

7. Groundwater Investigation and Remediation

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Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore Site and Site 300. The sites are similar in that the contamination is, for the most part, confined on site. The sites differ in that Site 300, with an area of 28.3 km² (10.9 mi²), is much larger than the Livermore Site and has been divided into nine operable units (OUs) based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore Site at 3.3 km² (1.3 mi²) is effectively one OU.

7.1 Livermore Site Environmental Restoration Project

Initial releases of hazardous materials occurred at the Livermore Site in the mid-to-late 1940s during operations at the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed VOCs, fuel hydrocarbons, metals, and tritium to the unsaturated zone and groundwater in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency National Priorities List in 1987.

An analysis of all environmental media showed that groundwater and both saturated and unsaturated soils are the only media that require remediation (Thorpe et al. 1990). Compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (MCLs) are TCE, PCE, 1,1-dichloroethylene, cis-1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, and carbon tetrachloride. PCE is also present at low concentrations slightly above the MCL in off-site plumes that extend from the southwestern corner of the Livermore Site. LLNL operates groundwater extraction wells in both on-site and off-site areas. In addition, LLNL maintains an extensive network of groundwater monitoring wells in the off-site area west of Vasco Road.

7.1.1 Physiographic Setting

The general topography of the Livermore site is described in **Chapter 1**. The Livermore Valley groundwater system consists of several semiconfined aquifers. Rainfall from the surrounding hills and seasonal surface water in the arroyos recharge the groundwater system, which flows toward the east-west axis of the valley.

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The thickest sediments and aquifers are present in the central and western portions of the Livermore Valley, where they form an important resource for the Zone 7 Water Agency. These sediments comprise two aquifers: the Livermore Formation and overlying alluvium. The Livermore Formation averages about 1,000 m in thickness and occupies an area of approximately 250 km². The alluvium, which is about 100 m thick, is the principal water-producing aquifer within the valley.

7.1.2 Hydrogeology of the Livermore Site

Sediments at the Livermore site are grouped into four grain-size categories: clay, silt, sand, and gravel. Groundwater flow beneath the site occurs primarily in alluvial sand and gravel deposits, which are bounded by lower permeability clay and silt deposits. The alluvial sediments have been subdivided into nine HSUs beneath the Livermore site. HSUs are defined as sedimentary sequences whose permeable layers show evidence of being hydraulically interconnected and geochemically similar. Six of the nine HSUs contain contaminants at concentrations above their MCLs: HSU-1B, -2, -3A, -3B, -4, and -5 (Blake et al. 1995; Hoffman et al. 2003). HSU-1A, -6, and -7 do not contain contaminants of concern above action levels.

7.1.3 Remediation Activities and Monitoring Results

In 2012, LLNL maintained and operated 28 ground water treatment facilities. The groundwater extraction wells and dual (groundwater and soil vapor) extraction wells produced more than 1,086 million L of groundwater and the treatment facilities removed 47 kg of VOCs. Since remediation began in 1989, approximately 17.7 billion L of groundwater have been treated, resulting in removal of more than 1,541 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2013).

LLNL also maintained and operated 9 soil vapor treatment facilities in 2012. The soil vapor extraction wells and dual extraction wells produced more than 1.5 million m³ of soil vapor and the treatment facilities removed 29 kg of VOCs. Since initial operation, nearly 15.3 million m³ of soil vapor has been extracted and treated, removing more than 1,504 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2013).

Seven treatment facilities remained offline in 2012:

- Treatment Facility A-West
- VTFD Helipad
- VTFD Hotspot
- TF5475-1
- TF5475-3
- VTF5475
- TF518 North

