCs, including *trans*-1,2-DCE; Freon 11; and 1,1,2-TCA, either did not exceed reporting limits or were detected slightly above reporting limits in some wells but did not exceed applicable MCL cleanup standards.

Tps-Tnsc$_2$ HSU

The intermediate-depth Tps-Tnsc$_2$ HSU is monitored by two wells, W-834-3706 and W-834-2119, the latter of which yielded the 2022 maximum TVOC concentration of 9,200 µg/L, comprised entirely of TCE, in January. The historical maximum concentration of 16,700 µg/L was detected in August 2012; since then TVOC concentrations have been stable to generally decreasing. The 2022 maximum concentration of PCE of 24 µg/L was detected in well W-834-3706 in October, matching the previous historical maximum PCE concentration observed in the HSU in well W-834-2119 in 2015.

In 2022, well W-834-2119 yielded maximum concentrations of the following primary COC VOCs:

- **TCE**: 9,200 µg/L in January.
- **1,1-DCE**: 2 µg/L in January.
- **Freon 11**: 1.5 µg/L In January.
- ***trans*-1,2-DCE**: 0.61 µg/L in January.
- **CFORM**: 3.1 µg/L in September.
- **CTET**: 1.1 µg/L in September.

The maximum *cis*-1,2-DCE concentrations of 91 µg/L occurred in October in well W-834-3706, which also had a single 3.4 µg/L detection of vinyl chloride also in October. Also, a maximum

1,1,2-TCA concentration of 1.6 µg/L was observed in January and February in wells W-834-2119 and W-834-3706, respectively. Other VOCs were not detected above their respective reporting limits, and only TCE, PCE, *cis*-1,2-DCE, and vinyl chloride exceeded their MCL cleanup standards.

$Tnbs_1$ HSU

In the distal area, the deep $Tnbs_1$ HSU is monitored by guard wells W-834-T1 and W-834-T3. TCE and other VOCs were not detected in any of the four samples collected from each well during this reporting period and have only been detected three times in these wells. These occurred once each in 1986 and 1987 when less than 4 µg/L of TCE were detected following installation of well W-834-T1, likely caused by well bore contamination with shallow soil during drilling, and once in 1994 when 1 µg/L of TCE was detected in well W-834-T3.

2.2.3.1.2. TBOS/TKEBS Concentrations and Distribution

TBOS/TKEBS is found primarily in the core area, with the highest concentrations observed in the Tpsg HSU. TBOS/TKEBS concentrations in groundwater have decreased from a 1995 historical maximum of 7,300,000 µg/L in core area Tpsg HSU monitor well W-834-D3 to a 2022 maximum of 4,800 µg/L in the same well.

During 2022, only five of the 38 wells in the Building 834 OU yielded TBOS/TKEBS concentrations above the 10 µg/L reporting limit, the following four of which are screened in the core area Tpsg HSU:

- **Monitor well W-834-1709**: 470 µg/L in January.
- **Monitor well W-834-C2**: 92 µg/L in January.
- **Extraction well W-834-D4**: 48 µg/L in January.
- **Monitor well W-834-D3**: 4,800 µg/L in March.

The remaining well is distal area monitor well W-834-1824 screened in the Tpsg HSU, which yielded a concentration of 14 µg/L in a duplicate sample taken in January; the routine sample did not exceed the laboratory reporting limit of 10 µg/L.

Reported TBOS/TKEBS concentrations often differ significantly from one sampling event to the next. Although several attempts have been made to identify and measure TBOS/TKEBS as a floating product, it was last visually observed in some core area wells in the mid-1990s. Wells where TBOS/TKEBS is a co-contaminant with TCE generally exhibit the highest concentrations of microbial degradation products, such as *cis*-1,2 DCE and vinyl chloride, accumulating under anaerobic conditions when the SVTS is not operational.

During 2022, TBOS/TKEBS was not detected in core area Tps-$Tnsc_2$ wells or any leachfield or distal area wells except for aforementioned W-834-1824. Because TBOS/TKEBS concentrations in Tpsg HSU wells in the leachfield and distal areas have historically been low or below reporting limits, sampling for TBOS/TKEBS in these areas is performed biennially, with approximately half the wells sampled during even-numbered years and the remaining half sampled during odd-numbered years. During 2022, four leachfield area Tpsg HSU wells and four distal area Tpsg HSU wells were sampled for TBOS/TKEBS analysis; except for a duplicate sample from well W-834-1824 in the distal area, no other wells yielded concentrations above the reporting limit of 10 µg/L.

The concentrations and extent of TBOS/TKEBS in groundwater are greater in the Tpsg HSU than in the underlying Tps-$Tnsc_2$ HSU, because these compounds are light non-aqueous-phase liquids. The historical maximum TBOS/TKEBS concentration in the underlying Tps-$Tnsc_2$ HSU of 110 µg/L was detected in W-834-U1 in 2009. During this reporting period, TBOS/TKEBS concentrations in the Tps-$Tnsc_2$ HSU were below reporting limits in samples collected in January, February, and March from four core area wells, one leachfield area well, and two distal area wells. Concentrations also remained below the reporting limit in March and September samples from deep $Tnbs_1$ HSU guard wells W-834-T1 and W-834-T3.

2.2.3.1.3. Nitrate Concentrations and Distribution

During 2022, nitrate concentrations in Tpsg HSU groundwater of the Building 834 OU ranged from below the 0.5 mg/L reporting limit to a maximum concentration of 460 mg/L in distal area monitor well W-834-T2B, as detected in February. Nitrate exceeded the 45 mg/L MCL cleanup standard in all three Building 834 areas:

- Four core area wells at concentrations ranging from 68 to 180 mg/L.
- Five leachfield area wells at concentrations ranging from 100 to 170 mg/L.
- Seven distal area wells at concentrations ranging from 61 to 460 mg/L.

These concentrations were within historical ranges observed in these wells since 2006. In the core area, nitrate concentrations in the Tpsg HSU varied spatially and temporally, potentially due to denitrification associated with the ongoing *in situ* biodegradation of VOCs. Concentrations in all other Tpsg HSU wells were below the 45 mg/L MCL cleanup standard or did not exceed the typical reporting limit of 0.5 mg/L. Although both natural (geological) and anthropogenic sources contribute to nitrate in the perched groundwater, the anthropogenic sources are more significant.

In the underlying Tps-$Tnsc_2$ HSU, nitrate concentrations in groundwater exceeded the 45 mg/L MCL cleanup standard in the following wells:

- **Core area well W-834-3302**: 86 mg/L in February.
- **Leachfield area well W-834-S9**: 87 mg/L and 77 mg/L, both in March.
- **Distal area well W-834-2119**: 97 mg/L in January.
- **Distal area well W-834-3706**: 110 mg/L, 110 mg/L, 120 mg/L, and 62 mg/L in February, April, September, and October, respectively.
- **Well W-834-T5, south of the distal area**: 83 mg/L in March.

As with concentrations found in the Tpsg HSU, these nitrate concentrations were within historical ranges observed in these wells since 2006. Nitrate concentrations in all other Tps-$Tnsc_2$ HSU wells were below the 45 mg/L MCL cleanup standard during the reporting period.

Nitrate concentrations in groundwater have decreased from a 2000 historical maximum of 749 mg/L in monitor well W-834-K1A to a 2022 maximum of 460 mg/L in well W-834-T2B in February. However, the persistence of elevated nitrate concentrations suggests an ongoing source of nitrate to groundwater that is likely a combination of both natural and anthropogenic sources, including the proximal leachfield septic system. Nitrate did not exceed the reporting limit in samples collected from deep $Tnbs_1$ HSU guard wells W-834-T1 and W-834-T3 in March and September.

2.2.3.1.4. Other Contaminant Concentrations and Distribution

The extent of diesel in Building 834 area groundwater is limited to the vicinity of a former underground storage tank located beneath the paved portion of the core area. Diesel concentrations have decreased from a 2004 historical maximum of 3,900,000 µg/L in well W-834-S8 to a 2022 maximum of 880 µg/L in Tps HSU well W-834-2001 in January. An August sample from well W-834-2001 yielded 250 µg/L of diesel. Two other core area wells, W-834-A1 and W-834-U1, sampled in January and March, respectively, did not yield diesel concentrations above the reporting limit of 200 µg/L. Routine and duplicate groundwater samples collected in March from leachfield area well W-834-S9, which is screened in the Tps HSU, did not yield diesel above the laboratory reporting limits of 200 µg/L and 50 µg/L in the January and March samples, respectively.

Diesel concentrations in groundwater tend to vary from one sampling event to the next, likely due to varying amounts of free-phase product in the subsurface and fluctuating groundwater levels. During 2022, no floating product was observed in groundwater.

One well in the Building 834 OU, W-834-2118, was sampled for perchlorate during 2022. Perchlorate concentrations have decreased from a 2005 historical maximum of 11 µg/L in well W-834-2118 to a 2022 maximum of 4.3 µg/L in March and 4.5 µg/L in September in the well, thus falling below the 6 µg/L MCL cleanup standard.

2.2.3.2. Remediation Optimization Evaluation

Historically, SVE has removed substantially more VOC mass than groundwater extraction in the Building 834 OU. During 2022, this disparity continued with the SVTS operating throughout the period while the GWTS was operated for approximately 3,267 hours or 37 percent of the entire year and approximately 2,935 hours or 67 percent of the second semester of 2022. During 2022, 3,476 g of VOCs were removed from the subsurface, mostly by SVE.

Similar to recent years, in 2022, the Building 834 SVTS treated approximately 3,397 g of VOCs or approximately 98 percent of the total VOC mass removed within the OU. Conversely, the GWTS was operated for only a portion of the year due to equipment issues and winter freeze-protection periods at the beginning and end of the year, removing approximately 79 g of VOCs during 2022.

Also during 2022, 11 kg of total nitrate mass and 0.047 g of TBOS/TKEBS mass were removed. Table Summ-1 lists the mass removed by each treatment facility during the entire year of 2022.

2.2.3.2.1. Core Area

During this reporting period, no modifications were made to the Tpsg HSU extraction wellfield within the Building 834 core area. This wellfield is expected to continue adequately capturing the highest VOC concentrations in groundwater when full and normal operations resume, as planned for 2023. VOC concentrations in core area monitor wells have been and will continue to be closely monitored to evaluate the performance of active dual extraction, in combination with intrinsic biodegradation during shutdown periods of the SVE system when the subsurface becomes oxygen-depleted and reducing.

Active groundwater extraction, SVE, and biodegradation have reduced TVOC concentrations in groundwater in the Tpsg HSU core area from a 1998 historical maximum of 1,100,000 µg/L in well

W-834-D5 to a 2022 maximum of 18,000 µg/L in well W-834-C5 in January. During the reporting period, the highest concentrations of TCE were detected in well W-834-D7 at 7,300 µg/L in October and of *cis*-1,2-DCE in well W-834-C5 at 12,000 µg/L in January. Maximum concentrations of vinyl chloride in 2022 included 53 µg/L in extraction well W-834-B3 in November, 37 µg/L in monitor well W-834-D5 in January, and 8.0 µg/L in extraction well W-834-D3 in March.

TCE biodegradation continues locally within the core area where a significant mass of TBOS/TKEBS has historically been present. During 2022, TBOS/TKEBs was detected at concentrations of 4,800 µg/L, 470 µg/L, 92 µg/L, and 48 µg/L in four core area Tpsg HSU wells, W-834-D3, W-834-1709, W-834-C2, and W-834-D-4, respectively; however, it was not detected above reporting limits in samples collected from the 15 other core area Tpsg HSU wells. Except for one distal area well, W-834-1824, no other Building 834 OU wells yielded TBOS/TKEBs at concentrations exceeding reporting limits.

During 2022, nitrate concentrations continued to show decreasing trends in Building 834 OU wells. Nitrate was detected in four core area wells, W-834-C4, W-834-D7, W-834-J1, and W-834-J2, at concentrations ranging from 68 to 180 mg/L, similar to those detected in 2021.

VOC concentrations in Tpsg HSU monitor wells W-834-B4 and W-834-C5 are being monitored during the current five-year review period to verify whether long-term decreasing concentration trends continue in these wells. Well W-834-B4 was not sampled in 2020 or 2021 due to insufficient water, and well W-834-C5 was dry in 2021 and not sampled. TVOC concentrations in well W-834-B4 decreased from 9,500 µg/L in 2011 to 1,100 µg/L in March 2022 while concentrations in well W-834-C5 decreased from 65,200 µg/L in 2012 to 18,100 µg/L in January 2022. Although TVOC concentrations in well W-834-C5 tend to fluctuate, being higher in the summer months and lower in the winter months, they have been decreasing overall since 2012. However, if significantly increasing VOC trends are identified during the current five-year review period, the installation of dual extraction wells in the vicinity of wells W-834-B4 and W-834-C5 or *in situ* bioremediation may be considered.

The highest VOC concentrations in the Building 834 OU and at Site 300 have been detected in the Tps-Tnsc$_2$ HSU. TVOC concentrations have decreased from a 2012 historical maximum of 298,000 µg/L to a 2022 maximum of 167,000 µg/L, both in Tps-Tnsc$_2$ HSU monitor well W-834-A1. In 2017, a well planned for dual extraction, W-834-3301, was drilled and screened in this HSU near existing well W-834-A1 to test the feasibility of extracting VOC-bearing groundwater and soil vapor from this low-permeability perching horizon. Due to limited water, this well was sampled for the first time in February 2018, yielding 2,600 µg/L of TVOCs, mostly comprised of TCE. Since then, concentrations have gradually decreased to 1,000 µg/L in September 2020, 400 µg/L in February 2021, and 132 µg/L and 128 µg/L in February and September 2022, respectively.

2.2.3.2.2. Leachfield Area

In the leachfield area, the extraction wellfield, when operating, has captured portions of the VOC plume in Tpsg HSU groundwater. To increase capture in the vicinity of monitor well W-834-2113, where the highest VOC concentrations exist, the well was converted to a dual extraction well and connected to the GWTS and SVTS in August 2017.

Monitored by wells W-834-S8 and W-834-S9, the Tps-$Tnsc_2$ HSU exhibits VOC concentrations significantly lower than in the overlying Tpsg HSU. TVOC concentrations in well W-834-S8 decreased from 5,200 µg/L in 2016 to 610 µg/L in 2017 and increased to 2,170 µg/L in September 2022. Similar concentrations were observed in well W-834-S9 where TVOC concentrations decreased from 4,600 µg/L in 2016 to 800 µg/L in 2017 and increased to 2,000 µg/L in September 2022. TVOC concentrations in both wells generally appear to exhibit an inverse correlation with water level fluctuations (i.e., concentrations decline as water levels rise). TVOC data will continue to be reviewed to determine the long-term trend of these concentrations; however, VOCs concentrations in groundwater are expected to continue to generally decrease as remediation progresses.

Concentrations of TBOS/TKEBS in both leachfield Tps-$Tnsc_2$ HSU wells have remained below the 10 µg/L reporting limit and nitrate remained above the 45 mg/L MCL cleanup standard during 2021 (when both wells were sampled) and 2022 (when W-834-S9 was sampled). The deep regional Lower $Tnbs_1$ HSU aquifer continues to be free of contaminants, as demonstrated by quarterly analyses of groundwater from guard wells W-834-T1 and W-834-T3.

2.2.3.2.3. Distal Area

Since 2005, the distal area has been the target of the long-term enhanced *in situ* bioremediation treatability study detailed in Section 2.2.3.4.

In 2021, Tps-$Tnsc_2$ HSU dual extraction well W-834-3706 was installed in the T2 portion of the distal area near existing monitor well W-834-2119. In this area, TVOC and nitrate concentrations had been increasing since monitoring began in 2005. TVOC concentrations in W-834-2119 reached a historical maximum of 16,700 µg/L in 2012. Since then, VOC concentrations in this well have been stable to slightly decreasing. New well W-834-3706 has been sampled six times with TVOC concentrations ranging between 3,300 µg/L in September 2021 and 4,500 µg/L in September 2022. This well will continue to be monitored for future trends.

2.2.3.3. T2 Treatability Study

Since 2005, the distal T2 area has been the target of a long-term enhanced *in situ* bioremediation treatability study in the Tpsg HSU, which has included biostimulation using sodium lactate from April 2007 to December 2008 and bioaugmentation using KB-1™, a consortium of dechlorinating bacteria containing *Dhc*, in August 2008. Since January 2009, post-treatment monitoring has continued to evaluate VOC concentration rebound since the suspension of biostimulation.

This treatability study assesses the performance of enhanced *in situ* bioremediation of TCE at concentrations greater than 10,000 µg/L in a water-bearing zone typical of TCE contaminant source areas at Site 300. After the successful implementation of the treatability study, DOE/LLNL prepared the *Phase 2 Pilot Study Work Plan for Enhanced In Situ Bioremediation at Building 834, Lawrence Livermore National Laboratory Site 300* (LLNL 2016). The regulatory agencies approved this work plan in September 2016. For Phase 2, ethyl lactate replaced sodium lactate as the preferred biostimulation agent because it is a more effective electron donor and does not add sodium to groundwater. Although a small-scale recirculation cell has been proposed for implementation, recent regional drought conditions and ongoing upgradient dual extraction operations have caused water levels to decline in several T2 area wells, leaving insufficient groundwater for the second phase of the treatability study. The *Draft Final Building 834, Pit 6, and Site-Wide Consolidated Five-Year Review Lawrence Livermore National Laboratory Site 300* further details the treatability study (Taffet et al. 2023).

The following subsections summarize recent analytical data from the T2 treatability study. The T2 treatment zone includes electron donor injection well W-834-1824; KB-1™ bioaugmentation well W-834-1825; key performance monitor wells W-834-T2, W-834-T2A, W-834-T2D, and W-834-1833; upgradient compliance monitor well W-834-2117; and downgradient compliance monitor well W-834-2118.

2.2.3.3.1. Well W-834-T2

Following sodium lactate injection into well W-834-1824 in April 2007 and bioaugmentation with KB-1™ in well W-834-1825 in August 2008, TVOC concentrations in well W-834-T2 decreased from a baseline concentration of 10,000 µg/L in January 2007 to a second semester 2022 maximum of 237 µg/L in September. In September, TCE and *cis*-1,2-DCE were detected in the well at concentrations of 23 µg/L and 140 µg/L, respectively. The vinyl chloride concentration of 74 µg/L confirmed that reductive dechlorination is still ongoing in well W-834-T2 and the surrounding subsurface, even though sodium lactate injections ceased in December 2008. Nitrate was not detected in this well in excess of the 0.5 mg/L reporting limit in February, and an ORP of -26 mV in September also indicates that conditions remain conducive to reductive dechlorination.

2.2.3.3.2. Well W-834-T2A

In well W-834-T2A, *in situ* reductive dechlorination has significantly decreased TVOC concentrations from a baseline concentration of 12,030 µg/L in January 2007 to 2,018 µg/L in September 2022. The second semester 2022 maximum TCE concentration was 2,000 µg/L in September, well below the 1988 historical maximum of 86,000 µg/L. Although the ORP was -37 mV in this well in September, the nitrate concentration of 60 mg/L in February suggests that subsurface conditions have locally changed from anoxic to aerobic, limiting reductive dechlorination. Subsurface heterogeneity is likely responsible for these varying redox conditions.

2.2.3.3.3. Well W-834-1825

During 2022, samples were not collected for chemical analyses from well W-834-1825 because it was dry. This well was last sampled in February 2021, when the TVOC concentration was 1,817 µg/L, comprised of 1,600 µg/L of TCE, 210 µg/L of *cis*-1,2-DCE, 3.7 mg/L of PCE, and 3.1 mg/L of *trans*-1,2-DCE; vinyl chloride was not detected above the 2.5 µg/L reporting limit. An ORP of 125 mV and nitrate concentrations of 12 mg/L, both in February 2021, indicate that the local subsurface has returned to aerobic conditions.

2.2.3.3.4. Well W-834-1833

This performance monitor well has exhibited limited evidence of being significantly impacted by treatability study activity, although TVOC concentrations have declined from a baseline of 13,050 µg/L in January 2007 to 2,733 µg/L by September 2022. The VOC composition of the September groundwater sample was primarily TCE and 1,2-DCE at concentrations of 2,600 µg/L and

120 µg/L, respectively. Vinyl chloride was not detected above the 0.5 µg/L reporting limit. Nitrate concentrations of 36 mg/L in January and an ORP of 107 mV in September suggest that conditions surrounding well W-834-1833 are aerobic and less conducive to reductive dechlorination.

2.2.3.3.5. Well W834-T2D

In well W834-T2D, VOC concentrations, consisting primarily of TCE, declined from 11,000 µg/L in January 2007 to 1,807 µg/L in September 2022; 2.4 µg/L of *cis*-1,2-DCE were detected, and vinyl chloride was not detected above the 0.5 µg/L reporting limit. Although TVOC concentrations in September represent a historical low for this performance monitor well, there is very little evidence that it has been impacted by any bioremediation study activities.

2.2.3.3.6. Well W-834-1824

Well W-834-1824 served as an injection well for both the tracer and sodium lactate used during the treatability study. *In situ* reductive dechlorination significantly decreased TVOC concentrations in this well from a baseline of 5,900 µg/L in August 2006 to 3.1µg/L in September 2022. In the September sample, TCE and *cis*-1,2-DCE concentrations were 1.8 µg/L and 0.81 µg/L, respectively, and vinyl chloride was not detected above the 0.5 µg/L reporting limit. Nitrate concentrations did not exceed the 5 mg/L reporting limit in January while the ORP was measured at 110 mV in September.

2.2.3.3.7. Wells W-834-2117 and W-834-2118

TVOC concentrations in upgradient well W-834-2117 decreased from a baseline of 20,200 µg/L in June 2005 to 2,450 µg/L by September 2022. This overall decreasing trend was also observed in performance monitor wells W-834-T2A, W-834-T2D, and W-834-1833. TVOC concentrations in well W-834-2118, located downgradient of the T2 treatment zone, have similarly decreased from 600 µg/L in 2005 to 65 µg/L in September 2022. TCE concentrations in groundwater are decreasing over time without any significant discernible support from *in situ* bioremediation.

2.2.3.3.8. Summary

Addition of sodium lactate and *Dhc* microorganisms to the subsurface has established redox conditions conducive to the complete reductive dechlorination of TCE in the Tpsg HSU. If Phase 2 of the treatability study occurs, performance would be judged primarily on the distribution of ethene beyond its current extent and the overall reduction in TVOC concentrations in the T2 area.

In 2023, DOE/LLNL will evaluate whether to commence the next phase of the bioremediation treatability study at T2 and also consider expanding dual-phase extraction in the T2 area as an alternative to continuing the treatability study.

2.2.3.4. Remedy Performance Issues

During the reporting period, groundwater operations in the Building 834 OU were significantly curtailed due to winter freeze protection followed by maintenance operations at the treatment facilities. Groundwater extraction and treatment were limited to approximately 135 days while SVE and treatment operations were conducted throughout most of the reporting period. The reduction in extraction and treatment may have temporarily affected the performance of the cleanup remedy in the Building 834 OU.

Full dual-extraction operations in the Building 834 core area and leachfield area will resume during 2023 and should continue to effectively reduce VOC mass and concentration in both groundwater and vapor. The remedy continues to be protective of human health and the environment and is making progress toward cleanup.

Per the recommendations presented in the fourth five-year review, VOC concentration trends are being monitored in Tps-$Tnsc_2$ HSU wells. Installation of additional extraction wells in this HSU may more effectively remediate VOCs beneath the core area. Additionally, DOE/LLNL will evaluate the feasibility and effectiveness of enhanced *in situ* bioremediation in the core area.

2.3. Pit 6 Landfill (OU 3)

The Pit 6 landfill covers an area of 2.6 acres at the southern boundary of Site 300. From 1964 to 1973, this landfill was used to bury waste in nine unlined debris trenches and animal pits. The buried waste, which includes shop and laboratory equipment and biomedical waste, is located on or adjacent to the Corral Hollow-Carnegie Fault. Farther east, the fault trends to the south of two nearby water-supply wells, CARNRW1 and CARNRW2. Located approximately 200 and 400 ft north of the fault, respectively, and approximately 1,000 ft east of the Pit 6 landfill, these active wells provide water for the nearby Carnegie State Vehicular Recreation Area (SVRA) and are monitored on a monthly basis.

In 1997, the Pit 6 landfill was capped and closed under CERCLA to prevent contaminants from further leaching as a result of rainwater percolating through the buried waste. An engineered, multi-layer cap has been installed to prevent rainwater infiltration into the landfill, mitigate potential damage caused by burrowing animals and vegetation, prevent potential hazards from the collapse of void spaces in the buried waste, and prevent the potential flux of VOC vapors through the soil. Additionally, surface water flow onto the landfill is minimized by a diversion channel on the north side and drainage channels on the east, west, and south sides of the cap.

Figure 2.3-1 is a map of the Pit 6 landfill OU showing the locations of its monitor and water-supply wells.

2.3.1. Groundwater and Surface Water Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring at the Pit 6 landfill OU. This appendix also explains deviations made from the plan.

During the second semester of 2022, groundwater monitoring was conducted in accordance with the CMP/CP monitoring and post-closure requirements, with the exception of the following 36 required analyses that could not be performed:

- A total of 30 analyses from three different wells, BC6-13, K6-15, and K6-21, were not performed because the wells were dry. These wells have generally lacked sufficient water for sampling since 2000.
- A total of six analyses from well K6-27 were not performed because its pump was inoperable. Although this pump was repaired in November 2020, it became inoperable again and is currently under repair.

Attachment 1 and Appendix D tabulate the analytical results and groundwater elevation measurements, respectively, that were obtained during 2022. Figure 2.3-2 is a map of groundwater potentiometric surface contours for the Qt-$Tnbs_1$ HSU within the Pit 6 landfill OU.

2.3.2. Remediation Progress Analysis

This section is organized into three subsections: analysis of contaminant distribution and concentration trends, remediation optimization evaluation, and performance issues.

2.3.2.1. Contaminant Distribution and Concentration

At the Pit 6 Landfill OU, the primary COCs in groundwater are VOCs (primarily CFORM and TCE), perchlorate, and tritium, and nitrate is the secondary COC. These constituents have historically been identified within the Qt-$Tnbs_1$ HSU, which is divided into the Qt-$Tnbs_1$ North HSU north of the Corral Hollow-Carnegie fault zone and Qt-$Tnbs_1$ South HSU within the Corral Hollow-Carnegie fault zone, due to the difference in saturated thickness and bedding orientation of bedrock strata on either side of this regional fault. Hydraulic responses to pumping from the off-site CARNRW water-supply wells, as well as to seasonal rainfall events, differ between the two HSUs. A deeper water-bearing zone, the $Tnbs_1$ Deep HSU, occurs north of the fault zone beneath a low-permeability confining layer at an approximate depth of 170 ft.

Transducers in guard wells K6-34 and W-PIT6-1819 continuously monitor water levels in the Qt-$Tnbs_1$ North HSU. During 2022, water-level data from these wells indicated an ongoing hydraulic response to the daily to weekly pumping of off-site wells CARNRW1 and CARNRW2. Although DOE/LLNL does not control the pumping of these nearby wells, the timing of pumping can be inferred from water-level responses in wells W-PIT6-1819 and K6-34. Hydraulic responses in 2022 continue to indicate that the CARNRW wells are pumping at a lower rate than the typical rate prior to 2014.

During the second semester of 2022, groundwater levels measured in Qt-$Tnbs_1$ North wells were approximately 0 to 6 ft lower than those measured during the second semester of 2021. More significant water level changes from 2021 to 2022, which occurred in the eastern monitor wells north of the fault, are attributed to continued groundwater extraction from the CARNRW wells. A combination of continued groundwater extraction from the CARNRW wells and below-average rainfall limiting recharge has likely caused the ongoing decline in the water table north of the Corral Hollow-Carnegie fault zone since 2017.

The concentrations and activity concentrations of COCs in Pit 6 groundwater have declined significantly from their historical maxima. In 2022, primary COC concentrations remained below their MCL cleanup standards, except for a single TCE detection of 5.3 µg/L at monitor well EP6-08 in January. Otherwise, VOC concentrations remained stable or slightly declined from 2021 to 2022. Nitrate exceeded the MCL cleanup standard in only two monitor wells, K6-18 and K6-23, during this period.

The following subsections discuss concentrations and distributions of VOCs, tritium, perchlorate, and nitrate in the Pit 6 landfill OU's HSUs. These discussions are supported by the following figures:

- **Figure 2.3-3**: Second semester TVOC isoconcentration contour map of the Qt-$Tnbs_1$ HSU with individual VOC concentrations.

- **Figure 2.3-4**: Second semester tritium activity isoconcentration contour map of the Qt-Tnbs$_1$ HSU.

Because each map is representative of contaminant concentrations during a particular semester, the maximum concentrations shown on the map may not match the maximum concentrations described in the following sections.

2.3.2.1.1. VOC Concentrations and Distribution

Historically, primary VOCs of concern in Pit 6 groundwater have included TCE and CFORM. Other VOCs detected in groundwater in the past include PCE, *cis*-1,2-DCE, and 1,1-DCA.

During 2022, VOCs were detected above their respective reporting limits in only one Qt-Tnbs$_1$ North HSU monitor well, EP6-08. No VOCs were detected above their respective MCL cleanup standards in any well within the Pit 6 landfill OU. However, PCE, which is not a COC, was detected above its MCL in monitor well EP6-08 at 5.3 µg/L in January and at 5 µg/L in December. VOCs did not exceed laboratory reporting limits in guard wells W-PIT6-1819 and K6-34.

Qt-Tnbs$_1$ North HSU

A total of 12 monitor wells and two guard wells are screened in the Qt-Tnbs$_1$ North HSU. The following general trends in VOC concentrations were observed in this HSU:

- **TCE:** The historical maximum TCE concentration is 2.9 µg/L, detected in January 2022 in well EP6-08, immediately east and downgradient of the Pit 6 landfill. TCE concentrations were historically very low in area wells until 2018, when rising groundwater levels apparently leached TCE to groundwater at well EP6-08. During 2022, no other wells screened in the Qt-Tnbs$_1$ North HSU had detectable concentrations of TCE.
- **CFORM**: The historical maximum CFORM concentration is 4.9 µg/L, detected in water-supply well CARNRW2 in 1990. The 2022 maximum CFORM concentration of 0.73 µg/L was detected in well EP6-08 in January. This was the only well screened in the Qt-Tnbs$_1$ North HSU yielding CFORM in excess of its laboratory reporting limit of 0.5 µg/L.

During 2022, PCE was detected in a single monitor well, EP6-08, at a maximum concentration of 5.3 µg/L in January. Concentrations declined slightly to 4.2 µg/L and 5 µg/L in September and December, respectively. EP6-08 was dry and could not be sampled between May 2008 and July 2017. The April 2008 sample yielded a TVOC concentration of 1.8 µg/L, comprised of 1.2 µg/L PCE and 0.56 µg/L TCE. Because the well was dry for nearly 10 years, recent increases in concentrations may be a result of an approximate 9 ft rise in the water levels between 2017 and 2019 that likely leached residual VOCs from the vadose zone into groundwater. The maximum depth of the bottom of the buried waste in Pit 6, immediately west of the well, is approximately 12 ft bgs. During 2022, water levels fluctuated between approximately 41 and 46 ft below the bottom of the buried waste (i.e., approximately 53 to 58 ft bgs). Following the 1998 El Niño recharge event, water levels in well EP6-08 were approximately 13 to 18 ft higher than current levels.

Other wells screened in the Qt-Tnbs$_1$ North HSU showed similar water level rises between 2017 and 2022, but individual VOC concentrations remained below reporting limits. VOCs were not detected in guard wells W-PIT6-1819 and K6-34.

Qt-Tnbs$_1$ South HSU

A total of 13 monitor wells and two guard wells are screened in the Qt-Tnbs$_1$ South HSU. The following general trends in VOC concentrations were observed in this HSU:

- TCE concentrations from declined from a 1998 historical maximum of 250 µg/L in well K6-19 to a 2022 maximum of 4.4 µg/L in monitor well EP6-09 in January. During 2022, the spatial extent of TCE remained limited to an area immediately southeast of Pit 6.
- CFORM concentrations also declined from a 1994 historical maximum of 14 µg/L in well K6-19 to below the 0.5 µg/L reporting limit in all Qt-Tnbs$_1$ South HSU wells in 2022.

During 2022, TCE was detected in groundwater samples from four Qt-Tnbs$_1$ South HSU monitor wells, EP6-09, K6-16, K6-18, and K6-19, at concentrations ranging from 0.51 to 4.4 µg/L. Groundwater levels in monitor wells EP6-09, K6-16, and K6-19 exhibited a strong recharge response to above-average precipitation during the 2017 and 2019 water years while water levels remained relatively stable in well K6-18. These rises in water levels may have leached minor residual vadose zone TCE into the groundwater at well EP6-09 and, to a lesser extent, at wells K6-16 and K6-19. For reference, monitor well EP6-09 is located at an approximate midpoint along the southern boundary of Pit 6 while well K6-19 is located at the southeast corner of Pit 6. Wells K6-16 and K6-18 are located approximately 200 ft downgradient and southeast of Pit 6. Guard well K6-17, which is located approximately 350 ft downgradient and southeast of Pit 6, had no detections of TCE in 2022.

While no longer a COC, *cis*-1,2-DCE was detected in monitor well K6-01S, located south of the Pit 6 landfill, at 2 µg/L in January and 1.9 µg/L in December. These limited *cis*-1,2-DCE detections are consistent with historical results and remain well below the 6 µg/L MCL cleanup standard. No other VOCs were detected in the Qt-Tnbs$_1$ South HSU during this reporting period.

Tnbs$_1$ Deep HSU

Well K6-26 monitors groundwater in the Tnbs$_1$ Deep HSU, within the fault zone. No VOCs were detected in this well during 2022. Historically, VOCs were only detected in this well twice and most recently in 1991 when 0.9 µg/L of 1,1,1-TCA was reported.

Water-Supply Wells

During the reporting period, VOCs were not detected in the two active water-supply wells, CARNRW1 and CARNRW2, nor the two inactive water-supply wells, CARNRW3 and CARNRW4.

2.3.2.1.2. Tritium Activity Concentrations and Distribution

Tritium has never been detected in Pit 6 landfill groundwater at activity concentrations exceeding the MCL cleanup standard of 20,000 pCi/L. During 2022, tritium was detected slightly above the 100 pCi/L reporting limit in a single monitor well, K6-19, which is screened in the Qt-Tnbs$_1$ South HSU. Measured tritium activity concentrations were accompanied by relatively large analytical uncertainties and, thus, are not indicative of exceedance of background (i.e., less than the 100 pCi/L reporting limit).

Qt-Tnbs$_1$ North HSU

In the Qt-Tnbs$_1$ North HSU, tritium activity concentrations have decreased from a 2000 historical maximum of 2,150 pCi/L in well K6-36 to below the 100 pCi/L reporting limit in 2022. The 2021 maximum activity concentration was 137 ±73.9 pCi/L in well K6-33 in August while, in January 2020, the Pit 6 landfill's maximum activity concentration of 400 ±124 pCi/L was detected at monitor well K6-36. Well K6-36 was dry and was not sampled in 2022.

At well EP6-07, tritium has not been detected above the 100 pCi/L reporting limit since 2005, other than a 255 ±100 pCi/L activity concentration in January 2016. No detections were reported in 2022.

Guard well W-PIT6-1819 is located approximately 200 ft west of the CARNRW1 and CARNRW2 water-supply wells and has historically defined the downgradient extent of tritium activity concentrations exceeding 100 pCi/L in Pit 6 groundwater. Since 2007, tritium activity concentrations in W-PIT6-1819 have fluctuated from less than 100 pCi/L to a maximum activity concentration of 295 pCi/L, as detected in April 2007, but indicate an overall decreasing trend. From July 2016 to present, with the exception of a single measurement of 110 ±70.5 pCi/L in July 2018, activity concentrations in W-PIT6-1819 have not exceeded the 100 pCi/L reporting limit.

In guard well K6-34, tritium has only been detected three times since monitoring began in 2000, with the most recent detection in October 2018 occurring just above the reporting limit at 107 ±73.9 pCi/L.

Qt-Tnbs$_1$ South HSU

In the Qt-Tnbs$_1$ South HSU, tritium activity concentrations have decreased from a 2000 historical maximum of 3,420 pCi/L at monitor well BC6-13, which monitors Spring 7, to a single detection of tritium at 102 ±74.2 pCi/L at K6-19 in January 2022. In December 2022, tritium activity concentrations in K6-19 were below the 100 pCi/L reporting limit.

