Title

Site Environmental Report for 2023

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Site Environmental Report for 2023

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Lawrence Berkeley National Laboratory
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DISCLAIMER

Department of Energy
Office of Science
Berkeley Site Office
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Berkeley, CA 94720

September 17, 2024

DISTRIBUTION

Subject: 2023 Site Environmental Report (SER) for the Ernest Orlando Lawrence Berkeley National Laboratory (LBNL)

This report, prepared by LBNL for the U.S. Department of Energy, Berkeley Site Office (DOE/BSO), provides a comprehensive summary of the environmental program activities at LBNL for calendar year 2023. SERs are prepared annually for all DOE sites with significant environmental activities, and distributed to relevant external regulatory agencies and other interested organizations or individuals.

To the best of my knowledge, this report accurately summarized the results of the 2023 environmental monitoring, compliance, and restoration programs at LBNL. This assurance can be made based on the reviews conducted by DOE/BSO, and LBNL, as well as quality assurance protocols applied to monitoring and data analyses at LBNL.

A reader survey form is posted with the SER at the LBNL website to provide comments or suggestions for future versions of the report. Your response is appreciated.

Questions or comments regarding this report may also be made directly to DOE/BSO, by contacting Kevin Hartnett of the Berkeley Site Office at (510) 486-6405, or by mail to the address above, or by email kevin.hartnett@science.doe.gov.

Sincerely,

PAUL GOLAN Digitally signed by PAUL GOLAN
Date: 2024.09.17 13:40:18 -07'00'

Paul Golan
Site Office Manager

Site Environmental Report for 2023

September 2024

Cover photo: Flowers and other plants grow in the traffic circle at the intersection of Chu, Alvarez, and Smoot Roads, at Lawrence Berkeley National Laboratory (Berkeley Lab), in Berkeley, California, 05/02/2023. The BioEPIC building construction can be seen in the background. Photograph by Thor Swift.

This work was supported by the Director, Office of Science, U.S. Department of Energy, under Contract Number DE-AC02-05CH11231.

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Executive Summary

Lawrence Berkeley National Laboratory (LBNL, Berkeley Lab) is a multiprogram scientific facility operated by the University of California (UC) for the U.S. Department of Energy (DOE). Berkeley Lab's research is focused on the physical, biological, environmental, and computational sciences, with the objective of delivering scientific knowledge and discoveries pertinent to DOE's mission. This annual report describes environmental protection activities and potential impacts resulting from operations conducted in calendar year 2023, unless otherwise indicated. The format and content of this report satisfy the requirements of both DOE Order 231.1B, Administrative Change 1 (Environment, Safety, and Health Reporting) (DOE, 2012b) and the operating contract between UC and DOE (DOE Contract No. DE-AC02-05CH11231, also known as Contract 31).

Berkeley Lab activities are planned and conducted with full regard to protecting employees, contractors, the public, and the environment, as well as complying with all applicable environment, safety, and health laws and regulations. In accordance with the Department of Energy Order 450.2, Change 1 (Integrated Safety Management) (DOE, 2017), Berkeley Lab implements and incorporates the key elements of its Integrated Safety Management (ISM) System to achieve the site's integrated safety and environmental management system goals. Through the Environmental Management System (EMS) integrated into the ISM, Berkeley Lab oversees environmental compliance activities and continually improves overall environmental performance while maintaining operational capability and sustaining its overall mission. Berkeley Lab ensures the site is operated in a safe and environmentally responsible manner, complying with applicable environment, safety, and health laws, regulations, standards, and other requirements. Managers and supervisors are responsible for ensuring that policies and procedures are understood and followed to protect the public, environment, and worker safety and health. Berkeley Lab also implements an Energy and Water Management System (EWMS), as well as other activities described in the Annual Report of Sustainability Practices, to meet its sustainability goals and requirements.

Throughout 2023, Berkeley Lab continued to strengthen its management systems. These systems provided a structured framework for Berkeley Lab to implement programs required by EO 14057 and DOE Order 436.1A. The effectiveness of the EMS and environmental programs is reviewed annually as part of the performance evaluation process of Contract 31. For fiscal year (FY) 2023, which began October 1, 2022, and ended September 30, 2023, the EMS was given a performance rating of A minus for its management of environmental activities (on a scale from A plus as the highest grade, to F as the lowest). The measurement and rating system was developed jointly by Berkeley Lab, UC, and DOE. The FY 2023 rating reflects how well Berkeley Lab met the objective in DOE's FY 2023 Performance Evaluation and Measurement Plan (Section J, Appendix B of Contract 31) of providing an efficient and effective EMS. Overall, the EMS at Berkeley Lab is effective, supporting compliance with all relevant environmental

statutory and regulatory requirements. Berkeley Lab continues to make progress with achieving performance metrics on key sustainability goals, including energy, water and waste management, sustainable acquisition, and decreases in greenhouse gas emissions.

The EMS was also graded through the federal Office of Management and Budget's annual EMS performance metrics, in which a reporting scorecard rates elements of the International Organization for Standardization (ISO) 14001 standard and the degree of integration between the EMS and Berkeley Lab's sustainability practices. Overall, scores can fall into one of three categories: green (highest), yellow (middle), or red (lowest). Berkeley Lab received a score of green in FY 2023, as described in Chapter 2.

As stated in the Environmental Management System Policy, Berkeley Lab is committed to complying with applicable environmental, public health, and resource conservation laws and regulations, and continually improving the Laboratory's environmental performance while maintaining operational capability and sustaining the overall mission of the Laboratory. An overview of environmental protection and restoration programs is provided in Chapter 3, including information about compliance activities, operating permits, and regulatory agency inspections and audits. In 2023, Berkeley Lab received four violations from the City of Berkeley:

- An incorrect contact name was listed in the *Spill Prevention, Control and Countermeasure (SPCC) Plan* and has since been corrected. The *SPCC Plan* is now maintained in a document management system that sends routine email reminders to review a document's content for updates.
- A tank re-assessment was not completed within the required 5-year period.
- High-pH wastewater was discharged in 2022 from the Building 2 fixed treatment system. Berkeley Lab is presently evaluating various management options for the treatment system to prevent potential future violations.

This report also includes information on environmental monitoring performed in 2023 (Chapter 4). Berkeley Lab monitors stack air, surface waters, wastewater, groundwater, soil, creek sediment, and vegetation. The results of the groundwater monitoring activities continue to confirm that groundwater cleanup actions have been effective in reducing concentrations of volatile organic compounds (VOCs) in the groundwater. Site groundwater plumes are stable or are attenuating, and VOCs are not migrating off-site.

In 2023, any potential radiological impacts to the public or the environment from LBNL operations were extremely low – well below regulatory thresholds. The radiological dose assessments (Chapter 5) performed in 2023 concluded that the maximum potential dose to a maximally exposed resident from Berkeley Lab's estimated airborne radionuclide releases was approximately 0.092% of the DOE and U.S. Environmental Protection Agency annual limit of 10 millirem per year (mrem/yr); the potential dose to the maximally exposed individual (hypothetical resident) from all radiation sources at Berkeley Lab was approximately 5.24 mrem, which is approximately 1.69% of the average natural background radiation dose of 310 mrem/yr in the United States, and approximately 5.24% of the DOE annual limit of 100 mrem/yr from all sources related to LBNL operations.

Preface

Each year Lawrence Berkeley National Laboratory prepares a Site Environmental Report that describes its environmental programs and performance for the most recent calendar year. This report provides an overview of Berkeley Lab, its Environmental Management System, and environmental compliance programs, including discussion of surveillance and monitoring activities, radiological dose assessment results, and quality assurance measures conducted in 2023. The document meets the reporting requirements of U.S. Department of Energy Order 231.1B, *Environment, Safety, and Health Reporting.*

This report was prepared under the direction of Lily Baldwin, Environmental Management System Program Manager for the Berkeley Lab Environmental Services Group (ESG). Primary contributors to the report were David Baskin, Jim Buehler, Deirdre Carter, John Cummings, Evelyn Davies, John Elliott, Kelley Etherington, Brie Fulton, John Jelinski, Ken Kievit, Jennifer Larson, Kushal Malvania, Brendan Mulholland, James Nunez, Jeff Phillibert, Samantha Robertson, Joseph Saadeh, Karen Salvini, Bernadette Santos, Amy Tanouye, and Suying Xu.

The Site Environmental Report can be viewed or downloaded from the Berkeley Lab Environmental Management website. Questions and feedback about the report can be emailed to ems@lbl.gov.

1 Site Overview

Lawrence Berkeley National Laboratory (LBNL, Berkeley Lab) is a member of the national laboratory system supported by the U.S. Department of Energy (DOE) through its Office of Science. Under management by the University of California (UC), Berkeley Lab is a multidisciplinary scientific research facility where nearly 4,000 scientists, engineers, support staff, and students work year-round, and several thousand more researchers visit each year or work remotely. This chapter provides a description of the location and physical aspects of the main site.

1.1 LOCATION

Figure 1-1 shows the locations of the Berkeley Lab main site and nearby satellite facilities, which are in the eastern region of the San Francisco Bay Area, commonly known as the East Bay. The main site is situated on the ridges and in the draws of Blackberry and Strawberry Canyons in the East Bay Hills about 3 miles east of San Francisco Bay. The site occupies approximately 200 acres of land immediately east of the UC Berkeley campus, and straddles the border of the cities of Berkeley and Oakland in Alameda County.

Figure 1-1 LBNL Main Site and Satellite Facility Locations in the East Bay

The Berkeley Lab main site and the majority of the land bordering it is owned by UC (see Figure 1-2). Most of the land to the south and east of the site is maintained in its natural state and adjoins wilderness and

recreation areas. Nearby points of interest include UC Berkeley's Strawberry Canyon Recreational Area, Botanical Garden, Lawrence Hall of Science, and the East Bay Regional Park District's Tilden Regional Park. To the north of Berkeley Lab is a low-density residential neighborhood of single-family homes, and to the west and southwest is a highly urbanized area that includes the UC Berkeley campus, commercial zones, and residential areas. LBNL satellite facilities in Berkeley, Emeryville, and Richmond consist of leased buildings in developed urban areas; LBNL also has a satellite facility called Donner Laboratory on the UC Berkeley campus.

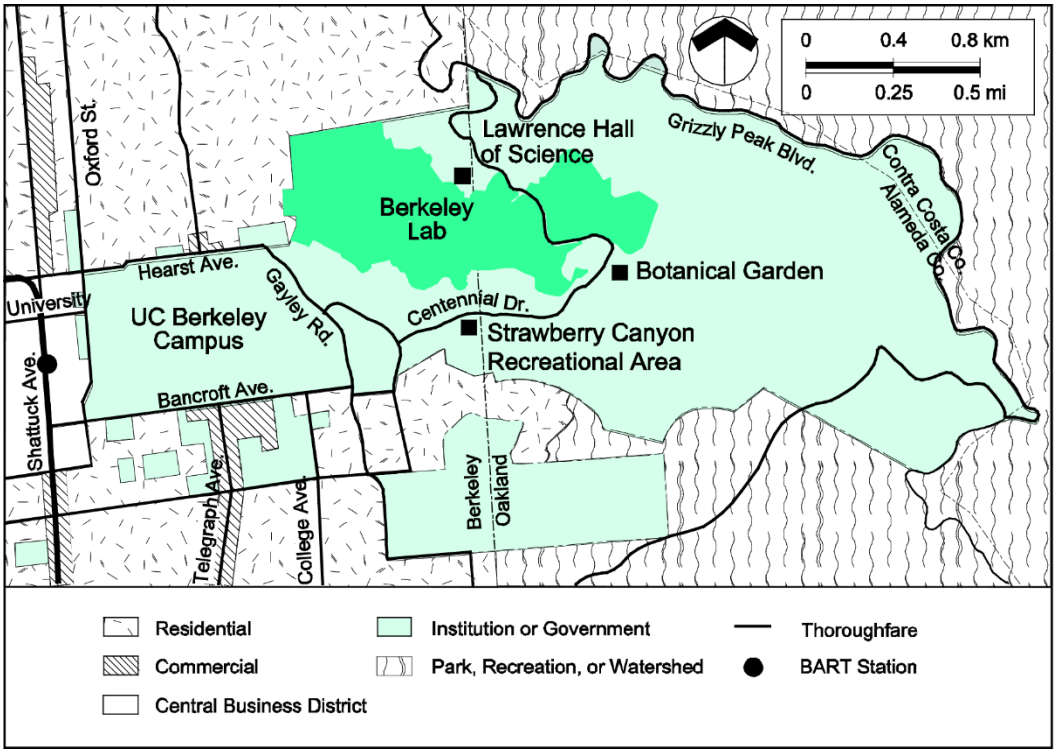

Figure 1-2 LBNL Main Site and Adjacent Land Use

1.2 ENERGY AND WATER SUPPLY

Electricity and natural gas are the predominant sources of energy used to operate research and support facilities at Berkeley Lab. All electric power for the main site is supplied by the Western Area Power Administration (WAPA) and transmitted by Pacific Gas & Electric (PG&E). Electricity is supplied to off-site facilities by PG&E or community choice aggregators that source electricity that is distributed by PG&E. Power purchases through WAPA are arranged through DOE's Northern California Power Purchase Consortium, which serves the electric power needs of the following DOE facilities in the San Francisco Bay Area: Berkeley Lab, Lawrence Livermore National Laboratory, Sandia/California National Laboratory, and SLAC National Accelerator Laboratory. Natural gas is provided by the Defense Logistics Agency and is transported through infrastructure belonging to PG&E. Berkeley Lab commissioned and installed a new natural gas meter in 2021 that allows for more accurate measurement of sitewide consumption. The previous measurement system relied on off-site readings for natural gas meters maintained by UC Berkeley.

Berkeley Lab began reporting natural gas consumption using the new, more accurate metering in the fall of 2022.

The East Bay Municipal Utility District (EBMUD) supplies domestic water (e.g., drinking water), which originates in Sierra Nevada watershed lands and is conveyed to the Bay Area and ultimately to Berkeley Lab through a system of rivers, lakes, aqueducts, treatment plants, supply lines, and pumping stations. EBMUD tests and treats the water to meet disinfection standards required by the 1974 Safe Drinking Water Act. Three large tanks store water on site for emergencies. For example, the tanks will support operation of the fire suppression systems in the event that the water supply from EBMUD is insufficient, as could occur following an earthquake. No water supply wells are located on site. Berkeley Lab installed two new meters at the main site in 2022 to directly measure water consumption without reliance on off-site meters maintained by UC Berkeley. Berkeley Lab began reporting water consumption using the new, more accurate metering in the fall of 2022. The new meters have improved water metering accuracy, indicating approximately 16% lower water consumption using the new metering than indicated by the previous billing methodology.

1.2.1 Maintained Energy and Water Savings

As of the end of FY 2023, Berkeley Lab achieved annual energy savings of 14.1 million kilowatt-hours (kWh) of electricity and natural gas and annual water savings of 6.6 million gallons – resulting in $1.2 million in annual utility bill savings. These energy and water savings are being generated primarily through improvements in facility operations, delivered by the Ongoing Commissioning (OCx) team and focused at Berkeley Lab's high-performance computing facility, as well as through higher performance new construction. Berkeley Lab has paid particular attention to reducing its natural gas use. Natural gas consumption has decreased sitewide 30% (weather-normalized) since FY 2015 (see Berkeley Lab Efficiency Savings Portfolio, updated monthly, and Energy Consumption Compared to Baseline, updated every six months). Water consumption per square foot of building space is 36% below 2007 levels. More energy and water data is available at sbldata.lbl.gov.

Berkeley Lab utilizes sophisticated custom data analytics in an energy management information system (EMIS) called SkySpark to monitor energy and water consumption and maintain previously achieved energy and water savings. Sustainable Berkeley Lab maintains alerts with custom thresholds for various energy and water meters that email specific people when alarm conditions are met for a particular watch period. Sustainable Berkeley Lab addresses each consumption alert by working with the appropriate parties, such as facility area managers and building managers, and dispatching Berkeley Lab's in-house OCx team to resolve the underlying issue, if appropriate.

1.2.2 Ongoing Commissioning

Berkeley Lab's dedicated cross-functional team of controls engineers and technicians from the Facilities Management division and the Sustainable Berkeley Lab group works continuously to identify, prioritize, and resolve operational problems in buildings in order to generate energy savings and improve operations. Ongoing commissioning savings are identified as "OCx" savings on the Berkeley Lab Efficiency Savings Portfolio, which is updated monthly. The OCx project profile at sbl.lbl.gov/progress and a more detailed conference paper available at ocx.lbl.gov describe the team and its approach in more detail.

1.3 METEOROLOGY

The temperate climate at the main site – cool, dry summers and relatively warm, wet winters – is heavily influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west, and the East Bay Hills to the east. Temperatures typically ranged between 40 and 70 degrees Fahrenheit (°F), with an average annual temperature of 55.2°F in 2023. Though temperatures seldom exceed 90°F or drop below 32°F, the maximum and minimum temperatures were 92.4°F and 33.6°F, respectively, in 2023.

Based on measurements taken on site from 1974 through 2023, the historical precipitation "water year" total average is 29.60 inches of rain (with no record of measurable snow). Hydrologists and climatologists use the term water year to represent rainfall occurring between October 1 of one year and September 30 of the next year because it characterizes California's seasonal rainfall cycle better than a calendar year. The precipitation total for the 2022/2023 water year – at 44.09 inches – is 148.9% of normal compared to the historical average water year.

Wind patterns recorded at the on-site meteorological station change little from year to year, as shown by the "wind rose" graphical comparison on Figure 1-3. The wind rose chart on the left shows the distribution of wind patterns for 2023, while the one on the right summarizes the wind patterns at the site since 1994. The most common wind pattern occurs with westerly winds blowing off the bay and ocean. The other predominant wind pattern is associated with stormy weather when south-to-southeast winds precede a storm system, then shift to the west or northwest after it passes. Current weather data at LBNL can be accessed at https://sites.google.com/a/lbl.gov/lbnl-meteorological-data/lbnl-weather-data.

1.4 VEGETATION

Vegetation at Berkeley Lab and the surrounding area comprises native plants, naturalized exotics, and ornamental species. Figure 1-4 presents an aerial view of the site's vegetation and ground cover. Extensive grazing and farming occurred in this region for about 150 years before Berkeley Lab development began in the 1930s. Vegetation is now managed in harmony with the local natural succession of native plant communities, as is evident in the less developed areas, where the wooded and savanna character is being maintained. Ornamental species are generally restricted to courtyards and areas adjacent to buildings. No known rare, threatened, or endangered plant species are present on site.

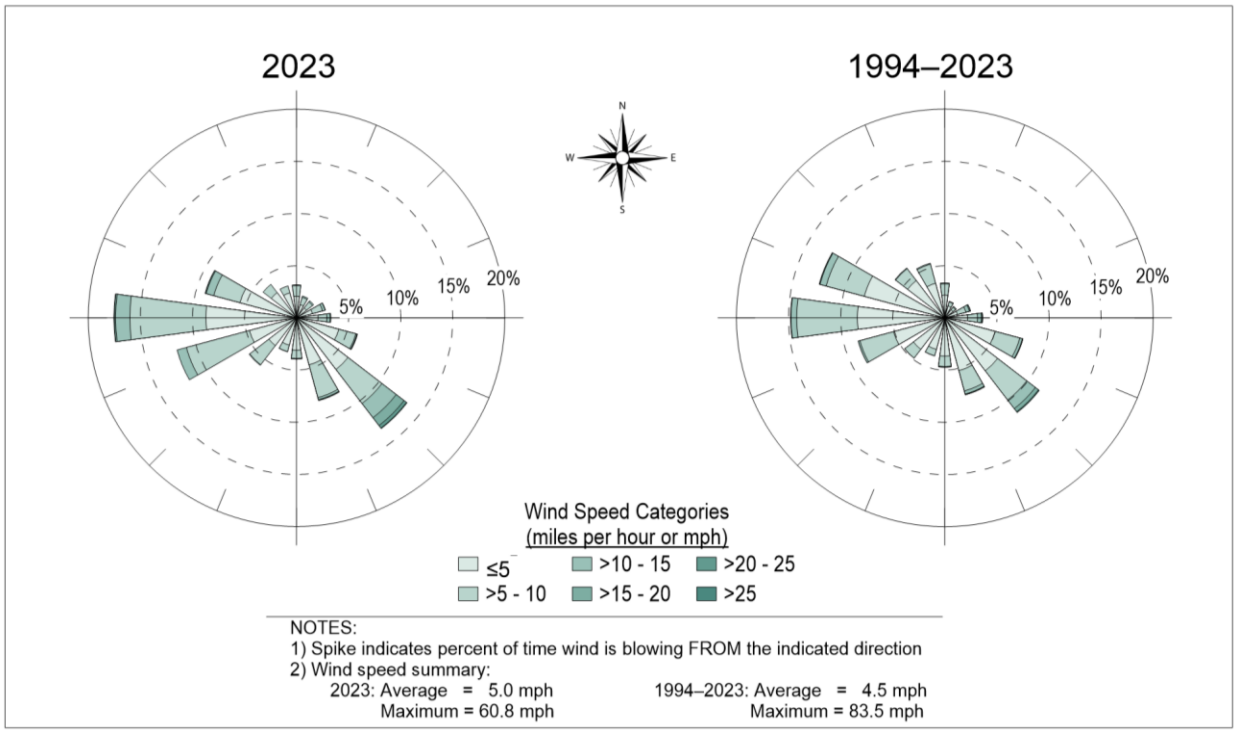

Figure 1-3 Annual Wind Patterns from 1994 Through 2023

Figure 1-4 Vegetation at the LBNL Site and Surrounding Area

1.5 WILDLIFE

Wildlife is common at Berkeley Lab as the site is adjacent to large tracts of open space land owned by the East Bay Regional Park District and UC. More than 120 species of birds, mammals, reptiles, and amphibians are thought to inhabit or traverse the site. These species are typical of those found in disturbed (previously grazed) areas of mid-latitude California with a temperate climate. The most abundant large mammal is the Columbian black-tailed deer.

The following habitats on site are protected by environmental laws or Berkeley Lab land use policies for species at risk:

- A small area of about 1 acre on the south-facing slope of Blackberry Canyon may be inhabited by the arachnid Lee's micro-blind harvestman (*Microcina leei*). *M. leei* is extremely rare and is considered a California "special animal."
- An approximately 5-acre area at the site's eastern boundary is included in the U.S. Fish and Wildlife Service's designated critical habitat for the Alameda whipsnake (*Masticophis lateralis euryxanthus*). This subspecies of the California whipsnake is listed as threatened under both federal and state law.

Potential impacts to wildlife from new projects are evaluated during siting and environmental assessment processes (e.g., National Environmental Policy Act) to ensure compliance with environmental laws protecting wildlife and wildlife habitat, such as the Migratory Bird Treaty Act and the Endangered Species Act.

1.6 GEOLOGY

Three principal bedrock units underlie most of the site, as follows:

1. **Great Valley Group.** Marine mudstones, sandstones, and shales of this unit underlie the western and southern portions of the site. The permeability of these rocks is relatively low, so the groundwater velocity is also low.
2. **Orinda Formation.** Non-marine sedimentary rocks of this unit overlie the Great Valley Group and constitute the exposed bedrock underlying most of the site's developed area. The Orinda Formation consists primarily of sandstones, mudstones, and conglomerates deposited in fluvial and alluvial environments. The permeability of this formation is generally much lower than that of the underlying Great Valley Group or overlying Moraga Formation, so the groundwater velocity in this unit is also very low.
3. **Moraga Formation.** This unit consists of volcanic rocks that underlie most of the higher elevations, as well as much of the central developed area, and constitutes the main water-bearing unit at the site. Permeabilities and groundwater velocities are significantly higher in this unit than in the Great Valley Group and the Orinda Formation.

In addition to the bedrock units described above, the Claremont Formation (primarily marine chert and shale) and the San Pablo Group (primarily marine sandstones) underlie small areas in the easternmost part of the site. In many areas of the site, the main bedrock units described above are overlain by unconsolidated surficial materials consisting primarily of soil, colluvium (sedimentary deposits that have accumulated by mass wasting processes on, or at the foot of, hill slopes), and artificial fill. Soil derived primarily from the bedrock units has accumulated to typical thicknesses of 3 or more feet across much of the site. Engineered cutting (i.e., excavation of rock and soil) and filling (i.e., placement of fill composed of compacted soils derived from nearby areas) of the hilly terrain have been necessary to provide suitable building sites for some building locations. The characteristics of the formations are important considerations in determining appropriate site remediation activities, which are discussed in Chapters 3 and 4.

1.7 GROUNDWATER

Figure 1-5 depicts groundwater elevation contours. The water table approximately mirrors surface topography, flowing from higher to lower elevation. Groundwater flow in the western portion of the site is generally westward toward Blackberry Canyon, while flow in other parts of the site is generally southward toward Strawberry Canyon. The depth to groundwater varies from the ground surface to approximately 100 feet below the surface, depending on location.

1.8 SURFACE WATERS

Berkeley Lab lies within the Strawberry Creek watershed. The two main creeks in this watershed receiving stormwater discharges from the site are the South Fork of Strawberry Creek (in Strawberry Canyon) and the North Fork of Strawberry Creek (in Blackberry Canyon). The creeks, which merge downstream from Berkeley Lab on the UC Berkeley campus, are shown on Figure 1-5, along with key tributaries on or near the site.

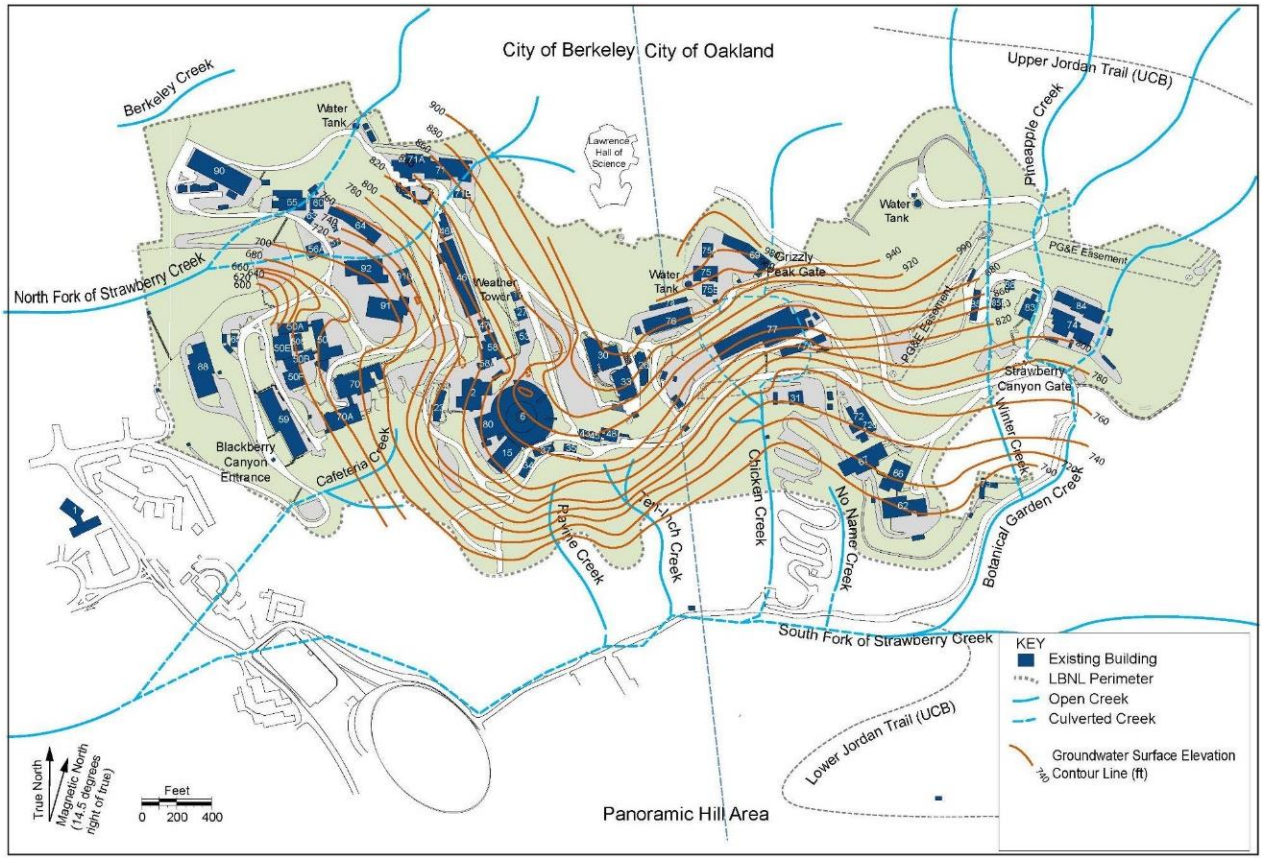

Figure 1-5 Surface Water Locations and Groundwater Elevations at Berkeley Lab

2 Environmental Management System

This chapter provides an overview of the Environmental Management System (EMS), Berkeley Lab's management approach to improving its environmental performance. Environmental compliance measures and activities are important elements of EMS and are further discussed in Chapter 3.

2.1 INTEGRATED SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEMS

Berkeley Lab's commitments to protecting the health and safety of on-site personnel, the public, and the environment are embodied in its environment, safety, and health (ES&H) core policy. Work at Berkeley Lab follows the five core functions of Integrated Safety Management (ISM), which is consistent with the EMS process:

- Define the scope of work
- Analyze the hazards, including environmental impacts
- Develop and implement hazards controls, including environmental controls
- Perform work within controls
- Provide feedback and continuous improvement

The ISM System Management Plan was updated in 2021 and describes how ISM and EMS management systems are integrated (LBNL, 2021b).

The ES&H core policy and other external environmental and sustainability requirements for Berkeley Lab are derived from numerous sources, including:

- DOE Contract No. DE-AC02-05CH11231 (also known as Contract 31), the prime contract between DOE and UC for the management and operation of Berkeley Lab
- Berkeley Lab program documentation included in the *Environment, Safety, and Health Manual* (PUB-3000)
- *Environmental Management System Program Manual* (LBNL, 2024a), in conformance with the ISO 14001 standard, Environmental Management Systems (ISO, 2015)
- Federal sustainability requirements (EO 14057, Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability; EO 12898, Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations; DOE orders; DOE Secretary memos; Federal Acquisition Regulations)
- Legal requirements (California Environmental Quality Act, Energy Independence and Security Act, and other California state and federal laws)
- Applicable provisions of the UC Sustainable Practices Policy

- *Energy and Water Management System Manual*, in conformance with the ISO 50001 standard, *Energy Management Systems* (ISO, 2018), an international standard for managing and improving energy performance

The EMS element of the ISM is essentially a systematic approach to improve environmental performance. DOE Order 436.1A, *Departmental Sustainability* (DOE, 2023), continues to require DOE sites such as Berkeley Lab to develop and maintain an EMS that conforms to the ISO 14001 standard, *Environmental Management Systems – Requirements with Guidance for Use* (ISO, 2015). Berkeley Lab has established an EMS that is designed to reduce environmental impacts in a manner that is well-managed, cost-effective, and compliant with environmental regulations.