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Treatment Facility A-West was decommissioned and replaced by the TFA Arroyo Seco Pipeline extension to expedite treatment of an offsite VOC ground water plume in 2012 (Bourne et al. 2011). VTFD Helipad remained off-line in support of the *in situ* bioremediation Enhanced Source Area Remediation (ESAR) treatability test at the TFD Helipad Source area. VTFD Hotspot was not operated during 2012 to evaluate an alternate approach of cyclic ground water extraction from the TFD Hotspot wells. The four remaining facilities were discussed in the DRAFT Focused Feasibility Study of Methods to Minimize Mixed Hazardous and Low Level Radioactive Waste from Soil Vapor and Ground Water Treatment Facilities at the Lawrence Livermore National Laboratory Site (Bourne et al. 2010) for Treatment Facilities TF5475-1, TF5475-3, VTF5475 and TF518 North. With the U.S. EPA concurrence, restart of these four facilities has been deferred pending the results of ESAR treatability tests. DOE/LLNL continue to monitor ground water for VOCs and tritium. See Buscheck et al. (2013) for more information on the Livermore Site ground water and soil vapor treatment facilities.

Restoration activities in 2012 at the Livermore Site were primarily focused on enhancing and optimizing ongoing operations at treatment facilities, while continuing to evaluate technologies that could be used to accelerate clean up of the Livermore Site source areas and to address the mixed-waste management issue discussed in the DRAFT Focused Feasibility Study of Methods to Minimize Mixed Hazardous and Low Level Radioactive Waste from Soil Vapor and Ground Water Treatment Facilities at the Lawrence Livermore National Laboratory Site (Bourne et al. 2010).

An ESAR bioremediation treatability test continued at the TFD Helipad, as did the ESAR conductive heating treatability test at TFE Eastern Landing Mat. Both are expected to continue through 2013. Data analysis and interpretation of the ESAR pneumatic fracturing treatability test at TFE Hotspot was conducted during 2012. Results of the test will be presented in a 2013 white paper. Preliminary findings from the test are being used to finalize the design of the proposed ESAR treatability test using pneumatic fracturing and zero valent iron (ZVI) to initiate *in situ* VOC destruction at TFC Hotspot.

Additional Livermore Site environmental restoration activities performed in 2012 included:

- Activation of two new extraction wells and pipelines at TFB.
- Improving Livermore Site treatment facility hours of operation by 6% over 2011, excluding treatment facilities in ESAR treatability test areas.
- Assisting with soil sampling in support of the Resource Conservation and Recovery Act (RCRA) closure of Building 419.
- Recompletion of eight monitor wells in the TFD and TFG areas, and redevelopment of extraction wells at TF406 Northwest and at TFD Southeast.

The Livermore Site environmental restoration project had 11 milestones scheduled for completion in 2012. All milestones were met (see Chapter 2).

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Groundwater concentration and hydraulic data indicate subtle but consistent declines in the VOC concentrations and areal extent of the contaminant plumes in 2012. Hydraulic containment along the western and southern boundaries of the site was fully maintained in 2012, and progress was made toward interior plume and source area clean up. See Buscheck et al. (2013) for the current status of cleanup progress.

7.1.4 Environmental Impacts

LLNL strives to reduce risks arising from chemicals released to the environment, to conduct all its restoration activities to protect environmental resources, and to preserve the health and safety of all site workers. LLNL's environmental restoration project is committed to preventing present and future human exposure to contaminated soil and groundwater, preventing further contaminant migration of concentrations above drinking water standards, reducing concentrations of contaminants in groundwater, and minimizing contaminant migration from the unsaturated zone to the underlying groundwater.

Remedial solutions that have been determined to be most appropriate for individual areas of contamination are implemented. The selected remedial solutions, which include groundwater and soil vapor extraction and treatment, have been agreed upon by DOE and the regulatory agencies with public input and are designed to achieve the goals of reducing risks to human health and the environment and satisfying remediation objectives, and of meeting regulatory standards for chemicals in water and soil, and other state and federal requirements.