Tnbs$_1$ Deep and Tmss HSUs

The historical maximum tritium activity concentration in the Tnbs$_1$ Deep HSU of 1,680 pCi/L was detected in 1999 in monitor well K6-26, considerably below the 20,000 pCi/L MCL cleanup standard. In 2022, K6-26 was also below the 100 pCi/L reporting limit for tritium.

Since monitoring began in Tmss HSU well K6-25 in 1995, tritium has been detected in only two sampling events: 215 pCi/L in 2005 and 116 ±83.9 pCi/L in 2020. Throughout 2022, tritium activity concentrations were below the reporting limit in this well, which will continue to be monitored for any future trends.

Water-Supply Wells

During this reporting period, tritium was not detected above the 100 pCi/L reporting limit in active wells CARNRW1 and CARNRW2 nor inactive wells CARNRW3 and CARNRW4.

Qal-Tts HSU

In July 2015, 187 ±83.5 pCi/L of tritium was detected in well W-33C-01, located approximately 60 ft south of the Site 300 boundary within the Carnegie SVRA and screened in the Qal-Tts stratigraphic unit. Other than the 2015 detection, tritium has not been measured above the reporting limit in this well since monitoring was initiated in 2000.

2.3.2.1.3. Perchlorate Concentrations and Distribution

The historical maximum concentration of perchlorate in the Qt-$Tnbs_1$ North HSU was detected in 2003 at 14 µg/L in well K6-35. Since 2004, perchlorate has not been detected above the reporting limit (4 µg/L through the first semester of 2021 and 2 µg/L after the second semester of 2021) in any Qt-$Tnbs_1$ North HSU well, including the two guard wells. In 2022, perchlorate was detected in two Qt-Tnbs1 South monitor wells, K6-18 and K6-19, at 2.4 and 7.1 µg/L, respectively.

Qt-$Tnbs_1$ South HSU

Perchlorate concentrations in Qt-$Tnbs_1$ South HSU wells have decreased from a 1998 historical maximum of 65.2 µg/L in well K6-19 to a current maximum concentration of 7.1 µg/L in the same well. This recent result, which slightly exceeded the MCL cleanup standard of 6 µg/L, is consistent with results obtained between 2017 and 2019 (6.6 µg/L in January 2018) when water levels rose beneath the pit.

At well K6-18, the 2022 detection of 2.4 µg/L was a decline from the recent maximum of 11 µg/L in January 2018. During 2020, ORP field measurements of -94 mV in January and -74 mV in September suggested that the microbial reduction of perchlorate under anaerobic conditions may have reduced concentrations to below reporting limits. Similar anaerobic subsurface conditions and lowered perchlorate concentrations were observed at this well in 2012 and 2013. Between 2014 and 2019, perchlorate concentrations ranging from 5.1 to 11 µg/L, accompanied by positive ORP measurements greater than +53 mV, indicated oxidizing conditions unsupportive of microbial reduction. ORP measurements increased during 2021 and reached 117 mV in 2022. Similarly, nitrate concentrations increased to 210 mg/L in 2015 and declined to 83 mg/L by September 2020 and 51 mg/L by August 2022.

These concentration decreases and increases at K6-18 since 2012 may have resulted from the bacterially-motivated reduction of nitrate and perchlorate, followed by an upgradient influx of oxygen-, perchlorate-, and nitrate-bearing water in 2014 and thereafter. Perchlorate trends in wells K6-16, K6-18, and K6-19 will continue to be closely monitored.

$Tnbs_1$ Deep and Tmss HSUs

Perchlorate did not exceed the 4 µg/L reporting limit in any $Tnbs_1$ Deep HSU or Tmss HSU wells during 2022.

Water-Supply Wells

During 2021, perchlorate was not detected above the 2 to 4 µg/L reporting limit in active wells CARNRW1 and CARNRW2 nor inactive wells CARNRW3 and CARNRW4.

2.3.2.1.4. Nitrate Concentrations and Distribution

During 2022, nitrate was detected in groundwater samples collected from wells screened in the Qt-$Tnbs_1$ North and South HSUs.

Qt-$Tnbs_1$ North HSU

In the Qt-$Tnbs_1$ North HSU, nitrate was detected at a maximum concentration of 10 mg/L in well K6-24 in January 2022, below the 45 mg/L MCL cleanup standard and a decrease from the 2019 concentration of 47 mg/L. The historical maximum nitrate concentration in this HSU of 63 mg/L was detected in this well in 2011. During the reporting period, nitrate was also detected in five other wells in this HSU at concentrations ranging from 0.59 to 5.3 mg/L.

From 1998 to 2006, nitrate concentrations in well K6-24 remained below 2 mg/L but increased to 63 mg/L in April 2011 before the well became dry during the second semester of 2011. By January 2017, water levels had recovered sufficiently, and the January sample contained 46 mg/L of nitrate. Samples taken in January 2018 and 2019 contained 46 mg/L and 47 mg/L, respectively, before concentrations declined to 10 mg/L in January 2022. Nearby well W-PIT6-2817 yielded only 2 mg/L of nitrate in January 2022.

During the first semester of 2022, nitrate concentrations remained below the 0.5 mg/L reporting limit at guard well W-PIT6-1819 and below the 1 mg/L reporting limit at guard well K6-34.

Qt-Tnbs$_1$ South HSU

During 2022, nitrate was detected in six Qt-Tnbs$_1$ South HSU wells at concentrations ranging from 3 to 190 mg/L; the 45 mg/L MCL cleanup standard was exceeded in two wells, K6-18 and K6-23. The historical maximum nitrate concentration in this HSU, 250 mg/L, was detected in 2019 in well K6-23. This well is located in proximity to the Building 899 septic system, which is the likely source of the nitrate at this location (Dibley et al. 2013).

Located approximately 240 ft west-northwest and upgradient of well K6-23 and the Building 899 septic system, well K6-18 had nitrate concentrations in groundwater that exceeded the MCL cleanup standard in 1998, an El Niño year, and in 2009. Nitrate concentrations increased significantly from 16 mg/L by January 2014 to 210 mg/L by January 2015 but declined to 51 mg/L by August 2022.

Nitrate concentrations in well K6-16, located approximately 80 ft south of K6-18 and 225 ft west and upgradient of the Building 899 septic system, declined to 25 mg/L by January 2022. Since January 2016, nitrate concentrations in this well have steadily risen from 10 mg/L to 44 mg/L by January 2020, followed by a concentration decline to 25 mg/L by January 2022, while groundwater elevations remained relatively stable. Variations in nitrate and perchlorate concentrations observed at this well may correlate with bacterially-motivated redox changes in the groundwater (i.e., nitrate concentrations are low when ORP data indicate anoxic or reducing geochemical conditions).

Located at the southeast corner of the Pit 6 landfill and approximately 400 ft west-northwest and upgradient of K6-23 and the Building 899 septic system, well K6-19 yielded a nitrate concentration of 6.1 mg/L in January 2022. This detection marks a significant decline from the 82 mg/L detected in January 2017, which was the only concentration that exceeded the MCL cleanup standard since the well was installed in 1988 and the first above the nitrate reporting limit since 2002. This detection may have been the result of water levels rising in well K6-19 by approximately 1.5 ft between the first semester of 2016 and the first semester of 2017, then stabilized from 2017 to 2022; this water-level rise may have caused the leaching of some available vadose zone nitrate into the groundwater.

Nitrate was not detected at concentrations above its MCL cleanup standard in groundwater samples from any other wells in the Qt-Tnbs$_1$ South HSU, and concentrations were below the 2 µg/L reporting limit in guard wells K6-17 and K6-22 in 2022.

During June 2022, monitor wells K6-18 and K6-23 were sampled for pharmaceutical and personal care product (PPCP) analyses to determine whether nitrate concentrations above MCLs arose from a septic system source. The analyses detected antibiotics, plastic compounds, and flame retardants in K6-18 and caffeine, plastic compounds, and antibiotics in K6-23, indicating that nitrate in excess of MCLs is likely sourced from the Building 899 septic system waste and not the Pit 6 landfill. Further discussed in the *Draft Final Building 834, Pit 6, and Site-Wide Consolidated Five-Year Review Lawrence Livermore National Laboratory Site 300* (Taffet et al. 2023), this determination is supported by the limited areal extent of nitrate above MCLs in the vicinity of the septic system and the absence of elevated nitrate concentrations in the immediate vicinity of the buried waste.

Tnbs$_1$ Deep HSU

In 2022, concentrations were below the 1 mg/L reporting limit in Tnbs$_1$ Deep HSU and Tmss HSU monitor wells. Nitrate has never been detected above its 45 mg/L MCL cleanup standard in groundwater samples from the Tnbs$_1$ Deep HSU or Tmss HSU.

Water-Supply Wells

The maximum nitrate concentrations of 9.5 mg/L and 1.8 mg/L from this reporting period were detected in inactive water-supply well CARNRW4 in March and active water-supply well CARNRW2 in July, respectively. Nitrate was not detected above reporting limits of 0.5 mg/L to 1 mg/L in active water-supply well CARNRW1 or inactive water-supply well CARNRW3. All nitrate concentrations were well below the 45 mg/L MCL cleanup standard in these water-supply wells.

2.3.2.2. Remediation Optimization Evaluation

The remedy for tritium and VOCs in Pit 6 Landfill groundwater is monitored natural attenuation (MNA). Groundwater levels and contaminants are monitored on a regular basis to evaluate the efficacy of natural attenuation in reducing contaminant concentrations and to detect any new chemical releases from the landfill.

During 2022, groundwater levels beneath the Pit 6 landfill ranged from approximately 30 ft below the buried waste in wells located within the Corral Hollow-Carnegie fault zone to 46 ft in wells located north of the Corral-Hollow-Carnegie fault zone. In general, concentrations of primary groundwater COCs (CFORM, TCE, perchlorate, and tritium) at the landfill continue to decrease.

Overall, VOC concentrations continue to exhibit decreasing trends. Except for very low concentrations detected in a single well, EP6-08, adjacent to the landfill, and cross-gradient well W-33C-01, screened in the Qal-Tts HSU, CFORM was below the reporting limit in all Pit 6 landfill wells. Although no longer a COC, *cis*-1,2-DCE was detected twice in a single well, K6-01S, during 2022 and has remained below the 6 µg/L MCL cleanup standard since 1993. During 2022, all Pit 6 wells were below the MCL cleanup standard of 5 µg/L.

Tritium activity concentrations in groundwater continue to remain far below the 20,000 pCi/L MCL cleanup standard and generally below background levels. During 2022, concentrations were detected above the 100 pCi/L reporting limit in only well, K6-19, at 102 ±74.2 pCi/L in January and were not detected in K6-19 in December. The very low, intermittently detected tritium activity concentrations in Pit 6 landfill wells appear to be the result of the relatively high analytical uncertainty for tritium in these samples (near the reporting limit) and are not indicative of increasing tritium trends in groundwater. Accordingly, these results confirm that the MNA remedy for tritium continues to be effective in this OU.

Perchlorate concentrations in Pit 6 landfill groundwater have decreased from a maximum of 65 µg/L in well K6-19, following the 1998 El Niño, to a maximum concentration of 7.1 µg/L in 2022. Perchlorate was detected in only two monitor wells, K6-18 and K6-19, during 2022. Well K6-18 had shown a consistent decreasing perchlorate trend between 1999 and 2013, after which concentrations increased slightly. The provenance of perchlorate at K6-18 and K6-19 is not known, although rising water levels in well K6-19 since the first semester of 2016 may have leached available vadose zone perchlorate into the groundwater. Otherwise, in well K6-16, the perchlorate concentration of 4.3 µg/L in January 2020 barely exceeded the reporting limit of 4 µg/L and represents the first perchlorate detection in this well since 2000. Concentrations subsequently declined to below the 4 µg/L reporting limit in March 2021 and the 2 µg/L reporting limit in January 2022. Except for these three wells, perchlorate concentrations have remained below the reporting limit and the 6 µg/L MCL cleanup standard in all other Pit 6 landfill OU wells since March 2009.

Nitrate continues to be consistently detected above its 45 mg/L MCL cleanup standard in wells K6-18 and K6-23, which are located near the Building 899 septic system. PPCP analyses have confirmed that these wells are impacted by this septic system, which is the likely source of nitrate at this location. From 2016 through 2019, nitrate was also detected slightly above the MCL cleanup standard in Qt-Tnbs1 South HSU well K6-24 before steadily declining to 10 mg/L by January 2022.

2.3.2.3. Performance Issues

Currently, the temporal and spatial extent of groundwater in excess of MCL cleanup standards at the Pit 6 landfill is very limited. The remedy continues to be effective and protective of human health and the environment while progressing toward cleanup.

2.4. High Explosives Process Area (OU 4)

Since the 1950s, the HEPA has been used for the chemical formulation, mechanical pressing, and machining of high explosives (HE) compounds into shaped detonation devices. Surface spills from 1958 to 1986 resulted in the release of contaminants at the former Building 815 steam plant. Subsurface contamination is attributed to HE wastewater discharges into closed unlined rinse-water lagoons. Additionally, a minor source of contamination in groundwater is contaminated waste that leaked from the former Building 829 waste accumulation area (WAA) near Building 829.

Figure 2.4-1 is a map of the HEPA OU showing the locations of wells and treatment facilities. The following four GWTSs operate in the HEPA:

- **Building 815-SRC**: This GWTS began removing VOCs (primarily TCE), HE compounds RDX and high-melting explosive (HMX), and perchlorate from groundwater in September 2000 and was upgraded during the first semester of 2017. During the second semester of 2022, groundwater was extracted from wells W-815-02 and W-815-04 at a combined flow rate of approximately 1.7 gpm. The current GWTS configuration consists of a Cuno® filter to remove particulates, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase GAC vessels connected in series for VOC and HE-compound removal. The treated effluent is injected into well W-815-1918 where *in situ* denitrification within the $Tnbs_2$ HSU reduces nitrate to nitrogen. Via naturally motivated *in situ* denitrification, indigenous microbes in the aquifer oxidize available electron donors (typically pyrite at Site 300) until all oxygen in the aquifer has been utilized. Then, bacterially-motivated anaerobic oxidation of the organic carbon occurs in concert with the step-wise reduction of nitrate to nitrogen gas (i.e., NO_3 to NO_2 to NO to N_2O to N_2), in which nitrogen oxides serve as terminal electron acceptors in the absence of oxygen.

- **Building 815-Proximal (815-PRX)**: This GWTS began operations in October 2002, initially removing only TCE and perchlorate from groundwater. However, in 2011, RDX was detected in groundwater samples collected from the extraction wells, at which time this HE compound was also targeted for removal. During the second semester of 2022, groundwater was extracted from wells W-818-08 and W-818-09 at a combined flow rate of approximately 1.4 gpm. The current GWTS configuration consists of a Cuno® filter to remove particulates, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase GAC vessels connected in series for TCE and RDX removal. The treated effluent is injected into well W-815-2134 to undergo *in situ* denitrification in the $Tnbs_2$ HSU.
- **Building 815-Distal Site Boundary (815-DSB)**: This GWTS began operations in September 1999 at the southern Site 300 boundary, extracting and treating groundwater with typical TCE concentrations of less than 10µg/L. During the second semester of 2022, groundwater was extracted from wells W-35C-04, W-6ER, and W-815-2608 at a combined flow rate of approximately 2.0 gpm. The current GWTS configuration consists of a Cuno® filter to remove particulates and three aqueous-phase GAC vessels connected in series for TCE removal. The treated effluent is discharged to an infiltration trench.
- **Building 817-Proximal (817-PRX)**: This GWTS began operations in September 2005, removing VOCs, RDX, and perchlorate from groundwater. During the second semester of 2022, groundwater was extracted from only well W-817-03 at a flow rate of approximately 1.2 gpm. Because of declining water levels and low recharge reducing the availability of water for pumping, extraction well W-817-2318 was non-operational for the entire reporting period. The current GWTS configuration consists of a Cuno® filter to remove particulates, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase GAC vessels connected in series to remove VOCs and HE compounds. Treated groundwater containing nitrate is injected into upgradient injection wells W-817-2109 and W-817-02 to undergo *in situ* denitrification in the $Tnbs_2$ HSU.

Additionally, the following two GWTSs were converted to and now operate as GWESs:

- **Building 817-Source (817-SRC)**: This GWTS began removing HE compounds RDX and HMX and perchlorate from groundwater in September 2003 before being converted to a GWES in April 2017. The single extraction well, W-817-01, extracts groundwater from a very low yield portion of the $Tnbs_2$ HSU. During the second semester of 2022, it operated for 4,345 hours using solar power and extracted a total of 762 gal of groundwater.

- **Building 829-Source (829-SRC)**: This GWES began operations in August 2005, removing VOCs, nitrate, and perchlorate from groundwater. Groundwater is currently extracted from well W-829-06 at a flow rate of approximately 30 gal per month, and a total of 375 gal was extracted during this reporting period.

Water from both of these GWESs is collected in portable tanks and transported to the 815-SRC or 815-PRX GWTSs for treatment.

2.4.1. Groundwater Extraction and Treatment System Operations and Monitoring

2.4.1.1. Compliance Summary

Throughout this reporting period, the 815-SRC, 815-PRX, 815-DSB, and 817-PRX GWTSs operated in compliance with the RWQCB substantive requirements for wastewater discharge. The 817-SRC and 829-SRC GWESs do not have regulatory discharge requirements.

The treatment facility sampling and analysis plan for the HEPA OU complies with the monitoring requirements in the CMP/CP. Appendix B contains the sampling and analysis plan for the first semester of 2023. During 2022, all required influent and effluent samples were collected according to the plans provided in the previous two CMRs.

2.4.1.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the HEPA OU:

- **Table 2.2**: Monthly volumes of groundwater extracted and discharged by treatment facilities in this OU for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater mass removal from this OU for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at facilities within this OU in 2022.
- **Table Summ-1**: The total volume of groundwater extracted and treated and total contaminant mass removed from this OU during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater treated and discharged and total contaminant mass removed from this OU.
- **Appendix A**: pH measurements.

2.4.1.3. Treatment Facility and Extraction Wellfield Modifications

No changes were made to the HEPA GWTSs or wellfields during the second semester of 2022.

2.4.2. Groundwater and Surface Water Monitoring

Appendix C contains the sampling and analysis plan for 2022 for groundwater and surface water monitoring at the HEPA OU. This appendix also explains deviations from the sampling plan and indicates any additions made to the CMP.

During the second semester of 2022, groundwater monitoring was conducted in accordance with the CMP/CP monitoring requirements, with the following exceptions:

- A total of 18 required analyses for 10 different wells and one spring were not performed because they were dry or had insufficient water for sample collection.
- A total of three required analyses were not performed for three wells due to non-operable equipment or restricted access.

Attachment 1 and Appendix D tabulate the analytical results and groundwater elevation measurements, respectively, that were obtained during 2022. Figure 2.4-2 shows groundwater elevations and individual VOC, perchlorate, RDX, and nitrate concentrations for the Tpsg-Tps HSU while Figure 2.4-3 shows the groundwater potentiometric surface map for the $Tnbs_2$ HSU.

2.4.3. Remediation Progress Analysis

This section is organized into three subsections: contaminant concentrations and distribution, remediation optimization evaluation, and remedy performance issues.

2.4.3.1. Contaminant Concentrations and Distribution

At the HEPA OU, VOCs consisting mainly of TCE are the primary COCs detected in groundwater, along with the secondary COCs, HE compounds (RDX, HMX, 4-amino-2,6-dinitrotoluene [4-ADNT]), perchlorate, and nitrate. Most of the groundwater contamination in this OU occurs in the $Tnbs_2$ HSU, although TCE, RDX, HMX, perchlorate, and nitrate have also been detected in perched groundwater within the Tpsg-Tps HSU in the vicinity of Buildings 815 and 817. Minor concentrations of VOCs, perchlorate, and nitrate are also present in perched groundwater within the $Tnsc_{1b}$ HSU beneath the former Building 829 WAA, located in the northwest portion of the HEPA. No contamination has been detected in the Upper and Lower $Tnbs_1$ HSUs in the HEPA OU.

The following subsections discuss concentrations and distributions of VOCs, HE compounds, perchlorate, and nitrate in the HEPA OU's HSUs. These discussions are supported by the following figures:

- **Figure 2.4-2**: Map of groundwater elevations and individual VOC, perchlorate, RDX, and nitrate concentrations for the Tpsg-Tps HSU.
- **Figure 2.4-4**: Total VOC isoconcentration contour map for the $Tnbs_2$ HSU.
- **Figure 2.4-5**: RDX isoconcentration contour map for the $Tnbs_2$ HSU.
- **Figure 2.4-6**: Perchlorate isoconcentration contour map for the $Tnbs_2$ HSU.
- **Figure 2.4-7**: Map showing nitrate concentrations in the $Tnbs_2$ HSU.
- **Figure 2.4-8**: Building 829 burn pit site map showing VOC, perchlorate, and nitrate concentrations for the $Tnsc_{1b}$ HSU.

2.4.3.1.1. VOC Concentrations and Distribution

Tpsg-Tps HSU

The following general trends in VOC concentrations were observed in the Tpsg-Tps HSU:

- TVOC concentrations decreased from a 1992 historical maximum of 450 µg/L in well W-815-01 to a 2022 maximum of 11 µg/L, comprised entirely of TCE, in extraction well W-817-2318 in August.
- VOC concentration trends remained stable or decreased during 2022, and the spatial distribution of TVOC concentrations above the 0.5 µg/L reporting limit remained very similar to what was observed in 2021.

VOCs, primarily TCE but also 1,1-DCE; 1,2-DCA; *cis*-1,2-DCE; CFORM; and CTET, have been detected in the perched water-bearing zones in the Tpsg-Tps HSU. VOCs remained below the 0.5 µg/L reporting limit in Tpsg-Tps monitor well W-35C-05, located near the southern site boundary. The lateral extent of the perched Tpsg-Tps HSU is dependent on seasonal recharge and groundwater extraction rates, thus varying from year to year. For this reason, some wells screened in the Tpsg-Tps HSU were dry or did not produce sufficient volumes of water for sampling during this reporting period.

During the second semester of 2022, VOCs other than TCE were only detected at concentrations above the 0.5 µg/L reporting limit in monitor wells W-809-01 and W-814-01. Samples collected from monitor well W-809-01 contained 1,1-DCE and CFORM at concentrations well below their MCL cleanup standards while samples collected from monitor well W-814-01 contained 1,2-DCA, *cis*-1,2-DCE, and CFORM with maximum concentrations of 0.57 µg/L, 1.1 µg/L, and 0.64 µg/L, respectively. The maximum 1,2-DCA concentration was slightly above the 0.5 µg/L MCL cleanup standard. Similar concentrations of these VOCs were detected in Tpsg-Tps wells during 2021.

Tnbs$_2$ HSU

The following general trends in VOC concentrations were observed in the Tnbs$_2$ HSU:

- TVOC concentrations decreased from a 1992 historical maximum concentration of 110 µg/L in extraction well W-818-08 to a 2022 maximum of 25 µg/L in the same well in August.
- VOC concentration trends in the Tnbs$_2$ HSU remained stable or decreased slightly in individual wells during the second semester of 2022, and spatial distributions of TVOC concentrations above the 0.5 µg/L reporting limit, the 5 µg/L MCL cleanup standard for TCE, and10 µg/L (twice that MCL), remained very similar to those observed in 2021.

In the Tnbs$_2$ HSU, the highest VOC concentrations are found downgradient of Building 815 in the 815-PRX extraction wellfield. During the reporting period, TCE was detected in the Tnbs$_2$ HSU, with concentrations exceeding the 5 µg/L MCL cleanup standard in 17 wells. Additionally, *cis*-1,2-DCE was detected in four wells, with a maximum concentration of 0.83 µg/L detected in well W-818-07 in September. No other VOCs were detected above their reporting limits in the Tnbs$_2$ HSU during the second semester of 2022.

At the southern end of the Building 832 Canyon, VOCs continue to be detected in Tnbs$_2$ HSU groundwater, likely originating from sources located in both the Building 832 Canyon and HEPA OUs.

Since June 2007, when extraction well W-830-2216 began pumping groundwater, TVOC concentrations have decreased from 20 µg/L in May 2007 to a 2022 maximum of 3.1 µg/L in April. A similar decrease in VOC concentrations has been observed in nearby monitor well W-830-13, from 21 µg/L in March 2007 to 2.9 µg/L in September 2022. VOC concentrations in these wells have remained stable since 2019.

VOCs were detected in well W-870-02 at a concentration of 1.0 µg/L in September, similar to the 0.77 µg/L concentration detected in September 2021 when VOCs were detected for the first time in this well since 2015. VOCs were also detected in new $Tnbs_2$ HSU monitor well W-815-3802, which was completed in June 2022, at a concentration of 1.0 µg/L in a baseline sample collected in July. VOCs were not detected above reporting limits in new $Tnbs_2$ HSU monitor wells W-830-3409 and W-815-3606, which were completed in 2018 and 2020, respectively.

During the reporting period, TCE was detected at concentrations below the 5 µg/L MCL cleanup standard in the samples from $Tnbs_2$ HSU on-site guard wells W-815-2110 and W-815-2111, located near the southern boundary of Site 300. The maximum TCE concentration was 1.2 µg/L in samples from both W-815-2110 and W-815-2111, which were collected in September. Similar TCE concentrations well below the 5 µg/L MCL cleanup standard were detected in these wells in 2021. VOCs were not detected in any other on- or off-Site 300 HEPA $Tnbs_2$ HSU guard wells during the reporting period.

Seventeen routine and duplicate samples were collected from one off-site water-supply well, GALLO1, where VOCs were not detected above the 0.5 µg/L reporting limit. During 2022, VOCs were also not detected above reporting limits in routine samples collected from new monitor well W-815-3606, which was completed in October 2020 and is located in the 815-DSB area, northwest of wells W-6H and W-6J. Completed in June 2022 and located southwest of Building 882, new monitor well W-815-3802 had a single 1 µg/L detection of TCE in a baseline sample collected in July.

***$Tnsc_{1b}$* HSU**

The following general trends in VOC concentrations were observed in the $Tnsc_{1b}$ HSU:

- TVOC concentrations decreased from a 1993 historical maximum of 1,013 µg/L in extraction well W-829-06 to a 2022 maximum of 30 µg/L, comprised entirely of TCE, in the same well in April.
- In 2022, the spatial distribution of TVOC concentrations in the $Tnsc_{1b}$ remained similar to what was observed in 2021.

At monitor well W-829-08, a 2022 maximum TVOC concentration of 4.8 µg/L was detected in August; concentrations of TCE at this well have been below the 5 µg/L cleanup standard since 2016. VOCs have never been detected in groundwater from nearby $Tnsc_{1b}$ monitor well W-829-1940 nor in nearby monitor wells screened in the Lower $Tnbs_1$ HSU.

2.4.3.1.2. HE Compound Concentrations and Distribution

Tpsg-Tps HSU

The following general trends in HE compound concentrations were observed in the Tpsg-Tps HSU:

- A historical maximum RDX concentration of 350 µg/L was detected in well W-815-01 in 1998. This well has not been sampled since 1999 because it has been dry or had insufficient water for sampling.
- HE compounds were not detected in any HEPA OU wells screened in the Tpsg-Tps HSU during 2022.
- In 2022, the spatial distribution of HE compounds in the Tpsg-Tps HSU remained similar to what was observed in 2021.

RDX was detected in 2018 in monitor well W-817-2318 at 1.2 µg/L and in monitor well W-817-03A at 4.2 µg/L; these wells had no detections above reporting limits in 2021 or 2022. Some wells in which HE compounds have previously been detected were either dry or had insufficient water for sampling during this reporting period.

$Tnbs_2$ HSU

The following general trends in HE compound concentrations were observed in the $Tnbs_2$ HSU:

- RDX concentrations decreased from a 1992 historical maximum of 204 µg/L in extraction well W-815-04 to a 2022 maximum of 35 µg/L in well W-815-02 in January.
- HMX concentrations decreased from a 1995 historical maximum of 57 µg/L in extraction well W-815-04 to a 2022 maximum of 16 µg/L in well W-817-01 in January.
- Overall, HE compound concentrations remained stable or decreased from 2021 concentrations in the $Tnbs_2$ HSU during 2022, and the spatial distribution remained similar to what was observed in 2021.

In 2022, RDX was detected at a concentration of 1.1 µg/L in guard well W-6H, where it had been detected for the first time at a concentration of 1.7 µg/L in March 2017, slightly above the 1 µg/L reporting limit. RDX was not detected in this well during 2020 or 2021. HMX concentrations remain significantly below the regional tapwater screening level of 1,000 µg/L (U.S. EPA 2017).

Concentrations of 4-ADNT in the $Tnbs_2$ HSU have declined from the 1997 historical maximum of 24 µg/L in extraction well W-817-01 to below the reporting limit in 2022. In January 2017, 1,3-dinitrobenzene was detected above the reporting limit in monitor well W-4B for the first time at a concentration of 110 µg/L. This concentration was the site-wide historical maximum for 1,3-dinitrobenzene, which was previously detected at a maximum of 3.1 µg/L in $Tnsc_2$ HSU monitor well W-6CI in March 2016. However, 1,3-dinitrobenzene was not detected above the reporting limit in a confirmatory sample taken in April 2018 nor in routine samples taken in 2020, 2021, and 2022. Hence, the 2017 detection is likely an anomaly and does not indicate the presence of HE compounds in the vicinity of monitor well W-4B. Nonetheless, W-4B will continue to be monitored closely.

2.4.3.1.3. Perchlorate Concentrations and Distribution

Tpsg-Tps HSU

The following general trends in perchlorate concentrations were observed in the Tpsg-Tps HSU:

- Perchlorate concentration decreased from a 2000 historical maximum of 19 µg/L in monitor well W-817-03A to a 2022 maximum of 12 µg/L in the same well in March.
- In 2022, perchlorate concentrations and distribution in the Tpsg-Tps HSU remained very similar to those observed in 2021.

The only other Tpsg-Tps well where perchlorate was detected above the 6 µg/L MCL cleanup standard was extraction well W-817-2318; at this well, 10 µg/L were detected in April.

$Tnbs_2$ HSU

The following general trends in perchlorate concentrations were observed in the $Tnbs_2$ HSU:

- Perchlorate concentrations decreased from a 1998 historical maximum of 50 µg/L in extraction well W-817-01 to a 2022 maximum of 19 µg/L in the same well in April.
- Perchlorate concentrations decreased or remained stable in the $Tnbs_2$ HSU in 2022, and the spatial distribution remained very similar to what was observed in 2021.

In the $Tnbs_2$ HSU, groundwater perchlorate concentrations exceeding the 6 µg/L MCL cleanup standard were detected in eight wells during the reporting period. Wells with the highest concentrations are located in the vicinities of the 815-SRC GWES, 817-SRC GWES, and 817-PRX GWTS. Perchlorate concentrations slightly exceeded the new 2 µg/L reporting limit in five routine samples and one duplicate sample collected from six wells during the reporting period, with concentrations ranging from 2.3 to 3.3 µg/L. Of these six wells, only W-830-05 had a previous perchlorate detection exceeding the 6 µg/L MCL, at 6.4 µg/L in a sample collected in December 1998.

To date, perchlorate has not been detected in any $Tnbs_2$ HSU guard wells or other monitor wells located near the Site 300 southern boundary, with the exception of a single 2.4 µg/L detection in well W-870-02 in September, slightly above the new perchlorate reporting limit of 2 µg/L. This well has not had any perchlorate detections above the previously established 4 µg/L reporting limit.

$Tnsc_{1b}$ HSU

The following general trends in perchlorate concentrations were observed in the $Tnsc_{1b}$ HSU:

- Perchlorate concentrations decreased from a 2000 historical maximum of 29 µg/L in extraction well W-829-06 to a 2022 maximum of 20 µg/L in the same well in July.
- In 2022, the spatial distribution of perchlorate concentrations in the $Tnsc_{1b}$ remained similar to what was observed in 2021.

During this reporting period, extraction well W-829-06 was the only $Tnsc_{1b}$ HSU well with perchlorate concentrations exceeding the 6 µg/L MCL cleanup standard. Perchlorate in monitor well W-829-1940 slightly exceeded the new 2 µg/L reporting limit with a concentration of 3.4 µg/L in March. Perchlorate has not been detected above the previously established reporting limit of 4 µg/L in monitor wells W-829-08 or W-829-1940 since 2009.

2.4.3.1.4. Nitrate Concentrations and Distribution

Tpsg-Tps HSU

In the Tpsg-Tps HSU, nitrate concentrations decreased from a 2016 historical maximum of 790 mg/L in well W-6CS to a 2022 maximum of 680 mg/L in the same well in March. No known nitrate sources associated with Site 300 operations are located near this well. However, a sheep ranch predating Site 300, discovered in a historical photo of the area, is a potential source of this localized, elevated nitrate.

Other wells screened in the Tpsg-Tps HSU had significantly lower nitrate concentrations in 2022, ranging from 120 mg/L in monitor well W-817-2318 to 15 mg/L in monitor well W-823-01, similar to the range observed in 2021.

$Tnbs_2$ HSU

In the $Tnbs_2$ HSU, nitrate concentrations decreased from a 1994 historical maximum of 421 mg/L in monitor well W-818-01 to a 2022 maximum of 110 mg/L in monitor well W-817-2609 in March.

During the reporting period, nitrate was detected in a single routine sample collected in February from off-Site 300 water-supply well GALLO1 at a low concentration of 2 mg/L. Nitrate was not detected above the reporting limit in the remaining 17 routine and duplicate samples collected from GALLO1 or above the 45 mg/L MCL cleanup standard in any of the $Tnbs_2$ HSU guard wells.

These recent data from the $Tnbs_2$ HSU wells continue to support the interpretation that nitrate is being attenuated *in situ* by natural processes, principally reductive denitrification, consistent with MNA. Nitrate concentrations also remain below the 45 mg/L MCL cleanup standard in all wells near the southern site boundary where groundwater is present under confined or artesian anoxic conditions, with concentrations ranging from 18 mg/L to under the reporting limit.

$Tnsc_{1b}$ HSU

In the $Tnsc_{1b}$ HSU, nitrate concentrations decreased from a 2000 historical maximum of 240 mg/L in extraction well W-829-06 to a 2022 maximum of 75 mg/L in the same well in July. In this extraction well, nitrate concentrations for 2022 were similar to those detected in 2021. Monitor wells W-829-08 and W-829-1940 were sampled in March and had nitrate concentrations below the 0.5 mg/L reporting limit and 42 mg/L, respectively.

2.4.3.2. Remediation Optimization Evaluation

Remediation at the HEPA OU is managed by balancing groundwater extraction at the southern Site 300 boundary with upgradient pumping in the source and proximal areas. This strategy is designed to aggressively remediate contaminant source areas while hydraulically capturing the leading edge of the VOC plume near the southern boundary of Site 300 and minimizing the migration of multiple, co-mingled plumes from their respective source areas.

Extraction well W-817-2318 pumps groundwater from the Tpsg-Tps HSU in an area with the highest VOC and perchlorate concentrations, which is located near Spring 5, downgradient of 817-SRC and adjacent to 817-PRX. Groundwater extraction from the Tpsg-Tps HSU is hampered by the HSU's low permeability as well as the dependence of groundwater elevation and spatial distribution on seasonal recharge. Despite this fact, TCE concentrations have declined in extraction well W-817-2318 from a 2007 historical maximum of 55 µg/L to a 2022 maximum of 11 µg/L in July.

During this reporting period, 815-PRX extraction wells W-818-08 and W-818-09 continued to hydraulically capture groundwater with the highest VOC concentrations, and extraction wells W-6ER, W-35C-04, and W-815-2608 continued to capture the leading edge of the VOC plume along the southern boundary of Site 300.

Concurrently, 815-SRC extraction wells W-815-02, W-815-04, and W-815-2803 and 817-SRC extraction well W-817-01 continue to extract groundwater from areas with the highest RDX concentrations. HE compound concentrations have generally exhibited a decreasing trend over the last five years, with some fluctuations in RDX concentrations observed in the vicinity of 815-SRC, likely related to injection of effluent into well W-815-1918 and variations in seasonal recharge.

During 2022, perchlorate concentrations in the $Tnbs_2$ HSU also declined considerably from concentrations detected in 1998, when monitoring for this COC began. The highest concentrations remain in the vicinity of the 817-SRC and 817-PRX treatment facilities. Perchlorate concentrations in the confined portions of the $Tnbs_2$ HSU near the southern site boundary have remained below the reporting limit, with the exception of a single detection of 2.4 µg/L in well W-870-02 in September, slightly above the new perchlorate reporting limit of 2 µg/L. Spatial and temporal perchlorate concentration trends suggest that perchlorate is being degraded *in situ* by natural processes similar to those confirmed for the natural attenuation of nitrate (principally bacterially-motivated reduction).