2.2 ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY

DOE Order 436.1A also requires integration of a site's sustainability goals into the EMS. As described in its annual Site Sustainability Plan and on the Sustainable Berkeley Lab webpage, Berkeley Lab builds on a strong foundation of sustainability over the last decade that includes the following objectives:

- **Deep efficiency gains driven by improvements in building operations**: The Lab's OCx Team manages a growing portfolio of energy- and water-saving measures, which are maintained over time. See ocx.lbl.gov for more information.
- **ISO-certified excellence in energy and water management**: Berkeley Lab is maintaining certification to ISO 50001 (an international energy management standard) to help ensure that its energy and water management activities are strategic, effective, and persistent. More information about the Lab's ISO 50001 program can be found at iso50001.lbl.gov.
- **Leadership in energy- and water-efficient high-performance computing**: Through a multi-year continual improvement effort, Berkeley Lab reduced the overhead energy use of its supercomputing facility by 42% and its annual water consumption by more than 500,000 gallons. This ongoing optimization effort continues as new systems are installed.
- **Sophisticated analytics to find and maintain energy and water savings**: Berkeley Lab has developed a significant analytical capability that is core to finding and maintaining savings. See more information about Berkeley Lab's use of data analytics for operations at da4ops.lbl.gov.
- **High-performance and electrified new construction**: Berkeley Lab has established a strong policy with its Sustainability Standards for New Construction and Major Renovations. For buildings occupied since 2015, LBNL has moved away from using natural gas for space and water heating, a key strategy to reduce greenhouse gas emissions.
- **Robust infrastructure for composting and recycling**: To divert materials from the landfill, Berkeley Lab maintains a comprehensive waste diversion program that includes both recycling and composting.
- **Transparent reporting of sustainability performance**: Berkeley Lab makes sustainability performance data available to its staff and the public at sbl.lbl.gov/data.

Sustainability goals and requirements are summarized at sbl.lbl.gov/goals and driven by federal sustainability requirements, legal requirements (California State or federal law), and applicable provisions of the University of California Policy on Sustainable Practices.

EO 14057 sets all federal sites on a firm path to decarbonization no later than 2045, with many interim milestones. Through late 2022 and early 2023, a cross-functional group of Berkeley Lab experts and stakeholders drafted a vision and roadmap for achieving this goal. The Berkeley Lab Net-Zero Vision and Roadmap was vetted across the Berkeley Lab community and led to more detailed integrated planning throughout operations divisions. It describes an approach to address the climate crisis, overcome challenges, and meet federal requirements to achieve net-zero greenhouse gas emissions for Berkeley Lab operations. The document presents overall targets and strategies along with 17 specific actions for reaching net-zero greenhouse gas emissions (described on Figure 2-1), provided DOE funding is received to supplement Berkeley Lab's financial investment. Berkeley Lab's progress and pathway to net-zero emissions is illustrated on Figure 2-2.

Net-Zero Actions

STOP	1	**GAS HEATING**: Stop replacing natural gas heating systems like-for-like.
	2	**FUEL VEHICLES AND EQUIPMENT**: Stop leasing or buying fossil-driven fleet vehicles and operations equipment when there are reasonable zero-emission alternatives.
START	3	**RENEWABLE ENERGY**: Start scaling up procurement of long-term renewable energy contracts.
	4	**ELECTRIFICATION OF EXISTING FACILITIES**: Start transitioning to fully electric infrastructure in existing facilities, building on experience in new construction.
	5	**ELECTRIFICATION OF FLEET**: Start accelerating the transition to zero-emission fleet vehicles.
	6	**BUSINESS TRAVEL**: Start working to optimize business travel.
	7	**CARBON REMOVAL**: Start cultivating long-term permanent carbon removal offsets to neutralize residual emissions.
	8	**LIVING LAB**: Start expanding support of applied, infrastructure-scale research related to net-zero.
	9	**EQUITY AND JUSTICE**: Start taking specific steps to address equity and climate justice in the Lab's net-zero effort.
	10	**UPSTREAM EMISSIONS**: Start exploring upstream emissions from food and purchased goods and services, then capture near-term emission reduction opportunities.
	11	**SUSTAINABLE PROCUREMENT**: Start strengthening procurement practices to streamline processes, reduce energy and water consumption, and lower GHG emissions.
	12	**TIME-OF-USE EMISSIONS**: Start exploring GHG emissions associated with electricity time-of-use.
CONTINUE	13	**EFFICIENT FACILITIES**: Continue deepening energy and water savings in the operation of buildings and research facilities.
	14	**NEW CONSTRUCTION**: Continue strengthening sustainability standards for new construction.
	15	**GREEN COMMUTES**: Continue to support alternative commutes and expand electric vehicle charging.
	16	**AIR, WATER, AND MATERIALS**: Continue pursuing net-zero related sustainability strategies including conserving water, managing air quality in buildings, cultivating a circular economy, and diverting waste.
	17	**SHARING AND LEARNING**: Continue sharing net-zero experiences to increase learning and climate action.

Figure 2-1 Net-Zero Actions for Reaching Net-Zero Greenhouse Gas Emissions

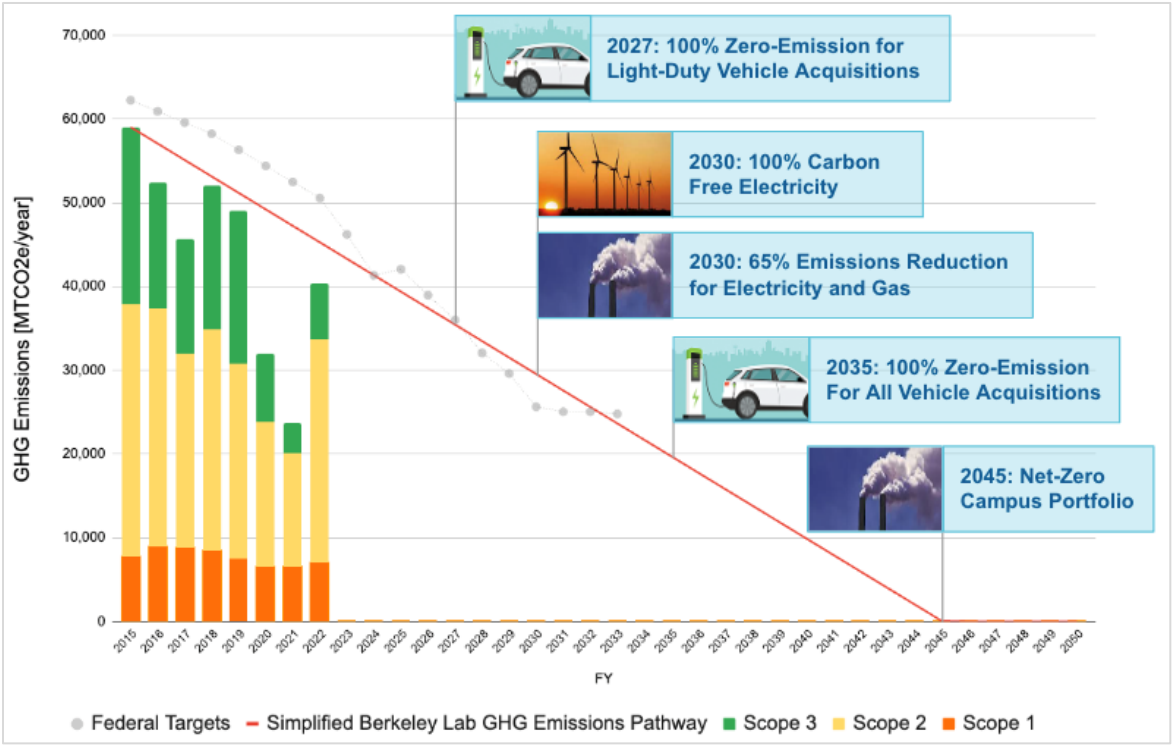

Figure 2-2 Berkeley Lab Progress and Pathway to Net-Zero

2.3 FRAMEWORK OF THE ENVIRONMENTAL MANAGEMENT SYSTEM

The EMS strives for continual improvement in environmental performance through the four-step "Plan-Do-Check-Act" framework for management systems. The integration of EMS's Plan-Do-Check-Act and ISM's five core functions (Section 2.1) is illustrated on Figure 2-3. Key elements of the ISO 14001 standard and Berkeley Lab's EMS are described in the following subsections.

Figure 2-3 EMS Integrated into ISM

2.3.1 Leadership and Commitment

The mission of Berkeley Lab's Operations directorate is to anticipate and deliver environmentally sound, exceptional operational services in support of the scientific mission of Berkeley Lab through effective and efficient infrastructure and programs. The framework for Berkeley Lab's operations is defined in a collection of policies, the *Requirements and Policies Manual* (LBNL, 2021d), which covers a broad range of topics, including policies for EMS and specific environmental programs. The objective of the manual is to translate DOE and UC requirements and federal, state, and local requirements into actionable everyday language for Berkeley Lab employees.

The Environment, Health & Safety (EHS) Division is chartered with the mission of helping Berkeley Lab achieve its commitment to perform all work safely and in a manner that strives for the highest degree of protection for employees, guests, the public, and the environment.

The EMS Policy demonstrates Berkeley Lab's commitment to the following environmental practices:

- Complying with applicable environmental, public health, and resource conservation laws and regulations
- Preventing pollution, minimizing waste, and conserving natural resources
- Mitigating environmental hazards and remediating legacy releases to the environment
- Continually improving environmental performance while maintaining operational capability and sustaining Berkeley Lab's overall mission

The framework for implementing Berkeley Lab's EMS Policy is described in the *Environmental Management System Program Manual* (LBNL, 2024a), which provides guidance on implementing Berkeley Lab's environmental policy in conformance with the ISO 14001 standard. An EMS "Core Team," with representatives from various divisions throughout Berkeley Lab, assists with implementing the integrated environmental and sustainability goals. Links to the *Environmental Management System Program Manual* and related documents can be found on Berkeley Lab's EMS website. At least once every year, leaders representing organizations across Berkeley Lab provide feedback and reaffirm their support to the EMS and EWMS (Section 2.2). The Annual Management Review is further described in Section 2.3.6.

2.3.2 Environmental Aspects

As part of the "plan" step for a management system, subject matter experts in the Environmental Services Group (ESG), Waste Management Group (WMG), and the EMS Core Team periodically review environmental aspects associated with Berkeley Lab Research and Operations. An environmental aspect is any element of Berkeley Lab's activities, products, or services that interact, whether adversely or beneficially, with the environment. These environmental aspects serve as the master list of potential opportunities to improve environmental compliance and performance under Berkeley Lab's EMS. When evaluating environmental aspects, reviewers consider change (e.g., planned or new developments) and new or modified activities, as

well as abnormal conditions and reasonably foreseeable emergency situations. Federal, state, and local agency requirements are considered during the aspects review.

As of 2023, the inventory of potential individual environmental aspects totals approximately 40 environmental aspects, which are grouped under four general categories, as follows:

1. Environmental compliance aspects (e.g., air emissions, storing hazardous materials and accumulating hazardous wastes, wastewater and potentially contaminated runoff into the storm drain system)
2. Emergency management
3. Materials and resources use (e.g., energy consumption, water consumption, life-cycle stewardship of electronics)
4. Managing change

In determining which aspects have the potential to be significant, reviewers evaluate the impact (or consequence) and likelihood of occurrence. This approach is consistent with risk severity guidelines from Berkeley Lab's Office of Institutional Assurance & Integrity (OIAI). The approach also follows OIAI's definitions of low, moderate, and high risk for impact and likelihood of occurrence. In general, an environmental aspect with consequence–likelihood combinations of high–high or high–moderate could be considered a risk that needs to be managed. As needed, the EMS Core Team engages subject matter experts to inform the discussion. If reviewers determine that additional information is needed to evaluate a particular environmental aspect, the EMS Program Manager oversees the collection of this information. The EMS Core Team then stewards an Environmental Action Plan if an identified risk needs to be managed.

2.3.3 Objectives and Plans to Achieve Them

As part of the "do" step for a management system, Environmental Action Plans document the objective, target, strategy, and actions for environmental aspects that need further management. Environmental Action Plans in place at the end of FY 2023 are listed in Table 2-1, along with a summary of each plan's objective, target, and status.

Table 2-1 Environmental Action Plans

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2023
Energy Management	• Improve operational efficiency • Demonstrate leadership in sustainable new construction • Protect efficiency savings • Reduce facility greenhouse gas (GHG) emissions	Improve facility energy efficiency 2% annually Maintain National Energy Research Scientific Computing Center (NERSC) power usage effectiveness below 1.1[a]	As of fiscal year 2023, LBNL-wide building energy consumption per square foot, excluding process loads, decreased 29% since FY 2015 NERSC power usage effectiveness for 2023 was 1.05

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2023
Fleet	• Transition from petroleum consumption to zero-carbon vehicles	100% zero-emission vehicle (ZEV)[b] acquisitions by FY 2035, including 100% light-duty acquisitions by FY 2027	Engaged a consultant to develop a comprehensive action plan for fleet electrification, initiated a feasibility study for a first round of electric vehicle (EV) charger installs, and continued to order EVs as replacements when suitable vehicles were available on the U.S. General Services Administration website
GHG Emissions	• Decarbonize Berkeley Lab's energy supply • Develop local renewable generation and storage	65% reduction in Scope 1 and 2 GHG emissions by FY 2030 (2008 baseline) A straight-line reduction in GHG emissions from 2015 baseline to reach net-zero no later than 2045	As of 2023, total reported GHG emissions are 41% below 2015 levels
Municipal Solid Waste Management	• Keep organics out of the landfill • Highlight impacts of food choices • Maximize effective recycling • Avoid single-use disposable items • Change upstream purchases and contracts • Re-engineer Berkeley Lab's waste hauling system	Minimum 50% waste diversion	Nonhazardous solid waste diversion from the landfill is estimated at 67% for FY 2023
Refrigerant Management	• Improve the compliance and implementation of refrigeration management and record keeping	Identify appliance/circuit regulatory requirements and ensure electronic record keeping is accurately documented	On target to complete actions identified in action plan to address potential risks, including establishing a protocol to monitor compliance status and procedures to create retrofit plan, if needed
Storage Tanks and Air Quality Compliance	• Improve the compliance and implementation of tank inspections and air permit record keeping	All tank inspections performed on time and as required by the regulations	Completed sitewide visual inspections of oil-filled equipment and tanks and inspections. Began development of GIS mapping of regulated assets.
Stormwater Management	• Return to "Baseline" compliance status under California's General Permit for Storm Water Discharges Associated with Industrial Activities	Maintain or reduce pollutant concentrations to below California Numeric Action Levels for the parameters being monitored under the General Industrial Permit	Completed all required sampling and met the objective and target; site is now on Baseline status and the Action Plan is retired
Sustainable Procurement	• Increase procurement opportunities for environmentally sustainable products	Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring that provisions and clauses for environmentally preferable products and services are included in all applicable contracts Purchases: 95% of eligible acquisitions each year are Electronics Product Environmental Assessment Tool (EPEAT) registered products	Sustainable Acquisition clauses were incorporated into 100% of applicable contracts in FY 2023 98% in FY 2023

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2023
Water Management	• Eliminate water waste • Develop water reuse opportunities	Reduce water consumption intensity 36% by 2025 (2007 baseline)	Potable water consumption per square foot in FY 2023 was 36% lower than FY 2007

[a]Power usage effectiveness, or PUE, is a measure of a data center's energy efficiency, where 1 represents the total energy used by computing. The amount above 1 indicates the relative amount of energy used for *non-compute* support loads such as cooling, lights, and heating, ventilation, and air conditioning (HVAC).

[b]ZEVs include battery electric or hydrogen vehicles only. Plug-in hybrids do not qualify.

2.3.4 Awareness and Communication

The success of the EMS depends on ongoing and multiple lines of communication. These lines vary depending on factors such as the potential environmental impact, the types of control in place to prevent potential negative impacts, the degree to which an environmental concern vertically and horizontally permeates the organization, and the level of effort needed to promote environmental compliance or enable performance goals.

EMS-related matters may be communicated in a number of ways at Berkeley Lab, including:

- The annual Site Environmental Report and Environmental Restoration Program Corrective Action Progress Report.
- Information (e.g., environmental documents and operating permits) posted on websites and lessons-learned databases.
- Articles in Berkeley Lab publications (e.g., *Elements*).
- One-on-one or small-group conversations between colleagues affiliated with Berkeley Lab, DOE, and UC.
- Access to ems@lbl.gov for Berkeley Lab employees and external parties to express ES&H concerns and interests.

Berkeley Lab employees and external parties are encouraged to visit the ESG website and submit questions or concerns about any environmental issue to ems@lbl.gov. Communications to be shared with members of the public may also be sent directly to Berkeley Lab's Government and Community Relations Office or Strategic Communications Office. The Government and Community Relations office also oversees Berkeley Lab's Community Advisory Group (CAG), which serves as a forum for discussion about Berkeley Lab's initiatives and activities (e.g., issues related to the environment) that affect the community. The group works to identify opportunities to collaborate in support of a vibrant and diverse community. Its members represent Berkeley Lab, the City of Berkeley, UC Berkeley, and neighborhoods, agencies, and organizations from around the East Bay. CAG meetings occurred five times in 2023; the meetings were held virtually, and recordings and meeting information are provided on the Berkeley Lab Community Advisory Group website. All meetings in 2023 included an Operations Update to share topics such as the following:

- impacts to the community from construction activities

- fire mitigation activities, such as hillside erosion prevention and tree removal, and hillside rescue tactics training with the Alameda County Fire Department
- impacts from "atmospheric river" events
- storm drain replacement and repair activities
- permit renewal of Berkeley Lab's Hazardous Waste Handling Facility
- real-time data available to the public from Berkeley Lab's weather tower

2.3.5 Monitoring, Measurement, Analysis, and Evaluation of Compliance

As part of the "check" step for the management system, Berkeley Lab's EMS is required by DOE to undergo a formal audit once every three years. Berkeley Lab also conducts internal assessments in the interim years between formal audits. The last formal audit was conducted in 2021 by a qualified party outside the control or scope of Berkeley Lab's EMS Program to verify that the EMS conforms to the ISO 14001 standard, as required by the Contractor Requirements Document of DOE Order 436.1A, *Departmental Sustainability*. In 2023, the internal assessment found that more rigor is needed to maintain (i.e., keep up to date) EMS documentation, such as the *EMS Program Manual*. In response, Berkeley Lab updated the *EMS Program Manual* and placed it on an annual review cycle. The internal assessment also found insufficient evidence of the information required by the Standard to be shared at the Annual Management Review meeting. The material presented at the Management Review meeting in February 2024 was expanded to include all the information required by ISO 14001.

Plans and procedures are prepared by EHS staff to comply with regulatory requirements for various environmental programs. These plans describe how programs are required to monitor, measure, analyze, and evaluate compliance. ESG has developed an extensive set of internal procedures that describe how the elements of a program are implemented. ESG maintains electronic records of its environmental regulatory correspondence and reporting to demonstrate environmental programs are in compliance with all applicable requirements.

2.3.6 Management Review

As part of the "act" step for the management system, senior management of organizations involved in implementing the EMS meet annually for an update on EMS Program status. Senior representatives from Berkeley Lab Research and Operations participate in discussions on EMS Program elements and provide feedback. The Sustainable Berkeley Lab Team, led by the Chief Sustainability Officer, partners with the EMS team in the annual management review dialogue for the EWMS. At a minimum, the review meetings cover the following topics cited in the ISO 14001 and 50001 standards:

- Results of internal audits and evaluations of compliance with legal and other requirements
- Communications from external interested parties

- Berkeley Lab's environmental performance
- The extent to which objectives and targets have been met
- Status of corrective and preventive actions
- Follow-up actions from previous management reviews
- Changing circumstances, including developments in legal and other requirements
- Recommendations for improvement

The management review for FY 2023, held in February 2024, covered key topics such as program updates and accomplishments for Environmental Action Plans, as detailed in Table 2-1.

2.4 ENVIRONMENTAL MANAGEMENT PERFORMANCE AND HIGHLIGHTS

Berkeley Lab is required to report to DOE on the performance of its EMS at the end of the federal fiscal year. One report assesses performance for numerous functional areas and is required by the operating contract between DOE and UC (DOE Contract No. DE-AC02-05CH11231, also known as Contract 31; DOE, 2019b). The second report is strictly limited to EMS activities and is required of all federal agencies and their contractors.

2.4.1 DOE's Evaluation of EMS Performance

Berkeley Lab received a weighted score of A minus – on a scale ranging from A plus (highest score) to F (lowest score) – in the DOE Berkeley Site Office's (BSO) *Performance Evaluation Report of the University of California for Management and Operations of Science and Technology at the Lawrence Berkeley National Laboratory* (DOE-BSO, 2023) for its integrated ES&H program and its EMS. This evaluation is based on objectives in DOE's FY 2023 Performance Evaluation and Measurement Plan (Attachment J.2, Appendix B of Contract 31); both the plan and report are required by Contract 31.

2.4.2 Federal Office of Management and Budget EMS Reporting Scorecard

The federal Office of Management and Budget collects annual performance information online to measure performance of a site's EMS and its integration of applicable sustainability goals. These five EMS performance metrics areas defined by DOE are scored from A (best) to D (worst):

1. Environmental aspects
2. Environmental objectives
3. Operational controls
4. Compliance with regulatory requirements / corrective actions
5. EMS–sustainability goals integration

Berkeley Lab's EMS Program earned the highest score of "green" in 2023 after receiving three A's and two B's for operational controls and compliance with regulatory requirements. The findings from environmental

audits and inspections described in Section 3.2 provide the background for the B grades. At least three A's and the rest B's (with no C's) are needed to obtain a green score.

2.4.3 Accomplishments, Awards, and Recognition

In 2023, a team led by Sustainable Berkeley Lab won the DOE Sustainability Awards in the category of innovative approach to sustainability for its approach to quantifying water consumption in laboratory spaces.

Berkeley Lab has received 14 awards recognizing leadership in areas of sustainability since 2019. See sbl.lbl.gov/awards for more detail.

- 5 awards for sustainable new construction
- 4 awards related to the use of ongoing commissioning and data analytics to generate energy and water savings
- 3 awards related to excellence in energy and water management, driven by the ISO 50001 standard
- 1 award for energy- and water-efficient high-performance computing
- 1 award for purchasing of environmentally preferred electronics

2.5 ENVIRONMENTAL TRAINING

To ensure that personnel are both aware and capable of fulfilling their responsibilities, Berkeley Lab maintains an extensive catalog of instructor-led and web-based environmental training courses. Workers are required to complete all appropriate, including environmental, training before they can perform their assigned work. For example, personnel who handle hazardous chemicals and waste are required to take specific training courses in chemical and waste management, waste minimization, pollution prevention, on-site transportation of hazardous chemicals and waste, and basic spill and emergency response as applicable to their responsibilities. Details on Berkeley Lab's training program, including completion information, are documented in the Berkeley Lab Training System. Notifications of new training requirements and expiring training are sent to workers and their supervisors.

In 2023, "Orientation to ISM" training was updated to include environmental safety; this training is required for all workers hired after May 2016. The training "Security and Emergency Services Briefing" was also updated to highlight fire prevention and designated smoking areas. The updated training provides examples for how and when to report safety and security concerns such as the release of hazardous materials and fire.

3 Environmental Program Summary

This chapter provides an overview of the environmental compliance programs that Berkeley Lab implements to protect air and water quality, manage hazardous materials in a safe and environmentally responsible manner, eliminate or minimize the generation of hazardous and nonhazardous waste, and protect human health and the environment. The sections in this chapter are organized by environmental protection programs, which describe the general regulatory requirements, permits issued by regulatory agencies, and audits and inspections conducted during the year. The status of Berkeley Lab's environmental monitoring programs is discussed in Chapter 4; the status of the environmental radiological program is discussed in Chapter 5.

3.1 ENVIRONMENTAL PERMITS

Certain activities or equipment require an operating permit issued by a government agency. Authorizations and permits held by Berkeley Lab for activities or equipment can be found online at the ESG home page and are summarized in Table 3-1 by permit type.

Table 3-1 Environmental Permits and Registrations

Permit Type	Issuing Agency	Description (Section with Details)	Location
Air quality	BAAQMD	Various activities with emissions to atmosphere (3.4.1)	Main Site
	CARB	Registration of equipment with emissions to the atmosphere (3.4.1)	
Hazardous Materials	ACEH CUPA (permit and registration)	Hazardous Materials Business Plan (HMBP) and hazardous waste generation (3.4.2)	EmeryStation East
	COB	Fixed treatment units (Regulated Waste)	Main Site
		HMBP and hazardous waste generation (3.4.2)	Main Site
		Underground storage tanks (Corrective Action Program)	Main Site
		HMBP and hazardous waste generation (3.4.2)	Berkeley West Biocenter
Hazardous Waste Emergency Permit (One Time)	DTSC	Temporary authorization for the management of hazardous waste that poses an imminent and substantial endangerment to human health or the environment (3.5.3)	Main Site
Notice of Intent to Handle e-Waste	DTSC	Registered Universal Waste Handling Facility (Regulated Waste)	Excess and Storage Operations/B915
Stormwater	SWRCB	Sitewide and construction stormwater discharges (Stormwater)	Main Site
Surface water and creek sediment	EBRPD	Surface water and creek sediment sampling (4.2, 4.5.2)	Tilden Park
Treatment, storage, and disposal facility Part B Permit	DTSC	Hazardous Waste Handling Facility operations (3.4.2)	Main Site
Wastewater	EBMUD	Sitewide and operation-specific wastewater discharges to sanitary sewer (Wastewater)	Main Site

ACEH = Alameda County Environmental Health
BAAQMD = Bay Area Air Quality Management District
CARB = California Air Resources Board
COB = City of Berkeley
CUPA = Certified Unified Program Agency
DTSC = Department of Toxic Substances Control
EBMUD = East Bay Municipal Utility District
EBRPD = East Bay Regional Park District
HMBP = Hazardous Materials Business Plan
SWRCB = State Water Resources Control Board

3.2 AUDITS AND INSPECTIONS

Regulatory agencies that enforce environmental requirements conduct periodic on-site inspections. A summary of 2023 audits and inspections is presented in Table 3-2 below. These inspections were conducted at the Berkeley Lab main site or EmeryStation East. Information about these inspections is summarized in Table 3-2 and discussed in Section 3.4.2 and the subsections Regulated Waste, Corrective Action Program, and Aboveground Oil Storage / Oil-Filled Equipment. The table includes the self-monitoring inspections conducted by Berkeley Lab as required by EBMUD wastewater discharge permits, since the self-monitoring results expose Berkeley Lab to potential regulatory actions.

Table 3-2 Summary of 2023 Environmental Audits, Inspections, and Appraisals

Organization	Inspection Type	Start Date	Violations
BAAQMD	Compliance inspection for Asbestos Job Notifications (B50A and B54 and surrounding hardscapes)	Apr. 17	0
COB[a]	Underground storage tank monitoring system and spill container certification (see Underground Storage Tanks)	Sept. 6	0
	Routine compliance inspection of aboveground storage tanks, fixed treatment units, HMBPs, and hazardous waste generator areas at the LBNL main site (see Regulated Waste)	May 9,10 and 12	3
EBMUD	B77A FTU 006 Inspected closed loop FTU 006 and the Ultra-High Vacuum Cleaning facility (see Wastewater)	Nov. 27	0
	B70A FTU 004, B2 FTU 005, B67 FTU 007 Collected 24-hour composite and grab samples from each of the FTUs; toured miscellaneous lab spaces in each building and met with researchers present at time of inspection (see Wastewater).	Sept. 14 and 15	0
EPA	Routine RCRA inspection of Hazardous Waste Handling Facility (HWHF) and hazardous waste generator areas at the LBNL main site (see Hazardous Waste Treatment and Storage)	Sept. 29	1
LBNL	Annual certification of unleaded gasoline and E85 dispensing systems (see Vehicle Fleet Management and Source Testing)	July 8 and 26	0
	Designated Operator Underground Storage Tank Visual Inspections (see Underground Storage Tanks)	Every 30 days	0
	Self-monitoring inspection required by EBMUD for groundwater treatment units (see Wastewater)	Feb. 5	0
	Self-monitoring inspection required by EBMUD for the Hearst and Strawberry sanitary sewer outfalls (see Wastewater)	Weekly	0
	Underground storage tanks line leak detector testing (see Underground Storage Tanks)	Sept. 6	0

ACDEH = Alameda County Department of Environmental Health
E85 = 85% ethanol / 15% unleaded gasoline fuel blend
EBMUD = East Bay Municipal Utility District
EPA = U.S. Environmental Protection Agency
FTU = fixed treatment unit
HMBP = Hazardous Materials Business Plan
RCRA = Resource Conservation and Recovery Act

[a] Permitted under California's Certified Unified Program Agency (CUPA).

3.3 DOE-REPORTABLE ENVIRONMENTAL INCIDENTS

The DOE Occurrence Reporting Program tracks environmental incidents across the DOE complex. There were no environmental incidents in 2023.

3.4 COMPLIANCE PROGRAMS

The primary laws driving Berkeley Lab compliance programs for federal, state, and local environmental regulations are the Clean Air Act, Emergency Planning and Community Right-to-Know Act (EPCRA), Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act, and Clean Water Act. The federal and state laws affecting Berkeley Lab's environmental planning for future activities are the National Environmental Policy Act and the California Environmental Quality Act (see Section 3.4.6). The following subsections provide brief descriptions of each of these environmental laws and associated regulations and highlight associated Berkeley Lab activities for this reporting year.

3.4.1 Clean Air Act and Other Air Quality Programs

The Clean Air Act of 1970 and subsequent amendments are the key statutory references for federal, state, and local air pollution control programs. Berkeley Lab manages the following four categories of air pollutants:

1. Hazardous air pollutants (e.g., radionuclides, air toxics)
2. Criteria air pollutants (e.g., VOCs, nitrogen oxides, particulate matter)
3. Ozone-depleting substances (e.g., chlorofluorocarbons, halons)
4. Greenhouse gases (GHGs; e.g., methane, carbon dioxide, and sulfur hexafluoride)

Berkeley Lab operates various sources of regulated air emissions, including a sand blast booth, paint booth, boilers, emergency/standby generators, gas-insulated equipment, refrigeration systems, research equipment, fueling station, fleets of vehicles, forklifts, and off-road equipment. In addition, GHGs, indirectly emitted via electricity use and employee travel, are actively tracked in accordance with the California Global Warming Solutions Act of 2006 (AB 32).

