BERKELEY LAB

Site Environmental Report for 2021

September 2022

Lawrence Berkeley National Laboratory
Environment, Health & Safety Division

LBNL-27170E-2022

DISCLAIMER

Department of Energy
Office of Science
Berkeley Site Office
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 90-1023
Berkeley, CA 94720

September 21, 2022

DISTRIBUTION

Subject: 2021 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 2021. 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 2021 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: 2022.09.21 13:07:55 -07'00'

Paul Golan
Site Office Manager

Site Environmental Report for 2021

September 2022

Cover photo: The Advanced Light Source (ALS), Building 6, dome as seen from an aerial drone at sunset looking towards the San Francisco Bay and Golden Gate at Lawrence Berkeley National Laboratory, Berkeley, California, February 23, 2021. 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.

Table of Contents

Figures

Tables

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 2021, 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, 2012) 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 Executive Order (EO) 13834, *Efficient Federal Operations*, then EO 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability* adopted in December 2021, 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. Berkeley Lab implements the Environmental Management System (EMS) component of the ISM to oversee environmental compliance activities and continually improve 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 both the environment and worker safety and health.

Throughout 2021, Berkeley Lab continued to strengthen its management systems. These systems provided a structured framework for Berkeley Lab to implement programs required by EO 13834, EO 14057, and DOE Order 436.1. 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) 2021, which began October 1, 2020, and ended September 30, 2021, 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 were developed jointly by Berkeley Lab, UC, and DOE. The FY 2021 rating was based on how Berkeley Lab met the objective in DOE's FY 2021 Performance Evaluation and Measurement Plan (Section J, Appendix B of Contract 31) of providing an efficient and effective EMS. Overall, the environmental management system at Berkeley Lab is effective, supporting compliance with all relevant environmental

statutory and regulatory requirements. Berkeley Lab continues to make progress achieving performance metrics on key environmental 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 sustainable practices. Overall scores fall into one of three categories: green (highest), yellow (middle), or red (lowest). Berkeley Lab received a score of green in FY 2021, as described in Chapter 2.

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 that occurred during 2021. Two minor[1] violations, both of which have been closed out, were issued during agency inspections, one governing underground storage tanks and the other a manifest records review.

Environmental monitoring data of emissions and discharges from LBNL operations were below environmental compliance thresholds.

This report also includes information on environmental monitoring performed in 2021 (Chapter 4). Berkeley Lab monitors stack air, surface waters, wastewater, groundwater, soil and 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, although concentrations appear to be reaching asymptotic levels in some areas. Site groundwater plumes are stable or are attenuating, and VOCs are not migrating off-site.

In 2021, 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 2021 concluded that the maximum potential dose to a hypothetical resident from Berkeley Lab's estimated airborne radionuclide releases was approximately 0.026% 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 0.3% of the average natural background radiation dose of 310 mrem/yr in the United States, and approximately 0.95% of the DOE annual limit of 100 mrem/yr from all sources related to LBNL operations.

[1] "Minor" as defined in California Environmental Protection Agency's (CalEPA, 2020) "Violation Classification Guidance for Unified Program Agencies" (https://calepa.ca.gov/wp-content/uploads/sites/6/2020/06/Violation-Classification-Guidance-Document-accessible.pdf).

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 2021. 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, Brandon Connelly, John Cummings, Evelyn Davies, John Elliot, Kelley Etherington, Brie Fulton, John Jelinski, Ken Kievit, Jennifer Larson, Brendan Mulholland, James Nunez, Carl Palladino, Jeff Philliber, Samantha Robertson, Joseph Saadeh, Karen Salvini, Bernadette Santos, Leana Sossikian, Amy Tanouye, Mike Torkelson, and Suying Xu.

The Site Environmental Report can be viewed or downloaded from the Environmental Publications page of the ESG website (https://ehs.lbl.gov/resource/documents/environmental-services/environmental-publications/), where many of the documents cited in this report can also be found. Questions and feedback about the report can be directed to Lily Baldwin at labaldwin@lbl.gov or 510-486-5283.

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 more than 3,500 scientists, engineers, support staff, and students work year-round, and several thousand more researchers visit each year. 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.

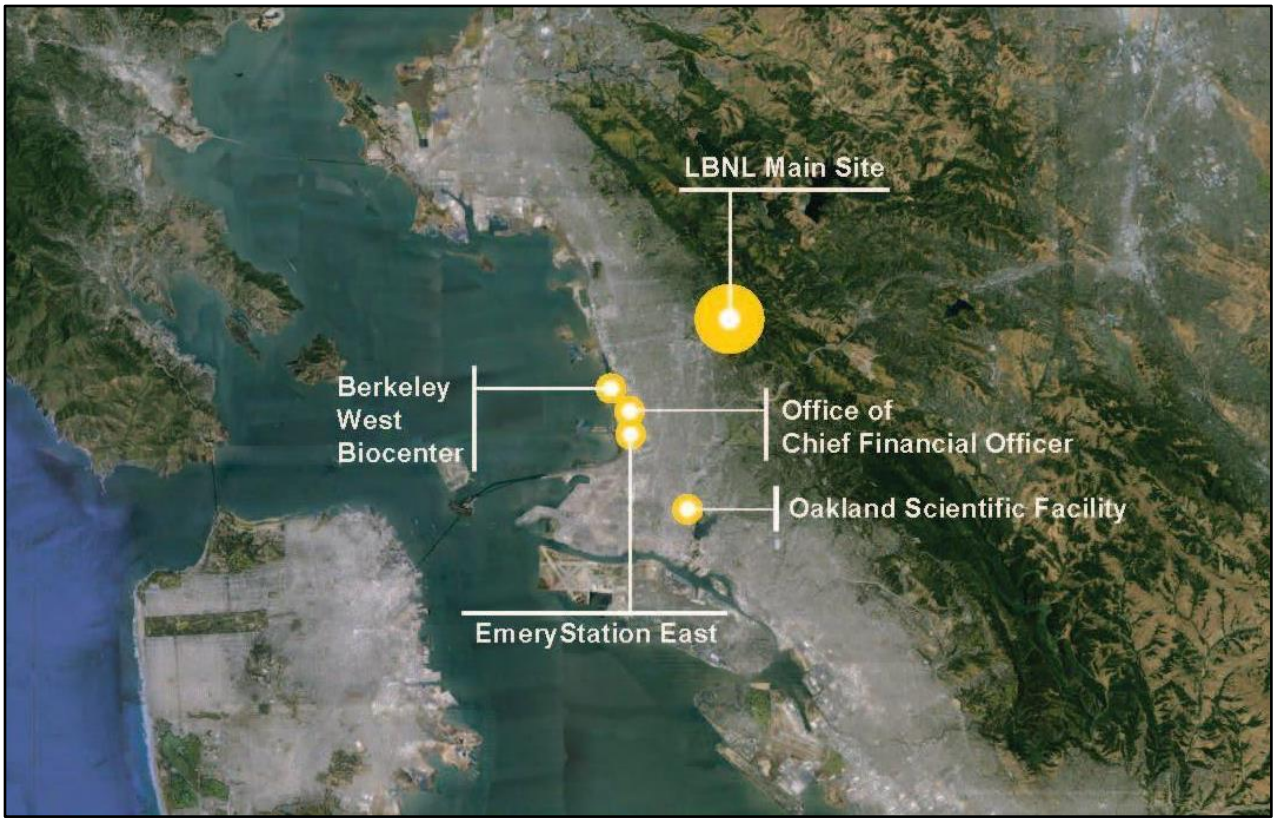

Figure 1-1 LBNL Main Site and Satellite Facility Locations in the East Bay

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 Oakland consist of leased buildings in developed urban areas.

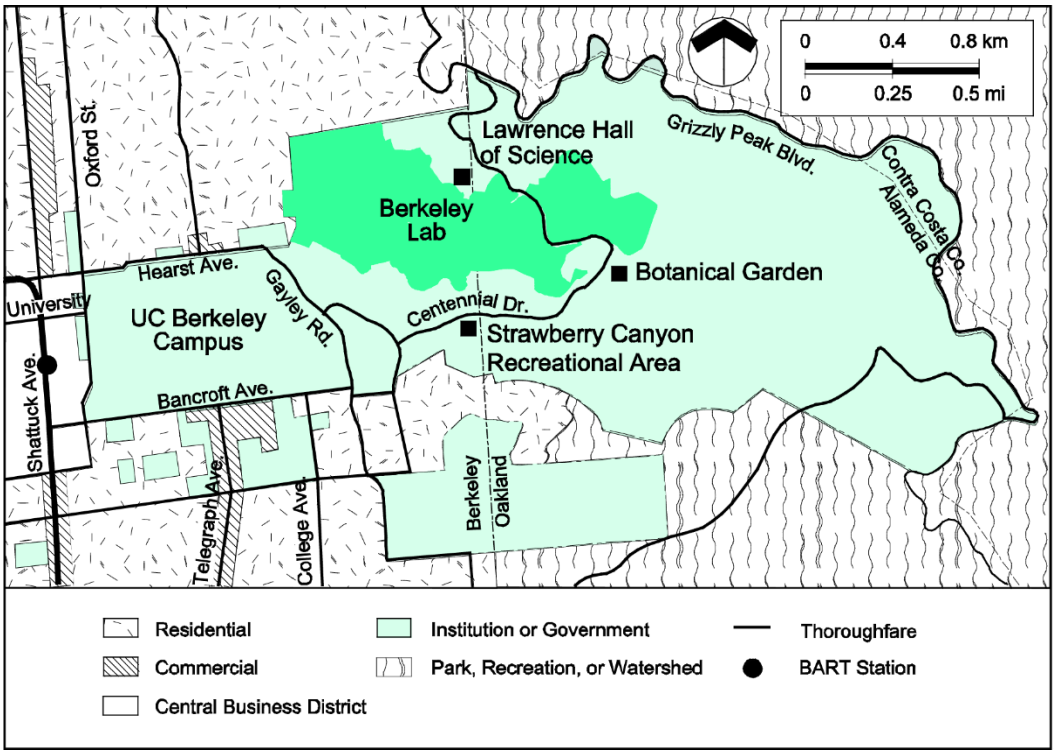

Figure 1-2 LBNL Main Site and Adjacent Land Use

1.2 ENERGY SUPPLY

Electricity and natural gas are the two 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. Electricity is supplied to off-site facilities by Pacific Gas & Electric or East Bay Community Energy, a community choice aggregator, and distributed by Pacific Gas & Electric. 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, and SLAC National Accelerator Laboratory.

Natural gas is provided by the Defense Logistics Agency and is transported through infrastructure belonging to the Pacific Gas & Electric Company.

In FY 2021, 25% of electricity consumption (and 19% of all energy consumption) was procured or generated from renewable sources, beyond the renewables included in the grid power mix. Renewable energy sources include power procured by WAPA from a 3.5-megawatt solar power array located at Lawrence Livermore National Laboratory, hydropower procured through WAPA, renewable power mix procured through East Bay Community Energy, and contract renewable energy credits purchased through WAPA.

1.3 WATER SUPPLY

The East Bay Municipal Utility District (EBMUD) supplies domestic water such as 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 the water for contaminants and treats it 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.

1.4 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 range between 40 degrees Fahrenheit (°F) and 70°F, with an average annual temperature of 55.5°F in 2021. Though temperatures seldom exceed 90°F or drop below 32°F, the maximum and minimum temperatures were 94°F and 36°F, respectively, in 2021.

Based on measurements taken on-site from 1974 through 2021, the historical precipitation “water year” total average is 29.31 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 2020/2021 water year – at 11.42 inches – is 38.4% 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 on the left shows the distribution of wind patterns for 2021, 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.

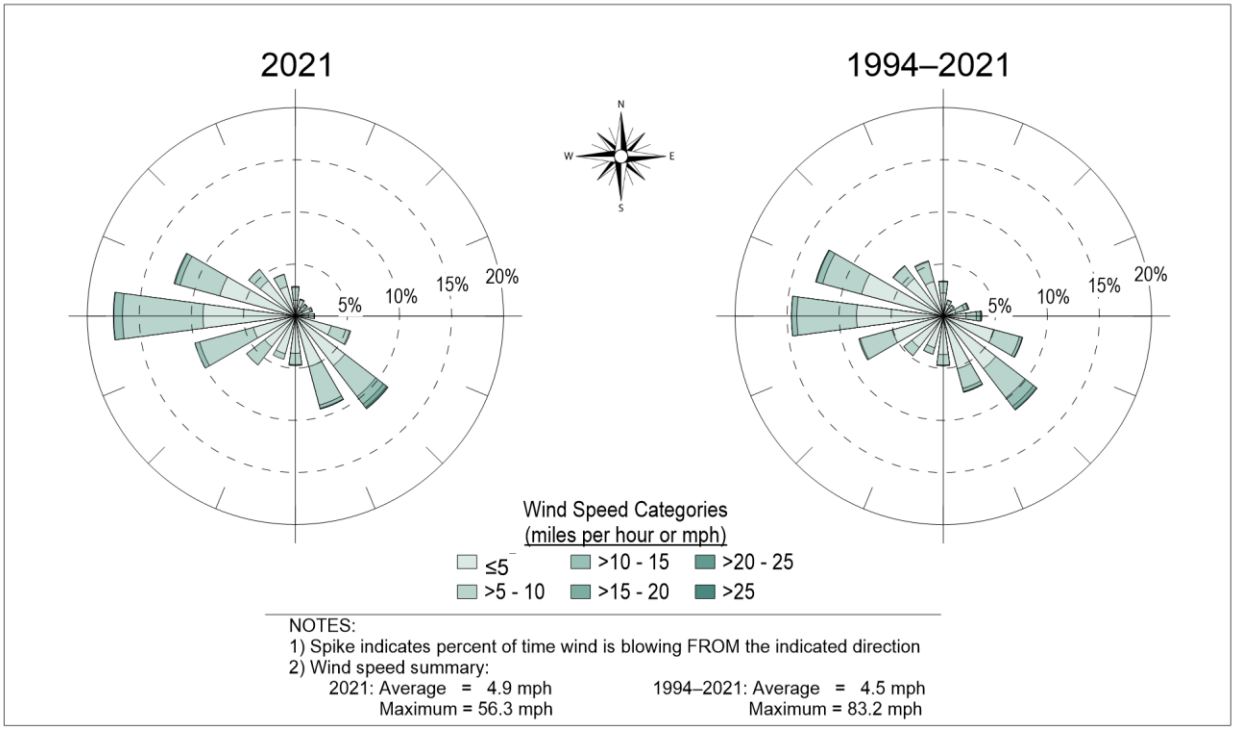

Figure 1-3 Annual Wind Patterns from 1994 Through 2021

1.5 VEGETATION

Vegetation at Berkeley Lab and the area surrounding it 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 1-4 Vegetation at LBNL Site and the Surrounding Area

1.6 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.