Nitrate concentrations in the confined portions of the $Tnbs_2$ HSU near the southern boundary of Site 300 continue to be near or below the reporting limit, demonstrating that MNA of nitrate remains effective even under pumping conditions.

Throughout the reporting period, pumping from HEPA extraction wells was effective in capturing COCs and preventing the migration of contaminated groundwater farther toward the Site 300 boundary. VOCs were not detected above reporting limits in off-site water-supply well GALLO1 and remained stable at very low concentrations in on-site guard wells W-815-2110 and W-815-2111. TCE was detected at 1.1 µg/L and 0.57 µg/L in routine samples taken in November from W-815-2110 and W-815-2111, respectively, and *cis*-1,2-DCE was detected at 0.50 µg/L in the same sample from W-815-2111 in November. Upgradient and downgradient pumping will continue to be balanced, so that hydraulic capture at the southern boundary is maintained without accelerating migration from upgradient sources. VOC concentrations in this area will also continue to be closely monitored, especially near GALLO1.

The HE compound RDX was detected at 2.7 µg/L in monitor well W-818-01 in August 2022 as well as at 2.7 µg/L and 1.5 µg/L in 815-PRX extraction wells W-818-08 and W-818-09, respectively, in October. These recent detections suggest an expanded influence due to continued pumping of the 815-PRX extraction wells. The spatial extent of these comingled plumes will be closely monitored, and any necessary modifications will be made to extraction wellfield operations to minimize further migration of these plumes toward the Site 300 boundary.

The total mass removed from all HEPA treatment facilities included 88 g of VOCs, 57 g of perchlorate, and 86 g of RDX during 2022. The volume of treated groundwater increased by approximately 12.5 percent from 2,122,000 gal in 2021 to 2,388,000 in 2022. Compared to the previous year, masses of VOC, perchlorate, and RDX removed increased by 14 percent, 58 percent, and 1 percent, respectively, during 2022. These increases are mostly attributed to increased operating times at all HEPA OU facilities and a reduction in COVID-19-related staffing shortages experienced during 2020 and 2021.

The 815-PRX GWTS, which captures groundwater containing the highest concentrations of VOCs from the $Tnbs_2$ VOC plume, operated for the entire year extracting groundwater from both extraction wells, W-818-08 and W-818-09. The 817-PRX GWTS, which extracts groundwater from the highest concentration portion of the $Tnbs_2$ and Tpsg-Tps perchlorate plumes, operated for the last four months of the year, extracting groundwater from only W-817-03, due to well W-817-2803 having insufficient water. Regardless, the masses of both perchlorate and VOCs removed at this facility approximately doubled compared to the masses removed in 2021. The 815-SRC GWTS, which extracts groundwater from the highest concentration portion of the $Tnbs_2$ RDX plume, operated with all three wells for the majority of the year (i.e., March through December) but extracted 21 percent less groundwater by volume compared to what was extracted in 2021. The masses of VOCs and RDX removed at this facility decreased from the previous year while the mass of perchlorate removed remained approximately the same. Nitrate in the $Tnbs_2$ HSU continued to undergo *in situ* biotransformation to benign nitrogen gas by anaerobic-denitrifying bacteria.

2.4.3.3. Remedy Performance Issues

During this reporting period, no new issues affected the performance of the cleanup remedy for the HEPA OU. The remedy continues to be effective and protective of human health and the environment and is making progress toward cleanup.

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

The Building 850/Pit 7 Complex OU consists of two main areas: Building 850 and the Pit 7 Complex. The following sections discuss the background and monitoring results for these two areas separately. Figure 2.5-1 is a map of the entire OU with key elements of the Building 850 area, including Building 850, the CAMU, wells, and other features, and the Pit 7 Complex area, including landfills, DDS, extraction and monitor wells, and the treatment system.

2.5.1. Building 850 Area

Outdoor HE experiments were conducted at the Building 850 firing table from the 1950s to 2008. During this period, the firing table was covered with gravel for shock absorption and, to reduce dust, routinely rinsed down with water after each experiment. Although this practice was discontinued in 2004, rinse water, as well as infiltrating direct rainfall and runoff, mobilized chemicals from the contaminated gravel to the underlying bedrock and groundwater. Until 1989, gravels from the firing table surface were periodically removed and disposed of in landfills in the northwest part of Site 300, which is now designated as the Pit 7 Complex.

In 2009, a CAMU was constructed adjacent to Building 850 as part of a non-time critical removal action. A total of 27,592 cubic yards (yd^3) of polychlorinated biphenyl- (PCB), dioxin-, and furan-contaminated soil were excavated from the Building 850 firing table, mixed with Portland cement and water, and consolidated and compacted to form the CAMU. The *Action Memorandum for the Removal Action at the Building 850 Firing Table, Lawrence Livermore National Laboratory Site 300* details this removal action (Dibley et al. 2008). The CAMU's design information is presented in the construction subcontractor's 100 percent design submittal (SCS Engineers 2009) while Section 2.5.1.2.4 describes its inspection and maintenance program.

In September 2011, an *in situ* bioremediation treatability study commenced to irreversibly transform perchlorate in groundwater immediately downgradient of Building 850 to benign end-products. Results indicate that injecting ethyl lactate has resulted in the bacterially motivated reduction of perchlorate and nitrate in the treatment zone to concentrations below their reporting limits. Section 2.5.2.3 summarizes the current status of this study, including its rebound monitoring results.

2.5.1.1. Groundwater Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater monitoring in the Building 850/Pit 7 Complex OU. This appendix also explains deviations made from the plan.

During the second semester of 2022, 297 required analyses were scheduled for the Building 850 area in accordance with the CMP. Of these analyses, 49 were not carried out because the wells or springs were dry and 16 were not carried out due to issues with sampling equipment.

Attachment 1 and Appendix D tabulate the analytical results and groundwater elevation measurements, respectively, that were obtained during 2022. Figures 2.5-2 and 2.5-3 are groundwater elevation contour maps for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively. Groundwater elevations in 2022 in both HSUs were similar to those observed in 2021.

2.5.1.2. Remediation Progress Analysis

This section is organized into five subsections: contaminant concentrations and distribution, remediation optimization evaluation, enhanced bioremediation treatability study, Building 850 CAMU monitoring, and remedy performance issues.

2.5.1.2.1. Contaminant Concentrations and Distribution

In the Building 850 area, tritium and perchlorate are the primary COCs detected in groundwater, and the secondary COCs are depleted uranium and nitrate. These constituents have been identified within the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs.

Wells W-850-2416 and NC7-69 are located 200 and 500 ft east of the Building 850 firing table, respectively, and are screened in the deeper $Tnsc_0$ and Tmss HSUs, respectively. These wells have never contained any COC at concentrations in excess of reporting limits and/or background ranges.

The following subsections discuss concentrations and distributions of tritium, uranium, nitrate, perchlorate, and HE compounds in the HSUs in the Building 850 area. These discussions are supported by the following figures:

- **Figure 2.5-4 and Figure 2.5-5**: Tritium activity concentration contour map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.
- **Figure 2.5-6 and Figure 2.5-7**: Uranium activity concentration map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.

- **Figure 2.5-8 and Figure 2.5-9**: Nitrate concentration map for the Qal/WBR and $Tnbs_1$/$Tnbs_0$ HSUs, respectively.
- **Figure 2.5-10 and Figure 2.5-11**: Perchlorate isoconcentration contour map for the Qal/WBR and $Tnbs_1$/$Tnbs_0$ HSUs, respectively. The lowest iso-contour values in these maps have been updated from 4 µg/L to 2 µg/L to reflect the new 2 µg/L reporting limit for perchlorate.

Tritium Activity Concentrations and Distribution

In 2022, tritium activity concentrations in the Building 850 area exceeded the 20,000 pCi/L MCL cleanup standard in one well. Maximum tritium activity concentrations have decreased from a 1985 historical maximum of 566,000 pCi/L in monitor well NC7-28 to a 2022 maximum of 24,200 pCi/L in $Tnbs_1$/$Tnbs_0$ HSU monitor well W-850-3701 in December.

Qal/WBR HSU

The following tritium activity concentrations were observed in the Qal/WBR HSU:

- The 2022 maximum tritium activity concentration was 15,600 pCi/L in April at well W-850-05, located near the southeastern corner of the Building 850 firing table. This maximum is a slight decrease from the 2021 maximum of 16,600 pCi/L in the same well.
- Tritium activity concentrations exceeding the 20,000 pCi/L MCL cleanup standard have not been detected in Qal/WBR HSU monitor wells since 2015.
- The extent of groundwater with tritium in excess of background in 2022 was similar to the extent in 2021.

Beginning in 2013, the extent of tritium exceeding the 20,000 pCi/L MCL cleanup standard began to decrease significantly and, since the first semester of 2015, tritium activity concentrations throughout the Qal/WBR HSU have remained below this cleanup standard in the Building 850 area. The highest activity concentrations are still detected in wells located immediately downgradient of the Building 850 firing table at wells NC7-70, W-850-2417, W-850-05, NC7-61, NC7-10 and NC7-28 but have generally declined.

During 2022, tritium activity concentrations detected in Qal/WBR HSU monitor wells were similar to or below 2021 activity concentrations except for one well. Located approximately 500 feet downgradient of the Building 850 firing table, monitor well NC7-10 yielded an increased tritium activity concentration, from a 2021 maximum of 6,820 pCi/L to 14,600 pCi/L in April. This increase is within normal fluctuations, and similar activity concentrations were detected in the well in 2016.

Located in Elk Ravine downgradient of the Pit 2 landfill, monitor wells W-PIT2-2301 and W-PIT2-2302 are used to determine the downgradient extent of tritium in the Qal/WBR HSU in this area. Tritium was not detected in excess of the reporting limit in either well during 2022.

$Tnbs_1$/$Tnbs_0$ HSU

The following tritium activity concentrations were observed in the $Tnbs_1$/$Tnbs_0$ HSU:

- The 2022 maximum tritium activity concentration was 24,200 pCi/L in December in monitor well W-850-3701, located approximately 400 ft downgradient and east of the

Building 850 firing table. This maximum activity concentration is a decrease from the 2021 maximum of 29,800 pCi/L in the same well.

- Tritium activity concentrations remained similar to 2021 levels in most $Tnbs_1/Tnbs_0$ HSU monitor wells sampled during 2022, and the extent of groundwater with tritium in excess of background was also similar to previous years.

During 2022, tritium activity concentrations exceeded the 20,000 pCi/L MCL cleanup standard in only one monitor well, W-850-3701, screened exclusively in the $Tnbs_1/Tnbs_0$ HSU.

Uranium Concentrations and Distribution

During 2022, uranium analyses were performed primarily by alpha spectroscopy with selected samples analyzed by inductively coupled plasma-mass spectrometry (ICP-MS). ICP-MS analysis is the only method providing high-precision uranium isotope data (e.g., uranium-235/uranium-238 [$^{235}U/^{238}U$] atom ratio) for determining the presence of depleted uranium are only available by ICP-MS analysis. The presence of depleted uranium is indicated by a $^{235}U/^{238}U$ atom ratio of less than 0.007.

Historical uranium isotope data indicate that regions of groundwater containing some added depleted uranium extend downgradient approximately 1,200 ft within the Qal/WBR HSU and 700 ft within the $Tnbs_1/Tnbs_0$ HSU from the Building 850 firing table and have remained relatively stable in extent. During 2022, uranium activity concentrations at or above the 20 pCi/L MCL cleanup standard were detected in one well, W-850-2315, in the Building 850 area. The 2013 historical maximum total uranium activity concentration for the Building 850 area is 24 pCi/L in well NC7-28, screened in both the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs.

During the process of reviewing the groundwater uranium data for this CMR, some issues with first semester 2022 ICP-MS sample results were found. Corrections to the data are reflected in this report, and all uranium groundwater data herein supersede those published in the *First Semester 2022 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300* (Buscheck et al. 2022). In all cases where data were corrected, the corrected total uranium activity concentrations were lower than values previously reported in the first semester 2022 CMR.

Qal/WBR HSU

The following uranium activity concentrations were observed in the Qal/WBR HSU:

- The 2022 maximum total uranium activity concentration was 8.4 pCi/L in November in monitor well NC7-28, located in the perchlorate bioremediation treatment zone. This maximum is a decrease from the 2021 maximum of 9.2 pCi/L in ethyl lactate injection well W-850-2417, located approximately 25 feet upgradient of NC7-28. W-850-2417 was not sampled during 2022 due to issues with sampling equipment.
- Total uranium activity concentrations remained generally similar to 2021 concentrations in all Qal/WBR HSU wells sampled during 2022.

During 2022, total uranium activity concentrations exceeding the 20 pCi/L MCL cleanup standard were not detected in any Qal/WBR HSU wells in the Building 850 area. In April, 10.8 pCi/L of uranium was detected at monitor well K2-04S, located approximately 1,500 ft east of the Building 850 firing table along Doall Ravine. A duplicate sample collected from the well on the same day yielded 2 pCi/L of uranium. Consequently, the 10.8 pCi/L detection has been identified as anomalous. Analytical data from future samples will clarify the uranium activity concentration in groundwater at K2-04S.

$Tnbs_1$/$Tnbs_0$ HSU

The following uranium activity concentrations were observed in the $Tnbs_1$/$Tnbs_0$ HSU:

- The 2022 maximum total uranium activity concentration was 21 pCi/L in November in monitor well W-850-2315, located approximately 1,400 ft southeast (cross-gradient) of Building 850. This maximum activity concentration is a slight increase from the 2021 maximum of 20.3 pCi/L in the same well.
- Total uranium activity concentrations in all $Tnbs_1$/$Tnbs_0$ HSU wells sampled during 2022 remained similar to those of 2021, as did the areal extent.

During 2022, monitor well W-850-2315 was the only $Tnbs_1$/$Tnbs_0$ HSU well in the Building 850 area that yielded a sample that exceeded the 20 pCi/L MCL cleanup standard for total uranium. Mass spectrometric data from November 2022 samples from this well continue to indicate a natural $^{235}U/^{238}U$ atom ratio (0.007267). W-850-2315 and NC7-29 (at a concentration of 18 pCi/L in November) are the only two wells to have ever exceeded the total uranium MCL in the $Tnbs_1$/$Tnbs_0$ HSU in the Building 850 area.

Nitrate Concentrations and Distribution

During 2022, nitrate was detected at concentrations at or above the 45 mg/L MCL cleanup standard in 11 wells in the Building 850 area. Historical data indicate that groundwater nitrate concentrations in the Qal/WBR and $Tnbs_1$/$Tnbs_0$ HSUs are limited in extent and relatively stable. With the exception of the *in situ* bioremediation treatment zone, the 2022 distribution and concentrations of nitrate in groundwater are generally consistent with those observed in previous years.

Qal/WBR HSU

The following nitrate concentrations were observed in the Qal/WBR HSU:

- The 2022 maximum nitrate concentration was 63 mg/L in May in monitor well NC7-44, located upgradient of the Building 850 firing table. This maximum is a slight increase from the 2021 maximum of 60 mg/L in the same well.
- The spatial extent of nitrate concentrations in excess of the 45 mg/L MCL cleanup standard remained similar to what was observed in 2021 in the Qal/WBR HSU wells sampled during 2022, except for NC7-28, where concentrations increased from 21 mg/L in 2021 to 50 mg/L in April.

Within the Building 850 area, the 1993 historical maximum nitrate concentration in the Qal/WBR HSU of 186 mg/L was detected in well K2-04S, located approximately 1,500 ft east of the Building 850 firing table along Doall Ravine. During 2022, four wells in this HSU exceeded the 45 mg/L MCL cleanup standard for nitrate. Of these wells, the following three are located within 700 ft downgradient of the Building 850 firing table:

- **NC7-11**: 49 mg/L in April.
- **NC7-61**: 54 mg/L in April.
- **NC7-28**: 50 mg/L in April.

The remaining well, NC7-44, which yielded 63 mg/L of nitrate in May, is located approximately 300 ft upgradient.

$Tnbs_1/Tnbs_0$ HSU

The following nitrate concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- The 2022 maximum nitrate concentration was 170 mg/L in April in monitor well NC7-29, located southeast and cross-gradient of Building 850, near HE storage Magazine M-80. This maximum is a decrease from the 2021 maximum of 180 mg/L in the same well.
- The extent of $Tnbs_1/Tnbs_0$ HSU groundwater containing nitrate concentrations in excess of the 45 mg/L MCL cleanup standard remained similar between 2021 and 2022.

The maximum historical nitrate concentration in $Tnbs_1/Tnbs_0$ HSU groundwater in the Building 850 area of 220 mg/L was reported in 2018 and 2019 in well NC7-29. During 2022, the following seven wells in this HSU exceeded the 45 mg/L MCL cleanup standard for nitrate:

- **K8-01**: Located near Building 801 and the Pit 8 landfill, 50 mg/L of nitrate was detected in June.
- **NC2-12S**: Located southeast of the Pit 2 landfill along the west branch of the Elk Ravine Fault, 84 mg/L of nitrate was detected in April.
- **NC7-29**: Located near HE storage Magazine M-80, 170 mg/L of nitrate was detected in April.
- **W-PIT1-2209**: Located near Building 804, 67 mg/L of nitrate was detected in June.
- **W-PIT1-2326**: Located 500 feet east of the Pit 1 landfill, 69 mg/L of nitrate was detected in August.
- **W-PIT2-1934**: Located immediately north of the Pit 2 landfill, 51 mg/L was detected in May.
- **W-PIT2-1935**: Located immediately north of the Pit 2 landfill, 45 mg/L was detected in May.

Perchlorate Concentrations and Distribution

During 2022, perchlorate concentrations exceeded the 6 µg/L MCL cleanup standard in 11 wells located east and south (i.e., downgradient) of Building 850, near HE storage Magazine M-80, and east (i.e., downgradient) of Pit 1. Enhanced *in situ* bioremediation treatability testing in the Building 850 source area has significantly reduced perchlorate concentrations within the treatment zone immediately downgradient of the firing table.

Qal/WBR HSU

The following perchlorate concentrations were observed in the Qal/WBR HSU:

- The 2022 maximum perchlorate concentration was 37 µg/L in November in NC7-28, located in the perchlorate bioremediation treatment zone. This maximum is a minor decrease from the 2021 maximum of 39 µg/L in ethyl lactate injection well W-850-2417, which was not sampled during 2022 due to issues with sampling equipment.
- During 2022, Qal/WBR HSU the extent of groundwater containing perchlorate concentrations in excess of the 6 µg/L MCL cleanup standard decreased compared to what

was observed in 2021 and extends approximately 1,200 ft downgradient from the Building 850 firing table.

The 2008 historical maximum perchlorate concentration in Qal/WBR HSU groundwater in the Building 850 area is 92 µg/L in monitor well NC7-28. During 2022, samples from the following five wells in this HSU exceeded perchlorate's 6 ug/L MCL cleanup standard and are located immediately downgradient of Building 850 and along Doall Ravine:

- **NC7-10**: 14 µg/L in February.
- **NC7-11**: 14 µg/L in April.
- **NC7-28**: 37 µg/L in November.
- **NC7-61**: 29 µg/L in April.
- **W-850-2313**: 13 µg/L in November.

$Tnbs_1/Tnbs_0$ HSU

The following perchlorate concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- The 2022 maximum perchlorate concentration was 7.3 µg/L in June in well NC2-17, located southeast of the Pit 2 landfill. This maximum is a slight decrease from the 2021 maximum of 7.4 µg/L in the same well.
- The 2022 extent of $Tnbs_1/Tnbs_0$ HSU groundwater containing perchlorate concentrations in excess of the 6 µg/L MCL cleanup standard was similar to the 2021 extent. Overall, concentrations in 2022 also remained similar to those in 2021 in Building 850 area wells.

The following six $Tnbs_1/Tnbs_0$ HSU wells in the Building 850 area exceeded the 6 µg/L MCL cleanup standard for perchlorate:

- **NC2-12I**: 6.7 µg/L in April.
- **NC2-17**: 7.3 µg/L in June.
- **NC7-27**: 6.8 µg/L in November.
- **NC7-29**: 6.7 µg/L in April.
- **NC7-43**: 6.4 µg/L in April.
- **W-PIT1-2620**: 6.6 µg/L in March.

HE Compound Concentrations and Distribution

During 2022, groundwater samples from 36 wells located in and around the Building 850 area were analyzed for HE compounds at typical reporting limits of 1 or 2 µg/L. HMX and RDX were detected at concentrations exceeding these reporting limits. The source of these HE compounds is the Building 850 firing table. Because of the limited number of wells in the Building 850 area that yield HE compound concentrations in excess of reporting limits, maps depicting these data are not included in the CMRs.

Qal/WBR HSU

The following HE compound concentrations were observed in the Qal/WBR HSU:

- The 2022 maximum HMX concentration was 8.9 µg/L in November in monitoring well NC7-28. This maximum is a decrease from the 2021 maximum of 11 µg/L in well W-850-2417, which was not sampled during 2022 due to issues with sampling equipment.
- The 2022 maximum RDX concentration was 4.8 µg/L in November in NC7-28. This maximum is a minor decrease from the 2021 maximum of 5.9 µg/L in ethyl lactate injection well W-850-2417, which was not sampled during 2022 due to issues with sampling equipment.
- HE concentrations remained similar to 2021 concentrations in all Qal/WBR HSU wells sampled during 2022.

During 2022, three Qal/WBR HSU wells in the Building 850 area yielded HMX concentrations that exceeded reporting limits, although these exceedances were significantly below the HMX regional tapwater screening level of 1,000 µg/L (U.S. EPA 2016). Located immediately downgradient of Building 850 or nearby along Doall Ravine, the same three wells also exceeded reporting limits for RDX:

- **NC7-28**: 8.9 µg/L and 4.8 µg/L of HMX and RDX, respectively, in November.
- **NC7-61**: 6.5 µg/L and 3.8 µg/L for HMX and RDX, respectively, in April.
- **NC7-10**: 3.1 µg/L and 2.3 µg/L for HMX and RDX, respectively, in April.

$Tnbs_1/Tnbs_0$ HSU

During 2022, HE compounds were not detected above reporting limits in any wells screened exclusively in the $Tnbs_1/Tnbs_0$ HSU downgradient of Building 850.

In 2017, well NC7-43 yielded 1.1 µg/L of HMX, slightly above the 1 µg/L reporting limit, and 4 µg/L of 3-nitrotoluene, above the 2 µg/L reporting limit. Although well NC7-43 did not yield a detection of HE in 2022, previously reported detections of HMX and 3-nitrotoluene suggest that HE compounds are present in the $Tnbs_1/Tnbs_0$ HSU, albeit at very low concentrations. Future monitoring data will further clarify the nature and extent of HE compounds in the HSU.

2.5.1.2.2. Remediation Optimization Evaluation

Recent analytical data indicate that natural attenuation (i.e., dispersion, radioactive decay, and a decreasing source term) remain effective in maintaining tritium activity concentrations in groundwater below the 20,000 pCi/L MCL cleanup standard. The leading edge of the tritium plume is stable within the interior of Site 300 and is expected to completely attenuate within its boundaries. While the highest tritium activity concentrations in groundwater continue to be located directly downgradient of sources at the Building 850 firing table, they are decreasing. In general, activity concentrations continue to decrease significantly below historical maxima throughout the Building 850 area.

The monitoring-only strategy for uranium implemented in the Building 850 area continues to be protective, given that total uranium activity concentrations in groundwater at and downgradient of Building 850 are below the 20 pCi/L MCL cleanup standard and/or are natural. The areal extent of depleted uranium has not changed during 2022, and temporal trends in $^{235}U/^{238}U$ atom ratios have remained relatively stable.

During 2022, the overall extent and maximum concentrations of nitrate and perchlorate in groundwater were similar to those observed in 2021. Concentrations of RDX and HMX do not exceed any drinking water standards and are confined to an area immediately downgradient of Building 850.

2.5.1.2.3. Enhanced Bioremediation Treatability Study

During the second semester of 2011, a perchlorate bioremediation treatability study commenced to evaluate the efficacy of *in situ* enhanced bioremediation in reducing perchlorate concentrations in the presence of elevated nitrate in Building 850 groundwater. To date, the test has consisted of extracting contaminated groundwater from wells W-850-2417 or NC7-70, mixing it with dilute ethyl lactate, and injecting the mixture into wells W-850-2417 (in 2011 and 2012) or NC7-70 (in 2013 and 2015) to facilitate the *in situ* bioremediation of perchlorate via indigenous bacteria. While awaiting rebound in perchlorate concentrations, the ethyl lactate mixture was not injected into groundwater from 2016 to 2022. Bioremediation performance is being evaluated primarily at downgradient performance monitor wells NC7-28 and NC7-61.

Perchlorate concentrations in wells NC7-70, NC7-28, and NC7-61 have decreased from pre-test (2011) concentrations of 45.6, 61.2, and 45 μg/L, respectively, to 2022 concentrations of below the 2 μg/L reporting limit in October, 37 μg/L in November, and 29 μg/L in April, respectively. During 2022, ethyl lactate injection well W-850-2417 was not sampled due to issues with sampling equipment.

With the last injection of ethyl lactate occurring in 2015, recent data reflect a rebound of perchlorate concentrations toward pre-injection levels. The persistence of perchlorate concentrations below the 2 μg/L reporting limit in injection well NC7-70 is indicative of a diminished upgradient perchlorate source and the longevity of electron donor ethyl lactate in sustaining perchlorate reduction in the presence of multiple electron acceptors, including dissolved oxygen (DO), nitrate, sulfate, and reactive hydrous ferrous oxide mineral surfaces on the solid matrix within the treatment zone.

Although not specifically targeted for bioremediation, nitrate and uranium are also monitored in injection wells W-850-2417 and NC7-70 and performance monitor well NC7-28. Nitrate concentrations in well NC7-70 have decreased from pre-injection maxima of 57 mg/L to less than 1 mg/L in April 2022. Nitrate concentrations in NC7-28 have decreased from a pre-injection maximum of 88 mg/L to 50 mg/L in April. Although nitrate concentrations remained low in well NC7-70, those in well NC7-28 are increasing towards pre-injection levels.

Uranium activity concentrations in wells W-850-2417, NC7-28, and NC7-70 initially decreased following ethyl lactate injections but fluctuated with some uranium activity concentrations exceeding pre-injection values. Following the injections, decreasing uranium trends appeared to result from concurrent reduction of U(VI) species (i.e., U^{+6} oxidation state) in groundwater to U(IV) (U^{+4} oxidation state) species, precipitating low-solubility mineral solids. Increases in groundwater uranium activity concentrations observed later likely arose due to the dissolution of natural uranium from the rock matrix under low pH conditions, oxidation of reduced uranium minerals, and desorption from mineral surfaces, in combination with the arrival of pre-existing dissolved uranium from upgradient of the treatment area.

Rebound monitoring indicates that current uranium activity concentrations in the Building 850 treatability test wells are generally similar to or lower than those measured before the ethyl lactate injections began in 2011. During 2022, wells NC7-70, NC7-28, and NC7-61 exhibited total uranium activity concentrations of 2 pCi/L and 0.59 pCi/L in April and November, 8.4 pCi/L in April and November, and 3.7 pCi/L in April, respectively.

2.5.1.2.4. Corrective Action Management Unit

In 2009, a CAMU was constructed in the Building 850 area as part of a removal action. The Building 850 CAMU is inspected each year before and after the rainy season and following major storms. It is maintained according to the requirements of the inspection and maintenance plan (SCS Engineers 2010).

Inspection Results

A pre-rainfall season inspection of the CAMU was conducted on October 12, 2022. Some erosion, dried grassy vegetation, and a small amount of animal burrows were observed on the slopes of the CAMU. Additionally, rocks, sediment and dried vegetation carried by previous storm water flows were found to be obstructing elements of the surface water drainage system, including a corrugated metal pipe inlet and rock gabions.

The following corrective actions and repairs are pending to protect the long-term integrity of the Building 850 CAMU:

- Remove rocks, sediment and dried vegetative debris obstructing drainage structures.
- Post warning signs to prohibit vehicle traffic on the CAMU.

Maintenance

During the first semester of 2022, maintenance on the Building 850 CAMU consisted of spraying pre-emergent herbicide on it to control vegetation. Maintenance work to address the blocked drainage structures was not performed in 2022 but has been scheduled for 2023.

2.5.1.2.5. Remedy Performance Issues

During this reporting period, no new issues affected the performance of the MNA cleanup remedy for tritium in the Building 850 area. The remedy for tritium continues to be effective and protective of human health and the environment.

During 2022, maximum tritium activity concentrations exceeded the 20,000 pCi/L MCL cleanup standard in a single well located 400 ft downgradient of the Building 850 firing table. Perchlorate, nitrate, uranium, and HE compound concentrations and extent in groundwater downgradient of the Building 850 firing table were generally consistent with those observed in previous semesters. Groundwater contaminants in the Building 850 area will continue to be closely monitored and reported.

Overall, the remedy for the Building 850 area continues to make progress towards cleanup and be protective of human health and the environment.

2.5.2. Pit 7 Complex Area

The Pit 7 Complex consists of four landfills, Pits 3, 4, 5, and 7. Used to dispose of debris and gravel, these landfills were constructed by excavating soil and alluvial materials to average depths of

15 to 20 ft (Taffet et al. 1989). The majority of the waste in the pits originated at the Buildings 850 and 851 firing tables and included wood, plastic material, and debris from tent structures, pea gravel, and exploded test assemblies, some of which contained tritium and depleted uranium. During above-normal rainfall years, the pit waste and unsaturated portions of the underlying Qal/WBR HSU were often inundated, causing residual tritium, depleted uranium, perchlorate, nitrate, and VOCs to be released to shallow groundwater.

In 1992, an engineered cap was constructed over the Pit 7 landfill in compliance with requirements outlined in the Resource Conservation and Recovery Act (RCRA). The cap has the following components:

- Interceptor trenches and surface water drainage channels.
- Top vegetative layer to prevent erosion.
- Biotic barrier layer to minimize animal burrowing.
- Clay layer with very low permeability.
- Gravel-filled trench on the west side to reduce infiltration of precipitation and resulting shallow subsurface interflow that could hasten the entry of shallow groundwater into Pit 7 and leach contaminants.

The Pit 7 cap covers 100 percent of Pit 7 and Pit 4 and approximately 30 percent of Pit 3. The original compacted native soil cover on most of Pit 3 and all of Pit 5 remains intact.

In 2008, the Pit 7 Complex DDS was designed and constructed to prevent additional releases of COCs from the pits and underlying bedrock to groundwater. This DDS is comprised of four components:

- A subsurface drainage network on the western hillslope.
- Upgraded riprap at the end of the existing north-flowing concrete channel for the Pit 7 cap.
- Vegetated surface-water diversion swale along the base of the eastern hillslope, along Route 4, including several culverts under this paved road and the dirt fire trails.
- Upgraded surface water-settling basin at the south end of the existing south-flowing concrete channel for the cap.

The Interim Remedial Design Document for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300 (Taffet et al. 2008) presents additional information on the Pit 7 cap and DDS. Section 3.6 summarizes the inspection results for the Pit 7 Complex landfill covers and cap and related concrete-lined drainage channels. Section 2.5.5.4 describes the detection monitoring, inspection, and maintenance program for the Pit 7 Complex.

In May 2010, the Pit 7-Source (PIT7-SRC) GWTS began operation. During 2022, groundwater was extracted from Qal/WBR HSU wells NC7-64, W-PIT7-2305, W-PIT7-2703, and W-PIT7-2705. The current GWTS configuration consists of two ion-exchange resin vessels to remove uranium, followed by one ion-exchange resin vessel containing a perchlorate-selective resin, two parallel sets (i.e., a total of four) of ion-exchange resin vessels containing a nitrate-selective resin, and three aqueous-phase GAC vessels in series to remove VOCs. The treated water, which still contains tritium, is discharged to an infiltration trench.

2.5.2.1. Groundwater Treatment System Operations and Monitoring

2.5.2.1.1. Compliance Summary

The PIT7-SRC GWTS operated in compliance with the RWQCB substantive requirements for wastewater discharge throughout this reporting period.

The treatment facility sampling and analysis plan for the first semester of 2023 is presented in Appendix B and complies with the monitoring requirements in the CMP/CP. No modifications were made to the plan for this reporting period.

2.5.2.1.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the Pit 7 Complex:

- **Table 2.2**: Monthly volumes of groundwater extracted and discharged by treatment facilities in this area for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater mass removal from this area for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at facilities within this area in 2022.
- **Table Summ-1**: The total volume of groundwater extracted and treated and total contaminant mass removed from this area during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater treated and discharged and total contaminant mass removed from this area.
- **Appendix A**: pH measurements.

The PIT7-SRC GWTS performed as designed during this reporting period. While the facility operated at reduced capacity due to equipment issues, DOE/LLNL plans to operate the PIT7-SRC GWTS at full capacity in 2023.

2.5.2.1.3. Treatment Facility and Extraction Wellfield Modifications

The wellfield configuration for the PIT7-SRC GWTS has changed several times over the last few years. During 2022, the GWTS received influent from four extraction wells, NC7-64, W-PIT7-2307, W-PIT7-2305, and W-PIT7-2705. The following wells were kept offline for the duration of the reporting period (unless otherwise specified) for the following reasons:

- **Well NC7-25**: To prevent the possibility of tritium activity concentrations in effluent exceeding those in the Qal/WBR HSU immediately downgradient of the injection trench and to reduce the potential for depleted uranium to be drawn into the $Tnbs_1/Tnbs_0$ HSU during prolonged pumping of the well.
- **Wells W-PIT7-2704 and W-PIT7-2306**: Insufficient water to operate the wells.
- **Extraction well W-PIT7-2705**: Taken offline from April through the end of the reporting period for equipment issued related to the submersible pump.
- **Extraction well W-PIT7-2703**: Equipment issued related to the submersible pump.

Efforts to address equipment issues are planned for 2023.

2.5.2.2. Groundwater Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater monitoring at the Building 850/Pit 7 Complex OU. This appendix also explains deviations made from the plan.

A total of 66 required analyses were scheduled in the Pit 7 Complex area in accordance with the CMP. Of these analyses, 25 were not carried out because the wells or springs were dry and two were not carried out because there were issues with access to the well locations.

Figures 2.5-2 and 2.5-3 are groundwater elevation contour maps for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively, where COCs are detected within this OU. Groundwater elevations in 2022 in both HSUs were similar to those in 2021.

2.5.2.3. Remediation Progress Analysis

This section is organized into four subsections: analysis of contaminant distribution and concentration trends, remediation optimization and performance evaluation, Pit 7 Complex DDS, and remedy performance issues.

2.5.2.3.1. Contaminant Concentrations and Distribution

In the Pit 7 Complex area, tritium is the primary COC in groundwater, and uranium, perchlorate, nitrate, and VOCs are the secondary COCs. These constituents have been identified within the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs.

The following subsections discuss concentrations and distributions of tritium, uranium, nitrate, perchlorate, and HE compounds in the Pit 7 Complex area's HSUs. These discussions are supported by the following figures:

- **Figure 2.5-4 and Figure 2.5-5**: Tritium activity concentration contour map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.
- **Figure 2.5-6 and Figure 2.5-7**: Uranium activity concentration map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.
- **Figure 2.5-8 and Figure 2.5-9**: Nitrate concentration map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.
- **Figure 2.5-10 and Figure 2.5-11**: Perchlorate isoconcentration contour map for the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs, respectively.

Tritium Activity Concentrations and Distribution

Commingled plumes of tritium in groundwater extend from Pit 3 and Pit 5 landfill sources. The Pit 7 landfill is not an apparent source of tritium to groundwater because most of the tritium-bearing experiments at Site 300 were conducted prior to its opening in 1979 (Taffet et al. 2008).

Located directly downgradient of Pit 7 and upgradient of Pit 3, monitor well NC7-48 has generally yielded groundwater samples that contain tritium activity concentrations within background ranges (i.e., below the 100 pCi/L reporting limit). The tritium activity concentration in a groundwater sample collected from this well during the second semester of 2022 (November) was also below 100 pCi/L. In general, activity concentrations continue to slowly decrease, and the extents in excess of background activity concentrations in both HSUs remain constant to decreasing.

Qal/WBR HSU

The following tritium activity concentrations were observed in the Qal/WBR HSU:

- Tritium activity concentrations have decreased from a 1998 historical maximum of 2,660,000 pCi/L in well NC7-63 to a 2022 maximum of 79,000 pCi/L in April in well NC7-51, located approximately 100 ft downgradient (east) of Pit 3 and Pit 5.
- The 2022 maximum is a minor increase from the 2021 maximum of 78,900 pCi/L in the same well.
- Tritium activity concentrations and spatial extent in excess of background and the cleanup standard remained stable in all Qal/WBR HSU wells sampled during 2022.

