BERKELEY LAB

Site Environmental Report for 2018

September 2019

Lawrence Berkeley National Laboratory
Environment, Health & Safety Division

LBNL-27170E-2019

DISCLAIMER

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September 24, 2019

DISTRIBUTION

Subject: 2018 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, Bay Area Site Office (DOE/BASO), provides a comprehensive summary of the environmental program activities at LBNL for calendar year 2018. 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 2018 environmental monitoring, compliance, and restoration programs at LBNL. This assurance can be made based on the reviews conducted by DOE/BASO, 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/BASO, by contacting Mary Gross of the Bay Area Site Office at (510) 486-4373, or by mail to the address above, or by email at mary.gross@science.doe.gov.

Sincerely,

Mary Gross for

Paul Golan
Site Office Manager

Site Environmental Report for 2018

September 2019

Cover photo: An Anna's hummingbird pauses between nectar takes from flowers in the drought-tolerant landscaping between Buildings 30 and 33. Photograph by Candace Flores, Environment, Health, and Safety Division.

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

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Executive Summary

Lawrence Berkeley National Laboratory (LBNL, Berkeley Lab) is a multi-program 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 LBNL operations conducted in 2018. The format and content of this report satisfy the requirements of both DOE Order 231.1B, Administrative Change 1 (*Environment, Safety, and Health Reporting*) and the operating contract between UC and DOE (DOE Contract No. DE-AC02-05CH11231, also known as Contract 31).

LBNL activities are planned and conducted with full regard to protecting employees, the public, and the environment, as well as complying with all applicable environmental, safety, and health laws and regulations. As presented in Chapter 2, Berkeley Lab implements an Environmental Management System (EMS) to oversee environmental compliance activities and continually improve overall environmental performance while maintaining operational capability and sustaining its overall mission.

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) 2018, which began October 1, 2017, and ended September 30, 2018, the EMS was given a performance rating of B plus for its management of environmental activities (on a scale from A plus as the highest grade, to F as the lowest). The measurement and rating system was developed jointly by Berkeley Lab, UC, and DOE. The FY 2018 rating was based on how Berkeley Lab met the objective in DOE's *FY 2018 Performance Evaluation and Measurement Plan* (Appendix B in Contract 31, Section J) of providing an efficient and effective EMS. Six significant accomplishments, which ranged from effective teaming on projects and with regulatory agencies to improved program assessment approaches, were factors in the rating.

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). For FY 2018, Berkeley Lab received a score of green. A week-long formal conformity audit of the EMS was conducted at the end of July by a qualified external party, as is required every three years. The audit team found that Berkeley Lab's EMS continues to conform to the ISO standard with no major nonconformance.

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 2018. Twenty-one minor violations and two Class II violations were issued during agency inspections of programs governing aboveground and underground storage tanks, hazardous waste treatment units, hazardous waste storage areas, hazardous materials management, and wastewater, stormwater, and air emission sources.

This report also includes information on environmental monitoring performed in 2018 (Chapter 4). The results of these monitoring activities confirmed 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. All emissions and discharges from LBNL operations were within environmental compliance release limits except oxides of nitrogen and carbon monoxide from boilers (under 5 million BTUs) from Buildings 2, 66, and 88.

The radiological dose assessments (Chapter 5) performed in 2018 concluded that the maximum potential dose to a hypothetical resident from Berkeley Lab's airborne radionuclide releases was approximately 0.04% of the DOE and U.S. Environmental Protection Agency annual limit of 10 millirem per year (mrem/yr); the potential dose from all radiation sources at Berkeley Lab was approximately 0.15% of the average natural background radiation dose of 310 mrem/yr in the United States, and about 0.5% of the DOE annual limit of 100 mrem/yr from all sources.

Preface

Each year Lawrence Berkeley National Laboratory (LBNL, Berkeley Lab) 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 the status of environmental compliance programs, surveillance and monitoring activities, radiological dose assessment results, and quality assurance measures conducted in 2018. 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 Ron Pauer, the environmental manager for the LBNL Environmental Services Group (ESG). Primary contributors to the report were David Baskin, Ned Borglin, David Diamond, Lisa Ehlers, Robert Fox, Zachary Harvey, John Jelinski, Maram Kassis, Ken Kievit, Gary Lucks, Brendan Mulholland, Jeff Phillibar, Nancy Sutherland, Patrick Thorson, Ricky Villarreal, 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/service/environmental-services/), where many of the documents cited in this report can also be found. Questions about the report can be directed to Ron Pauer at ropauer@lbl.gov or 510-486-7614. Feedback on the report can be provided via a short reader survey form that is also located on the ESG Publications page. Bound copies of Site Environmental Reports are available at the Berkeley Public Library, Oakland Public Library, and UC Berkeley Public Health Library.

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 3,800 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 LBNL 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 LBNL 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 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, Oakland, and Walnut Creek consist of leased buildings in developed urban areas.

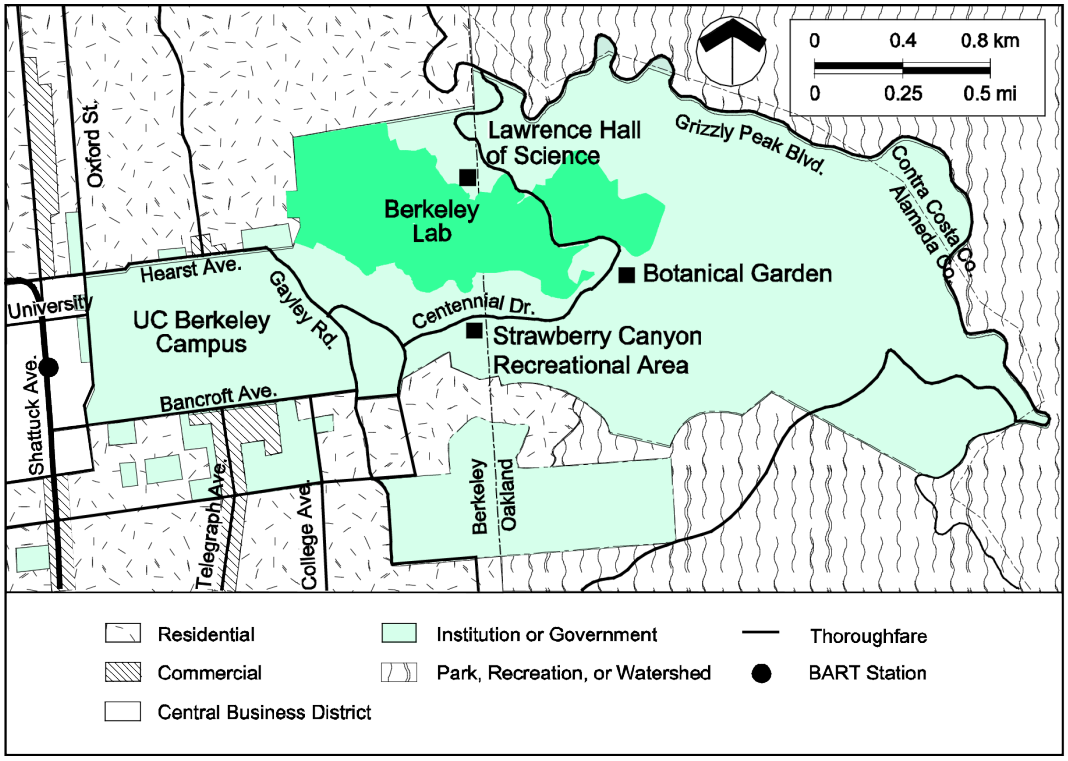

Figure 1-2 LBNL Main Site and Adjacent Land Use

1.2 ENERGY SUPPLY

Electricity and natural gas are the two sources of energy used to operate research and support facilities at Berkeley Lab. Nearly all electric power for the LBNL site is provided by the Western Area Power Administration, with a small amount of renewable power obtained from a solar power array located at Lawrence Livermore National Laboratory. Power purchases are arranged through DOE's Northern California Power Purchase Consortium, which serves the electric power needs of the 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 and Electric Company. In 2018, renewable electricity energy consumption accounted for nearly half of total energy use by Berkeley Lab.