California's air pollution control program, led by the California Air Resources Board (CARB), created regional air districts to regulate air emissions sources (California Health and Safety Code, 1967). In the case of Berkeley Lab, the Bay Area Air Quality Management District (BAAQMD) is responsible for administering and enforcing federal and state air quality requirements for most nonradiological stationary air emissions activities. CARB administers regulations on mobile sources such as vehicles, as well as regulations for refrigerants, certain toxic chemicals, and GHGs. Berkeley Lab is subject to three federal air quality programs that are administered by U.S. Environmental Protection Agency (U.S. EPA) Region 9, as follows:

1. National Emission Standards for Halogenated Solvent Cleaning (Code of Federal Regulations, Title 40, Part 63, Subpart T)
2. Hazardous air pollutants (e.g., radionuclides)
3. Ozone-depleting substances (e.g., chlorofluorocarbons, halons)

Berkeley Lab's Permit to Operate covering sitewide activities and equipment at the main site (BAAQMD, 2023a) issued on July 6, 2023, includes authorization for 35 permitted sources, 12 registered sources, and 1 exempt source under the BAAQMD permit. The permit was re-issued on December 22, 2023 to include 3 additional permitted sources for portable diesel air compressors and removal of 2 boilers. The December 22, 2023, permit had a total of 50 emission sources with permits to operate. A second Permit to Operate (BAAQMD, 2023b) was issued on May 9, 2023, for the Gasoline Dispensing Facility Operation. All current operating permits for Berkeley Lab activities are available at https://ehs.lbl.gov/resource/documents/environmental-services/operating-permits-for-lbnl-activities/. The renewal application process includes submitting usage information on permitted sources.

Asbestos and Demolition Project Notification Program

For projects that involve the demolition or significant renovation of existing structures, or the management of regulated asbestos-containing material, Berkeley Lab is required to provide advance notice to the BAAQMD. Each year, pursuant to BAAQMD Regulation 11, Rule 2, Berkeley Lab submits a renovation notification form to the BAAQMD that addresses small demolition/renovation projects involving removal of asbestos-containing material. Small renovation projects are those disturbing less than 100 linear feet of asbestos-containing material during demolition and/or renovation activity. Large projects (those disturbing more than 100 linear feet or 35 cubic feet of building material) are managed by LBNL contractors who prepare and submit asbestos management plans to the BAAQMD. Renovation and demolition projects were evaluated by the LBNL Air Quality Program Manager for the purpose of air quality protection. Based on the projects' scope and the results of pre-work asbestos surveys, asbestos demolition/renovation notifications are submitted to the BAAQMD for these projects.

Vehicle Fleet Management and Source Testing

Berkeley Lab has vehicles regulated under the following regulations as nonstationary emissions sources: Advanced Clean Fleets, Truck and Bus Regulation, In-Use Off-Road Diesel-Fueled Fleets Regulation, and Large Spark-Ignition Engine Fleet Requirements Regulation. Each regulation and its associated reportable fleet are listed below:

- **Advanced Clean Fleets** – consists of 73 vehicles
- **In-Use Off-Road Diesel-Fueled Fleets Regulation** – consists of 6 off-road vehicles, 5 of which are registered as low use
- **Large Spark-Ignition Engine Fleet Requirements Regulation** – consists of 22 forklifts, all of which are registered as low use
- **Truck and Bus Regulation** – consists of 4 low-use exemption vehicles

Associated annual reports, which include odometer/hour meter readings, for each regulation were submitted to CARB in 2024 for calendar year 2023 data. Berkeley Lab uses each vehicle in the low-use category less than 200 engine hours annually. Vehicles in the LBNL fleet are replaced and upgraded as resources allow.

Berkeley Lab identified during an internal audit in 2021 that a Large Entity One-Time Advanced Clean Trucks Report was due to CARB by May 1, 2021. Upon discovery Berkeley Lab notified CARB and has the completed report on file.

The BAAQMD operating permit for Berkeley Lab's on-site unleaded gasoline and E85 dispensing systems requires annual testing. Testing was performed on July 3, 2023, and both systems passed and met acceptance criteria.

Greenhouse Gas Inventory and Baseline

GHG emissions are divided into three categories, or scopes. Scope 1 emissions are generated on site and are under the direct control of the facility, such as those produced by combustion of natural gas in a boiler. The majority of Berkeley Lab's GHG emissions are Scope 2, indirect emissions resulting from the generation of electricity purchased and used by an organization, due to its high demand for electricity. Scope 3 emissions are business-related but are generated off-site. Employee commuting and business travel account for the majority of emissions in this category.

Berkeley Lab tracks and reports GHGs annually to the DOE Sustainability Performance Division as required by DOE Order 436.1A. As of 2023, total reported GHG emissions are 41% below 2015 levels (see Overall Greenhouse Gas Emissions - Performance Against Targets for more information).

As part of its GHG management program, CARB regulates sulfur hexafluoride (SF_6) emissions and other covered insulating gas emissions from gas-insulated equipment (GIE) by setting a maximum annual emission rate and requiring an annual report. SF_6 is a potent GHG having a global warming potential 23,900 times that of carbon dioxide. Berkeley Lab had 12 active SF_6-containing switches and breakers in service at the end of 2023. One leaking SF_6-containing switchgear was removed from service in 2023. A construction project is underway to replace this one leaking switchgear with a non-gas solid dielectric type of switch. Design has been completed and Berkeley Lab is awaiting receipt of the switchgear for installation. A total of 1.1 pounds of SF_6 was emitted to the atmosphere from the leaking switchgear in 2023.

LBNL facilities do not emit GHGs in quantities that exceed reporting thresholds for Scope 1 emissions under other regulations such as the U.S. EPA's Greenhouse Gas Reporting Program and AB 32, the California Global Warming Solutions Act of 2006.

Berkeley Lab is subject to EPA Section 608 refrigerant management regulations. However, Berkeley Lab does not currently meet the threshold for annual reporting under the CARB Refrigerant Management Program because of a determination that all refrigerant systems were utilized for comfort cooling. Berkeley Lab is

currently utilizing the Sphera Solutions Refrigerant Compliance Management software program to track compliance documentation and record keeping.

Radiological Emissions

LBNL research activities involving radionuclide emissions to the atmosphere must comply with the following regulations:

- Code of Federal Regulations (CFR), Title 40, Part 61, Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities (U.S. EPA, 1989)
- DOE Order 458.1, Limited Change 4, *Radiation Protection of the Public and the Environment* (DOE, 2020) (see Chapters 4 and 5 for further discussion)

The U.S. EPA administers the regulations in 40 CFR 61, National Emission Standards for Hazardous Air Pollutants (NESHAP), which limit the dose to the public from a facility's airborne radionuclide emissions to 10 millirem per year (mrem/yr). The U.S. EPA–approved methodology was used to calculate potential dose, and the estimated potential dose from LBNL activities in 2023 was approximately 0.092% of this limit.

Berkeley Lab documents its NESHAP review and compliance status annually and submits it to DOE and the U.S. EPA. The *Radionuclide Air Emissions Report for Compliance Year 2023* (LBNL, 2023c), the most recent report, is available on the Environmental Publications page of ESG's website.

3.4.2 Emergency Planning and Community Right-to-Know Act

The EPCRA, which was passed in 1986 as Title III of the Superfund Amendments and Reauthorization Act (SARA), establishes requirements for emergency planning, notification, and reporting. In California, the requirements of SARA Title III are incorporated into the state's Hazardous Materials Release Response Plans and Inventory law (California Health and Safety Code, 1985).

As a federal facility, Berkeley Lab is subject to EPCRA Toxics Release Inventory reporting requirements (40 CFR Part 372, Section 313). If annual usage exceeds threshold quantities (i.e., 10,000 pounds for the chemicals used at Berkeley Lab), a U.S. EPA Form R must be submitted. As in previous years, Berkeley Lab determined in 2023 that no chemical usage exceeded the chemical-specific Toxics Release Inventory criterion for a listed substance; therefore, preparation of a Form R was not required. Table 3-3 summarizes Berkeley Lab's assessments involving chemical usage/inventory quantities since 2013.

In addition to not exceeding chemical-specific thresholds specified in Section 313 of the regulations, the majority of Berkeley Lab's chemical usage is utilized in laboratory activities under the supervision of a technically qualified individual. Therefore, the quantities of those chemicals are not required to be considered when determining whether an applicable threshold has been exceeded.

Table 3-3 Trends in Quantities of Chemicals for Process-Type Operations Subject to EPCRA Toxics Release Inventory Reporting

Substance	Quantity Used per Year (pounds)										
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chlorofluorocarbons	61	132	87	327	390	270	429	225	809	367	171
Methanol	172	127	100	130	126	82	61	50	52	78	70
Nitric acid	633	556	78	90	90	21	502	21	38	86	77

The City of Berkeley Toxics Management Division and Alameda County Department of Environmental Health administer certain hazardous materials regulations that fall under the requirements of EPCRA and the corresponding state law. Berkeley Lab complies with applicable federal hazardous materials reporting requirements, and each year voluntarily submits HMBPs that meet state requirements, even though Berkeley Lab is not subject to state hazardous materials regulations.

The HMBP includes a hazardous materials inventory. The inventory consists of all hazardous materials present at Berkeley Lab in amounts exceeding state-specified aggregate threshold quantities (e.g., 55 gallons for liquids, 500 pounds for solids, and 200 cubic feet for compressed gases) for each building that exceeds these threshold amounts. In addition to the chemical inventories, each HMBP includes the following information:

- Emergency plans
- Procedures
- Training
- Facility maps

The HMBP for each facility listed below was updated in 2023 and submitted electronically to the California Environmental Reporting System (http://cers.calepa.ca.gov/):

- LBNL main site
- Berkeley West Biocenter
- EmeryStation East

3.4.3 Resource Conservation and Recovery Act

RCRA was enacted to create a management system to regulate waste from “cradle to grave.” In 1984, the Hazardous and Solid Waste Amendments were added to the Solid Waste Disposal Act to reduce or eliminate the generation and disposal of hazardous wastes. Between 1984 and 1988, RCRA was further expanded to regulate underground storage tanks (USTs) and leaking waste storage facilities.

RCRA's primary goals are to protect the public from harm caused by waste disposal, to clean up spilled or improperly stored wastes, and to encourage reuse, reduction, and recycling. RCRA affects the following LBNL operations:

- On-site management of hazardous waste generated
- Hazardous waste minimization efforts
- Treatment and storage of hazardous waste (including the hazardous component of mixed waste)
- Investigation and cleanup of historical releases of hazardous chemicals to the environment
- Storage of petroleum products in USTs

Berkeley Lab uses a computerized waste tracking system to track hazardous, mixed, and radioactive wastes from the time a pickup request is initiated until the wastes are transported to an appropriate disposal facility off-site. The waste tracking system includes information that is required for regulatory reporting, such as the Annual Facility Report for the Hazardous Waste Handling Facility (HWHF), Biennial Hazardous Waste Report, Site Treatment Plan reporting, the annual waste inventory for the HMBP, and the State Bill (SB) 14 Waste Minimization Plan.

Regulated Waste

Berkeley Lab generates and manages the following regulated wastes:

- Hazardous waste
- Medical waste
- Mixed and combined waste (RCRA or non-RCRA hazardous and radioactive waste)
- Radioactive waste
- Treated wood waste (TWW)
- Universal waste

The Department of Toxic Substances Control (DTSC) administers the hazardous waste program in California. DTSC incorporates the provisions of both the federal RCRA and state hazardous waste laws (California Health and Safety Code, 1972) and includes oversight of hazardous waste generation, permitting, and enforcement. With the exception of the RCRA-permitted HWHF, these programs are delegated to the City of Berkeley and Alameda County under the CUPA program.

Satellite accumulation areas (SAAs) and waste accumulation areas (WAAs) are used to accumulate hazardous and mixed wastes generated on site. SAAs are deployed extensively in laboratories and in some facilities' operations. SAAs are an integral part of the hazardous waste management process at Berkeley Lab, as they allow generators to efficiently manage small quantities of regulated wastes that are produced during

laboratory and facility activities. WAAs are used to accumulate larger quantities of hazardous waste, as well as hazardous waste from SAAs.

Berkeley Lab policy requires hazardous waste to be removed from SAAs and mixed waste to be removed from mixed-waste SAAs within 275 days of initial generation or within 3 days of accumulating 55 gallons of hazardous waste or 1 quart of acute or extremely hazardous waste. The policy also requires that hazardous and mixed waste be removed from WAAs within 60 days of initial generation. On the main site, with the exception of large lab cleanouts and remediation/construction projects, regulated waste is collected from generators' SAAs and WAAs and transferred to the permitted HWHF for treatment (if needed) and storage. The waste is then packaged and shipped off-site to regulated commercial, hazardous waste treatment, storage, and disposal facilities (TSDFs). Wastes generated from large lab cleanouts and remediation/construction projects are shipped directly from the generator locations to third-party TSDFs. DOE orders define low-level radioactive waste requirements. Mixed waste is subject to both California regulations and DOE orders and is managed at Berkeley Lab in accordance with the Site Treatment Plan for mixed waste (DOE, 1995). Combined waste is a term used to describe radioactive waste that has been combined with California "non-RCRA" hazardous waste, and it is managed in accordance with applicable California hazardous waste regulations as well as radioactive waste regulations.

Universal waste includes batteries, mercury-containing devices, specific types of lamps, non-empty aerosol cans, and electronic waste (e-waste). Berkeley Lab's e-waste is managed at its excess property and storage operations in Richmond, California prior to being shipped out for recycling. The Facilities Division manages universal waste lamps and the EHS Waste Management Group manages the remaining types of universal waste.

Medical waste management adheres to the requirements found in the Medical Waste Management Act (California Health and Safety Code, 2017). Berkeley Lab sends its medical waste off-site for incineration. Medical waste does not include biohazardous waste that is commonly generated during DNA research. These wastes are sent off-site for autoclaving.

Treated wood waste (TWW) is wood that has been treated with a chemical preservative for the purposes of protecting the wood against attacks from insects, microorganisms, fungi, and other environmental conditions that can lead to decay. The chemical preservative is registered pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. Sec. 136 et seq.). These preservatives often include one or more of the following constituents: arsenic, chromium, copper, pentachlorophenol, and creosote. Berkeley Lab manages treated wood under the Alternative Management Standards (AMS) found in statutes HSC 25230–25230.18 established by Assembly Bill 332. This allows handling of TWW in accordance with the AMS in lieu of the requirements for hazardous waste management. In 2023, Berkeley Lab generated over 10,000 pounds of TWW and notified DTSC as required by the regulation.

Hazardous Waste Treatment and Storage

California's permitting program for hazardous waste treatment and storage facilities has five tiers, which are listed in Table 3-4 in order of decreasing regulatory complexity. Berkeley Lab's activities fall under three of the tiers.

Table 3-4 Overview of California's Tiered Permitting Program

Program Tier	Regulatory Agency	LBNL Facilities/Units Under Each Program Tier
Full permit	DTSC	Hazardous Waste Handling Facility
Standardized permit	DTSC	–
Permit-by-rule	City of Berkeley	FTU 006, FTU 007
Conditional authorization	City of Berkeley	FTU 004, FTU 005
Conditional exemption	City of Berkeley	–

DTSC = Department of Toxic Substances Control
FTU = fixed treatment unit (see Table 3-6 for details on each FTU)

The HWHF operates under a DTSC-issued full permit (the highest tier), which authorizes storage and treatment of certain hazardous and mixed wastes at the facility. Table 3-5 provides a timeline of Berkeley Lab's permit renewal application process, which began in June 2016, when the 10-year expiration date for the 2006 permit was approaching. The 2006 HWHF permit, and the multiple DTSC-approved permit modifications that followed, remained effective and enforceable throughout 2022 and into 2023. The final revised application was submitted to DTSC in December 2022. DTSC approved the revised application in 2023 and issued the new permit, which became effective on June 9, 2023.

Table 3-5 Timeline of Berkeley Lab's HWHF Permit Renewal Application to DTSC

Date	Event
June 2016	Berkeley Lab submits an application to DTSC to renew its HWHF permit.
January 2018	DTSC requests additional information and changes to the application.
July 2018	Berkeley Lab responds to DTSC's requests.
December 2019	DTSC provides preliminary feedback on Berkeley Lab's response.
June 2022	DTSC presents a path forward that would address both parties' concerns related to the resolution of one issue/request broached in 2018.
December 2022	Berkeley Lab submits its revised permit renewal application to DTSC.[a]
June 2023	Renewed HWHF permit becomes effective.

[a] Permit documents are available for public review via DTSC's EnviroStor website. EnviroStor is DTSC's online data management system for tracking California's cleanup, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known or suspected contamination issues.

The EPA performed a routine inspection of the HWHF in September 2023 and found one compliance issue: compact fluorescent lamps were stored in an open container of universal waste. The lamps were placed

inside a closed container immediately after the close of the inspection, and HWHF staff received additional training to prevent a recurrence of the incident.

Each year, DTSC assigns hazardous waste facilities in California to one of three compliance tiers based on a "Violations Scoring Procedure" (VSP) (22 CCR 66271.54). In 2023, the HWHF was assigned a score that places it in the highest, most compliant tier.

Administration and enforcement for the permit-by-rule and conditional authorization permit tiers are delegated by DTSC to the City of Berkeley under the California CUPA program for the operation of four fixed treatment units (FTUs) at Berkeley Lab under a hazardous wastewater treatment permit. This permit is renewed annually as part of the HMBP submission process for the main site. The City of Berkeley now issues electronic permits, with relevant information on these permitted activities available on the California Environmental Reporting System (https://cers.calepa.ca.gov/).

For FTU 004, acidic wastewater is generated in various laboratories in Building 70A. Waste acids discharged to FTU 004 include hydrochloric acid, phosphoric acid, sulfuric acid, acetic acid, nitric acid, and other acids. These wastewaters are routed to the treatment system, located below Building 70A in a sheltered overhang, treated via pH adjustment, and discharged to the sanitary sewer system.

For FTU 005, acidic wastewater is generated in various laboratories in Building 2. Waste acids discharged include hydrochloric acid, phosphoric acid, sulfuric acid, acetic acid, nitric acid, and other acids. These wastewaters are routed to the treatment system, located on the ground floor of Building 2, treated via pH adjustment, and discharged to the sanitary sewer system.

For FTU 006, cleaning processes at the Ultra-High Vacuum Cleaning Facility at Building 77 include passivating (making a metal surface less chemically reactive), acid and alkaline cleaning, and ultrasonic cleaning of metal parts used in research and support activities. Acid and alkaline rinse waters that contain hazardous waste metals (listed in 22 CCR § 66261.24(a)(2)) are routed to FTU 006; treated via pH adjustment, ion exchange, and evaporation; and then returned to the Building 77 shop for reuse.

For FTU 007, wastewater from Building 67 (Molecular Foundry) is generated from the etching and rinsing of wafers used in the Nanofabrication Laboratory. The caustic waste may contain 10% or more of potassium hydroxide or similar alkaline waste. The acidic waste may contain over 10% of any of several different acids. These rinse waters are routed to the treatment system located on the ground floor under a sheltered overhang, treated via pH adjustment, and discharged to the sanitary sewer system.

FTU treatment descriptions and operational throughput are summarized in Table 3-6.

In May 2023, the City of Berkeley CUPA conducted a routine inspection of hazardous materials and hazardous waste storage areas, which included the FTUs, at the Berkeley Lab main site. The following violations were recorded:

- Failing to designate a person accountable for discharge prevention and who reports to facilities management per HSC 6.67 25270.4.5(a): 40 CFR 112.7(f)(2)

- Enforcement for high-pH liquid release at the Building 02 FTU in April 2022
- Not obtaining a current five-year tank integrity assessment at the Building 67 FTU

Table 3-6 Summary of Fixed Treatment Unit Operations

FTU	Building No.	Treatment Descriptions	Approx. Quantity of Wastewater Treated in 2023 (gallons)
004	70A/70F	Acid neutralization by pH adjustment	511,675
005	2	Acid neutralization by pH adjustment	69,804
006	77	Metals precipitation and acid neutralization by pH adjustment, ion exchange, and evaporation	9,241 (100% is recycled or evaporated with no discharge)
007	67	Acid and alkaline neutralization by pH adjustment	17,395

The May 2023 City of Berkeley inspection also included a review of Berkeley Lab's HMBP chemical inventory and the operation and management of the aboveground storage tanks and hazardous waste accumulation areas. No violations were recorded.

Corrective Action Program

Berkeley Lab is currently in the Corrective Measures Implementation phase of the RCRA Corrective Action Program. This phase consists of operating, maintaining, and monitoring the actions in the *Corrective Measures Study Report for Lawrence Berkeley National Laboratory* (LBNL, 2005) approved by DTSC for cleaning up contaminated groundwater. These measures are intended to reduce or eliminate the potentially adverse effects to human health or the environment caused by past releases of chemicals at Berkeley Lab.

The following DTSC-approved corrective measures are being used to clean up contaminated groundwater:

- **In situ soil flushing** involves extracting contaminated groundwater from the subsurface, cleaning the water on site using granular activated carbon (GAC), and then recirculating the treated groundwater by injecting it into the subsurface. In situ soil flushing increases the rate at which soil contaminants dissolve into the groundwater and promotes the flow of contaminated groundwater toward locations where it can be extracted and cleaned.
- **Groundwater capture and treatment** consists of extracting groundwater at the leading edges of groundwater contaminant plumes to prevent further migration, cleaning the extracted groundwater on site using GAC, and then either injecting the treated water into the subsurface, if needed for soil flushing, or discharging the treated water to the sanitary sewer system.
- **Monitored natural attenuation** (i.e., reliance on natural processes) is also being used at some locations where monitoring of groundwater chemistry shows that site cleanup may be achieved through natural contaminant degradation processes.

The *Soil Management Plan for Lawrence Berkeley National Laboratory* (LBNL, 2017b) and the *Groundwater Monitoring and Management Plan* (LBNL, 2006) describe the nature and extent of contamination in the soil

and groundwater, the controls used to reduce potential risk to human health and the environment from the contaminants, and the requirements for ongoing groundwater and surface water monitoring. In addition, the S*oil Management Plan* establishes policies and procedures to ensure that excavated soil does not adversely affect human health or the environment and is handled, stored, reused on site, or disposed of off-site in accordance with applicable laws and regulations. These plans, as well as other RCRA Corrective Action Program documents prepared by Berkeley Lab, are available to the public on ESG's Environmental Restoration Program website. Berkeley Lab's groundwater, soil, and creek sediment sampling and monitoring are also summarized in Chapter 4.

Underground Storage Tanks

In the early 1980s, California began addressing groundwater contamination from leaking USTs through a rigorous regulatory and remediation program (California Health and Safety Code, 1983). The state program's requirements for USTs containing hazardous materials address permitting, construction, design, monitoring, record keeping, inspection, accidental releases, financial responsibility, and tank closure. The program satisfies the provisions of the federal RCRA requirements (42 USC § 6991, 1988). The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab's main site. Six permitted USTs located on site contain either diesel or unleaded gasoline, as listed in Table 3-7.

Table 3-7 Underground Storage Tanks Requiring Operating Permits

Registration ID	Location (Building)	Contents	Capacity (Gallons)	Year Installed
Fiberglass tanks, double-walled				
2-TK-3	2	Diesel	4,000	1988
2-TK-4	2	Diesel	1,000	1988
85-TK-1	85	Diesel	2,500	1995
Glass-lined steel tanks, double-walled, with fiberglass-reinforced plastic corrosion protection				
55-TK-1	55	Diesel	1,000	1986
76-TK-5	76	Unleaded gasoline	10,000	1990
76-TK-6	76	Diesel	10,000	1990

Berkeley Lab activities in 2023 included annual UST line leak and spill container testing and monitoring system certification in September (for tank systems 2-TK-3, 2-TK-4, 76-TK-5, and 76-TK-6). "Safe" suction line testing was performed on tanks 55-TK-001 and 85-TK-001.

UST line tightness testing was performed on Berkeley Lab's UST system, and there were no compliance issues.

3.4.4 Toxic Substances Control Act

The objective of the Toxic Substances Control Act (TSCA) of 1976 is to minimize the exposure of humans and the environment to chemicals used in manufacturing, processing, commercial distribution, and disposal activities. TSCA establishes a protocol for evaluating chemicals before they are introduced to the

marketplace, then regulating their use once they are approved for manufacturing. TSCA regulations are administered by the U.S. EPA.

Polychlorinated biphenyls (PCBs), the principal substances at Berkeley Lab currently subject to TSCA regulations, require additional tracking and documentation beyond that required for RCRA-only regulated wastes. The only remaining equipment containing TSCA-regulated PCBs are four large low-voltage capacitors in Building 88. These capacitors remain in use and contain an estimated 375 pounds of regulated PCB dielectric fluid, which is below the U.S. EPA annual reporting threshold for capacitors for PCBs.

In 2014, PCBs were detected in soil samples collected during a preliminary environmental hazard assessment of the Old Town area at levels that required notification to U.S. EPA Region 9 and cleanup under Region 9 oversight. Efforts to characterize the extent of PCB contamination continued into 2023; cleanup of the PCB contamination, which began in early 2017 under a cleanup plan approved by the U.S. EPA, is ongoing. See Chapter 4 for creek sediment sampling in 2023.

3.4.5 Clean Water Act

The 1972 Clean Water Act regulates the discharge of pollutants from both point and nonpoint sources to the waters of the United States by establishing pollutant discharge standards and limitations, as well as a permit and licensing system to enforce the standards. California is authorized by the U.S. EPA to administer the principal components of the federal water quality management program.

The California Porter-Cologne Water Quality Control Act (California Water Code, 1969) established a comprehensive statewide system for protecting water quality and provided for a three-tiered system of regulatory administration and enforcement:

1. State Water Resources Control Board
2. Nine Regional Water Quality Control Boards
3. Local governments

The agencies responsible for regulatory programs at Berkeley Lab are the San Francisco Bay Regional Water Quality Control Board (herein referred to as the “SF Bay Regional Water Board”) for stormwater discharges and EBMUD for wastewater discharges.

Aboveground Oil Storage / Oil-Filled Equipment

Aboveground storage tanks (ASTs) fall under the authority of the Clean Water Act, which, together with the state’s Aboveground Petroleum Storage Act (California Health and Safety Code, 1989), outlines the applicable regulatory requirements for ASTs containing chemicals or hazardous materials. At Berkeley Lab, these requirements apply to storage tanks for standby/emergency diesel generators, oil-filled equipment, storage drums at WAAs, and storage drums at product distribution areas. The City of Berkeley is responsible for enforcing the regulations that apply to ASTs at the main site.

Under the authority of the Clean Water Act, Berkeley Lab is required to prepare a Spill Prevention, Control, and Countermeasure (SPCC) Plan. Berkeley Lab maintains an SPCC Plan for the main site with the goal of preventing and, if needed, mitigating spills or leaks from oil storage containers and oil-filled equipment. A total of 38 ASTs, 12 drum storage/WAAs, and 63 oil-filled equipment (comprising research equipment, hydraulic elevators, and transformers) are listed in Revision 7, Amendment 2 of SPCC Plan (LBNL, 2024b). The SPCC Plan underwent a 5-year review and update in September 2023.

Wastewater

EBMUD is the public utility district that regulates all industrial and sanitary discharges to its wastewater treatment facilities. Berkeley Lab holds EBMUD wastewater discharge permits for the following activities at the main site:

- General sitewide wastewater (EBMUD, 2023)
- Treated groundwater from hydraugers (subsurface drains) and groundwater extraction wells (EBMUD, 2022)
- "Zero-waste-discharge" treated rinse water recycled from the metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77 (EBMUD, 2019)

Permits specify standard terms and conditions, individual discharge limits and provisions, and monitoring and reporting requirements. Berkeley Lab submits periodic self-monitoring reports specified under each permit. No discharge violations were measured in the self-monitoring sampling events. A summary of monitoring results is provided in Chapter 4.

In November 2022, EBMUD personnel conducted a site visit to assess the suitability of using Berkeley Lab's FTUs as points of compliance for sample collections. EBMUD revised and reissued the permit in January 2023, eliminating Berkeley Lab's Hearst and Strawberry sanitary sewer outfalls as points of compliance and replacing the outfalls with the following sample collection locations:

- Building 2, FTU 005
- Building 67, FTU 007
- Building 70A, FTU 004

In September 2023, EBMUD personnel collected samples at each of the aforementioned FTUs, and reported that all sample parameters were in compliance with permissible discharge limits.

The sitewide permit requires annual self-monitoring, which is discussed in Chapter 4, and annual certification by Berkeley Lab that it is in compliance with the radiological conditions of the permit. Berkeley Lab was in compliance with both the radiological and nonradiological requirements of the EBMUD sitewide permit in 2023.

Stormwater

Berkeley Lab's stormwater releases are permitted under the statewide General Permit for Stormwater Discharges Associated with Industrial Activities (SWRCB, 2014), commonly referred to as the Industrial General Permit. This permit is issued by the State Water Resources Control Board and is administered and enforced locally by the SF Bay Regional Water Quality Control Board. Under this permit, Berkeley Lab has implemented a Stormwater Pollution Prevention Plan (SWPPP; LBNL, 2023e), which includes the site's *Stormwater Monitoring Implementation Plan* (LBNL, 2023d).

The purpose of the SWPPP is to identify sources of pollution that could affect the quality of stormwater discharges, and to describe the practices implemented to reduce pollutants in these discharges. The *Stormwater Monitoring Implementation Plan* describes the rationale for selecting sampling locations, collecting and analyzing samples, and ensuring the quality and reporting of the results. Together, these documents represent Berkeley Lab's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

Berkeley Lab's Site Environmental Report is based on the calendar year, while the State Water Board's stormwater reporting year begins July 1 of any given year and ends on June 30 of the following year. For this reason, the sampling events discussed here are based on four sample collection results: two samples collected during the second half of the 2021/2022 reporting season and two during the first half of the 2022/2023 reporting season. The annual report covering stormwater activities for the 2022/2023 reporting year was submitted using the State Water Board's online Stormwater Multiple Application and Report Tracking System (SMARTS) at smarts.waterboards.ca.gov/smarts. The annual report includes results from the annual compliance evaluation, a summary of any changes made to the SWPPP, and analytical results for all sampling events during the reporting year.

Stormwater sampling results and State Water Board compliance status are discussed in more detail in Section 4.2.2.

Stormwater discharges from construction activity disturbing one or more acres of soil are regulated under the state's General Permit for Stormwater Discharges Associated with Construction Activities (SWRCB, 2022a), also referred to as the Construction General Permit. During 2023, three projects at Berkeley Lab required coverage under the Construction General Permit program:

1. Old Town Demolition Project
2. BioEPIC (Biological and Environmental Program Integration Center) Project within the Bayview Area
3. Seismic Safety and Modernization (SSM) Project and Transit Hub Utilities Project (THUP)

Similar to the Industrial General Permit, each of these projects required that a SWPPP and an annual report be submitted to SMARTS. Unlike the Industrial General Permit, no stormwater sampling was required; however, project site inspections were required (i.e., before a predicted rain event on a business day, during extended rain events, after rain events, and quarterly non-stormwater discharge). Inspection logs were included in the annual report. All three projects were compliant with their permit requirements in 2023.

The Construction General Permit for the Old Town Demolition Project was terminated in June 2023. The BioEPIC stormwater permit became active in November 2019, continued through 2023, and will be terminated upon completion of the BioEPIC Project. The SSM and THUP stormwater permit became active in September 2021 and will be terminated when the project is completed.