1.7 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 rate of groundwater flow 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 groundwater flow rates in this unit are 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, which is commonly referred to as "Old Town." The Moraga Formation constitutes the main water-bearing unit at the site. Permeabilities and groundwater flows 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 has 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.

1.8 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.

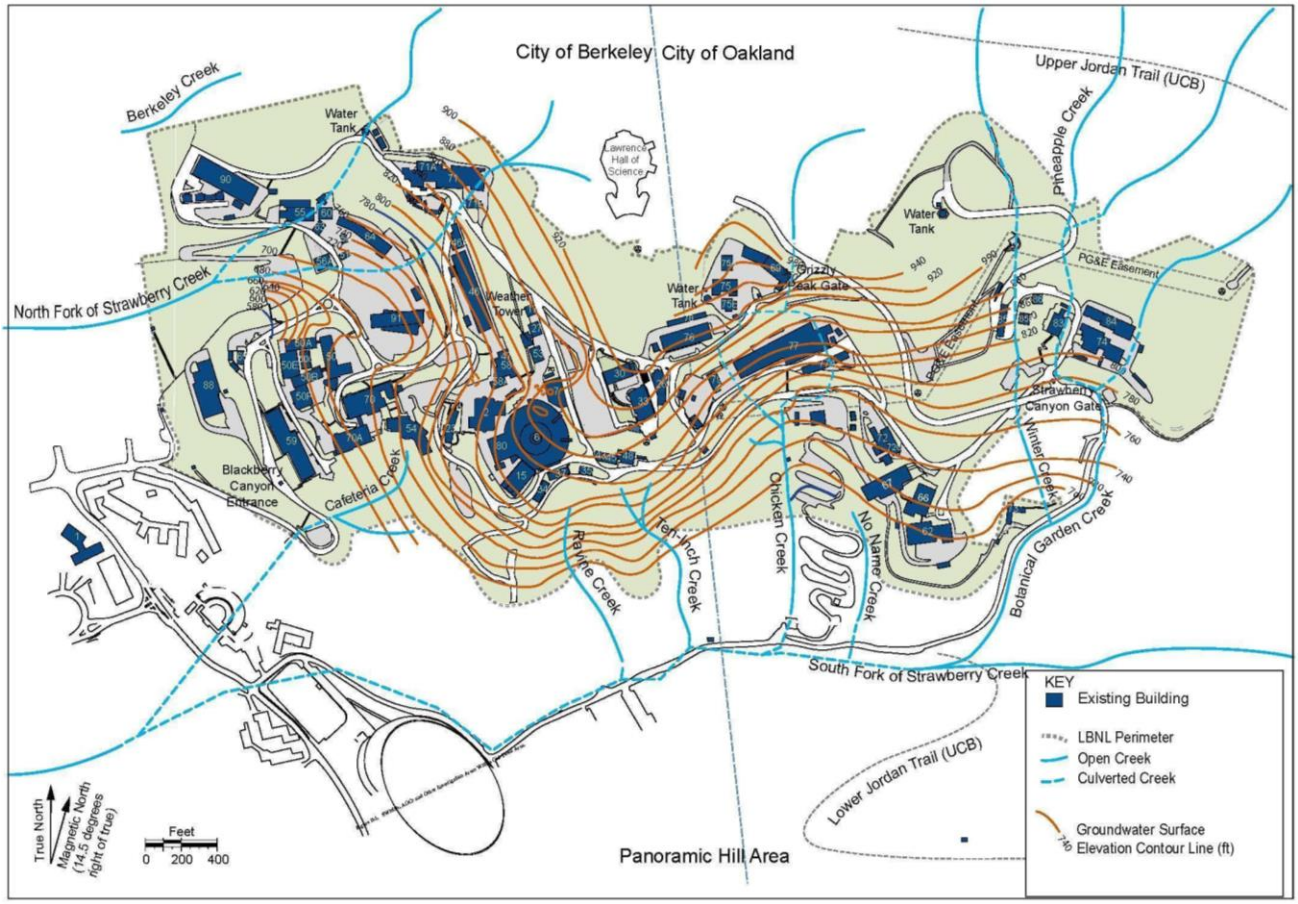

Figure 1-5 Surface Water Locations and Groundwater Elevations at Berkeley Lab

1.9 GROUNDWATER

Figure 1-5 also 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.

2 Environmental Management System

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

2.1 INTEGRATED SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEM

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:

- Analyze the hazards, which includes defining the scope
- Develop and implement hazard controls
- Perform work within controls
- Provide feedback
- Provide continuous improvement

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

- DOE Contract No. DE-AC02-05CH11231 (also known as Contract 31), the prime contract between DOE and UC for Berkeley Lab
- DOE-approved site compliance plans for contractual DOE directives
- Berkeley Lab program documentation included in the *Environment, Safety, and Health Manual* (PUB-3000)
- *Environmental Management System Program Manual* (LBNL, 2021c)
- Federal sustainability requirements (Executive Order 13834, which was replaced by 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, in December 2021; 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* (LBNL, 2021b), in conformance with the ISO 50001 standard, *Energy Management Systems* (ISO, 2018), an international standard for managing and improving energy performance

The EMS portion of the ISM is essentially a systematic approach to improve environmental performance. DOE Order 436.1, *Departmental Sustainability* (DOE, 2011), requires 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. The EMS strives for continual improvement in environmental performance through the four-step "Plan-Do-Check-Act" framework for management systems.

DOE Order 436.1 also requires that a site's sustainability goals be integrated into the EMS. Berkeley Lab's annual Site Sustainability Plan (LBNL, 2020a) sets performance goals in the following areas:

- Energy management
- Water management
- Waste management
- Fleet management
- Renewable energy
- Sustainable buildings
- Acquisition and procurement
- Measures, funding, and training
- Travel and commute
- Fugitive gases and refrigerants
- Electronic stewardship
- Resilience

In total, more than 25 sustainability goals are set forth in these areas by Executive Order (EO) 13834, *Efficient Federal Operations* (issued in 2018), which was in effect for 2021, and by law. Berkeley Lab's annual Site Sustainability Plan is available online at http://sbl.lbl.gov/results/reports.html.

2.2 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. For example, personnel who handle hazardous chemicals and waste are provided training in chemical and waste management, waste minimization, pollution prevention, on-site transportation of hazardous chemicals and waste, and basic spill and emergency response. Details on Berkeley Lab's training program are available at training.lbl.gov. Workers are required to complete all appropriate, including environmental, training before they can perform their assigned work. Training is documented in the Berkeley Lab Training System for every worker and contractor receiving training, and notifications of new and expiring training are sent to workers and supervisors as required.

2.3 FRAMEWORK OF THE ENVIRONMENTAL MANAGEMENT SYSTEM

Key elements of the ISO 14001 standard that contribute to the framework of Berkeley Lab's EMS are described in the following subsections.

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* (PUB-201; LBNL, 2021e), 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 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 specifically 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
- Sustaining Berkeley Lab's overall mission

These practices are incorporated into Berkeley Lab's *Environmental Management System Program Manual* (LBNL, 2021d), which provides guidance on implementing environmental policy in compliance with the ISO 14001 standard. An EMS "Core Team," with representatives from various divisions at 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 the EMS website.

2.3.2 Environmental Aspects

As part of the "plan" step for a management system, Environmental Services Group (ESG) subject matter experts and the EMS Core Team periodically review environmental aspects associated with Berkeley Lab Research and Operations. An environmental aspect is any element of and the 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 2021, 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 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 and 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 and likelihood combinations of high-high or high-moderate could be considered a risk that needs to be managed. As needed, the EMS Core Team may engage subject matter experts to inform the discussion. If reviewers determine that additional information is needed to evaluate a particular product or activity, the EMS Program Manager oversees the collection of this information. The EMS Core Team then stewards an Environmental Action Plan if a significant risk is identified that 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 reducing significant impacts to the environment. Environmental Action Plans in place at the end of FY 2021 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 2021
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	LBNL-wide energy use intensity, excluding process loads, has decreased 29% since fiscal year (FY) 2015 NERSC power usage effectiveness for FY 2021 was 1.08
Water Management	• Eliminate water waste • Develop water reuse opportunities	Reduce water consumption intensity 36% by 2025 (2007 baseline)	Potable water use intensity is 26% below FY 2007 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	Achieve zero waste (>90% annual waste diversion) Reduce waste by 50% of 2016 levels by 2030	Nonhazardous solid waste diversion from the landfill is estimated at 61%
Sustainable Acquisition	• 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	100% of applicable contracts 96%
GHG Emissions	• Decarbonize Berkeley Lab's energy supply • Develop local renewable generation and storage	Reduce overall GHG emissions 30% by 2025 (2015 baseline)	Total reported GHG emissions are 60% below 2015 levels
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	Did not meet target goal for stormwater reporting year 2020/2021 because of dry weather

Aspect/Activity	Objective(s)	Target(s)	Status at End of 2021
Sanitary Sewer	• Cost-effectively eliminate sanitary sewer overflows	Zero sanitary sewer overflows annually	No sanitary sewer overflows in 2021
Hazardous and Mixed Waste Management	• Strengthen hazardous waste management compliance at accumulation areas	Zero hazardous waste notices of violation	Targeted self-assessments were performed for 2021
Environmental Legal Registry	• Systematically and sustainably track and analyze relevant federal, state, and regional environmental regulatory requirements	Develop and maintain an updated environmental legal register, with a mechanism to stay apprised of new or changed operations and requirements	Environmental legal registry completed and will be reviewed annually starting in 2022
Storage Tanks and Air Quality Compliance	• Improve the compliance and implementation of tank inspections and air permit recordkeeping	All tank inspections performed on time and as required by the regulations	Developed Action Plan to address potential risks

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, as follows:

- The annual Site Environmental Report and Environmental Restoration Program 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 also initiated an online Lunch and Learn series, starting with a presentation by EHS and Facilities Engineering on SmartCover monitors that were installed in 2021 to help Berkeley Lab engineers monitor and prevent wastewater overflows from the sanitary sewer system.

Relationships established with colleagues over years of working together are also an excellent way to communicate EMS-related matters. These relationships may be within the Berkeley Lab community or external, such as with DOE and UC communities.

When appropriate, articles on EMS topics are included in LBNL publications, such as *Elements*. These articles may be prepared by ESG staff or EMS Core Team members. The LBNL community can also learn more about EMS Program activities through occasional presentations provided by a Core Team member to groups such as the Safety Advisory Committee and Division Safety Coordinators.

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 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., including 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 2021; the meetings were held virtually to accommodate COVID-19 safety protocols. Recordings and meeting information can be found on the Planning Information Center for the LBNL Community Advisory Group website.

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. The audit is conducted by a qualified party outside the control or scope of the EMS Program. The purpose of the audit is to verify that the EMS conforms to the ISO 14001 standard, as required by the Contractor Requirements Document of DOE Order 436.1, *Departmental Sustainability*. A virtual, external audit was performed during the summer of 2021. The external auditor verified that all findings from the 2018 audit were closed out and identified no major findings. The external auditor found one minor nonconformance: there was no evidence of an EMS internal audit as required by ISO 14001:2015. Berkeley Lab prepared a corrective action plan to develop and implement annual internal audits starting in 2022.

Plans and procedures are prepared by EHS staff to comply with regulatory requirements for various environmental programs. These plans also describe how programs are required to monitor, measure, analyze, and evaluate compliance. For example, a Stormwater Pollution Prevention Plan details how Berkeley Lab will comply with California stormwater requirements. Similarly, a Spill Prevention, Control, and Countermeasure (SPCC) Plan describes measures that Berkeley Lab will take to prevent the discharge of oils into nearby waters, as overseen by both federal and state regulatory agencies (LBNL, 2017c).

ESG has developed an extensive set of internal procedures that describe how to implement one or more aspects of a program plan. For example, ESG Procedure 210, *SPCC Compliance Inspection for Petroleum Drum Storage Areas*, provides guidance on implementing part of the SPCC Plan.

Berkeley Lab maintains correspondence with regulatory agencies to demonstrate that its environmental programs are maintaining their compliance status. ESG keeps internal electronic records of its environmental regulatory correspondence and reporting, organized by fiscal year.

The EMS Program Manager is responsible for the care, maintenance, disposition, and archiving of EMS-related records in accordance with Berkeley Lab's record management policies and procedures, as described in the Information Management section of the *Requirements and Policies Manual* (LBNL/PUB-201; LBNL, 2021e).

2.3.6 Management Review

As part of the "act" step for a management system, senior management of organizations involved in implementing the EMS meet annually with the EMS Program Manager to conduct management reviews of the program's status. The meetings are attended by a representative who reports to the Deputy Director for Research and a representative who reports to the Deputy Director for Operations. These senior representatives can then share relevant information with others in the Research and Operations areas who do not attend the management review meetings. Because the EMS is required to be integrated with sustainability goals, the Sustainable Berkeley Lab Team, led by the Chief Sustainability Officer, partners with the EMS Program in conducting the annual management reviews.

At a minimum, the review meetings cover the following topics cited in the ISO 14001 standard:

- 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 2021 was held in January 2022. Key topics included program updates and accomplishments for Environmental Action Plans detailed in Table 2-1. The review meeting also provided an update on Energy and Water Management System activities as required by the ISO 50001 standard that is led by the Sustainable Berkeley Lab Team.

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 (FY), which begins October 1 and ends September 30. One report is required by the operating contract between DOE and UC that assesses performance for numerous functional areas (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 D (lowest score) – in the DOE Berkeley Site Office's *Performance Evaluation Report of the University of California for Management and Operations of Science and Technology at the Lawrence Berkeley National Laboratory* (DOE-BSO, 2021) for its integrated ES&H program and its EMS. This evaluation is based on objectives in DOE's FY 2021 Performance Evaluation and Measurement Plan (Section J, 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 requirement for the EMS Reporting Scorecard originated from Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, issued in 2007. Most recently, this reporting was associated with Executive Order 13834, *Efficient Federal Operations,* which was issued in 2018. Though EO 13834 was revoked by EO 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, issued in December 2021, EO 13834 was still in effect for the duration of this document's reporting period.