1.3 WATER SUPPLY

The East Bay Municipal Utility District (EBMUD) supplies domestic 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 both the federal and state Safe Drinking Water Acts. Three large tanks store water on site for emergencies. 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°F. The temperature seldom exceeds 90°F or drops below 32°F. The maximum and minimum temperatures in 2018 were 88.2°F and 34.4°F, respectively.

Based on measurements taken on site beginning in the early 1960s, the precipitation total for a "water year" averages 29.11 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 2017/2018 water year – at 21.9 inches – is a little below an 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 2018, 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.

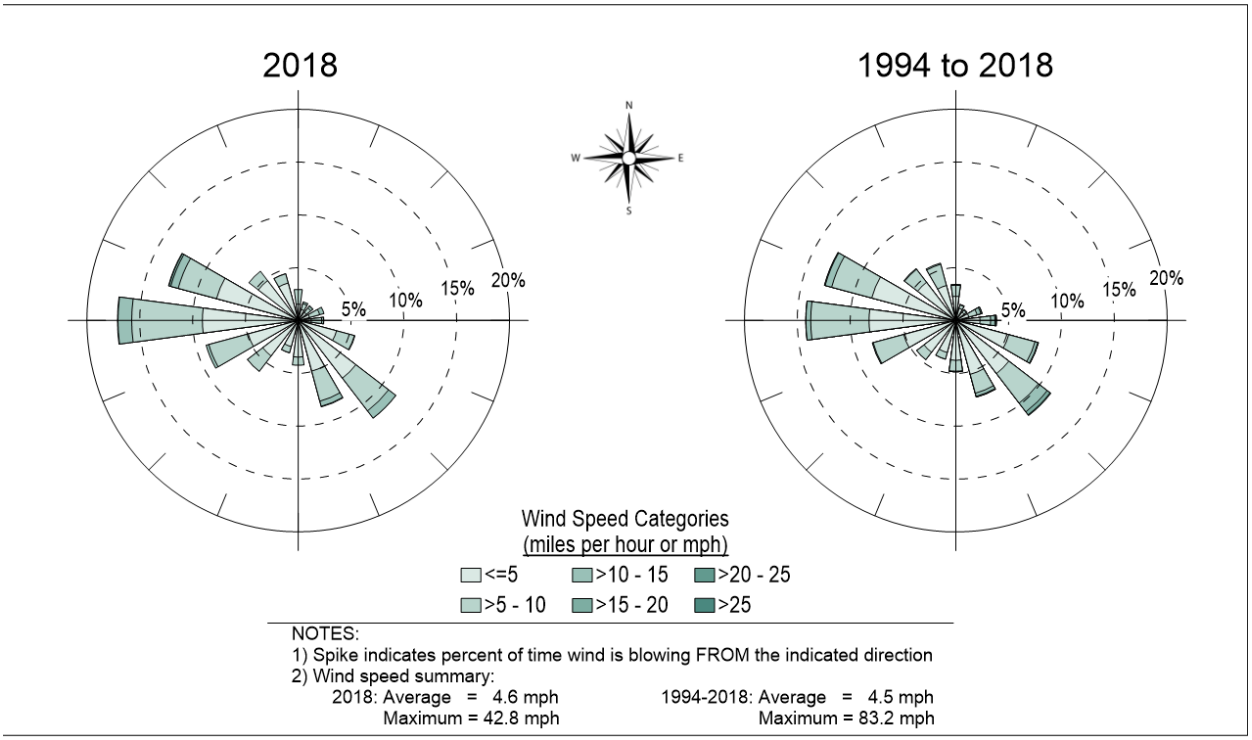

Figure 1-3 Annual Wind Patterns from 1994 to 2018

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 site 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 LBNL 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 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.

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 feet or more 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.

1.8 SURFACE WATERS

Berkeley Lab lies within the Strawberry Creek watershed. The two main creeks in this watershed receiving stormwater discharges from the LBNL 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 the LBNL site on the UC Berkeley campus, are shown on Figure 1-5, along with key tributaries on or near the site.

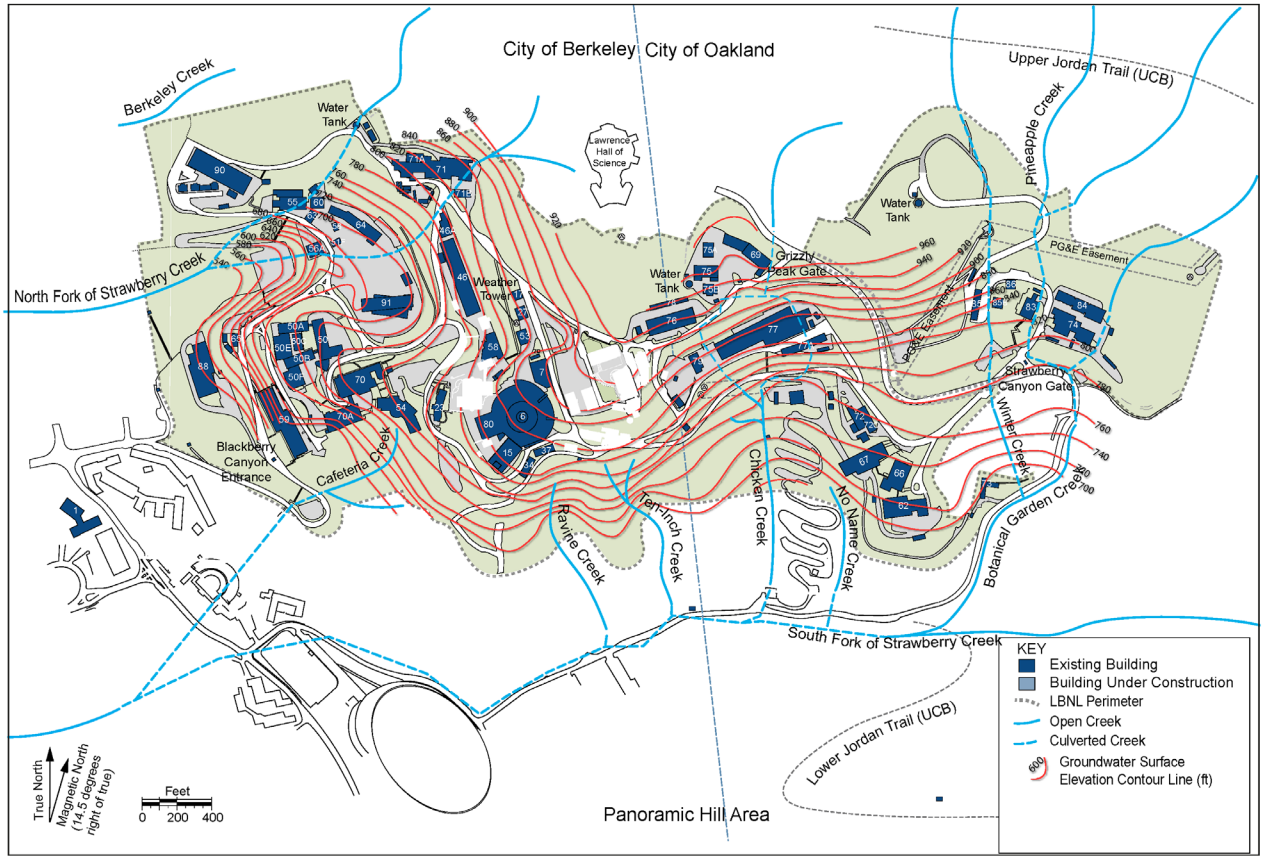

Figure 1-5 Surface Water Locations and Groundwater Elevations at Berkeley Lab

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 100 feet below the surface, depending on location.