In 2022, the following 11 Qal/WBR HSU wells in the Pit 7 Complex area contained tritium activity concentrations equal to or in excess of the 20,000 pCi/L tritium MCL cleanup standard:

- **K7-01**: 21,800 pCi/L in November.
- **NC7-16**: 24,600 pCi/L in November.
- **NC7-21**: 23,800 pCi/L in April.
- **NC7-40**: 42,400 pCi/L in April.
- **NC7-51**: 76,500 pCi/L in February.
- **NC7-64**: 78,900 pCi/L in April.
- **W-PIT7-03**: 62,700 pCi/L in February.
- **W-PIT7-1918**: 31,400 pCi/L in April.
- **W-PIT7-2305**: 29,000 pCi/L in March.
- **W-PIT7-2703**: 59,300 pCi/L in April.
- **W-PIT7-2705**: 23,400 pCi/L in March.

$Tnbs_1/Tnbs_0$ HSU

The following tritium activity concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- Tritium activity concentrations have decreased from a 1999 historical maximum of 770,000 pCi/L to a 2022 maximum of 103,000 pCi/L in April in well W-PIT7-3406, located approximately 250 ft downgradient (northeast) of the Pit 3 landfill.
- The 2022 maximum is a decrease from the 2021 maximum of 171,000 pCi/L in nearby extraction (currently monitor) well NC7-25, which was dry and not sampled during 2022.
- Tritium activity concentrations and spatial extent in excess of background and the cleanup standard remained stable in all $Tnbs_1/Tnbs_0$ HSU wells sampled during 2022.

In 2022, the following five $Tnbs_1/Tnbs_0$ HSU wells in the Pit 7 Complex area yielded activity concentrations in excess of the 20,000 pCi/L MCL cleanup standard:

- **K7-03**: 24,000 pCi/L in April.
- **NC7-52**: 22,600 pCi/L in August.
- **W-PIT7-13**: 26,200 pCi/L in April.

- **W-PIT7-2307**: 36,400 pCi/L in April.
- **W-PIT7-3406**: 103,000 pCi/L in April.

Uranium Concentrations and Distribution

As was the case for the Building 850 area, total uranium and individual isotope activity concentrations for the Pit 7 Complex area were obtained using alpha spectroscopy, with selected samples from monitor wells analyzed by ICP-MS to define total uranium activity concentrations and isotope atom ratios.

Qal/WBR HSU

The following uranium concentrations were observed in the Qal/WBR HSU:

- Total uranium activity concentrations have decreased from a 1998 historical maximum of 781 pCi/L in monitor well NC7-40 to a 2022 maximum of 122.6 pCi/L in October in well NC7-64, located immediately downgradient of Pit 3.
- The 2022 maximum is a minor decrease from the 2021 maximum of 123 pCi/L, also in well NC7-64.
- Uranium activity concentrations and extent in excess of the cleanup standard remained stable in all Qal/WBR HSU wells sampled during 2022.

In well NC7-64, total uranium activity concentrations analyzed by ICP-MS were significantly lower for a sample collected on the same day as the sample that yielded the annual maximum activity concentration, as analyzed by alpha spectroscopy. The sample analyzed by ICP-MS yielded a total activity concentration of 11 pCi/L with a $^{235}U/^{238}U$ atom ratio of 0.0072, indicating natural uranium. Since sampling for total uranium began in 1991, this is the second lowest activity concentration observed in this well, with the lowest activity concentration of 7 pCi/L recorded in 1993. Similarly, $^{235}U/^{238}U$ atom ratios indicating natural uranium have not been seen since 1995. Uranium activity concentrations in Qal/WBR groundwater in this area will continue to be closely monitored.

During 2022, the following eight Qal/WBR HSU wells in the Pit 7 Complex area exhibited total uranium activity concentrations exceeding the 20 pCi/L MCL cleanup standard:

- **NC7-64**: 122.6 pCi/L in October.
- **W-PIT7-03**: 33.9 pCi/L in April.
- **W-PIT7-1917**: 70.4 pCi/L in April.
- **W-PIT7-2703**: 112.5 pCi/L in March.
- **W-PIT7-2705**: 32.7 pCi/L in March.
- **NC7-40**: 93 pCi/L in April.
- **NC7-51**: 40 pCi/L in February.
- **W-PIT7-1918**: 47 pCi/L in April.

All wells where uranium activity concentrations exceeded the 20 pCi/L MCL cleanup standard have historically shown $^{235}U/^{238}U$ atom ratios indicating some depleted uranium in the groundwater. The spatial extent of shallow groundwater impacted by depleted uranium has remained relatively stable for the past two decades. Historically, areas of depleted uranium have been bounded by wells that exhibit $^{235}U/^{238}U$ atom ratios indicative of natural uranium. Mass spectrometric analytical data for samples collected to date do not indicate any significant change in the footprint of shallow groundwater impacted by depleted uranium. Sorption and ion-exchange on aquifer mineral surfaces are likely responsible for retarding and attenuating the migration of depleted uranium in groundwater compared to conservative contaminants such as tritium.

$Tnbs_1/Tnbs_0$ HSU

The following uranium activity concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- Uranium activity concentrations have decreased from a 2014 historical maximum activity concentration of 100 pCi/L in extraction (currently monitor) well NC7-25 to a 2022 maximum of 21 pCi/L in April in monitor well W-PIT7-3406, located approximately 200 ft downgradient and northeast of Pit 3.
- The 2022 maximum is a decrease from the 2021 maximum of 40 pCi/L in immediately adjacent well NC7-25, which was dry and not sampled during 2022.
- Uranium activity concentrations remained similar to those of 2021 in all $Tnbs_1/Tnbs_0$ HSU wells that were sampled during 2022.

Of the $Tnbs_1/Tnbs_0$ HSU wells in Pit 7 Complex, only monitor well W-PIT7-3406, with 21 pCi/L of total uranium, contained groundwater with activity concentrations in excess of the 20 pCi/L MCL cleanup standard during 2022. Well W-PIT7-3406 exhibited a $^{235}U/^{238}U$ atom ratio of 0.0072, which is indicative of natural uranium.

Nitrate Concentrations and Distribution

Qal/WBR HSU

The following nitrate concentrations were observed in the Qal/WBR HSU:

- Nitrate concentrations have decreased from a 2017 historical maximum of 140 mg/L in monitor well W-PIT7-2305 to a 2022 maximum of 53 mg/L in May in monitor well K7-01, located immediately downgradient of Pit 5.
- The 2022 maximum is a minor decrease from the 2021 maximum of 55 mg/L in the same well.
- Nitrate concentrations remained similar to 2021 concentrations or decreased in all Qal/WBR HSU wells sampled during 2022.

During 2022, the following four Qal/WBR HSU wells in the Pit 7 Complex area contained nitrate concentrations equal to or exceeding the 45 mg/L MCL cleanup standard:

- **K7-01**: 53 mg/L in April.
- **NC7-17**: 45 mg/L in April.
- **NC7-64**: 52 mg/L in April.
- **W-PIT7-2305**: 47 mg/L in April.

$Tnbs_1/Tnbs_0$ HSU

The following nitrate concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- Nitrate concentrations have decreased from a 2002 historical maximum of 77 mg/L in well NC7-25 to a 2022 maximum of 60 mg/L in April in well W-PIT7-13, located approximately 800 feet downgradient (east) of Pit 5.
- The 2022 maximum is an increase from the 2021 maximum of 48 mg/L in extraction (currently monitor) well NC7-25, which was dry and not sampled during 2022.
- Nitrate concentrations remained similar to 2021 concentrations in all $Tnbs_1/Tnbs_0$ HSU wells sampled during 2022.

Well W-PIT7-13 was the only $Tnbs_1/Tnbs_0$ HSU well in the Pit 7 Complex area that contained nitrate above the 45 mg/L MCL cleanup standard during 2022.

Perchlorate Concentrations and Distribution

In supporting the following discussions, the lowest iso-contour in the perchlorate groundwater concentration maps for the Building 850/Pit 7 Complex OU (i.e., Figure 2.5-10 and Figure 2.5-11) has been updated from 4 µg/L to 2 µg/L to reflect the new 2 µg/L reporting limit.

Qal/WBR HSU

The following perchlorate concentrations were observed in the Qal/WBR HSU:

- Perchlorate concentrations have exhibited generally stable to decreasing trends from a 2009 historical maximum of 40 µg/L in extraction well W-PIT7-2306 to a 2022 maximum of 11 µg/L in October in extraction well W-PIT7-2305, located immediately downgradient of Pit 5.
- The 2022 maximum is a minor decrease from the 2021 maximum of 12 µg/L in monitoring well NC7-34 and extraction well W-PIT7-2305.
- Perchlorate concentrations remained similar to 2021 concentrations in all Qal/WBR HSU wells sampled during 2022.

During 2022, the following seven Qal/WBR HSU wells in the Pit 7 Complex area exhibited perchlorate concentrations at or above the 6 µg/L MCL cleanup standard:

- **K7-01**: 8.9 µg/L in April.
- **NC7-40**: 10 µg/L in April.
- **NC7-51**: 7.5 µg/L in April.
- **W-PIT7-03**: 8.1 µg/L in April.
- **W-PIT7-1918**: 9.1 µg/L in April.
- **W-PIT7-2305**: 11 µg/L in October.
- **W-PIT7-2703**: 6 µg/L in April.

$Tnbs_1$/$Tnbs_0$ HSU

The following perchlorate concentrations were observed in the $Tnbs_1$/$Tnbs_0$ HSU:

- Perchlorate concentrations have decreased from a 2005 historical maximum of 29 µg/L in monitor well K7-03 to a 2022 maximum of 12 µg/L in November in monitor well W-PIT7-3406, located approximately 250 ft downgradient (northeast) of the Pit 3 landfill.
- The 2022 maximum is a minor increase from the 2021 maximum of 11 µg/L in W-PIT7-3406 and NC7-68.
- Perchlorate concentrations remained similar to 2021 concentrations in all $Tnbs_1$/$Tnbs_0$ HSU wells that during 2022.

During 2022, the following three $Tnbs_1$/$Tnbs_0$ HSU wells in the Pit 7 Complex area exhibited perchlorate concentrations at or above the 6 µg/L MCL cleanup standard:

- **NC7-68**: 9.6 µg/L in April.
- **W-PIT7-2307**: 7.4 µg/L in April.
- **W-PIT7-3406**: 12 µg/L in November.

VOC Concentrations and Distribution

VOC COCs in Pit 7 Complex groundwater include TCE and 1,1-DCE. Because of the limited number of wells in the Pit 7 Complex area that yield VOC concentrations in excess of reporting limits and MCL cleanup standards, maps depicting these data are not included in the CMRs.

Qal/WBR HSU

The following VOC concentrations were observed in the Qal/WBR HSU:

- TVOC concentrations have decreased from a 1995 historical maximum of 21 µg/L in monitor well NC7-51, comprised of 15 µg/L of TCE and 6.2 µg/L of 1,1-DCE, to no detections of individual VOCs in excess of reporting limits in any 2022 groundwater samples.
- The absence of individual VOCs in excess of reporting limits in any 2022 sample represents a decrease from the 2021 maximum concentration of 0.63 µg/L, comprised entirely of TCE, in well NC7-51.

Since monitoring began in the early 1980s, 2020 and 2022 are the only two years during which no VOCs were detected in excess of reporting limits in any sample of groundwater collected from the Qal/WBR HSU in the Pit 7 landfill area.

$Tnbs_1$/$Tnbs_0$ HSU

The following VOC concentrations were observed in the $Tnbs_1$/$Tnbs_0$ HSU:

- TVOC concentrations decreased from a 1985 historical maximum of 15.2 µg/L, comprised of 8.7 µg/L of TCE, 4.5 µg/L of 1,2-DCE, 0.8 µg/L of PCE, and 1.2 µg/L of 1,1,1-TCA, in well K7-03 to a 2022 maximum concentration of 7.3 µg/L in both April and October in W-PIT7-2307.

- The 2022 VOC concentrations are similar to those of 2021 when 1.1 μg/L of TCE were detected in monitor well K7-03 and 3 μg/L TCE and 1 μg/L of 1,1-DCE were detected in extraction well W-PIT7-2307.

During 2022, TVOC concentrations exceeded the individual VOC reporting limit of 0.5 μg/L in the following two $Tnbs_1$/$Tnbs_0$ HSU monitor wells, located immediately downgradient of Pit 5, in the Pit 7 Complex area:

- **K7-03**: 0.51 μg/L of TCE in April.
- **W-PIT7-2307**: 7.3 μg/L of TVOCs, comprised of 5.3 μg/L of TCE and 2 μg/L of 1,1-DCE, in April and October.

2.5.2.3.2. Remediation Optimization and Performance Evaluation

In 2022, the PIT7-SRC GWTS extracted and treated 19,125 gal of groundwater during the second semester of 2022, and 0.8 g of VOCs, 1.1 g of perchlorate, 5.2 kg of nitrate, and 2.8 g of uranium were removed from the extracted groundwater. No effluent compliance samples contained any COCs (nitrate, perchlorate, uranium, VOCs) in excess of effluent discharge limits.

Despite the release of COCs to groundwater in 2017, the extents of COCs in excess of MCL cleanup standards and background concentrations have not expanded, and natural attenuation of all COCs continues to occur within less than 1,500 ft of the landfills, as supported by groundwater monitoring results from 2017, 2018, 2019, 2020, 2021, and 2022. Monitoring will continue to provide data to verify whether this natural attenuation, the limited extent of these COCs in excess of MCL cleanup standards and background, and long-term decreasing trends in COC concentrations continue.

Furthermore, concentrations of COCs will continue to be closely monitored in downgradient performance monitor wells. Spatial and temporal COC trends in these wells will be used to determine the relative magnitude of any future releases to groundwater and the distribution of localized residual vadose zone COC sources within and beneath the pits.

2.5.2.3.3. Drainage Diversion System

The DDS is inspected and maintained according to the requirements of the inspection and maintenance plan (Taffet et al. 2008).

Inspection Results

Monthly rainy season and post-storm inspections were performed routinely during the second semester of 2022. The DDS was inspected on September 21, October 12, November 14, December 15, and December 27, 2022. During these inspections, all components were determined to be satisfactory.

Maintenance

Maintenance activities at the DDS included removing tumbleweeds from the southern settling basin area, the southern rip-rap, several culverts, the vegetated swale, and the northern rip-rap.

2.5.2.3.4. Precipitation and Groundwater Elevations

In general, annual precipitation and groundwater elevations in the Qal/WBR and $Tnbs_1$/$Tnbs_0$ HSUs of the Pit 7 Complex area are positively correlated. Rainfall event frequency, duration, and intensity affect the rate and direction of groundwater elevation change. At the request of the U.S. EPA, DOE/LLNL has produced Figures H-1 through H-13 in Appendix H. These figures are time-series plots of daily precipitation totals at Site 300 and the groundwater elevations for key wells located near Pits 3 and 5 in the Pit 7 Complex area. Pits 3 and 5 are the two primary source areas of COCs in the Pit 7 Complex and were partially inundated by rising groundwater in 1998 and 2017.

Total precipitation for the 2022 water year (October 1, 2021, to September 30, 2022) was 9.1 inches, an increase from the 4.4 inches recorded during the 2021 water year, which was representative of drought conditions. The highest annual rainfall recorded at Site 300 since 1980 was 19.4 inches of total precipitation during the 1998 water year.

The time-series graphs pertaining to precipitation and groundwater elevations near the Pit 7 Complex contain precipitation data from more than one water year. The current reporting period spans two water years. The time-series graphs in Appendix H display all data for the 2022 water year (October 1, 2021, to September 30, 2022) and data for the part of the 2023 water year that coincides with the reporting period of this annual CMR (October 1, 2022, to December 31, 2022).

On the time-series graphs, a horizontal line has been added to represent the approximate elevation of the bottom of Pit 3 or Pit 5 projected to each key well. By showing the projected pit bottom elevations, the hydrographs are an approximate representation of the groundwater elevations in vertical relation to the pit bottom elevations. These projected pit bottom elevations are dependent on the location of each well and were graphically determined from the electrical resistivity survey data for Pit 3 and Pit 5 combined with other observations.

The key wells located near Pits 3 and 5 are W-PIT3-02, NC7-75, W-PIT7-2306, W-PIT7-2704, W-PIT7-2307, W-PIT7-02, NC7-34, NC7-24, W-PIT5-01, NC7-36, W-PIT5-02, W-PIT7-03, NC7-37, K7-10. Figures 2.5-1, 2.5-2, and 2.5-3 show the locations of these wells in relation to the landfills. As shown in Figures H-1 through H-13, during 2022, groundwater elevations in these key wells varied from 8 ft to 30 ft below the Pit 3 and Pit 5 bottoms and did not indicate any pit inundation.

2.5.2.3.5. Remedy Performance Issues

While DOE/LLNL continues to evaluate opportunities to optimize the efficiency and effectiveness of the GWTS for improved operations and expedited cleanup, optimization is limited by the hydraulic characteristics of the HSUs and the availability of groundwater to treat.

Overall, the remedy for the Pit 7 Complex area continues to make progress toward cleanup and be protective of human health and the environment.

2.6. Building 854 (OU 6)

The Building 854 area has been used to test the stability of weapons and weapon components under various environmental conditions, including mechanical and thermal stresses. To remediate groundwater and soil vapor contamination, two GWTSs, 854-SRC and 854-PRX; one GWES, 854-Distal (DIS); and the 854-SRC SVTS operate in the OU. Figure 2.6-1 is a map of the Building 854 OU showing the locations of monitor and extraction wells and treatment facilities.

The 854-SRC GWTS began operation in December 1999 to remove VOCs and perchlorate from groundwater and was upgraded in 2016. The system consists of a particulate filtration system, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase

GAC vessels connected in series for VOC removal. After perchlorate and VOC treatment, the nitrate-bearing effluent water is discharged via a misting tower onto the landscape for indigenous grasses to utilize. While operating in 2022, the flow rates for the two extraction wells serving this GWTS, W-854-2218 and W-854-02, averaged approximately 4.5 to 5.5 gpm and 1 to 2 gpm, respectively.

In addition to groundwater treatment at 854-SRC, soil vapor treatment began in November 2005. This system consists of a rotary-lobe blower to create a vacuum at the wellhead and a series of pipes leading to three vapor-phase GAC vessels that remove VOCs from extracted soil vapor. Treated vapors are discharged to the atmosphere under a permit issued by the SJVAPCD. In 2022, soil vapor was extracted from one SVE well, W-854-1834, at an approximate flow rate of 33 scfm.

The 854-PRX GWTS, began operation in November 2000, removing VOCs, nitrate, and perchlorate from groundwater. This system consists of a particulate filtration system, two ion-exchange resin columns connected in series for perchlorate removal, and three aqueous-phase GAC vessels connected in series for VOC removal. Influent concentrations of nitrate have been below the 45 mg/L MCL cleanup standard since 2010. Treated effluent is discharged to the subsurface via an infiltration trench. In 2022, groundwater was extracted at a flow rate of approximately 3 gpm from a single extraction well, W-854-03, located southeast of the immediate Building 854 area.

The 854-DIS GWES, was initially operated as a GWTS from July 2006 to July 2019, removing VOCs and perchlorate from groundwater using two ion-exchange resin columns connected in series for perchlorate treatment, followed by three aqueous-phase GAC vessels connected in series for VOC removal prior to discharge to an infiltration trench. Due to the low volumes of water treated at this location, DOE/LLNL proposed converting the GWTS into a GWES, similar to the Building 817-SRC and 829-SRC systems. The regulatory agencies agreed with this proposal at the RPM meeting held on June 14, 2018. All treatment media and components were subsequently removed from the system, a collection tank was added, and engineering modifications and upgrades were completed in July 2019. The system extracts groundwater from a single well, W-854-2139, which operates cyclically. Extracted water is regularly transferred to the 854-SRC GWTS or other approved system, when needed, for treatment. In 2022, the GWES remained secured while engineering upgrades were made to the controls and data collection system; work on these upgrades continues.

2.6.1. Groundwater Treatment System Operations and Monitoring

2.6.1.1. Compliance Summary

During 2022, the 854-SRC GWTS and 854-PRX GWTS operated in compliance with the RWQCB substantive requirements for wastewater discharge, except for the two incidents detailed in the following subsections. The 854-SRC SVTS operated in compliance with its SJVAPCD permit.

2.6.1.1.1. 854-SRC GWTS

On August 25, 2022, the facility operator noted a leak from a broken part between the 854-SRC GWTS batch tank and misting towers. The RWQCB was notified on August 26.

Upon finding the broken part on August 25, the operator secured the facility and conducted repairs on the same day. The facility, however, remained secured for further evaluation. Review of operational data, specifically the water levels in the batch tank, showed that the broken part initially failed and caused the leak on August 11. Well W-854-02, which was in operation at the time of this event, extracts groundwater cyclically. As a result, the leak was not visually confirmed.

Groundwater extraction from the well and the consequent leak occurred from Thursday, August 11, at 15:11 to Saturday, August 13, at 11:00 as well as from Thursday, August 18, at 13:50 to Saturday, August 20 at 10:00. The leak occurred along a section of pipeline conveying groundwater that had been treated for perchlorate and VOCs but not yet treated for nitrate via the misting tower. Thus, the approximately 9,000 gal of leaked groundwater released to the ground next to the facility were partially treated. Effluent samples collected from the treatment facility on July 5 indicated that perchlorate and VOC concentrations were below reporting limits, and the nitrate concentration in the sample collected from well W-854-02 on July 6 was 55 mg/L. Given the volume of partially treated groundwater released to ground, approximately 1.9 kg of nitrate was released.

The 854-SRC GWTS remained secured from August 25 to August 30 while facility engineers reviewed facility data and operational parameters. On August 30, the facility was temporarily restarted to test the repair made when the leak was first discovered. With personnel present, groundwater was extracted from well W-854-02 and treated for perchlorate and VOCs prior to being collected in the treatment facility's batch tank. After approximately three hours of operation, the water level in the batch tank had not risen to a level sufficient to cause the discharge pump to automatically turn on and discharge water to the misting towers. Furthermore, no leaks were observed during this event. On August 31, the facility was temporarily restarted once more. With personnel present, groundwater was extracted from well W-854-02, treated for perchlorate and VOCs, and discharged to the misting towers. Again, no leaks were observed. The 854-SRC GWTS resumed normal operations on September 7.

2.6.1.1.2. 854-PRX GWTS

At 854-PRX GWTS, influent and effluent samples for nitrate analysis were collected on August 1, 2022. On August 10, the analytical data were received, indicating 46 mg/L of nitrate, which is in excess of the 45 mg/L discharge limit in the ROD. The facility was secured on August 11 and the RWQCB was notified of the discharge limit exceedance.

In 2019, the RWQCB issued DOE/LLNL an exemption from 24-hour non-compliance reporting for short-term nitrate discharge limit exceedances caused by non-routine malfunctioning of an otherwise compliant facility (Phiri 2019). However, the exceedance in the sample collected on August 1 did not meet the conditions of the exemption because facility operations were continuous and not interrupted by an unplanned event, such as a power outage. Because influent concentrations of nitrate have been below 43 mg/L since 2012, this exceedance of the effluent discharge limit was unexpected.

On August 11, prior to shutting down the 854-PRX GWTS, the effluent was resampled for nitrate analysis. The effluent concentration was 44 mg/L, below the 45 mg/L discharge limit but in excess of the 42 mg/L concentration in the influent sample, which was collected on August 1.

To further evaluate the system, the treatment facility was temporarily restarted on August 17 while diverting effluent to a portable tank. After approximately three hours of operation, samples were collected from the influent, between each treatment media vessel, and from the effluent, all for nitrate analysis. The resulting nitrate concentrations were higher in the samples collected after the GAC vessels than in the influent. Therefore, DOE/LLNL initiated a change out of all treatment media (i.e., ion exchange resins and GAC) at the 854-PRX GWTS on September 15. On September 20, the facility was temporarily restarted again while diverting the effluent to a portable tank, and a set of samples were collected. All sample results were below the nitrate discharge limit. On October 3, the 854-PRX GWTS resumed normal operation.

2.6.1.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the Building 854 Canyon OU:

- **Table 2.2**: Monthly volumes of groundwater and soil vapor extracted and discharged by treatment facilities in this OU for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater and soil vapor mass removal from this OU for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at facilities within this OU in 2022.
- **Table Summ-1**: The total volume of groundwater and soil vapor extracted and treated and total contaminant mass removed from this OU during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater and soil vapor treated and discharged and total contaminant mass removed from this OU.
- **Appendix A**: pH measurements.

2.6.1.3. Treatment Facility and Extraction Wellfield Modifications

During 2022, no treatment facility or extraction wellfield modifications were performed on the 854-SRC or 854-PRX facilities. The 854-DIS GWES remained secured while engineering upgrades were made to the controls and data collection system; work on these upgrades continues.

2.6.2. Groundwater and Surface Water Monitoring

Appendix C contains the 2022 groundwater and surface water sampling and analysis plan for the Building 854 OU. This table also explains any deviations from the plan.

During the reporting period, 188 analyses from 38 wells or springs were required to meet CMP/CP monitoring requirements. Monitoring was conducted in compliance, with the following exceptions:

- A total of 39 required analyses from nine different wells or springs could not be performed because the wells or springs were dry or contained insufficient water for sample collection.
- Two required analyses from one well were not performed because the sampling pump was inoperable.

2.6.3. Remediation Progress Analysis

This section is organized into three subsections: analysis of contaminant distribution and concentration trends, remediation optimization evaluation, and remedy performance issues.

2.6.3.1. Contaminant Concentrations and Distribution

At the Building 854 OU, TCE and perchlorate are the primary COCs detected in groundwater, and nitrate is the secondary COC. These COCs have been detected primarily in the $Tnbs_1/Tnsc_0$ HSU.

The following subsections discuss concentrations and distributions of VOCs, perchlorate, and nitrate in this OU's HSUs. These discussions are supported by these figures:

- **Figure 2.6-2**: Groundwater potentiometric surface map for the $Tnbs_1/Tnsc_0$ HSU for the second semester of 2022.
- **Figure 2.6-3**: TVOC isoconcentration contour map and individual VOC concentrations for the $Tnbs_1/Tnsc_0$ HSU.
- **Figure 2.6-4**: Perchlorate isoconcentration contour map for the $Tnbs_1/Tnsc_0$ HSU.
- **Figure 2.6-5**: Map showing nitrate concentrations in the $Tnbs_1/Tnsc_0$ HSU.
- **Figure 2.6-6**: Map showing groundwater elevations and TVOC, perchlorate, and nitrate concentrations measured during 2022 in the $Qls/Tnbs_1$ HSU.

2.6.3.1.1. VOC Concentrations and Distribution

$Qls/Tnbs_1$ HSU

The following general trends in groundwater VOC concentrations were observed in the $Qls/Tnbs_1$ HSU:

- TVOC concentrations decreased from a 2015 historical maximum of 60 µg/L in well W-854-10 to a 2022 maximum of 45 µg/L in the same well in October.
- During 2022, wells W-854-10 and W-854-14 were the only $Qls/Tnbs_1$ locations where VOCs were present above the reporting limit.
- The 2022 spatial distribution of TVOC concentrations above the 0.5 µg/L reporting limit remained similar to what was observed in 2021.

During 2022, VOCs were detected above the 0.5 µg/L reporting limit in two $Qls/Tnbs_1$ HSU wells, W-854-10 and W-854-14. CFORM was detected in well W-854-14 at a concentration of 1.7 µg/L in May, which is below the 80 µg/L MCL cleanup standard. In November, the CFORM concentration in W-854-14 was once again below the reporting limit. Prior to May 2022, CFORM was only detected above the reporting limit one other time in this well, at a concentration of 3.8 µg/L in March 1999.

TCE was detected in well W-854-10 at a maximum concentration of 45 µg/L in October. Since 2006, TVOC concentrations in groundwater in this well have fluctuated and, similar to what was observed in 2021, varied from 19 µg /L in May to 45 µg/L in October during 2022. This fluctuation is concurrent with the general decline in water levels that has resulted from drought conditions. Also, similar to 2021 conditions, water levels at well W-854-10 rose approximately 1 ft during the first semester of 2022 and then declined approximately 1 ft during the second semester of 2022. Ultimately, water levels in this well decreased to the previous lowest water level observed in 2015, during which time TVOC concentrations were also at a maximum of 60 µg/L.

Even in relatively dry years more representative of drought conditions, residual VOCs in the vadose zone can be released to groundwater when water levels briefly rise after the rainy season. During periods with higher water levels, VOCs released to groundwater may be more diluted because of a thicker saturated zone, resulting in lower concentrations. This scenario may explain the current, sporadic increases in concentrations in W-854-10 amid lower water levels.

$Tnbs_1/Tnsc_0$ HSU Groundwater

The following general trends in groundwater VOC concentrations were observed in the $Tnbs_1/Tnsc_0$ HSU:

- TVOC concentrations decreased from a 1997 historical maximum of 2,900 µg/L in well W-854-02 to a 2022 maximum of 73 µg/L in the same well in July.
- During 2022, wells W-854-17 and W-854-3308 were the only locations that contained VOCs other than TCE. Cis-1,2 DCE was detected at a maximum concentration of 16 µg/L in well W-854-17 in October while CFORM was detected at a maximum concentration of 0.65 µg/L in well W-854-3308 in August.
- The 2022 spatial distribution of TVOC concentrations above the 0.5 µg/L reporting limit remained similar to what was observed in 2021.

In the 854-SRC area, VOC concentrations in groundwater remained stable during 2022, with no apparent increasing or decreasing trends. In this area, VOCs other than TCE were detected at only one well, monitor well W-854-17, where cis-1,2 DCE was detected in October at a maximum concentration of 16 µg/L, above its 6 µg/L MCL cleanup standard. The overall extent of VOCs in excess of the 0.5 µg/L reporting limit has remained relatively stable since remediation began. However, the extent of the northern VOC plume with concentrations greater than 50 µg/L has decreased and is currently limited to the immediate vicinity of the Building 854-SRC area. TVOC concentrations in $Tnbs_1/Tnsc_0$ HSU groundwater in the 854-SRC area have also decreased from the historical pre-remediation maximum of 2,900 µg/L to a 2022 maximum of 73 µg/L in July at extraction well W-854-02. TVOC concentrations in other wells in this area were similar to those reported in 2021.

In the 854-PRX area, groundwater extraction and treatment have hastened the steady decrease in TVOC concentrations (consisting entirely of TCE) from a 1999 historical pre-remediation maximum of 270 µg/L to a 2022 maximum of 2.4 µg/L in July at extraction well W-854-03. When well W-854-03 was secured from August 11 to October 3, 2022, TCE concentrations slightly rebounded to 5.6 µg/L in October but are expected to decrease again with the resumption of continuous operation.

Immediately downgradient of the 854-PRX GWTS, only one well contained VOCs. CFORM was detected at a maximum concentration of 0.65 µg/L in well W-854-3308 in August 2022. Because VOC concentrations in this well prior to and after this sample was collected were below reporting limits, as were concentrations in samples collected from adjacent wells W-854-1823 and W-854-3309, this CFORM detection appears to be anomalous.

The high-concentration portion of the southern VOC plume is located near the 854-DIS GWES. This VOC plume extends south from this area toward Spring 10 and Spring 11. Since 1983, TCE has been sporadically detected in Spring 10 at concentrations of up to 32 µg/L in August 2000 and at Spring 11 at concentrations of up to 2.8 µg/L in October 2011. Spring 10 has been dry since 2012 and Spring 11 has been dry since 2019.

During this reporting period, VOC concentrations remained stable in the 854-DIS area, despite the 854-DIS GWES remaining secured for upgrades. The extent of the southern VOC plume with concentrations greater than 10 µg/L has decreased since remediation began, and concentrations generally continue to exhibit decreasing trends, except at well W-854-07. TCE concentrations in this well decreased from a 2009 historical maximum of 58 µg/L to 5.7 µg/L in June 2016 before rising to 28 µg/L in October 2019. In 2022, TCE concentrations in this well decreased to a maximum of 18 µg/L in June.

In the Building 858 drop tower area, VOC concentrations in groundwater, including in recently installed monitor well W-854-3803, remained below their respective reporting limits during this reporting period.

$Tnbs_1$/$Tnsc_0$ HSU Soil Vapor

The following general trends in soil vapor VOC concentrations were observed in the $Tnbs_1$/$Tnsc_0$ HSU:

- TVOC concentrations consisting entirely of TCE decreased from a 2005 historical maximum of 4.4 $ppm_{v/v}$ (24,000 µg/m^3) in vapor extraction well W-854-1834 to a 2022 maximum of 0.17 $ppm_{v/v}$ (910 µg/m^3) in the same well in January.
- Since 2008, TCE concentrations have remained below 0.5 $ppm_{v/v}$ (i.e., 2,700 µg/m^3), both during operation and in rebound samples.

In the 854-SRC area, the historical maximum soil vapor TVOC concentrations, consisting entirely of TCE, was 4.4 $ppm_{v/v}$ (24,000 µg/m^3) in 2005 in vapor extraction well W-854-1834 and was representative of conditions when the 854-SRC SVTS began operation. With continued operation, TCE concentrations decreased to less than 0.5 $ppm_{v/v}$ (2,700 µg/m^3) by 2008 and have remained below 0.5 $ppm_{v/v}$ (2,700 µg/m^3) during normal facility operations as well as during shutdown periods used to evaluate potential rebound in concentrations. In 2022, the maximum TCE vapor concentration in well W-854-1834 was 0.17 $ppm_{v/v}$ (910 µg/m^3) in January.

VOC concentrations in vapor at this location are diffusion-limited. The slow but continual decrease in concentrations indicates progress towards remediating VOCs in this area.

2.6.3.1.2. Perchlorate Concentrations and Distribution

Qls/$Tnbs_1$ HSU

During 2022, perchlorate concentrations only exceeded the 2 µg/L reporting limit in one well screened in the Qls/$Tnbs_1$ HSU, monitor well W-854-05. In this well, perchlorate was detected at a maximum concentration of 4.1 µg/L in May before decreasing to 3.5 µg/L by October. Prior to these detections, perchlorate was only detected above the previous reporting limit of 4 µg/L three other times in this well: 4.1 µg/L in November 2001, 4.4 µg/L in May 2014, and 4.1 µg/L in November 2021.

$Tnbs_1$/$Tnsc_0$ HSU

The following general trends in groundwater perchlorate concentrations were observed in the $Tnbs_1$/$Tnsc_0$ HSU:

- Perchlorate concentrations decreased from a 2006 historical maximum concentration of 30 µg/L in monitor well W-854-17 to a 2022 maximum of 29 µg/L in monitor well W-854-3308 in January. Concentrations at well W-854-3308 were increasing since its development in 2017 but appear to have stabilized.

- The 2022 spatial distribution of perchlorate above the 2 µg/L reporting limit remained similar to what was observed in 2021, with the exception of the Building 858 drop tower area where perchlorate was detected in recently installed monitor well W-854-3803, expanding the plume northward.

In the 854-SRC area, extraction well W-854-02 historically contained perchlorate in groundwater above the 6 µg/L MCL cleanup standard, with concentrations typically ranging between 4.9 and 7.2 µg/L. The 2022 maximum perchlorate concentration in this well was 5.7 µg/L in July. In slightly upgradient monitor well W-854-2611, perchlorate was detected at a concentration of 5 µg/L in October.

In well W-854-08, concentrations have ranged from below the previous 4 µg/L reporting limit to up to 6.4 µg/L in February 2000. During 2022, perchlorate was detected in this well at a concentration of 4.6 µg/L in May. However, well W-854-08 periodically does not contain enough water to sample due to prolonged drought conditions and declining water levels. Thus, recent samples may be lower in concentration and not fully representative of the local perchlorate plume.

In the 854-PRX area, perchlorate concentrations at extraction well W-854-03 declined below the reporting limit in 2015, after engineering upgrades increased groundwater extraction flow rates from this well. When well W-854-03 is pumping, perchlorate concentrations are below the 2 µg/L reporting limit. However, under the non-operating conditions that occurred in 2020, concentrations in this well increased to 7.6 µg/L by August 2020. Shortly after groundwater extraction resumed at well W-854-03, concentrations again decreased to below the 2 µg/L reporting limit, with the exception of 4.5 µg/L in a single sample collected in October 2022. Perchlorate concentrations at nearby performance monitor well W-854 3405 ranged from 5.8 µg/L in February 2019 to 11 µg/L in January 2022. Thus, extraction well W-854-03 appears to be pumping water from fractures with multiple flow regimes and capturing clean water in addition to perchlorate-bearing groundwater, effectively diluting perchlorate concentrations to below reporting limits.