The federal Office of Management and Budget collects annual performance information online to measure performance against goals established in this executive order for five categories, as follows:

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

The fifth category, EMS/Sustainability goals integration, is graded by responses to how a site has addressed the sustainability goals listed in Section 2.1 above.

Berkeley Lab's EMS Program earned the highest score of "green" in 2021. Each category listed above is scored from A (best) to D (worst). A green score signifies that at least three A's and the rest B's were received.

2.4.3 Accomplishments, Awards, and Recognition

No More Gasoline Blowers and Line Trimmers: In 2021, after a brief pilot period, the Lab switched to using battery-operated leaf blowers and line trimmers, transitioning away from fuel use for landscape management.

Berkeley Lab Achieves a Seventh LEED Certification: In FY 2021, the Lab's newest building, the Integrative Genomics Building (IGB), achieved LEED Gold. The Lab now has six LEED Gold buildings and one LEED Platinum building.

The Lab's sustainability efforts were also recognized by three awards in 2021:

1. Berkeley Lab's IGB received the UC's highest recognition for sustainability in new construction, a 2021 Best Practice Award for Overall Sustainable Design.
2. The IGB was awarded a 2021 DOE Sustainability Award Honorable Mention for the Outstanding Sustainability Program/Project category.
3. The National Energy Research Scientific Computing Center (NERSC) Efficiency Optimization Team was presented a 2020 DOE Sustainability Award for the Sustainable HPC/Data Center category.

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 (3.4.3.1)	Main Site
		HMBP and hazardous waste generation (3.4.2)	Main Site
		Underground storage tanks (3.4.3.3)	Main Site
		HMBP and hazardous waste generation (3.4.2)	Berkeley West Biocenter
Treatment, storage, disposal facility Part B Permit	DTSC	Hazardous Waste Handling Facility operations (3.4.2)	Main Site
Stormwater	SWRCB	Sitewide and construction stormwater discharges (3.4.5.3)	Main Site
Surface water and sediment	EBRPD	Surface water and sediment sampling (4.2, 4.5.2)	Tilden Park
Wastewater	EBMUD	Sitewide and operation-specific wastewater discharges to sanitary sewer (3.4.5.2)	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. Two minor violation notices resulted from seven inspections in 2021. These inspections were conducted at the Berkeley Lab main site or the Berkeley West BioCenter. Information about these inspections is summarized in Table 3-2 and discussed in Sections 3.4.2, 3.4.3.1, 3.4.3.3, and 3.4.5.1. 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 Environmental Audits, Inspections, and Appraisals

Organization	Inspection Type	Start Date	Violations
LBNL	Annual certification of unleaded gasoline and E85 dispensing systems	July 23	0
	Designated Operator Underground Storage Tank Visual Inspections	Every 30 days	0
COB[a]	Underground storage tank monitoring system and spill container certification	Sept. 3	1
	Routine compliance inspection of aboveground storage tanks, fixed treatment units, HMBP, and hazardous waste generation at LBNL main site	Sept. 27-30	0
	Routine compliance inspection for the HMBP and hazardous waste generation at Berkeley West BioCenter	Nov. 4	1
	Underground storage tank overfill prevention equipment inspection/certification	Sept. 3	0
	Underground storage tanks line tightness testing	Sept. 3	0
LBNL	Self-monitoring inspection required by EBMUD for groundwater treatment units	Feb. 5	0
	Self-monitoring inspection required by EBMUD for the Hearst and Strawberry sanitary sewer outfalls	Sept. 23	0

E85 = 85% ethanol / 15% unleaded gasoline fuel blend

[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. The following two incidents were reported in 2021:

1. During a routine inspection of hazardous waste generator areas at LBNL's main site by City of Berkeley Toxics Management Division in September 2021, the spill bucket for a tank near Building 85 failed the annual spill container test performed by a certified vendor. The spill container was subsequently replaced. Berkeley Lab will continue to visually inspect the spill bucket for any cracks or integrity issues as part of the 30-day designated operator inspections.
2. During a routine inspection of hazardous generation waste for Berkeley Lab's Berkeley West BioCenter facility by the CUPA in November 2021, the inspector noted that a manifest was not properly processed. The issue was immediately addressed during the inspection.

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, 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., volatile organic compounds, 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 diesel trucks, 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, "the Air District") 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)

In the Permit to Operate, issued on July 1, 2021, Berkeley Lab held 35 permitted sources, 11 registered sources, and 1 exempt source under the Air District permits covering activities and equipment at the main site, Plant #723 (BAAQMD, 2021). All permits issued by the Air District are listed in Table 3-3.

BAAQMD operating permits must be renewed annually. The renewal application process includes submitting usage information on permitted sources. The Air District did not conduct any inspections in 2021 of permitted equipment or activities.

An internal audit at Berkeley Lab identified three unpermitted emission sources (two diesel fire pumps and one natural gas/propane emergency generator). Berkeley Lab subsequently submitted a "Loss of Exemption" permit application to the BAAQMD. Berkeley Lab is awaiting final determination.

3.4.1.1 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, the Lab submits a renovation notification form to the Air District 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 Air District. During calendar year 2021, 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, four asbestos demolition/renovation notifications were submitted to BAAQMD for these projects.

Table 3-3 BAAQMD Air Emission Sources

BAAQMD Permit Category	Description (No. of Sources)	Building(s)	Abatement Type
Combustion equipment – engines	Standby emergency generators (4)	64, 66, 67, 70	Catalytic converter
	Standby emergency generators (6)	30, 48, 50A, 59, 72, 91	Catalyzed diesel particulate filter
	Standby emergency generators (16)	2, 33, 37 (2), 50B, 55, 62, 64, 68, 74, 77, 84B, 85, plus three portable units	None
	Standby emergency generators (5)	Five portable units	DOC, EGR, SCR
Combustion equipment – boilers	Boilers (11)	2, 66, 67, 77, 88	None
Gasoline dispensing	Fueling stations: unleaded and E85 (2)	76	Vapor recovery
Surface coating and painting	Paint spray booth (1)	77	Dry filter
Surface preparation and cleaning	Sandblast booth (1)	77	Baghouse
	Wipe-cleaning (1)	Sitewide	None
Miscellaneous	Soil vapor extraction system (1)	58	Activated carbon

DOC = diesel oxidation catalyst
E85 = 85% ethanol / 15% unleaded gasoline fuel blend
EGR = exhaust gas recirculation
SCR = selective catalytic reduction

3.4.1.2 Vehicle Fleet Management and Source Testing

Berkeley Lab has three fleets of vehicles regulated under the following regulations as nonstationary emissions sources: Truck and Bus Regulation, In-Use Off-Road Diesel-Fueled Fleets Regulation, and Large Spark-Ignition (LSI) Engine Fleet Requirements Regulation. Information about each regulation and its associated reportable fleet are as follows:

- **Truck and Bus Regulation**
  - Report includes four low-use exemption vehicles
- **In-Use Off-Road Diesel-Fueled Fleets Regulation**
  - Report includes an inventory of six off-road vehicles, five of which are registered as low use
- **Large Spark-Ignition Engine Fleet Requirements Regulation**
  - Report includes an inventory of 22 forklifts that are registered as low-use

Associated annual reports, which include odometer/hour meter readings, for each regulation were submitted to CARB in 2022 for calendar year 2021 data. Each vehicle in the low-use category is used less than 200 engine hours annually. Berkeley Lab continues to replace and upgrade its fleet as resources allow.

An internal audit review identified that Berkeley Lab did not submit a Large Entity One-Time Advanced Clean Trucks Report to CARB, which was due on May 1, 2021. Berkeley Lab is currently following up with CARB to determine if there is any additional action needed.

The BAAQMD operating permit for Berkeley Lab's on-site unleaded gasoline and E85 dispensing systems requires annual testing. Testing was performed on July 23, 2021, and both systems passed and met acceptance criteria.

3.4.1.3 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 436.1. In FY 2021, Berkeley Lab achieved a 47% reduction in Scope 1 and 2 emissions, and a 60% reduction in total emissions, relative to a FY 2015 baseline. Reduced commuting, travel, and building operations owing to COVID-19 contributed in part to this continued reduction in FY 2021 as well as significant energy efficiency savings that have been achieved since 2015 (see Efficiency Savings graph on https://sbldata.lbl.gov/energy).

As part of its GHG management program, CARB regulates sulfur hexafluoride (SF_6) emissions from gas-insulated switchgear (GIS) by setting a maximum annual emission rate and requiring an annual usage report. SF_6 is a potent GHG having a global warming potential 23,900 times that of carbon dioxide. Berkeley Lab had 15 active SF_6-containing switches and breakers in service in 2021. A total of 1.5 lbs of SF_6 was added to gas-insulated equipment in 2021. Maintenance is performed on a three-year cycle; however, inspections are performed every two weeks on switches at Berkeley Lab. Replacement of the two gas-insulated switches in the Strawberry East Canyon switching station is in the design phase for reducing the LBNL annual GHG emission rate for SF_6 by replacing these two switches with non-gas solid dielectric-type switches.

Since 2010, at the end of each fiscal year, Berkeley Lab has reported its annual GHG emissions to DOE. This reporting was required by EO 13834 in 2021, though subsequently revoked by EO 14057 in December 2021. The order contains more than 25 sustainability goals, including those for GHG emissions and fleet activities. More information on these sustainability goals is available in the *Lawrence Berkeley National Laboratory Annual Site Sustainability Plan* (LBNL, 2020a) (available at sbl.lbl.gov/reports).

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.

3.4.1.4 Radiological Emissions

Berkeley Lab 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)

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 2021 was approximately 0.026% 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 2021* (LBNL, 2021d), 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 Emergency Planning and Community Right-to-Know Act (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). 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 2021 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 3-4 summarizes Berkeley Lab's assessments of high-use process-type operations involving chemical usage quantities since 2011.

Table 3-4 Trends in Quantities of Chemicals for Process-Type Operations Subject to EPCRA Toxics Release Inventory Reporting

Substance	Quantity Used per Year (pounds)									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Chlorofluorocarbons	183	61	132	87	327	390	270	429	188	75
Methanol	103	172	127	100	130	126	82	61	50	52
Nitric acid	633	633	556	78	90	90	21	502	38	106

The City of Berkeley Toxics Management Division and Alameda County Department of Environmental Health implement 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 it voluntarily submits HMBPs that meet state requirements, even though it is not subject to state hazardous materials regulations.

The HMBP includes the Hazardous Materials Inventory Statement. 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 2021 and submitted electronically to the California Environmental Reporting System (http://cers.calepa.ca.gov/):

- LBNL main site
- Berkeley West Biocenter
- EmeryStation East

The HMBPs are also available on the Environmental Publications page of ESG's website. The City of Berkeley Certified Unified Program Agency (CUPA) conducted audits in 2021 during which no non-conformances were identified.

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 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 underground storage tanks

3.4.3.1 Regulated Waste

Berkeley Lab generates and manages the following regulated wastes:

- Hazardous waste
- Mixed and combined waste (RCRA or non-RCRA hazardous and radioactive)
- Radioactive waste
- Universal waste
- Medical 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 Hazardous Waste Handling Facility (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 and lamps, non-empty aerosol cans, and electronic waste. The CUPA has the authority to audit universal waste management practices for regulatory compliance.

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

California's permitting program for hazardous waste treatment and storage facilities has five tiers, which are listed in Table 3-5 in order of decreasing regulatory complexity. Berkeley Lab has activities falling under three of the tiers.

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. In June 2016, Berkeley Lab submitted an application to DTSC to renew the permit, as required every 10 years. In January 2018, DTSC issued a first Notice of Deficiency (NOD) letter requesting changes to the application and additional information, to which Berkeley Lab responded in July 2018. In 2019, DTSC provided preliminary feedback on Berkeley Lab's response, and in 2020, DTSC presented the Lab with a path forward that would address both parties' concerns related to the resolution of one deficiency identified in the 2018 NOD. Meanwhile, the 2006 permit, with the associated DTSC-approved permit modifications, including the most recent modifications that became effective in 2020, remained effective and enforceable in 2021. When the application is complete, DTSC will prepare a draft permit that will involve a public comment period before a final permit is issued.

During a routine hazardous waste generation inspection of Berkeley Lab's Berkeley West BioCenter facility by the CUPA in November 2021, the inspector noted that a manifest was not properly processed. The observation was immediately addressed during the inspection, and a violation was issued in December.

Table 3-5 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	–

FTU = fixed treatment unit (see Table 3-6 for details on each FTU)

Administration and enforcement for the three lower permit tiers are delegated to the City of Berkeley under the California CUPA program. Four fixed treatment units (FTUs) operate at Berkeley Lab under a hazardous wastewater treatment permit issued by the City of Berkeley at the permit-by-rule and conditional authorization tiers. 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.

Table 3-6 Summary of Fixed Treatment Unit Operations

FTU	Building No.	Treatment Descriptions	Approx. Quantity of Wastewater Treated in 2021 (gallons)
004	70A/70F	Acid neutralization by pH adjustment	368,464
005	2	Acid neutralization by pH adjustment	67,210
006	77	Metals precipitation and acid neutralization by pH adjustment, ion exchange, and evaporation	1,997 (100% is recycled with no discharge)
007	67	Acid and alkaline neutralization by pH adjustment	31,168

In September 2021, the City of Berkeley CUPA performed a routine inspection of hazardous materials storage areas/HMBPs, aboveground storage tanks, fixed treatment units, and hazardous waste accumulation areas at the Berkeley Lab main site. No violations were observed.

3.4.3.2 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 approved by DTSC in the *Corrective Measures Study Report for Lawrence Berkeley National Laboratory* (LBNL, 2005) 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 in the downgradient portions and 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 *Soil 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 the Environmental Restoration Program website (https://ehs.lbl.gov/resource/environmental-restoration-program/).