2 Environmental Management System

2.1 BACKGROUND

DOE Order 436.1, *Departmental Sustainability* (DOE, 2011a), requires that DOE sites such as Berkeley Lab develop and maintain an Environmental Management System (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 ensure that environmental activities reduce environmental impacts and are well managed, cost-effective, and compliant. 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 sets performance goals in the following areas:

- Greenhouse gas reduction
- Sustainable buildings
- Clean and renewable energy
- Water use efficiency and management
- Fleet management
- Sustainable acquisition
- Pollution prevention and waste reduction
- Energy performance contracts (accelerate investment in cost-effective energy conservation measures)
- Life-cycle stewardship of electronics
- Climate change resilience

In total, more than 30 sustainability goals are set forth in these areas by Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, issued in 2015. Berkeley Lab's annual Site Sustainability Plan is available online at http://sbl.lbl.gov/results/reports.html.

2.2 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.

2.2.1 Leadership and Commitment

The mission of Berkeley Lab's Operations directorate is to anticipate and safely deliver exceptional operational services in support of the scientific mission of Berkeley Lab through effective and efficient infrastructure and programs. The framework for LBNL operations is defined in a collection of policies, the *Requirements and Policies Manual* (PUB-201), 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 LBNL employees.

The Environment, Health & Safety (EHS) Division of LBNL Operations 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 cleaning up existing environmental problems
- 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 Plan* (LBNL, 2012a), which provides guidance on implementing environmental policy in compliance with the ISO 14001 standard. An EMS "Core Team," consisting of representatives from various divisions at Berkeley Lab, assists with implementing the integrated environmental and sustainability goals. A link to the *Environmental Management System Plan* and related documents is available on the Environmental Services Group (ESG) website (https://ehs.lbl.gov/service/environmental-services/).

2.2.2 Environmental Aspects

As part of the "plan" step for a management system, ESG subject matter experts and the EMS Core Team periodically review environmental aspects associated with LBNL Research and Operations. An environmental aspect is any activity, product, or service that interacts, whether adversely or beneficially, with the environment. These environmental aspects serve as the master list of potential risks and opportunities to improve environmental compliance and stewardship 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 2018, the inventory of individual environmental aspects totals approximately 40 environmental aspects, which are grouped under two general categories, as follows:

1. Environmental compliance aspects
    a. Air emissions (e.g., from diesel-powered equipment)
    b. Storing hazardous material and accumulating hazardous wastes
    c. Wastewater and contaminated runoff into the storm drain system
2. Materials and resources use
    a. Energy consumption
    b. Water consumption
    c. Life-cycle stewardship of electronics

In determining which aspects are significant, reviewers evaluate the following risk factors for each aspect: the likelihood of occurrence and the impact from occurrence. This approach is consistent with the *Risk Severity Guidelines for Issues Management* issued by Berkeley Lab's Office of Institutional Assurance and Integrity (OIAI)

and found in its *Risk Management Program Manual.* The approach also follows OIAI's definitions of low (1), moderate (2), and high (3) risk for likelihood of occurrence and impact of occurrence. Multiplying the numeric values for both risk factors results in a score. In general, an aspect with risk combinations of high-high and high-moderate, or a score of at least six (i.e., 3 x 2 = 6), from this first step in the process will likely be considered significant. When deciding on risk factors for these environmental aspects, reviewers may consider the life cycle of the activity or service, plus the potential impact on all facets of the environment, such as the following:

- Cost
- Duration
- Effect on Berkeley Lab's mission
- Effect on public image
- Potential for improvement
- Potential legal exposure

The next step is to foster a discussion between the reviewers and the EMS Program Manager on aspects that are found to be significant from the initial risk scoring so that their combined professional judgment can be used to determine a final classification (e.g., significant) for each aspect in this group. If any aspect is significant, the rationale for that rating is documented and an Action Plan is developed. If reviewers determine that additional information is needed to evaluate a particular product or activity, the EMS Program Manager can assign the responsibility for collecting that information to an appropriate reviewer.

2.2.3 Objectives and Plans to Achieve Them

As part of the "do" step for a management system, aspects deemed significant require developing and maintaining an Action Plan document to define the objective, target, strategy, and actions for reducing significant impacts to the environment. The Action Plans in place at the end of fiscal year (FY) 2018 are listed in Table 2-1, along with a summary of each plan's objective, target, and status. These Action Plans are part of more than 30 sustainability goals mentioned in Section 2.1. Berkeley Lab's annual *Site Sustainability Plan* (LBNL, 2018a) contains more details on changes, strategy, and actions for all sustainability goals.

Table 2-1 Environmental Management Programs

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2018
Energy Use	Implement sustainable practices to achieve energy efficiency.	Reduce energy use intensity 2.5% each year through end of FY 2025 (baseline: FY 2015).	Consumption was 25% lower than FY 15 baseline, exceeding the target goal.
Greenhouse Gas (GHG) Emissions	Track, report, and reduce GHG emissions from LBNL activities.	Reduce Scope 1 and 2 GHG emissions by 50% and selected Scope 3 emissions 25% by end of FY 2025 (baseline: FY 2008).[a]	Scope 1 and 2 emissions were 21% below baseline. Scope 3 emissions were 32% below baseline, exceeding the target goal.
Petroleum Use	Reduce vehicle fleet petroleum consumption.	75% of light-duty vehicles to consist of alternative fuel vehicles. 50% of passenger vehicle acquisitions to consist of zero-emission or plug-in hybrid electric vehicles by FY 2025.	100% of light-duty vehicles achieved in 2018, exceeding the target goal. 45% of passenger vehicle acquisitions were zero-emission or plug-in hybrid.

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2018
Clean & Renewable Energy	Increase clean and renewable and alternative energy.	Achieve 25% of total electric and thermal energy to be 25% clean and 30% renewable by FY 2025 and each year thereafter.	31% of energy was clean energy and 39% renewable, exceeding the target goal.
Solid Waste Diversion	Increase solid waste diversion.	Divert at least 50% of nonhazardous solid waste, excluding construction and demolition debris. Divert at least 50% of construction and demolition debris.	76% diversion for nonhazardous solid waste, exceeding the target goal. 84% diversion for construction and demolition debris, exceeding the target goal.
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.	FY 2018 status changed from Level 2 to Baseline, meeting the target goal.
Sustainable Acquisition	Increase procurement opportunities for environmentally sustainable products.	Increase the percentage of priority sustainable products purchased (baseline: FY 2012). Purchase 95% of eligible EPEAT-registered product acquisitions and 100% of eligible PCs, laptops, and monitors to be power management enabled annually.	86% of new applicable subcontract actions were reviewed to ensure they included appropriate sustainable acquisition provisions and clauses. Achieved 87% purchase of eligible EPEAT products and 100% of PCs, laptops, and monitors are power managed enabled.
Green Building	Expand sustainable and net-zero buildings.	17% (by building count) of existing buildings (>5,000 gsf) to meet high-performance sustainable building (HPSB) standards and 1% be net-zero buildings (by FY 2025). All new buildings (>5,000 gsf) to achieve net-zero energy beginning in FY 2020	14% of existing buildings meet the HPSB standards. No existing or new buildings have yet achieved net-zero performance.
Water Use	Implement sustainable practices to reduce water use intensity.	Reduce potable water use consumption intensity 36% by end of FY 2025 (baseline: FY 2007).	Potable water use consumption was 23% below baseline.

[a] Scope 1 and 2 emissions are, respectively, direct and indirect GHG emissions from sources owned or controlled by Berkeley Lab. Scope 1 emissions can include those from fossil fuels burned on site or entity-leased vehicles. Scope 2 emissions can include those resulting from the generation of purchased electricity. Scope 3 emissions include indirect GHG emissions from sources not owned or directly controlled by Berkeley Lab, but related to its activities. The most common activity is GHG emissions associated with employee travel and commuting.

2.2.4 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 level of environmental impact, the types of control, the degree to which an environmental concern vertically and horizontally permeates the organization, and the level of effort needed to promote environmental compliance or performance goals.

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

- Publication of the annual Site Environmental Report and Environmental Restoration Program Progress Report.
- Posting information (e.g., environmental documents and operating permits) on websites and lessons-learned databases.
- Articles in LBNL publications (e.g., *Today at Berkeley Lab*) prepared by ESG staff or EMS Core Team members.
- One-on-one or small-group conversations between colleagues affiliated with Berkeley Lab, DOE, and UC.
- Access to a webpage for LBNL employees and external parties to express environment, safety, and health concerns and interests.