Immediately downgradient of the 854-PRX GWTS, perchlorate concentrations in $Tnbs_1/Tnsc_0$ HSU groundwater remained high, with a 2022 maximum concentration of 29 µg/L detected in January at monitor well W-854-3308. Perchlorate concentrations in other nearby wells completed in this HSU ranged from a low of 14 µg/L in well W-854-3309 to maximum of 18 µg/L in well W-854-1823 during 2022. Since W-854-3308 and W-854-3309 were developed in 2017 and well W-854-1823 was developed in late 2018, perchlorate concentrations had been increasing but now appear to have stabilized.

In the 854-DIS area, perchlorate concentrations remained stable during the reporting period despite the 854-DIS GWES remaining secured for upgrades. Except for one unusually high 14 µg/L detection in a July 2017 sample at extraction well W-854-2139, perchlorate concentrations have typically ranged from below reporting limits to a maximum of 8.6 µg/L at monitor well W-854-07 in December 2000. Concentrations remained within this range during 2022, with a maximum perchlorate concentration of 5.6 µg/L in well W-854-07 in October. In extraction well W-854-2139, the sole source of groundwater for the 854-DIS GWES, the 2022 maximum perchlorate concentration was 4.5 µg/L in January, less than the concentration detected in July 2017.

In the Building 858 drop tower area, perchlorate concentrations in well W-854-45 have ranged from 8.1 µg/L to 15 µg/L. The 2022 maximum concentration in this area was 11 µg/L in October at wells W-854-45, W-854-3306, and W-854-3307, which is similar to the 2021 maximum of 13 µg/L detected in well W-854-3306 in April. At recently installed monitor well W-854-3803, perchlorate concentrations in 2022 were similar to those in other monitor wells in the area and ranged from 8.7 µg/L in August to 3.6 µg/L in November.

2.6.3.1.3. Nitrate Concentrations and Distribution

Qls/Tnbs$_1$ HSU

The following general trends in groundwater nitrate concentrations were observed in the Qls/Tnbs$_1$ HSU:

- The maximum nitrate concentration in this HSU typically occurs in well W-854-14, where concentrations have historically ranged from 11 mg/L in May 2018 to 270 mg/L in May 2009, with an increase to a new maximum nitrate concentration of 460 mg/L by May 2022.
- During 2022, other Qls/Tnbs$_1$ HSU wells contained 8.1 mg/L to 58 mg/L of nitrate, with no apparent spatial trend.

During 2022, nitrate concentrations in the Qls/Tnbs$_1$ HSU in the 854-SRC and 854-PRX areas ranged from 8.1 mg/L in well W-854-15 to 58 mg/L in well W-854-05, slightly exceeding the 45 mg/L MCL cleanup standard. Nitrate concentrations in these areas are relatively stable, with no apparent spatial trend.

Nitrate is also present in the Building 854 drop tower area, in well W-854-14, where concentrations have ranged from 11 mg/L in May 2018 to 270 mg/L in May 2009.By May 2022, the maximum nitrate concentration in this well increased to 460 mg/L.

Tnbs$_1$/ Tnsc$_0$ HSU

The following general trends in groundwater nitrate concentrations were observed in the Tnbs$_1$/Tnsc$_0$ HSU:

- The historical maximum nitrate concentration of 180 mg/L occurred in 1996 in monitor well W-854-08. However, since 2002, nitrate concentrations in this well have ranged from 30 mg/L to 53 mg/L.
- Nitrate concentrations trends in this HSU remained stable in 2022.
- The 2022 spatial distribution of nitrate above the 45 mg/L MCL cleanup standard remained similar to what was observed in 2021.

In the 854-SRC area, four wells, W-854-02, W-854-08, W-854-2218, and W-854-2611, contained nitrate near or above the 45 mg/L MCL cleanup standard, with a 2022 maximum nitrate concentration of 55 mg/L in extraction well W-854-02 in July.

In the 854-PRX area, nitrate concentrations in extraction well W-854-03 have remained below the MCL cleanup standard since 2010. In 2022, the maximum concentration in this well was 43 mg/L in July. Concentrations in nearby monitor well W-854-3405 were higher, with a 2022 maximum of 47 mg/L in January. Concentrations in downgradient wells W-854-1823, W-854-3308, and W-854-3309 remained below the MCL, with a 2022 maximum of 30 mg/L in well W-854-1823 in May.

In the 854-DIS area, nitrate concentrations remained below the MCL cleanup standard, with a 2022 maximum of 21 mg/L in extraction well W-854-2139 in January.

At the Building 858 drop tower area, the 2022 maximum nitrate concentration in the $Tnbs_1/Tnsc_0$ HSU was 58 mg/L in well W-854-45 in May. Concentrations in this well have shown a steadily increasing trend from the 16 mg/L detected in 2004 to the present but appear to be possibly stabilizing near the current maximum. No other $Tnbs_1/Tnsc_0$ HSU wells in this area have sufficiently long histories for comparing nitrate concentration trends.

During 2022, wells W-854-3306 and W-854-3307 both contained 57 mg/L of nitrate in May, above the 45 mg/L MCL cleanup standard. W-854-3305, the third well installed in the area in 2017, did not contain nitrate above the 2 mg/L reporting limit when sampled in 2022. In recently installed monitor well W-854-3803, nitrate concentrations in 2022 ranged from 25 mg/L in August to 11 mg/L in November.

2.6.3.2. Remediation Optimization Evaluation

Table 2.5 lists O&M issues associated with the treatment facilities within the Building 854 OU. The table documents several periods of downtime at the 854-SRC GWTS in 2022. It remained secured from January 1 until March 14 for freeze protection and was also shut down for several days throughout the year due to power outages and control system issues as well as for sampling. As discussed in Section 2.6.1.1.1, the facility was also secured from August 25 to September 7 to replace a broken valve that resulted in a release of approximately 9,000 gal of partially treated groundwater. Finally, the 854-SRC GTWS was secured again on November 15 for freeze protection.

During 2022, the 854-SRC GWTS extracted and treated approximately 1.11 million gal of groundwater, an approximately 20 percent decrease in volume compared to 2021 as a result of extraction well W-854-2218 being secured for pump replacement from June 21 to October 3. The GWTS removed 91 g of VOCs, 5.1 g of perchlorate, and 196 kg of nitrate from extracted groundwater, which are an approximately 20 percent decrease in VOC and nitrate masses removed when compared to 2021. This result is another reflection of the lower volume of groundwater extracted from well W-854-2218. Meanwhile, the perchlorate mass removed remained similar to what was removed in 2021 and was not impacted by the downtime for well W-854-2218, as the perchlorate concentration in this well remains below the 2 µg/L reporting limit.

Similar to the GWTS, the 854-SRC SVTS was shut down for several days in 2022 due to power outages but otherwise ran consistently. The SVTS extracted approximately 16.1 million cf of soil vapor and removed 329 g of VOC mass. Despite consistently low VOC vapor concentrations, substantial VOC mass continues to be removed from the source area due to relatively high vapor flow rates of approximately 33 scfm. This VOC mass is volatilizing from residual TCE in the vadose zone beneath the Building 854 source area and from the dissolved VOC plume in $Tnbs_1/Tnsc_0$ HSU groundwater beneath the SVE well.

The 854-PRX GWTS was also shut down for several days in 2022 due to power outages and, from August 11 to October 3, was secured due to effluent nitrate concentrations exceeding the discharge limit. Amid these instances of downtime, the 854-PRX GWTS treated approximately 1.29 million gal of groundwater, an approximately 15 percent decrease from volumes treated in 2021, and 17 g of

VOCs, 6.1 g of perchlorate, and 198 kg of nitrate were removed from the extracted groundwater. The nitrate and VOC masses removed represent a decrease of approximately 15 percent and 45 percent, respectively, from masses removed in 2021, reflecting the lower volume extracted but also declining VOC concentrations in the 854-PRX area.

The mass of perchlorate removed from extracted groundwater varies from semester to semester, with the calculation being affected by the sampling dates relative to each extraction well's recent pumping history. When extraction well W-854-03 is not operating, concentrations are approximately 6 to 7 µg/L. After pumping for several days or weeks, the well appears to begin extracting cleaner water, effectively diluting perchlorate concentrations to below the reporting limit and resulting in calculations of "zero" mass removed. In 2015, this perceived "dilution" began having a noticeable effect on mass removal estimates when the facility was upgraded from bio-treatment units that were only capable of treating extracted water at rates less than 1.5 gpm. The current 854-PRX GWTS treats extracted water at a rate of 3 gpm.

The 854-DIS GWES remained secured during 2022 while engineering upgrades were made to the controls and data collection system; these upgrades are currently in progress.

2.6.3.3. Remedy Performance Issues

No new issues affected the performance of the cleanup remedy at the Building 854 OU.

Perchlorate concentrations remain above the 6 µg/L MCL cleanup standard in several areas of the OU. A work plan is being developed to implement an enhanced *in situ* bioremediation treatability study at one or more subareas. If implemented, an electron donor, most likely ethyl lactate, will be mixed with groundwater or treated effluent and injected to biotically reduce perchlorate concentrations. The work plan will be submitted for regulatory review.

The remedy at the Building 854 OU continues to be effective and protective of human health and the environment and to make progress toward cleanup.

2.7. Building 832 Canyon (OU 7)

From the late 1950s until 1985, facilities in the Building 830 and Building 832 areas, which together comprise the Building 832 Canyon OU, were used to test the stability of weapon components under various environmental conditions. During these tests and operational activities, contaminants were released from Buildings 830 and 832 through piping leaks and surface spills. To extract and treat these contaminants, three GWTSs, 832-SRC, 830-SRC, and 830-DISS, and two SVTSs, 832-SRC and 830-SR, currently operate in the Building 832 Canyon OU. Figure 2.7-1 is a map of the Building 832 Canyon OU showing the locations of monitor and extraction wells and treatment facilities.

The 832-SRC GWTS began operation in September 1999, removing VOCs, perchlorate, and nitrate from groundwater; the SVTS came online a month later in October, removing VOC mass from soil vapor. During 2022, wells W-832-01, W-832-10, and W-832-25, and W-832-3020 extracted groundwater for treatment while dual extraction wells W-832-12, W-832-15, and W-832-3019 extracted both groundwater and soil vapor for treatment. The average combined flow rate from all wells was less than 0.5 gpm for groundwater and approximately 4 to 5 scfm for soil vapor.

The current GWTS configuration consists of two ion-exchange resin columns connected in series to remove perchlorate and three aqueous-phase GAC vessels connected in series to remove VOCs. Nitrate-bearing treated effluent is then discharged via a misting tower onto the landscape for indigenous grasses to utilize. The SVTS currently employs a positive displacement rotary lobe blower to create a vacuum at selected wellheads through a system of piping manifolds. The contaminant-bearing vapors are treated using three vapor-phase GAC vessels connected in series prior to discharge to the atmosphere in compliance with a permit issued by the SJVAPCD.

The 830-SRC GWTS began operation in February 2003, removing VOCs, perchlorate, and nitrate from groundwater. In May 2003, the SVTS came online, removing VOCs from soil vapor. During 2022, wells W-830-19, W-830-57, W-830-59, W-830-60, W-830-2214, W-830-2215, and W-830-2701 extracted groundwater for treatment while dual extraction wells W-830-49 and W-830-1807 extracted both groundwater and soil vapor for treatment. When operating, these nine wells extract groundwater at a combined flow rate of approximately 8 to 12 gpm, and the two dual extraction wells extract soil vapor at a combined flow rate of approximately 12 to 14 scfm.

The current GWTS, which was redesigned in 2014 and restarted operations during the second semester of 2015, consists of two ion-exchange resin columns connected in series to remove perchlorate and three aqueous-phase GAC vessels connected in series to remove VOCs. A manifold located between the ion-exchange resin columns and the GAC vessels enables non-perchlorate-bearing influent to bypass perchlorate treatment. Nitrate-bearing treated effluent is discharged via a misting tower onto the landscape for indigenous grasses to utilize. The SVTS operates by creating a vacuum using a liquid-ring pump, which is connected to wells W-830-49 and W-830-1807. The VOC-bearing vapors are treated in three vapor-phase GAC vessels connected in series before being discharged to the atmosphere under a permit issued by the SJVAPCD.

The 830-DISS GWTS began operation in 2000, removing VOCs, perchlorate, and nitrate from groundwater. When this facility is operational, groundwater is extracted from wells W-830-51, W-830-52, and W-830-53 via natural artesian pressure at a flow rate of less than 1 gpm as well as well W-830-2216, which uses a pump. Together, these wells have a combined flow rate of approximately 3 gpm. Extracted groundwater flows through ion-exchange columns to remove perchlorate at the 830-DISS facility, and groundwater is piped to the CGSA GWTS for VOC removal. Nitrate-bearing treated effluent from the CGSA is then discharged via a misting tower onto the landscape for indigenous grasses to utilize.

2.7.1. Groundwater and Soil-Vapor Extraction and Treatment System Operations and Monitoring

2.7.1.1. Compliance Summary

During the reporting period, the 832-SRC GWTS, 830-SRC GWTS, and 830-DISS GWTS operated in compliance with the RWQCB substantive requirements for waste discharge and 832-SRC SVTS and 830-SRC SVTS operated in compliance with the SJVAPCD permit.

Appendix B contains the first semester 2023 treatment facility sampling and analysis plan for the Building 832 Canyon OU. This plan complies with the monitoring requirements in the 2009 CMP/CP, and no modifications were made to it for this reporting period.

2.7.1.2. Facility Performance Assessment and Operations and Maintenance Issues

The following tables and appendix summarize O&M issues and performance metrics for treatment facilities in the Building 832 Canyon OU:

- **Table 2.2**: Monthly volumes of groundwater and soil vapor extracted and discharged by treatment facilities in this OU for the second semester of 2022; this table also lists the operational hours of these facilities.
- **Table 2.3**: Monthly estimates of groundwater and soil vapor mass removal from this OU for the second semester of 2022.
- **Table 2.4**: Analytical results for influent and effluent samples collected from the treatment facilities during the second semester of 2022.
- **Table 2.5**: O&M issues encountered at facilities within this OU in 2022.
- **Table Summ-1**: The total volume of groundwater and soil vapor extracted and treated and total contaminant mass removed from this OU during the reporting period.
- **Table Summ-2**: Historical total volumes of groundwater and soil vapor treated and discharged and total contaminant mass removed from this OU.
- **Appendix A**: pH measurements.

2.7.1.3. Treatment Facility and Extraction Wellfield Modifications

As described in Table 2.5, the 832-SRC GWTS and SVTS were offline for most of the reporting period for freeze protection and maintenance. In June, the 832-SRC GWTS started operating, but the 832-SRC SVTS remained secured for system testing until the end of September. Both systems were secured once again for freeze protection on November 14 but are expected to restart in 2023.

During 2022, misting towers were used to discharge treated groundwater from all groundwater treatment facilities in the Building 832 Canyon OU. DOE/LLNL continues to evaluate long-term alternatives for the final disposition of treated effluent, including potential injection into existing wells. Groundwater will continue to be discharged at the misting towers until a final decision is made. Any proposed changes in the discharge method will be presented to the regulatory agencies for concurrence.

No treatment facility modifications were made at the 830-SRC GWTS and SVTS or the 830-DISS GWTS during 2022.

2.7.2. Groundwater and Surface Water Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring at the Building 832 Canyon OU. This table also explains deviations from the sampling plan and indicates any additions made to the CMP.

During 2022, groundwater monitoring was conducted in accordance with the CMP/CP monitoring requirements with the following exceptions:

- A total of 82 analyses from 27 different wells or springs were not performed because the locations were dry or there was insufficient water for sample collection.
- A total of four analyses for two different wells were not performed because of restricted access.

2.7.3. Remediation Progress Analysis

This section is organized into three subsections: analysis of contaminant distribution and concentration trends, remediation optimization evaluation, and remedy performance issues.

2.7.3.1. Contaminant Concentrations and Distribution

At the Building 832 Canyon OU, VOCs (predominantly TCE) are the primary COCs detected in groundwater, and perchlorate and nitrate are the secondary COCs. These constituents have been detected primarily in the Qal/WBR and $Tnsc_{1ab}$ HSUs, but VOCs and perchlorate have also been detected at relatively low concentrations in the $Tnbs_2$ and Upper $Tnbs_1$ HSUs.

The following subsections discuss concentrations and distributions of VOCs, HE compounds, perchlorate, and nitrate in this OU. These discussions are supported by the following figures:

- **Figure 2.7-5**: Map showing individual VOC concentrations for the Qal/WBR HSU.
- **Figures 2.7-6 and 2.7-7**: Total VOC isoconcentration contour map and individual VOC concentrations for the $Tnsc_{1ab}$ and Upper $Tnbs_1$ HSUs, respectively.
- **Figure 2.7-8**: Map showing perchlorate concentrations for the Qal/WBR HSU
- **Figure 2.7-9**: Perchlorate isoconcentration contour map for the $Tnsc_{1ab}$ HSU.
- **Figures 2.7-10 and 2.7-11**: Maps showing nitrate concentrations for the Qal/WBR and $Tnsc_{1ab}$ HSUs, respectively.

2.7.3.1.1. VOC Concentrations and Distribution in Groundwater

In the Building 832 area, TCE is the predominant VOC detected in groundwater. During 2022, *cis*-1,2-DCE; CFORM; Freon 11; and chloroethane were also present above their reporting limits. Of these VOCs, only TCE and *cis*-1,2-DCE were present at concentrations above their MCL cleanup standards of 5 µg/L and 6 µg/L, respectively.

In the Building 830 area, which includes the 830-SRC and 830-DISS areas, TCE is the predominant VOC detected in groundwater. During 2022, PCE; *cis*-1,2-DCE; *trans*-1,2-DCE; CFORM; 1,2-DCA; and Freon 11 were also detected above their reporting limits. Of these VOCs, only TCE and 1,2-DCA were present at concentrations above their MCL cleanup standards of 5 µg/L and 0.5 µg/L, respectively.

Qal/WBR HSU

The following general trends in groundwater VOC concentrations were observed in the Qal/WBR HSU:

- TVOC concentrations decreased from a 2003 historical maximum of 10,000 µg/L in 830-SRC monitor well SVI-830-035 to a 2022 maximum of 420 µg/L in the same well in February.
- VOC concentrations trends in this HSU largely remained stable or decreased slightly from 2021 to 2022, and the spatial distribution of VOC concentrations remained very similar to what was observed in 2021.

Since remediation in the Building 832 source area began in 1999, groundwater TVOC concentrations in Qal/WBR HSU wells have decreased from a 1998 historical maximum of 1,800 µg/L in well W-832-18 to a 2022 maximum of 180 µg/L in W-832-23 in September. The highest TVOC concentrations in this HSU are found in the 830-SRC area, where remediation began in 2000. Here, concentrations have decreased from a 2003 historical maximum of 10,000 µg/L in monitor well SVI-830-035 to a 2022 maximum of 420 µg/L in SVI-830-035 in February.

During 2022, several wells in the 830-DISS area were not sampled because they were dry when accessed. The only Qal/WBR HSU well that contained sufficient water for sampling was well W-880-02, where PCE was detected at concentrations of 0.5 µg/L in February and 0.54 µg/L in April, below the MCL cleanup standard of 5 µg/L. Confirmatory routine samples collected during the second semester of 2022 did not contain PCE above the 0.5 µg/L reporting limit.

PCE was previously detected in well W-880-02 in 2019 and more regularly before 2015. The two 2022 detections are within the historically observed range of 0.5 µg/L to 1 µg/L. When the HSU is more saturated and sufficient water is available for sampling, concentrations of TCE in 830-DISS area groundwater typically range from below the reporting limit in well W-880-02 to approximately 15 µg/L in W-832-3017. Between 2011 and 2018, VOC concentrations in the Qal/WBR HSU in this area were below their respective MCL cleanup standards.

$Tnbs_2$ HSU

In the $Tnbs_2$ HSU, groundwater TVOC concentrations decreased from a 2007 historical maximum of 20 µg/L in extraction well W-830-2216 to a 2022 maximum of 3.1 µg/L in the same well in April.

Well W-830-2216 has been extracting groundwater from the $Tnbs_2$ HSU since 2007. The COCs in this well can likely be attributed to releases from several source areas in the HEPA and Building 832 Canyon OUs. Although the $Tnbs_2$ HSU wells are technically located within the bounds of the Building 832 Canyon OU, the boundaries of the HEPA OU overlap the Building 832 Canyon OU boundaries in this area. Section 2.4 discusses the performance of these wells as well as the remedy for the entire $Tnbs_2$ HSU.

$Tnsc_{1ab}$ HSU

The following general trends in groundwater VOC concentrations were observed in the $Tnsc_{1ab}$ HSU:

- TVOC concentrations decreased from a 2003 historical maximum of 13,000 µg/L in well W-830-49 to a 2022 maximum of 2,305 µg/L in extraction well W-830-19 in April.
- In 2022, VOC concentrations in this HSU remained stable or decreased slightly in individual wells, and the spatial distribution of VOC concentrations remained very similar to what was observed in 2021.

Since remediation of the $Tnsc_{1ab}$ HSU began in 2000, TVOC concentrations in Building 832-SRC area groundwater have generally decreased from the 1998 (i.e., pre-2016) historical maximum of 1,700 µg/L in monitor well W-830-27. However, with the installation of well W-832-3019 in 2015, TVOC concentrations have ranged from 110 µg/L in April 2021 to 1,900 µg/L in August 2016, which is the historical maximum for TVOCs in 832-SRC area groundwater. The 2022 maximum TVOC concentration in W-832-3019 was 940 µg/L in August under non-pumping conditions. Concentrations of TVOCs measured in other $Tnsc_{1ab}$ HSU wells within the 832-SRC area were generally similar to concentrations documented during recent reporting periods.

The highest VOC concentrations in the $Tnsc_{1ab}$ HSU are found in the 830-SRC area, where remediation began in 2000. TVOC concentrations in groundwater at the Building 830-SRC area have decreased from a 2003 historical maximum of 13,000 µg/L in well W-830-49 to a 2022 maximum of 2,305 µg/L in W-830-19 in April. TVOC concentrations measured in other $Tnsc_{1ab}$ HSU wells in the 830-SRC area were generally similar to those observed in 2021.

In the 830-DISS area, TVOC concentrations in $Tnsc_{1ab}$ HSU wells decreased from a 2002 historical maximum of 170 µg/L in extraction well W-830-52 to a 2022 maximum of 29.5 µg/L in monitor well W-830-2311 in February.

Farther south along the Building 832 Canyon, the leading edge of the $Tnsc_{1ab}$ VOC plume continues to be contained within Site 300, as indicated by TVOC concentrations below the 0.5 µg/L reporting limits for individual compounds in guard wells W-880-03, W-830-1730, and W-4C.

Upper $Tnbs_1$ HSU

The following general trends in groundwater VOC concentrations were observed in the Upper $Tnbs_1$ HSU:

- TVOC concentrations decreased from a 1998 historical maximum of 100 µg/L in well W-830-28 to a 2022 maximum of 19.5 µg/L in monitor well W-830-60 in July.
- VOC concentration trends in this HSU increased slightly in a few wells but largely remained stable or decreased slightly from 2021 to 2022, and the spatial distribution of VOC concentrations remained very similar to what was observed in 2021.

At the Building 830-SRC area, well W-830-18, which serves as the performance monitor well for adjacent extraction well W-830-2215, exhibited an increasing TVOC concentration trend from 2006 through 2013 when well W-830-2215 was extracting groundwater. This trend has remained relatively stable since then to the present. Meanwhile, TVOC concentrations at well W-830-2215 have slightly increased from 2015, ranging from 15 µg/L in 2015 to 29 µg/L in 2018. This distribution indicates that the extraction well is once again capturing the highest VOC concentrations in the area after being idle for much of 2015 and 2016 to accommodate engineering upgrades and modifications.

In the Upper $Tnbs_1$ HSU in the downgradient area, VOC concentrations have not exceeded their reporting limits in guard wells W-830-15 and W-832-2112 since the wells were installed in 1995 and 2005, respectively.

Lower $Tnbs_1$ HSU

During 2022, VOCs have not been detected above reporting limits in any wells screened within the Lower $Tnbs_1$ HSU. Historically, the only Lower $Tnbs_1$ HSU well where VOCs have been detected in the Building 832 Canyon OU is W-830-29, with a historical maximum concentration of 1.8 µg/L in June 1999. However, VOCs have not been detected in this well above reporting limits since August 2009. No other Lower $Tnbs_1$ HSU wells in this OU have historically yielded VOCs in excess of reporting limits in any samples.

2.7.3.1.2. VOC Concentration and Distribution in Soil Vapor

Qal/WBR and $Tnsc_{1ab}$ HSUs

Currently, the Building 832 Canyon OU houses five vapor extraction wells. In the 832-SRC area, wells W-832-12 and W-832-15 are completed across both the Qal/WBR and $Tnsc_{1ab}$ HSUs and well W-832-3019 is completed in the $Tnsc_{1ab}$ HSU. In the 830-SRC area, well W-830-1807 is completed in the Qal/WBR HSU and well W-830-49 is completed in the $Tnsc_{1ab}$ HSU. Because of the close relationship between the $Tnsc_{1ab}$ and Qal/WBR HSUs, the VOC concentrations and distribution for both HSUs are described together in this section.

The following general trends in soil vapor VOC concentrations were observed in the Qal/WBR and $Tnsc_{1ab}$ HSUs:

- During 2022, the primary VOC detected above reporting limits in soil vapor was TCE. Additionally, 0.0051 $ppm_{v/v}$ (20 µg/m^3) of cis-1,2 DCE was detected in one sample from well W-832-15 in June, just above the reporting limit of 0.005 $ppm_{v/v}$ (20 µg/m^3).
- TVOC concentrations decreased from a 2007 historical maximum of 259 $ppm_{v/v}$ in dual extraction well W-830-49 to a 2022 maximum of 42 $ppm_{v/v}$ in W-830-3019 in April.
- Soil vapor samples from wells W-832-12 and W-832-15 have not yielded TVOC concentrations above 0.76 $ppm_{v/v}$ since 2011, including during rebound tests.
- VOC soil vapor concentration trends remained stable or decreased slightly in individual wells from 2021 to 2022, and the spatial distribution of VOC concentrations remained very similar to what was observed in 2021.

During the first semester of 2022, 832-SRC area well W-832-3019 was not sampled as its non-operational state caused water levels to rise above the screened interval. However, during the second semester of 2022, an initial sample taken during the startup of 832-SRC SVTS contained 42 $ppm_{v/v}$ (230,000 µg/m^3) of TCE, and a subsequent sample collected after a month of operation contained 2.9 $ppm_{v/v}$ (16,000 µg/m^3) of TCE. This result represents an expected concentration decrease after significant runtime of the facility.

Under non-operating conditions, TVOC concentrations in soil vapor at W-832-3019 have ranged from 5.1 $ppm_{v/v}$ in April 2021 to 140 $ppm_{v/v}$ in September 2021. Since 2011, neither dual extraction well W-832-12 or W-832-15 has yielded TVOC concentrations greater than 0.76 $ppm_{v/v}$, including during rebound testing. In 2022, soil vapor samples collected from wells W-832-12 and W-832-15 yielded maximum respective TVOC concentrations of 0.23 $ppm_{v/v}$, consisting entirely of TCE, and 0.72 $ppm_{v/v}$, comprised of TCE and cis-1,2 DCE.

At the 830-SRC area, soil vapor concentrations at dual extraction wells W-830-49 were similar to those observed in recent reporting periods. During 2022, TVOC concentrations consisting entirely of TCE ranged from 0.12 $ppm_{v/v}$ (640 µg/m^3) in W-830-1807 in February to 5.3 $ppm_{v/v}$ (28,000 µg/m^3) in W-830-49 in July.

2.7.3.1.3. HE Compound Concentrations and Distribution

Including in 2022, HE compounds have never been detected in groundwater in any Building 832 Canyon OU well. The HE compound HMX is a COC in surface and subsurface soil in the 832-SRC area of the Building 832 Canyon OU.

2.7.3.1.4. Perchlorate Concentrations and Distribution

Qal/WBR HSU

The following general trends in perchlorate concentrations were observed in the Qal/WBR HSU:

- Perchlorate concentrations have decreased from a 1998 historical maximum of 51 µg/L in monitor well W-830-13 to a 2022 maximum of 14 µg/L in monitor well W-832-18 in February.
- Perchlorate has only been detected above the typical 4 µg/L reporting limit in a few wells in this HSU of the Building 832 Canyon OU.

In the 832-SRC area of the Qal/WBR HSU, perchlorate concentrations in groundwater ranged from 2.4 µg/L in well W-832-12 in August to 14 µg/L in well W-832-18 in February. Wells W-832-12 and W-832-15 have historically contained perchlorate at maximum concentrations of 9 mg/L in 2004 and 15 µg/L in 2006, respectively.

In the 830-SRC area, the only detections of perchlorate in the Qal/WBR HSU during the reporting period were in wells SVI-830-031 and SVI-830-035, with 2022 maximum concentrations of 2.1 µg/L and 2 µg/L, respectively. In the 830-DISS area, perchlorate was not detected above the 2 µg/L reporting limit in Qal/WBR HSU wells, including guard wells W-35B-01 and W-880-02.

$Tnbs_2$ HSU

Perchlorate observed in $Tnbs_2$ HSU wells in the Building 832 Canyon OU represents an extension of the downgradient portion of the perchlorate plume originating in the HEPA OU. During 2022, perchlorate concentrations in the $Tnbs_2$ HSU ranged from 2.4 µg/L in well W-870-02 in February to 3.2 µg/L in well W-830-17 in January. While $Tnbs_2$ HSU wells are technically located within the bounds of the Building 832 Canyon OU, the boundaries of the HEPA OU overlap the Building 832 Canyon OU in this area. Section 2.4 discusses the performance of these wells as well as the remedy for the entire $Tnbs_2$ HSU.

$Tnsc_{1ab}$ HSU

The following general trends in perchlorate concentrations were observed in the $Tnsc_{1ab}$ HSU:

- Perchlorate concentrations decreased from a 2017 historical maximum of 38 µg/L in dual extraction well W-832-3019 to a 2022 maximum of 14 µg/L in monitor well W-832-18 in February.
- Perchlorate concentration trends in this HSU remained stable in individual wells from 2021 to 2022, and the spatial distribution of perchlorate concentrations remained very similar to what was observed in 2021, even with new detections identified as a result of the lowered reporting limit.

Within the $Tnsc_{1ab}$ HSU in the Building 830 and 832 source areas and in the entire OU, the historical maximum perchlorate concentration of 38 µg/L was detected in well W-832-3019 in February 2017. Prior to this elevated concentration, perchlorate in well W-832-3019 had fluctuated between 8.3 µg/L and 18 µg/L. Concentrations in samples from August and December 2017 were both 13 µg/L, and the 2018 maximum concentration in this well was also 13 µg/L. The 2019, 2020, 2021, and 2022 maxima of 13 µg/L, 11 µg/L, 10 µg/L, and 12µg/L, respectively, suggest that the 38 µg/L result from February 2017 is atypical of perchlorate concentrations in this well, although higher concentrations are possible nearby in the same HSU.

Baseline sampling at monitor well W-830-3601 yielded 17 µg/L of perchlorate in October 2020. Located to the west of the 830-SRC area, this well helps delineate the extent of the $Tnsc_{1ab}$ perchlorate plume along its western edge between monitor wells W-832-3304 and W-830-2806, where perchlorate has not been detected above reporting limits. Subsequent sampling of W-830-3601 during 2021 and 2022 did not yield perchlorate above the 2 µg/L reporting limit. Concentrations at this well will continue to be monitored closely. The spatial distribution of perchlorate concentrations in the 832-SRC and 830-SRC areas remained very similar between 2022 and 2021, even with the additional detections that arise with the more recent 2 µg/L reporting limit.

In the 830-DISS area, perchlorate concentrations were below reporting limits, except in artesian extraction wells W-830-51, W-830-52, and W-830-53 and nearby monitor well W-830-2311 where concentrations ranged from 3.9 µg/L to 4.9 µg/L. These results are comparable with previous data, and the distribution is similar to those of previous reporting periods. Including in 2022, perchlorate has never been detected above the historical 4 µg/L or current 2 µg/L reporting limits in $Tnsc_{1ab}$ HSU guard wells W-830-1730 and W-4C.

Upper $Tnbs_1$ HSU

Including in 2022, perchlorate concentrations in the Upper $Tnbs_1$ HSU have not exceeded the historical 4 µg/L or current 2 µg/L reporting limits since 2005, except for several concentrations that appear spurious.

Lower $Tnbs_1$ HSU

Including in 2022, perchlorate concentrations in the Lower $Tnbs_1$ HSU have not exceeded the historical 4 µg/L or current 2 µg/L reporting limits.

2.7.3.1.5. Nitrate Concentrations and Distribution

During 2022, maximum nitrate concentrations in groundwater remained high both in the vicinity of the Building 832 and Building 830 source areas and in the shallow Qal/WBR HSU. Concentrations were low or below the 0.5 mg/L reporting limit in the downgradient, deeper portions of all Building 832 Canyon HSUs. Spatial and temporal nitrate concentration trends in all HSUs in this OU continue to support the interpretation that nitrate is naturally attenuating in the groundwater.

Qal/WBR HSU

The following general trend in nitrate concentrations were observed in the Qal/WBR HSU:

- Nitrate concentrations have decreased from a 2008 historical maximum of 240 mg/L in monitor well SVI-830-033 to a 2022 maximum of 130 mg/L in monitor well W-830-19 in January and July.

During 2022, nitrate concentrations in wells screened in the Qal/WBR HSU in all areas ranged from a maximum of 130 mg/L in monitor well W-832-19 to 1.1 mg/L in 830-DISS guard well W-880-02 in March. Generally, concentrations followed a decreasing trend downgradient from the 832-SRC area to the 830-DISS area.

During 2022, nitrate concentrations remained below 1 mg/L in guard well W-35B-0 and remained very low in guard well W-880-02 with a maximum concentration of 2.8 mg/L in February; both wells are located near the Site 300 boundary.

$Tnsc_{1ab}$ HSU

The following general trends in nitrate concentrations were observed in the $Tnsc_{1ab}$ HSU:

- Nitrate concentrations have decreased from a 1998 historical maximum of 440 mg/L in extraction well W-830-49 to a 2022 maximum of 130 mg/L in monitor wells W-830-19 in January, W-832-19 in February, W-832-3019 in August, and W-832-3303 in February.

During 2022, nitrate concentrations in this HSU generally remained moderate to high, but stable, ranging from below variable reporting limits of 0.5 mg/L to 2 mg/L to a maximum of 130 mg/L near the Buildings 830 and 832 source areas. Nitrate concentrations continue to exhibit a significant decreasing trend in the downgradient direction toward the Site 300 boundary, where confined hydraulic conditions conducive to *in situ* microbial denitrification exist. Since 2011, nitrate concentrations in downgradient $Tnsc_{1ab}$ HSU guard wells W-830-1730 and W-4C have generally been below the historical reporting limits of 0.1 mg/L and 0.5 mg/L and never exceeded the 3.1 mg/L detected in well W-830-1730 in 2013. Together, these data support the interpretation that nitrate continues to naturally attenuate within the OU.

Upper $Tnbs_1$ HSU

The following general trends in nitrate concentrations were observed in the Upper $Tnbs_1$ HSU:

- Nitrate concentrations have decreased from a 2018 historical maximum of 27 mg/L in monitor well W-830-3409 to a 2022 maximum of 24 mg/L in the same well in January.
- Nitrate concentrations in other Upper $Tnbs_1$ HSU locations were all below 11 mg/L.

During 2022, nitrate concentrations remained low in guard well W-830-15, with a 2022 maximum concentration of 5.7 mg/L in January. Concentrations at this location have varied from below reporting limits to a maximum of 8.7 mg/L in 2004. At new monitor well W-832-3602, 7.3 mg/L of nitrate was detected in the baseline sample collected in August 2020. The 2022 maximum concentration of 11 mg/L was detected in May representing the highest concentration in the HSU other than the 24 mg/L detected in W-830-3409 in February. During 2022, nitrate concentrations in all monitor wells remained below the 45 mg/L MCL cleanup standard.

The very low nitrate concentrations in the downgradient areas and the absence of detectable nitrate in the southern Site 300 boundary guard wells are consistent with the interpretation that nitrate is naturally attenuating due to *in situ* microbial denitrification in the Upper $Tnbs_1$ and other Neroly Formation bedrock HSUs.