3.4.6 National Environmental Policy Act and California Environmental Quality Act

The National Environmental Policy Act (NEPA) of 1969 and the California Environmental Quality Act (CEQA) of 1970 require that potential environmental impacts of proposed actions be considered in the decision-making process by the designated lead agency. As it upgrades facilities and expands research programs, Berkeley Lab provides subject matter expert analysis and documentation to assist DOE in meeting its NEPA compliance requirements; similar efforts support UC's CEQA decision-making pertinent to Berkeley Lab projects and activities. Though there are no tribes physically near the Berkeley Lab site such that they would be part of the NEPA area of potential effect for any of Berkeley Lab's normal projects, there are five California tribes that Berkeley Lab consults with as appropriate during the CEQA process as part of Assembly Bill (AB) 52 requirements. There is no tribal land or land associated with prehistoric or tribal artifacts on the Berkeley Lab main site.

In 2023, DOE made four Categorical Exclusion (CX) determinations pursuant to NEPA for proposed federally supported activities at Berkeley Lab and its off-site leased spaces. Review documents for each CX are available online at the DOE website for the Office of NEPA Policy and Compliance. No NEPA Environmental Assessments were prepared for Berkeley Lab activities in 2023. Approximately five proposed projects were determined to be either categorically exempt under CEQA or covered pursuant to CEQA §15168 under Berkeley Lab's 2006 Long-Range Development Plan Environmental Impact Report. No Berkeley Lab Initial Study / Negative Declarations or Environmental Impact Reports were certified in 2023.

3.4.7 Environmental Justice Analysis

In accordance with DOE's *Guidance for EO 12898 Compliance* (DOE, 2012a), Berkeley Lab implements the EO by considering and "including environmental justice analyses in documents prepared pursuant to the National Environmental Policy Act (NEPA)." This consideration includes determining whether minority and/or low-income populations are subject to high or adverse impacts from any proposed major Berkeley Lab actions subject to NEPA review. "If such effects are found, the NEPA document will describe measures designed to mitigate them."

Environmental Assessments and Environmental Impact Statements prepared for Berkeley Lab projects also address environmental justice issues per EO 12898 requirements and DOE guidance. Most federal actions at Berkeley Lab subject to NEPA review are found to be categorically excludable, pursuant to 10 CFR 1021, Part 410, et seq. Categorically excludable actions "do not individually or cumulatively have a significant effect on the human environment." Such actions, by definition, would not render high or adverse impacts on

any populations, including those targeted by EO 12898. For that reason, and even though environmental justice implications are considered in every NEPA review, Berkeley Lab's categorical exclusion documents typically do not include written environmental justice analyses.

Most of Berkeley Lab's major federal actions take place at Berkeley Lab's 202-acre main site. Major actions include construction, renovation, and demolition of facilities; modification of landforms and landscape; and overall laboratory operations. With the exception of off-site transport of materials, selected air emissions, and surface water runoff, most environmental effects from LBNL activities are confined to the main site itself, or in limited instances (e.g., noise, light and glare, dust emissions), effects may be experienced by Berkeley Lab's immediate neighbors. For this reason, the demographics of Berkeley Lab's surrounding neighbors are critical for determining the potential for environmental justice impacts under NEPA.

Berkeley Lab has no immediately surrounding neighborhoods that qualify as minority and/or low-income populations.[1] Adjacent to the LBNL main site to the northeast, east, south, and southwest is UC Berkeley campus land, which is mostly open space. To the west and northwest are City of Berkeley residential neighborhoods. As shown on Figure 3-1, the surrounding neighborhoods are high income, with the exception of the Berkeley Northside neighborhood to the west, whose residents have a below-average median income. The Northside neighborhood is heavily populated by UC Berkeley students. Its demographics are mostly white (43%) and Asian (32%) and highly educated (37% of residents, compared with 13% nationwide, have an advanced degree; 83% have a college degree or are likely still in school) (see https://www.niche.com/places-to-live/n/northside-berkeley-ca/residents/ for more neighborhood demographics). Berkeley Lab does not consider UC Berkeley students to be a target population under EO 12898, as students are typically short-term residents with relatively high income potential. Because they are focusing on academics and not career work, most students are expected to have little or no income for the duration of their schooling.

LBNL activities with the potential to directly (and environmentally) impact minority and/or low-income populations, in neighborhoods at further distance and not directly adjacent to the Berkeley Lab main site, would most likely involve transportation, certain toxic air contaminant emissions, and surface water runoff. Air and water emissions are heavily regulated by government agencies and carefully monitored by Berkeley Lab. Stormwater leaving the main site flows into Berkeley's Strawberry Creek, which is not a source of subsistence fishing and is largely channelized and flows to the San Francisco Bay. Because they are closely monitored to meet regulatory standards and because of dispersion, air emissions and water runoff from Berkeley Lab are not likely to have a substantial adverse impact on distant neighbors, including those EO 12898 intends to protect.

[1] Minority and/or low-income populations as intended by EO 12898.

Large diesel trucks hauling materials for LBNL construction projects could, during peak operations such as concrete pouring or soil removal activities, be of concern to communities along local truck routes. Such trucks can generate diesel emissions, dust, noise and vibration, roadway wear-and-tear, and traffic congestion. To avoid significant impacts in general and to minority and/or low-income populations in particular, Berkeley Lab follows these truck-hauling practices:

- Large trucks must travel a City of Berkeley–approved route along University Avenue from the LBNL main site to Interstate 80. This route is a major thoroughfare designed for high-volume commercial traffic.
- Trips for LBNL construction trucks are managed through a construction truck trip program that spaces out and limits travel to below daily significance thresholds.
- LBNL truck trips are generally limited to business hours.
- Trucks are required to be properly maintained and loads properly secured and covered.

The only portion of University Avenue that abuts a low-income residential area is a four-block stretch on the south side of University Avenue between San Pablo Avenue and Sacramento Street.

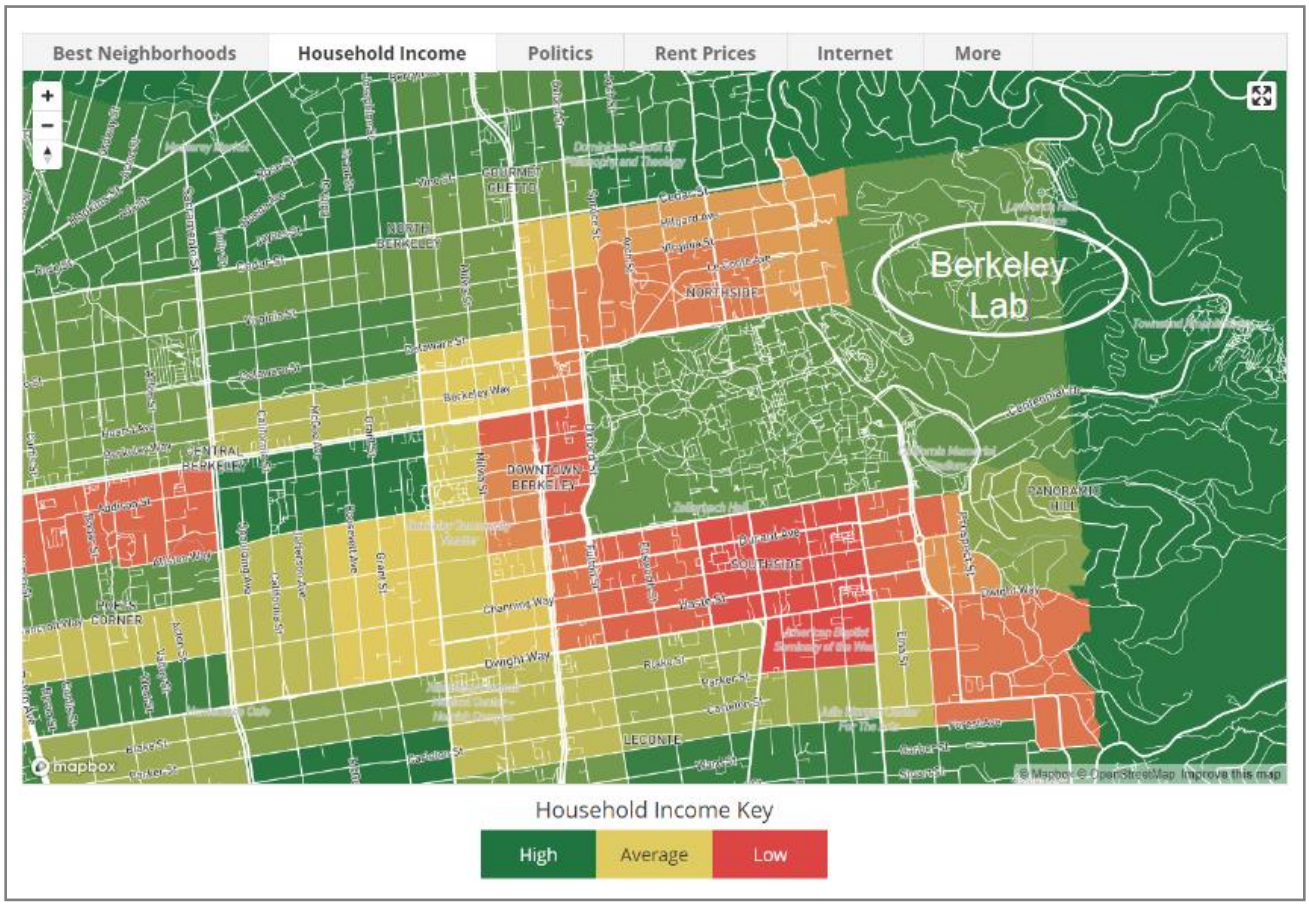

Figure 3-1 Neighborhoods (by Household Income) Adjacent to Berkeley Lab

3.5 OTHER NOTABLE ENVIRONMENTAL ACTIVITIES AND ACCOMPLISHMENTS

3.5.1 Chemical Life-Cycle Management Initiative and New Chemical Inventory Database, CMS 2.0

Since 2020, Berkeley Lab has made substantial progress on a comprehensive initiative to improve chemical life-cycle management "from cradle to grave" as expected by LBNL leadership, UC Office of the National Laboratories, and DOE Site Office management. This chemical management initiative addresses six core and seven supporting focus areas related to chemical life-cycle management. Berkeley Lab execution of the initiative began in early January 2021. In July 2022, CMS 2.0 was implemented and includes an integrated hazardous chemical screening and approval process. A central chemical receiving facility (CCRF) began operations in October 2022 to control arrival of hazardous chemicals, support CMS 2.0 accuracy, and save researcher time. Radio frequency identification (RFID) tracking of the hazardous chemical inventory was implemented to facilitate safer and more efficient chemical inventory management. These substantial program improvements were refined in 2023. A new chemical inventory reconciliation process using RFID is currently being used to complete a site-wide effort to account for hazardous chemicals, establish accurate locations, and address safety concerns. Funding was approved for a permanent CCRF, which is expected to be operational by early 2025. Relevant performance metrics and assurance processes are also being established.

3.5.2 Per- and Polyfluoroalkyl Substances (PFAS)

The DOE Deputy Secretary issued on September 16, 2021, the memorandum "Addressing Per- and Polyfluoroalkyl Substances at the Department of Energy" (DOE, 2021), establishing a DOE policy that acknowledged the need for a comprehensive departmental approach to PFAS and provided direction to assess, contain, reduce, and/or remove PFAS potential contamination and use at DOE sites. On August 18, 2022, DOE released the *Per- and Polyfluoroalkyl Substances (PFAS) Strategic Roadmap: DOE Commitments to Action 2022-2025* (*Roadmap*) to address PFAS at DOE sites across the country, committing DOE sites and headquarters (HQ) to a broad set of actions over the next three years. In late 2022, Berkeley Lab developed an implementation plan to address the relevant actions of the *Roadmap*. The implementation plan identified several PFAS-related actions already completed at Berkeley Lab, including:

- Completion of an Initial Assessment in 2021 of current inventory and past uses of PFAS.
- Verification of the current inventory of PFAS containing aqueous film forming foam (AFFF), which includes one fire suppression system and two hose reels at a single building (Building 85 RCRA-permitted TSDF).
- Verification of any PFAS containing AFFF from this system that may be released in an emergency, which will be fully contained and subject to efficient removal and proper disposal. Worker protection protocols are also in place to protect first responders and cleanup workers.

- Verification that all domestic and fire protection water supplies provided by the local water utility meet all current drinking water standards and are compliant with California requirements for PFAS monitoring and notifications. Watershed sources are considered low risk by the State of California.

The implementation plan also identified actions to be completed over the next several years, including:

- Evaluate alternative firefighting systems and begin the permit modification process for replacement of the AFFF in the fire suppression system and two hose reels in Building 85.
- Continue to track and report PFAS chemical inventory as required.
- Continue to monitor drinking water testing results performed by the local water utility and development of PFAS-related drinking water standards.
- Continue to operate in accordance with DOE requirements for handling, storage, and disposal of PFAS-contaminated materials and wastes.

3.5.3 Chemical Reconciliation and Disposal of Unwanted Chemicals

The Waste Management Group (WMG) coordinates periodic chemical cleanouts to reduce the number of unwanted chemicals stored in laboratories and improve safety. Some of the specific tasks completed in 2023 to reduce chemical inventory and improve inventory management are listed as follows:

- Continuing, comprehensive initiative to improve chemical life-cycle management "from cradle to grave" (Section 3.5.1)
- A multidivisional team of chemical safety, waste management, and hazard analysis experts continued to evaluate chemicals that are expired and/or potentially unstable. The WMG obtained an Emergency Permit from DTSC to use a high-hazard chemical vendor to stabilize 51 potentially unstable chemicals in January 2023 before shipping them off-site for disposal.
- More than 100 gas cylinders that could not be returned to the gas supplier company were disposed of as hazardous waste. Many of these cylinders were toxic, flammable, and/or corrosive.
- Waste management professionals continued their visual inspections of potentially high-risk waste containers so the containers were deemed safe before they were transferred to the HWHF.

3.5.4 Hazardous Waste Tracking

Berkeley Lab uses a computerized waste tracking system to track hazardous, mixed, and radioactive wastes from the time a pickup request is initiated until the wastes are transported to an appropriate disposal facility off-site. The waste tracking system includes information that is required for regulatory reporting, such as the EPCRA Toxics Release Inventory Determination Report, Annual Facility Report for the Hazardous Waste Handling Facility (HWHF), Biennial Hazardous Waste Report, the annual waste inventory for the HMBP, and the SB 14 Waste Minimization Plan

3.5.5 Hazardous Waste Minimization

SB 14 is the Hazardous Waste Source Reduction and Management Review Act of 1989 and requires hazardous waste generators to seriously consider source reduction as the preferred method of managing hazardous waste. In accordance with SB 14, Berkeley Lab prepares a Waste Minimization Plan every four years. The most recent plan was prepared in 2023 for waste generated in 2022. Overall, the amount of hazardous waste shipped off-site for disposal in 2022 declined from the 2018 baseline year. Some strategies employed at Berkeley Lab to promote continued waste reductions are listed as follows:

- Encouraging best management practices during SAA inspections to minimize the amount of nonhazardous laboratory trash that is being managed as hazardous waste.
- Promoting the repair or replacement of equipment that leaks oil to minimize the generation of waste oil.
- Flagging procurement requests for restricted chemicals that require safety reviews prior to purchase.
- Reviewing procured chemicals for safe storage and management through a centralized chemical receiving facility (Section 3.5.1).
- Promoting the option to check Berkeley Lab's chemical inventory database before ordering chemicals, to look for stores of those chemicals that they may be able to use.
- Controlling the types and volumes of the equipment parts to reduce the need for cleaning, and thus the volumes of generated waste streams.
- Discussing opportunities for chemical substitution, reduction, and elimination with LBNL employees.

3.5.6 Municipal Waste Management and Minimization

Nonhazardous waste can be grouped into municipal solid waste, construction and demolition (C&D) debris, scrap metal originating from radiological areas ("moratorium metal"), and nonhazardous industrial waste. Berkeley Lab's strategies for continual improvement include a waste policy as part of the LBNL Sustainability Standards for Operations and an online Waste Guide to promote employee awareness. This guide details the types of waste generated at Berkeley Lab, how staff should dispose of them, and how they are treated. Berkeley Lab also performs annual waste characterizations for insight into materials in the waste stream.

Municipal solid waste diversion from the landfill in FY 2023 is estimated at 67%. The term *municipal solid waste* refers to the following waste streams generated at Berkeley Lab:

- Beverage containers (glass, aluminum, plastic)
- Cardboard
- Garden/landscaping waste

- Landfill (nonrecyclable waste), including metal from radiological areas (per DOE's suspension on the release of metal for recycling from radiation areas)
- Organics (food waste, food-soiled paper products, paper towels)
- Paper (white paper, mixed paper)
- Salvage sales and transfers
- Scrap metal
- Scrap wood

A number of materials are not accepted by the waste hauler that services Berkeley Lab's municipal solid waste. In FY 2023, Berkeley Lab continued its focus on plastic consumables generated in laboratories. Following a pilot program with an alternate recycler in 2022 to recycle lab plastics in the Integrative Genomics Building, Berkeley Lab launched a program in FY 2023 with Polycarbin, a company with a circular economy system to recycle the lab plastics and create new lab plastics with the recycled resins. With Polycarbin, Berkeley Lab increased the amount of plastics recycled from the 2022 pilot program.

Berkeley Lab also resumed its practice of waste characterizations, which had been on pause since 2020. In FY 2023, the first sitewide waste characterization study for LBNL waste was performed. Prior waste characterizations had been performed at a small scale at the building level by Berkeley Lab personnel. This inaugural sitewide study was conducted by the Lab's waste hauler at its facility, in conformance with a new waste characterization stipulation in Berkeley Lab's contract. The sitewide waste characterization provided insight into the overall composition and contamination of the three waste streams: landfill, recycling, and organics.

C&D debris diversion is estimated at 84% for FY 2023. C&D debris includes a variety of nonhazardous materials generated as a result of construction projects (concrete, wood, metal, gypsum board, etc.). Berkeley Lab's major construction and renovation contracts include requirements for recycling of C&D waste to promote high diversion rates. Details on how this waste is treated can be found in the C&D Waste Management Specification (LBNL, 2012a), which all contractors must follow.

100% of e-waste was recycled in FY 2023. Berkeley Lab is working toward transitioning its recycling contracts to electronics recyclers certified under either the e-Stewards or Responsible Recycling (R2) programs.

Moratorium metal. In 2000, DOE suspended the release of metal for the purpose of recycling from "radiological areas" (as defined by 10 CFR Part 835). Berkeley Lab has a system in place to ensure that metal removed from radiological areas is not recycled. The metal is surveyed by Berkeley Lab's Radiation Protection Group and either managed as radiologically contaminated debris or stored securely until it is landfilled.

3.5.7 Water Assessment

In March 2024, Sustainable Berkeley Lab prepared a site-level water assessment that:

- Described water supply and end-uses
- Reported actual water consumption from FY 2015 through FY 2023 and actual water cost for FY 2023
- Forecasted water consumption and costs through FY 2034
- Presented a sitewide water balance for FY 2023 (see Figure 3-2 below)
- Described ongoing water monitoring efforts
- Identified water conservation control and retrofit measures
- Outlined additional considerations for future water conservation efforts, particularly around growth in high-performance computing and associated cooling demands

The Berkeley Lab water assessment addressed several drivers:

- **DOE Order 436.1A:** DOE elements must develop, implement, and update a Water Management Plan at least every 5 years that documents current water use, projected water use, planned water efficiency improvements and conservation activities, and water-reduction goals.
- **E.O. 14057 Sec 206:** Agencies will set ambitious, data-driven 2030 goals and annual targets for energy and water reductions based on leading performance benchmarks for building type categories and the composition of the agency's building portfolio.
- **42 U.S.C. § 8253(b):** Agencies are required to install all life-cycle cost-effective energy and water conservation measures in owned buildings to the maximum extent practicable, as soon as practicable after October 1, 2022.

The water assessment included a site-wide water balance for Berkeley Lab's main site for FY 2023, which is provided on Figure 3-2.

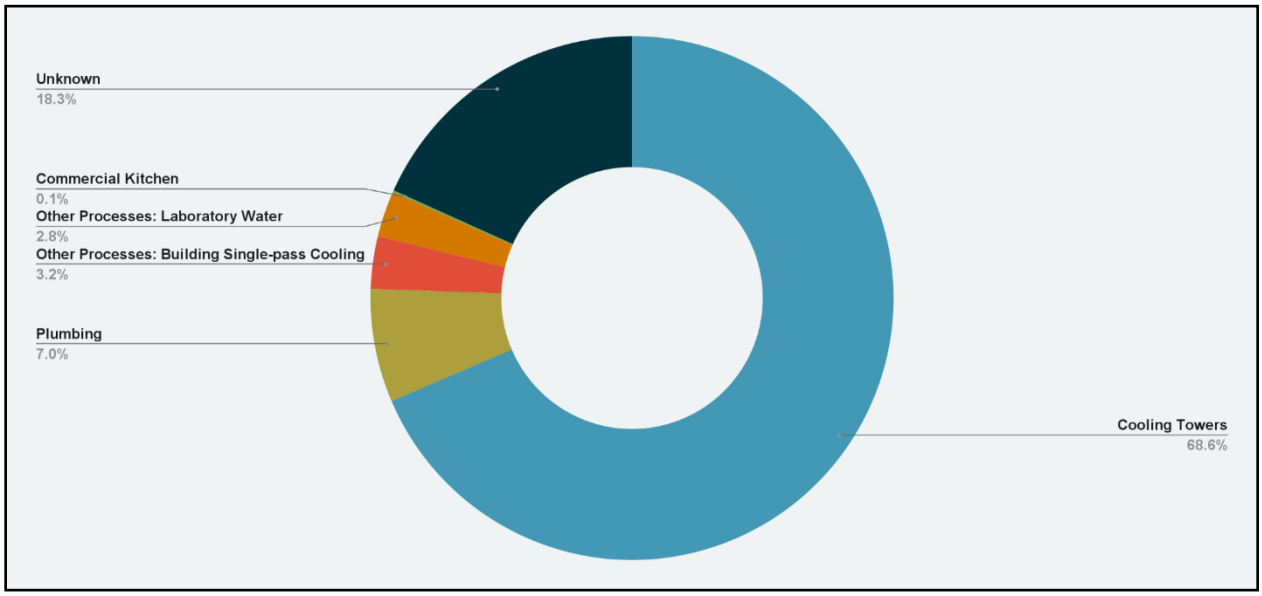

Figure 3-2 Sitewide Water Balance for Berkeley Lab's Main Site for FY 2023

As described in the water assessment, Berkeley Lab's largest water-consuming end-use is cooling demand for high-performance computing at the National Energy Research Scientific Computing Center (NERSC), which consumed 30% of Berkeley Lab's water in FY 2023. NERSC is also Berkeley Lab's greatest potential anticipated growth in water consumption since increases in compute capacity at NERSC will increase cooling needs. Berkeley Lab is working to mitigate this risk by planning to install, during the next facility upgrade at Building 59, air-cooled heat exchangers (ACHEs), also known as dry coolers, which can reject heat without consuming water. Berkeley Lab is seeking to maximize the installation of ACHEs during the next facility upgrade.

4 Environmental Monitoring

Berkeley Lab's environmental monitoring programs assess the impact of its emissions on public health and the environment, which is important for measuring environmental stewardship performance and demonstrating compliance with requirements established by federal, state, and local agencies. These programs also confirm adherence to DOE environmental protection policies and support environmental management decisions. This chapter presents summaries of 2023 sampling and monitoring results for the following media and processes:

- Groundwater
- Penetrating radiation monitoring
- Radiological clearance of property
- Soil and creek sediment
- Stack air
- Surface water
- Vegetation and foodstuffs
- Wastewater

4.1 STACK AIR

Berkeley Lab's air monitoring program is designed to assess the impacts from radiological air emissions due to operational activities, and consists of exhaust stack sampling, real-time monitoring, and dispersible inventory evaluation. This program is conducted in accordance with the U.S. EPA and DOE requirements, which are referenced in more detail in the subsection Radiological Emissions.

Numerous radionuclides are used in research programs across Berkeley Lab, and small quantities of additional radioactive materials are generated by some of the on-site accelerators. When the radioactive material is dispersible, it is typically emitted from a stack via the building's exhaust system, and Berkeley Lab is required to assess the potential impacts from those radionuclide emissions using U.S. EPA–approved computer software codes CAP88-PC and COMPLY. This process is covered in more detail in Section 5.3. The purpose of the evaluation (in addition to meeting regulatory drivers) is to determine under which U.S. EPA Region 9–approved NESHAP Categories (see Table 4-1) an emissions source falls. The NESHAP Category then indicates the appropriate monitoring scheme for that source. Potential emissions are most often estimated conservatively (i.e., modeled using the limit of authorized values), whereas actual emissions are either sampled or monitored at the stacks through which the emissions are released. *Sampling* is the collection of radionuclides on a filter or absorbent media, and subsequent analysis of the filters or media at an analytical

laboratory, whereas *monitoring* is the continuous measurement of radionuclides in a medium, such as an exhaust stack effluent, in real time.

Each year, new and renewed activities involving dispersible radioactive materials are evaluated for their potential to emit radionuclides to the air. In 2023, all radioactive air emissions sources were found to be less than 0.1 mrem/yr (i.e., minor emissions sources), and thus fall into either Category 3, which requires periodic sampling, or Category 4, which requires a dose evaluation but no sampling or monitoring. Berkeley Lab did not have any major emissions sources (Category 1 or 2) in 2023, and has never been noncompliant with the U.S. EPA radioactive air emissions regulations.

Table 4-1 U.S. EPA–Approved Radionuclide Emissions Measurement Approach

Category	AEDE (mrem/yr)	Requirements
Noncompliant	AEDE ≥ 10	Reduction or relocation of the source and re-evaluation before authorization
1	10 > AEDE ≥ 1	Continuous sampling with weekly collection and real-time monitoring for short-lived radionuclides
2	1 > AEDE ≥ 0.1	Continuous sampling with monthly collection or real-time monitoring for short-lived radionuclides
3	0.1 > AEDE ≥ 0.01	Periodic sampling 25% of the year
4	0.01 > AEDE	Potential dose evaluation before project starts and when project changes; no sampling or monitoring required

AEDE = annual effective dose equivalent

At some locations, Berkeley Lab follows a more conservative approach that may include either real-time monitoring or more frequent sampling than required to better characterize emissions. In 2023, 21 effluent stack samplers were involved in Berkeley Lab's NESHAP program, of which 6 drew exhaust air continuously with monthly particulate filter changeouts and 15 ran for one month at a time every quarter. Continuous real-time monitoring was also performed on three stacks associated with Berkeley Lab's accelerators. Sampling and monitoring locations are shown on Figure 4-1.

Stack exhaust samples were analyzed for four radiological parameters – gross alpha, gross beta, gamma spectroscopy, and tritium – and the real-time stack air monitoring systems measured for the positron emitters such as Fluorine-18 and Carbon-11. Fluorine-18 (half-life of 1.83 hours) produced from the Building 56 accelerator was the predominant radionuclide measured, accounting for approximately 54.5% of Berkeley Lab's emitted activity, but was only roughly 0.05% of the regulatory emissions limit. Additional details on stack emissions are available in Berkeley Lab's annual Radionuclide Air Emissions Report, which is submitted to DOE and the U.S. EPA and is available on the Environmental Publications page of ESG's website. For information on the estimated dose from radionuclide emissions, see Chapter 5.

4.2 SURFACE WATER

Surface water quality is evaluated at and around Berkeley Lab by sampling creek water and stormwater.

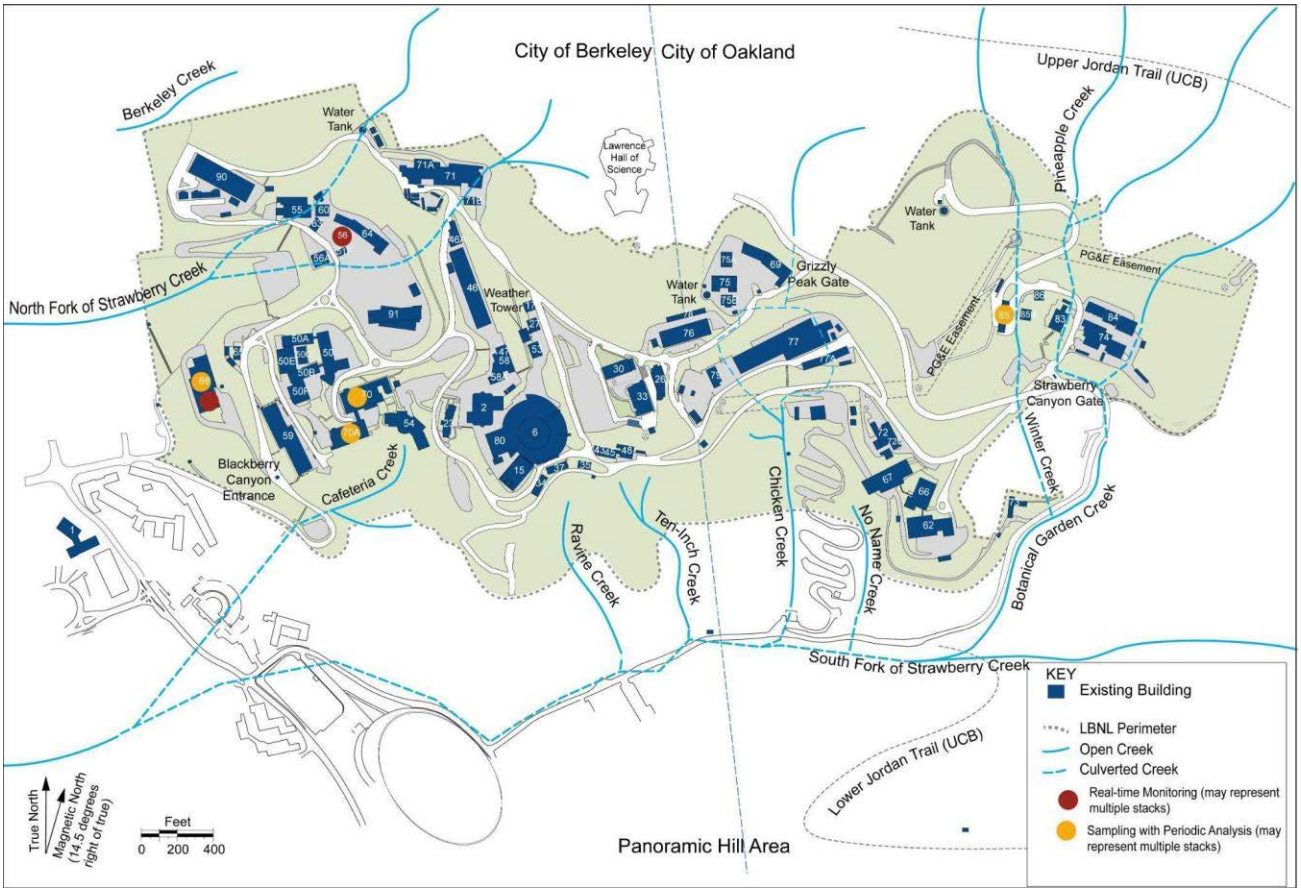

Figure 4-1 Building Exhaust Sampling and Monitoring Locations

4.2.1 Creek Sampling

The sampled creeks either flow through or originate within the LBNL site. The following creeks are sampled within the Strawberry Creek watershed (from west to east on Figure 4-2):

- Botanical Garden Creek
- Cafeteria Creek
- Chicken Creek
- No Name Creek
- North Fork of Strawberry Creek
- Ravine Creek
- Ten-Inch Creek
- Winter Creek, which is sampled at two locations (inflow and outflow points to the site)

The creeks are normally sampled twice a year – once during the wet season and once during the dry season. Creek samples are analyzed for VOCs to monitor for the potential off-site migration of groundwater contaminants. The only compound detected in 2023 was chloroform. The detection is suspected to be the

result of analytical laboratory contamination or possibly insufficient post-decontamination drying of sampling equipment. Chloroform is a disinfection byproduct of the chlorination of drinking water.