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.

Whenever appropriate, articles on EMS topics are included in LBNL publications, such as *Today at Berkeley Lab*. 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.

LBNL 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 for members of the public may be also 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, which is managed by LBNL staff and includes residents of communities adjacent to Berkeley Lab. The purpose of the group, which meets five times a year, is to serve as a liaison between Berkeley Lab and the community for discussion of initiatives and activities, including issues related to the environment.

2.2.5 Monitoring, Measurement, Analysis, and Evaluation of Compliance

As part of the "check" step for a management system, Berkeley Lab's EMS is required by DOE to undergo a formal audit once every three years. The audit must be conducted by a qualified party outside the control or scope of the EMS. 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.*

An external conformity audit performed during the week of July 30, 2018, met this requirement. The auditors performed a desktop review of program documents and a week-long series of interviews and site visits. The audit resulted in no major nonconformances and five minor nonconformance findings, which led to the development of a formal corrective action plan and two issues entered into the LBNL Corrective Action Tracking System. The audit identified the following EMS strengths:

- Berkeley Lab has established hazardous waste satellite accumulation areas (SAAs) throughout the site; regular walk-throughs by safety and waste management representatives help facilitate proper management of hazardous waste.

- The Joint BioEnergy Institute has designated responsible area owners who provide oversight and direction for laboratories that are shared by several workers.
- The Joint Center for Artificial Photosynthesis (JCAP) has implemented colored stickers on hazardous waste containers as a visual indicator that a container is nearing the nine-month SAA limit.
- JCAP initiated a marking study to determine which brands and types of pens and tapes work best for maintaining legibility of labeled items in a laboratory setting.
- ISO 50001 Energy Management System implementation will strengthen both the Energy Management System and the Environmental Management System and should continue to provide opportunities for efficiency, such as consolidated management review.

Five minor nonconformance findings were observed, as follows:

1. The designated area signage for one fume hood was missing a control to manage documentation revisions and the chemicals in use differed from the chemical inventory on the sign.
2. Regulatory noncompliance that was noted consisted of eight boilers that were not tested annually.
3. A 55-gallon drum of used oil at the Building 77 SAA was not listed in the Spill Prevention, Control, and Countermeasure (SPCC) Plan inventory and was not inspected in accordance with SPCC requirements.
4. The 200-gallon reservoir at Building 77 was not in the SPCC Plan inventory and was not inspected in accordance with SPCC Plan requirements.
5. Not all personnel conducting SPCC inspections had received the annual SPCC Plan training.

Auditors verified that Berkeley Lab's EMS implementation conforms to the ISO 14001 standard and recommended that a statement of continuing conformance be issued by the DOE Berkeley Site Office. Berkeley Lab prepared a corrective action plan to address the minor nonconformances described above. The DOE Berkeley Site Office declared the EMS in conformance with the ISO standard on September 18, 2018.

Plans and procedures are prepared by EHS staff to comply with regulatory requirements for various environmental programs. For example, a Stormwater Pollution Prevention Plan details how Berkeley Lab will comply with California stormwater requirements. Similarly, an 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.

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.

Correspondence between regulatory agencies and Berkeley Lab is often vital for showing an environmental program's compliance status. ESG maintains an electronic record of correspondence between Berkeley Lab and regulatory agencies. The record, an Excel spreadsheet, is organized by fiscal year and can be accessed by everyone in the group.

Many of the monitoring records are found in an ESG database, which is used for storing sampling results from all environmental monitoring programs that are reported in Chapter 4 of this document. Other monitoring records, such as calibration results for monitoring instrumentation, are also maintained and available on a shared computer drive.

Records management is a line management function at Berkeley Lab. The EMS Program Leader 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 listed in PUB-201, LBNL *Requirements and Policies Manual*, Information Management section.

2.2.6 Management Review

As part of the "act" step for a management system, senior management of organizations involved in implementing the EMS meet periodically with the EMS Program Manager to review the program's status. The meetings are attended by a representative who reports to the Deputy Director for Research and one 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.

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

- Results of internal and external 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

Because the EMS is required to be integrated with sustainability goals, and Berkeley Lab is developing an ISO 50001 (Energy Management) program, the LBNL Chief Sustainability Officer participates in the management reviews. Management reviews were held on January 23 and December 19, 2018. Key topics of discussion were program accomplishments, such as implementation of a streamlined risk-ranking process for environmental aspects; linking EHS systems with the Facilities Division's work order database Maximo; new underground storage tank regulations; and Berkeley Lab's stormwater program's return to Baseline compliance status. In addition, management was informed of the need to improve processes by the Facilities Division to track environmental compliance requirements in which they play a role.

2.3 ENVIRONMENTAL MANAGEMENT PERFORMANCE AND HIGHLIGHTS

At the end of the federal fiscal year, which begins October 1 and ends September 30 the following year, Berkeley Lab is required to report on the performance of its EMS. As discussed below, one report is required by the operating contract between DOE and UC (DOE Contract No. DE-AC02-05CH11231, also known as Contract 31; DOE, 2018) that assesses performance for numerous functional areas. The second report is strictly limited to EMS activities and is required of all federal agencies and their contractors.

2.3.1 DOE's Evaluation of EMS Performance

Berkeley Lab received a weighted score of B plus – on a scale ranging from A plus (highest score) to D (lowest score) – in the DOE Berkeley Site Office's (BSO) *Performance Evaluation Report of the University of California for*

Management and Operations of Science and Technology at the Lawrence Berkeley National Laboratory for the Period October 1, 2017 to September 30, 2018 (DOE/BSO, 2018) for its integrated environment, safety, and health program and its EMS. This evaluation is based on objectives in DOE's *FY 2018 Performance Evaluation and Measurement Plan* (Section J, Appendix B in DOE, 2018); both the plan and report are required by Contract 31. The following activities and accomplishments contributed to earning a B plus performance rating and were described in the report as follows:

- Most notable are the EMS, Stormwater Pollution Prevention Program, operation of the Hazardous Waste Handling Facility, Groundwater Remediation and National Emission Standards for Hazardous Air Pollutants (NESHAP) program.
- ESG partnered successfully with the Old Town Demolition Project team. Radiation Protection Group personnel worked closely with the project to review and approve work packages, Final Status Survey Instruction Plans, and Final Status Survey Reports, and to coordinate radiological and hazardous material cleanup activities. ESG coordinated cleanup activities to address radioactive soil, polychlorinated biphenyls (PCBs), and other hazardous waste. EHS's support was critical to BSO's completion of Independent Verification Reports for Phases 1, 3, and 4 of the Old Town Demolition Project.
- According to BSO, while the environmental programs at Berkeley Lab are strong, it could benefit from ensuring that departing Principle Investigators dispose of their chemical inventory before they leave, as part of the checkout process. BSO noted that on several occasions, chemicals and materials have been left that required laboratory analysis to determine their proper disposition because the departing Principal Investigator's generator knowledge could not be used.
- BSO recommended that Berkeley Lab seek opportunities to reuse chemicals as well as to evaluate whether lower-risk chemicals may be substituted to perform experimental work.

2.3.2 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. This reporting is now associated with Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, issued in 2015. The EMS scorecard evaluated environmental impacts, environmental performance objectives, the performance of operational controls for environmental impacts, and compliance with regulatory requirements/corrective actions.

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/Executive Order 13693 goals integration

The fifth category, EMS/Executive Order 13693 goals integration, is graded by responses to how a site has addressed the following 10 sustainability goals:

1. Greenhouse gas reduction
2. Sustainable buildings
3. Clean & renewable energy
4. Water use efficiency & management
5. Fleet management
6. Sustainable acquisition
7. Pollution prevention & waste reduction
8. Electronic stewardship & data centers
9. Climate change resilience
10. Energy performance contracts

For FY 2018, Berkeley Lab reported that sustainability goals 1 through 9 were applicable and were addressed by the organization. Although goal 10 was not applicable, Berkeley Lab commented in its reporting that it has been able to successfully address energy efficiency projects without energy service performance controls or utility contracts for energy service performance. Berkeley Lab addressed goal 9 by completing (and submitting to DOE) a climate change vulnerability screening in January 2018, as required by the October 2016 Secretary of Energy memorandum on Climate Change Preparedness and Resilience.