Lower $Tnbs_1$ HSU

Including in 2022, nitrate concentrations in the Lower $Tnbs_1$ HSU have not exceeded the highest historical reporting limit of 4 mg/L since 1994, except for two instances. Well W-832-09 contained 44 mg/L of nitrate in a 1994 baseline sample, which is likely a result of sampling or analytical issues or poor well development. Nitrate concentrations in groundwater samples collected from this location since then have not exceeded reporting limits. W-830-29 also yielded 18 mg/L of nitrate in 2013, although concentrations in other samples collected from this location have not exceeded reporting limits.

2.7.3.2. Remediation Optimization Evaluation

Despite the recent shutdown of several GWTSs and SVTSs, data indicate that, overall, the remedy in the Building 832 Canyon OU is making progress in preventing off-Site 300 plume migration, reducing source area contaminant concentrations, and removing contaminant mass. However, hydraulic capture remains difficult to assess in areas where wells cannot maintain continuous pumping. The low well yields are caused by water-bearing geologic materials with low hydraulic conductivity combined with the effects of dewatering, which results from ongoing groundwater extraction amid limited recharge.

In the Qal/WBR and $Tnsc_{1ab}$ HSUs, the extraction wellfields target the highest VOC plume concentrations emanating from the Building 832 and Building 830 source areas. However, steep terrain and unstable canyon bottom soil conditions limit the availability of sites where new wells can be drilled. In recent years, groundwater extraction has been further constrained by limited recharge and declining water levels in both source areas.

In the $Tnbs_2$ HSU, remediation continues via extraction well W-830-2216, which has resumed consistent operation following recent engineering upgrades made at the CGSA GWTS. The contamination in this area likely arises from a combination of sources located in both the HEPA and Building 832 Canyon OUs. Decreasing VOC concentration trends in this extraction well and nearby monitor well W-830-13 suggest that remediation has been effective in removing mass in this area.

Active remediation of the $Tnsc_{1ab}$ HSU began in 2000, and the extraction wellfield currently consists of 10 groundwater extraction wells and five dual extraction wells. Water levels continue to decline in both the 830-SRC and 832-SRC areas, limiting continuous extraction from the $Tnsc_{1b}$ and $Tnsc_{1a}$ stratigraphic intervals that comprise the $Tnsc_{1ab}$ HSU. However, to increase operational time and mass removal, upgrades have been made to existing 832-SRC extraction wells. Additionally, groundwater extraction well W-832-2020 and dual extraction well W-832-3019 were connected to 832-SRC. The 832-SRC GWTS resumed full operation during 2022.

Extraction wells in the Upper $Tnbs_1$ HSU target areas with the highest TVOC concentrations. Since remediation began in this HSU, the overall extent of VOCs has decreased significantly, and concentrations in monitor well W-830-1832 have been below reporting limits since March 2010. Groundwater in Upper $Tnbs_1$ HSU guard wells W-830-15 and W-832-2112, located downgradient of well W-830-1832 and upgradient of water-supply Well 20, continues to exhibit concentrations below reporting limits for all COCs except nitrate, the concentrations of which were significantly below the 45 mg/L MCL cleanup standard.

2.7.3.2.1. Mass Removal

In the Building 832-SRC area, COC concentration trends in extraction wells have remained stable for several years as a result of declining water levels and low yields limiting groundwater extraction. During 2022, the 832-SRC GWTS and SVTS were secured from January 1 to June 1 for freeze protection and maintenance. From June 1 through September 26, the 832-SRC GWTS operated without dual extraction wells W-832-12, W-832-15, and W-832-3019 to accommodate additional testing on the 832-SRC SVTS. From September 26 through November 15, both the GWTS and SVTS operated with all wells until being secured for freeze protection.

During 2022, approximately 31,000 gal of groundwater and 187,000 cf of soil vapor were extracted and treated at the 832-SRC GWTS and SVTS, respectively. A total of 17 g of VOCs, 0.4 g of perchlorate, and 13 kg of nitrate were removed from groundwater while 119 g of VOCs were removed from soil vapor. Once these systems resume operation with all wells in 2023, increased mass removal rates in both soil vapor and groundwater can be expected in this area. The data-acquisition capabilities added as part of the recently completed upgrades will also provide the data needed to better optimize mass removal from existing wells in this area.

The 830-SRC GWTS and SVTS were secured from January 1 to April 6 and from November 10 through the end of the reporting period for freeze protection and otherwise remained in operation, aside from the instances described in Table 2.5. In total, 1.25 million gal of groundwater and 1.71 million cf of soil vapor were treated during 2022, roughly equal to the 1.24 million gal of groundwater and 1.54 million cf of soil vapor treated in 2021, with similar facility runtimes. During 2022, a total of 413 g of VOCs, 1.5g of perchlorate, and 64 kg of nitrate were removed from groundwater and 384 g of VOCs were removed from soil vapor, compared to the 427 g of VOCs, 1.3 g of perchlorate, and 49 kg of nitrate were removed from groundwater and 316 kg of VOC mass removed from soil vapor in 2021. Overall, the mass removal at 830-SRC GWTS and SVTS in 2022 was within the historical range for periods of similar operational time, with variations mostly due to small differences in COC concentrations between time periods.

To increase operational uptime and the efficacy of the effluent discharge process, operational maintenance and engineering upgrades are planned for the misting towers. As noted in Section 2.7.1.3, DOE/LLNL continues to evaluate long-term alternatives for the final disposition of treated effluent, including injection into wells. Until a final decision is made on the disposition of treated effluent, groundwater will be discharged at the misting towers. Any proposed changes to discharge methods for treated effluent will be presented to the regulatory agencies for concurrence.

The 830-DISS GWTS was secured for most of first semester due to freeze protection and maintenance issues at the CGSA GWTS and from November 7 to the end of the reporting period for freeze protection. When operational, the facility operated with only two extraction wells, W-830-2216 and W-830-51, as wells W-830-52 and W-830-53 did not contain sufficient hydraulic head to flow freely at the surface. Regardless, during 2022, approximately 373,000 gal of groundwater were extracted and treated and 4 g of VOCs, 3.4 g of perchlorate, and 87 kg of nitrate were removed. These numbers are expected to increase during 2023, when operational runtimes of both the CGSA GWTS and 830-DISS GWTS are expected to return to normal following freeze protection.

As remediation proceeds at the 832-SRC, 830-SRC, and 830-DISS areas, water levels and potentiometric surfaces in all Building 832 Canyon HSUs are expected to continue to decline. The anticipated long-term decline in water levels will impact the long-term performance of extraction wells. VOC concentration trends in the Upper $Tnbs_1$ HSU continue to be monitored closely, given that changes to the pumping schedules of water-supply Well 20 and backup water-supply Well 18 have the potential to hydraulically influence the vertical distribution of contaminants.

2.7.3.3. Remedy Performance Issues

During this reporting period, no new issues were identified that could impact the long-term performance of the cleanup remedy for the Building 832 Canyon OU. The remedy continues to make progress toward cleanup and be protective of human health and the environment.

2.8. Site 300 Site Wide (OU 8)

2.8.1. Building 801 and Pit 8 Landfill

The Building 801 firing table was used for explosives testing. Debris from the firing table was buried nearby in the Pit 8 landfill until 1974. In 1998, testing at the firing table was discontinued, and the gravel and some underlying soil were removed and disposed of at the Nevada Test Site (now known as Nevada National Security Site). Waste fluid discharges to the Building 801D dry well from the late 1950s to 1984 resulted in VOC contamination in soil and groundwater.

Figure 2.8-1 is a map of the Building 801/Pit 8 landfill subarea showing the locations of the buildings, firing table, landfill, and monitor wells.

2.8.1.1. Groundwater Monitoring

Eight wells, K8-01, K8-02B, K8-03B, K8-04, K8-05, W-PIT8-3201, W-PIT8-3202, and W-PIT8-3203, monitor groundwater in the $Tnbs_1/Tnbs_0$ HSU for contaminants that may have been released from the Building 801 firing table and facilities or the Building 801D dry well. Wells K8-02B, K8-04, K8-05, W-PIT8-3201, W-PIT8-3202, and W-PIT8-3203 also monitor for potential chemical releases from the Pit 8 landfill, as discussed in Section 3.4.

Wells in the Building 801/Pit 8 landfill subarea are scheduled for sampling and analysis primarily during the second quarter of the calendar year. Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring in this subarea. This table also explains deviations from the plan and indicates any additions made to the CMP. During 2022, all CMP/CP monitoring requirements were met for the Building 801/Pit 8 landfill subarea except for five analyses from well K8-03B during the first semester, which were not performed because the well was inaccessible.

2.8.1.2. Contaminant Concentrations and Distribution

At the Building 801/Pit 8 subarea, the VOCs CFORM, 1,2-DCA, and TCE are the primary COCs detected in groundwater, and perchlorate and nitrate are the secondary COCs. No COCs in groundwater are attributable to the Pit 8 landfill.

The eight monitor wells in the subarea are screened in the $Tnbs_1/Tnbs_0$ HSU. Well K8-05, which is scheduled to be sampled during odd years, has been dry since it was installed in 1988.

In addition to relevant features, Figure 2.8-1 shows groundwater elevations and COC concentrations in the Building 801/Pit 8 landfill subarea for 2022. The following general trends in primary and secondary COC concentrations were observed in the $Tnbs_1/Tnbs_0$ HSU:

- **TVOC**: TVOC concentrations decreased from a 1990 historical maximum of 10 µg/L in well K8-01 to a 2022 maximum of 3.5 µg/L in a duplicate sample from the same well in June.

- **TCE**: TCE concentrations decreased from a 1992 historical maximum of 6.0 µg/L in well K8-01 to a 2022 maximum of 2.9 µg/L in the routine sample in June and the duplicate sample in November, both also in K8-01.
- **1,2-DCA**: 1,2-DCA concentrations decreased from a 1990 historical maximum of 5.0 µg/L in well K8-01 to a 2022 maximum of 1.1 µg/L in a duplicate sample from the same well in June.
- **CFORM**: The historical maximum CFORM concentration of 2.4 µg/L was detected in 1992 in well K8-01. Since 2008, CFORM has remained below the 0.5 µg/L reporting limit in all subarea wells, including in 2022.
- **Perchlorate**: Perchlorate concentrations decreased from a 2003 historical maximum of 5.0 µg/L in well K8-04 to a 2022 maximum of 4 µg/L in the same well in June and November.
- **Nitrate**: Nitrate concentrations decreased from a 2015 historical maximum of 80 mg/L in well K8-04 to a 2022 maximum of 74 mg/L in the same well in June.

As was the case in 2021, in the subarea, the 2022 maximum TVOC concentration of 3.5 µg/L was observed in well K8-01, comprised of 2.4 µg/L of TCE and 1.1 µg/L of 1,2-DCA in a duplicate sample and 2.9 µg/L of TCE and less than 0.5 µg/L of 1,2-DCA in a routine sample. These concentrations are well within ranges observed since 1990.

Of the groundwater COCs, only 1,2-DCA was detected above its 0.5 µg/L MCL cleanup standard and reporting limit during 2022. These detections occurred in two wells in June:

- **K8-01**: 1.1 µg/L in a routine sample.
- **K8-04:** 0.95 µg/L and 0.96 µg/L in duplicate and routine samples, respectively.

Otherwise, 1,2-DCA was not detected above the 0.5 µg/L reporting limit in samples from the remaining wells, including W-PIT8-3203, which yielded 0.72 µg/L of 1,2-DCA in August 2016.

During 2022, TCE was not detected above its 5 µg/L MCL cleanup standard, and CFORM was not detected above its 0.5 µg/L reporting limit in any samples taken from the Building 801/Pit 8 landfill monitor wells. Overall, TVOC concentrations detected in groundwater samples collected from wells downgradient of Building 801 have decreased since 1990.

The spatial extent of the VOCs TCE and 1,2-DCA has generally remained unchanged. The presence of VOC maxima in well K8-01 (located immediately downgradient of Building 801 and upgradient of the Pit 8 landfill) and lower concentrations observed intermittently in well K8-04 (located immediately downgradient of the Pit 8 landfill) define a continuation of the VOC plume originating at the Building 801D dry well. Thus, this plume does not originate from the Pit 8 landfill.

In 2022, perchlorate was detected but did not exceed the 6 µg/L MCL cleanup standard in the following four subarea wells:

- **K8-04**: 3.8 µg/L and 4 µg/L in routine and duplicate samples, respectively, in June and 4 µg/L in November.
- **W-PIT8-3203**: 3.1 µg/L and 2.9 µg/L in November and June, respectively.
- **K8-01**: 2.5 µg/L and 2.4 µg/L in routine and duplicate samples, respectively, in June and 2.4 µg/L in November.

- **K8-02B**: 2 µg/L in March. Routine and duplicate samples in June, August, and November did not exceed the perchlorate laboratory reporting limit of 2 µg/L, lowered from 4 µg/L in 2021.

In 2021, perchlorate was detected in two wells, K8-04 and K8-01. A routine sample from K8-04 yielded 7.1 µg/L, which represents the historical maximum and the first time perchlorate concentrations ever exceeded the 6 µg/L MCL cleanup standard in subarea wells. However, a duplicate sample from the same well was analyzed by a different laboratory and yielded 4 µg/L of perchlorate, indicating that the 7.1 µg/L concentration may be anomalous. In K8-01, perchlorate was detected at 2.6 µg/L and 2.0 µg/L in December duplicate and routine samples, respectively. Prior to December 2021, concentrations had never exceeded the MCL cleanup standard in subarea wells. Perchlorate concentrations will continue to be closely monitored in well K8-04 and other wells for future trends.

The 2022 maximum nitrate concentration was 74 mg/L in both the routine and duplicate samples collected from well K8-04 in June. Since 2004, concentrations in this well have ranged from 51 mg/L to 80 mg/L, with the historical maximum nitrate concentration of 80 mg/L detected in 2015.

Nitrate was also detected slightly above the 45 mg/L MCL cleanup standard in two other wells:

- **W-PIT8-3203**: 59 mg/L and 56 mg/L in June and November, respectively.
- **K8-01**: 50 mg/L in a duplicate sample taken from well K8-01 in June, with the routine sample yielding 35 mg/L.

Concentrations in these wells are consistent with previous results, which have, since 2016, ranged from 36 mg/L to 50 mg/L in well K8-01 and from 46 mg/L to 61 mg/L in well W-PIT8-3203.

Nitrate concentrations in other Building 801/Pit 8 landfill subarea wells did not exceed the 45 mg/L MCL cleanup standard during 2022, and concentrations detected in subarea groundwater were generally similar to those observed in previous years. Nitrate and 1,2-DCA are the only COCs with concentrations currently above their MCL cleanup standards in the subarea.

2.8.2. Building 833

From 1959 to 1982, TCE was used as a heat-exchange fluid at Building 833 and was released by spills and rinse-water disposal, thus contaminating soil and shallow perched groundwater. Figure 2.8-2 is a map of the Building 833 subarea showing the locations of the building and monitor wells.

2.8.2.1. Groundwater Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring in the Building 833 subarea. This table also explains deviations from the plan and indicates any additions made to the CMP.

Because all CMP/CP monitoring requirements for this subarea are scheduled during the first semester of 2022, monitoring was not performed during the second semester. During the first semester, groundwater monitoring was conducted in accordance with monitoring requirements for two wells. Eight scheduled analyses from eight wells in the Tpsg HSU were not conducted, because the wells were dry. These dry wells have generally contained insufficient or no groundwater for sampling since 1993.

2.8.2.2. Contaminant Concentrations and Distribution

At Building 833, the VOCs TCE and *cis*-1,2-DCE are the primary COCs in shallow, perched groundwater. There are no secondary COCs. The Tpsg HSU is an ephemeral, perched water-bearing zone equivalent to the contaminated HSU in the Building 834 OU, and during heavy rainfall events, this HSU can become saturated. From 1993 to present, quarterly monitoring in the Building 833 subarea has shown variable levels of saturation, including in many wells that are now dry (W-833-03, W-833-12, W-833-18, W-833-22, W-833-28, W-833-33, W-833-34, and W-833-43). Monitoring conducted since 1988 has shown that, when saturated, Tpsg HSU groundwater experiences a significant decline in VOC concentrations compared to the highest concentrations, which were observed in the early 1990s.

In the Building 833 subarea, wells are screened in the following HSUs:

- Eight monitor wells in the Tpsg HSU.
- One well, W-841-01, screened in the Upper $Tnbs_1$ HSU.
- Two wells, W-833-30 and W-840-01, screened in the Lower $Tnbs_1$ HSU.

As mentioned in Section 2.8.2.1, only two wells had sufficient water available for sampling during 2022: Lower $Tnbs_1$ HSU well W-833-30, which is scheduled for sampling in odd years, and Upper $Tnbs_1$ HSU well W-841-01. Both wells yielded concentrations below the 0.5 µg/L individual VOC laboratory reporting limit. In addition to relevant features, Figure 2.8-2 shows groundwater elevations and COC concentrations in the Building 833 subarea for 2022.

2.8.3. Building 845 Firing Table and Pit 9 Landfill

From 1958 until 1963, the Building 845 firing table was used to conduct explosives experiments, and, until 1968, the Pit 9 landfill was used to dispose of approximately 4,400 yd^3 of firing table debris (Lamarre and Taffet 1989). Leaching from the debris slightly contaminated subsurface soil with depleted uranium and HMX. In 1988, firing table gravel and soil from a berm at the firing table were removed and disposed of in the Pit 1 landfill.

Figure 2.8-3 is a map of the Building 845 firing table/Pit 9 landfill subarea showing the locations of the building, landfill, and monitor wells.

2.8.3.1. Groundwater Monitoring

No groundwater COCs have been identified in the Building 845 firing table/Pit 9 Landfill subarea. Seven wells screened in the $Tnbs_1$/$Tnbs_0$ HSU, K9-01, K9-01-02, K9-01-03, K9-01-04, W-PIT9-3204, W-PIT9-3205, and W-PIT9-3206, monitor groundwater to detect any potential future releases from the Pit 9 landfills as well as potential impacts that subsurface soil COCs HMX and uranium may have on groundwater. Section 3.5 discusses detection monitoring of the Pit 9 landfill.

Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring in the Building 845 firing table/Pit 9 landfill subarea. This table also explains deviations from the plan and indicates any additions made to the CMP.

Because all CMP/CP monitoring requirements for this subarea are scheduled during the first semester of 2022, monitoring was not performed during the second semester. During the first semester, groundwater monitoring was conducted in accordance with monitoring requirements for five wells, K9-01, K9-02, K9-03, K9-04, and W-PIT9-3204, of the total seven wells in this subarea. Samples could not be collected from wells W-PIT9-3205 and W-PIT9-3206 for 16 scheduled analyses, because these wells were inaccessible.

2.8.3.2. Contaminant Concentrations and Distribution

In the Building 845 firing table/Pit 9 landfill subarea, seven landfill detection monitor wells are screened in the $Tnbs_1/Tnbs_0$ HSU. During the first semester of 2022, samples from wells K9-01, K9-02, K9-03, K9-04, and W-PIT9-3204 were collected and analyzed for detection monitoring constituents (VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, Title 22 metals, lithium, and fluoride), as scheduled. In 2022, concentrations and activity concentrations of the detection monitoring constituents were either below reporting limits or within the range of background.

Because HMX and uranium were identified as COCs in the subsurface soil in the Building 845 firing table/Pit 9 landfill subarea, groundwater in this subarea is also monitored for these constituents. During the first semester of 2022, HMX concentrations in groundwater samples remained below the 1 µg/L reporting limit. HMX has not been detected above its reporting limit since 1989, when the first monitor wells were installed in the subarea. During the first semester, five of the seven wells in the subarea were sampled for mass spectrometric analysis of uranium isotopes. Total uranium activity concentrations in groundwater from all five wells remained below 0.37 pCi/L, well below both the 20 pCi/L MCL cleanup standard for total uranium and background levels. The $^{235}U/^{238}U$ atom ratio, as determined by mass spectrometry, where quantifiable, indicated the presence of only natural uranium in the five sampled wells.

In addition to relevant features, Figure 2.8-3 shows groundwater elevations and COC concentrations in the Building 845 firing table/Pit 9 landfill subarea for 2022. Section 3.5 presents the results of detection monitoring of the Pit 9 landfill.

2.8.4. Building 851 Firing Table

The Building 851 firing table has been used since 1962 to conduct explosives experiments. Former experiments conducted prior to 2008 resulted in the release of uranium-238 including depleted uranium to groundwater. Figure 2.8-4 is a map of the Building 851 subarea showing the locations of the firing table and monitor wells.

2.8.4.1. Groundwater Monitoring

Appendix C contains the 2022 sampling and analysis plan for groundwater and surface water monitoring in the Building 851 firing table subarea. This table also explains deviations from the plan and indicates any additions made to the CMP.

During the second semester of 2022 and the entire year, groundwater monitoring was conducted in accordance with the CMP/CP monitoring requirements for all six wells in this subarea.

2.8.4.2. Contaminant Concentrations and Distribution

In the Building 851 firing table subarea, six monitor wells, W-851-05, W-851-06, W-851-07, W-851-08, W-851-3207, and W-851-3208 are screened in the Tmss HSU. Uranium is the primary and only COC detected in groundwater. There are no secondary COCs. Uranium is considered a groundwater COC, because historical mass spectrometric analysis previously confirmed the presence of some depleted uranium in groundwater samples.

In this subarea, uranium activity concentrations in Tmss HSU groundwater have always been well below the 20 pCi/L MCL cleanup standard and within the range of background. Although background uranium activity concentrations at Site 300 may vary in relation to groundwater age, major-ion chemistry, and aquifer lithology, single-digit uranium activity concentrations are clearly within the range of Site 300 background. However, groundwater continues to be monitored to detect any impacts from depleted uranium in surface and subsurface soil and rock.

In addition to relevant features, Figure 2.8-4 shows groundwater elevations and uranium activity concentrations in the Building 851 firing table subarea for 2022. In the Tmss HSU, uranium activity concentrations have decreased from a 2016 historical maximum of 7.9 pCi/L in well W-851-3207 to a 2022 maximum of 1.9 pCi/L in the same well in June, which is similar to or lower than ranges observed in this well since 2018 (between 1.9 pCi/L and 3.9 pCi/L). Uranium activity concentrations have decreased over time, remaining relatively stable since 1998.

The 2022 maximum total uranium activity concentration of 1.9 pCi/L in well W-851-3207 was associated with a $^{235}U/^{238}U$ atom ratio, as measured by mass spectrometry, which indicates a natural source of uranium as has historically been the case. The following wells also yielded total uranium activity concentrations above the laboratory reporting limit during the reporting period:

- **W-851-08**: 1.2 pCi/L in June.
- **W-851-3208**: 0.31 pCi/L in June.
- **W-851-07**: 0.16 pCi/L in June.
- **W-851-06**: 0.017 pCi/L in June.
- **W-851-05**: 0.0067 pCi/L in June.

The uranium detections in wells W-851-08, W-851-3208, W-851-07, and W-851-05 were accompanied by $^{235}U/^{238}U$ atom ratios indicating a natural source of uranium. However, the sample from well W-851-06 yielded a $^{235}U/^{238}U$ atom ratio of 0.00561, indicating a slightly depleted uranium content, albeit at very low activity concentrations. The maximum total uranium activity concentration in this well of 0.99 pCi/L was detected in December 1998. Since 2010, the uranium activity concentration in the well has never exceeded 0.16 pCi/L.

Typically, $^{235}U/^{238}U$ atom ratios for some groundwater samples from the Building 851 firing table subarea cannot be quantified due to low ^{235}U concentrations that are often below mass spectrometry reporting limits. In this report, these $^{235}U/^{238}U$ atom ratios are quantified as "<" values due to the "<" value in the numerator. For strict correctness, these ratios should be reported as non-quantifiable (NQ). DOE/LLNL will correct the reporting of these $^{235}U/^{238}U$ atom ratios in the near future. Overall, uranium activity concentrations in groundwater during the reporting period are similar to those observed in previous years and remain well below the 20 pCi/L MCL cleanup standard.

During 2022, discretionary groundwater samples were collected from all seven monitor wells in the subarea and analyzed for VOCs, nitrate, perchlorate, metals, and HE compounds. No VOCs were detected above their 0.5 µg/L individual compound reporting limits in any samples collected during the reporting period, as has been the case since 2018. Nitrate and perchlorate were not detected in any sample above their reporting limits of 2.5 mg/L and 4 µg/L or 2 µg/L, respectively. Of the metals, only barium and zinc were detected slightly above their laboratory reporting limits and well within natural background ranges. Barium was detected in wells W-851-06, W-851-07, W-851-08, and W-861-3208 in June and in well W-861-3208 in December. Zinc was detected in wells W-851-05, W-851-08, and W-851-3208 in June. HE compounds were not detected above individual compound reporting limits in any samples from the seven wells sampled. The analytical results obtained between 2018 and 2022 indicate no impact to groundwater from these constituents.

3. Detection Monitoring, Inspection, and Maintenance Program for the Pit 1, 2, 3, 4, 5, 6, 7, 8, and 9 Landfills and Inspection and Maintenance Program for the Drainage Diversion System and Building 850 CAMU

The detection monitoring program for Site 300 is designed to detect any future releases of contaminants from the Pits 1, 2, 3, 4, 5, 6, 7, 8, and 9 landfills. This section presents the results of groundwater detection monitoring of these landfills and any inspections or maintenance conducted on them during the reporting period.

3.1. Pit 1 Landfill

From 1961 to 1988, the Pit 1 landfill received debris from the firing tables in the East Firing Area. In 1989, the landfill was closed and, under RCRA, covered with an engineered low-permeability cap between 1991 and 1992.

The current groundwater monitoring network at Pit 1 consists of 12 wells, which include eight detection monitor wells and four evaluation monitor wells. The following detection monitor wells are used to sample groundwater and detect any new releases of COCs in the vicinity of Pit 1:

- Wells K1-01C and K1-07, located hydrologically upgradient from Pit 1.
- Downgradient wells K1-02B, K1-04, K1-05, and W-PIT1-2326.
- Cross-gradient wells K1-08 and K1-09.

Evaluation monitor wells K1-06, W-PIT1-2620, W-PIT1-2209, and W-865-2005 are all located downgradient of the detection monitor wells. These wells were added to the Pit 1 monitoring and reporting requirements to track existing plumes of perchlorate and tritium from upgradient sources.

3.1.1. Sampling and Analysis Plan Modifications

During the second semester of 2022, samples for 25 analyses were not collected from K1-01C and K1-06 because the wells were dry. Additionally, samples for 21 analyses were not collected from well K1-07 due to inoperable sampling equipment.

3.1.2. Detection and Evaluation Monitoring Results

Monitoring data indicate no new releases of contaminants from Pit 1 during this reporting period. Constituent concentrations and activity concentrations generally remained stable between 2021 and 2022. In 2022, depth to groundwater beneath Pit 1 was an average of approximately 120 ft bgs.

During the second semester of 2022, 9 of the 12 groundwater monitoring wells in the Pit 1 network were sampled for metals and the other detection monitoring constituents. Monitor wells K1-01C, K1-06, and K1-07 were not sampled for the reasons specified in Section 3.1.1.

The following sections present the detection and evaluation monitoring results that were obtained from the groundwater monitoring network wells in the Pit 1 landfill area.

3.1.3. Metals

In 2022, the following metals were sampled for within the Pit 1 groundwater monitoring network:

- **Arsenic**: Nine wells contained arsenic concentrations above the California Title 22 drinking water MCL of 0.010 mg/L. Well W-PIT1-2620 exhibited the maximum arsenic concentration of 0.017 mg/L in June. For the past five years, arsenic concentrations in Pit 1 groundwater monitoring wells have remained stable, with concentrations ranging from 0.002 to 0.017 mg/L. These arsenic concentrations are typical of groundwater in other parts of Site 300 and appear to represent background conditions.
- **Barium**: Nine wells contained barium in excess of the reporting limit of 0.025 mg/L but all concentrations were below the state MCL of 1 mg/L. Barium concentrations in Pit 1 groundwater monitor wells remained stable between 2021 and 2022.
- **Beryllium**: Beryllium was not detected in any wells in excess of the 0.0005 mg/L reporting limit, as was the case for 2021. The state MCL for beryllium is 0.004 mg/L.
- **Cadmium**: Cadmium was not detected in any wells in excess of the reporting limit or 0.005 mg/L state MCL, as was the case in 2021.
- **Chromium**: Chromium was detected above the reporting limit of 0.001 mg/L in downgradient well K1-05 at a concentration of 0.0016 mg/L, which is within historical ranges. A September sample in the same well did not yield chromium in excess of the reporting limit.
- **Cobalt, copper, and lead**: As in 2021, these metals were not detected in any wells in excess of their individual reporting limits of 0.025, 0.01, and 0.002 mg/L, respectively.
- **Manganese**: Manganese was not detected in any well above the reporting limit of 0.03 mg/L; this result is a decrease from a single 0.15 mg/L detection in upgradient well K1-07 in 2021.
- **Mercury**: Mercury was detected above the reporting limit of 0.0002 mg/L in downgradient well W-PIT1-2620 at a concentration of 0.00028 mg/L, which is within historical ranges.
- **Nickel**: Nickel was detected above the reporting limit of 0.005 mg/L in downgradient well K1-02B at a concentration of 0.0071 mg/L, which is within historical ranges.
- **Selenium**: Seven wells contained selenium in excess of the 0.002 mg/L reporting limit but below the state MCL of 0.05 mg/L. Selenium concentrations in the Pit 1 groundwater monitor wells remained stable between 2021 and 2022.
- **Vanadium**: Eight wells contained vanadium in excess of the 0.025 mg/L reporting limit. The maximum vanadium concentration of 0.072 mg/L was detected in well K1-01C in

March; there is no federal or state MCL for vanadium. Vanadium concentrations in the Pit 1 monitor wells remained stable between 2021 and 2022.

- **Zinc**: Eight wells contained zinc in excess of the 0.02 mg/L reporting limit, with a maximum of 0.025 mg/L in well K1-04 in August. Zinc concentrations in the Pit 1 monitor wells remained stable between 2021 and 2022.

3.1.4. Nitrate and Perchlorate

During 2022, W-PIT1-2209 and W-PIT1-2326, located downgradient of Pit 1, contained nitrate concentrations above the 45 mg/L MCL cleanup standard at 67 mg/L in June and 69 mg/L in August. The August concentration in W-PIT1-2326 represents a minor increase from the 2021 maximum of 68 mg/L in W-PIT1-2209.

Overall, nitrate concentrations in wells within the Pit 1 detection monitoring network are similar to those of 2021 and consistent with historical ranges, with the exception of W-PIT1-2326. The 69 mg/L nitrate concentration in this well in August 2022 was a significant increase from its historical concentration range of 29 mg/L to 35 mg/L, dating back to 2008. Routine and duplicate samples collected from well W-PIT1-2326 in December 2022 yielded nitrate concentrations of 30 and 33 mg/L.

During 2022, perchlorate was detected at a concentration above the 6 µg/L MCL cleanup standard in evaluation monitor well W-PIT1-2620 at 6.6 µg/L in March and 6.1 µg/L in October. During 2021, perchlorate was not detected above the cleanup standard in any detection monitor or evaluation monitor well. Perchlorate was also detected in excess of the 2 µg/L reporting limit in detection monitor wells K1-02B, K1-04, and W-PIT1-2326, at maximum concentrations of 4.9 µg/L in May, 2.9 µg/L in December, and 5.3 µg/L in December; and in evaluation monitor wells W-PIT1-2209 and W-PIT1-2620 at maximum concentrations of 3 µg/L in October and 6.6 µg/L in March. Well K1-06 has been dry since mid-2018.

Evaluation monitor wells and other monitor wells define a perchlorate plume originating from Pit 1. The extent of the perchlorate plume has remained stable for over a decade and will continue to be closely monitored. For the past five years, nitrate and perchlorate concentrations in the Pit 1 area have generally been temporally and spatially stable.

3.1.5. Tritium

Tritium activity concentrations in the Pit 1 detection monitoring network are well below the 20,000 pCi/L MCL cleanup standard. The 2022 maximum tritium activity concentration at Pit 1 was 2,310 pCi/L in August at downgradient well K1-02B. This maximum is a minor decrease from the 2021 maximum tritium activity concentration of 2,420 pCi/L in the same well.

Tritium observed in groundwater samples from the Pit 1 area in excess of background is related to upgradient sources in the Building 850 portion of OU 5.

3.1.6. Uranium

Total uranium activity concentrations in the Pit 1 detection monitoring network are all below the 20 pCi/L MCL cleanup standard. The 2022 maximum total uranium activity concentration at Pit 1 was

6.6 pCi/L in June in well W-PIT1-2620. This maximum is a minor increase from the 2021 maximum total uranium activity concentration of 5.7 pCi/L in the same well.

Previous studies indicate that the uranium $^{235}U/^{238}U$ atom ratios observed in the Pit 1 monitor wells are natural and within the range of background (Chan 2020).

3.1.7. Other Constituents

During 2022, HMX, RDX, radium-226, thorium-228, and thorium-232 did not exceed individual reporting limits in any groundwater samples collected from the Pit 1 monitoring network wells. Well K1-04 yielded 0.152 pCi/L of thorium-230, just above the 0.15 pCi/L reporting limit. However, a December sample in the same well did not yield thorium-230 in excess of the reporting limit.

3.1.8. Landfill Inspection Results

An annual engineering inspection was performed on the Pit 1 landfill cap on May 22, 2022. Inspection results are summarized in the *2022 LLNL Site Pit 1 Cap Annual Engineering Inspection Report* (Abri Environmental Engineering 2022a), which states that the cap on Pit 1 was in good condition, the vegetation cover on the cap was thick, there was no visible erosion, the drainage system was in good condition and appeared to be functioning as intended, and the groundwater monitoring system was also in good condition. Some weed growth was observed in the drainage channel.

LLNL inspected the Pit 1 landfill cap on April 19, 2022. Results from the inspection indicate that the cap was in good overall condition.

3.1.9. Annual Subsidence Monitoring Results

Annual subsidence monitoring was conducted during the second semester of 2022. No evidence of subsidence was detected.

3.1.10. Maintenance

Maintenance was performed on the Pit 1 landfill cap on October 5, 2022. Maintenance included removing vegetative debris and sediment from the drainage ditch and the dissipator, removing weeds from drainage ditch joints, resealing all drainage ditch points, and filling animal burrows.

3.2. Pit 2 Landfill

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

3.2.1. Sampling and Analysis Plan Modifications

Detection monitoring of wells located downgradient of the Pit 2 landfill is conducted annually for VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, Title 22 metals, lithium, and fluoride. The detection monitor wells include W-PIT2-1934, W-PIT2-1935, K2-01C, and NC2-08.

Appendix C contains the sampling and analysis plan for the groundwater detection monitoring program implemented for the Pit 2 landfill. During 2022, no requested analyses were missed.

3.2.2. Contaminant Detection Monitoring Results

The following sections present summaries of tritium, uranium, nitrate, and perchlorate concentration or activity concentration data in groundwater samples collected in 2022 from the four Pit 2 landfill detection monitor wells. Concentrations of other detection monitoring constituents, including VOCs, HE compounds, metals, lithium, and fluoride, in samples collected during 2022 were either below reporting limits or within the range of background (Ferry et al. 1999). Monitoring data indicate no evidence of new contaminant releases from the Pit 2 landfill. Depth to groundwater within the $Tnbs_1/Tnbs_0$ HSU beneath the landfill currently ranges from 45 ft to over 70 ft.

3.2.3. Tritium

Within the $Tnbs_1/Tnbs_0$ HSU in the area immediately south of the Pit 2 landfill, the 2022 maximum tritium activity concentration was 2,010 pCi/L in May in detection monitor well K2-01C. This concentration represents a slight decrease from the 2021 maximum of 2,000 pCi/L in the same well. The historical maximum tritium activity concentration of 49,100 pCi/L was detected in groundwater samples collected from detection monitor well K2-01C in 1986.

Overall, tritium activity concentrations in the Pit 2 landfill detection monitor wells over the last few years are stable to declining .

3.2.4. Uranium

When the groundwater uranium data for this CMR were reviewed, some issues with first semester ICP-MS sample results were found. Corrections to these data are reflected in this report, and all uranium groundwater data herein supersede those published in the first semester 2022 CMR. In all cases where data were corrected, the updated total uranium activity concentration was lower than the value previously reported in the first semester 2022 CMR.