3.4.3.3 Underground Storage Tanks

In the early 1980s, California began addressing groundwater contamination from leaking underground storage tanks (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, recordkeeping, 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 2021 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 and witnessed by the City of Berkeley CUPA Inspector. In September 2021, Berkeley Lab received a minor[2] violation for not maintaining a liquid-tight spill container at the Building 85 UST system. The spill bucket was replaced and the corrective action was completed. Berkeley Lab will continue to test the spill bucket on an annual basis to ensure its integrity per the regulations.

[2] "Minor" as defined in CalEPA's (2020) "Violation Classification Guidance for Unified Program Agencies."

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 in preparation for demolition of Buildings 5 and 16 and the Building 52 building slab. Efforts to characterize the extent of PCB contamination continued into 2017 under the regulatory authority of U.S. EPA Region 9. Cleanup of this contamination began in early 2017 under a cleanup plan approved by the U.S. EPA, and is ongoing.

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 Board
2. nine Regional Water Quality Control Boards
3. local governments

The agencies responsible for regulatory programs 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 drinking water supply and wastewater discharges.

3.4.5.1 Aboveground Oil Storage

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 petroleum storage tanks for standby/emergency diesel generators, 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 aboveground storage tanks are listed in the September 2020 SPCC Plan.

3.4.5.2 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, 2019b)
- Treated groundwater from hydraugers (subsurface drains) and groundwater extraction wells (EBMUD, 2016)
- "Zero-waste-discharge" treated rinse water recycled from the metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77 (EBMUD, 2019c)
- Treated rainwater from the Old Town Demolition Project and Bayview Parcel 1 / Site Utilities Relocation Project (SURP) (EBMUD, 2019a)

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. Accordingly, no wastewater discharge limits were exceeded.

EBMUD periodically samples the site's sanitary sewer discharge without notice. The agency did not collect any wastewater samples from Berkeley Lab's two sewer outfalls, Strawberry and Hearst, in 2021.

The sitewide wastewater discharge permit is renewed periodically by EBMUD. This permit requires annual self-monitoring, which is discussed in Chapter 4. The sitewide permit also requires annual certification by Berkeley Lab that it is in compliance with the radiological conditions of the permit. Berkeley Lab was in compliance with the radiological requirements of the EBMUD permit.

Berkeley Lab also holds a special EBMUD permit for discharging treated rainwater collected within excavations at the Old Town Demolition Project and Bayview Parcel 1 / SURP construction sites. Treatment consists of using a zeolite media bed to reduce metals, particulate filter cartridges to collect sediment, and activated charcoal to remove PCBs, total petroleum hydrocarbons, and VOCs that may have accumulated in the rainwater runoff collected at the site.

3.4.5.3 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. Although the State Water Board issues this permit, it is administered and enforced locally by the SF Bay Regional Water Board. Under this permit, Berkeley Lab has implemented a Stormwater Pollution Prevention Plan (SWPPP; LBNL, 2019c), which includes the site's *Stormwater Monitoring Implementation Plan* (LBNL, 2019b).

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 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 three sample collection results: two samples collected during the 2020/2021 reporting season and one during the first half of the 2021/2022 reporting season. The annual report covering stormwater activities for the 2020/2021 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 releases 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, 2012), also referred to as the Construction General Permit. During 2021, three projects at Berkeley Lab required coverage under the Construction General Permit program:

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

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. Both projects were compliant with their permit requirements for 2021.

The Construction General Permit for the Old Town Demolition Project has remained active since May 2015. The Bayview Parcel 1 / SURP / BioEPIC stormwater permit became active in November 2019 and continued through 2021; it will be terminated when the BioEPIC project is completed. The SSM and THUP Project 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.

In 2021, DOE made five 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 2021. Approximately six 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 Initial Study / Negative Declarations or Environmental Impact Reports were prepared in 2021.

3.5 OTHER NOTABLE ENVIRONMENTAL ACTIVITIES AND ACCOMPLISHMENTS

3.5.1 Soil Vapor Investigation

At times, Berkeley Lab engages in projects that require additional environmental investigation and characterization activities in support of continued modernization of its research facilities. One such project was the soil vapor investigation study conducted in the Bayview Area at Berkeley Lab.

Historical operations have contributed to the presence of volatile organic compounds (VOCs) in soil, soil vapor, and groundwater beneath portions of the Bayview Area. In support of design activities for the BioEPIC building, a soil vapor investigation was performed in 2018 to assess potential impacts to indoor air quality and risk to future building occupants.

The results of the investigation indicated that there was a risk to future BioEPIC building occupants from the potential intrusion of chlorinated VOCs in soil vapor into indoor air. An engineered vapor mitigation system has been incorporated into the building design to address this concern. *The Final Vapor Intrusion Mitigation*

Design Report, BioEPIC Building, Lawrence Berkeley National Laboratory was submitted to DTSC for review and approval in December 2021.

3.5.2 Chemical Lifecycle Management Initiative and New Chemical Inventory Database, CMS 2.0

Since 2020, the Lab has made substantial progress on a comprehensive initiative to improve chemical lifecycle management "from cradle-to-grave" as expected by Lab 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 lifecycle management. Berkeley Lab execution of the initiative began in early January 2021.

Several notable accomplishments were performed in 2021, including enhanced chemical purchasing, acquisition, and work planning; launching a new training course for time-sensitive chemicals; establishing clear roles, responsibilities, authorities, and accountabilities for chemical management; improving chemical waste planning processes, such as the chemical inventory transition process for departing researchers; and procuring a new chemical management system, CMS 2.0.

3.5.3 Per- and Polyfluoroalkyl Substances (PFAS)

DOE Deputy Secretary issued on September 16, 2021, the memorandum "Addressing Per- and Polyfluoroalkyl Substances at the Department of Energy'' (DOE, 2021a), 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. To this end, Berkeley Lab is replacing the one fire sprinkler system on-site that uses Aqueous Film Forming Foam (AFFF) containing PFAS, with a water-only fire sprinkler system. Until the system is replaced, Berkeley Lab has also installed plugs in the wall flutes of the building containing the AFFF system, and has installed a deflector shield on the end fire sprinkler to prevent AFFF-laden water onto the hillside. No environmental sampling of PFAS is currently required by regulatory agencies.

3.5.4 Disposal of Unwanted Chemicals

The EHS Division implemented an initiative in 2018 to reduce the unwanted chemicals stored in laboratories. Some of the specific tasks completed in 2021 to reduce chemical inventory and improve inventory management are listed as follows:

- A multidivisional team of chemical safety, waste management, and hazard analysis experts continue to evaluate chemicals that are expired and/or potentially unstable. The team obtained a permit from DTSC to use a high-hazard chemical vendor to stabilize 99 potentially unstable chemicals in January 2021 before shipment off-site for disposal.
- More than 5,300 unwanted chemicals were disposed of during laboratory chemical cleanouts.

- Waste management professionals continue their visual inspections of potentially high-risk waste containers so the containers are deemed safe before they are transferred to the HWHF.

3.5.5 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 they 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 TSDF Facility Report, Biennial Hazardous Waste Report, the annual waste inventory for the HMBP, and the State Bill (SB) 14 Waste Minimization Plan.

3.5.6 Hazardous Waste Minimization

An SB 14 Waste Minimization Plan was prepared in 2019 for waste generated in the previous calendar year. The next plan is due in 2023 for calendar year 2022. Overall, the amount of hazardous waste shipped off-site for disposal in 2018 declined from the 2014 baseline year. Some strategies that are used 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 lab trash that is being managed as hazardous waste.
- Promoting fixing or replacing equipment that leaks oil to minimize the generation of waste oil.
- Flagging procurement requests for restricted chemicals that require safety reviews prior to purchase.
- Educating researchers on 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.
- Purchasing oilless pumps and cyclone dewatering devices.
- 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.

3.5.7 Municipal Waste Management and Minimization

Nonhazardous waste can be grouped into municipal solid waste, construction and demolition (C&D) debris, e-waste, and nonhazardous industrial waste. Berkeley Lab's strategies for continual improvement include a waste auditing program, a waste policy as part of the Lab's Sustainability Standards for Operations, and an online Waste Guide (https://sbl.lbl.gov/wasteguide/) to promote employee awareness. The guide also details the types of waste generated at Berkeley Lab and how they are treated. The Lab has moved to a model of self-service for personal waste bins that is intended to encourage staff to sort their waste and reduce recyclable and compostable materials sent to the landfill.

Municipal solid waste diversion from the landfill in 2021 is estimated at 61%. The term *municipal solid waste* refers to the following waste streams generated at Berkeley Lab:

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

Construction and demolition debris diversion is estimated at 90%. 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 2021. Berkeley Lab is working toward transitioning its recycling contracts to electronics recyclers certified under either the e-Stewards or Responsible Recycling (R2) programs.

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 2021 sampling and monitoring results for the following media and processes:

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

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 and real-time monitoring, as well as dispersible inventory evaluation. This program is conducted in accordance with the U.S. EPA and DOE requirements, which are discussed in more detail in Section 3.4.1.4.

Numerous radionuclides are used in Berkeley Lab's radiochemical and biomedical research programs, and radioactive materials are generated by particle accelerators. These research and accelerator operations may produce very small amounts of airborne radionuclides, which are typically emitted from a stack via a building's exhaust system. Berkeley Lab is required to assess the potential impacts from radionuclide emissions where radionuclides are used or generated. If the dose from potential emissions exceeds U.S. EPA Region 9–approved thresholds listed in Table 4-1, Berkeley Lab must follow U.S. EPA–approved methods for measuring emissions by sampling or monitoring stacks through which 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, and then compared with the thresholds listed in Table 4-1. In 2021, all potential doses were found to be less than 0.1 mrem/yr, indicating that the applicable

requirements are either Category 3, which requires periodic sampling, or Category 4, which requires dose evaluation but no sampling or monitoring.

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 2021, 19 locations were sampled as part of the air monitoring program – 4 on a monthly schedule, 14 on a quarterly schedule, and 1 on an annual schedule. One stack was both sampled and monitored, and real-time monitoring was performed on three stacks continuously. Sampling and monitoring locations are shown on Figure 4-1.

Stack exhaust samples were analyzed for three radiological parameters: gross alpha, gross beta, and tritium, and the real-time stack air monitoring systems measured alpha emitters and positron emitters. Fluorine-18 (half-life of 1.83 hours) produced from the B56 accelerator was the predominant radionuclide measured, accounting for approximately 31.1% of the Lab's emitted activity, but was only roughly 0.008% 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.

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):

- North Fork of Strawberry Creek
- Cafeteria Creek
- Ravine Creek
- Ten-Inch Creek
- Chicken Creek

- No Name Creek
- Winter Creek, which is sampled at two locations (inflow and outflow points to the site)
- Botanical Garden Creek

The creeks are normally sampled twice a year – once during the wet season and once during the dry season.

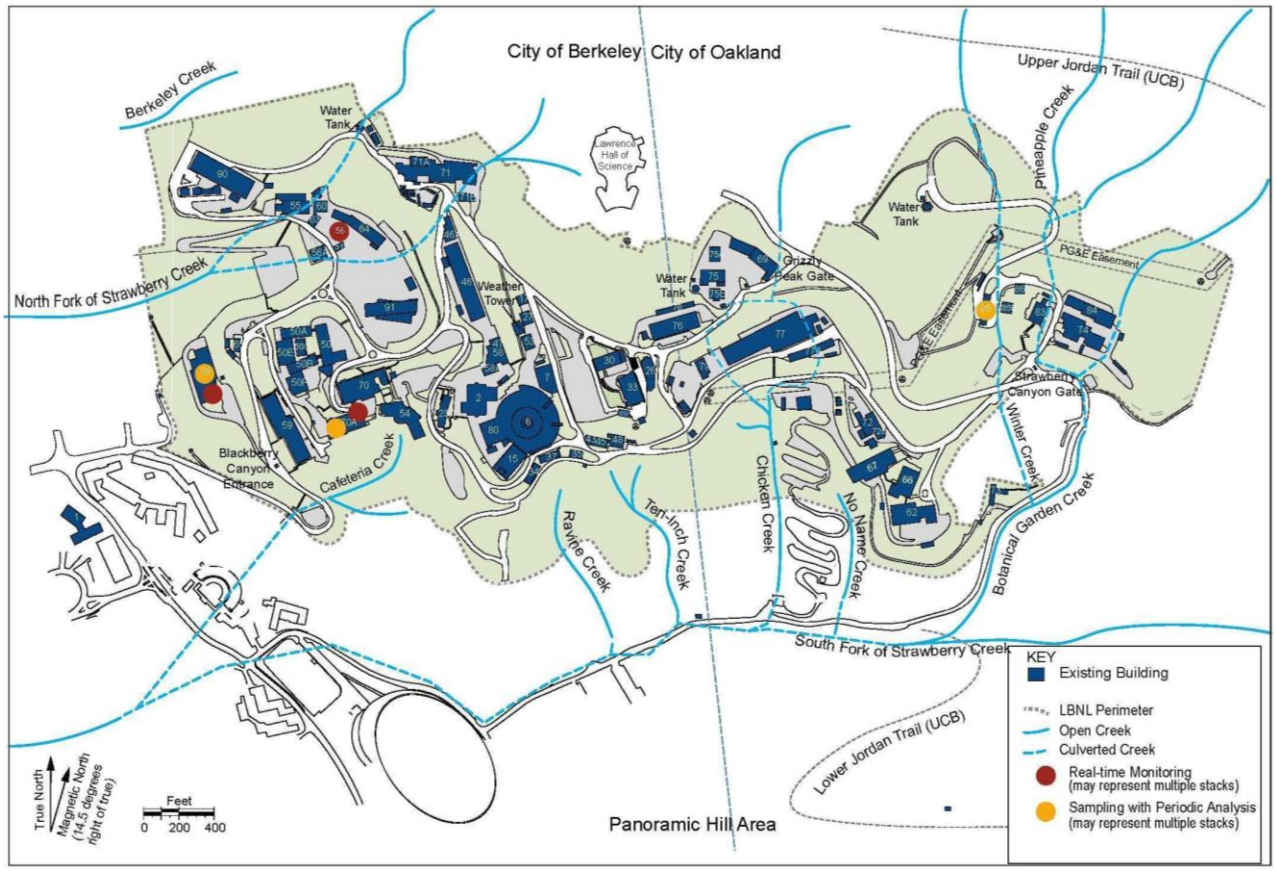

Figure 4-1 Building Exhaust Sampling and Monitoring Locations

To establish background water quality values for the area, samples were also 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. Wildcat Creek originates in Tilden Park and flows in a northwest direction away from Berkeley Lab.