Based on collective ratings in the five Office of Management and Budget categories for the FY 2018 reporting period, Berkeley Lab's EMS program earned the highest score of "green." Each category 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. Berkeley Lab received all A's for the reporting period. BSO accepted the FY 2018 EMS Scorecard information in the Fed Center database in January 2019. The site score for Berkeley Lab was "green."

While the responses were not factored into the scoring of a site, the EMS Reporting Scorecard asked questions regarding EMS experiences in terms of best practices and effect on an organization's mission. Regarding EMS best practices, Berkeley Lab noted that management review meetings now cover both environmental management and sustainability activities. This helps show the integration of the two as required by DOE Order 436.1, as well as simultaneously address the management review requirements of ISO 14001 (Environmental Management) and ISO 50001 (Energy Management).

Another best practice mentioned – bringing in environmental project managers to coordinate environmental requirements for several large capital projects – has improved the effectiveness of environmental management through a single point of contact and faster response to project questions. In addition, before the annual management meeting, the EMS Manager provides an executive summary covering all considerations required of a management review by the ISO 14001 standard. This summary organizes and documents EMS performance and activities in a way that helps those attending the management review meeting focus on the most important topics.

Regarding Berkeley Lab's experiences with EMS and the effect on its mission, Berkeley Lab maintains strong environmental compliance programs that foster good relationships with the regulatory community and neighbors. Limiting distractions from compliance deficiencies help Berkeley Lab's research community focus on its research. One example mentioned was updating Berkeley Lab's soil management processes during the reporting period. The

improvements made, with input from the regulatory oversight agency, will streamline the handling of potentially contaminated soil associated with areas of the site available for future development.

2.3.3 Accomplishments, Awards, and Recognition

Berkeley Lab substantially reduced the number of groundwater monitoring wells and the amount of groundwater sampling required by the Department of Toxic Substances Control (DTSC) since 2014 by approximately 33% by decommissioning wells and modifying sampling frequency, with DTSC concurrence. Berkeley Lab also improved stormwater pollution prevention compliance and returned to Baseline compliance status by establishing controls on potential sources of metals discharges and received concurrence from the San Francisco Bay Regional Water Quality Control Board (RWQCB). Finally, Berkeley Lab established subcontracts to provide scalable and timely environmental protection and restoration support for construction and demolition projects. The Green Electronics Council recognized Berkeley Lab as an EPEAT (Electronic Product Environmental Assessment Tool) Four-Star Award Winner for purchases in four IT product categories (personal computers and displays, imaging equipment, mobile phones, and televisions). Award winners earned one star for each product category in which they committed to purchasing EPEAT-registered products.

3 Environmental Program Summary

This chapter summarizes the status of environmental compliance programs and includes general regulatory requirements, permits issued by regulatory agencies, and audits and inspections conducted during the year.

3.1 ENVIRONMENTAL PERMITS AND PROGRAMS

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 (https://ehs.lbl.gov/service/environmental-services/) and are summarized in Table 3-1 by permit type.

Table 3-1 Environmental Permits

Permit Type	Issuing Agency	Description (Section with Details)	Location
Air quality	BAAQMD[a]	Various activities or equipment with emissions to atmosphere (3.4.1.2)	Main Site
		Standby emergency generators (3.4.1.2)	Joint Genome Institute
CUPA[b] (permit and registration)	ACEH[c]	Hazardous Materials Business Plan and hazardous waste generator areas (3.4.2)	EmeryStation East
	CCHS[d]	Aboveground storage tanks (3.4.5.1) Hazardous Materials Business Plan and hazardous waste generator areas (3.4.2)	Joint Genome Institute
	COB[e]	Aboveground storage tanks (3.4.5.1) Fixed treatment units (3.4.3.1) Hazardous Materials Business Plan and hazardous waste generator areas (3.4.2) Underground storage tanks (3.4.3.3)	Main Site
		Hazardous Materials Business Plan and hazardous waste generator areas (3.4.2)	Berkeley West Biocenter
Hazardous waste	DTSC[f]	Hazardous Waste Handling Facility operations and hazardous waste generator areas (3.4.3.1)	Main Site
Stormwater	SWRCB[g]	Sitewide and construction stormwater discharges (3.4.5.3)	Main Site
Surface water and sediment	EBRPD[h]	Surface water and sediment sampling (4.2.1, 4.5.2)	Tilden Park
Wastewater	CCCSD[i]	Wastewater discharges to sanitary sewer (3.4.5.1)	Joint Genome Institute
	EBMUD[j]	Sitewide and operation-specific wastewater discharges to sanitary sewer (3.4.5.1)	Main Site

[a] Bay Area Air Quality Management District
[b] Certified Unified Program Agency
[c] Alameda County Environmental Health
[d] Contra Costa Health Services
[e] City of Berkeley
[f] Department of Toxic Substances Control
[g] State Water Resources Control Board
[h] East Bay Regional Park District
[I] Central Contra Costa Sanitary District
[j] East Bay Municipal Utility District

3.2 AUDITS AND INSPECTIONS

The regulatory agencies that enforce environmental requirements conduct periodic on-site inspections. Twenty – one minor violation notices and two Class II violations resulted from eight inspections in 2018 resulting in no monetary fines. In addition, five minor nonconformity findings emerged from a third-party DOE audit of Berkeley Lab's EMS. Information about these inspections and audits is summarized in Table 3-2 and discussed in Sections 2.2.5, 3.4.1.2, 3.4.2, 3.4.3.1, 3.4.3.3, 3.4.5.2, and 3.4.5.3. 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
ACEH[a]	Hazardous Materials Business Plan and hazardous waste generation at Emery Station*	May 11	2
BAAQMD	Inspection of permitted soil vapor treatment system, paint spray booth, solvent wipe-cleaning operations, and several standby generators	Oct. 31	0
CCCSD	Wastewater and stormwater inspection at the Joint Genome Institute*	Nov. 15	0
COB[a]	Hazardous Materials Business Plan at Berkeley West Biocenter*	Jan. 24	2
	Aboveground storage tanks, fixed treatment units, and hazardous waste accumulation areas	July 11–13	11
	Underground storage tank – monitor certification	Nov. 26	5
	Underground storage tanks pressurized line integrity testing	Dec. 19	1
DOE	Triennial EMS Conformity Audit	July 30–Aug. 3	5
EBMUD	Groundwater treatment systems, Hazardous Waste Handling Facility, and Earth and Environmental Sciences Area laboratory spaces	Aug. 23	0
LBNL	Self-monitoring inspections required by EBMUD for groundwater treatment units	Feb. 15 Sept. 26	0 0
	Self-monitoring inspections required by EBMUD for the Hearst and Strawberry sanitary sewer outfalls	March 14 Sept. 20	0 0
RWQCB	Site review of stormwater controls	May 23	0
U.S. EPA[b]	RCRA[c] inspection of the Hazardous Waste Handling Facility (Building 85) and Building 77A	June 4 June 6	0

* Inspection of off-site facilities

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

[b] U.S. Environmental Protection Agency; COB and DTSC representatives also participated.

[c] Resource Conservation and Recovery Act.

3.3 DOE-REPORTABLE ENVIRONMENTAL INCIDENTS

The DOE Occurrence Reporting Program tracks environmental incidents across the DOE complex. No environmentally related occurrence reports were associated with LBNL activities during 2018.

3.4 COMPLIANCE PROGRAMS

The primary federal laws driving LBNL compliance programs for federal, state, and local environmental regulations are the Clean Air Act, the Emergency Planning and Community Right-to-Know Act, the Resource Conservation and Recovery Act (RCRA), the Clean Water Act, and the Toxic Substances Control Act. The federal and state laws impacting Berkeley Lab's environmental planning for future activities are the National Environmental Policy Act and the California Environmental Quality Act. The sections below briefly describe each of these environmental laws and associated regulations, and highlight associated LBNL activities for this reporting year.