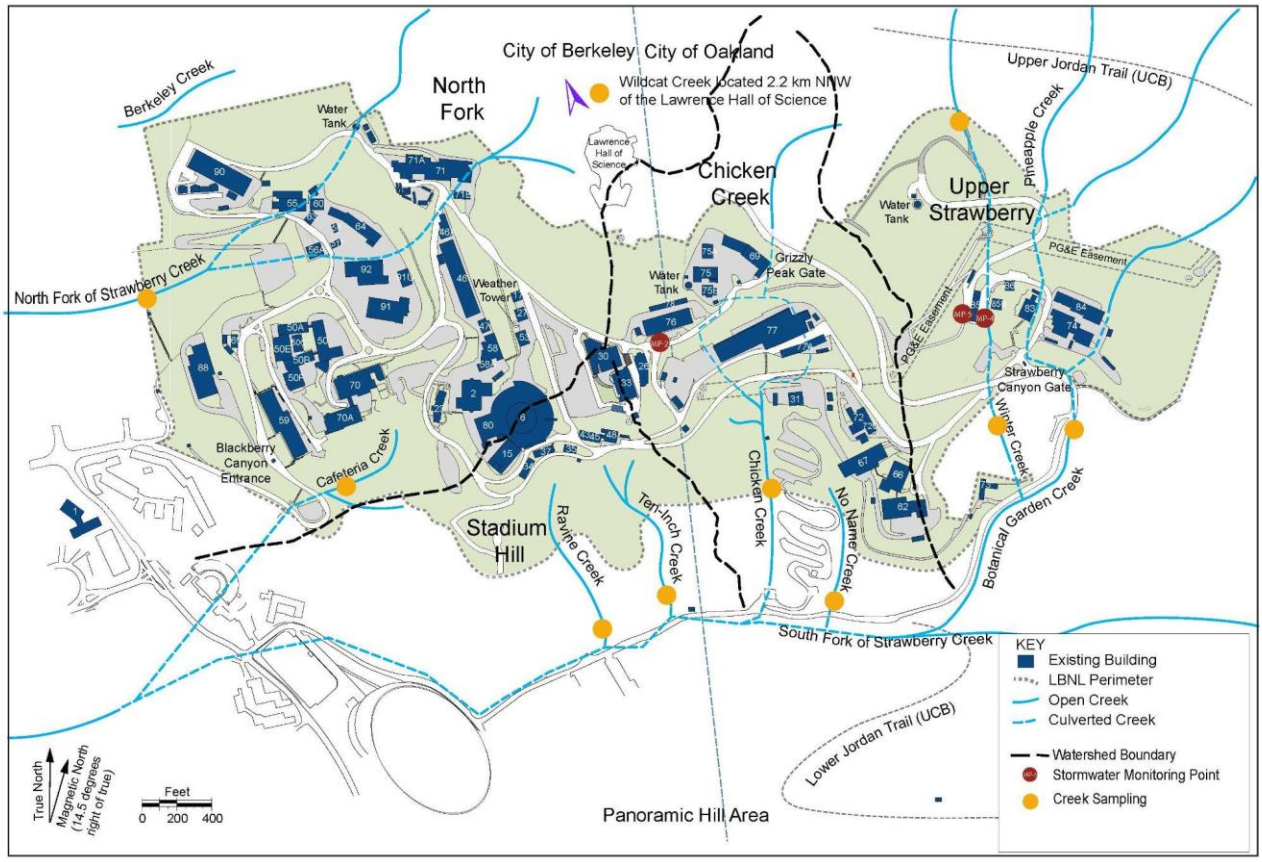

Figure 4-2 Surface Water Sampling Locations for Stormwater Reporting Year 2022–2023

Samples from the following subset of creeks were collected and analyzed for gross alpha, gross beta, gamma spectroscopy, and tritium in accordance with DOE Order 458.1 requirements: Chicken Creek, the North Fork of Strawberry Creek, Wildcat Creek, and Winter Creek (inflow and outflow points). Samples were collected from Wildcat Creek at a location in Tilden Regional Park approximately 1.4 miles (2.2 km) north-northwest of UC's Lawrence Hall of Science to establish background water quality values for the area. Wildcat Creek originates in Tilden Park and flows in a northwest direction away from Berkeley Lab.

Although LBNL surface waters are not used as a source for public drinking water, Berkeley Lab evaluates creek water results against conservative maximum contaminant level (MCL) drinking water standards, as well as the water quality objectives stated in the *Water Quality Control Plan for the San Francisco Bay Basin* (commonly known as the Basin Plan; RWQCB, 2021). The federal and state MCL values for radionuclides in drinking water are as follows (RWQCB, 2019; U.S. EPA, 1976):

- gross alpha – 15 picocuries per liter (pCi/L)
- gross beta, federal – 4 milliroentgen equivalent man per year (mrem/yr)

- gross beta, state – 50 pCi/L
- radium-226 and radium-228 (combined) (Ra-266/Ra-228)– 5 pCi/L
- tritium – 20,000 pCi/L

Laboratory analysis reported 31 of the 45 analytical results (68.8%) as below minimum detectable concentrations (MDCs). As shown in Table 4-2, there were three detectable gross alpha results, six detectable gross beta results, and five detectable Ra-226/Ra-228 results, though none of the results represent a background-subtracted result. In other words, these are gross detections above analytical MDCs absent the context of background measurements. As such, naturally occurring radioactive materials, such as potassium-40, uranium-238, and thorium-232, as well as their (naturally occurring) products, are commonly measured in the environment (including at LBNL) and are considered to contribute the majority of, if not all, the detectable gross alpha, gross beta results, and Ra-226/Ra-228 results. Tritium was not detected in any of the samples.

Table 4-2 Detectable Radiological Results from 2023 Creek Sampling

			State		Federal	
Activity	Creek	Concentration (pCi/L)	MCL[a] (pCi/L)	% of MCL	MCL (mrem/yr)	% of MCL
Gross alpha	North Fork Strawberry Creek	1.63	15	10.87%	N/A	N/A
Gross alpha	North Fork Strawberry Creek	1.80	15	12.00%	N/A	N/A
Gross alpha	Winter Creek	1.96	15	13.07%	N/A	N/A
Gross beta	Chicken Creek	1.91	50	3.8%	4	1.1%
Gross beta	Chicken Creek	2.73	50	5.5%	4	1.6%
Gross beta	North Fork Strawberry Creek	1.22	50	2.4%	4	0.7%
Gross beta	North Fork Strawberry Creek	2.88	50	5.8%	4	1.7%
Gross beta	Wildcat Creek	2.31	50	4.6%	4	1.4%
Gross beta	Winter Creek	1.03	50	2.1%	4	0.6%
Ra-226/Ra-228	Chicken Creek	0.45	5	9.0%	N/A	N/A
Ra-226/Ra-228	North Fork Strawberry Creek	0.597	5	11.9%	N/A	N/A
Ra-226/Ra-228	Wildcat Creek	0.499	5	10.0%	N/A	N/A
Ra-226/Ra-228	Wildcat Creek	0.581	5	11.6%	N/A	N/A
Ra-226/Ra-228	Winter Creek	0.35	5	6.9%	N/A	N/A

[a] MCL = maximum contaminant level for drinking water, in picocuries per liter (pCi/L)

Using gamma spectroscopy measurement for specific radionuclides, the results indicated that 68 of the 73 analytes (93.1%) measured during 2023 creek sampling were not detected above MDCs (U.S. EPA, 1980). Radiological activities for the remaining samples (5 analytes) with detectable results above MDCs were within environmental and historical concentrations monitored by Berkeley Lab. Because Berkeley Lab does not discharge radionuclides to liquid effluent, these detected concentrations are attributed to naturally occurring radioactive material, such as uranium and thorium decay chain progeny, that are ubiquitous in the environment.

4.2.2 Stormwater Sampling

Berkeley Lab's *Stormwater Monitoring Implementation Plan* describes the sampling rationale, sampling locations (see Figure 4-2), and analytical parameters for each specific industrial activity (LBNL, 2023d). The Industrial General Permit also requires visual observation of the surface water runoff from each qualifying storm event, monthly dry weather visual observations of non-stormwater discharges, and an annual sitewide inspection.

Under the terms of the Industrial General Permit, Berkeley Lab must conduct stormwater sampling each reporting year during four storm events that meet a set of permit-specific conditions. Two of the sampling events typically occur within the first half of each reporting year (July 1 through December 31), with the remaining two then taking place during the second half of the reporting year (January 1 through June 30).

Berkeley Lab routinely conducts sitewide pollutant source assessments (PSAs) to identify potential point source areas of industrial activity conditionally subject to the General Permit's monitoring requirements. Based on the PSA findings and the General Permit's monitoring requirements, in stormwater reporting year 2022/2023, stormwater samples were collected and analyzed for the following five parameters:

1. aluminum
2. iron
3. pH
4. oil and grease
5. total suspended solids

During 2015/2016, the Industrial General Permit set all facilities in the state operating under this permit at the "Baseline" compliance status. To remain at Baseline, a facility would need to maintain the average results for each sampled parameter below that parameter's Numeric Action Level (NAL) established by the State Water Board.

Based on stormwater sampling results from the reporting year 2022/2023, Berkeley Lab did not exceed annual NALs for each of the five parameters analyzed. As a result, Berkeley Lab returned to Baseline status for all parameters for reporting year 2023/2024.

The following table summarizes Berkeley Lab's discharger status for aluminum and iron since adoption of the General Permit in 2015.

Table 4-3 Industrial Stormwater General Permit Discharge Status for Aluminum and Iron

Stormwater Reporting Year	Discharge Status[a]
2015–2016	Baseline
2016–2017	Level 1
2017–2018	Level 2
2018–2019	Baseline
2019–2020	Level 2
2020–2021	Level 2
2021–2022	Level 2
2022-2023	Level 2
2023-2024	Baseline

[a] Discharge Status as defined by the Industrial Stormwater General Permit

A change in status results in a requirement that Berkeley Lab identify additional stormwater controls in order to prevent future exceedances of NALs. These additional controls are either administrative or structural/treatment controls:

1. Administrative controls included updating procedures and expanding stormwater training for LBNL staff, vendors, and contractors.
2. Structural/treatment controls included additional asphaltic berms and check dams, and enhanced filtration for metal treatment.

The change in discharge status continues to result in updates to the SWPPP to include stormwater controls.

4.3 WASTEWATER

As required by permits issued by EBMUD, Berkeley Lab samples wastewater for radiological monitoring at its two monitoring stations downstream of the main site, and at three of four on-site FTUs for nonradiological monitoring. Sampling is also conducted to assess permit compliance for discharges of treated water from hydraugers and groundwater extraction wells.

For 2023, all monitoring results were below EBMUD discharge limits. Monitoring results, an overview of monitoring locations, and a summary of any sanitary sewer spills are discussed in the following subsections.

4.3.1 Wastewater Monitoring Locations

As discussed in the subsection Wastewater, Berkeley Lab holds EBMUD wastewater discharge permits for general sitewide activities and for the discharge of treated groundwater operations at eight locations. Each permit specifies periodic monitoring and reporting requirements.

Berkeley Lab's sanitary sewer system, shown on Figure 4-3, has two radiological monitoring stations, each located near the outfall of one of the two main sewer system branches:

1. Hearst Monitoring Station is located at the head of Hearst Avenue below the western edge of Berkeley Lab immediately before the connection to the City of Berkeley's sewer main. Discharges from Berkeley Lab's western and northern areas flow through this monitoring station.
2. Strawberry Monitoring Station is located next to Centennial Drive in lower Strawberry Canyon. Discharges from Berkeley Lab's eastern and southern areas, as well as from several upstream UC Berkeley campus facilities, are routed through this monitoring station before tying into UC-owned piping downstream and then into the City of Berkeley's sewer system.

As indicated on Figure 4-3, Berkeley Lab also has four FTUs that are permitted points of compliance for sanitary sewer discharges. Berkeley Lab collects samples for nonradiological analysis at three of the four on-site FTUs. Additional details are provided in the subsection Nonradiological Monitoring.

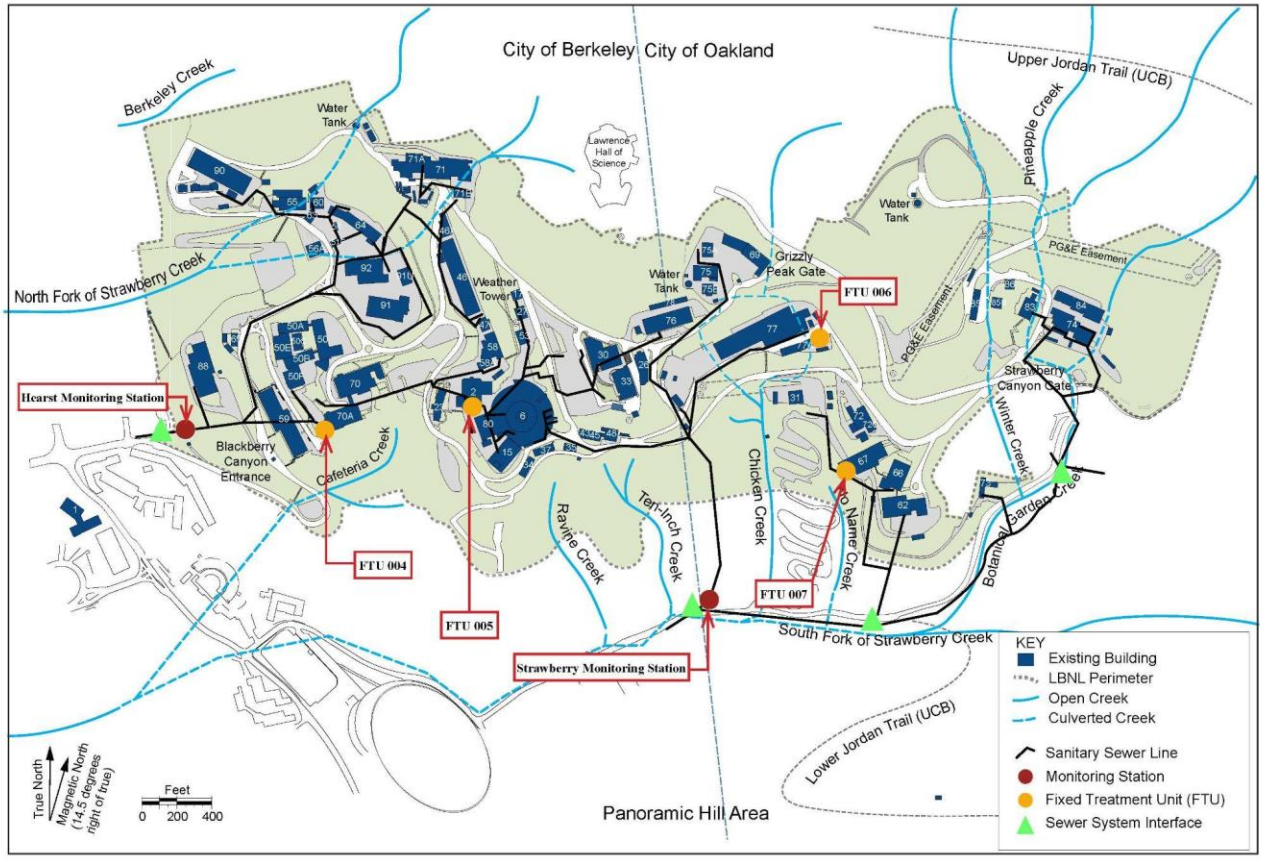

Figure 4-3 Sanitary Sewer System (Main Lines)

4.3.2 Hearst and Strawberry Sewer Outfalls

In 2023, Berkeley Lab discharged approximately 29.1 million gallons through the Hearst branch of the sewer system and 25.4 million gallons through the Strawberry branch, as measured by flow meters installed at

both outfalls. Sampling and monitoring are conducted at these sewer outfalls as described briefly below; additional details are given in the subsections Radiological Monitoring and Nonradiological Monitoring.

Radiological Monitoring

Radiological monitoring is required by DOE Order 458.1 (DOE, 2020) and corresponding guidance (DOE, 2015). Monitoring verifies compliance with radiological limits established by DOE to regulate the use of radioactive materials.

For radiological monitoring, composite sampling is collected semiannually at the Hearst and Strawberry outfalls and analyzed by a DOE-accredited, state-certified laboratory for gross alpha, gross beta, iodine-125, tritium, Ra-226/Ra-228, and carbon-14. All samples taken at the Hearst and Strawberry sanitary sewer outfalls in 2023 were below the MDCs for carbon-14, iodine-125, gross alpha, and tritium. Although sewer discharges are not used for drinking water, positive results are conservatively compared to state and federal MCLs as a demonstration of compliance with DOE Order 458.1 (DOE, 2020). Positive results for gross beta and Ra-226/Ra-228 were consistently detected throughout the year at the Hearst and Strawberry sewer outfalls, and are attributed to the naturally occurring radioactive materials that are ubiquitous in nature. The highest characterized gross beta concentration detected throughout the year was 10.4 pCi/L, which is below the state MCL for drinking water of 50 pCi/L, and is equivalent to approximately 0.61 mrem/yr, which is below the federal MCL for drinking water of 4 mrem/yr.

In accordance with DOE guidance (DOE, 2022b), annual discharges are conservatively estimated by multiplying the maximum sample result's concentration by the total annual volume discharged for each radionuclide being evaluated. In instances where no detectable concentrations of a radionuclide were evaluated, the highest value reported by the analytical laboratory is used in order to produce a conservative estimate, and the highest concentration per radionuclide (detected or otherwise) is assumed constant throughout the year. For carbon-14, iodine-125, gross alpha, and tritium results, because all results were below the MDCs and the MDCs met LBNL's stated data quality objectives, these values are considered estimated values. The annual discharge estimates are summarized in Table 4-4.

Table 4-4 Comparison of Estimated Annual Discharge to DOE O 458.1 Discharge Activity Limits

Radionuclide	Estimated Annual Discharge (Ci)	Percentage of Discharge Activity Limit
carbon-14	2.32×10^{-3} Ci	0.23% of the carbon discharge limit of 1 Ci
tritium	7.46×10^{-3} Ci	0.15% of the tritium discharge limit of 5 Ci
gross alpha, gross beta, iodine-125, Ra-226, Ra-228	2.38×10^{-3} Ci	0.24% of the combined discharge limit of 1 Ci

DOE Order 458.1 requires facilities to control discharges into sanitary sewers if average monthly activity at the point of discharge is greater than five times Derived Concentration Standard (DCS) values for ingested water specified in DOE-STD-1196-2022, *Derived Concentration Technical Standard* (DOE, 2022b). Compliance

is demonstrated when the fraction of each DCS value is calculated, based on consecutive 12-month average concentrations, and totaled. Berkeley Lab does not discharge radionuclides to the sanitary sewers, and has ceased that activity since 2010, which makes this DOE O 458.1 requirement not applicable. Nevertheless, Berkeley Lab compared analytical sewer sample data, and tabulated the results in Table 4-4 against DOE DCS values in Table 4-5. The calculated discharges for gross alpha (thorium-232), gross beta (strontium-90), carbon-14, iodine-125, Ra-226, Ra-228, and tritium were 0.015 (1.5%) and 0.015 (1.5%) of the allowable sum fractional DCS values in the Strawberry and Hearst sanitary sewer systems, respectively. Thus, all results were well below the DOE DCS values.

Table 4-5 Comparison of Average Hearst and Strawberry Sanitary Sewer Concentrations to the Derived Concentration Technical Standard (Table 6 of DOE-STD-1196-2022)

Outfall	Radionuclide	Average Concentration (Bq/L)	DOE DCS (Bq/L)	Fraction of DOE DCS
Hearst Sanitary Sewer	Gross Beta (Sr-90)	2.34E-01	6.3E+01	3.7E-03
	Gross Alpha (Th-232)	3.71E-02	2.3E+01	1.6E-03
	Carbon-14	1.06E-01	1.2E+04	8.7E-06
	Tritium	1.83E-01	9.6E+04	1.9E-06
	Iodine-125	8.29E-02	1.5E+02	5.6E-04
	Ra-226	4.50E-02	1.0E+01	4.3E-03
	Ra-228	1.28E-02	2.7E+00	4.8E-03
				Sum: 0.015
Strawberry Sanitary Sewer	Gross Beta (Sr-90)	2.82E-01	6.3E+01	4.5E-03
	Gross Alpha (Th-232)	1.19E-02	2.3E+01	5.2E-04
	Carbon-14	8.50E-02	1.2E+04	7.0E-06
	Tritium	5.32E-01	9.6E+04	5.5E-06
	Iodine-125	-7.40E-04	1.5E+02	-5.0E-06
	Ra-226	4.80E-02	1.0E+01	4.6E-03
	Ra-228	1.51E-02	2.7E+00	5.6E-03
				Sum: 0.015

Bq/L = becquerels per liter

Nonradiological Monitoring

As described in the subsection Wastewater, Berkeley Lab collects nonradiological samples from the following on-site FTUs:

- Building 2, FTU 005
- Building 67, FTU 007
- Building 70A, FTU 004

In accordance with permit requirements, sample collection is performed each year in March and September. Nonradiological samples collected at the FTUs are analyzed for pH, total identifiable chlorinated hydrocarbons, chemical oxygen demand, total suspended solids, and specific metals.

All metals and total identifiable chlorinated hydrocarbon results were below EBMUD permissible discharge limits, and pH results were well above 5.5, as required by the permit. Total suspended solids and chemical oxygen demand do not have discharge limits and are measured to determine wastewater strength, which forms the basis for EBMUD's wastewater treatment charges.

4.3.3 Treated Hydrauger and Extraction Well Discharge

Berkeley Lab currently has nine treatment systems permitted by EBMUD to discharge treated groundwater to the sanitary sewer. Sources of this treated groundwater are certain hydraugers, groundwater extraction wells, and well purging and development activities. The treatment process consists of first filtering the groundwater to remove sediment and then passing the contaminated groundwater through a GAC system to remove hydrocarbons. Samples of the treated water are collected and analyzed for VOCs using U.S. EPA–approved methods. Sampling results have never exceeded the EBMUD permissible discharge limits.

4.3.4 Building 77 Ultra-High Vacuum Cleaning Facility Wastewater

Cleaning processes at the Ultra-High Vacuum Cleaning Facility at Building 77 include passivating (making a metal surface less chemically reactive), acid and alkaline cleaning, and ultrasonic cleaning of metal parts used in research and support activities. Acid and alkaline rinse waters that contain metals from this facility's operations are routed to Building 77A's FTU 006, which is a zero-waste-discharge recycling system. The EBMUD permit requires that Berkeley Lab submit an annual discharge prevention compliance report certifying that Building 77 is not discharging any regulated process wastewater to the sanitary sewer. The annual discharge prevention compliance report for 2023 was submitted in January 2024.

4.3.5 Sewer System Management Plan

In December 2022, the State Water Board adopted Statewide General Waste Discharge Requirements for Sanitary Sewer Systems, Water Quality Order No. 2022-0103-DWQ (Sanitary Sewer Systems General Order), which became effective on June 5, 2023. The Sanitary Sewer Systems General Order requires public agencies that own or operate sanitary sewer systems to develop and implement sewer system management plans and report all sanitary sewer spills to the State Water Board's online California Integrated Water Quality System (CIWQS) Sanitary Sewer System Database.

In May 2023, Berkeley Lab requested and received approval from the Water Board to terminate regulatory coverage under Order 2022-0103-DWQ, effective June 5, 2023. Berkeley Lab is a DOE federal agency site, and per the Order's enrollee definition, Berkeley Lab would require coverage if deemed necessary by either the State or Regional Board based on LBNL's history of spills, proximity to surface waters, or other factors

supporting regulatory coverage. Berkeley Lab provided the Water Board with the following assessment of nonapplicability and justifications for termination of coverage:

- Since 2006, Berkeley Lab's history of minor spills (or lack thereof) and history of regulatory reporting and supporting documentation completeness.
- LBNL's relatively small, 6.1-mile sanitary sewer, which is a gravity system with no force mains, lift stations, or other pressurized components.
- Berkeley Lab's network of SmartCover level and flow monitors to detect abnormalities and prevent sanitary sewer overflows.
- Numerous procedures and training for wastewater monitoring and spill response within LBNL's Facilities and EHS Divisions.

Berkeley Lab's *Sewer System Management Plan* (LBNL, 2020) addresses the proper operation, maintenance, overflow prevention, and funding for maintenance and capital improvements to the LBNL sanitary sewer system. The plan is reviewed every five years to ensure that information is current and available. The plan was last updated in March 2023 with minor edits and revisions.

No sanitary sewer overflows occurred in 2023.

4.4 GROUNDWATER

This section describes Berkeley Lab's groundwater monitoring program and provides a brief summary of the site's groundwater contaminant plumes and the corrective measures applied to each. More detailed information on RCRA Corrective Action Program activities is provided in the Environmental Restoration Program's Annual Progress Reports, which contain the site groundwater monitoring data, maps showing monitoring well locations and contaminant concentrations, and graphs showing variations in contaminant concentrations over time. These reports are available on the program's website at https://ehs.lbl.gov/resource/environmental-restoration-program/regulatory-documents/.

4.4.1 Groundwater Monitoring Overview

The groundwater monitoring network consists of more than 170 wells, including 10 that are used to monitor for potential migration of VOC-contaminated groundwater beyond the developed areas of the site and one for the potential off-site migration of tritium (see Figure 4-4). The objectives of groundwater monitoring are as follows:

- Evaluate the continued effectiveness of the corrective measures that have been implemented for cleanup of contaminated groundwater.
- Document that groundwater plumes continue to be stable or attenuating and are not migrating off-site.

- Monitor progress toward attaining the required groundwater cleanup levels.
- Monitor progress toward attaining the long-term goal of restoring all groundwater at the site to drinking water standards, if practicable. (Groundwater at Berkeley Lab is not used for domestic supply, irrigation, or industrial purposes.)

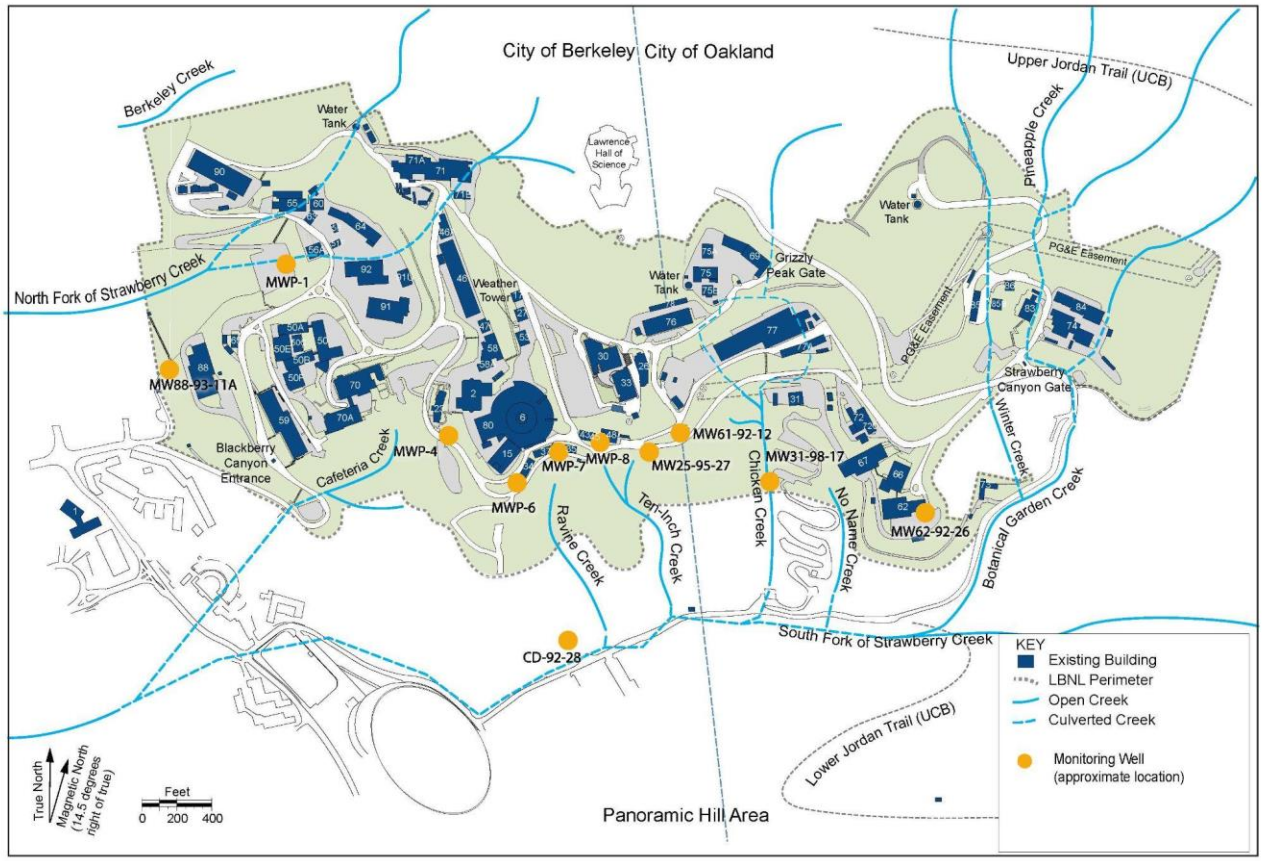

Figure 4-4 Groundwater Monitoring Wells Closest to the Downgradient Site Boundary

The groundwater monitoring data continue to indicate that the corrective measures have been effective in reducing VOC concentrations in the groundwater, and that groundwater contaminant plumes are stable or diminishing and contaminants are not migrating off-site.

VOCs: Berkeley Lab has identified four principal plumes of VOC-contaminated groundwater at the site: Old Town, Building 51/64, Building 51L, and Building 71B. The geometry and distribution of chemicals in the Old Town Plume indicate that the plume consists of three lobes – Building 7, Building 25A, and Building 52 – that were originally separate plumes but subsequently merged. In addition to the four principal plumes, VOC-contaminated groundwater is present in the following six localized areas: former Building 51A, former

Building 51 Vacuum Pump Room, Building 69A, Building 75/75A, Building 76, and Building 77. The locations of the plumes and other areas of groundwater contamination are shown on Figure 4-5.[2]

The primary VOCs detected in the groundwater are chlorinated VOCs (e.g., tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride) and their associated degradation products (e.g., 1,1-dichloroethylene, cis-1,2-dichloroethylene, 1,1-dichloroethane, and vinyl chloride). Concentrations of VOCs in most areas have declined significantly, mainly as a result of the implemented corrective measures. However, VOC concentrations remain above MCLs for drinking water in several areas.