Samples from the following subset of creeks were collected and analyzed for gross alpha, gross beta, gamma emission 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).

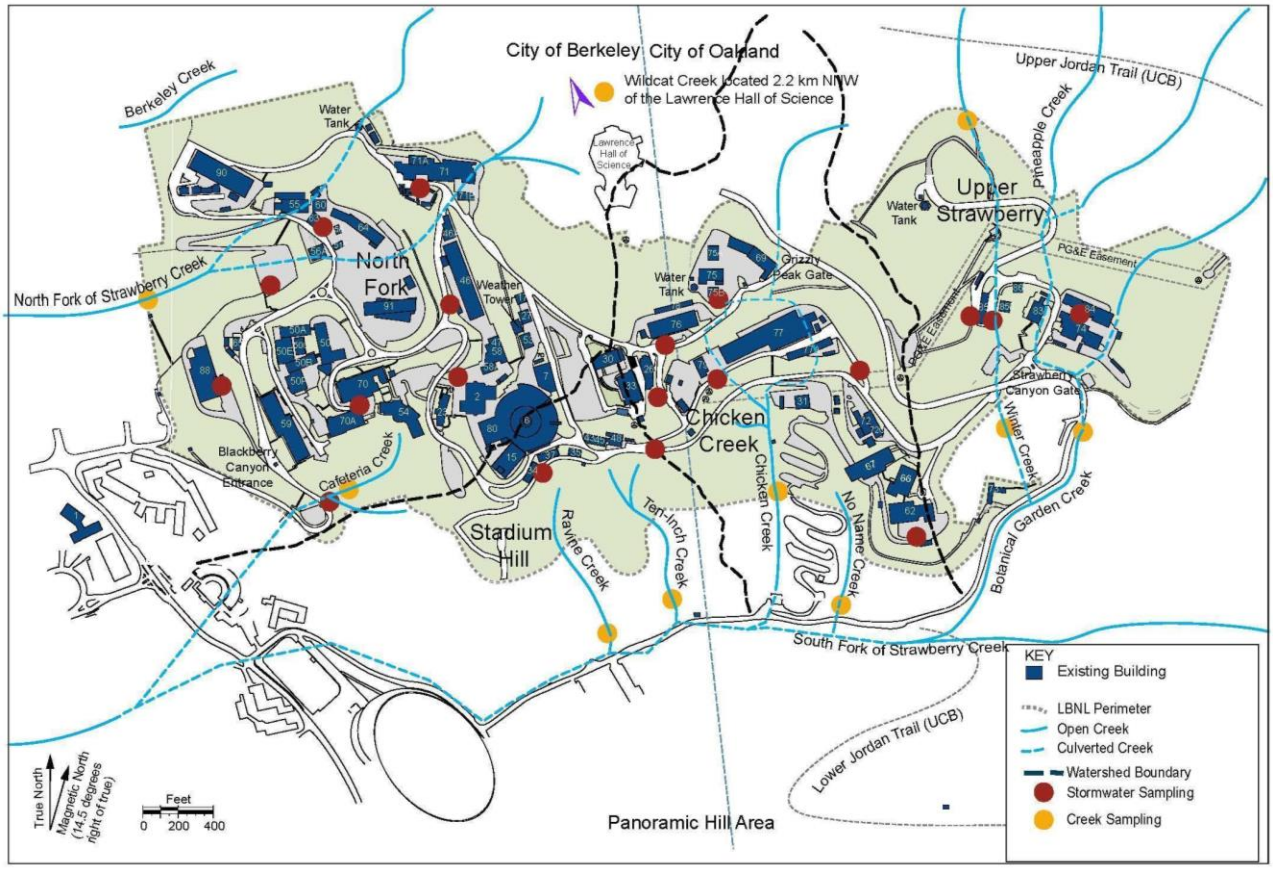

Figure 4-2 Surface Water Sampling Locations

Although LBNL surface waters are not used as a source of public drinking water, Berkeley Lab evaluates creek water results against conservative maximum contaminant level (MCL) drinking water standards, as well as water quality objectives as stated in the *Water Quality Control Plan for the San Francisco Bay Basin* (commonly known as the Basin Plan; RWQCB, 2015). The federal and state MCL values for drinking water are as follows (U.S. EPA, 1976; RWQCB, 2019):

- gross alpha – 15 picocuries per liter (pCi/L)
- gross beta – 50 pCi/L
- tritium – 20,000 pCi/L

Laboratory analysis reported 36 of the 39 samples (92%) as below detectable levels. As shown in Table 4-2, two samples had detectable levels of gross beta, although these were no greater than 8% of the federal and state MCL values for drinking water, and one sample had detectable levels of gross alpha. Naturally occurring radioactive materials, such as potassium-40, uranium-238, and thorium-232, as well as their (naturally occurring) daughter products, are common in the environment and are believed to contribute the majority, if not all, of the detectable gross beta results. Tritium was not detected in any of the samples.

Table 4-2 Detectable Radiological Results from 2021 Creek Sampling

Activity	MCL[a] (pCi/L)	Creek	Sample (pCi/L)	% of MCL
Gross alpha	15	Chicken Creek	2.8	18.7
Gross beta	50	Chicken Creek	4.8	9.6
Gross beta	50	North Fork Strawberry Creek	2.9	5.8

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

Using gamma spectroscopy for specific radionuclides, the results indicated that 65 of the 89 analytes (73%) measured during 2021 creek sampling were not detected by the analytical laboratory. Radiological activities for the remaining samples (24 analytes) with detectable results (concentrations above analytical MDC) 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.

Creek samples were also sampled and analyzed for PCBs, VOCs, pH, and metals. No PCBs were detected, though the following VOCs were detected: acetone, chloromethane, and chloroform. These compounds are common by-products of laboratory cleaning and chlorine treatment of drinking water. The detections are suspected to be the result of laboratory contamination or possibly insufficient post-decontamination drying of sampling equipment. In addition, the following metals were detected: aluminum, antimony, arsenic, barium, chromium, copper, iron, lead, molybdenum, nickel, selenium, vanadium, and zinc. Metals and pH results were within historical levels for Berkeley Lab, well below the water quality objectives listed in the Basin Plan, and well below the drinking water standard.

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, 2019b). 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–December 31), with the remaining two then taking place during the second half of the reporting year (January 1–June 30).

In August 2018, Berkeley Lab evaluated the applicability of its historical Standard Industrial Classification (SIC) codes and revised its classification from multiple codes to the single SIC code #8733 Noncommercial Research Organization, which best describes current site activities. In addition, in September, Berkeley Lab

conducted a sitewide pollutant source assessment (PSA), which identified four potential point-source areas of industrial activity conditionally subject to the General Permit's monitoring requirements. Based on Berkeley Lab's current SIC code, the PSA findings, and the General Permit's monitoring requirements, beginning in the first half of the 2018/2019 season, stormwater samples were collected for the following five parameters:

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

The 2015/2016 reporting year was the first under a significantly modified Industrial General Permit, which initially 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. The results from the four sampling events for the first reporting year under the new permit showed that two parameters sampled by Berkeley Lab, aluminum and iron, exceeded their NALs of 0.750 and 1.000 mg/L, respectively. This resulted in a change in compliance status from Baseline to Level 1 for the 2016/2017 reporting year. In the subsequent reporting year (2017/2018), sample results again showed that averages for aluminum (at 1.271 mg/L) and iron (at 1.75 mg/L) were above their respective NALs, causing Berkeley Lab's compliance status to change from Level 1 to Level 2.

The change in status resulted in a requirement that Berkeley Lab identify additional stormwater controls to implement in order to prevent future exceedances of NALs. These additional controls fell into the following two categories of administrative and structural/treatment controls:

1. Administrative controls were in the areas of updated 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 status also resulted in an update to the SWPPP to include the additional stormwater controls, then submitting an Exceedance Response Action Level 2 Report to the State Water Board outlining actions taken for the site.

With additional best management practices in place to address aluminum and iron for the 2017/2018 reporting year, Berkeley Lab was successful in achieving sample results that were below the NALs, thereby allowing its return to the Baseline compliance status for the 2018/2019 reporting year. However, repeated exceedances of aluminum and iron detected in reporting year 2019/2020 have again elevated Berkeley Lab's

status to Level 2 for reporting year 2020/2021. The Lab implemented additional stormwater controls to reduce concentrations of aluminum and iron in stormwater runoff.

4.3 WASTEWATER

As required by permits issued by EBMUD, Berkeley Lab samples wastewater discharges at its two monitoring stations downstream of the main site. Sampling is also conducted to assess permit compliance for discharges of treated water from hydraugers and groundwater extraction wells. Sampling was performed at the Building 77 Ultra-High Vacuum Cleaning Facility until April 2018, when the treatment system was shut down to upgrade to a wastewater recycling system. In August 2019, EBMUD representatives inspected the newly installed zero-discharge treatment system at the Building 77 Ultra-High Vacuum Cleaning Facility, and a new permit was issued for the system in September 2019.

For the current reporting year, 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 Section 3.4.5.2, 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 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.

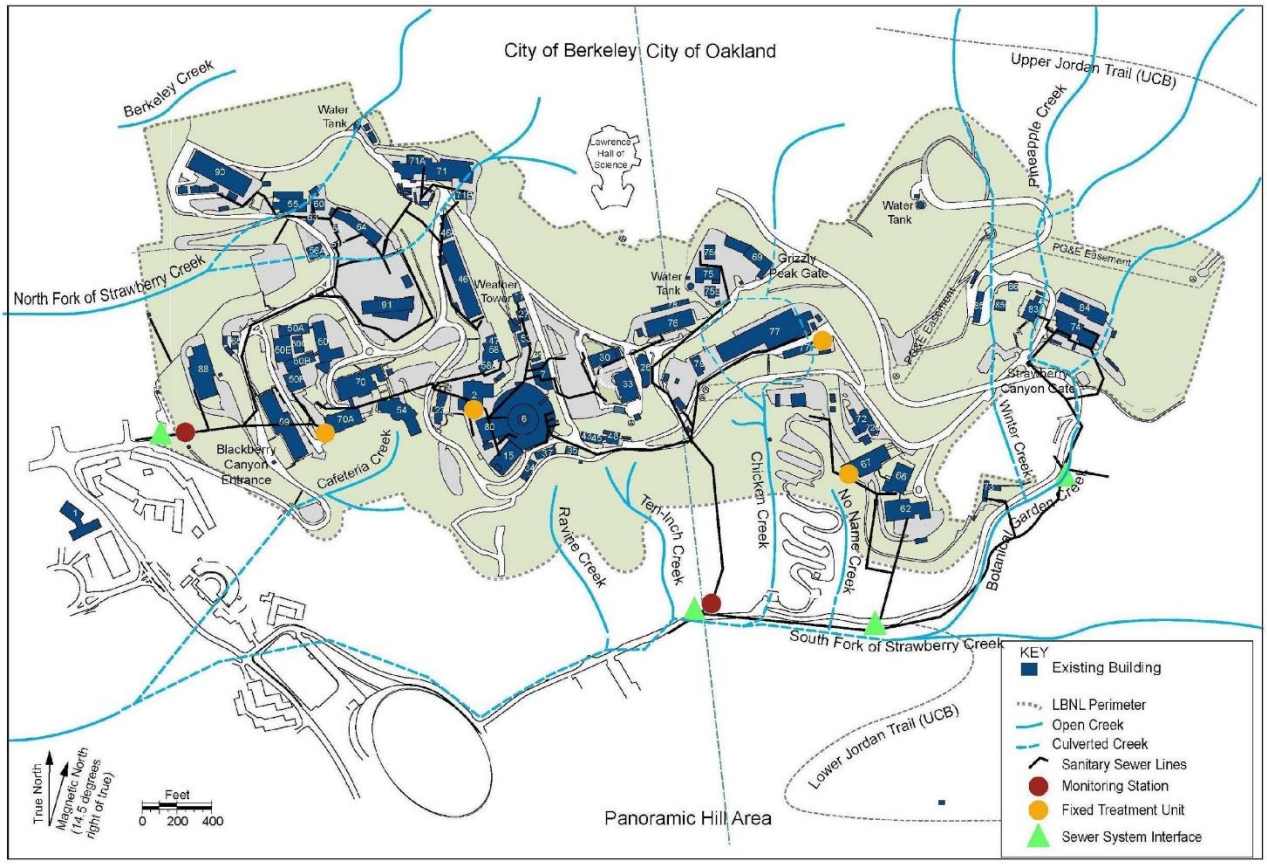

Figure 4-3 Sanitary Sewer System (Main Lines)

4.3.2 Hearst and Strawberry Sewer Outfalls

In 2021, Berkeley Lab discharged approximately 17.7 million gallons through the Hearst branch of the sewer system and 11.7 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 Sections 4.3.2.1 and 4.3.2.2.

- 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.
- Nonradiological samples collected at the Hearst and Strawberry outfalls are analyzed for pH, total identifiable chlorinated hydrocarbons, chemical oxygen demand, PCBs, total suspended solids, and specific metals.

4.3.2.1 Radiological Monitoring

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, and carbon-14.

All samples taken at the Hearst and Strawberry sanitary sewer outfalls in 2021 were below the minimum detectable activity levels for carbon-14, iodine-125, and tritium. Although sewer discharges are not used for drinking water, positive results are conservatively compared to MCLs as a demonstration of compliance with DOE Order 458.1 (DOE, 2020). Positive results for gross beta were consistently detected throughout the year at the Hearst and Strawberry sewer outfalls, and are likely due to naturally occurring radioactive material such as potassium-40. The highest characterized gross beta concentration was 11.9 pCi/L, which is below the federal and state MCLs for drinking water of 50 pCi/L.

