Executive Summary

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs including countering the proliferation of weapons of mass destruction, strengthening homeland security, and conducting major research in atmospheric, earth, and energy sciences, bioscience and biotechnology, and engineering, basic science, and advanced technology. The Laboratory is managed and operated by Lawrence Livermore National Security, LLC (LLNS) and serves as a scientific resource to the U.S. government and a partner to industry and academia.

LLNL operations have the potential to release a variety of constituents into the environment via atmospheric, surface water, and groundwater pathways. Some of the constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to research facilities like LLNL. All releases are highly regulated and carefully monitored. Engineering and administrative controls are applied to minimize releases.

LLNL strives to maintain a safe, secure, and efficient operational environment for its employees and neighboring communities. Experts in environment, safety, and health (ES&H) support all Laboratory activities. LLNL's radiological control program ensures that radiological exposures and releases are reduced to as low as reasonably achievable to protect the health and safety of its employees, contractors, the public, and the environment.

LLNL is committed to enhancing its environmental stewardship and managing potential operational impacts on the environment through a formal Environmental Management System (EMS). The Laboratory encourages public participation in matters related to LLNL's environmental impact on the community. LLNL also provides public access to information about ES&H activities through websites and public meetings.

LLNL consists of two sites – the Livermore Site and Site 300. The Livermore Site is an urban site in Livermore, California which occupies 1.3 square miles. Site 300 is a rural Experimental Test Site near Tracy, California which occupies 10.9 square miles. In 2022, the Laboratory had a staff of approximately 8,500.

Purpose and Scope of the Environmental Report

The purposes of the *Environmental Report 2022* are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present environmental monitoring results. Specifically, the report discusses LLNL's EMS; describes significant accomplishments in pollution prevention; presents the results of air, water, vegetation, and foodstuff monitoring; reports radiological doses from LLNL operations; summarizes LLNL's activities involving special status wildlife, plants, and habitats; and describes the progress LLNL has made in remediating groundwater contamination.

Environmental monitoring at LLNL, including analysis of samples and data, is conducted according to documented standard operating procedures. Duplicate samples are collected and analytical results are reviewed and compared to internal acceptance standards.

This report is prepared for DOE by LLNL's Environmental Functional Area (EFA). Submittal of the report satisfies requirements under DOE Order 231.1B, "Environment, Safety and Health Reporting" and DOE Order 458.1, "Radiation Protection of the Public and Environment." The report is distributed electronically and is available to the public at https://aser.llnl.gov. Previous LLNL annual environmental reports beginning with 1994 are also available on the website.

Regulatory Permitting and Compliance

LLNL undertakes substantial activities to comply with many federal, state, and local environmental laws. The major permitting and regulatory activities that LLNL conducts are required by the Clean Air Act (CAA); the Clean Water Act (CWA) and related state programs; the Emergency Planning and Community Right-to-Know Act (EPCRA); the Resource Conservation and Recovery Act (RCRA) and state and local hazardous waste regulations; the National Environmental Policy Act (NEPA); the Endangered Species Act (ESA); the National Historic Preservation Act (NHPA); the Antiquities Act; and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Integrated Safety Management System and Environmental Management System

LLNL established its EMS to meet the requirements of the International Organization for Standardization (ISO) 14001:1996 in June 2004 and has remained certified since that time, updating to revised standards in June 2006 (14001:2004) and May 2018 (14001:2015). LLNL identifies, documents, and updates environmental aspects of the EMS every three years and plans actions to address the most significant aspects annually. In FY2022, two ES&H Action Plans addressed environmental aspects including implementing measures to reduce greenhouse gas emissions and improve hazardous waste operations.

Pollution Prevention

A strong Pollution Prevention/Sustainability Program (P2S) is an essential supporting element of LLNL's EMS. LLNL operations have reduced the quantity and toxicity of waste generated, reduced or eliminated pollutant releases, and recycled common and unique materials. P2S Program efforts in 2022 included participation in workgroups to determine a recycling pathway for excess refrigerants, refining construction and demolition waste tracking, installing additional electric vehicle charging infrastructure, and expanding the recycling and composting program to additional buildings. The P2S program also supported the Green Hotline.

Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2022. Estimated nonradioactive emissions are low compared to local air district emission criteria.

Releases of radioactivity to the environment from LLNL operations occur through stacks and from diffuse area sources. In 2022, radioactivity released to the atmosphere was monitored at five facilities at the Livermore Site and at one facility at Site 300. In 2022, 74.3 Ci (2,749 GBq) of tritium was released from the Tritium Facility and 8.0 Ci (296 GBq) of tritium was released from the National Ignition Facility (NIF). Additionally in 2022, the NIF released a total of 1.1×10^{-6} Ci (4.1×10^{-5} GBq) of Iodine-131 vapor and 4.0×10^{-7} Ci (1.5×10^{-5} GBq) of Bromine-82. The Contained Firing Facility (CFF) at Site 300 had measured stack emissions in 2022 for depleted uranium. A total of 3.2×10^{-8} Ci (1.2×10^{-6} GBq) of uranium-234, 4.4×10^{-9} Ci (1.6×10^{-7} GBq) of uranium-235, and 2.3×10^{-7} Ci (8.5×10^{-6} GBq) of uranium-238 was released in particulate form. The doses to the hypothetical, site-wide maximally exposed individual (SW-MEI) members at the Livermore Site and Site 300 are less than one percent of the annual National Emissions Standards for Hazardous Pollutants (NESHAPs), which is 100 μSv/y (10 mrem/y) total site effective dose equivalent. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2022.

The magnitude of nonradiological releases (e.g., reactive organic gases/precursor organic compounds [ROGs/POCs], nitrogen oxides [NOx], carbon monoxide, particulate matter, sulfur oxides) is estimated based on specifications of equipment and hours of operation. Livermore Site air pollutant emissions were low in 2022 compared to the daily releases of air pollutants from all sources in the entire Bay Area. For example, the average daily emission of NOx in the Bay Area was approximately 2.70×10^5 kg/d, compared to the estimated daily release from the Livermore Site of 41.6 kg/d, or 0.015% of total Bay Area source emissions for NOx. The 2022 Bay Area Air Quality Management District (BAAQMD) estimate for ROGs/POCs daily emissions throughout the Bay Area was approximately 2.35×10^5 kg/d, while the daily emission estimate for 2022 from the Livermore Site was 14.2 kg/d, or 0.006% of the total Bay Area source emissions for ROGs/POCs. Nonradiological releases from LLNL continue to be a small fraction of releases from all sources in the Bay Area or San Joaquin County.

In addition to air effluent monitoring, LLNL samples ambient air for tritium, radioactive particles, and beryllium. Some samplers are situated specifically to monitor areas of known contamination; some monitor potential exposure to the public; and others, distant from the two LLNL sites, monitor the natural background. In 2022, ambient air monitoring data was used to determine source terms for resuspended plutonium-contaminated soil, resuspended fallout from previous atmospheric testing, or resuspended fallout from the Fukushima nuclear accident; and tritium diffusing from area sources at the Livermore Site and resuspended uranium-contaminated soil at Site 300. In 2022, radionuclide particulate, tritium, and beryllium concentrations in air at the Livermore Site and in the Livermore Valley were well below the levels that would cause concern for the environment or public health.

Water Monitoring

Water monitoring is carried out to determine whether any radioactive or nonradioactive constituents released by LLNL have a negative impact on public health and the environment. According to monitoring data, discharges to the surface water and groundwater do not have any apparent environmental impact.

LLNL Wastewater Discharge Permit #1250 (2021 – 2026) regulates discharges of treated groundwater from the Livermore Site Ground Water Project (GWP) to the City of Livermore sanitary sewer system. During 2022, monitoring data complied with all discharge limits and most of the measured values were a small fraction of the allowable limits. There were no discharges to the sanitary sewer from GWP activities. Additionally, all discharges to the Site 300 sewage evaporation and percolation ponds regulated under Waste Discharge Requirements (WDR) Order No. R5-2008-0148 were within permitted limits and groundwater monitoring related to this area showed no measurable impacts.