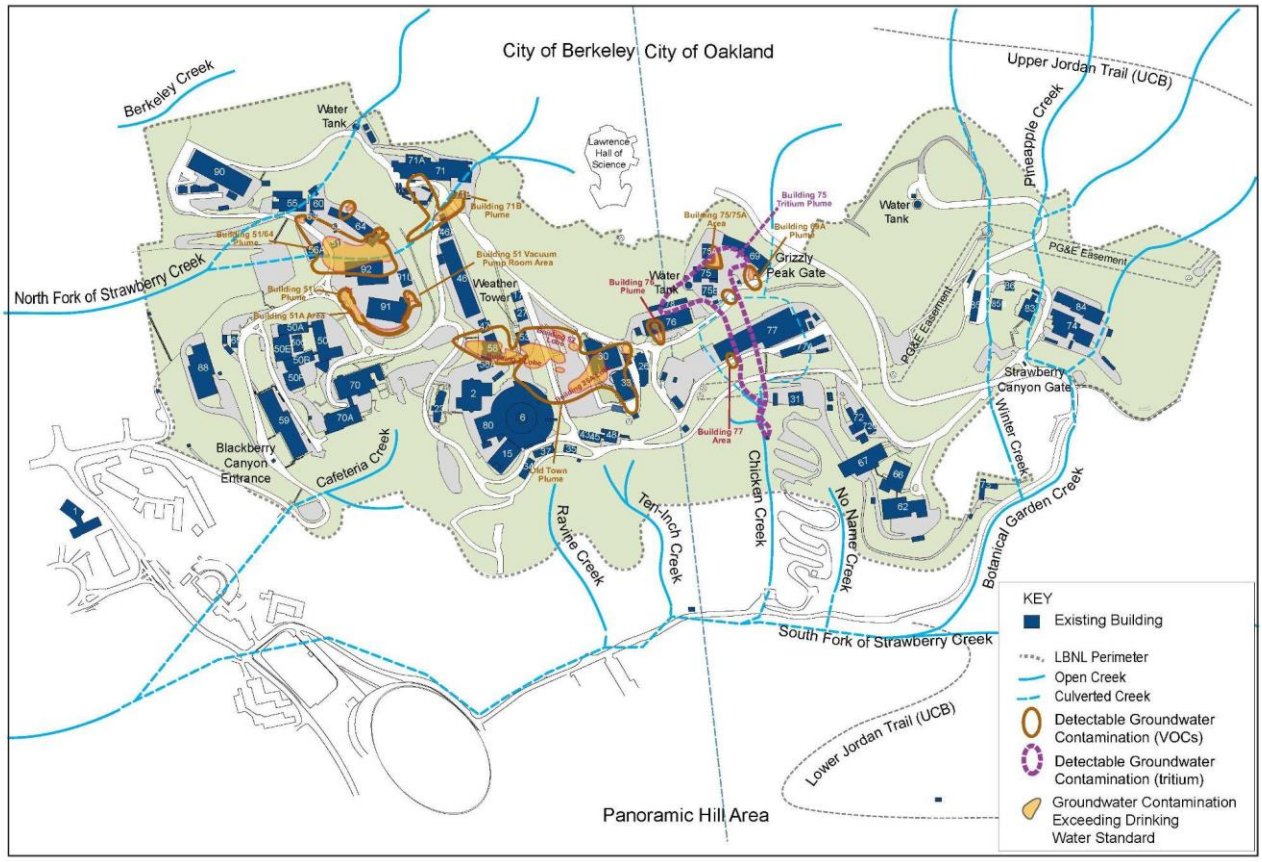

Figure 4-5 Locations of Groundwater Contamination

Tritium: A plume of tritium-contaminated groundwater extends southward from the Building 75 area. The source of the plume was the former National Tritium Labeling Facility (NTLF), which ceased operation in December 2001. Since closure of the NTLF, concentrations of tritium detected in the groundwater have declined steadily, with concentrations below the drinking water standard of 20,000 pCi/L (U.S. EPA, 1976;

[2] Several of the buildings for which the groundwater plumes and other areas of groundwater contamination were named have been demolished, including Buildings 51, 51A, 51L, 7, 25A, and 52.

RWQCB, 2021) since February 2005. The maximum concentration of tritium detected in 2023 was approximately 25% of the MCL. The location of this tritium plume is shown on Figure 4-5.

4.4.2 Treatment Systems

Berkeley Lab is extracting contaminated groundwater from collection trenches, extraction wells, and subdrains to control the migration of groundwater plumes, clean up contaminated groundwater, and prevent the release of contaminated groundwater to surface water. Ten GAC treatment systems continued to operate in 2023 to treat extracted groundwater, which totaled approximately 6.96 million gallons for the year. The cumulative volume of groundwater treated from 1991 through the end of 2023 was approximately 219 million gallons. The treated water is either injected into the subsurface, if needed for soil flushing, or discharged to the sanitary sewer system in accordance with the EBMUD permit for this type of discharge (EBMUD, 2022).

4.5 SOIL AND CREEK SEDIMENT

This section summarizes monitoring results for soil and creek sediment samples collected in 2023 as required by DOE Order 458.1 and guidance (DOE, 2015). Locations for soil and sediment sampling are shown on Figure 4-6.

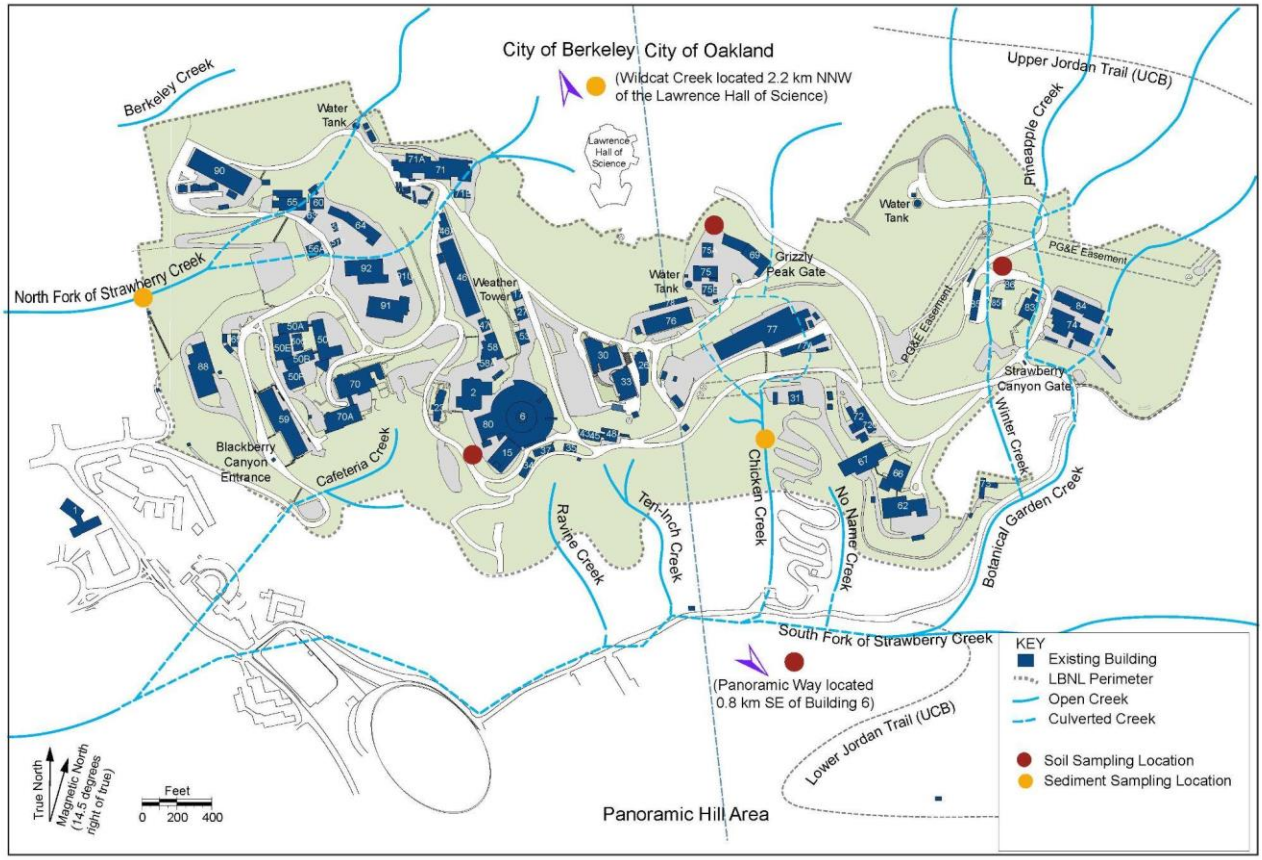

Figure 4-6 Soil and Sediment Sampling Sites

4.5.1 Soil Sampling

Soil samples obtained from the top 2 inches of surface soil were collected from three locations within the LBNL site (near Buildings 75, 80, and 85) and from one off-site environmental monitoring station (on Panoramic Way southeast of Building 6). The sample from the Building 85 location was split for quality control purposes. Samples were analyzed for gross alpha, gross beta, gamma emitters, and tritium.

The radiological results for gross alpha, gross beta, and gamma emitters at each of the sampling locations were within background threshold values at the main site and similar to background levels that would be attributable to naturally occurring radioactive elements commonly found in soils (Eisenbud, 1973; NCRP, 1987). Tritium measurements at each sampling location were below MDCs.

4.5.2 Creek Sediment Sampling

Creek sediment samples were collected at Chicken Creek and the North Fork of Strawberry Creek within the LBNL main site and at Wildcat Creek in Tilden Regional Park. At each sample location, grab samples were collected and then composited for analysis of gross alpha, gross beta, gamma emitters, and tritium. Most radionuclides measured were not detected above minimum detectable concentrations, and all other analytes were indistinguishable from background per LBNL's main site natural background criteria (LBNL, 2022a).

4.6 VEGETATION AND FOODSTUFFS

Sampling and analysis of vegetation and foodstuffs can provide information regarding the presence, transport, and distribution of radioactive emissions in the environment. This information can be used to detect and evaluate changes in environmental radioactivity resulting from LBNL activities, and to calculate the potential human dose that would occur from consuming vegetation and foodstuffs.

As a result of past air emissions from the former NTLF located at Building 75, vegetation near that site contains measurable concentrations of tritium. Berkeley Lab analyzes vegetation for both chemical forms in which tritium occurs, namely, organically bound tritium and tissue-free water tritium. Since the closure of the NTLF in December 2001, tritium emissions from LBNL activities have decreased sharply, as noted in Section 4.4.1. Tritium concentrations in vegetation have decreased also, albeit more slowly, as a result of radioactive decay and biological elimination (use) of the uptake tritium.

In 2023, LBNL performed comprehensive vegetation sampling and analysis activities to characterize the current tritium concentration in vegetation and, if able, release the area from further sampling requirements. The results of this characterization demonstrated that all locations and vegetation (i.e., tree core, leaf, and duff) sampled were within background concentrations for tritium, and statistical analysis concurred with the findings. Therefore, the formerly impacted area of vegetation due to NTLF operations has now returned to background concentrations.

4.7 PENETRATING RADIATION MONITORING

Radiation-producing machines (e.g., accelerators, X-ray machines, and irradiators) and a myriad of radionuclides are used at Berkeley Lab for high-energy particle studies and biomedical research. By magnitude, accelerator operations are the primary contributors of penetration radiation, such as gamma and neutron radiation. The accelerators at Berkeley Lab include the Advanced Light Source (Building 6), the Biomedical Isotope Facility (Building 56), the 88-Inch Cyclotron (Building 88), and the Laser Accelerator Center (Building 71). Of these accelerators, the ones located at Buildings 56 and 71 do not produce measurable penetrating gamma or neutron radiation into the environment. The accelerator at Building 71 is an experimental, smaller scale laser-driven accelerator, and the one at Building 56 is a mini medical cyclotron that primarily contributes to airborne emissions in the form of fluorine-18. Smaller radiation-producing machines (X-ray machines and irradiators) at Berkeley Lab do not measurably increase the dose to the public.

Berkeley Lab uses the following two methods to determine the environmental radiological impact from accelerator operations:

1. Real-time monitoring systems and associated telemetry that continuously detect and record gamma and neutron dose associated with accelerator operations, as well as positron-sensitive real-time monitoring at Building 56 and Building 88 effluent stacks.
2. Passive detectors known as optically stimulated luminescence dosimeters (OSLDs) and neutron-sensitive dosimeters, which provide an integrated gamma and neutron dose at various locations on site and at the site perimeter. Monitoring locations were chosen to best represent potential maximally exposed individual (MEI) locations and sources of penetrating radiation.

Although real-time monitoring is primarily used for occupational dose monitoring, telemetry data is also incorporated as part of LBNL's overall environmental monitoring program. Passive detectors are chosen (both in models and placement) to confirm that any external dose due to penetrating radiation from LBNL operations complies with the public dose constraints of DOE O 458.1. The locations of the dosimeters are shown on Figures 4-7 and 4-8, and the results of the public dose evaluation are discussed further in Section 5.2. Because geology affects radiological background (due to varied composition and concentration of naturally occurring radioactive material) and monitoring locations fall in different geologic units, Berkeley Lab has three locations for background dose: Tilden Park, Panoramic, and the hillside behind Building 85. These locations are considered unimpacted locations and are used to subtract from the reported dose at the MEI-monitoring dosimeter locations.

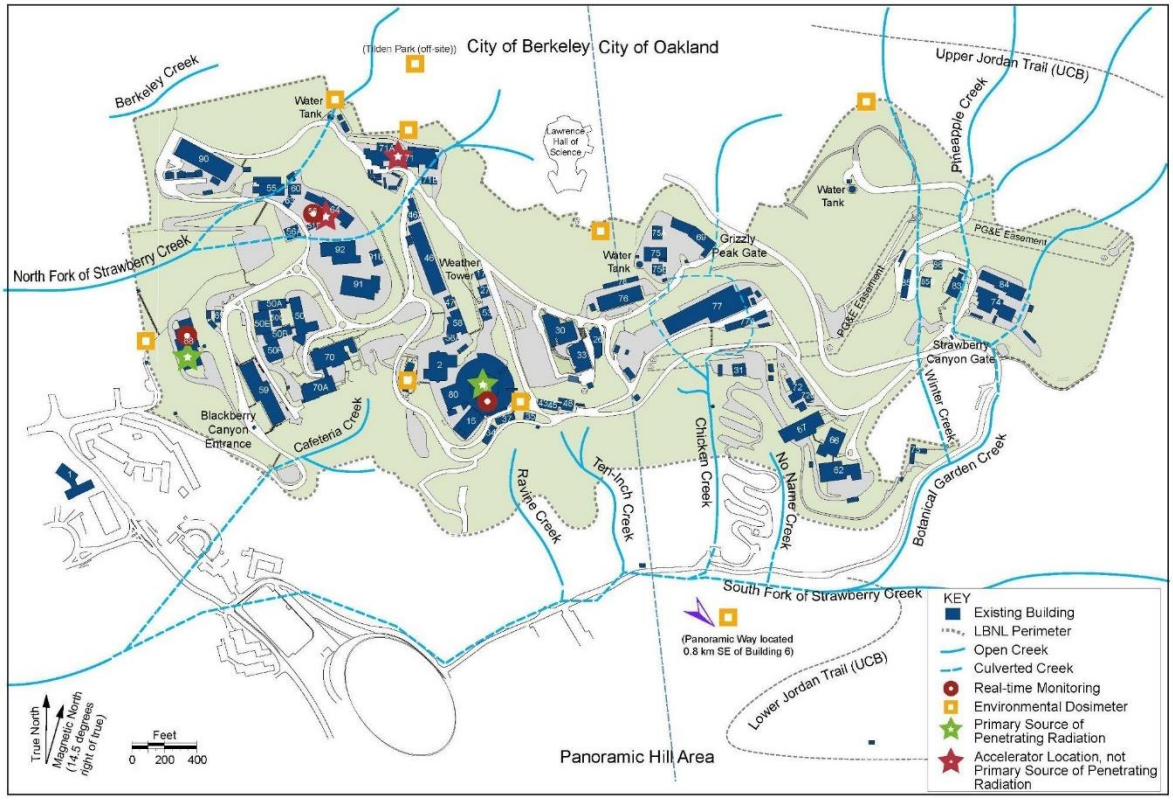

Figure 4-7 Primary Sources of Penetrating Radiation and Environmental Monitoring Locations

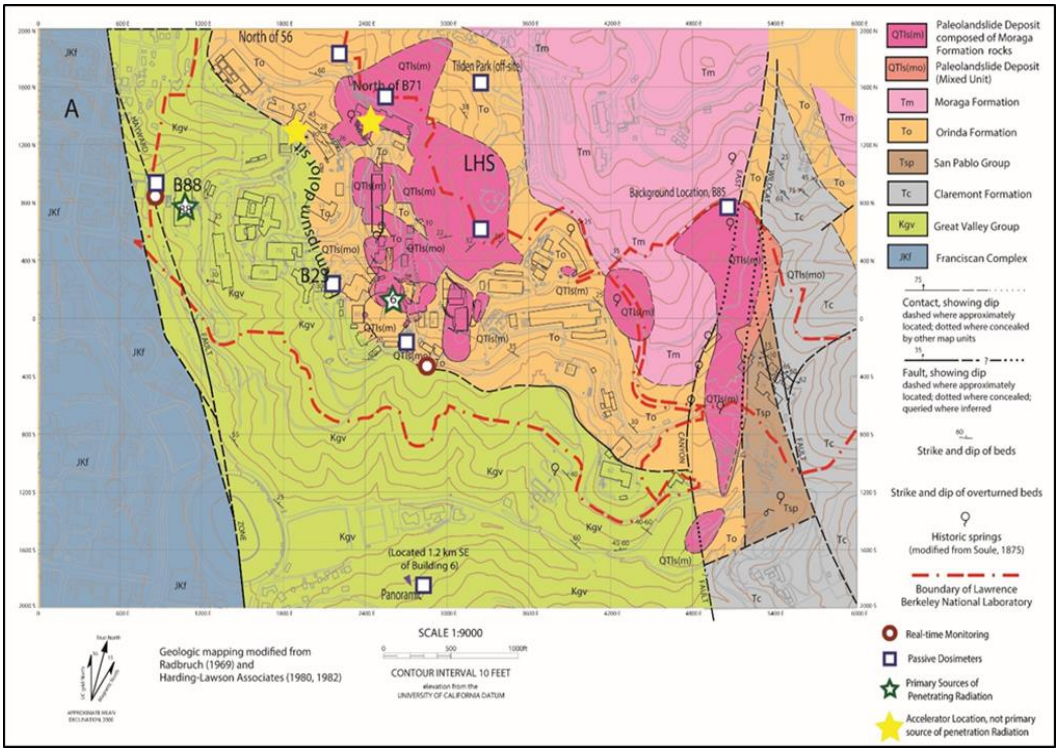

Figure 4-8 LBNL Geologic Units and Site Monitoring Parameters for Penetrating Radiation (LBNL Final RCRA Facility Investigation Report, September 2000)

4.8 RADIOLOGICAL CLEARANCE OF PROPERTY

Radiological clearance is the process by which radiologically impacted (or potentially impacted) real or personal property is evaluated to determine if it meets DOE release criteria. Requirements for this process are set by DOE Order 458.1 and 10 CFR 835, and specify the thresholds for evaluation. LBNL applies a three-tiered process when evaluating property (real or personal) for release and clearance:

- Tier 1 – the property has been demonstrated through process knowledge, radiological survey, or both to not contain residual radioactive material; that is, it is determined to be indistinguishable from natural background.
- Tier 2 – the property has been characterized sufficiently to demonstrate that the residual radioactivity is below the pre-approved DOE authorized limits (including project-specific Derived Concentration Guideline Levels [DCGLs]).
- Tier 3 – the property contains residual radioactive material in concentrations greater than the pre-approved authorized limits, and may be subject to a restricted release if the recipient of the property is authorized to possess the property by all applicable jurisdictions.

In 2023, there were no Tier 3 releases.

In addition, Berkeley Lab's safety principle of "as low as reasonably achievable" (ALARA) requires that property not be cleared for unrestricted release from radiological control under DOE Order 458.1 and 10 CFR 835 if it contains residual radioactivity that is distinguishable from background.

Berkeley Lab applies the required release and clearance criteria to all property under consideration, and property is released only when it can be demonstrated that it either does not contain residual radioactive material, or that residual radioactivity has been characterized sufficiently through process knowledge, radiological survey, and/or analytical measurement to conclude it only contains levels of radioactivity that are within release criteria. Any property that does not meet release criteria is transferred either to another DOE radiological facility for reuse or to a licensed radioactive waste facility for disposal.

In 2023, Berkeley Lab's Radiation Protection Group performed 158 release and clearance surveys. The survey results were used to determine whether the equipment could subsequently be reused on site without radiological controls or qualify for unrestricted release, such as disposal in a nonradiological landfill.

4.9 METEOROLOGICAL MONITORING

Berkeley Lab operates and maintains a 26-meter tower located west of Building 27. The tower uses instruments for monitoring meteorological parameters that include wind speed and direction, temperature, dew point, relative humidity, barometric pressure, precipitation, and solar radiation. Berkeley Lab processes weather tower data for the following purposes:

- Characterize historical and current meteorological conditions at the site for assessing risks.

- Provide critical information for the stormwater monitoring program necessary for complying with the California Water Board's industrial and construction permit requirements and submitting required information into SMARTS.
- Perform air dispersion modeling necessary for assessing off-site radiological doses and preparing the annual Radionuclide Air Emission Report, which is required by the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulation and submitted to the DOE and U.S. EPA.
- Support various research and operational support activities that require information regarding site meteorological conditions.
- Provide real-time information to on-site and off-site emergency responders in the event of a nearby accidental release of airborne contaminants or a wildland fire event.

Approximately twice per year, Berkeley Lab subcontracts with a third party to perform an independent audit of the sensors on the meteorological monitoring tower. The third-party inspections satisfy the intention of the regulatory guidance recommendation for independent audits. The audit procedures employed are consistent with Meteorological Monitoring Guidance for Regulatory Modeling Applications, February 2000, and the *EPA Quality Assurance Handbook for Air Pollution Measurement Systems*, Volume IV, Version 2.0 Final (U.S. EPA, 2008) and in accordance with manufacturer recommendations.

5 Radiological Dose Assessment

Radiological dose is the energy deposited in tissue mass through external irradiation, inhalation, or ingestion due to exposure from a source of radiation, such as radioactive material or a radiation-generating device like an X-ray machine. Berkeley Lab routinely conducts dose evaluations throughout the year to ensure dose to LBNL personnel, the public, and the environment is ALARA and remains very low. The health effects due to the estimated doses to the public and the environment from routine research and operations are either too small to be observed or nonexistent (Health Physics Society, 2010).

5.1 BACKGROUND

This chapter presents the maximum potential estimated dose results from Berkeley Lab's penetration radiation, biota (animals and plants) dose, and airborne radionuclide emissions, as well as the methodology for these determinations. The results include the annual dose to nearby individual members of the public and the dose to the general population in the region extending 50 miles from the site. Within this region, the daytime population is approximately 7,687,461 (LandScan, 2020). The maximum potential estimated dose to the public is presented in Sections 5.2, 5.3, and 5.4. The radiological impact of Berkeley Lab's operations on local biota is discussed in Section 5.5.

To ensure that radiological impacts to the public and the environment remain very low, Berkeley Lab manages work activity so that radioactive emissions and external exposures are ALARA. Berkeley Lab's Environmental Radiological Protection Program ensures that a screening (qualitative) review is performed on activities that could result in a dose to the public or the environment. Potential dose from activities that may generate airborne radionuclides is estimated through the required NESHAP regulatory process (U.S. EPA, 1989), as discussed in Section 4.1. In accordance with LBNL's *Environmental ALARA Program Plan* (LBNL, 2023b), a tiered approach for ALARA reviews of potential dose to the public is used, ranging from a qualitative review to an in-depth quantitative analysis. The criteria for these tiers is presented in Table 5-1. No quantitative ALARA reviews were required or performed in 2023.

Table 5-1 Criteria for Determining the Required ALARA Analysis

Analysis	Maximum Exposed Individual (mrem in a year)	Collective Dose (mrem in a year)
Qualitative	<1.0	<10
Semi-quantitative	≥1.0 to <10	≥10 to <100
Quantitative	≥10	>100

5.2 DOSE FROM PENETRATING RADIATION

In accordance with DOE Order 458.1, Berkeley Lab evaluates the total effective dose (TED; sum of the external effective dose equivalent [EDE] and internal committed effective dose [CED]) to members of the

public exposed to LBNL sources of radiation. The penetrating radiation evaluation represents the estimated external EDE portion of the TED. To accomplish this, Berkeley Lab implements an environmental monitoring program (see Section 4.7), which uses photon-sensitive OSLDs and neutron-sensitive (Model CR-39) dosimeters at strategic locations on site. These dosimeters are deployed on a quarterly basis and processed by Landauer Inc., and a dose to the MEI is calculated in accordance with ESG Procedure 207, *Dose Measurements and Calculations for Monitoring Environmental External Radiation.* The methodology for calculating the dose to the MEI is provided in Appendix A.

The annual net dose and the estimated dose to the MEI for each monitored location are tabulated in Tables 5-2 and 5-3. Because the net dose represents the gross dose reported at a location minus the background (unimpacted) dosimeter gross dose result, it is possible to have a negative result. Negative results were not used to calculate radiation dose to the MEI because negative radioactivity (although mathematically possible) is not physically representative, and would risk diluting reported doses. Additionally, because dosimeters are designed to record a representative dose for an exposure period at a specific location, the highest estimated dose to each of LBNL's prospective MEI locations is reported independently in Table 5-4. The sum of the doses to the MEI would not be representative due to spatial dependence. It should be noted that the dose estimates reported in this document are inherently conservative because they assume that the modeled person(s) is(are) present at each MEI location for the entirety of the monitoring period (one year; broken into quarterly results) and do not factor in any additional attenuation (e.g., buildings, clothing, further distance due to moving) other than the fixed air distance from the dosimeter to the MEI location.

Table 5-2 Photon Annual External EDE to the MEI Results

Dosimeter Location								
Site No.	Site	Annual Net Dose (mrem)	Nearest MEI	Nearest Source	Dosimeter to Nearest Source Distance (m)	Source to MEI Distance (m)	Annual Dose to the MEI (mrem)	Annual Dose to the MEI Post-Attenuation (mrem)
1	B88	6.1	Apartment building	B88	67	110	2.19	2.21
2	B82/Tilden	0.0	Residential house on Campus Drive	ALS	2,052	623	0.00	0.00
3	B71A	1.2	Residential house on Campus Drive	B88	465	590	1.06	1.11
4	B75/LHS	-1.2	LHS	ALS	304	442	-0.19	-0.20
5	B85	0.0	LHS	ALS	897	442	0.00	0.00
6	B6/ALS	1.7	LHS	ALS	58	442	0.04	0.04
7	Pano (13C)	0.0	Guesthouse	ALS	1,179	136	0.00	0.00
8	B75A	5.6	LHS	ALS	443	423	5.05	5.24
16	Guesthouse	-0.3	Guesthouse	ALS	136	136	-0.20	-0.20

ALS = Advanced Light Source
B = building
LHS = Lawrence Hall of Science
m = meters
MEI = maximally exposed individual
mrem = milliroentgen
No. = number
Pano = Panoramic

Table 5-3 Neutron Annual External EDE to the MEI Results

Dosimeter Location		Annual Net Dose		Nearest	Dosimeter to Nearest	Source to MEI	Annual Dose to
Site No.	Site	(mrem)	Nearest MEI	Source	Source Distance (m)	Distance (m)	the MEI (mrem)
1	B88	0	Apartment building	B88	67	110	0.0
2	B82/Tilden	0	Residential house on Campus Drive	ALS	2,052	623	0.0
3	B71A	0	Residential house on Campus Drive	B88	465	590	0.0
4	B75/LHS	0	LHS	ALS	304	442	0.0
5	B85	0	LHS	ALS	897	442	0.0
6	B6/ALS	0	LHS	ALS	58	442	0.0
7	Pano (13C)	0	Guesthouse	ALS	1,179	136	0.0
8	B75A	0	LHS	ALS	443	423	0.0
16	Guesthouse	0	Guesthouse	ALS	136	136	0.0

ALS = Advanced Light Source
B = building
LHS = Lawrence Hall of Science
m = meters
MEI = maximally exposed individual
mrem = milliroentgen
No. = number
Pano = Panoramic

Table 5-4 Calculated Net Gamma and Neutron Annual External EDEs to MEI by Location for 2023

MEI Location	Annual Gamma Dose to MEI (mrem)	Annual Neutron Dose to MEI (mrem)	Annual Total Dose to MEI (mrem)
Apartment building	2.27	0	2.21
LBNL Guesthouse	0	0	0.00
LHS	6.38	0	5.24
Residential house on Campus Drive	0.79	0	1.11

LBNL = Lawrence Berkeley National Lab
LHS = Lawrence Hall of Science
MEI = maximally exposed individual
mrem = milliroentgen equivalent man

As shown in Tables 5-2, 5-3, and 5-4, there were no detectable measurements of neutron dose by the environmental dosimeters. These results are expected, as Berkeley Lab does not operate significant neutron-producing sources outside of radiologically controlled and shielded locations, which are monitored by occupational radiation telemetry and dosimetry inside the respective complexes. Collective dose estimates based on the highest dosimeter result per primary source of penetrating radiation (B88 and B6) are included in Appendix B. The annual collective dose to people in the surrounding region that extends 50 miles from the site was conservatively estimated at 2.20 person-rem, based on the most recent population figure and the highest measured dose from the 88-Inch Cyclotron and the Advanced Light Source accelerator. The dose from penetrating radiation is not affected by wind patterns.

In addition to the primary location dosimeters, two control dosimeters (one photon and one neutron) functioned as quality control duplicate results on a rotating quarterly basis. For quality control purposes, the relative percent difference between the primary location dosimeters and their control dosimeters (for that quarter) was calculated; a relative percent difference exceeding ±30% would have required further investigation but was not necessary during the 2023 monitoring year. Two dosimeters (one photon and one neutron; both from an unimpacted internal building) were also shipped to Landauer during quarterly sampling along with the location dosimeters to verify there was no contamination during transport in the reported results. The EX9 photon dosimeters are sensitive from 1 mrem to 1,000 rem for an energy range from 5 keV to 20 mega electron volts (MeV), and the Model CR-39 neutron dosimeters (fast, intermediate, and thermal) are sensitive from 10 mrem to 25 rem for an energy range of 0.25 eV to 40 MeV. These performance capabilities are sufficiently sensitive for monitoring the 100 mrem per year dose constraint required in DOE O 458.1. Quality control results for photon and neutron dosimeters are tabulated in Appendix C.