7.2 Site 300 Environmental Restoration Project

A number of contaminants were released to the environment during past LLNL Site 300 operations including waste fluid disposal to dry wells, surface spills, piping leaks, burial of debris in unlined pits and landfills, detonations at firing tables, and discharge of rinse water to unlined lagoons. Environmental investigations at Site 300 began in 1981. As a result of these investigations, VOCs, high explosive compounds, tritium, depleted uranium, organosilicate oil, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals were identified as contaminants of concern in soil, rock, groundwater, or surface water. This contamination is confined within the site boundaries with the exception of VOCs that are present in off-site monitor wells near the southern site boundary. LLNL maintains an extensive network of on-site and off-site wells to monitor this contamination. All characterized contaminant release sites that have a CERCLA pathway have been assigned to one of nine OUs based on the nature, extent, and sources of contamination, and topographic and hydrologic considerations. Site 300 was placed on the U.S. Environmental Protection Agency National Priorities List in 1990. Cleanup activities began at Site 300 in 1982 and are ongoing.

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in Webster-Scholten (1994), *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300* (Taffet et al., 2005), and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006).

7.2.1 Physiographic Setting and Geology of Site 300

Site 300 is located in the southeastern Altamont Hills of the Diablo range. The topography of Site 300 consists of a series of steep hills and canyons generally oriented northwest to southeast. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones of the late Miocene Neroly Formation (Tn), and a Pliocene nonmarine unit (Tps). The bedrock units are locally overlain by mid- to late-Pleistocene terrace deposits and late-Pleistocene to Holocene floodplain, ravine fill, landslide, and colluvial deposits.

The bedrock within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site.

7.2.2 Contaminant Hydrogeology of Site 300

Site 300 is a large and hydrogeologically diverse site. Due to the steep topography and structural complexity, stratigraphic units and groundwater contained within many of these units are discontinuous across the site. Consequently, site-specific hydrogeologic conditions govern the occurrence and flow of groundwater and the fate and transport of contaminants beneath each OU.

An HSU is a water-bearing zone that exhibits similar hydraulic and geochemical properties. At Site 300, HSUs have been defined consisting of one or more stratigraphic intervals that compose a single hydraulic system within one or more OU. Groundwater movement and contaminant migration in groundwater are discussed in the context of HSUs.

Groundwater contamination at Site 300 occurs in three types of water-bearing zones:

1. Quaternary deposits including the alluvium and weathered bedrock (Qal/WBR HSU), alluvial terrace deposits (Qt), and landslide deposits (Qls HSU).
2. Tertiary perched groundwater in fluvial sands and gravels (Tpsg HSU) and semilithified silts and clay of the Tps HSU.
3. Tertiary Neroly Formation bedrock including the Tnsc₂, Tnbs₂, Tnsc_{1b}, Tnbs₁, Tnbs₀, and Tnsc₀ HSUs.

Groundwater in bedrock is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out.

7.2.3 Remediation Activities and Monitoring Results

Cleanup activities were initiated at Site 300 in 1982 and are underway or are in the process of being implemented at all nine OUs. These activities include:

- Operating up to 20 groundwater and soil vapor extraction and treatment facilities.
- Capping and closing four landfills, six high explosives rinse water lagoons and one high explosives burn pit.

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- Removal and/or closure of numerous dry wells throughout the site.
- Removal of contaminated soil from source areas throughout the site.
- Installation of a drainage diversion system at the Pit 7 Complex to prevent groundwater from rising into the landfills and releasing contaminants in the waste.
- Remediation (consolidation and solidification) of 29,000 cubic yards of PCB-, dioxin-, and furan-contaminated soil in a Corrective Action Management Unit (CAMU) at Building 850.
- Treatability studies for the *in situ* bioremediation of VOCs and perchlorate in groundwater.
- Installation and sampling of over 680 groundwater monitor wells to track plume migration and remediation progress.

These remediation efforts have resulted in (1) the elimination of risk to on-site workers from contaminant exposure at eight locations throughout Site 300, (2) a reduction in maximum concentrations of the primary contaminant (VOCs) in Site 300 groundwater by 50% to 99%, and (3) the remediation of VOCs in groundwater in the Eastern General Services Area to meet cleanup standards (see Chapter 2).