Under the current storm water Industrial General Storm Water Permit (IGP) (2014-0057-DWQ), the only regulated industrial activities at the Livermore Site and Site 300 are those related to Treatment, Storage, and Disposal Facilities (TSDF). This includes the Decontamination and Waste Treatment Facility (DWTF) and Area 612 Facilities at the Livermore Site and B883, Explosive and Waste Treatment Facility (EWTF), and Explosives Waste Storage Facility (EWSF) at Site 300. LLNL has five storm water runoff sampling locations at the Livermore Site and two at Site 300. Storm water runoff samples were collected for three storm events at the Livermore Site and one storm event at Site 300 in 2022. Samples were collected from all five required storm water locations at the Livermore Site and Building 883 at Site 300. Based on annual sampling results, both the Livermore Site and Site 300 remain at Exceedance Response Action Level 2 for magnesium. LLNL has provided data and analysis that show the magnesium exceedance is due to aerial deposition from natural sources and not industrial activities at LLNL.

The annual storm water reports for the Livermore Site National Pollutant Discharge Elimination System (NPDES) General Permit 2014-0057-DWQ (Waste Discharge Identification Number [WDID] 2 01I025682) and Site 300 (NPDES General Permit 2014-0057-DWQ, WDID 5S39I021179) are available through the Stormwater Multiple Applications and Report Tracking System (SMARTS) managed by the California State Water Resources Control Board (SWRCB).

The Central Valley Regional Water Quality Control Board (CVRWQCB) issued a Water Code Section (WCO) 13267 Order for *Submittal of Technical and Monitoring Reports for the Active Building 851 Firing Table, Lawrence Livermore National Laboratory Site 300, San Joaquin County* (CVRWQCB 2020b) requesting a sediment and storm water runoff monitoring program during the Building 851 Firing Table operational period at Site 300. Only sediment samples were collected in 2022.

In addition to CERCLA-driven monitoring (i.e., for volatile organic compounds [VOCs]) conducted by LLNL's Environmental Restoration Department (ERD), extensive surveillance

monitoring of groundwater occurs at and near the Livermore Site and Site 300. Groundwater from wells downgradient from the Livermore Site is analyzed for anions, hexavalent chromium, and radioactivity. To detect any off-site contamination quickly, the well water is sampled in the uppermost water-bearing layers. Near Site 300, monitored constituents in off-site groundwater include explosives residue, nitrate, perchlorate, metals, volatile and semivolatile organic compounds, tritium, uranium, and other radioactivity constituents (gross alpha and gross beta). No constituents attributable to LLNL operations at the Livermore Site or Site 300 were detected in the off-site groundwater supplies.

Surface waters and drinking water are analyzed for tritium and gross alpha and gross beta radioactivity. In the Livermore Valley, the maximum tritium measurement was less than 1% of the drinking water standard and the maximum gross alpha and gross beta measurements were less than 17% and 8% of their respective drinking water standards. At Site 300, operation and maintenance of the drinking water system did not have an adverse impact on surrounding waters.

Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil in 2022 was insignificant. Surface soils at the Livermore Site and in the surrounding Livermore Valley are analyzed for plutonium, alpha-, beta- and gamma-emitting radionuclides, and tritium. Surface soils at Site 300 are analyzed for alpha-, beta- and gamma-emitting radionuclides and beryllium. Plutonium concentrations in soil at the Livermore Water Reclamation Plant continued to be elevated compared to other sampled locations, but even this concentration was only 1.5% of the screening level for cleanup recommended by the National Council on Radiation Protection (NCRP). At Site 300, uranium-235 and uranium-238 concentrations in soils were below NCRP-recommended screening levels.

Vegetation and Livermore Valley wine were sampled for tritium. In 2022, the median of concentrations in all off-site far vegetation samples was below the analytical method's lower limit of detection (approximately 2.0 Bq/L). In 2022, median concentrations at the near and intermediate locations were 3.4 Bq/L and 2.5 Bq/L, respectively. For Livermore Valley wines purchased in 2022, the highest tritium concentration of 3.5 Bq/L was just 0.47% of the Environmental Protection Agency's (EPA's) standard for maximal permissible level of tritium in drinking water.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background. In 2020, the method for calculating the quarterly doses was updated to better reflect recommendations in American National Standards Institute/Health Physics Society (ANSI/HPS) N13.37-2014 (R2019), resulting in higher annual averages. If these were calculated using previous methods, the results for 2020 – 2022 would be consistent with those of previous years.