The 2022 maximum uranium activity concentration in the Pit 2 landfill area was 3.1 pCi/L in May in detection monitor well W-PIT2-1934. This activity concentration is below the 20 pCi/L MCL cleanup standard and within the range of natural background (Ferry et al. 1999). Uranium activity concentrations in the Pit 2 area continue to decrease from the 27.4 pCi/L historical maximum measured in 1994 in well K2-01C.

As mentioned in the introduction of Section 3.2, prior to 2005, potable water was discharged within a drainage channel that extends south and along the northern and eastern margin of the Pit 2 landfill to maintain a wetland habitat for red-legged frogs, a federally listed endangered species. While this discharge occurred, increased uranium activity concentrations and declining $^{235}U/^{238}U$ atom ratios were observed in several Pit 2 area wells. The $^{235}U/^{238}U$ atom ratios in groundwater samples from wells K2-01C, W-PIT2-1934, and W-PIT2-1935 indicated the presence of depleted uranium. This depleted uranium appears to have been released from Pit 2 as a result of the discharge of potable water. This practice was discontinued in 2005, and since then, total uranium activity concentrations in groundwater collected from the Pit 2 detection monitor wells have decreased and $^{235}U/^{238}U$ atom ratios continue an increasing trend toward a natural $^{235}U/^{238}U$ atom ratio of approximately 0.0072.

During 2022, $^{235}U/^{238}U$ atom ratios in groundwater collected from wells NC2-08, W-PIT2-1935, K2-01C, and W-PIT2-1934 were 0.0069 in April, 0.0072 in May, 0.0071 in May, and 0.0068 (May), respectively. These atom ratios indicate a negligible presence of depleted uranium and are similar to those observed in 2021.

3.2.5. Nitrate and Perchlorate

During 2022, nitrate concentrations equaled or exceeded the 45 mg/L MCL cleanup standard in samples collected in May from W-PIT2-1934 and W-PIT2-1935 at 45 mg/L and 51 mg/L, respectively.

During 2022, perchlorate was detected at concentrations exceeding the 2 μg/L reporting limit but below the 6 μg/L MCL cleanup standard in detection monitor wells NC2-08, K2-01C, and W-PIT2-1935 at maximum concentrations of 3.5 μg/L in December, 4.7 μg/L in November, and 3.3 μg/L in November, respectively.

3.2.6. Landfill Inspection Results

The Pit 2 landfill cover was inspected on January 19, April 19, July 13, and October 5, 2022. No maintenance issues were identified.

3.2.7. Annual Subsidence Monitoring Results

Annual subsidence monitoring was conducted during the second semester of 2022. No evidence of subsidence was detected.

3.2.8. Maintenance

No maintenance was needed at the Pit 2 landfill during 2022.

3.3. Pit 6 Landfill

The 1964 to 1973, the Pit 6 landfill was used to bury waste, including shop and laboratory equipment, and biomedical waste, in nine unlined debris trenches and animal pits. In 1997, this landfill was capped and closed to prevent further leaching of contaminants that likely resulted from percolation of rainwater through the buried waste. Detection monitoring of the Pit 6 Landfill is conducted to identify any future releases to groundwater, in accordance with the requirements of the post-closure plan included in the *Compliance Monitoring Program for the CERCLA–Closed Pit 6 Landfill, Annual Report 2007* (Campbell and Taffet 2007).

3.3.1. Modifications to the Sampling and Analysis Plan

In 2022, groundwater monitoring was conducted in accordance with CMP requirements. Appendix C contains the plan for the Pit 6 groundwater detection monitoring program.

Detection monitoring of wells located downgradient of the Pit 6 landfill, EP6-06, EP6-08, EP6-09, K6-01S, K6-19, and K6-36, is conducted semi-annually for VOCs and tritium, and annually for aromatic VOCs (benzene, toluene, ethylbenzene, and xylenes), beryllium, mercury, total uranium, gross alpha and beta radioactivity, perchlorate, and nitrate.

When detection monitor well K6-01S is dry, deeper well K6-01 serves as an alternate detection monitor well and is sampled for the same constituents. During the reporting period, however, well

K6-01S had available groundwater for the sampling and analysis of detection monitoring constituents, so well K6-01 was not needed as an alternate. Well EP6-08 was continuously dry from 2009 to 2017 and, in 2013, well EP6-07 was designated as an alternate detection monitor well to EP6-08 and was first sampled for the same constituents. However, since 2017, EP6-08 has yielded sufficient water to be sampled for detection monitoring constituents, including during this reporting period.

Of the six detection monitor wells, the only well that could not be sampled during this reporting period was well K6-36. This well has generally been dry since 2006 but yielded groundwater for the successful sampling of the detection monitoring constituents in January 2020. The well again went dry and was not sampled in July 2020 and has since remained dry, including throughout 2022. Since 2013, however, well K6-35 has been designated an alternate detection monitor well to K6-36 and has been sampled for the same constituents.

3.3.2. Contaminant Detection Monitoring Results

This section presents the results of the contaminant detection monitoring conducted at the Pit 6 landfill. This discussion is supported by the following figures:

- **Figure 2.3-1**: Map showing the locations of monitor wells at the Pit 6 Landfill.
- **Figure 2.3-2**: Groundwater elevation contour map for the Qt-Tnbs$_1$ HSU.
- **Figures 2.3-3 and 2.3-4**: Distribution of TVOCs and tritium in the Qt-Tnbs$_1$ HSU, respectively.

Attachment 1 tabulates groundwater analytical results for 2022, and Appendix D lists groundwater elevations measured during sampling. During 2022, groundwater levels ranged from approximately 30 ft beneath the buried waste in wells located within the Corral Hollow-Carnegie fault zone to 46 ft beneath the buried waste in wells located north of the Corral-Hollow-Carnegie fault zone.

The 2022 data collected through groundwater detection monitoring do not indicate evidence of a new contaminant release from Pit 6. Compared to 2021 data, concentrations of COCs in samples collected during 2022 slightly decreased, continuing the decrease from 2020.

Statistical analyses are conducted for each of the Pit 6 landfill detection monitor wells so statistical limits (SLs) may be set for the COCs. EP6-08 was dry between 2009 and 2017, therefore, COC data were insufficient to establish SLs for the well. In 2017, after water was again present in EP6-08 for the first time in nine years, DOE/LLNL recommended that revised SLs be calculated using at least four quarters of recent baseline data for all detection monitoring constituents (Buscheck et al. 2018). The sampling and analysis frequency for VOCs, gross alpha, gross beta, tritium, and uranium in this well was increased to quarterly so these data could be acquired for calculating SLs.

Analytical results for samples collected from well EP6-08 during 2022 are summarized as follows:

- **Total uranium**: Total uranium was detected at 13.7 pCi/L in January; 12.4 and 11.2 pCi/L in September routine and duplicate samples, respectively and 8.5 and 9.0 pCi/L in December routine and duplicate samples, respectively. These results are comparable with the 2021 maximum of 13.9 pCi/L, and none exceeded the 20 pCi/L MCL cleanup standard. The January 2018 historical maximum for total uranium is 23.9 pCi/L, exceeding the previous 1997 historical maximum of 9.65 pCi/L. A sample collected in April 2008 yielded a $^{235}U/^{238}U$ atom ratio which indicated the presence of only natural uranium. No other historical mass spectrometric atom ratio data are available for this well.

- **Gross alpha radioactivity**: Gross alpha radioactivity in EP6-08 was 6.41 ±1.91 pCi/L in April; 6.02 ±2.19 and 4.77 ±1.83 pCi/L in September routine and duplicate samples, respectively, and 5.55 ±2.44 pCi/L and 10.4 ±3.3 pCi/L in December routine and duplicate samples, respectively. None of these activity concentrations exceeded the MCL cleanup standard of 15 pCi/L. The historical maximum for gross alpha radioactivity in well EP6-08 is 35.2 pCi/L, detected in May 1996.
- **Gross beta radioactivity**: Gross beta radioactivity in well EP6-08 was 8.35 ±2.16 pCi/L in January; 11.8 ±2.7 pCi/L and 8.81 ±1.94 pCi/L in September routine and duplicate samples, respectively, and 10.7 ±2.33 pCi/L and 8.87 ±2.03 pCi/L in December routine and duplicate samples, respectively. None of these, nor any historical data have exceeded the MCL cleanup standard of 50 pCi/L. The historical maximum for EP6-08 is 27.3 ±4.4 pCi/L in 1996.
- **TCE**: TCE was detected in well EP6-08 at a historical maximum concentration of 2.9 µg/L in January, 2.2 µg/L in September, and 2.7 µg/L in December. None of these detections exceeded the MCL cleanup standard of 5 µg/L. The previous TCE historical maximum for this well was 2.8 µg/L in 2019.
- **PCE**: PCE was detected in well EP6-08 at 5.3 µg/L in January, 4.2 µg/L in September, and 4.6 µg/L and 5 µg/L in December. The January detection slightly exceeded and the December detection equaled the MCL cleanup standard of 5 µg/L. Results from 2022 show a slight concentration decline from the January 2019 historical maximum of 6.2 µg/L. Groundwater samples collected since July 2017 have yielded the highest concentrations of PCE at well EP6-08, ranging from 2.8 µg/L to 6.2. µg/L. The previous maximum concentration was 1.7 µg/L in 2007.
- **CFORM**: CFORM was detected in well EP6-08 at 0.73 µg/L in January, fell below the 0.5 µg/L reporting limit in September, and was detected at 0.58 µg/L and 0.59 µg/L in December routine and duplicate samples, respectively—all well below the MCL cleanup standard of 80 µg/L.
- **1,1-DCA**: 1,1-DCA was detected in well EP6-08 at 0.59 µg/L in January 2022 and was not detected in the September and December samples. Since 2018, 1,1-DCA has been detected in this well at concentrations between the reporting limit and a maximum of 0.6 µg/L in November 2020.
- **Tritium**: Tritium activity concentrations in January and December samples from well EP6-08 did not exceed reporting limits.

The uranium activity concentrations, gross alpha and beta radioactivities, and VOC concentrations detected at EP6-08 between 2017 and 2022 suggest the mobilization of residual contamination in the vadose zone beneath Pit 6, adjacent to well EP6-08, as induced by an approximately 8.5 ft rise in water levels from 2017 to 2020, as compared to the April 2008 sampling event. Water levels in this well are still over 45 ft below the bottom of the buried waste in the landfill and do not suggest a new release from the landfill.

The following subsections summarize trends observed in COC data collected during this reporting period in Pit 6 landfill detection monitor wells.

3.3.2.1. Total Uranium

During 2022, total uranium activity concentrations in well K6-19 were 4.3 pCi/L in January, 3.6 pCi/L in June, 3.9 pCi/L in September, and 3.8 pCi/L in December, indicating a continued decline from the historical maximum of 10.3 pCi/L in January 2017. The historical maximum detection corresponded with a 2.5 ft rise in water levels from October 2016 to January 2017. Historical $^{235}U/^{238}U$ atom ratios indicate the presence of only natural uranium, most recently in a sample collected in October 2018. In 2022, the maximum total uranium activity of 4.3 pCi/L was well below the MCL cleanup standard of 20 pCi/L. Total uranium activities will continue to be closely monitored.

3.3.2.2. Gross Alpha Radioactivity

During the reporting period, gross alpha radioactivity did not exceed the MCL cleanup standard of 15 pCi/L. Only one detection monitor well, EP6-09, exceeded its SL of 4.9 pCi/L in January at 7.1±2.8 pCi/L, in June at 6.34 ±2.85 pCi/L, and in September at 7.05 ±2.57 pCi/L. However, gross alpha radioactivity in this well was below the SL in December at 2 ±1.09 pCi/L. The 2022 gross alpha radioactivity results from well EP6-09 demonstrate a continued activity concentration decline from the historical maximum of 14.9 pCi/L, detected in January 2019 following a rise in water levels in 2017.

In monitor well EP6-08, gross alpha activity concentrations declined to 6.4 pCi/L in January 2022 after a detection exceeding the MCL in October 2021 (20.5 ±4.8 pCi/L and 15.1±5.0 pCi/L in routine and duplicate samples, respectively). The 2022 December duplicate sample detection of 10.4 ±3.3 pCi/L at EP6-08 was the highest gross alpha activity concentration in a Pit 6 detection monitor well during this reporting period. The historical maximum at well EP6-08 was detected in May 1996 at 35.2 pCi/L, and minor detections of gross alpha radioactivity have occurred since water levels rose in 2017. Since January 2018, when there was a detection of 23.4 pCi/L, activity concentrations have shown an overall decreasing trend.

3.3.2.3. Gross Beta Radioactivity

During the reporting period, gross beta radioactivity did not exceed applicable SLs nor the MCL cleanup standard of 50 pCi/L in any Pit 6 landfill detection monitor wells. The highest gross beta activity concentration during the reporting period was detected in well K6-01S at 14.6 ±3.71 pCi/L in January 2022. The historical maximum gross beta radioactivity for this well is 38.5 pCi/L in 1998.

The 2022 gross beta results from well EP6-08 (10.7 ±2.33 pCi/L and 8.87 ±2.03 pCi/L in December (routine and duplicate samples, respectively) indicate a continued overall decline in radioactivities after an increase in 2018, following a rise in water levels during 2017. The historical maximum gross beta radioactivity in this well is 27.3 pCi/L in 1996.

3.3.2.4. VOCs

During 2022, VOCs were not detected in Pit 6 landfill detection monitor wells above their SLs or applicable MCL cleanup standards. The highest concentrations of VOCs were all detected in January as follows:

- **PCE**: 5.3 µg/L in well EP6-08.
- **TCE**: 4.4 µg/L in well EP6-09 .
- ***cis*-1,2-DCE**: 2.0 µg/L in well K6-01S.
- **Chloroform**: 0.73 µg/L in well EP6-08.
- **1,1-DCA**: 0.59 µg/L in well EP6-08.

Of these concentrations, only PCE, which is not a COC, exceeded its 5 mg/L MCL cleanup standard. All other VOC concentrations were very low or below laboratory reporting limits. Section 2.3.2.1.1 presents further discussions of VOC concentrations detected at Pit 6.

3.3.2.5. Tritium

During 2022, tritium activity concentrations were detected above reporting limits in a single detection monitor well, K6-19, at 102 ± 74.2 pCi/L in January 2022. In December 2022, activity concentrations were below the reporting limit in this well. Tritium activity concentrations in well K6-19 have declined since October 1999, when the Pit 6 landfill OU historical maximum of 2,520 pCi/L was detected.

Following a statistical analysis conducted in September 2013, the SL for tritium in well K6-19 was revised from 100 pCi/L to 317 pCi/L. Since then, tritium activity concentrations in this well have generally decreased to below the reporting limit of 100 pCi/L and have always been well below the 20,000 pCi/L MCL cleanup standard (Campbell and Taffet 2007; Blake et al. 2011).

In 2022, tritium concentrations at all other Pit 6 monitor wells were below the reporting limit, and SLs were not exceeded. In well K6-36, 400 ±124 pCi/L of tritium was detected in January 2020, the first time since 2006 that this well had available groundwater for sampling. An SL for tritium has not been established for this well. The historical maximum tritium activity concentration for this well was detected in 2000 at 2,150 pCi/L. Because K6-36 has been dry since January 2020, no samples were collected during 2022.

3.3.3. Landfill Inspection Results

The Pit 6 landfill was inspected on April 19, 2022 and December 28, 2022. Minor cracks were observed in the concrete drainage channel during the December inspection.

Abri Engineering completed the *2022 LLNL Site 300 Pit 6 Cap Annual Engineering Inspection Report* in May (2022b) and identified no significant maintenance issues. One survey benchmark was confirmed missing, and minor amounts of vegetative debris were observed in the drainage ditch.

3.3.4. Annual Subsidence Monitoring Results

Annual subsidence monitoring conducted in April and December 2022 found no evidence of subsidence.

3.3.5. Maintenance

Vegetation and sediment was cleared from the drainage ditch, and the drainage ditch joints were resealed on October 10, 2022.

3.4. Pit 8 Landfill

The Pit 8 landfill received debris from the Building 801 firing table until 1974, when it was covered with approximately 2 ft of compacted soil.

3.4.1. Sampling and Analysis Plan Modifications

Detection monitoring of wells located downgradient of the Pit 8 landfill (i.e., K8-02B, K8-04, K8-05, and W-PIT8-3203) is conducted annually for VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, Title 22 metals, lithium, and fluoride. Data from monitor wells K8-01, W-PIT8-3202, W-PIT8-3201, and K8-03B, located upgradient of the Pit 8 landfill and downgradient of the Building 801 area, are also used for comparative purposes.

Appendix C contains the 2022 sampling and analysis plan for the Pit 8 landfill groundwater detection monitoring program. Wells in this area are scheduled for sampling and analysis primarily during the second quarter of the calendar year. During the first semester of 2022, groundwater monitoring was conducted in accordance with the CMP monitoring requirements with the exception of five required analyses for well K8-03B. These analyses could not be performed because, during two attempts, the well was inaccessible due to a locked gate. All second semester 2022 CMP monitoring requirements were met.

3.4.2. Contaminant Detection Monitoring Results

Figure 2.8-1 is a map of the Building 801 firing table and Pit 8 landfill area showing the locations of buildings, the former Building 801 firing table, Pit 8, and monitor wells.

Historical and current data indicate that VOCs detected in groundwater in the Pit 8 landfill area-are the result of VOCs released from the former Building 801D dry well, which have migrated downgradient from Building 801 to beneath the landfill. During 2022, VOCs were detected in groundwater samples from wells in the vicinity of Pit 8. TCE was detected in wells K8-01, K8-02B, and K8-04, and 1,2-DCA was detected in wells K8-01 and K8-04. The 2022 maximum TVOC concentration of 3.5 µg/L, comprised of 2.4 µg/L of TCE and 1.1 µg/L of 1,2-DCA, was detected in well K8-01, located upgradient of Pit 8 and downgradient of Building 801 in June. These data are similar to historical results.

The historical maximum VOC concentration is 10 µg/L, which was detected four times between 1988 and 1990 in samples from well K8-01. The most recent of these samples was collected on February 9, 1990 and the VOCs were comprised of 6 µg/L of TCE and 4 µg/L 1,2-DCA. As in the past, the presence of VOCs in Pit 8 landfill area wells appears to be a continuation of the VOC plume originating at the Building 801 dry well and is not indicative of a release from the Pit 8 landfill.

As was the case in 2021 and 2020, groundwater nitrate concentrations in wells K8-01, K8-04, and W-PIT8-3203 exceeded the 45 mg/L MCL cleanup standard during 2022. The maximum 2022 nitrate concentration was 74 mg/L in routine and duplicate samples collected in June from downgradient detection monitor well K8-04, which also yielded the 2021 maximum nitrate concentration of 73 mg/L. Well K8-04 also yielded the 2015 historical maximum nitrate concentration in the Pit 8 landfill area of 80 mg/L. During the reporting period, the nitrate MCL cleanup standard of 45 mg/L was exceeded in well W-PIT8-3203 with 59 mg/L in June and 56 mg/L in November. The nitrate MCL was also exceeded at well K8-01 with 50 mg/L in a routine sample collected in June (the duplicate sample yielded 35 mg/L). Overall, area nitrate concentrations are similar to historical results and are not indicative of a new release from Pit 8.

During 2022, wells K8-01 and W-PIT8-3201 yielded the only detectable tritium activity concentrations in groundwater. Well K8-01 yielded 108 ±84.6 pCi/L in a routine sample taken in June but did not exceed the 100 pCi/L laboratory reporting limit in the duplicate sample or in the sample collected in November. Similarly, well W-PIT8-3201 had a June detection of 111 ±85.2 pCi/L in a duplicate sample with no activity concentrations exceeding the laboratory reporting limit in the paired routine sample or the sample collected in November. Tritium in all other wells did not exceed the laboratory reporting limit of 100 pCi/L. The 2021 maximum tritium activity concentration detected in groundwater in the Pit 8 Landfill area was 183 ±81.8 pCi/L in a routine sample from well K8-01 (the duplicate sample yielded 136 ±76.6 pCi/L). These recent tritium activity concentrations above the reporting limit at well K8-01, which is upgradient of the Pit 8 landfill, appear to represent the leading edge of the tritium plume originating at the Building 850 firing table.

During the reporting period, perchlorate was detected in the following four wells within the Building 801/Pit 8 landfill area:

- **Well K8-04**: 4 µg/L and 3.8 µg/L in duplicate and routine and samples, respectively, in June and at 4 µg/L in November.
- **Well W-PIT8-3203**: 2.9 µg/L and 3.1 µg/L in June and November, respectively.
- **Well K8-01**: 2.5 µg/L and 2.4 µg/L in routine and duplicate samples respectively, in June.
- **Well K8-02B**: 2.0 µg/L in March.

Perchlorate was not detected above the typical 2 µg/L reporting limit in any other wells. During 2021, perchlorate was detected in the following three wells:

- **K8-04**: 7.1 µg/L in a routine sample, exceeding the 6 µg/L MCL cleanup standard for the first and only time in a Pit 8 detection monitor well (the duplicate sample yielded 4 µg/L).
- **W-PIT8-3203**: 3 µg/L.
- **K8-01**: 2.6 µg/L.

During 2020, perchlorate was detected in only one well, K8-01, at 2.3 µg/L. The historical distribution of these very low concentrations of perchlorate suggest a past minor release at the former firing table or landfill. Concentrations will be closely monitored to identify future trends.

During the first semester of 2022, five wells in the subarea were sampled for mass spectrometric analysis of uranium isotopes. Groundwater from well W-PIT8-3203 yielded the highest activity concentration of uranium at 20 pCi/L, matching the MCL cleanup standard. Other area wells yielded activity concentrations of 6 pCi/L to 14 pCi/L of total uranium. Over the previous three years, only uranium in well W-PIT8-3203 has exceeded the 20 pCi/L MCL cleanup standard at 24 pCi/L in 2021, 25 pCi/L in 2020, and 23 pCi/L in 2019. Total uranium activity concentrations in this well have decreased from the maximum of 31 pCi/L, which was detected in 2017. The $^{235}U/^{238}U$ atom ratio (0.0074) for the May sample from well W-PIT8-3203 indicated a natural uranium provenance and was consistent with the atom ratio observed in 2017. A similar trend was observed in all area wells during the reporting period.

During 2022, arsenic concentrations slightly exceeded the 0.01 mg/L MCL cleanup standard of 0.01 mg/L in four of the five wells sampled in June:

- **W-PIT8-3203**: 0.082 mg/L.
- **K8-04**: 0.025 mg/L.
- **K8-02B**: 0.025 mg/L.
- **W-PIT8-3202**: 0.019 mg/L.

During 2021, arsenic concentrations slightly exceeded the MCL cleanup standard in all five wells sampled in May:

- **W-PIT8-3203**: 0.078 mg/L.
- **K8-04**: 0.027 mg/L.
- **K8-02B**: 0.022 mg/L.
- **W-PIT8-3202**: 0.019 mg/L.
- **W-PIT8-3201**: 0.015 mg/L.

During 2020, arsenic concentrations exceeded the MCL cleanup standard in three wells:

- **W-PIT8-3203**: 0.056 mg/L.
- **K8-04**: 0.023 mg/L.
- **W-PIT8-3202**: 0.018 mg/L.

Since these wells were installed in 2016, groundwater arsenic concentrations have ranged between 0.041 mg/L and 0.082 mg/L in well W-PIT8-3203 and 0.016 mg/L and 0.2 mg/L in well W-PIT8-3202. From 1989 through 2021, arsenic concentrations in well K8-04 have ranged between 0.017 mg/L and 0.030 mg/L and from less than 0.005 mg/L to 0.028 mg/L in well K8-02B. While the reason for these arsenic concentrations slightly in excess of the MCL cleanup standard is unknown, they are likely natural in origin. Wells W-PIT8-3203, K8-04, and K8-02B are located along the downgradient edge of Pit 8 while W-PIT8-3202 is located approximately 450 ft northwest and approximately cross-gradient of Pit 8. Historically, background arsenic concentrations at Site 300 range from 0.002 mg/L to 0.22 mg/L (Ferry et al. 1999). Thus, the arsenic concentrations observed in the Pit 8 wells during the first semester of 2022 are within the range of background. Arsenic concentrations will be closely monitored during future sampling events.

During 2022, nickel concentrations in June routine and duplicate samples from well W-PIT8-3201 were 0.14 mg/L and 0.12 mg/L, respectively, slightly exceeding the California state MCL cleanup standard of 0.1 mg/L. A federal MCL cleanup standard has not been established for nickel. Between 2016, when the well was installed, and 2021, nickel concentrations ranged from 0.073 mg/L to below the laboratory reporting limit of 0.02 mg/L. W-PIT8-3201 was the only well to exceed the California state MCL cleanup standard amongst all area wells during the first semester of 2022; this well is located approximately 800 ft south-southeast and generally cross-gradient, historically, of Pit 8.

In December 2020, the nickel concentration in a groundwater sample from well K8-02B was 0.27 mg/L, exceeding the California state MCL cleanup standard of 0.1 mg/L, but decreased to 0.032 mg/L in 2021. During the first semester of 2022, concentrations decreased to below the laboratory reporting limit of 0.02 mg/L. The previous historical maximum nickel detections in well K8-02B were 0.02 mg/L in 2004; 0.01 mg/L in 2005; 0.005 mg/L in 2007, 2008, and 2010; and 0.008 mg/L in 2009 and 2011. All other historical results for this well have not exceeded the laboratory reporting limit, which ranged from 0.02 mg/L to 0.005 mg/L. Well K8-02B is located approximately 100 ft east and, prior to 2021, generally downgradient of Pit 8. The reason for the 2020 increase in nickel concentrations at this well is unknown, but future concentrations will be closely monitored. Nickel concentrations in other Building 801/Pit 8 landfill area wells did not exceed the laboratory reporting limit during 2021 and, historically, have never exceeded the California state MCL cleanup standard of 0.1 mg/L.

During 2022, samples were collected from wells upgradient, cross-gradient, and downgradient of the Pit 8 landfill for analysis of other metals, as well as other detection monitoring constituents, including HE compounds, lithium, and fluoride. Concentrations in these samples were either below MCLs cleanup standards or reporting limits or within the range of background concentrations. Of the constituents that were monitored in $Tnbs_1/Tnbs_0$ HSU groundwater in the Pit 8 landfill area during the first semester of 2022, only 1,2-DCA, nitrate, and arsenic concentrations exceeded their federal MCL cleanup standards.

Groundwater detection monitoring data for this reporting period indicate no evidence of a new contaminant release from the Pit 8 landfill.

3.4.3. Landfill Inspection Results

During 2022, the Pit 8 landfill was inspected on January 20, April 19, July 13, and October 5. No maintenance issues were identified.

3.4.4. Annual Subsidence Monitoring Results

LLNL conducted annual subsidence monitoring during the second semester of 2022. No evidence of subsidence was detected.

3.4.5. Maintenance

No maintenance was necessary at Pit 8 during the second semester of 2022.

3.5. Pit 9 Landfill

From 1958 to 1963, 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.

3.5.1. Sampling and Analysis Plan Modifications

Detection monitoring for VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, metals, lithium, and fluoride is conducted annually in wells located downgradient of the Pit 9 landfill (K9-01, K9-02, K9-03, K9-04, W-PIT9-3204, W-PIT9-3205, and W-PIT9-3206).

Appendix C contains the sampling and analysis plan for the Pit 9 landfill groundwater detection monitoring program. During the first semester of 2022, two of the seven wells, W-PIT9-3205 and W-PIT9-3206, were inaccessible due to poor road conditions and could not be sampled, resulting in 16 missed CMP-required analyses. The remaining five wells, K9-01, K9-02, K9-03, K9-04, and W-PIT9-3204, were successfully sampled in accordance with all CMP monitoring requirements. No samples for CMP-required analyses were scheduled for the second semester.

3.5.2. Contaminant Detection Monitoring Results

Figure 2.8-3 is a map of the Building 845 firing table and Pit 9 landfill area showing the locations of the building, landfill, and monitor wells.

During 2022, arsenic concentrations slightly exceeded the 0.01 mg/L MCL cleanup standard in one well, K9-02, at 0.023 mg/L in June. The same well yielded an arsenic concentration of 0.018 mg/L in 2021 and 0.056 mg/L in 2020. Since this well was installed in 1989, groundwater arsenic concentrations have ranged from 0.0032 mg/L to 0.056 mg/L. Since 2013, maximum arsenic concentrations slightly increased from 0.03 mg/L in 2019 to 0.056 mg/L in 2020 before decreasing to 0.018 mg/L in 2021 and 0.023 mg/L in June 2022.

The reason for these arsenic concentrations slightly in excess of the MCL cleanup standard is unknown, but they are likely natural in origin. Well K9-02 is located approximately 25 ft south and generally cross-gradient of Pit 9, and the observed arsenic concentrations are within background ranges tabulated in the *Site-Wide Feasibility Study for Lawrence Livermore National Laboratory* (Ferry et al. 1999). Future arsenic concentrations will be closely monitored. Arsenic did not exceed the MCL cleanup standard in the other four wells that were sampled during the reporting period.

During the reporting period, samples were collected from the Pit 9 area wells for analysis of other metals and detection monitoring constituents including VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, lithium, and fluoride. All concentrations and activity concentrations in the samples were either below reporting limits or within the range of background concentrations. There was no evidence of a new release of any constituent from the Pit 9 landfill during 2022.

3.5.3. Landfill Inspection Results

During 2022, the Pit 9 landfill was inspected on January 20, April 19, July 13, and October 3. No maintenance issues were identified.

3.5.4. Annual Subsidence Monitoring Results

LLNL conducted annual subsidence monitoring during the second semester of 2022. No evidence of subsidence was detected.

3.5.5. Maintenance

No maintenance was necessary at Pit 9 during the second semester of 2022.

3.6. Pit 7 Complex Landfills

The Pit 3, 4, 5, and 7 landfills comprise the Pit 7 Complex. From the 1950s through 1989, firing table debris containing tritium, depleted uranium, and metals was placed in the pits. Between 1991 and 1992, all of Pits 4 and 7 and approximately 30 percent of Pit 3 were capped.

During years of above-average rainfall (e.g., the 1997–1998 El Niño), groundwater rose into the bottom of the landfills and underlying contaminated bedrock, resulting in the release of tritium, uranium, VOCs, perchlorate, and nitrate to groundwater. In addition to these COCs, groundwater samples from detection monitor wells in the Pit 7 Complex area are now analyzed for metals, HE compounds, and PCBs, which may exist in the firing table gravels placed in the landfills.

3.6.1. Sampling and Analysis Plan Modifications

Detection monitoring is conducted annually in wells located downgradient of the Pit 7 Complex for VOCs, nitrate, tritium, perchlorate, HE compounds, uranium isotopes, Title 22 metals, lithium, fluoride, and PCBs.

Appendix C contains the 2022 sampling and analysis plan for the groundwater detection monitoring program implemented at the Pit 7 Complex landfills. During 2022, samples for 23 requested analyses were not collected in this area due to the wells being dry.

3.6.2. Contaminant Detection Monitoring Results

The *Interim Remedial Design Document for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300* (Pit 7 RD) (Taffet et al. 2008) lists the wells comprising the detection monitor well network for the Pit 7 Complex. These wells are K7-03, NC7-24, NC7-37, NC7-40, NC7-48, NC7-51, W-PIT3-02, and W-PIT7-03. Table 4-1 of the CMP/CP contains the detection monitoring sampling and analysis plans for the landfills that make up the Pit 7 Complex.

The detection monitoring data, summarized below, do not indicate the release of any detection monitoring constituents from any of the landfills or underlying vadose zone during this reporting period.

3.6.3. Tritium

The Pit 3 and 5 landfills have been identified as sources of previous releases of tritium to groundwater. Conversely, the Pit 7 landfill is not an apparent source of tritium in groundwater because most tritium-bearing experiments conducted at Site 300 occurred prior to its opening in 1979 (Taffet et al. 2008).

During 2022, tritium activity concentrations in routine and duplicate groundwater samples collected from four Pit 7 Complex detection monitor wells, K7-03, NC7-40, W-PIT7-03, and NC7-51, exceeded the 20,000 pCi/L MCL cleanup standard at 22,500 pCi/L in April, 42,400 pCi/L in April, 62,700 pCi/L in February, and 79,000 pCi/L in April, respectively. Overall, tritium activity concentrations in these wells have remained stable between 2021 and 2022.

3.6.4. Uranium

Depleted uranium was previously released to groundwater from Pits 3, 5, and 7 (Taffet et al. 2008). During 2022, uranium activity concentrations exceeded the 20 pCi/L MCL cleanup standard in three Pit 7 Complex detection monitor wells W-PIT7-03, NC7-40, and NC7-51 at 34 pCi/L in April, 93 pCi/L in April, and 40 pCi/L in February, respectively. The extent of total uranium in Qal/WBR and $Tnbs_1$/$Tnbs_0$ HSU groundwater is similar to what has been observed in recent years.

3.6.5. Nitrate

None of the groundwater samples collected from Pit 7 Complex detection monitor wells during 2022 contained nitrate concentrations exceeding the 45 mg/L MCL cleanup standard. Overall, nitrate concentrations in these wells have remained stable since 2017.

3.6.6. Perchlorate

During 2022, perchlorate concentrations exceeded the 2 μg/L reporting limit and 6 μg/L MCL cleanup standard in wells W-PIT7-03, NC7-51, and NC7-40 at 8.1 μg/L, 7.5 μg/L, and 10 μg/L, respectively, all in April. Overall, perchlorate concentrations in the Pit 7 Complex detection monitor wells have remained stable or have decreased since 2017.

3.6.7. Volatile Organic Compounds

During 2022, TCE was the only VOC detected in the Pit 7 Complex; a concentration of 0.51 μg/L was reported in the April sample from detection monitor well K7-03. The historical maximum TVOC concentration of 15.2 μg/L, composed of 8.7 μg/L of TCE, 0.8 μg/L of PCE, 1.2 μg/L of 1,1,1-TCA, and 4.5 μg/L of 1,2-DCE was detected in a 1985 sample from monitor well K7-03. VOC concentrations have generally decreased in this well since the 1985 maxima.

3.6.8. Title 22 Metals and Lithium

During 2022, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc, and lithium were not detected in the Pit 7 Complex detection monitor wells at concentrations in excess of background.

3.6.9. High Explosives Compounds

During 2022, HE compounds were not detected in the Pit 7 Complex detection monitor wells at concentrations in excess of individual compound reporting limits of 1 to 2.5 μg/L.

3.6.10. Polychlorinated Biphenyls

During 2022, PCB compounds were not detected in the Pit 7 Complex area detection monitor wells at concentrations in excess of the individual compound reporting limits of approximately 0.5 μg/L.

3.6.11. Landfill Inspection Results

The annual engineering inspection of the Pit 7 landfill cap was performed on May 4, 2022. Inspection results are summarized in the 2022 *Pit 7 Cap Annual Engineering Inspection Report* (Abri Environmental Engineering 2022c), which indicated that the cap was in good condition, the vegetation cover on the cap was thick, there was no visible erosion, the drainage system was in good condition and appeared to be functioning as intended, and the groundwater monitoring system appeared to be in good condition. A large burrow was observed on the cap.

LLNL inspections of the Pit 3 and Pit 5 landfill covers were performed on January 19, April 19, July 13, and October 5, 2022. Results indicated that the covers were in good condition.

3.6.12. Annual Subsidence Monitoring Results

Annual subsidence monitoring was conducted during the second semester of 2022. No evidence of subsidence was detected.

3.6.13. Maintenance

On October 5, 2022, maintenance was performed on the Pit 7 landfill cap to remove vegetative debris and sediment from the drainage ditch and dissipator, seal all drainage ditch joints, and fill animal burrows. Maintenance was not required on the Pit 3 or Pit 5 landfill covers in 2022.

4. Risk and Hazard Management Program

The Site 300 risk and hazard management program aims to protect human health and the environment by controlling exposure to contaminants during remediation. At Site 300, risk and hazard management is conducted in areas where the exposure point risk exceeded 1×10^{-6} or the hazard index exceeded 1 in the baseline risk assessment (Webster-Scholten et al. 1994). The land use controls presented in Appendix E have been implemented to manage risks at Site 300. The CMP/CP requires that these institutional controls be evaluated annually.

4.1. Human Health Risk and Hazard Management

The CMP/CP requires the annual reevaluation of the risk and hazard associated with volatile contaminants in the subsurface that could migrate upward into indoor or outdoor ambient air and be inhaled by workers, where the risk exceeds 1×10^{-6} and hazard index exceeds 1. This reevaluation must be conducted using current data.

Section 4.1.1 is a discussion of the on-site worker inhalation risk associated with VI of VOCs potentially migrating from subsurface contamination into indoor and outdoor air. Section 4.1.2 documents the on-Site 300 worker inhalation risk associated with springs.