3.4.1 Clean Air Act

The Clean Air Act of 1970 is the key statutory reference for federal, state, and local air pollution control programs. Regulations are based on four categories of air pollutants, as follows:

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

3.4.1.1 Radiological Emissions

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

- Code of Federal Regulations (CFR), Title 40, Part 61, Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities (U.S. EPA, 1989)
- DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE, 2013)

The U.S. Environmental Protection Agency (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) (U.S. EPA, 1989). The estimated potential dose from LBNL activities in 2018 was approximately 0.04% of this limit.

Berkeley Lab documents its NESHAP review and compliance status annually; the *Radionuclide Air Emission Report for 2018* (LBNL, 2019) is the most recent report submitted to the U.S. EPA. The report is available on the Environmental Publications page of ESG's website (https://ehs.lbl.gov/service/environmental-services/).

3.4.1.2 Non-radiological Emissions

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, "Air District") is responsible for administering and enforcing federal and state air quality requirements for most non-radiological air emission activities. CARB administers regulations on mobile sources such as vehicles, as well as regulations on certain toxic chemicals and greenhouse gases (GHGs).

At the end of 2018, Berkeley Lab held 35 operating permits issued by the Air District (BAAQMD, 2018); 33 permits cover activities and equipment at the main site, and 2 permits cover standby emergency diesel generators at the Joint Genome Institute (JGI) in Walnut Creek. Additionally, 11 industrial boilers with a combustion rating of at least 2 million BTUs per hour and less than 10 million BTUs per hour are registered with the Air District. All permits issued by the Air District are listed in Table 3-3.

Table 3-3 BAAQMD-Permitted Air Emission Sources

BAAQMD Permit Category	Description (No. of Permitted Sources)	Building	Abatement Type
Combustion equipment	Standby emergency generators (4)	64, 66, 67, 70	Catalytic converter
	Standby emergency generators (7)	30, 48, 50A, 59, 72, plus two portable units	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 (2)	JGI	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

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

BAAQMD operating permits must be renewed annually. The renewal application process includes submitting usage information on permitted sources, as well as sitewide adhesive and sealant annual usage under a BAAQMD-approved alternative recordkeeping agreement for compliance with Regulation 8, Rule 51: Adhesive and Sealant Products. Information submitted in the application also satisfies requirements of the state's Air Toxics "Hot Spots" Information and Assessment Act of 1987 (California Health and Safety Code, 1987).

Each year, pursuant to BAAQMD Regulation 11, Rule 2, Berkeley 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.

The Air District conducted one inspection in 2018 of permitted equipment or activities. The inspection focused on the paint spray booth, the soil vapor extraction unit, and several diesel generators, in addition to sitewide solvent wipe-cleaning operations. No violations were reported for the inspection.

CARB regulates sulfur hexafluoride (SF_6) emissions from gas-insulated switchgear 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 2018, and reported 5.8 pounds of SF_6 emissions from one switch that was removed from service that was below the annual CARB emission rate of 3.0%. Maintenance is performed biannually ~~two years~~ on switches at Berkeley Lab and includes testing for leaks. No leaks were detected in 2018. The 5.8 pounds of SF_6 reported as emissions was apparent when, during salvage of the old switch, only 6.2 pounds of SF_6 was recovered from the unit whose name plate SF_6 capacity was 12 pounds.

CARB's Refrigerant Management Program regulates stationary nonresidential refrigeration systems that use more than 50 pounds of a refrigerant with a high global warming potential by requiring use reporting and fee payment. Berkeley Lab's 51 refrigeration systems affected by this program are all on the main site.

Since 2010, at the end of each fiscal year, Berkeley Lab has submitted a report to DOE on its annual GHG emissions. The current requirement for this reporting is Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*. The order contains more than 30 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, 2017a).

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

Berkeley Lab has three different fleets of vehicles regulated by CARB as nonstationary air emission sources. The Off-Road Diesel fleet has six vehicles, all of which are designated as permanently low-use vehicles. Each vehicle in the low-use category is used less than 200 engine hours annually. Six other vehicles are in CARB's Heavy-Duty Truck and Bus program. A total of 23 forklifts are in CARB's Large Spark-Ignition Engine program, 13 of which are registered as low use.

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 Toxic Release Inventory reporting requirements. 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 2018 that no chemical usage exceeded the chemical-specific Toxic 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 highest chemical usage quantities since 2007.

Table 3-4 Trends in Highest Quantities of Chemicals Subject to EPCRA Toxic Release Inventory Reporting

Substance	Quantity Used per Year (pounds)									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Chlorofluorocarbons	169	142	319	183	61	132	87	327	390	270
Methanol	181	147	88	103	172	127	100	130	126	82
Nitric acid	614	592	634	633	633	556	78	90	90	21

The City of Berkeley, Alameda County Environmental Health, and Contra Costa Health Services are the local administering agencies for 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 Hazardous Materials Business Plans (HMBPs) that meet state requirements, even though it is not subject to state hazardous materials regulations.

Each HMBP provides the following information:

- All hazardous materials present in amounts exceeding the state's aggregate threshold quantities per building (i.e., 55 gallons for liquids, 500 pounds for solids, and 200 cubic feet for compressed gases)
- Emergency plans
- Procedures
- Training
- Facility maps

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

- LBNL main site
- Berkeley West Biocenter
- EmeryStation East (Joint BioEnergy Institute and the Advanced Biofuels Process Demonstration Unit)
- Joint Genome Institute

The HMBPs are also available on the Environmental Publications page of ESG's website (https://ehs.lbl.gov/service/environmental-services/).

The City of Berkeley Certified Unified Program Agency (CUPA) performed an inspection of the fixed treatment units, aboveground storage tanks, satellite accumulation areas (SAAs), waste accumulation areas (WAAs), and HMBP and hazardous waste generator areas at the Berkeley Lab main site and identified two minor container management violations: a container holding hazardous waste was open, and another container was susceptible to rupturing or causing a leak.

The Alameda County Environmental Health CUPA performed an inspection of the EmeryStation HMBP and hazardous waste generator areas and identified one minor violation involving five containers collecting high-performance liquid chromatography waste were not equipped with a cap to cover the discharge tubes.

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
- 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 Hazardous Waste

In California, the Department of Toxic Substances Control (DTSC) administers the hazardous waste program. The state's program incorporates the provisions of both the federal and state hazardous waste laws (California Health and Safety Code, 1972) and includes oversight of hazardous waste generation, permitting, and enforcement. These programs are delegated to the City of Berkeley under the CUPA program.

At Berkeley Lab, SAAs and WAAs are used to accumulate hazardous 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 hazardous waste produced during daily laboratory and facility activities. WAAs are used to temporarily accumulate larger quantities of hazardous waste, including hazardous waste from SAAs.

Berkeley Lab policy requires hazardous waste and mixed waste to be removed from SAAs, including mixed-waste SAAs, within 270 days of initial generation, and from WAAs within 60 days of initial generation. Generally, all regulated waste is collected from generators' SAAs and WAAs and transferred to the Hazardous Waste Handling Facility for storage and treatment as needed, then packaged and shipped off site to appropriate commercial, hazardous waste treatment, storage, and disposal facilities (TSDFs). Large quantities of hazardous waste and other waste generated from special projects, such as construction and demolition, are shipped directly from generator locations to TSDFs.

Radioactive waste containing hazardous waste is exempt from RCRA. This type of waste is managed as radioactive waste in accordance with the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended.

The state'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.

Table 3-5 Overview of California's Tiered Permitting Program

Program Tier	Regulatory Agency	LBNL Facilities 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	–

Note: See Table 3-6 for details about each FTU (fixed treatment unit).

The Hazardous Waste Handling Facility operates under a DTSC-issued full permit (the highest tier), which authorizes storage and treatment of certain hazardous and mixed wastes at the facility. The expiration date for this permit, which is valid for 10 years, was December 2016. In June 2016, Berkeley Lab submitted an application to DTSC to renew the permit. DTSC determined in July of that same year that the application was administratively complete. In January 2018, DTSC notified Berkeley Lab that the agency had completed its technical review and issued a first Notice of Deficiency (NOD) letter requesting additional information on 32 items. As of this writing, Berkeley Lab has responded to the NOD letter and awaits DTSC's feedback. In the meantime, the existing permit remains effective and enforceable. When the application is complete, DTSC will prepare a draft permit that will involve a public comment period prior to issuing a final permit.