In accordance with DOE guidance (DOE, 2021b), annual discharges are estimated by multiplying the maximum sample result's activity by the total annual volume discharged, even when the activity level is below the minimum detection limits. Since carbon-14, iodine-125, and tritium were below minimum detectable concentration levels, they are considered estimated values. The federal and state regulatory limits for radioisotopes in wastewater are based on total amounts discharged per year. The annual discharge estimated from tritium values totaled 7.05×10^{-3} Ci, or 0.14% of the tritium discharge limit of 5 Ci. The annual discharge estimated from carbon-14 values totaled 2.44×10^{-3} Ci, or 0.24% of the carbon-14 discharge limit of 1 Ci. These estimates are very conservative because they use the maximum concentration for each sample result, even if this value is below the minimum detectable concentration. For example, all sample results for carbon-14 and tritium were below the minimum detectable concentration. The estimated annual discharge for all other radioisotopes (gross alpha, gross beta, and iodine-125) was 3.75×10^{-3} Ci, or 0.38% 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-1196-2021, *Derived Concentration Technical Standard* (DOE, 2021b). 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 using conservative assumptions to the radionuclides responsible for the gross alpha (thorium-232), gross beta (strontium-90), carbon-14, iodine-125, and tritium activity, the calculated discharges were 0.004 (0.4%) and 0.00 (0.7%) of the allowable fractional DCS values in the Strawberry and Hearst sanitary sewer systems, respectively.

4.3.2.2 Nonradiological Monitoring

Berkeley Lab collects two nonradiological samples from both the Hearst and Strawberry outfalls in March and September, in accordance with the self-monitoring sample collection schedule specified by the EBMUD permit.

All metals and total identifiable chlorinated hydrocarbon results were below EBMUD permit limits, and many were also below detection limits. All 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. Samples were also analyzed for 176 different PCB congeners as required by the permit, although EBMUD has not designated a discharge limit for PCB congeners in wastewater.

4.3.3 Treated Hydrauger and Extraction Well Discharge

Berkeley Lab currently has eight 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 FTU 006. As noted earlier, this FTU was shut down in April 2018 to upgrade to a zero-waste-discharge recycling system. EBMUD issued a permit for the system in September 2019, which 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 was submitted in January 2021 as required by the permit.

4.3.5 Sewer System Management Plan

Berkeley Lab's *Sewer System Management Plan* (LBNL, 2020b) addresses the State Water Board's requirements (Order No. 2006-0003-DWQ) for maintaining Berkeley Lab's sanitary sewer systems and preventing and reporting overflows. State Water Board regulations require that any public agency owning or operating a wastewater collection system with piping longer than 1 mile prepare a written Sewer System Management Plan to address the proper operation, maintenance, and funding for maintenance and capital improvements of the system. This plan must be reviewed every five years to ensure that information is current and available. In addition, the plan must be audited by an independent party every two years. The audit was completed in 2021 and identified various minor edits and revisions, which have been addressed and corrected.

The State Water Board's Sanitary Sewer Order, *Amending Monitoring and Reporting Program for Statewide General Waste Discharge Requirements for Sanitary Sewer Systems*, requires that all spills be reported. Also, monthly reporting is required regardless of whether any sanitary sewer overflow has occurred (SWRCB, 2013). Sanitary sewer overflow reporting is accomplished through the online California Integrated Water

Quality System (http://www.waterboards.ca.gov/ciwqs/), which is used by the State Water Board and the Regional Water Quality Control Boards to track water quality–related information. No sanitary sewer overflows occurred in 2021.

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 each year in the Environmental Restoration Program's Annual Progress Reports, which contains 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/.

4.4.1 Groundwater Monitoring Overview

The groundwater monitoring network consists of more than 170 wells, including 11 that are used to monitor for potential downgradient migration of VOC-contaminated groundwater beyond the developed areas of the site (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.)

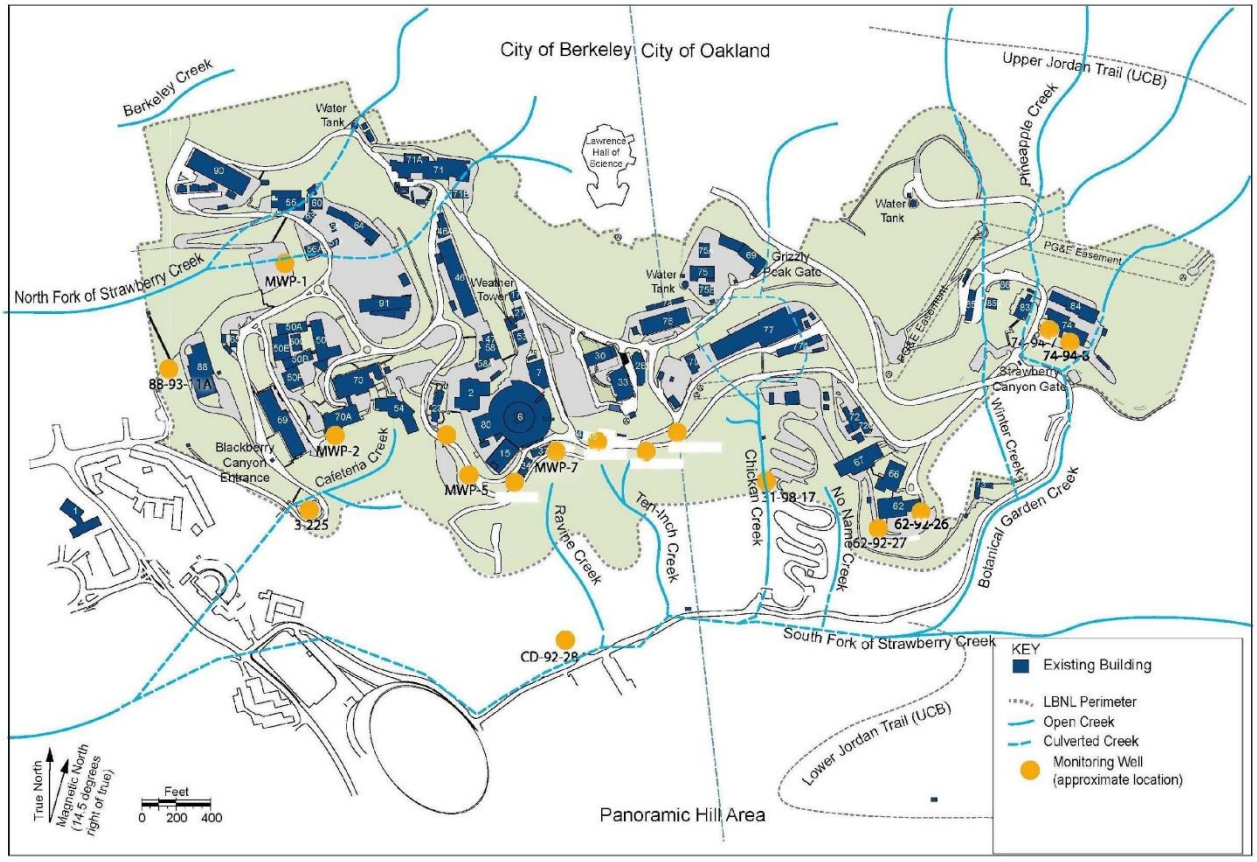

Figure 4-4 Groundwater Monitoring Wells Closest to the Downgradient Site Boundary

The groundwater monitoring data continues 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 lobes – 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.

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 in several areas. The areas where VOC concentrations in the groundwater exceed MCLs are shown on Figure 4-5.

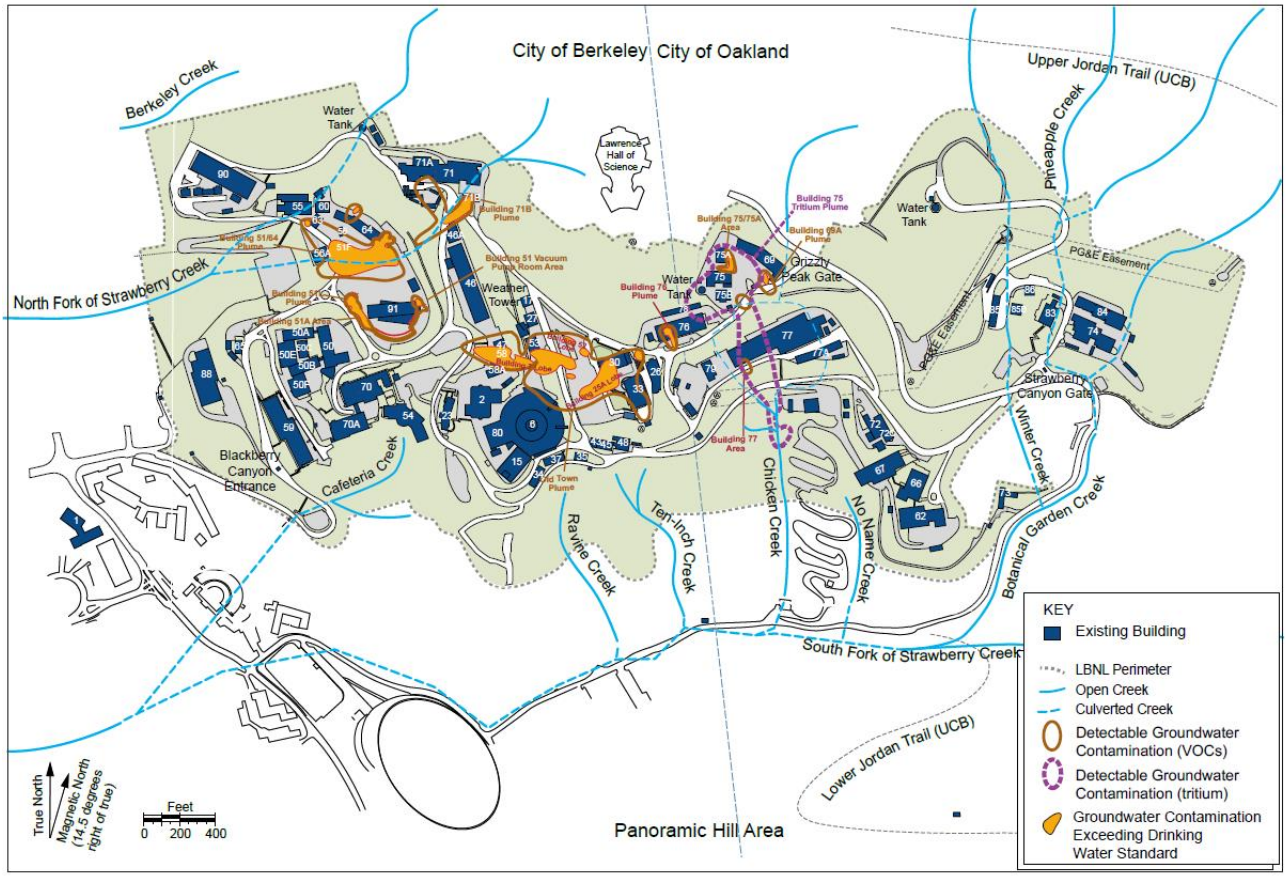

Figure 4-5 Locations of Groundwater Contamination

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; RWQCB, 2015) since February 2005. The maximum concentration of tritium detected in 2021 was approximately 30% of the MCL. The location of this tritium plume is shown on Figure 4-5.

Tritium has also been detected in groundwater samples collected in two other areas. In 2011, tritium was detected at a maximum concentration of 3% of the drinking water standard in groundwater samples collected beneath the central area of the Bevatron site during Bevatron demolition activities. Tritium has not been detected in groundwater samples collected regularly since 2011 in wells downgradient from that area. Tritium has also been occasionally detected in the Building 71B area, including in 2020, when it was detected at a concentration of 1.4% of the MCL. In 2019, DOE approved Berkeley Lab's request to eliminate the requirement to sample Building 71B area wells for tritium based on the relatively low and diminishing concentrations.

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 and to clean up contaminated groundwater. Ten GAC treatment systems continued to operate in 2021 to treat extracted groundwater, which totaled approximately 3.2 million gallons for the year. The cumulative volume of groundwater treated from 1991 through the end of 2021 is approximately 210 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, 2016).

4.5 SOIL AND SEDIMENT

This section summarizes monitoring results for soil and sediment samples collected in the fall of 2021 and required by DOE Order 458.1 and guidance (DOE, 2015). Locations for soil and sediment sampling are shown on Figure 4-6.

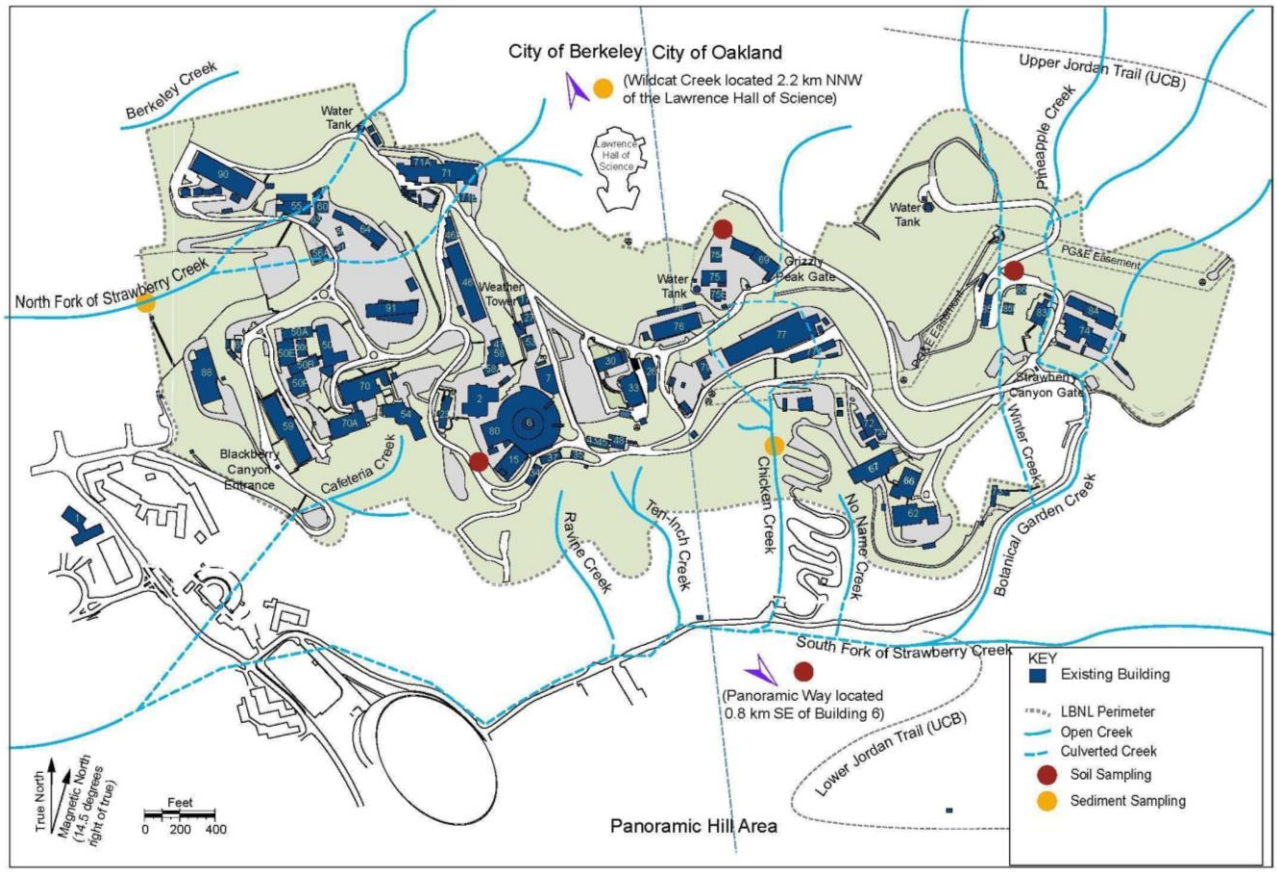

Figure 4-6 Soil and Sediment Sampling Sites

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, tritium, moisture content, pH, and 15 metals.