Environmental monitoring of penetrating gamma radiation at Berkeley Lab in 2023 resulted in a sum of the net annual gamma EDE per location ranging from background to 5.9 mrem. There was no detectable neutron dose at any of the environmental dosimeter locations. An estimated dose to the MEI was calculated for each of LBNL's assumed MEI locations (based on the presence of public individuals and their proximity to Berkeley Lab and sources of penetrating radiation), resulting in an annual EDE estimate of 5.24, 1.11, 2.21,

and 0 mrem per year at the following MEI locations: the Lawrence Hall of Science, nearest residential house located on Campus Drive, an adjacent apartment building to the Building 88 fence line, and the LBNL Guesthouse, respectively. The highest value of these estimates, 5.24 mrem per year, is used for the public dose estimate as it is the most conservative value. These annual doses are 5.24%, 1.11%, 2.21%, and 0%, respectively, of the DOE O 458.1 public dose limit of 100 mrem. Therefore, LBNL operations were well below public dose constraints and in compliance with the requirements in the Order.

5.3 DOSE FROM DISPERSIBLE AIRBORNE RADIONUCLIDES

Dose due to dispersible contaminants represents the time-weighted exposure to a concentration of a substance, whether the contaminant is inhaled in air, ingested in drink or food, or absorbed through skin contact with soil or other environmental media. Very small quantities of dispersible radionuclides originate as emissions from building exhaust points that are generally located on rooftops, as discussed in Section 4.1. Once emitted, these radionuclides may interact with environmental media such as air, water, soil, plants, and animals. Each of these media represents a potential pathway of exposure affecting human dose.

The dose to an individual or the population is calculated by computer programs that estimate dispersion of airborne radionuclide emissions while factoring in wind speed and direction, atmospheric stability, and precipitation. The radiological NESHAP regulation requires DOE facilities that potentially release airborne radionuclides to assess the impact of such releases using a U.S. EPA–approved computer program. Berkeley Lab satisfies this requirement by using both CAP88-PC and COMPLY. Details of dose calculations from dispersible airborne radionuclide emissions are included in the *Lawrence Berkeley National Laboratory Radionuclide Air Emissions Report for Compliance Year 2023* (LBNL, 2023c).

In compliance with NESHAP requirements, Berkeley Lab must determine the location of the MEI to airborne emissions. For the main LBNL site, this location was identified as the Lawrence Hall of Science, a UC Berkeley public science center located just beyond the northern edge of the site and downwind of the primary contributing source: fluorine-18 emissions from Building 56. The maximum possible dose at this location is a hypothetical and conservative value because the exposure calculation assumes that the person is always present at the location during the entire year. For 2023, the calculated annual dose from airborne radionuclides was 9.2×10^{-3} mrem, which is approximately 0.092% of the DOE and U.S. EPA annual limit for airborne radionuclides of 10 mrem/yr (DOE, 2020; U.S. EPA, 1989).

As with penetrating radiation, the collective dose from airborne radionuclides to the population is estimated within a radius of 50 miles of the site. The estimated population dose from all airborne emissions from the LBNL main site for 2023 was approximately 2.98×10^{-1} person-rem. There is no regulatory standard for the collective dose metric.

5.4 TOTAL DOSE TO THE PUBLIC

The total radiological impact to the public from penetrating radiation and airborne radionuclides is well below applicable standards and less than local background radiation levels by several orders of magnitude. As shown on Figure 5-1, the maximum EDE from penetrating radiation and airborne radionuclides from LBNL operations to an individual residing near Berkeley Lab in 2023 was approximately 5.25 mrem/yr. Penetrating radiation (i.e., gamma and neutron radiation) from accelerators at Berkeley Lab and radionuclides from airborne radionuclide emissions contributed to this total dose, which is a conservatively high estimate since the locations of the maximum dose for penetrating and airborne radiation differ slightly, as described in previous sections. Yet this value is very low at approximately 1.69% of the average natural background radiation dose (310 mrem/yr) in the United States (NCRP, 2009), and approximately 5.24% of the DOE annual limit from all sources (100 mrem/yr) (DOE, 2020).

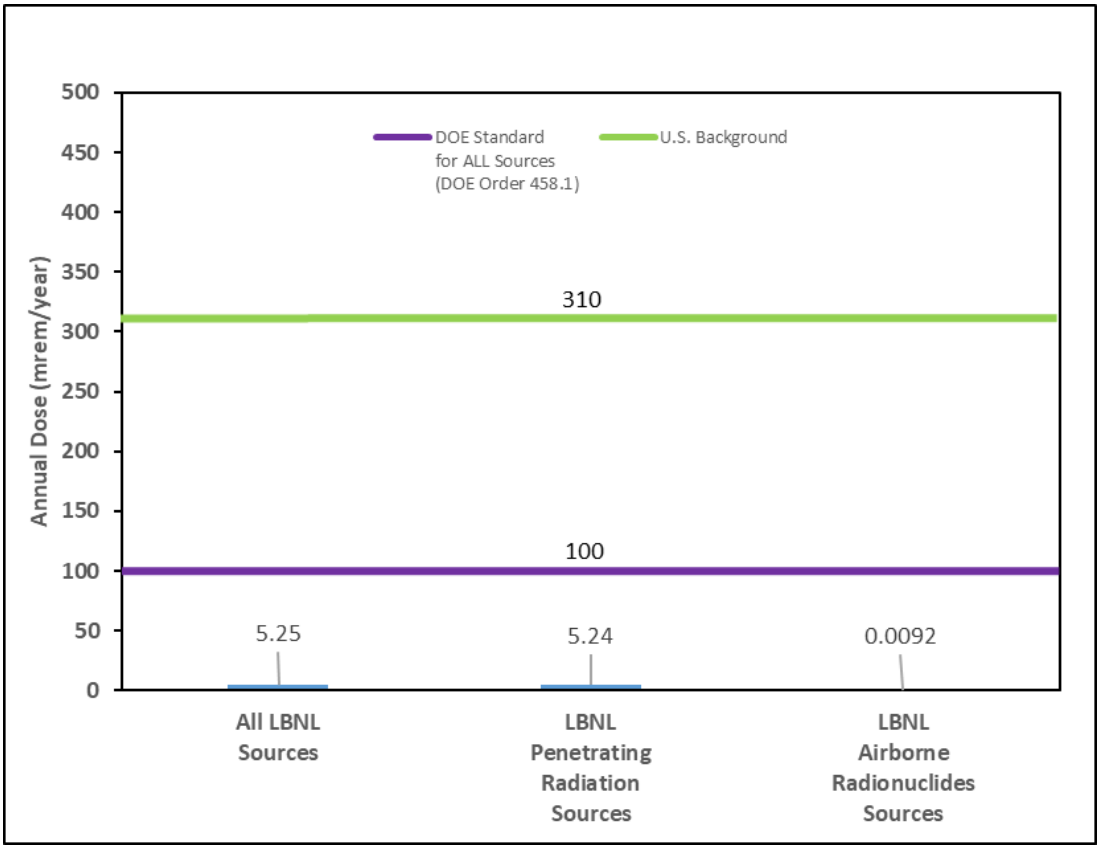

Figure 5-1 Comparative Radiological Doses for 2023

5.5 DOSE TO ANIMALS AND PLANTS

Berkeley Lab is required by DOE Order 458.1 to protect biota from radiological activities conducted at the LBNL site. If actions taken to protect humans – both workers and the public – from radiation and radioactive materials are not sufficient to protect biota, then additional measures to protect biota must be implemented. The DOE-approved method used to determine whether biota are sufficiently protected is provided in DOE technical standard DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses*

to Aquatic and Terrestrial Biota (DOE, 2019a). This method employs a graded (three-phased) approach – data assembly phase, general screening phase, and the analysis phase – to demonstrate if radiation and radioactive emissions from Berkeley Lab operations are sufficiently low that biota are also protected. As demonstrated by the following analyses, the actions taken by Berkeley Lab in 2023 to protect humans (workers and the public) from radiological exposure are sufficiently protective of biota and no additional measures are required.

The DOE standard requires that the following details of the biota dose evaluation be documented and retained for future reference:

- Regulatory biota dose limits
- Methods used to verify compliance with the biota dose limits, by comparison to the DOE standard's Biota Concentration Guides (BCGs)
- Area of evaluation, sources of exposure, organism types, media types, and radionuclide data
- Results of the evaluation and parameters used

The following biota dose limits have been adopted for this evaluation:

- Aquatic animals and terrestrial plants: 1 radiation absorbed dose per day (rad/day) or 10 milligray per day (mGy/day)
- Riparian and terrestrial animals: 0.1 rad/day (1 mGy/day)

In accordance with DOE-STD-1153-2019, Berkeley Lab performed the required evaluation using the following method:

1. Complete data assembly phase by determining the area to be evaluated, identifying receptors, and considering exposure pathways.
2. Perform the general screening phase by conducting a conservative assessment using RESRAD-BIOTA Version 1.8 software in accordance with the DOE standard to compare the highest potential creek water, creek sediment, and soil sample results to the BCGs. RESRAD-BIOTA was used for evaluating radiation exposures of nonhuman biota, including flora and fauna in aquatic and terrestrial ecosystems. In keeping with the conservative nature of the standard, analytical results that were below detection limits were reported using either the highest MDCs or RESRAD's solid/solution distribution coefficient (K_d) derived concentrations. K_d is defined as the ratio of mass of solute species absorbed or precipitated on the soil or sediment to the solute concentration in the water (DOE, 2019a). RESRAD uses this coefficient with built-in equations to calculate conservative estimates of radionuclide concentrations at co-located samples (samples from the same location), such as creek water and creek sediment.

For instances where there were detectable concentrations of radionuclides in one co-located sample but not the other, RESRAD's K_d-derived concentration was used to estimate the concentration. Although inherently conservative, this approach produces an estimate that is derived from analytical data at co-located samples above MDC and is thus preferable to assigning the highest MDC to the sample below detection limits. If the results of the general screening phase (RESRAD-BIOTA Level 1 evaluation) verify that radionuclide concentrations are less than BCGs, and the dose to receptors is below biota dose limits, then no further analysis is required, per the DOE standard.

Because the general screening phase did not exceed the BCGs, biota are demonstrated to be sufficiently protected from radiation and radioactive materials due to LBNL operations. Therefore, the analysis phase was not required. When performing a general screening phase biota evaluation, the DOE standard allows the evaluator to use general knowledge of an area's sources, receptors, and routes of exposure when defining the parameters of the evaluation.

To be included in the dose evaluation, an area must meet the following three criteria:

1. Radioactivity should be present or anticipated to be present in the environment as a result of DOE activities.
2. Receptors (i.e., plants or animals, or both) should be present in the vicinity of those sources.
3. Routes of exposure should exist from those sources to the receptors.

5.5.1 Evaluation Area

The evaluation area for the general screening biota evaluation is the Berkeley Lab main site (see Figure 5-2), comprising approximately 200 acres (0.3125 square miles) of land.

5.5.2 Exposure Sources

Exposure pathways that could contribute to an external dose to biota include external irradiation and skin contact via radionuclides in water, soil, and sediment. Pathways that could contribute to an internal dose in biota include ingestion of water, vegetation, and soil particles, and inhalation of air and soil particles. Uptake of water from air and soil via ingestion of vegetation could also contribute to an internal dose.

5.5.3 Organism Types

Receptors (organisms that could be exposed to radionuclides) include vegetation (grasses and forbs, brush, and trees) and the many species of birds, mammals, reptiles, and amphibians for which vegetation provides cover, food, and breeding sites.

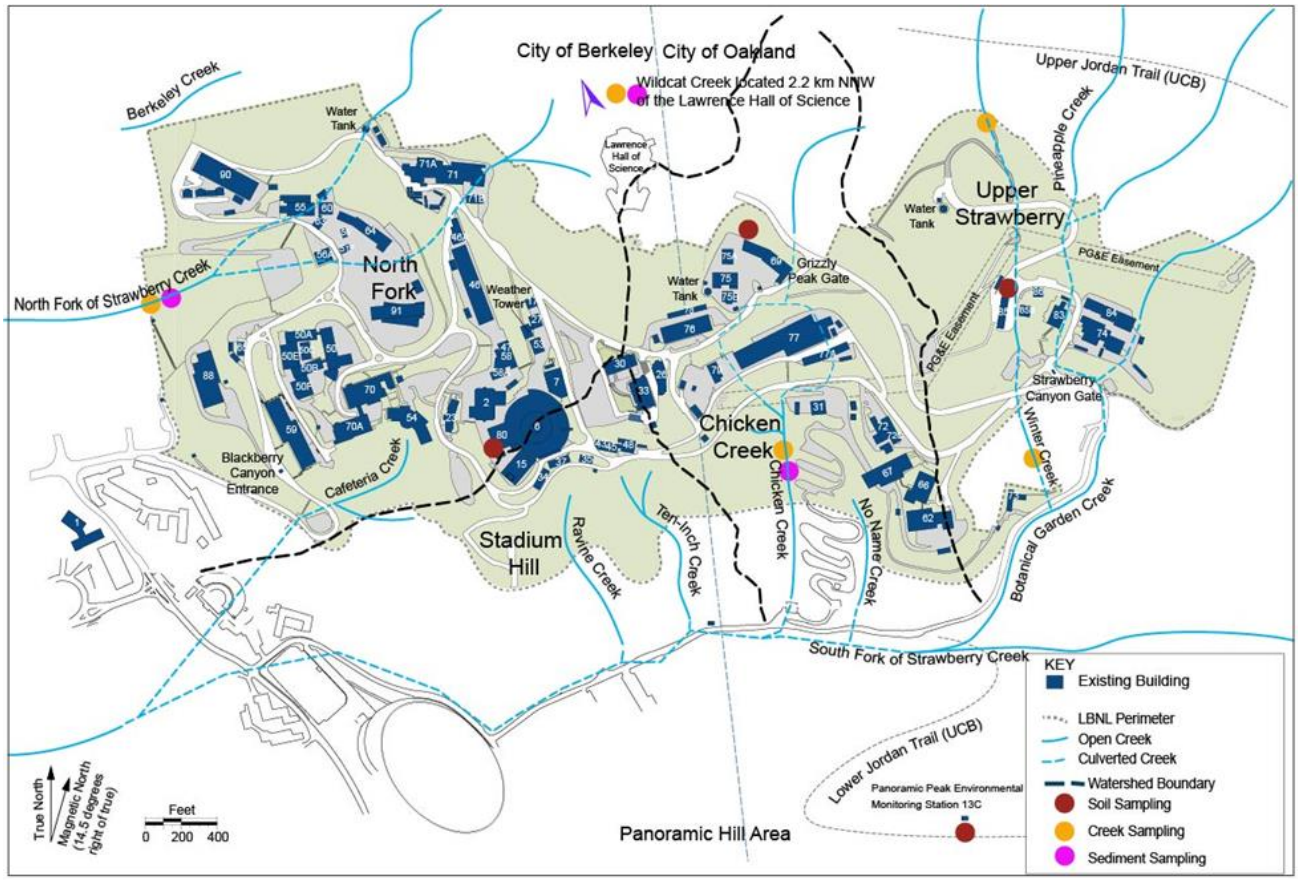

Figure 5-2 Biota Evaluation Area 2023

5.5.4 Media Types

The media analyzed were creek water, creek sediment, and soil. Samples were collected in 2023 for analysis using methods described in two LBNL Environmental Services Group (ESG) procedures: ESG Procedure 266, *Soil and Vegetation Sampling for the Environmental Radiological Protection Program*, and ESG Procedure 263, *Creek Water, Sediment, and Stormwater Monitoring*. Sampling locations are shown on Figure 5-2.

5.5.5 Radionuclides Evaluated

Fifteen samples were collected in 2023 from creeks on, downgradient of, or near the Berkeley Lab main site and analyzed for radionuclides, and soil samples were collected from other locations on or near the Berkeley Lab site and analyzed for radionuclides. Some of these samples were split or duplicate samples were collected to verify that proper quality controls were applied. The analytical laboratories measured several radionuclides in these samples at levels that are similar to fallout (from nuclear weapons testing) and natural background values. It should be noted that water samples are not filtered before analysis, so they are likely to contain suspended soil and sediment having background levels of fallout and natural radionuclides that would bias the results high.

The following radionuclides relevant to the Berkeley Lab site are included in the DOE standard:

- actinium-228 (228Ac), progeny of thorium-232 (232Th)
- cesium-137 (137Cs)
- europium-152 (152Eu)
- radium-226 (226Ra)
- tritium (3H)
- uranium-238 (238U)

Other radionuclides that were analyzed as part of Berkeley Lab's standard analytical suite were bismuth-212 (212Bi), bismuth-214 (214Bi), cobalt-56 (56Co), gross alpha, gross beta, lead-212 (212Pb), lead-214 (214Pb), potassium-40 (40K), thallium-208 (208Tl), and thorium-234 (234Th). These radionuclides, however, were not considered in the biota dose evaluation because most are naturally occurring radionuclides readily found in the environment, and their concentrations were less than Berkeley Lab's radiological background threshold values. Furthermore, 212Bi, 214Bi, 56Co, gross alpha, gross beta, 212Pb, 214Pb, and 208Tl were not considered because either they are not included in the DOE standard and/or their parent that is included in the DOE standard is not in secular equilibrium.

Water, sediment, and soil samples were collected at off-site locations in order to quantify expected background fallout and natural radionuclide concentrations. These background levels are compared to areas that have been potentially affected by LBNL operations. For water and sediment, the background location is Wildcat Creek, which is 1.5 miles from Berkeley Lab. Wildcat Creek is not connected to the creeks that traverse or receive drainage from the LBNL site. For soil, the background location is at the environmental monitoring station on Panoramic Peak, the next ridge southeast of the LBNL boundary, as shown in the lower right-hand corner of Figure 5-2. Background water, sediment, and soil results were used to develop input values for RESRAD-BIOTA. Using the DOE-endorsed software RESRAD-BIOTA, concentrations or MDCs of the radionuclides 3H, 137Cs, 152Eu, 226Ra, 228Ac, and 238U measured in creek water, sediment, and soil were compared to BCGs for aquatic and terrestrial biota. As required by the DOE standard, a screening approach was used to initially compare the conservative-model assumed maximum concentrations of radionuclides in water, sediment, and soil to BCGs. If the screening evaluation did not meet the limits of the standard, then the graded approach required additional evaluation in the analysis phase.

5.5.6 Aquatic Biota Dose

For the aquatic biota dose screening evaluation, Berkeley Lab used data from co-located sediment and water samples, as preferred by the DOE standard. When a radionuclide was analyzed for but not detected in one co-located water or sediment sample (but was detected in the other co-located sample), a conservative estimate was produced using RESRAD's built-in K_d functionality. If a radionuclide was analyzed for but was not detected in either the co-located water or sediment sample, the highest MDCs for both media types were used instead.

Of the radionuclides used in this evaluation and sampled for in water, only 226Ra was detected above MDC. The concentrations of 228Ac, 3H, 137Cs, and 238U were derived using RESRAD's K_d function from co-located sediment sample results, and 152Eu was assigned an MDC value due to not being detected in either the primary or in the co-located media. For sediment, 228Ac, 3H, 137Cs, 226Ra, and 238U were all detected above MDC, with the highest concentrations present in Chicken Creek, and 152Eu was conservatively assigned an MDC value due to not being detected in either the primary or the co-located media. The input values and the results are provided in the report generated by the RESRAD-BIOTA program for aquatic biota, and the results are summarized in Table 5-5. The measured radionuclides are less than their corresponding BCGs. The sum of the concentration-to-BCG ratios for radionuclides in sediment ("sediment ratio") and water ("water ratio") is less than 1. Both have passed the screening evaluation, and no further action is necessary.

Table 5-5 RESRAD-BIOTA Level 1 Screening Aquatic BCG Report

Total Ratio for Limiting Organism	Water Ratio for Limiting Organism	Sediment Ratio for Limiting Organism
3.36E-01	3.26E-01	1.06E-02

5.5.7 Terrestrial Biota Dose

For the terrestrial biota dose evaluation, data from co-located soil and water samples are not required by the DOE standard. In soil, concentrations of 228Ac, 137Cs, and 226Ra were detected in low concentrations above the MDC (but below background threshold values), and 238U, 3H, and 152Eu were conservatively assigned an MDC value due to not being detected. The input values and the results are shown in the report generated by the RESRAD-BIOTA program for terrestrial biota, and the results are summarized in Table 5-6. The measured radionuclides are less than their corresponding BCGs. In addition, the sum of the concentration-to-BCG ratios for radionuclides in water ("water ratio") and soil ("soil ratio") is less than 1. Since Berkeley Lab passes the terrestrial screening, further investigation is not required.

Table 5-6 RESRAD-BIOTA Level 1 Screening Terrestrial BCG Report

Total Ratio for Limiting Organism	Water Ratio for Limiting Organism	Soil Ratio for Limiting Organism
2.99E-02	1.84E-04	2.97E-02

5.5.8 Biota Dose Evaluation Results

At Berkeley Lab, the dose from LBNL effluent to plants and animals is below the biota dose limits prescribed in the DOE standard because the on-site radionuclide concentrations do not exceed the BCGs. Therefore, the absorbed dose rate from potential exposure to radionuclides in the LBNL environment is below the DOE standard for aquatic animals and terrestrial plants of 1 rad/day, and for riparian and terrestrial animals of 0.1 rad/day, in compliance with DOE Order 458.1. The conclusion of this assessment for 2023 is that actions taken by Berkeley Lab to protect humans (workers and the public) from radiological exposure are sufficiently protective of biota and no additional measures are required.

6 Quality Assurance

Berkeley Lab's environmental quality assurance (QA) program ensures that environmental samples are collected and analyzed in accordance with QA policy. Berkeley Lab's overarching QA policy is documented in the *Requirements and Policies Manual* (LBNL, 2021c). Details on the operating principles and practices used by organizations to achieve reliable, safe, and high-quality performance are provided in the *EHS Assurance Systems Manual* (LBNL, 2016a), which describes the elements necessary to integrate QA, management systems, and process controls into LBNL operations. The *EHS Assurance Systems Manual* provides the framework for Berkeley Lab administrators, managers, supervisors, and staff to plan, manage, perform, and assess their work.

Guidance from DOE (2015) and the U.S. EPA (1989) is also part of the QA system. The monitoring and sampling activities and results presented in this report were conducted in accordance with those guidelines. Whenever extra QA and quality control (QC) measures are required, a Quality Assurance Project Plan is developed and implemented. Both the radiological NESHAP Compliance Program (LBNL, 2019) and the Environmental Restoration Program (LBNL, 2017a) have a program-specific Quality Assurance Project Plan. Additionally, Berkeley Lab's Environment, Waste & Radiation Protection Department implements elements of the *EHS Assurance Systems Manual* through its *Quality Management Plan* (LBNL, 2016b), which describes a graded approach to quality and programmatic assurance based on the scope of the department's technical programs.

Complementing the objectives of the *EHS Assurance Systems Manual*, the DOE Bay Area Site Office provides an oversight program plan to enable its staff to participate in LBNL operational activities such as audits/inspections, document reviews, and day-to-day communications and to comply with DOE Contract 31 clause H.30 as described in *University of California Contractor Assurance System Description for Lawrence Berkeley National Laboratory* (LBNL, 2021d). This interaction provides an effective and efficient means of meeting contractual requirements between DOE and UC while allowing Berkeley Lab to accomplish its assigned missions. This assurance system includes attributes such as metrics and targets to assess performance, rigorous self-assessment and improvement, identification and correction of negative performance trends before they become significant issues, and timely communication with BSO on assurance-related information.

6.1 ENVIRONMENTAL MONITORING SAMPLES AND RESULTS PROFILE

In 2023, a total of 805 individual air, sediment, soil, and water samples were collected under Berkeley Lab's environmental monitoring programs, both routine and project-specific, generating 19,878 analytical results. Samples were obtained from over 403 locations on or surrounding the main site. Some of these locations are shown on figures in the Chapter 4 sections that summarize program results; others are in the referenced

project or program documents, such as those available on the Environmental Restoration Program's website.

The sampling result totals include those from all activities associated with the Old Town Demolition Project that were carried out by the demolition subcontractor and provided to Berkeley Lab.

6.2 SPLIT AND DUPLICATE SAMPLING

An essential activity undertaken to measure the quality of environmental monitoring results is the regular collection and analysis of split and duplicate samples. In 2023, a total of 24 split and 16 duplicate samples were collected for either radiological or nonradiological analyses, or both. QA activities resulted in 766 split and 135 duplicate results. In addition, 73 blank samples were submitted for QA purposes. The primary purpose of a blank sample is to identify contamination that might be introduced during sample collection, during transport, or at the analytical laboratory.

Berkeley Lab uses the metrics of relative percent difference and relative error ratio to determine whether paired results, such as split or duplicate samples, are within control limits. *Relative percent difference* is defined as the absolute value of the difference between two results divided by the mean of the two results. *Relative error ratio* is defined as the absolute value of the difference between two results divided by the sum of the analytical error of the two results. Relative percent difference is determined in all cases; relative error ratio is applicable only to radiological analyses for which analytical error is included in the same result.

When the primary sample and the split or duplicate sample results are below analytical detection limits, the results from these tests are not meaningful. When QA pair results exceed control limits, the program leader investigates the cause of the discrepancy.

6.3 ANALYTICAL LABORATORIES

In 2023, Berkeley Lab contracted with the following five commercial analytical laboratories for specific analytical services:

1. PBC Laboratories (Bakersfield, California)
2. ECO Laboratories (Arvada, Colorado)
3. EMO Laboratories (Earth City, Missouri)
4. GEL Laboratories (Charleston, South Carolina)
5. Pace Analytical (Baton Rouge, Louisiana)

All five laboratories are certified through California's Environmental Laboratory Accreditation Program (ELAP) by having demonstrated the capability to analyze samples for environmental monitoring using approved testing methods (California Department of Public Health, 1994). These laboratories must meet demanding QA and QC specifications and certifications that were established to define, monitor, and

document laboratory performance (DoD/DOE, 2018; LBNL, 2012b), and their QA and QC data are incorporated into Berkeley Lab's data quality assessment processes.

Each data set (batch) received from these analytical laboratories is systematically evaluated and compared to established data quality objectives before the results can be authenticated and accepted into the environmental monitoring database. Categories of data quality objectives include accuracy, precision, representativeness, comparability, and completeness. When possible, quantitative criteria are used to define and assess data quality.

In addition to the ELAP certification, analytical laboratories supporting DOE facilities are subject to third-party audits by accrediting bodies. Once audited, these analytical laboratories receive accreditation to perform work for DOE facilities following DOE's Quality Systems Manual (DoD/DOE, 2018). In 2023, all five analytical laboratories were state certified, as required. In addition, four of the five state-certified analytical laboratories were also accredited under the DOE Consolidated Audit Program–Accreditation Program to perform work for DOE facilities.

6.4 ANALYTICAL LABORATORY QUALITY CONTROL TESTING

Analytical laboratories routinely perform QC tests to assess the quality and validity of their sample results. These tests are run with each batch of environmental samples submitted by Berkeley Lab. The same relative percent difference and relative error ratio metrics are used to evaluate these control sample results, with the relative error ratio test applicable only to radiological analyses.

In 2023, the five ELAP-certified analytical laboratories performed approximately 950 radiological and nonradiological QC analyses to validate the environmental samples submitted by Berkeley Lab. These QC analyses include various types of blank, replicate (duplicate), matrix spike, and laboratory control samples. In addition to the relative percent difference and relative error ratio tests, lower and upper control limits are established for each analyte and for each type of QC test. As with split and duplicate QA, an investigation is performed to determine the cause of the discrepancy when QC results exceed established criteria.

6.5 ERRATA

Appendix D provides Berkeley Lab's protocol for errata in its Site Environmental Reports as well as a list of errata for previous reports.

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Abbreviations

AB 32	California Global Warming Solutions Act of 2006
ACEH	Alameda County Environmental Health
AEDE	annual effective dose equivalent
AFFF	aqueous film forming foam
ALARA	as low as reasonably achievable
AST	aboveground storage tank
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan for the San Francisco Bay Basin
BASO	Bay Area Site Office
BCG	Biota Concentration Guide
Berkeley Lab	Lawrence Berkeley National Laboratory
BioEPIC	Biological and Environmental Program Integration Center
BioGEM	Biological Genome Engineering and Manufacturing Facility
BSO	Berkeley Site Office
CAG	Community Advisory Group
CAP88-PC	Clean Air Act Assessment Package-1988
CARB	California Air Resources Board
CATS	Corrective Action Tracking System
CCR	California Code of Regulations
CCRF	central chemical receiving facility
C&D	construction and demolition
CED	committed effective dose
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
Ci	curie
CIWQS	California Integrated Water Quality System
COB	City of Berkeley

CUPA	Certified Unified Program Agency (California)
CX	Categorical Exclusion
DCGL	Derived Concentration Guideline Level
DCS	derived concentration standard
DOC	diesel oxidation catalyst
DOE	U.S. Department of Energy
DTSC	Department of Toxic Substances Control (California)
E85	85% ethanol / 15% unleaded gasoline fuel blend
EBMUD	East Bay Municipal Utility District
EBRPD	East Bay Regional Park District
EDE	effective dose equivalent
EGR	exhaust gas recirculation
EHS	Environment, Health & Safety (the division at Berkeley Lab)
ELAP	Environmental Laboratory Accreditation Program
EMIS	energy management information system
EMS	Environmental Management System
EO	Executive Order
EPCRA	Emergency Planning and Community Right-to-Know Act
EPEAT	Electronics Product Environmental Assessment Tool
ESG	Environmental Services Group
ES&H	environment, safety, and health (the subject and policy)
EV	electric vehicle
e-waste	electronic waste
F	Fahrenheit
FTU	fixed treatment unit
FY	fiscal year (October 1–September 30)
GAC	granular activated carbon
gal	gallon(s)
g/cm^3	gram per cubic centimeter
GHG	greenhouse gas

GIE	gas-insulated equipment
GIS	gas-insulated switchgear
HMBP	Hazardous Materials Business Plan
HQ	headquarters
HVAC	heating, ventilation, and air conditioning
HWHF	Hazardous Waste Handling Facility
IGB	Integrative Genomics Building
ISM	Integrated Safety Management
ISO	International Organization for Standardization
JGI	Joint Genome Institute
keV	kiloelectron volt
kg	kilogram(s)
kWh	kilowatt hour
L	liter(s)
LBNL	Lawrence Berkeley National Laboratory
MCL	maximum contaminant level
MDC	minimum detectable concentration
MeV	mega electron volt
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mGy	milligray
mrem	millirem (one thousandth of a rem, or 1×10^{-3} rem)
mrem/yr	millirem per year
NAL	Numeric Action Level
NEPA	National Environmental Policy Act
NERSC	National Energy Research Scientific Computing Center
NESHAP	National Emission Standards for Hazardous Air Pollutants
NTLF	National Tritium Labeling Facility
OCx	Ongoing Commissioning
OIAI	Office of Institutional Assurance & Integrity

OSLD	optically stimulated luminescence dosimeter
PCB	polychlorinated biphenyl
pCi/L	picocuries (one trillionth of a curie) per liter
PFAS	per- and polyfluoroalkyl substances
PG&E	Pacific Gas & Electric
PSA	pollutant source assessment
PUE	power usage effectiveness
QA	quality assurance
QAPD	Quality Assurance Program Description
QC	quality control
R2	Responsible Recycling
rad	radiation absorbed dose
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RFID	radio frequency identification
RWQCB	San Francisco Bay Regional Water Quality Control Board
SAA	satellite accumulation area
SARA	Superfund Amendments and Reauthorization Act
SB	State Bill
SCR	selective catalytic reduction
SER	Site Environmental Report
SF_6	sulfur hexafluoride
SIC	Standard Industrial Classification
SMARTS	Stormwater Multiple Application and Report Tracking System
SPCC	Spill Prevention, Control, and Countermeasure
SSM	Seismic Safety and Modernization
SURP	Site Utilities Relocation Project
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TED	total effective dose

THUP	Transit Hub Utilities Project
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
UC	University of California
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
VSP	Violations Scoring Procedure
WAA	waste accumulation area
WAPA	Western Area Power Administration
ZEV	zero-emission vehicle

Glossary

accuracy

The closeness of a measurement to its true value.