4.1.1. Annual Inhalation Risk Evaluation

Following issuance of revised guidance from the EPA in 2015 and ensuing RPM discussions during regulatory review of five-year review documents for Site 300, DOE/LLNL began reevaluating inhalation risks from VOCs potentially migrating from subsurface contamination into indoor air in 2017. In 2018 and 2019, DOE/LLNL conducted indoor air sampling within 21 buildings at Site 300 identified as having the highest potential for VOC VI. More than 170 air samples were collected from indoor air, outdoor ambient air, crawl spaces, confined spaces, and areas of preferential pathways.

The results of this sampling campaign demonstrated that there is currently no short-term risk to occupants of Site 300 buildings due to VI from subsurface contamination into indoor air, with the exception of Building 833. In 2019, DOE/LLNL deployed an SSDS as part of a mitigative action at

Building 833, and this system remains operational. Building 833 has not been occupied since 2018 and remained unoccupied in 2022. The addenda to the five-year reviews for all OUs document these results and resultant recommendations (Demir et al. 2021a, 2021b, 2021c, 2021d, 2021e, and 2021f).

In 2022, DOE/LLNL completed the second year of the long-term indoor air sampling program in response to addenda recommendations. Appendix F-1 presents the program's building prioritization list, Appendix F-2 presents the status of the program, and Appendix F-3 presents target indoor air concentration screening levels. Attachment 1, Table 1-3, presents 2022 indoor air sampling results in units of ppm_v, as reported by the analytical laboratories, and in units of $\mu g/m^3$, per regulatory request.

DOE/LLNL collected indoor air samples at Site 300 from 11 buildings in 2022. Two sampling events were completed in each building—one during the winter months and another during the summer months—to evaluate the impact of the different weather conditions. A total of 87 air samples were collected from indoor air, crawl spaces, confined spaces, and areas of preferential pathways, and 28 outdoor ambient air samples were also collected as part of the program.

TCE or PCE was detected in 5 of the 11 buildings; however, there were no PCE detections above its indoor air screening level, and only one building had a TCE detection above its long-term cancer indoor air screening level but below the hazardous non-cancer, accelerated response, and urgent response screening levels for TCE. In January 2022, TCE was detected in excess of the long-term cancer indoor air screening level in a single room in Building 834C (Room 103C). This building is currently unoccupied and was resampled in March 2022 and all results from this sample event, as well as the summer sampling event in July 2022, were below the indoor air screening levels.

Per a recommendation in the five-year review addenda, DOE/LLNL developed a contingency plan for additional indoor air sampling in the event that a SVE system or VI mitigation system is offline for more than 30 days. Appendix F-4 presents this contingency plan. During 2022, all Site 300 SVE systems, except 830-SRC and 832-SRC, remained operational and were never offline for more than 30 days. The 830-SRC SVE system was offline for more than 30 days during the winter months to protect the facility from freeze damage, but nearby Building 830 was not sampled because the structure is unoccupied and scheduled for demolition. The 832-SRC SVE system was also offline for more than 30 days, but nearby buildings were not sampled because the initial VI evaluation was completed when the SVE system was offline. Thus, additional contingency sampling was not conducted during this reporting period.

In 2023, DOE/LLNL will continue to implement the long-term sampling program and evaluate the potential risk of VI from residual subsurface contamination to indoor air, submit indoor air sampling result tables to the regulatory agencies when indoor air screening levels are exceeded, and provide updates during RPM meetings.

4.1.2. Spring Ambient Air Inhalation Risk Evaluation

4.1.2.1. VOC-Contaminated Springs

The CMP requires annual sampling of outdoor air above VOC-contaminated surface water, when present, to determine VOC concentrations.

An unacceptable risk or hazard was identified during the baseline risk assessment for the inhalation of VOCs at four locations (Webster-Scholten 1994):

- **Spring 3 (Building 832 Canyon OU)**: Cumulative risk of 7 x 10^{-5}, hazard index of 2.3 due to TCE and PCE.
- **Spring 5 (HEPA OU)**: Cumulative risk of 1 x 10^{-5} due to 1,1-DCE and TCE.
- **Spring 7 (Pit 6 Landfill OU)**: Cumulative risk of 4 x 10^{-5}, hazard index of 1.5 due to TCE, PCE, 1,2-DCA, and CFORM.
- **The Carnegie SVRA pond (off-site, east of the Pit 6 landfill)**: Hypothetical cumulative risk of 3 x 10^{-6} due to TCE.

Spring 3 was accessed on February 23 and August 1, 2022, but was dry during these visits. Similarly, Spring 5 was visited on March 22 and September 21, 2022, and Spring 7 (BC6-13) was visited on January 26, June 2, August 3, and December 5, 2022, but these locations were dry during all visits. Because Site 300 remains a restricted-access, experimental test site, workers do not work in the vicinity of Springs 3, 5, or 7 except to collect water samples. Spring water is not used for drinking water at the site.

Water-supply well CARNRW2 is used to fill the Carnegie SVRA pond for dust and fire suppression. The baseline risk assessment conservatively estimated that, if the VOC source in the Pit 6 landfill was not controlled, contaminated groundwater could migrate to well CARNRW2 and result in an unacceptable risk from inhaling VOC vapors volatilizing from the pond (Webster-Scholten 1994). However, an engineered cap was constructed over the Pit 6 landfill to prevent infiltration of precipitation and further releases of contaminants from the landfill. The VOC plume originating at the Pit 6 landfill continues to not impact CARNRW2 or any groundwater beyond the Site 300 boundary. In 2022, CARNRW2 was sampled on a monthly basis, and VOCs were not detected in excess of reporting limits in any of the samples. Thus, no unacceptable risk or hazard currently exists.

4.1.2.2. Tritium-Contaminated Springs

The baseline risk assessment identified an unacceptable cumulative risk of 1 x 10^{-3} for the inhalation of tritium at the Well 8 Spring in the Building 850 area. This risk was determined using the maximum historical tritium activity concentration of 770,000 pCi/L, which was reported in 1972. Over the ensuing decades, tritium activity concentrations in Well 8 Spring have steadily decreased. The CMP/CP indicated that the inhalation risk associated with tritium in surface water volatilizing to outdoor ambient air will be reevaluated annually when surface water is present. Thus, when present, surface water at the Well 8 Spring is sampled and analyzed for tritium annually.

Surface water was last observed at the Well 8 Spring in 2017, when the tritium activity concentration of 52,800 pCi/L was measured. This activity concentration was compared to the preliminary remediation goal (PRG) for tap water, which was obtained using the current PRG calculator as outlined by regulatory guidance (US EPA 1991). The U.S. EPA has not defined a PRG for the activity concentration of tritium in standing water that may present an inhalation risk to outdoor workers. As a result, the PRG calculator was used to determine a screening level for the inhalation pathway of tritium in tap water using the residential scenario and making site-specific modifications to the exposure parameters in the calculator to determine a PRG for tritium in an on-site spring. This exposure scenario is for an on-site worker who collects a quarterly sample of water at the spring, given that this sampler would spend the maximum time at the spring of any individual.

The exposure parameters were modified as follows:

- Remove any child exposure scenarios by using a value of zero for child exposure duration, frequency, and time.
- Set the exposure parameters for an adult to a duration of 25 years, a frequency of four days a year, and an exposure time of one hour per day.
- Define an inhalation rate for an adult of 20 cubic meters per day.
- Define zero for the number of water intake and bathing events.
- Define zero for ingestion of produce grown in the vicinity of the spring.

The 2017 activity concentration of tritium in the Well 8 Spring is below the site-specific PRG-calculator-derived activity of 52,800 pCi/L for the inhalation pathway of tritium in tap water and well below the MCL drinking water standard of 20,000 pCi/L.

Since 2018, the Well 8 Spring has been dry, and no water samples have been collected. The spring was accessed on May 31 and December 13, 2022, and was dry during both visits. Workers will not occupy this spring in the near future, site use restrictions will be maintained, and the annual sampling will continue when water is available until tritium activity concentrations remain below acceptable levels for at least two years.

4.2. Ecological Risk and Hazard Management

4.2.1. Ecological Risk and Hazard Management Measures and Contingency Plan Actions Required by the 2009 Compliance Monitoring Report/Contingency Plan

The ecological risk and hazard management measures described in the CMP/CP were developed to meet the remedial action objectives for environmental protection. These objectives are designed to meet the following goals:

- Ensure that ecological receptors important at the individual level of ecological organization, including special-status species (i.e., State of California or federally-listed threatened or endangered species, or State of California species of special concern) do not reside in areas where relevant hazard indices exceed 1.
- Ensure that any changes in contaminant conditions do not threaten wildlife populations and vegetation communities.

The CMP/CP requires the following ecological risk and hazard management measures:

- Periodically evaluate available biological survey data from the Building 801 and Building 851 areas and the HEPA OU to determine potential population-level impacts to ground squirrel and deer exposed to cadmium in surface soil in these areas as well as reevaluate the ecological hazard associated with cadmium in surface soil in these areas. Evaluations reported in the 2011 and 2012 annual CMRs showed the presence of cadmium to no longer be a potential ecological hazard to deer and ground squirrel populations or to burrowing or ground-dwelling special-status species. Therefore, cadmium is no longer considered an ecological COC in these areas and has been eliminated from further consideration.

- Ensure the integrity of the Pit 7 Complex landfill caps in preventing uranium exposure to burrowing animals.
- Evaluate changes in existing contaminant and ecological conditions in OUs 1 through 8 every five years, including reevaluating VOCs in burrow air in the event that groundwater VOC concentrations increase to levels that previously posed a risk to burrowing animals. The following five-year ecological reviews have been conducted to date:
    - **The 2008 five-year ecological review (Dibley et al. 2009)**: Evaluated chemical data collected from January 1, 1999, through December 31, 2007, and ecological data collected from January 1, 1999, through December 31, 2008.
    - **The 2013 five-year ecological review (Dibley, Ferry, and Buscheck 2014)**: Evaluated chemical data collected from January 1, 2008, through December 31, 2012, and biological data collected from January 1, 2009, through December 31, 2012.
    - **The 2018 five-year ecological review (Buscheck et al. 2019)**: Evaluated chemical and biological data collected from January 1, 2013, through December 31, 2017.

The 2008 five-year ecological review identified several new constituents in surface water for which ecological hazard could not be adequately evaluated due to either a limited data set or the lack of background data. Most of these constituents have been addressed and reported in the two subsequent CMRs. The remaining constituents were also noted in the 2013 and 2018 five-year ecological reviews and are further discussed in Section 4.2.3.

The CMP/CP also includes a contingency plan that demands periodically reviewing available biological survey data, such as biological data collected when surveying ground-disturbing programmatic activities, biological monitoring data, surveys conducted for environmental impact statement (EIS) or environmental impact report (EIR) preparation, for the presence of new special-status species is required. Any new special-status species identified is to be evaluated for potential impact from the presence of contamination using the process described in the CMP/CP. The results of these periodic reviews are reported in the annual CMRs and specifically in Section 4.2.4.

This and subsequent CMRs that abide by the CMP/CP will continue to provide updates on the required ecological risk and hazard management measures and ecological contingency plan actions.

4.2.2. Uranium in Subsurface Soil within the Pit 7 Complex Landfills

The CMP/CP requires that the Pit 7 Complex landfills be inspected and any burrows or holes in the cover be filled to prevent unacceptable exposure of animals to uranium in the pit waste. This work is completed as part of the inspection and maintenance program implemented at the Pit 7 Complex. Section 3.4 describes the results of the annual landfill engineering inspection and subsidence monitoring as well as any maintenance that was performed.

In May 2022, Abri Environmental Engineering conducted an annual engineering inspection of the Pit 7 cap and found it to be in good condition, and the vegetation cover was thick with no visible erosion (Abri Environmental Engineering 2022c). Some recent animal burrows were also observed.

LLNL inspected the Pit 3 and 5 landfill covers on January 19, April 19, July 13, and October 5, 2022, and determined that they were in good condition.

4.2.3. Constituents Identified in Five-Year Ecological Reviews Requiring Additional Monitoring

The 2018 five-year ecological review identified several constituents in surface soil and subsurface soil for which data were not sufficient to determine a potential ecological hazard. Ecological screening levels were exceeded for several metals and radionuclides present in surface and subsurface soil samples collected in the northeast corner of Site 300 and the Building 851 area. Sampling was conducted in the northeast corner of Site 300 as part of the project to determine background concentrations of metals and radionuclides in soil. Sampling was conducted in the Building 851 area as part of an investigation of constituents in local soil. Both efforts are ongoing. Ecological hazards from metals and radionuclides in the Building 851 soil will be determined when updated background concentrations for metals and radionuclides are established.

With the exception of perchlorate in the Well 8 Spring, no significant changes in COC concentrations were identified in the 2018 five-year ecological review of Site 300 springs located in the OUs covered by the CMP/CP. However, both the 2013 and 2018 five-year ecological reviews noted that data were not sufficient to determine potential ecological hazard for the constituents discussed in the following subsections.

4.2.3.1. Perchlorate

Information presented in the *Focused Remedial Investigation/ Feasibility Study for Perchlorate at the Building 850 Area Lawrence Livermore National Laboratory Site 300* (Verce et al. 2019) determined that perchlorate in the Well 8 Spring, in the Building 850 area of the Building 850/Pit 7 Complex OU, poses a risk to the aquatic life stage of amphibian species. While the spring does not currently support breeding habitats for amphibians, it is located in an area used by special-status amphibian species such as the California tiger salamander and California red-legged frog.

To help evaluate the potential risk posed by perchlorate in the Well 8 Spring, monitoring for the presence of amphibian breeding habitat and special-status amphibians was added to the ecological risk and hazard management program in 2021, in time for the 2023 five-year ecological review.

4.2.3.2. Uranium

The 2013 five-year ecological review identified uranium in Springs 10 and 11 in the Building 854 OU as a constituent for which data were not sufficient to determine potential ecological hazard. While uranium activity concentrations in Spring 11 were not more than 50 percent greater than those detected in review periods previous to 2013, they were greater than the background level at Site 300 (Ferry et al. 1999), and uranium concentrations, as mg/L, were greater than the ecological screening level established for the ecological risk assessment of Building 812 (Carlsen et al. 2012).

The maximum total uranium concentration at Spring 11 in June 2002 and at Spring 10 June 2003 exceeded the Site 300 background concentration at that time. Samples from both springs were analyzed for uranium isotopes using mass spectrometry, and both results showed a natural $^{235}U/^{238}U$ atom ratio of 0.0072. Spring 11 was sampled again in August 2012 and contained a high concentration of uranium of 0.074 mg/L, surpassing the previous maximum background uranium concentration at Site 300, which was 0.028 mg/L as detected in Spring 16. A $^{235}U/^{238}U$ atom ratio of 0.0072 again indicated natural uranium. Spring 10 was dry at this time and remained dry through the 2019 review period.

The natural $^{235}U/^{238}U$ atom ratios in samples collected from the Springs 10 and 11 indicate that these uranium concentrations, though elevated, likely represent background conditions. Uranium concentrations will be periodically monitored in these springs when and if water is present to sample. Due to limitations on personnel during the shelter-in-place protocols demanded by the COVID-19 pandemic, Springs 10 and 11 were only accessed once in 2020 (December) after which they were both dry again. The springs were also dry when accessed in June and December 2021 and June and November 2022. The original location of Spring 11 was buried by a mudslide a few years ago, and its new location south of the original spring has only been observed with, at best, damp soil when accessed.

4.2.3.3. Chloride

The 2013 five-year ecological review also identified chloride in Spring 14 in the HEPA OU as a constituent for which data were not sufficient to determine potential ecological hazard. The historical chloride concentrations detected in Spring 14 in samples collected through May 2001, which ranged from 160 mg/L to 420 mg/L, periodically exceeded the maximum concentration of 210 mg/L observed in Site 300 background springs. However, the chloride concentrations in the two most recent samples collected in December 2003 and March 2013 were at or below this background level at 170 mg/L and 210 mg/L, respectively.

While chloride in Spring 14 does not appear to be an ecological concern, it will be periodically monitored when water is available in this spring to ensure concentrations remain within background levels. Spring 14 was inaccessible in 2017 and 2019 due to overgrown vegetation conditions and has otherwise been dry since 2015. Spring 14 was again dry when accessed in March 2021 and was not accessed during 2022.

4.2.3.4. Phosphorous (as P)

The 2013 five-year ecological review also identified total phosphorus (as P) and ammonia nitrogen in Spring 4 in the Building 832 Canyon OU as constituents for which data were not sufficient to determine potential ecological hazard. The single sample collected in June 2000 from Spring 4 contained 4 mg/L of total phosphorus, exceeding the previous 0.3 mg/L maximum concentration of total phosphorus observed in Site 300 background springs. The 8.7 mg/L maximum concentration of ammonia nitrogen in Spring 4 was also detected in the June 2000 sample, which is the most recent sample available that was analyzed for this constituent. Spring 17, a Site 300 background spring, was sampled in August 2012 (during the review period for the 2013 five-year ecological review), and ammonia nitrogen was detected at a concentration of 0.52 mg/L.

Spring 4 has been dry since 2007 and was still dry when accessed in August and November 2022. Spring 4 will be periodically sampled for ammonia nitrogen and total phosphorus analysis when water is available to provide additional data for these constituents.

4.2.4. Identification and Evaluation of New Special-Status Species

Contingency actions described in the CMP/CP include periodically evaluating available biological survey data for the presence of new special-status species and reporting the results of the evaluation in the annual CMRs. DOE/LLNL wildlife biologists obtain the results of biological surveys and determine any changes in the regulatory status of species occurring at Site 300.

In 2022, routine monitoring surveys were conducted at Site 300 for California red-legged frogs, California tiger salamanders, western burrowing owls and other nesting raptors, tricolored blackbirds, and rare plants. These species continue to occur in areas and habitat within Site 300, as described in the 2018 five-year ecological review (Buscheck et al. 2019).

4.2.4.1. California Red-legged Frog and California Tiger Salamander

Year-to-year variations in the suitability of Site 300 seasonal pools for California tiger salamander and California red-legged frog breeding are normal. However, Site 300 amphibians are particularly vulnerable to changes in rainfall patterns because they rely on seasonal pools that are only expected to fill with water during years of average or greater rainfall. Several seasonal pools that provide breeding habitat for the California tiger salamander and California red-legged frog at Site 300 did not fill in the winter of 2021–2022.

While Pools M1a and M1b continue to be the most successful, consistent breeding habitats for California red-legged frogs at Site 300, extreme drought conditions during the winters of 2020–2021 and 2021–2022 impacted the breeding success of this species. No evidence of California red-legged frog reproduction was observed at Site 300 in 2021, the first time since the initial habitat restoration project at this location was conducted in 2005. In 2022, Pools M1a and M1b did fill late in March, and one California red-legged frog egg mass was observed.

Three daytime amphibian surveys were conducted at Spring 8 during the 2021–2022 winter, specifically between October 2021 and February 2022. The wetland was unusually dry during this time, and no California red-legged frogs were observed. These frogs were not expected to use the Spring 8 wetland in 2022 due to drought conditions. Spring 8 is within the distance from Pool M2, Pool A, and Pool SG, known California red-legged frog aquatic habitats where that these frogs are known to migrate (U.S. FWS 2010), and it is possible they disperse through the Spring 8 area very infrequently. In 2022, no evidence of aquatic or breeding habitats for the California red-legged frog was observed at Spring 8.

In 2022, California tiger salamander eggs were observed in Pool OS and a concrete v-ditch that is part of the Pit 7 landfill cap drainage system. The remaining Site 300 seasonal pools, Pools A, H, M2, HC1, S, M3, and Lower and Upper D, did not fill in 2022 due to drought conditions. Therefore, California tiger salamanders were not able to reproduce in these locations. None of the pools, including Pool OS, remained inundated long enough for California tiger salamander metamorphosis.

4.2.4.2. Western Burrowing Owls and Swainson’s Hawks

In the spring and summer of 2022, surveys to determine the location and success of nesting pairs of western burrowing owls were conducted throughout Site 300. Five pairs of nesting western burrowing owls were observed throughout Site 300 at locations previously used by this species. In

2022, a pair of western burrowing owls successfully nested within the area where over 27,000 yd^3 of PCB-bearing soil were excavated and disposed of in a CAMU in 2009. The presence of this nesting area, approximately 350 feet west of Building 850, indicates that the grassland habitat surrounding Building 850 has largely recovered from the impact of the soil remediation.

Surveys for nesting raptors other than western burrowing owls were also conducted at Site 300 in the spring and summer of 2022. Although no Swainson's hawks were observed nesting during these surveys, wildlife biologists observed them foraging over the northern half of Site 300 during the summer of 2022. Common raptor species, including red-tailed hawks, great-horned owls, and barn owls, were observed nesting at Site 300 in 2022.

4.2.4.3. Tricolored Blackbirds

LLNL biologists annually track a nesting tricolored blackbird colony at Site 300. Tricolored blackbirds (*Agelaius tricolor*) are listed as threatened under the California Endangered Species Act and as protected by the federal Migratory Bird Treaty Act. This species occurs in colonies that travel seasonally between nesting and foraging habitat.

Tricolored blackbirds are known to nest within wetland habitat in Elk Ravine both upstream and downstream of Building 812 and occasionally in a small, isolated wetland north of Elk Ravine. In 2022, a tricolored blackbird colony was observed at Site 300, arriving in mid-March and remaining onsite until mid-May. The colony continued to be very small with less than 500 tricolored blackbirds observed within Elk Ravine.

4.2.4.4. Fire Trail Surveys

In 2022, routine biological surveys included pre-activity surveys conducted prior to fire trail grading. Approximately 85 miles of dirt fire trails are graded annually at Site 300, and fire trail surveys are conducted each spring in preparation. During fire trail surveys, LLNL wildlife biologists traverse all Site 300 fire trails in a six-wheeled off-road vehicle or a four-wheel drive truck, making stops at vantage points or sensitive habitat features and performing surveys with binoculars or on foot. Biologists typically search for burrows that can provide habitat for protected species (i.e., California red-legged frogs, California tiger salamanders, badger, burrowing owls) and nesting birds. Other special status species are noted when observed.

In 2022, Blainsville's horned lizards and American badger were observed during the fire trail surveys, showing that these two California Special Status Species occurred in several areas throughout Site 300.

5. Data Management Program

Data collected during the second semester of 2022 is managed through an internal data management process and protocols established in ERD's standard operating procedures (SOPs) (Goodrich and Lorega 2016). This process includes sample planning, chain-of-custody (COC) tracking, sample collection history, electronic and hard copy analytical results receipt, strict data validation and verification, data quality control procedures, and data retrieval and presentation.

From the initial sampling plan through data storage and reporting, a relational database is used to track sample and analytical information. ERD employs The Environmental Information Management System (TEIMS), web-based system that facilitates data management and retrieval and promotes a consistent data set of known quality. Quality assurance and control (QA/QC) are performed regularly on all data. Improvements and additions to the data management process are continuously implemented in an ongoing effort to automate and upgrade applications.

5.1. Modifications to Existing Procedures

During the second semester of 2022, the relational database's software, Oracle version 19.15.2.0.0, was kept current by regularly applying security patches, and the operating system remained Linux RHEL 7.9. General maintenance and refinements continued in both the database and web-application programming.

Furthermore, the following improvements were released during this reporting period:

- The ability to send email notifications from the Account Request tool was improved.
- Several features were added to Sampling Estimator tool. Specifically, a column for parameter code was added to the pivoted grid, quantity was added to the Wishlist selection, and sample-collection information was incorporated.
- The Report Wizard air log report was modified to include more date options, improved footnotes, standardized calculation for operational days, a note to Site 300 air logs for the start date of data collection, and the addition of document reference numbers for both Livermore Site and Site 300 air log reports.
- Selectors used to generate the quarterly monitoring report (QMR) analytical tables were modified to automatically default to the current reporting year and quarter, and an error in the page numbering was corrected.
- Document reference numbers were added to the self-monitoring reports (SMRs) and land observations.
- Table 2.4 of the CMR was modified to use the standard method for calculating total uranium.
- More information regarding how negative numbers are handled was added to Tool Help in the Total Uranium tool.
- Password requirements to log in to Oracle were modified to align more closely with LLNL's institutional password requirements.
- Wastewater discharge authorization record (WDAR) report tables and single record views were updated to provide a CSV download link that replaces options for unusable data table downloads.
- A link was added to the "Import Holding Tables to Work Tables" screen for a Tableau report that groups together the four related electronic data-deliverable files. An additional link was also included to the Confluence page to explain how to use the Tableau report.
- The ability to search by analytical laboratory was added to the advanced search options of Sample Event Tracker.

- The Treatment Facility Real-Time Data tool was modified to allow influent tank data to be displayed for legacy facilities.
- A standard for selecting appropriate location types for certain tool queries, such as borehole/well spec and borehole lithology, was implemented.
- Red asterisks were added to identify required fields in the Field Location Entry tool.
- Seconds were added to the electronic data-deliverable file names to allow analytical laboratories to upload files more quickly.
- A new verification was added to check for duplicated batch numbers in the QC analysis table. The work sample table Verification 132, which checks for duplicates, was modified to include analytes in the comparison. Additionally, a new verification 158 that compares wsample to coc_details was added; it returns rows where the wsample.log_no + wsample.sampled match coc_details.log_no + coc_details.sampled (for date, not time) but the field location identifiers do not match. Verifications for global COC data were also modified to only search the last three months, thus reducing the number of rows returned and making these verifications more useful. Additionally, a verification was added to prevent duplicating sample date and time for more than one location on a single COC.

5.2. New Procedures

To improve maintainability and user efficiency, existing computer programs that generate data-driven web pages continue to be rearchitected. At this time, the foundational infrastructure code is being updated from the programming language Perl to Python, and the user interface and web page capabilities are being improved.

The following software development processes and procedures have been implemented as part of the rearchitecting effort:

- The underlying design is moving to a service-oriented architecture. Common functionalities have been encapsulated into independent services to increase code reusability and maintainability, allowing individual services to be changed and upgraded with minimal disruption to the rest of the system.
- Static analysis is being included for the early identification of syntax and other errors. This improvement is incorporated into integrated developer environments (IDE) and also performed automatically as a prerequisite to any code being checked into production-bound code repositories.
- Software development standards have been established to promote consistency among all components to reduce the overall burden of system maintenance.
- Software-based tests are now being enforced as a requirement to accomplish unit, functional, integration, and regression testing. Test coverage metrics are tracked per component per application, as well as for the overall system, with a coverage target of above 80 percent.
- All software code undergoes peer review prior to being incorporated into production-bound code repositories.

- All applications undergo multiple reviews by users and customers prior to production release, and web tools are beta-tested prior to formal release.

The following new web tool was also released:

- The COC PDF was converted to new software and released in all applications using COC.

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7. Acronyms and Abbreviations

1,1-DCA	1,1-Dichloroethane
1,2-DCA	1,2-Dichloroethane
1,1-DCE	1,1-Dichloroethene
1,2-DCE	1,2-Dichloroethene (total)
1,1,1-TCA	1,1,1-Trichloroethane
1,1,2-TCA	1,1,2-Trichloroethane
2-ADNT	2-Amino-4,6-dinitrotoluene
4-ADNT	4-Amino-2,6-dinitrotoluene
815	Building 815
817	Building 817
829	Building 829
830	Building 830
832	Building 832
834	Building 834
845	Building 845
850	Building 850
851	Building 851
854	Building 854
A	annual
amsl	above mean sea level
AS	alpha spectrometry
As N	as nitrogen
As $CaCO_3$	as calcium carbonate
BA	blanket agreement
BGS	below ground surface
BTEX	benzene, toluene, ethyl benzene, and xylene
°C	degrees Celsius
C12-C24	diesel range organic compounds in the 12 carbon to 24 carbon range
CAL	contracted analytical laboratories
CAMU	corrective action management unit
CAP	corrective and preventative action program
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cf	cubic feet
cfm	cubic feet per minute
CFORM	chloroform
CGSA	Central General Services Area
CHC	Corral Hollow Creek
cis-1,2-DCE	*cis*-1,2-Dichloroethene
CMP/CP	compliance monitoring plan/contingency plan
CMR	compliance monitoring report

CO_2	carbon dioxide
COC	contaminant of concern
CTA	cleanup time analysis
CTET	carbon tetrachloride
DDS	drainage diversion system
DIS	discretionary sampling (not required by the CMP)
DISS	distal south
DMW	detection monitor well
DNAPL	dense non-aqueous-phase liquid
DO	dissolved oxygen
DOE	Department of Energy
DOECAP	Department of Energy Consolidated Audit Program
DSB	distal site boundary
DTSC	Department of Toxic Substances Control
DUP	duplicate or collocated QC sample
E	effluent (acronym found in treatment facility sampling plan tables)
E	sample to be collected during even numbered years (i.e., 2016) (acronym found in sampling plan tables)
EcoSSLs	ecological soil screening levels
EFA	environmental functional area
EGSA	Eastern General Services Area
EIS/EIR	environmental impact statement/environmental impact report
EMS	environmental management system
EPA	Environmental Protection Agency
ES&H	Environmental Safety and Health
EV	effluent vapor
EW	extraction well
FEFLOW	finite element subsurface FLOW system
Freon 11	trichlorofluoromethane
Freon 113	1,1,2-trichloro-1,2,2-trifluoroethane
ft	feet
ft^3	cubic feet
FY	fiscal year
g	gram(s)
GAC	granular activated carbon
gal	gallon(s)
GIS	geographic information systems
gpd	gallons per day
gpm	gallons per minute
GSA	General Services Area
GTU	groundwater treatment unit
GW	guard well

GWES	groundwater extraction system
GWTS	groundwater treatment system
GW-ADV	groundwater to indoor air pathway, advanced version
HE	high explosives
HEPA	High Explosives Process Area
HMX	high-melting explosive
HQ	hazard quotient
HSU	hydrostratigraphic unit
I	influent
ICP-MS	inductively coupled plasma-mass spectrometry
IDE	integrated developer environments
inHg	inches of mercury
ISMA	*in situ* microcosm array
ISMS	integrated safety management system
ISO	International Organization for Standardization
ITS	issues tracking system
IV	influent vapor
IW	injection well
IWS	integrated work sheet
JEM	Johnson and Ettinger Model
K-40	potassium-40
KB-1™	consortium of dechlorinating bacteria that contain *Dehalococcoides ethenogenes*
kft^3	thousands of cubic feet
kg	kilograms
kgal	thousands of gallons
KPA	kinetic phosphorescence analysis
LAS	Lidar Base Specification from the National Geospatial Program for file formats
LCS	laboratory control sample
LHC	light hydrocarbon
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security
LNAPL	light non-aqueous-phase liquid
µg/L	micrograms per liter
µg/m^3	micrograms per meters cubed
µmhos/cm	micro ohms per centimeter
µS	microsiemens
M	monthly
MCL	maximum contaminant level
MeCL	methylene chloride
Mgal	millions of gallons
Mg/kg/d	milligram per kilogram per day

mg/L	milligrams per liter
MNA	monitored natural attenuation
MS	mass spectrometry
MSA	mean sea level
mV	millivolts
MWB	monitor well used for background
N	no
NB	nitrobenzene
N_2	nitrogen gas
NO_3	nitrate
NA	not applicable
NT	nitrotoluene
NTU	nephelometric turbidity units
O	sample to be collected during odd numbered years (i.e., 2015)
OR	occurrence report
ORP	oxidation/reduction potential
OU	operable unit
O&M	operations and maintenance
P/PO_4	phosphorus/phosphate ion
PBA	programmatic biological assessment
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
pCi/L	picoCuries per liter
pH	measure of the acidity or alkalinity of an aqueous solution
ppb_v	parts per billion by volume
$ppm_{v/v}$	parts per million on a volume-to-volume basis
PPCP	pharmaceutical and personal care product analytes
PRG	preliminary remediation goal
PRX	proximal
PRXN	proximal north
PTU	portable treatment unit
PVC	polyvinyl chloride
Q	quarterly
Qal	quaternary alluvium
QA/QC	quality assurance/quality control
QC	quality control
QIF	quality improvement form
RAOs	remedial action objectives
R1	receiving water sampling point located 100 ft upstream
R2	receiving water sampling point located 100 ft downstream
RCRA	Resource Conservation and Recovery Act
RD	remedial design

RDX	Research Department Explosive
REA	reanalysis
Redox	reduction-oxidation reaction
REVAL	remediation evaluation process
REX	resample
RHEL	Red Hat® Enterprise Linux®
RI/FS	remedial investigation/feasibility study
ROD	record of decision
ROI	radius of influence
RPM	remedial project manager
RWQCB	Regional Water Quality Control Board
S	semi-annual
scfm	standard cubic feet per minute
SJVAPCD	San Joaquin Valley Air Pollution Control District
SLs	statistical limits
SOP	standard operating procedure
SPACT	sample planning and chain of custody tracking
SPR	spring
SRC	source
STFCS	standard treatment facility control system
STU	solar-powered treatment unit
SVE	soil vapor extraction
SVTS	soil vapor treatment system
SVI	soil vapor influent
SVRA	State Vehicular Recreation Area (Carnegie)
SWEIS	site-wide environmental impact statement
SWRESR	site-wide remediation evaluation summary report
SWFS	site-wide feasibility study
SWPPP	Storm Water Pollution Prevention Program
SWRI	site-wide remedial investigation
T2	study area within the distal area of Building 834
TBOS	tetrabutyl orthosilicate
TCE	trichloroethene
TCEP	tris (2-chloroethyl) phosphate
TDS	total dissolved solids
TEIMS	The Environmental Information Management System
TF	treatment facility
TFRT	treatment facility real time
THMs	trihalomethanes
TKEBS	tetrakis (2-ethylbutyl) silane
TNB	trinitrobenzene
TNT	trinitrotoluene

Total-1,2-DCE	1,2-Dichloroethene (total)
trans-1,2-DCE	*trans*-1,2-dichloroethene
TRV	toxicity reference value
TVOC	total volatile organic compounds
TWA	time-weighted average
t-1,2-DCE	*trans*-1,2-Dichloroethene
$^{235}U/^{238}U$	atom ratio of the isotopes uranium-235 and uranium-238
U.S.	United States
VC	vinyl chloride
VCF4I	fourth vapor phase granular activated carbon filter influent
VE	vapor effluent
VES	vapor extraction system
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound
WAA	waste accumulation area
WBR	weathered bedrock
WDR	waste discharge requirements (program)
WGMG	water guidance and monitoring group
WP&C	institutional-wide work planning and control
WS	water-supply well
Y	yes
yd^3	cubic yards

Stratigraphic Units

Qal =	Quaternary alluvium
Qls =	Quaternary landslide deposits
Qt =	Quaternary terrace deposits
WBR =	weathered bedrock
Tps =	Pliocene non-marine unit
Tpsg =	Pliocene non-marine unit (gravel facies)
$Tnsc_2$ =	Miocene Neroly Formation upper siltstone/claystone
$Tnbs_2$ =	Miocene Neroly Formation upper blue sandstone
$Tnsc_{1a}$, $Tnsc_{1b}$, $Tnsc_{1c}$ =	Sandstone bodies within the $Tnsc_1$ Neroly Formation middle siltstone/claystone ($Tnsc_1$) (1a = deepest)
$Tnbs_1$ =	Neroly Formation lower blue sandstone
Upper $Tnbs_1$ ($UTnbs_1$) =	Upper member of the Neroly Formation lower blue sandstone, above claystone marker bed
Lower $Tnbs_1$ =	Lower member of the Neroly Formation lower blue sandstone, below claystone marker bed (regional aquifer)
$Tnbs_0$ =	Neroly Formation basal sandstone
$Tnsc_0$ =	Miocene Neroly Formation lower siltstone/claystone
Tmss =	Miocene Cierbo Formation
Tts =	Eocene Tesla Formation

Data Qualifier Flag Definitions

B = Analyte found in method blank, sample results should be evaluated.
D = Analysis performed at a secondary dilution or concentration.
E = The analyte was detected below the LLNL reporting limit, but above the analytical laboratory minimum detection limit.
F = Analyte found in field blank, trip blank, or equipment blank.
G = Quantitated using fuel calibration but does not match typical fuel fingerprint.
H = Sample analyzed outside of holding time, sample results should be evaluated.
I = Surrogate recoveries were outside of QC limits.
J = Analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
L = Spike accuracy not within control limits.
O = Duplicate spike or sample precision not within control limits.
R = Sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
S = Analytical results are rejected due to serious deficiencies in the ability to analyze the sample and meet QC criteria. The presence or absence of the analyte cannot be verified.
T = Analyte is tentatively identified compound; result is approximate.