Biota

Through monitoring and compliance activities in 2022, LLNL avoided known impacts to special status species and enhanced habitats. LLNL studies, preserves, and improves the habitat of five species at Site 300 that are covered by the federal or California Endangered Species Acts – California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus*), valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), and the large-flowered fiddleneck (*Amsinckia grandiflora*) – as well as species that are rare and otherwise of special interest. At Site 300, LLNL monitors populations of rare plant species and continues restoration activities for the four rare plant species known to occur at Site 300 – large-flowered fiddleneck, big tarplant (*Blepharizonia plumosa*), diamond-petaled California poppy (*Eschscholzia rhombipetala*), and shining navarretia (*Navarretia nigelliformis* ssp. *radians)*.

LLNL took several actions to control invasive species in 2022. Measures taken at the Livermore Site to control bullfrogs, which are a significant threat to California red-legged frogs, included surveying and dispatching any bullfrogs observed in Lake Haussmann and Arroyo Las Positas. To reduce populations of bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in September 2022 by temporarily halting groundwater discharges to the arroyo.

The 2022 radiological doses calculated for biota at the Livermore Site and Site 300 were far below screening limits set by DOE, even though highly conservative assumptions maximized the potential effect of LLNL operations on biota.

Radiological Dose

Annual radiological doses at the Livermore Site and Site 300 in 2022 were found to be well below the applicable standards for radiation protection of the public. Doses calculated to the SW-MEI for 2022 were 2.9×10^{-2} µSv (2.9×10^{-3} mrem) at the Livermore Site and 2.8×10^{-3} µSv (2.8×10^{-4} mrem) at Site 300. These doses are well below the federal NESHAPs Site-Wide standard of 100 µSv (10 mrem) and are significantly less than the doses from natural background radiation.

Groundwater Remediation

Groundwater at both the Livermore Site and Site 300 is contaminated from historical operations; the contamination is mostly confined to each site. Groundwater at both sites is undergoing cleanup under the CERCLA. Remediation activities removed contaminants from groundwater and soil vapor at both sites and investigations continue to meet regulatory milestones.

At the Livermore Site, contaminants include VOCs, fuel hydrocarbons, metals, and tritium, but only the VOCs in groundwater and saturated and unsaturated soils need remediation. Combinations of VOCs, nitrate, perchlorate, tritium, high explosives, depleted uranium,

organosilicate oil, polychlorinated biphenyls, dioxins, furans, and metals have been identified for remediation at one or more of the nine Operable Units (OUs) at Site 300.

In 2022, concentrations continued to decrease in most of the Livermore Site VOC plumes due to active remediation and the removal of more than 42 kg of VOCs from both groundwater and soil vapor. Groundwater concentration and hydraulic data indicate subtle but consistent declines in the VOC concentrations and areal extent of the contaminant plumes in 2022.

In 2022 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 5.2 kg of VOCs. Each Site 300 OU has a different profile of contaminants, but overall, groundwater and soil vapor extraction and natural attenuation continue to reduce the mass of contaminants in the subsurface. Cleanup remedies have been fully implemented and are operational at eight of the nine OUs at Site 300. The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011 and characterization activities continued in 2022. All milestones were met or renegotiated with the regulatory agencies (see **Chapter 2**).

Conclusion

LLNL's EMS provides a framework that integrates environmental protection into all work planning processes. The success of EMS is evidenced by LLNL's certification to the ISO 14001:2015 standard, coupled with a consistent record of environmental stewardship and compliance. The combination of surveillance and effluent monitoring, source characterization, and dose assessment showed that the radiological dose to the hypothetical, maximally-exposed individual member of the public caused by LLNL operations in 2022 was substantially less than the dose from natural background. Potential dose to biota was well below DOE screening limits. LLNL demonstrated compliance with permit conditions for releases to air and to water. Air and water monitoring results showed minimal contributions from LLNL operations. Remediation efforts at both the Livermore Site and Site 300 further reduced concentrations of contaminants of concern in groundwater and soil vapor.

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