Administration and enforcement for the three lower tiers are delegated to the City of Berkeley under California's 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 (http://cers.calepa.ca.gov/).

FTU treatment types and operational throughput are summarized in Table 3-6. The FTU serving Building 70A treats over 75% of all FTU wastewater generated on site, and recycled approximately 32% of that by diverting it to a nearby cooling tower to replace the water consumed by the cooling process. Nearly 154,000 gallons of water was recycled in this manner in 2018. The volume treated by the Building 77 FTU was significantly less than that in 2017 because the FTU was shut down in April 2018 in order to upgrade to a recycling system.

Berkeley Lab also sends hazardous, universal, mixed, medical, and radioactive waste generated at its operating locations to permitted off-site facilities for disposal. The state's Medical Waste Management Act (California Health and Safety Code, 1991) regulates the disposal of medical waste. 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).

Table 3-6 Summary of Fixed Treatment Unit Operations

FTU	Building	Treatment Types	Approx. Quantity of Wastewater Treated in 2018 (gallons)
004	70A	Acid neutralization	480,981 (153,496 estimated recycled)
005	2	Acid neutralization	104,300
006	77	Metals precipitation and acid neutralization	3,336
007	67	Acid and alkaline neutralization	37,657

In June, representatives of the U.S. EPA, accompanied by representatives of DTSC and the City of Berkeley, conducted a two-day inspection involving a records review and visits to hazardous waste units 1–4 and mixed-waste units 1–8 in or adjacent to Building 85 and Building 77A. No violations were cited from this inspection. In July 2018, representatives of the City of Berkeley conducted a three-day CUPA inspection of the main site. The inspection of wastewater treatment systems subject to California's Tiered Permitting Program and SAAs, and aboveground tanks resulted in nine minor violations and two Class II violations, as follows:

1. Accumulating hazardous waste longer than 90 days in the Building 77 FTU (Class II violation).
2. Improperly labeled hazardous waste tank (Building 77, Tank 4) and missing an accumulation start date (Class II violation).
3. Failure to determine whether used gloves, Kimwipes, and an unlabeled plastic bag constituted hazardous waste at Building 70. Wastes were later determined to be nonhazardous (minor violation).
4. Waste containers in Building 70 are not labeled with all required elements, including the words "Hazardous Waste," initial date of accumulation, physical state, and hazards (minor violation).
5. Failure to inspect a fire extinguisher outside FTU 006 (minor violation).
6. Incorrectly identifying the number of treatment tanks for FTU 005 at Building 2 (minor violation).
7. Incorrectly identifying the number of treatment tanks FTU 004 at Building 70A (minor violation).
8. Incorrectly identifying the number of treatment tanks for FTU 007 at Building 67 (minor violation).
9. Failure to provide written notice to the City of Berkeley before beginning to close hazardous waste tanks at FTU 006 at Building 77 (minor violation).
10. The Spill Prevention, Control, and Countermeasure (SPCC) Plan did not describe a buried pipe used for gravity flow filling the Building 70 engine generator (minor violation).
11. Failure to perform annual aboveground tank inspections and failure to perform monthly tank inspections for one tank 2-64 (minor violation).

The violations have been corrected and documented in the Corrective Action Tracking System.

The City of Berkeley CUPA performed an inspection of the Berkeley West Bio Center involving a review of the HMBP and hazardous waste generator areas. The CUPA issued a minor citation involving an open hazardous waste container and another minor violation involving a container holding hazardous waste that had the potential to rupture or cause it to leak.

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 environmental restoration measures approved by DTSC in the *RCRA Corrective Measures Study Report for the Lawrence Berkeley National Laboratory* (LBNL, 2005). These measures are intended to reduce or eliminate the potentially adverse effects to human health or the environment caused by past releases of chemicals to soil and groundwater 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 of groundwater contaminant plumes to minimize 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.
- **Hydrogen Release Compound (HRC®)**, an environmentally safe polylactate ester formulate, has been injected into certain contaminated areas to enhance the natural biodegradation of volatile organic compounds (VOCs).
- **Monitored natural attenuation** (i.e., reliance on natural processes) is also being used at some locations within the context of a controlled and monitored site cleanup approach.

In December, Berkeley Lab finalized the *Soil Management Plan for Lawrence Berkeley National Laboratory* (LBNL, 2017b), which replaced the plan prepared in 2006. The new Soil Management Plan and the *Groundwater Monitoring and Management Plan* (LBNL, 2006) describe the nature and extent of contamination, the controls used to reduce potential risk to human health and the environment from contaminants in soil and groundwater, and the requirements for ongoing groundwater and surface water monitoring. These plans, as well as other RCRA Corrective Action Program documents prepared by Berkeley Lab, are available to the public at the main branch of the Berkeley Public Library and on the Environmental Restoration Program website at 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 for USTs containing hazardous materials addresses permitting, construction, design, monitoring, recordkeeping, inspection, accidental releases, financial responsibility, and tank closure, and it 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 and shown on Figure 3-1. Berkeley Lab has removed nine USTs since 1993 following the regulatory closure process; no USTs were removed in 2018.

Table 3-7 Underground Storage Tanks Requiring Operating Permits

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

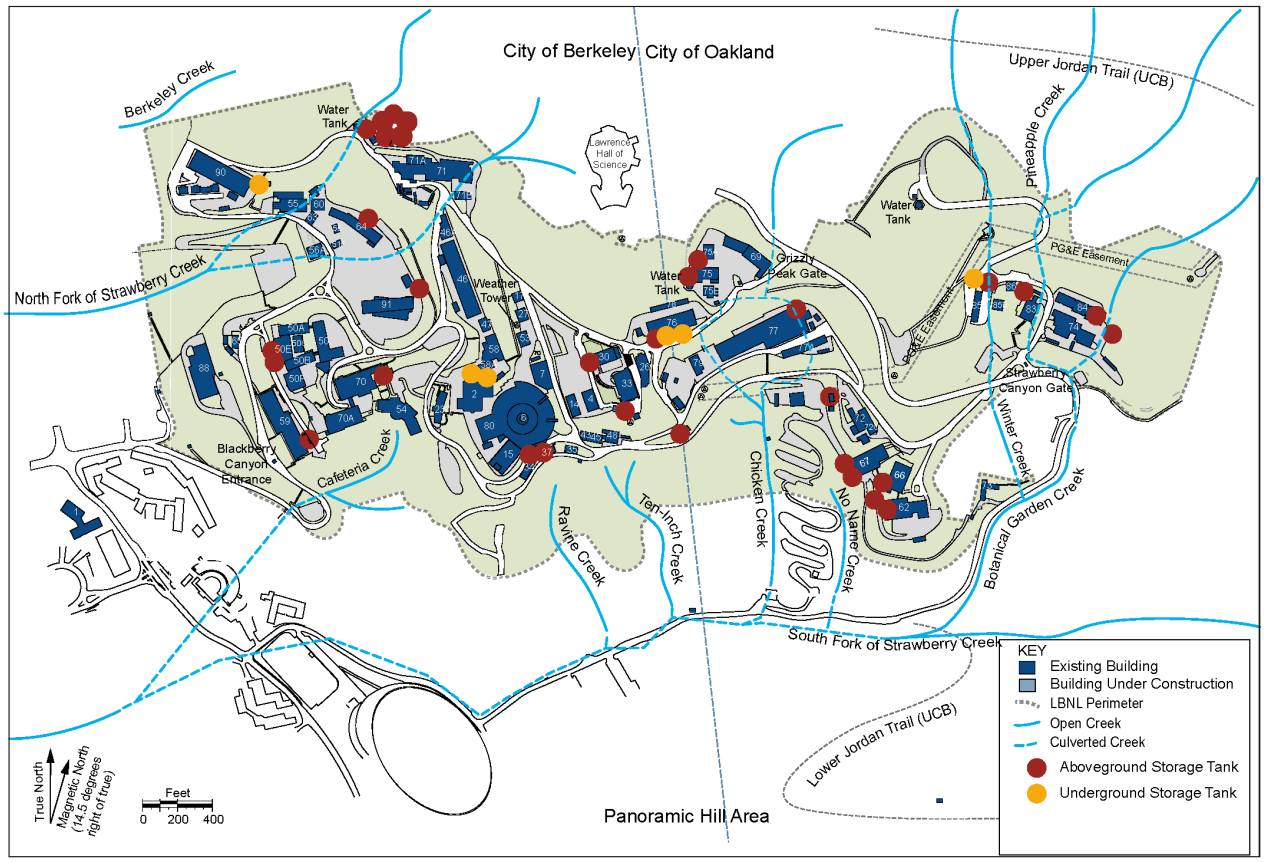

Figure 3-1 Locations of Petroleum-Containing Aboveground and Underground Storage Tanks