In 2012, the Site 300 Environmental Restoration Project operated 15 groundwater and 5 soil vapor treatment facilities extracting and treating approximately 38.3 million L of groundwater and 2.8 million m³ of contaminated soil vapor. The Site 300 treatment facilities removed nearly 20 kg of VOCs, 0.081 kg of perchlorate, 1,500 kg of nitrate, 0.19 kg of the high explosive compound RDX, 0.00023 kg of silicone oils (TBOS/TKEBS), and 0.0049 kg of uranium in 2012. Since groundwater remediation began in 1990, approximately 1,538 million L of groundwater and over 20.4 million m³ soil vapor have been treated, resulting in removal of more than 580 kg of VOCs, 1.3 kg of perchlorate, 12,000 kg of nitrate, 1.8 kg of RDX, 9.5 kg of silicone oils, and 0.017 kg of uranium. Tritium in ground water continues to decay on site, reducing tritium activities in Site 300 ground water. Detailed flow and mass removal by OU is presented in Dibley et al. (2013).

Cleanup remedies have been fully implemented and are operational in eight of the nine OUs at Site 300 to date (Operable Unit 8 and General Services Area, Building 834, Pit 6 Landfill, High Explosives Process Area, Building 850/Pit 7 Complex, Building 854, and Building 832 Canyon OUs). The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011. Building 812 characterization activities were initiated in 2011 and continued in 2012. These activities included:

- Drilling three new ground water monitor wells and 31 boreholes to better characterize ground water and surface and subsurface soil contamination.
- Sampling surface soil, vegetation, and invertebrates for laboratory analysis.
- Performing High Purity Germanium (HPGe) detector gamma surveying for uranium-238 in subsurface soil to better determine the vertical extent of uranium in subsurface soil.

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- Conducting a seismic survey of alluvium and decomposed bedrock to determine the volume and geometry of rippable material that can be excavated with conventional equipment in the Building 812 Canyon to support development of soil remediation alternatives.
- Continuing gamma radiation surveying to better define the extent of uranium-238 in Building 812 surface soil.

The results of the surface soil gamma survey indicate that additional characterization activities are necessary to bound uranium activities in surface soil in the Building 812 area. These activities are being scheduled for 2013.

Additional Site 300 Environmental Restoration Project activities performed in 2012 included:

- Installing four new ground water monitor wells and one groundwater extraction well to increase contaminant capture and mass removal.
- Completing the Building 815-Distal Site Boundary treatment facility extraction wellfield expansion to increase capture of contaminants at the site boundary.
- Inspecting and maintaining the Pit 7 drainage diversion system and Building 850 Corrective Action Management Unit.
- Continuing the Building 850 In Situ Perchlorate Bioremediation Treatability Test.
- Completing the Pit 7- Source and Building 815-Source treatment facility extraction wellfield expansions to increase contaminant mass removal.
- Finalizing the Exposure Parameters for the Deer Mouse and Rock Wren at Lawrence Livermore National Laboratory Site 300.
- Submitting the Draft Mammalian and Avian Toxicity Reference Values for use in the Building 812 Baseline Ecological Risk Assessment at Lawrence Livermore National Laboratory Site 300.
- Submitting the Draft Eastern General Services Area Final Close Out Report.

The Site 300 environmental restoration project had 8 milestones scheduled for completion in calendar year 2012. All milestones were met (see Chapter 2).

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2012 provided evidence of continued progress in reducing contaminant concentrations in Site 300 soil vapor and groundwater, controlling and cleaning up contaminant sources, and mitigating risk to on-site workers. A more detailed description of remediation progress at the Site 300 OUs in 2012 is available in the *2012 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2013).

7.2.4 Environmental Impacts

LLNL strives to reduce elevated risks arising from chemicals released to the environment at Site 300, to conduct its activities to protect ecological resources, and to protect the health and

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safety of site workers. LLNL's cleanup remedies at Site 300 are designed and implemented to achieve the goals of reducing risks to human health and the environment and satisfying remediation action objectives, meeting cleanup standards for chemicals and radionuclides in water and soil, and preventing contaminant migration in groundwater to the extent technically and economically feasible. These remedies are selected by DOE and the regulatory agencies with public input. These actions include groundwater and soil vapor extraction and treatment; source control through the capping of lagoons and landfills, removal and remediation of contaminated soil, and hydraulic drainage diversion; and monitored natural attenuation, monitoring, and institutional controls.