Advanced Light Source

An accelerator at Berkeley Lab that is a third-generation synchrotron light source, one of the world's brightest sources of ultraviolet and soft X-ray beams.

alpha particle

A charged particle comprising two protons and two neutrons, which is emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.

analyte

The subject of a chemical analysis.

background radiation

Ionizing radiation from sources other than Berkeley Lab. Background radiation may include cosmic radiation; radiation from naturally occurring radioactivity in the earth (terrestrial radiation), air, and water; and radiation from naturally occurring radioactive elements in the human body.

beta particle

A charged particle identical to the electron that is emitted during decay of certain radioactive atoms. Most beta particles are stopped by less than 0.2 inches of aluminum.

CAP88-PC (Clean Air Act Assessment Package-1988)

Computer code for estimating the dose and risk from emissions of radioactive material to the air. Used by the EPA for determining compliance with NESHAP regulations.

COMPLY

Computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides. Used by EPA for determining compliance with NESHAP regulations.

contaminant

Any hazardous or radioactive material present above background levels in an environmental medium such as air, soil, water, or vegetation. *See also* pollutant.

cosmic radiation

High-energy particulate and electromagnetic radiation that originates outside the earth's atmosphere. Cosmic radiation is part of natural background radiation.

curie

Unit of radioactive decay equal to 2.22×10^{12} disintegrations per minute.

detection limit

The lowest concentration of an analyte that can be measured and reported with 99% confidence that the concentration is greater than zero.

discharge

The release of a liquid or pollutant to the environment or to a system (usually of pipes) for disposal.

dose

The quantity of radiation energy absorbed by a human, animal, or vegetation. Dose to humans is also called effective dose equivalent (measured in units of rem), which takes into account the type of radiation and the parts of the body exposed. Dose to animals and vegetation is also called absorbed dose (measured in units of rad), which is the energy deposited per unit of mass.

dosimeter

A portable detection device for measuring the total accumulated dose from ionizing radiation. *See also* optically stimulated luminescence dosimeter.

duplicate samples

Two samples taken from and representative of the same population and carried through all steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variance of the total method, including sampling and analysis.

effective dose equivalent

A measure of the whole-body biological damage to living tissue as a result of external radiation exposure.

emission

A release of air to the environment that contains gaseous or particulate matter having one or more contaminants.

environmental aspect

An element of an organization’s activities or products or services that interacts or can interact with the environment.

environmental monitoring

The collection and analysis of samples or direct measurements of environmental media (e.g., air, water, soil, foodstuff, biota) from LBNL facilities and their environs for possible contaminants with the purpose of determining compliance with applicable standards and permit requirements, assessing radiation exposures of members of the public, and assessing the effects, if any, on the local environment.

federal fiscal year

October 1 through September 30 of the following year.

fiscal year

The 12-month period for which an organization plans the use of its funds. For the federal government and its contractors, this is the period from October 1 to September 30 the following year.

gamma radiation

Short-wavelength electromagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength (high energy), gamma radiation can cause ionization. Other electromagnetic radiation, such as microwaves, visible light, and radio waves, has longer wavelengths (lower energy) and cannot cause ionization.

greenhouse gas

Any of the atmospheric gases (e.g., carbon dioxide, water vapor, and methane) that contribute to the greenhouse effect. The greenhouse effect is the trapping and buildup of heat in the upper atmosphere by gases that absorb infrared radiation. These gases then reradiate some of this heat back toward the earth's surface.

groundwater

Water below the earth's surface in a zone of saturation.

groundwater velocity

Linear distance groundwater moves over a specific time period.

half-life, radioactive

The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains (1/2 × 1/2); after three half-lives, one-eighth of the original activity remains (1/2 × 1/2 × 1/2); and so forth.

hazardous waste

Waste exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or extraction procedure-toxicity (yielding toxic constituents in a leaching test). Because of its concentration, quantity, or physical or chemical characteristics, it may (1) cause or significantly contribute to an increase in mortality rates or cases of serious irreversible illness or (2) pose a substantial present or potential threat to human health or the environment when improperly treated, stored, transported, disposed of, or handled.

hydrauger

A sub-horizontal drain used to extract groundwater for slope stability purposes.

low-level radioactive waste

Waste containing radioactivity that is not classified as high-level waste, transuranic waste, spent nuclear fuel, by-product material (as defined in Section 11(e)(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material.

millirem

A common unit for reporting human radiation dose. One millirem is one thousandth (10^{-3}) of a rem. *See also* rem.

mixed waste

Any radioactive waste that is also a RCRA-regulated hazardous waste.

nuclide

A species of atom characterized by what constitutes the nucleus, which is specified by the number of protons, number of neutrons, and energy content; or alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be able to exist for a measurable length of time.

optically stimulated luminescence dosimeter

A type of dosimeter in which the material that has been exposed to radiation luminesces after being stimulated by laser light. The amount of light that the material emits is proportional to the amount of radiation absorbed (dose). *See also* dosimeter.

organic compound

A chemical whose primary constituents are carbon and hydrogen.

person-rem

The sum of the radiation doses to individuals of a population. *See also* population dose.

pH

A measure of hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH less than 7, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.

plume

A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction in which they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

pollutant

Any hazardous or radioactive material present in an environmental medium such as air, water, or vegetation. *See also* contaminant.

population dose (person-rem)

An estimate of the collective dose to a population expressed in units of person-rem (person-Sv). It is the product of the average effective dose per person times the number of people exposed in a particular area, usually within a radial distance outward from a release point. For example, if 1,000 people were estimated to receive an effective dose of 1 rem, the population dose would be 1,000 person-rem.

positron

A particle that is equal in mass to the electron but opposite in charge. A positively charged beta particle.

precision

The degree of agreement between measurements of the same quantity.

rad

The conventional unit of absorbed dose from ionizing radiation, commonly used for dose to animals and vegetation.

radiation

Electromagnetic energy in the form of waves or particles.

radioactivity

The property or characteristic of a nucleus of an atom to spontaneously disintegrate, accompanied by the emission of energy in the form of radiation.

radiological

Arising from radiation or radioactive materials.

radionuclide

An unstable nuclide. *See also* nuclide, radioactivity.

relative percent difference

The absolute value of the difference between two results divided by the mean of the two results.

relative error ratio

The absolute value of the difference between two results divided by the sum of the analytical error of the two results.

rem

Acronym for “roentgen equivalent man.” A unit of ionizing radiation, equal to the amount of radiation needed to produce the same biological effect to humans as one rad of high-voltage X-rays. It is the product of the absorbed dose, quality factor, distribution factor, and other necessary modifying factors. It describes the effectiveness of various types of radiation in producing biological effects.

remediation

The process of improving a contaminated area to an uncontaminated or safe condition.

source

Any operation or equipment (e.g., pipe, ditch, well, or stack) that produces, discharges, and/or emits pollutants, or the location where a pollutant was released to the environment.

split sample

A single well-mixed sample that is divided into parts for analysis and comparison of results.

stack

A pipe, usually vertical, through which air and contaminants are vented to the atmosphere. A stack may be associated with a building or a vehicle (e.g., bus, heavy-duty truck). At Berkeley Lab, stacks are typically constructed of metal; they may discharge air from a local area such as a fume hood, or they may carry air from multiple areas of a building.

terrestrial

Pertaining to or deriving from the earth.

terrestrial radiation

Radiation emitted by naturally occurring radionuclides, with the major radionuclides of concern being potassium-40, uranium-235, uranium-238, thorium-232, and their decay products; radiation levels over oceans and other large bodies of water tend to be about one-tenth of the terrestrial background.

tritium

A radionuclide of hydrogen with a half-life of 12.3 years, which decays by emitting a low-energy beta particle.

water year

The term used by hydrologists and climatologists to represent rainfall occurring between October 1 of one year and September 30 of the next year.

weather normalization

A method to enable a like-for-like comparison of energy consumption from different periods. Generally, weather normalization factors out variations in outside air temperature to allow for a fairer comparison of energy performance.

wind rose

Meteorological diagram that depicts the distribution of wind direction over a period of time.

Appendix A

Methodology for Calculating the Dose to the Maximally Exposed Individual (MEI)

For photon radiation, the following point source relationship was used to extrapolate the dose to the MEI from the net dose by the nearest dosimeter to that location:

$$D(MEI) = D(n)x\left[\frac{L(n)^2}{L(MEI)^2}\right]$$

where:

$D(n)$ is the net dose for the dosimeter at location n.

$L(n)$ is the distance in meters between the source and location n.

$L(MEI)$ is the distance in meters between the source and the MEI associated with location n.

For the final net doses related to photons, air mass attenuation is applied to the results.

$$\dot{X} = B\dot{X}_0 e^{-\left(\frac{u}{p}px\right)}$$

where:

$\dot{X}$ is the attenuated exposure rate.

$\dot{X}_0$ is the unattenuated exposure rate.

B is the buildup factor for air, based on an average photon energy of 700 kiloelectron volts (keV).

u/p is the mass attenuation coefficient of 0.0756 square centimeters per gram (cm^2/g).

p is the density of dry air of 0.001205 grams per cubic centimeter (g/cm^3).

x is the distance between the unattenuated source and the location of interest.

For neutron radiation, a point source approximation is not appropriate because neutrons do not obey the inverse-square law. Consequently, neutron dose extrapolation was derived from the Lindenbaum approximation (Jenkins, 1974) below:

$$D = K\frac{e^{-\frac{r}{\lambda}}}{L}$$

to the following:

$$D(MEI) = D(n)x \left[\frac{L(n)}{L(MEI)}\right] x \left(\frac{\left[\exp\left\{-\frac{L(MEI)}{250\ m}\right\}\right]}{\left[\exp\left\{-\frac{L(n)}{250\ m}\right\}\right]}\right)$$

where:

D(*n*) is the net dose for the dosimeter at location *n*.

L(*n*) is the distance in meters between the source and location *n*.

L(*MEI*) is the distance between the source and the MEI associated with location *n*.

250 m (meters) is the approximate mean free path of neutrons in air.

Appendix B

Collective Dose Due to Operations at Buildings 88 and 6

2023 Dose to Population based on 2020 LandScan grid

Building 88

Annual dose at B88 Dosim 6.10 mrem at distance= 0.067 km from B88 is 2.20E+00 person-rem

	Distance (km)													
Direction	**0.5**	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**80**	**Grand Total**
NNE	2.65E-02	0.00E+00	3.42E-05	7.12E-04	2.43E-03	3.96E-03	3.16E-03	1.21E-02	2.44E-03	1.96E-03	3.71E-04	5.75E-05	6.64E-05	5.38E-02
NE	0.00E+00	0.00E+00	0.00E+00	9.13E-06	1.11E-04	8.39E-04	4.50E-04	4.59E-03	2.29E-04	2.07E-06	5.36E-06	4.16E-05	1.40E-05	6.29E-03
ENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06	7.56E-05	2.37E-03	2.81E-04	6.16E-04	1.18E-03	7.20E-04	1.31E-04	5.37E-03
E	2.74E-01	5.42E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	3.24E-03	2.86E-03	3.21E-04	8.53E-04	5.09E-05	1.21E-05	2.91E-01
ESE	0.00E+00	2.87E-02	2.57E-03	7.30E-04	3.58E-04	2.37E-04	1.18E-02	5.94E-04	8.82E-07	4.13E-05	3.59E-04	1.12E-04	6.29E-04	4.62E-02
SE	0.00E+00	0.00E+00	8.66E-03	3.81E-03	7.57E-03	1.70E-02	2.58E-02	1.94E-04	7.13E-04	6.87E-04	6.01E-04	5.89E-04	2.64E-04	6.59E-02
SSE	0.00E+00	7.47E-02	1.42E-02	5.55E-03	7.97E-03	2.16E-02	6.25E-03	2.45E-03	2.92E-03	5.34E-05	1.14E-05	8.72E-06	1.71E-08	1.36E-01
S	0.00E+00	1.13E-01	3.37E-02	8.38E-03	2.18E-02	4.06E-03	0.00E+00	2.49E-03	4.14E-04	2.04E-05	0.00E+00	0.00E+00	0.00E+00	1.84E-01
SSW	0.00E+00	0.00E+00	1.71E-01	8.64E-03	1.03E-02	5.87E-03	5.19E-04	2.47E-02	1.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E-01
SW	0.00E+00	3.99E-01	5.77E-02	1.06E-02	5.47E-03	3.10E-02	8.00E-04	3.66E-02	6.56E-03	1.97E-04	0.00E+00	0.00E+00	0.00E+00	5.48E-01
WSW	0.00E+00	0.00E+00	4.27E-02	1.19E-02	1.10E-02	5.24E-02	2.35E-02	7.26E-06	4.93E-03	7.66E-04	2.00E-04	3.17E-06	1.34E-06	1.47E-01
W	2.39E-01	0.00E+00	1.55E-02	6.57E-03	7.48E-03	4.02E-02	2.95E-02	1.16E-03	1.06E-03	3.67E-03	2.50E-03	1.48E-04	1.23E-05	3.47E-01
WNW	0.00E+00	0.00E+00	2.77E-03	2.54E-03	2.31E-03	1.65E-02	3.13E-02	1.30E-02	5.62E-03	3.78E-03	2.17E-03	8.36E-03	2.03E-03	9.04E-02
NW	0.00E+00	1.70E-03	2.08E-03	2.21E-03	3.85E-04	6.09E-03	1.94E-03	1.71E-03	1.94E-03	1.55E-03	2.57E-04	2.64E-05	7.65E-06	1.99E-02
NNW	0.00E+00	0.00E+00	4.11E-05	0.00E+00	8.56E-06	1.18E-03	5.00E-03	1.91E-03	3.84E-03	1.09E-03	8.82E-04	2.19E-04	3.19E-04	1.45E-02
N	0.00E+00	2.19E-04	3.15E-04	1.95E-04	1.10E-04	5.54E-03	7.72E-03	4.36E-03	1.29E-04	3.12E-04	5.45E-04	1.51E-04	1.55E-04	1.98E-02
Total	5.40E-01	6.23E-01	3.52E-01	6.19E-02	7.73E-02	2.07E-01	1.52E-01	1.11E-01	3.51E-02	1.51E-02	9.93E-03	1.05E-02	3.64E-03	**2.20E+00**
														person-rem

Population based on the 2020 LandScan grid daytime file (from ORNL, 3/21/22)

	Distance (km)													
Direction	**0.5**	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**80**	**Grand Total**
22.5	2.42E+02	0.00E+00	5.00E+00	2.34E+02	1.42E+03	3.61E+03	1.15E+04	1.77E+05	8.02E+04	1.14E+05	3.39E+04	7.56E+03	1.55E+04	4.46E+05
45	0.00E+00	0.00E+00	0.00E+00	3.00E+00	6.50E+01	7.66E+02	1.64E+03	6.70E+04	7.53E+03	1.21E+02	4.89E+02	5.47E+03	3.27E+03	8.64E+04
67.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	2.76E+02	3.46E+04	9.25E+03	3.60E+04	1.07E+05	9.47E+04	3.05E+04	3.13E+05
90	2.51E+03	1.98E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+04	4.73E+04	9.41E+04	1.88E+04	7.79E+04	6.69E+03	2.83E+03	2.64E+05
112.5	0.00E+00	1.05E+03	3.75E+02	2.40E+02	2.09E+02	2.16E+02	4.31E+04	8.68E+03	2.90E+01	2.41E+03	3.27E+04	1.48E+04	1.47E+05	2.51E+05
135	0.00E+00	0.00E+00	1.27E+03	1.25E+03	4.42E+03	1.55E+04	9.44E+04	2.84E+03	2.34E+04	4.01E+04	5.49E+04	7.75E+04	6.16E+04	3.77E+05
157.5	0.00E+00	2.73E+03	2.08E+03	1.82E+03	4.66E+03	1.97E+04	2.28E+04	3.58E+04	9.58E+04	3.12E+03	1.04E+03	1.15E+03	4.00E+00	1.91E+05
180	0.00E+00	4.14E+03	4.92E+03	2.75E+03	1.28E+04	3.71E+03	0.00E+00	3.64E+04	1.36E+04	1.19E+03	0.00E+00	0.00E+00	0.00E+00	7.95E+04
202.5	0.00E+00	0.00E+00	2.50E+04	2.84E+03	6.03E+03	5.36E+03	1.90E+03	3.60E+05	3.93E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.41E+05
225	0.00E+00	1.46E+04	8.44E+03	3.50E+03	3.20E+03	2.83E+04	2.92E+03	5.35E+05	2.16E+05	1.15E+04	0.00E+00	0.00E+00	0.00E+00	8.23E+05
247.5	0.00E+00	0.00E+00	6.23E+03	3.90E+03	6.43E+03	4.79E+04	8.57E+04	1.06E+02	1.62E+05	4.48E+04	1.82E+04	4.17E+02	3.14E+02	3.76E+05
270	2.18E+03	0.00E+00	2.26E+03	2.16E+03	4.37E+03	3.67E+04	1.08E+05	1.70E+04	3.48E+04	2.15E+05	2.28E+05	1.95E+04	2.87E+03	6.72E+05
292.5	0.00E+00	0.00E+00	4.04E+02	8.34E+02	1.35E+03	1.51E+04	1.14E+05	1.90E+05	1.85E+05	2.21E+05	1.98E+05	1.10E+06	4.74E+05	2.50E+06
315	0.00E+00	6.20E+01	3.04E+02	7.26E+02	2.25E+02	5.56E+03	7.09E+03	2.49E+04	6.37E+04	9.05E+04	2.34E+04	3.47E+03	1.79E+03	2.22E+05
337.5	0.00E+00	0.00E+00	6.00E+00	0.00E+00	5.00E+00	1.08E+03	1.83E+04	2.79E+04	1.26E+05	6.40E+04	8.05E+04	2.88E+04	7.46E+04	4.21E+05
360	0.00E+00	8.00E+00	4.60E+01	6.40E+01	6.40E+01	5.05E+03	2.82E+04	6.38E+04	4.24E+03	1.83E+04	4.98E+04	1.99E+04	3.61E+04	2.25E+05
Grand Total	4.93E+03	2.27E+04	5.14E+04	2.03E+04	4.52E+04	1.89E+05	5.54E+05	1.63E+06	1.15E+06	8.80E+05	9.07E+05	1.38E+06	8.51E+05	7.69E+06
cumulative	4.93E+03	2.77E+04	7.90E+04	9.94E+04	1.45E+05	3.33E+05	8.87E+05	2.52E+06	3.67E+06	4.55E+06	5.46E+06	6.84E+06	7.69E+06	

2023 Dose to Population based on 2020 LandScan grid

ALS (Building 6)

Annual dose at B6/ALS Dosimete 1.70 mrem at distance= 0.058 km from B6 is 4.59E-01 person-rem

	Distance (km)													
Direction	**0.5**	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**80**	**Grand Total**
NNE	5.54E-03	0.00E+00	7.15E-06	1.49E-04	5.08E-04	8.26E-04	6.60E-04	2.53E-03	5.09E-04	4.09E-04	7.76E-05	1.20E-05	1.39E-05	1.12E-02
NE	0.00E+00	0.00E+00	0.00E+00	1.91E-06	2.32E-05	1.75E-04	9.40E-05	9.58E-04	4.78E-05	4.32E-07	1.12E-06	8.69E-06	2.92E-06	1.31E-03
ENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.29E-07	1.58E-05	4.94E-04	5.88E-05	1.29E-04	2.46E-04	1.50E-04	2.73E-05	1.12E-03
E	5.73E-02	1.13E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.95E-04	6.77E-04	5.98E-04	6.71E-05	1.78E-04	1.06E-05	2.52E-06	6.08E-02
ESE	0.00E+00	6.00E-03	5.36E-04	1.53E-04	7.47E-05	4.94E-05	2.47E-03	1.24E-04	1.84E-07	8.62E-06	7.49E-05	2.35E-05	1.31E-04	9.64E-03
SE	0.00E+00	0.00E+00	1.81E-03	7.95E-04	1.58E-03	3.55E-03	5.40E-03	4.06E-05	1.49E-04	1.43E-04	1.26E-04	1.23E-04	5.51E-05	1.38E-02
SSE	0.00E+00	1.56E-02	2.97E-03	1.16E-03	1.66E-03	4.51E-03	1.31E-03	5.12E-04	6.09E-04	1.11E-05	2.37E-06	1.82E-06	3.57E-09	2.83E-02
S	0.00E+00	2.37E-02	7.03E-03	1.75E-03	4.56E-03	8.49E-04	0.00E+00	5.21E-04	8.64E-05	4.26E-06	0.00E+00	0.00E+00	0.00E+00	3.85E-02
SSW	0.00E+00	0.00E+00	3.58E-02	1.80E-03	2.15E-03	1.23E-03	1.08E-04	5.15E-03	2.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E-02
SW	0.00E+00	8.32E-02	1.21E-02	2.22E-03	1.14E-03	6.47E-03	1.67E-04	7.65E-03	1.37E-03	4.11E-05	0.00E+00	0.00E+00	0.00E+00	1.14E-01
WSW	0.00E+00	0.00E+00	8.91E-03	2.48E-03	2.30E-03	1.09E-02	4.90E-03	1.52E-06	1.03E-03	1.60E-04	4.17E-05	6.62E-07	2.81E-07	3.08E-02
W	4.98E-02	0.00E+00	3.24E-03	1.37E-03	1.56E-03	8.41E-03	6.17E-03	2.42E-04	2.21E-04	7.67E-04	5.22E-04	3.10E-05	2.56E-06	7.24E-02
WNW	0.00E+00	0.00E+00	5.78E-04	5.30E-04	4.82E-04	3.46E-03	6.54E-03	2.71E-03	1.17E-03	7.89E-04	4.54E-04	1.75E-03	4.24E-04	1.89E-02
NW	0.00E+00	3.55E-04	4.35E-04	4.61E-04	8.04E-05	1.27E-03	4.06E-04	3.56E-04	4.05E-04	3.23E-04	5.36E-05	5.52E-06	1.60E-06	4.15E-03
NNW	0.00E+00	0.00E+00	8.58E-06	0.00E+00	1.79E-06	2.47E-04	1.04E-03	3.99E-04	8.03E-04	2.29E-04	1.84E-04	4.57E-05	6.67E-05	3.03E-03
N	0.00E+00	4.58E-05	6.58E-05	4.07E-05	2.29E-05	1.16E-03	1.61E-03	9.11E-04	2.69E-05	6.53E-05	1.14E-04	3.15E-05	3.23E-05	4.13E-03
Total	1.13E-01	1.30E-01	7.35E-02	1.29E-02	1.62E-02	4.31E-02	3.17E-02	2.33E-02	7.34E-03	3.15E-03	2.07E-03	2.19E-03	7.60E-04	**4.59E-01**
														person-rem

Population based on the 2020 LandScan grid daytime file (from ORNL, 3/21/22)

	Distance													
Direction	**0.5**	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**80**	**Grand Total**
22.5	2.42E+02	0.00E+00	5.00E+00	2.34E+02	1.42E+03	3.61E+03	1.15E+04	1.77E+05	8.02E+04	1.14E+05	3.39E+04	7.56E+03	1.55E+04	4.46E+05
45	0.00E+00	0.00E+00	0.00E+00	3.00E+00	6.50E+01	7.66E+02	1.64E+03	6.70E+04	7.53E+03	1.21E+02	4.89E+02	5.47E+03	3.27E+03	8.64E+04
67.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	2.76E+02	3.46E+04	9.25E+03	3.60E+04	1.07E+05	9.47E+04	3.05E+04	3.13E+05
90	2.51E+03	1.98E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+04	4.73E+04	9.41E+04	1.88E+04	7.79E+04	6.69E+03	2.83E+03	2.64E+05
112.5	0.00E+00	1.05E+03	3.75E+02	2.40E+02	2.09E+02	2.16E+02	4.31E+04	8.68E+03	2.90E+01	2.41E+03	3.27E+04	1.48E+04	1.47E+05	2.51E+05
135	0.00E+00	0.00E+00	1.27E+03	1.25E+03	4.42E+03	1.55E+04	9.44E+04	2.84E+03	2.34E+04	4.01E+04	5.49E+04	7.75E+04	6.16E+04	3.77E+05
157.5	0.00E+00	2.73E+03	2.08E+03	1.82E+03	4.66E+03	1.97E+04	2.28E+04	3.58E+04	9.58E+04	3.12E+03	1.04E+03	1.15E+03	4.00E+00	1.91E+05
180	0.00E+00	4.14E+03	4.92E+03	2.75E+03	1.28E+04	3.71E+03	0.00E+00	3.64E+04	1.36E+04	1.19E+03	0.00E+00	0.00E+00	0.00E+00	7.95E+04
202.5	0.00E+00	0.00E+00	2.50E+04	2.84E+03	6.03E+03	5.36E+03	1.90E+03	3.60E+05	3.93E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.41E+05
225	0.00E+00	1.46E+04	8.44E+03	3.50E+03	3.20E+03	2.83E+04	2.92E+03	5.35E+05	2.16E+05	1.15E+04	0.00E+00	0.00E+00	0.00E+00	8.23E+05
247.5	0.00E+00	0.00E+00	6.23E+03	3.90E+03	6.43E+03	4.79E+04	8.57E+04	1.06E+02	1.62E+05	4.48E+04	1.82E+04	4.17E+02	3.14E+02	3.76E+05
270	2.18E+03	0.00E+00	2.26E+03	2.16E+03	4.37E+03	3.67E+04	1.08E+05	1.70E+04	3.48E+04	2.15E+05	2.28E+05	1.95E+04	2.87E+03	6.72E+05
292.5	0.00E+00	0.00E+00	4.04E+02	8.34E+02	1.35E+03	1.51E+04	1.14E+05	1.90E+05	1.85E+05	2.21E+05	1.98E+05	1.10E+06	4.74E+05	2.50E+06
315	0.00E+00	6.20E+01	3.04E+02	7.26E+02	2.25E+02	5.56E+03	7.09E+03	2.49E+04	6.37E+04	9.05E+04	2.34E+04	3.47E+03	1.79E+03	2.22E+05
337.5	0.00E+00	0.00E+00	6.00E+00	0.00E+00	5.00E+00	1.08E+03	1.83E+04	2.79E+04	1.26E+05	6.40E+04	8.05E+04	2.88E+04	7.46E+04	4.21E+05
360	0.00E+00	8.00E+00	4.60E+01	6.40E+01	6.40E+01	5.05E+03	2.82E+04	6.38E+04	4.24E+03	1.83E+04	4.98E+04	1.99E+04	3.61E+04	2.25E+05
Grand Total	4.93E+03	2.27E+04	5.14E+04	2.03E+04	4.52E+04	1.89E+05	5.54E+05	1.63E+06	1.15E+06	8.80E+05	9.07E+05	1.38E+06	8.51E+05	7.69E+06
cumulative	4.93E+03	2.77E+04	7.90E+04	9.94E+04	1.45E+05	3.33E+05	8.87E+05	2.52E+06	3.67E+06	4.55E+06	5.46E+06	6.84E+06	7.69E+06	

Appendix C

Control Dosimeter Results

Table C-1 Photon Control Dosimeter Results

	Quarter 1 2023 Result (mrem)	Quarter 2 2023 Result (mrem)	Quarter 3 2023 Result (mrem)	Quarter 4 2023 Result (mrem)
Primary	13.7	22.0	17.5	21.2
Duplicate/control	14.7	20.6	22.8	23.8
Relative percent difference	0	6.6%	26.3%	11.6%

% = percent
mrem = milliroentgen equivalent man

Table C-2 Neutron Control Dosimeter Results

	Quarter 1 2023 Result (mrem)	Quarter 2 2023 Result (mrem)	Quarter 3 2023 Result (mrem)	Quarter 4 2023 Result (mrem)
Primary	0/ND	0/ND	0/ND	0/ND
Duplicate/control	0/ND	0/ND	0/ND	0/ND
Relative percent difference	0/ND	0/ND	0/ND	0/ND

mrem = milliroentgen equivalent man
ND = not detect

Appendix D

Errata

Protocol for Errata in Berkeley Lab's Site Environmental Reports

The primary form of publication for the Berkeley Lab Site Environmental Reports (SERs) is electronic and posted on the internet. Up through the SER for 2018 (published in September 2019), a limited number of copies were printed and distributed; printed copies can be accessed at the Oakland Public Library and the UC Berkeley Public Health Library. If errors are found after publication, the internet version is corrected. Because the printed versions cannot be corrected, errata for these versions are published in a subsequent report. In this way, the equivalency of all published versions of the report is maintained.

Beginning in September 2023, the following protocol for post-publication revisions apply:

- The website on which the SER is posted must clearly convey that corrections, if any, have been made and provide a link to a list of the errata.
- The internet version must be the most current version, incorporating all corrections.
- The electronic and printed versions must be the same, in that the printed version plus errata, if any, combined provide the same information as the internet version.

Archives of the Berkeley Lab SERs can be accessed at https://sites.google.com/a/lbl.gov/ems_public/environmental-report/full-reports.

List of Errata

SER	Publication Date	Correction(s)
2020	August 2021	In Table 3-4, the quantity of chlorofluorocarbons was misreported as 188 lbs. for 2020. The updated quantity, subject to the EPCRA report, is 225 lbs.
		An earlier version listed only Berkeley Lab's general permit to operate from the Bay Area Air Quality Management District (BAAQMD) in the References. Another listing was added to reference the Permit to Operate for Berkeley Lab's Gasoline Dispensing Facility. Citations associated with these references have been adjusted accordingly in the text.
2021	September 2022	In Section 3.4.5.3, the original version of this document stated the water reporting year as 2020/2021. The correct water reporting year is 2019/2020.
		In Table 3-4, the quantities of chlorofluorocarbons were misreported as 188 lbs. and 75 lbs. for 2020 and 2021, respectively. The updated quantities, subject to the EPCRA report, are 225 lbs. and 809 lbs., respectively.
		An earlier version listed only Berkeley Lab's general permit to operate from the Bay Area Air Quality Management District (BAAQMD) in the References. Another listing was added to reference the Permit to Operate for Berkeley Lab's Gasoline Dispensing Facility. Citations associated with these references have been adjusted accordingly in the text.
2022	September 2023	An earlier version stated that Berkeley Lab commissioned and installed a new natural gas meter in 2022. The meter was commissioned and installed in 2021.

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