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 minimum detectable concentrations.

Moisture content and pH levels at each of the sampling locations were within the historical range for soils at Berkeley Lab. Metals results were within both the established LBNL background levels and levels commonly found in soils in the United States (Shacklette and Boerngen, 1984).

4.5.2 Sediment Sampling

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. Due to limited sediment availability, several grab samples from the general sampling area of each location were composited and analyzed for gross alpha, gross beta, gamma emitters, tritium, 15 metals, moisture content, pH, petroleum hydrocarbons (diesel and oil/grease), and PCBs. The sample from Chicken Creek was split for quality control purposes.

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 of naturally occurring radioactive elements commonly found in soils (Eisenbud, 1973; NCRP, 1987). Tritium measurements at each sampling location were below detection limits.

The results of nonradiological analysis for pH, moisture content, and petroleum hydrocarbons (diesel and oil/grease) measurements at each of the sampling locations were within the historical range for sediments at Berkeley Lab. PCB measurements at each sampling location were below detection limits. Metals results were within both the established LBNL soil background levels (LBNL, 2009) and levels commonly found in soils in the United States (Shacklette and Boerngen, 1984).

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.

To document changes in the concentrations of tritium in the local vegetation, Berkeley Lab has sampled vegetation every five years since the NTLF was closed. The most recent sampling, in the fall of 2020, confirmed that although vegetation in the vicinity of the former NTLF hillside stack contains measurable tritium concentrations, the concentration continues to decrease. All other concentrations outside of the immediate NTLF hillside were either below detection limits or project reporting limits.

4.7 PENETRATING RADIATION MONITORING

Radiation-producing machines (e.g., accelerators, X-ray machines, and irradiators) and various radionuclides are used at Berkeley Lab for high-energy particle studies and biomedical research. Accelerator operations are the primary contributors of penetrating radiation, and when operating, accelerators may produce gamma and neutron radiation. The accelerators 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). The system in Building 71 is an experimental laser-driven accelerator that does not emit measurable gamma or neutron radiation into the environment. 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 monitors (near Building 6 and Building 88) that continuously detect and record gamma radiation and neutron dose.
2. Passive detectors known as optically stimulated luminescence dosimeters (at eight site locations and one background location), which provide an integrated gamma radiation dose over time.

The real-time monitors are used as part of Berkeley Lab's environmental monitoring program to meet DOE Order 458.1's requirements on demonstrating compliance with public dose limits due to operational activities.

Passive detectors supplement the real-time monitors and confirm that the dose from Berkeley Lab operations is negligible and comparable to the measured background location. The locations of real-time monitors and dosimeters are shown on Figure 4-7. The results of both measurement methods are given in terms of dose (see Section 5.2).

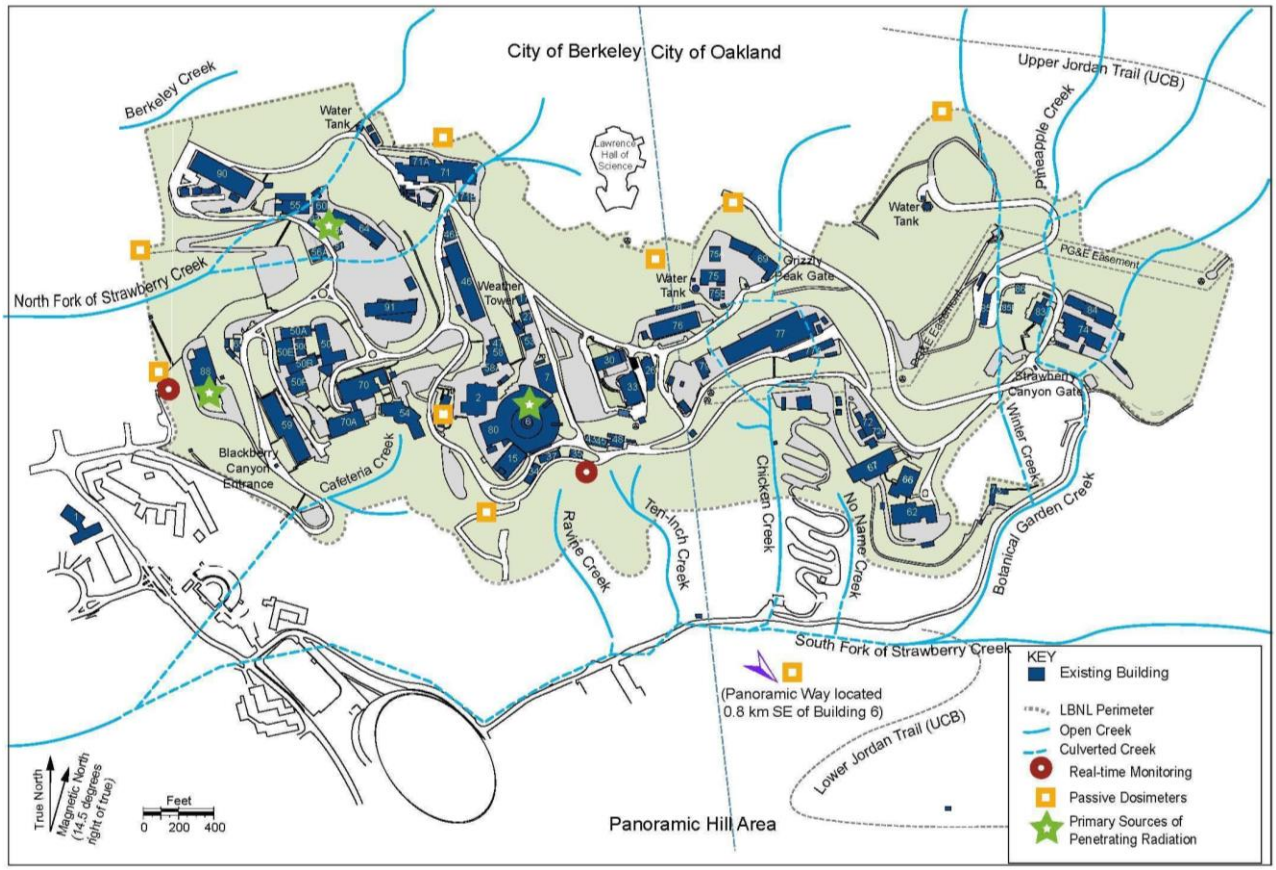

Figure 4-7 Environmental Penetrating Radiation Primary Sources and Monitoring Stations

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. Broadly speaking, release criteria includes demonstrating that real or personal property meets one of the following: is indistinguishable from background, below pre-approved DOE screening levels, or within project-specific Derived Concentration Guideline Levels (DCGLs). 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 2021, Berkeley Lab's Radiation Protection Group performed 75 release and clearance surveys. The survey results were used to determine whether the equipment could subsequently be reused on-site or released to the public.

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 its Stormwater Multiple Application and Report Tracking System.
- Perform air dispersion modeling necessary for assessing off-site radiological doses and preparing the annual Radionuclide Air Emission Report, required by the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulation and submitted to the DOE and U.S. Environmental Protection Agency (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.

Berkeley Lab subcontracts with a third party to perform an independent audit of the sensors on the meteorological monitoring tower approximately twice per year. 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, Volumes I, II, and IV (T&B Systems, 2002).

5 Radiological Dose Assessment

Radiological dose is the energy deposited in tissue mass through external irradiation, inhalation, or ingestion due to exposure to radioactive material. The annual dose to the public and the environment from Berkeley Lab's radiological operations is very low. The health effects from such a low dose are either too small to be observed or nonexistent (Health Physics Society, 2010).

5.1 BACKGROUND

This chapter presents maximum potential estimated dose results from Berkeley Lab's penetrating radiation and airborne radionuclide monitoring programs. 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 7,253,000 (LandScan, 2014). The potential dose to humans projected from each monitoring program is presented in Sections 5.2 and 5.3, and the results are discussed in Section 5.4 in terms of the overall impact of Berkeley Lab's radiological activities on members of the public in the form of total dose. The radiological impact of Berkeley Lab's operations on local animals and plants 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. An in-depth quantitative review is required if the potential for a public dose is greater than 1 mrem to an individual or 10 person-rem to a population. No quantitative reviews were required or performed in 2021.

5.2 DOSE FROM PENETRATING RADIATION

As discussed in Section 4.7, penetrating radiation from LBNL operations is measured by real-time monitors and passive dosimeters. The results of real-time penetrating radiation measurements indicate that the maximum potential annual dose from gamma and neutron radiation to a person outside the northern boundary of the site was 0.9 mrem (LBNL, 2021a). This potential dose was located at the Lawrence Hall of Science, about 2,300 feet from the primary contributing source, which was the Building 88 Cyclotron. This dose is higher than the measured background for Berkeley Lab, but represents a small fraction (0.9%) of the DOE Order 458.1 compliance limit of 100 mrem per year for the dose to any member of the public.

The annual population dose to people in the surrounding region that extends 50 miles from the site was estimated at 1.5 person-rem, based on the most recent population figure and measured dose from the 88-Inch Cyclotron and the Advanced Light Source accelerator. A network of passive optically stimulated

luminescence dosimeters located around the Berkeley Lab site validates the real-time penetrating radiation measurements and confirms that the dose from LBNL activities is negligible. The dose from penetrating radiation is not affected by wind patterns.

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 2021* (LBNL, 2021d).

In compliance with NESHAP requirements, the location of the maximally exposed individual to airborne emissions must be determined. 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 the entire year. For 2021, the calculated annual dose from airborne radionuclides was 2.5×10^{-3} mrem, which is approximately 0.026% 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 2021 was approximately 7.5×10^{-3} 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 effective dose equivalent from penetrating radiation and airborne

radionuclides from LBNL operations to an individual residing near Berkeley Lab in 2021 was approximately 0.95 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 location of the maximum dose for penetrating and airborne radiation differ slightly, as described in previous sections. Yet this value is very low at approximately 0.3% of the average natural background radiation dose (310 mrem/yr) in the United States (NCRP, 2009), and approximately 0.95% of the DOE annual limit from all sources (100 mrem/yr) (DOE, 2020).

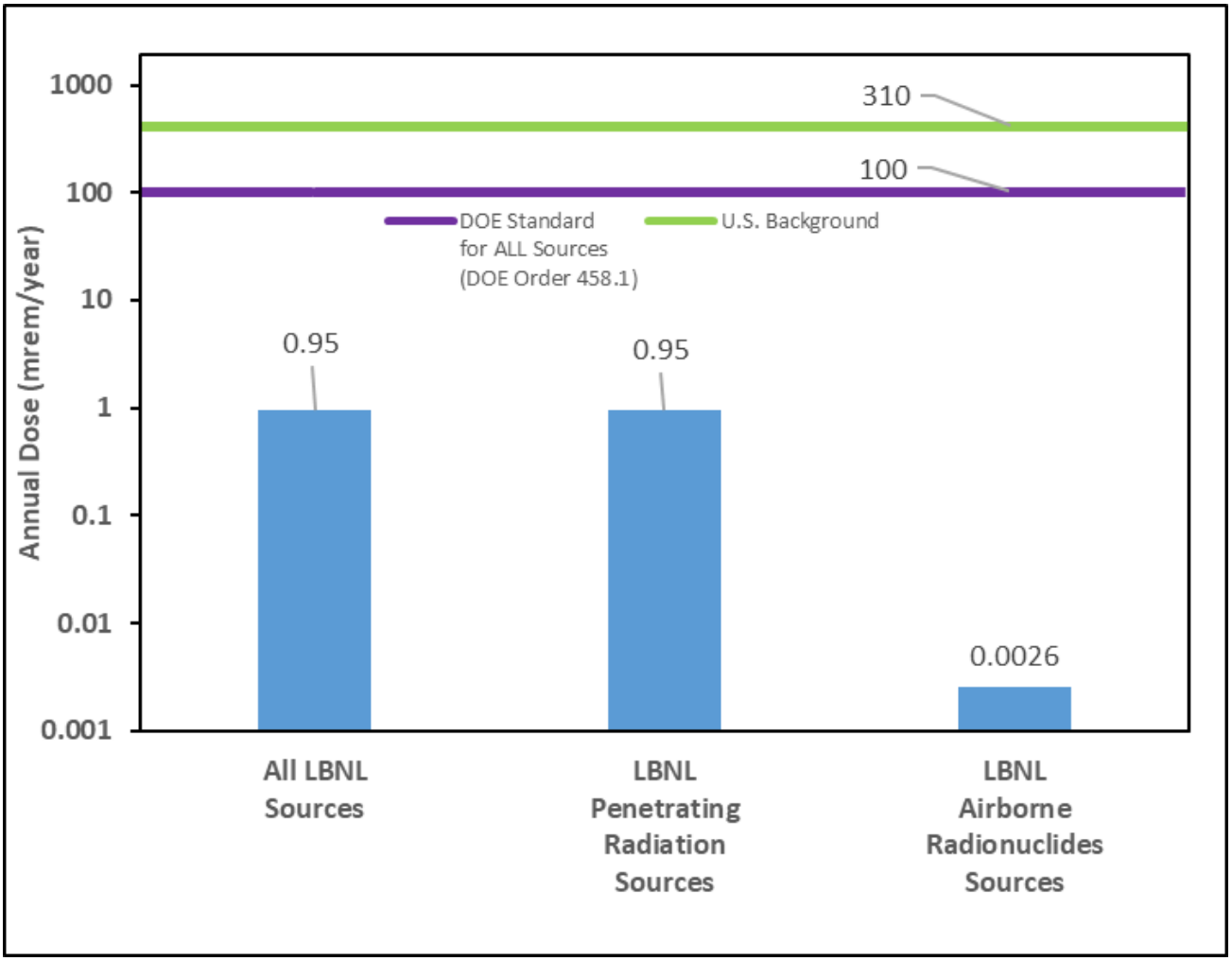

Figure 5-1 Comparative Radiological Doses for 2021

5.5 DOSE TO ANIMALS AND PLANTS

As described in DOE technical standard DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota* (DOE, 2019a), DOE requires that animals and plants be protected from liquid and airborne emissions by limiting the radiation dose to aquatic animals and terrestrial plants (1 rad/day) and riparian and terrestrial animals (less than 0.1 rad/day).

To estimate the dose to animals and plants, the following sources of exposure were considered:

- Animal ingestion of vegetation, water, and soil
- Animal inhalation of dusty soil
- Plant uptake of water
- External exposure of animals and plants to radionuclides in water, soil, and sediment

Samples of creek water, sediment, and soil were collected and analyzed for several radionuclides, including tritium and gamma-emitting radionuclides. Measured levels of these radionuclides were either similar to natural background levels or well below applicable standards. The impact of these sample results was evaluated using the DOE-endorsed computer model RESRAD-BIOTA. This evaluation showed that both terrestrial and aquatic systems passed the “general screening phase” described in DOE-STD-1153-2019, and confirmed that the calculated dose for terrestrial or aquatic systems is far below DOE dose limit requirements.

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, 2021e). 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. The radiological NESHAP Compliance Program (LBNL, 2019a) and the Environmental Restoration Program (LBNL, 2017a) both 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's Oversight Program Plan (DOE-BASO, 2021) enables its staff to participate in LBNL operational activities such as audits/inspections, document reviews, and day-to-day communications and comply with DOE Contract 31 clause H.30 as described in *University of California Contractor Assurance System Description for Lawrence Berkeley National Laboratory* (LBNL, 2021f). 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 the DOE Bay Area Site Office on assurance-related information.

6.1 ENVIRONMENTAL MONITORING SAMPLES AND RESULTS PROFILE

In 2021, a total of 2,016 individual air, sediment, soil, and water samples were collected under Berkeley Lab's environmental monitoring programs, both routine and project-specific, generating 59,841 analytical results. These numbers represent approximately 70% more results than in 2020. Samples were obtained from over 407 locations on or surrounding the main site. Some of these locations are shown on figures in

the sections of Chapter 4 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 and Bayview project that were carried out by the demolition subcontractor and provided to Berkeley Lab. These projects accounted for over 27% of the environmental monitoring programs' sampling locations, almost 47% of the individual samples collected, and nearly 53% of the analytical results in 2021.

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 2021, a total of 41 split and 116 duplicate samples were collected for either radiological or nonradiological analyses, or both. QA activities resulted in 731 split and 2,938 duplicate results. In addition, 163 blank samples were submitted for QA purposes. The primary purpose of a blank sample is to identify artificially introduced contamination.

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 2021, Berkeley Lab contracted with the following five commercial analytical laboratories for specific analytical services:

1. ALS (Fort Collins, Colorado)
2. BC Laboratories (Bakersfield, California)
3. GEL Laboratories (Charleston, South Carolina)
4. Vista Analytical Laboratory (El Dorado Hills, California)
5. Pace Analytical (Baton Rouge, Louisiana)

All of these 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 2021, all five analytical laboratories were state certified, as required. Four 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 2021, the five ELAP-certified analytical laboratories performed approximately 2,000 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, when QC results exceed established criteria, an investigation is performed to determine the cause of the discrepancy.

References

Bay Area Air Quality Management District (BAAQMD), 2021. *Permit to Operate for Lawrence Berkeley National Laboratory (Plant No. 723 and GDF No. 106134).*

California Department of Public Health (CDPH), 1994. Certification and Amendment Process, 22 CCR § 64803 (as amended).

California Environmental Protection Agency (CalEPA), 2020. Violation Classification Guidance for Unified Program Agencies.

California Health and Safety Code §39000 *et seq.*, 1967. Air Resources (as amended).

California Health and Safety Code §25100 *et seq.*, 1972. Hazardous Waste Control Law (as amended).

California Health and Safety Code §25280 *et seq*., 1983. Underground Storage of Hazardous Substances (as amended).

California Health and Safety Code §25500 *et seq*., 1985. Hazardous Materials Release Response Plans and Inventory Law (as amended).

California Health and Safety Code §25270 *et seq.*, 1989. Aboveground Petroleum Storage Act (as amended).

California Health and Safety Code §§117600–118360, 2017. Medical Waste Management Act (as amended).

California Water Code §13000 *et seq*., 1969. California Porter-Cologne Water Quality Control Act (as amended).

East Bay Municipal Utility District (EBMUD), 2016. Wastewater Discharge Permit No. 5034789-1 [groundwater treatment systems] for Lawrence Berkeley National Laboratory.

EBMUD, 2019a. Special Discharge Permit No. 19644654 [Old Town Demolition Project] for Lawrence Berkeley National Laboratory.

EBMUD, 2019b. Wastewater Discharge Permit No. 0660079-1 [sitewide] for Lawrence Berkeley National Laboratory.

EBMUD, 2019c. Wastewater Discharge Prevention Permit No. 50238911 for Lawrence Berkeley National Laboratory Building 77.

Eisenbud, M., 1973. *Environmental Radioactivity*, 2nd Edition, Academic Press Inc. September.

Environment, Safety, and Health Manual (PUB-3000), https://sites.google.com/lbl.gov/eshmanual/home#h.p_PdL4HcnVEXKn

Executive Order 13423, 2007. *Strengthening Federal Environmental, Energy, and Transportation Management*.

Executive Order 13834, 2018. *Efficient Federal Operations*.

Executive Order 14057, 2021. *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability.*

Health Physics Society, 2010. *Radiation Risk in Perspective*. Position Statement of the Health Physics Society.

International Organization for Standardization (ISO), 2015. *Environmental Management Systems: Requirements with Guidance for Use*, ISO 14001:2015. September.

ISO, ISO 50001, Environmental Management Systems, 2018.

LandScan population distribution data, available at http://web.ornl.gov/sci/landscan/.

LBNL, 2005. *RCRA Corrective Measures Study Report for Lawrence Berkeley National Laboratory, Environmental Restoration Program*. February.

LBNL, 2006. *Groundwater Monitoring and Management Plan*. March.

LBNL, 2009. *Analysis of Background Distributions of Metals in the Soil at Lawrence Berkeley National Laboratory*. April.

LBNL, 2012a. *Construction Waste Management*, Facilities Master Specification 017419-1. October.

LBNL, 2012b. *Statement of Work for Analytical Services*. April.

LBNL, 2016a. *EHS Assurance Systems Manual.* October.

LBNL, 2016b. *Quality Management Plan*, EWRP 03. Environment, Waste & Radiation Protection Department. February.

LBNL, 2017a. *Quality Assurance Program Plan for the Lawrence Berkeley National Laboratory Environmental Restoration Program*. March.

LBNL, 2017b. *Soil Management Plan for Lawrence Berkeley National Laboratory.* December.

LBNL, 2017c. *Spill Prevention, Control, and Countermeasure Plan*. September. Amended September 2020.

LBNL, 2019a. *Quality Assurance Program Plan for NESHAP Compliance*. November.

LBNL, 2019b. *Stormwater Monitoring Implementation Plan.* December.

LBNL, 2019c. *Stormwater Pollution Prevention Plan*. December.

LBNL, 2020a. *Lawrence Berkeley National Laboratory Annual Site Sustainability Plan*. December.

LBNL, 2020b. *Sewer System Management Plan.* September.

LBNL, 2021a. *Calculation of 2021 Annual Dose to Public from Gamma/Neutron Radiation*. March.

LBNL, 2021b. *Energy and Water Management System Manual*. May.

LBNL, 2021c. *Environmental Management System Program Manual*, LBNL-PUB-3180. January.

LBNL, 2021d. *Lawrence Berkeley National Laboratory Radionuclide Air Emissions Report for 2021.* June.

LBNL, 2021e. *Requirements and Policies Manual*, LBNL/PUB-201. March.

LBNL, 2021f. *University of California Contractor Assurance System Description for Lawrence Berkeley National Laboratory,* LBNL PUB-5520 Revision 5. December.

National Council on Radiation Protection and Measurements (NCRP), 1987. *Exposure of the Population of the United States and Canada from Natural Background Radiation*, NCRP Report No. 94.

NCRP, 2009. *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 160.

(San Francisco Bay) Regional Water Quality Control Board (RWQCB), 2015. *Water Quality Control Plan for the San Francisco Bay Basin*, Chapter 3.

RWQCB, 2019. *Environmental Screening Levels* (Interim Final). June.

Shacklette, H.T., and J.G. Boerngen, 1984. *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States*, U.S. Geological Survey Professional Paper 1270.

State Water Resources Control Board (SWRCB), 2012. *General Permit for Stormwater Discharges Associated with Construction and Land Disturbance Activities*, Order No. 2009-0009-DWQ as amended, NPDES No. CAS000002. July.

SWRCB, 2013. *Amending Monitoring and Reporting Program for Statewide General Waste Discharge Requirements for Sanitary Sewer Systems*, Order No. WQ 2013-0058-EXEC. August.

SWRCB, 2014. *General Permit for Storm Water Discharges Associated with Industrial Activities*, Order 2014-0057-DWQ, NPDES General Permit No. CAS000001. April.

T&B Systems, 2002. *General Meteorological System and Performance Audit Procedures for Radar Wind Profilers, Sodars, Surface Meteorological and Air Quality Stations*.

U.S. Code, Title 42, Chapter 82, Subchapter IX, §6991 (42 USC §6991), 1988. *Resource Conservation and Recovery Act, Regulation of Underground Storage Tanks* (as amended).

U.S. Department of Defense / Department of Energy (DoD/DOE), 2018. *Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*, Version 5.1.1. February.

U.S. Department of Energy (DOE), 1995. *Site Treatment Plan for the Lawrence Berkeley National Laboratory, Berkeley, California*. October.

U.S. Department of Energy (DOE), 2011. Order 436.1, *Departmental Sustainability*. May.

U.S. Department of Energy (DOE), 2012. Order 231.1B, Administrative Change 1, *Environment, Safety and Health Reporting*. November.

U.S. Department of Energy (DOE), 2015. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, DOE-HDBK-1216-2015. March.

U.S. Department of Energy (DOE), 2019a. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE-STD-1153-2019.

U.S. Department of Energy (DOE), 2019b. *Contract Between the United States of America and The Regents of the University of California*, UC-DOE Prime Contract (No. DE-AC02-05CH11231).

U.S. Department of Energy (DOE), 2020. Order 458.1, Limited Change 4, *Radiation Protection of the Public and the Environment.* September.

U.S. Department of Energy (DOE), 2021a. "Addressing Per- and Polyfluoroalkyl Substances at the Department of Energy," memorandum from DOE Deputy Secretary, September 16.

U.S. Department of Energy (DOE), 2021b. DOE-STD-1196-2021, *Derived Concentration Technical Standard*.

U.S. Department of Energy Bay Area Site Office (DOE-BASO), 2021. *Berkeley Site Office Oversight Program Plan*. July.

U.S. Department of Energy Berkeley Site Office (DOE-BSO), 2021. *Performance Evaluation Report of the University of California for Management and Operations of Science and Technology at the Lawrence Berkeley National Laboratory for the Period October 1, 2020, to September 30, 2021*. December.

U.S. Environmental Protection Agency (U.S. EPA), 1976. National Primary Drinking Water Standards, 40 CFR 141, Subpart B (amended).

U.S. EPA, 1989. National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities, 40 CFR Part 61, Subpart H (amended).

Abbreviations

AEDE	annual effective dose equivalent
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
BioEPIC	Biological and Environmental Program Integration Center
BSO	Berkeley Site Office
CAG	Community Advisory Group
CARB	California Air Resources Board
CATS	Corrective Action Tracking System
CCR	California Code of Regulations
C&D	construction and demolition
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
Ci	curie
COB	City of Berkeley
CUPA	Certified Unified Program Agency (California)
CX	Categorical Exclusion
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
EGR	exhaust gas recirculation
EHS	Environment, Health & Safety (the division at Berkeley Lab)
ELAP	Environmental Laboratory Accreditation Program
EMS	Environmental Management System
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)
F	Fahrenheit
FTU	fixed treatment unit
FY	fiscal year (October 1–September 30)
GAC	granular activated carbon
gal	gallon(s)
GHG	greenhouse gas
GIS	gas-insulated switchgear
HMBP	Hazardous Materials Business Plan
HWHF	Hazardous Waste Handling Facility
IGB	Integrative Genomics Building
ISM	Integrated Safety Management
ISO	International Organization for Standardization
JGI	Joint Genome Institute
kg	kilogram(s)
L	liter(s)
LBNL	Lawrence Berkeley National Laboratory
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
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
NOD	Notice of Deficiency
NTLF	National Tritium Labeling Facility
OIAI	Office of Institutional Assurance and Integrity
PCB	polychlorinated biphenyl
pCi/L	picocuries (one trillionth of a curie) per liter
PSA	pollutant source assessment
QA	quality assurance
QAPD	Quality Assurance Program Description
QC	quality control

RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RWQCB	San Francisco Bay Regional Water Quality Control Board
SAA	satellite accumulation area
SARA	Superfund Amendments and Reauthorization Act
SCR	selective catalytic reduction
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
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
WAA	waste accumulation area
WAPA	Western Area Power Administration

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.

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 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.

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.

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.

wind rose

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

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

21-EHS-15054