In November, the City of Berkeley conducted an inspection of the six permitted USTs at the main site. Five minor violations were cited, as follows:

1. The "Designated UST Operator Visual Inspection" report was documented on an outdated state form.
2. UST Monitor system certification was completed seven weeks past the required 12-month frequency.

3. UST tank systems have two modes of overfill protection: audiovisual alarms and fill tube shutoff valves. Audiovisual alarms were inspected as required. However, fill tube shutoff valves were not inspected by October 13, 2018, as required by new regulation.
4. The interstitial sensor on TK-5-76 failed and was replaced during the inspection.
5. The spill bucket on TK-5-76 failed and was repaired during the inspection. Testing was performed seven weeks past the required 12-month frequency.

The City of Berkeley CUPA returned in December to perform the annual UST pressurized line integrity test and found that one line test was not performed within the year because the contractor provided a technician who had not received confined space training and was unable to perform the testing by the deadline.

3.4.4 Chemical Facility Anti-Terrorism Standards

The Department of Homeland Security (DHS) is responsible for administering the Chemical Facility Anti-Terrorism Standards (CFATS) program (6 CFR Part 27), which requires facilities of any size to determine whether they have chemicals of interest in quantities that exceed screening thresholds. Because Berkeley Lab qualifies as a high-risk chemical facility, it is required to submit to DHS a Security Vulnerability Assessment to determine its security risk and a Site Security Plan to describe existing or planned security measures appropriate to the risk level. The Security Vulnerability Assessment identifies chemicals that require risk screening. Chemicals that require screening are further analyzed and modeled for security and sabotage scenarios to identify potential consequences. The analysis uses worst-case scenarios to determine the potential off-site consequences using EPIcode (Emergency Prediction Information code) – a software program that assists in developing protection strategies for Berkeley Lab.

The Site Security Plan outlines the protection levels and strategies that includes administrative and engineering controls that either deter or mitigate the potential for a chemical sabotage contamination event.

3.4.5 Clean Water Act

The federal 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 program 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 (also known as the California Water Code) established a comprehensive statewide system for regulating water use and provided for a three-tiered system of regulatory administration and enforcement:

1. California State Water Resources Control Board (SWRCB, “State Water Board”)
2. nine Regional Water Quality Control Boards
3. local governments

For the LBNL main site, the agencies responsible for regulatory programs are the San Francisco Bay Regional Water Quality Control Board (herein referred to as the RWQCB) for stormwater discharges, and EBMUD for drinking water supply and wastewater discharges to the sanitary sewer. For the Joint Genome Institute (JGI), which is

located in Walnut Creek, the responsible agency for both wastewater and stormwater discharges is the Central Contra Costa Sanitary District.

3.4.5.1 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) fall under the authority of the federal 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 petroleum products or hazardous materials. At Berkeley Lab, these requirements apply to petroleum storage tanks for standby emergency diesel generators, storage drums at SAAs, and storage drums at product distribution areas. The City of Berkeley is responsible for administering and enforcing the regulations that apply to ASTs at the main site. Berkeley Lab has 31 of these ASTs registered with the city; their locations are shown on Figure 3-1.

LBNL replaced two single-walled ASTs at Buildings 68 (68-TK-004) and 82 (82-TK-004). These concrete bermed secondary-contained ASTs were replaced with double-walled tanks equipped with high and low fuel alarms and alarmed interstitial space (i.e., space between the double walls). The new AST at Building 68 has a 300-gallon capacity and the new AST at Building 82 has a 359-gallon capacity. Another single-walled AST was replaced at Building 37 (37-TK-102) with a new doubled-walled 550-gallon AST equipped with high and low fuel alarms and alarmed interstitial space. Two ASTs were removed from service at Building 64. One AST (64C-TK-02) contained 60 gallons of engine motor oil and the other was a 6,000-gallon diesel tank (64C-TK-01) once used to supply fuel to a backup standby generator.

Under the authority of the federal Clean Water Act, Berkeley Lab is required to prepare a Spill Prevention, Control, and Countermeasure (SPCC) Plan for petroleum-containing aboveground tanks. Berkeley Lab maintains an SPCC Plan for the main site with the goal of preventing and, if needed, mitigating spills or leaks from petroleum-containing tanks (LBNL, 2017c). These ASTs are provided with secondary containment or spill kits to capture any potential leaks. A 4,000-gallon AST at the JGI facility supports two standby emergency generators, and JGI maintains a separate SPCC Plan for this AST (LBNL, 2014b).

3.4.5.2 Wastewater

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

- General sitewide wastewater (EBMUD, 2018)
- Treated groundwater from hydraugers and groundwater extraction wells (EBMUD, 2016)
- Treated rinse water from the metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77 (EBMUD, 2017b)
- Treated rainwater from the Old Town Demolition Project (EBMUD, 2017a)

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, and in 2018 no wastewater discharge limits were exceeded. A summary of monitoring results is provided in Chapter 4.

EBMUD periodically inspects the site's sanitary sewer discharge without notice. The agency collected wastewater samples from both the Strawberry and Hearst sewer outfalls in May and November. No discharge violations were measured during the inspections or in the associated wastewater sampling results.

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

The permit for the Building 77 Ultra-High Vacuum Cleaning Facility wastewater facility FTU ceased operation in April 2018 and ceased discharge to the sanitary sewer, Berkeley Lab requested termination of the wastewater discharge permit for the Building 77 FTU in May 2018. Berkeley Lab submitted an application to EBMUD for a Zero Discharge Wastewater Discharge Permit in October 2018 for the B77 FTU, which is required for nonsignificant categorical industrial users for the new recycling system expected in 2019.

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

Berkeley Lab also holds a Class III Industrial User Permit for general wastewater discharged from the JGI facility in Walnut Creek. The Central Contra Costa Sanitary District (Central San) renewed this permit in late 2017, effective through December 2021. The permit specifies requirements for inspections and reporting. No monitoring is required. In November, Central San performed its annual inspection of the JGI facility for wastewater and stormwater and issued no citations.

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 RWQCB. Under this permit, Berkeley Lab has implemented a Stormwater Pollution Prevention Plan (SWPPP) (LBNL, 2016d), which includes the site's *Stormwater Monitoring Implementation Plan* (LBNL, 2016c).

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.

The annual report covering stormwater activities for the 2017/2018 season was submitted by the July 15 deadline using the State Water Board's online Stormwater Multiple Application and Report Tracking System (smarts.waterboards.ca.gov). 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 season. Under modifications to the Industrial General Permit that took effect at the beginning of the 2016/2017 season, Berkeley Lab began the year at the Level 1 compliance level, given the previous season's elevated levels of

aluminum and iron. However, because concentrations of aluminum and iron continued to exceed Numeric Action Levels for these parameters, the State Water Board changed Berkeley Lab's compliance status to Level 2 for the 2017/2018 season.

Berkeley Lab conducted an evaluation to determine whether additional measures could be implemented to lower pollutant levels, and submitted a Level 2 Exceedance Response Action report to the State Water Board. Implementation of additional stormwater controls identified in the report resulted in significant reduction of aluminum and iron concentrations, which improved Berkeley Lab's compliance status lowering it to "Baseline" for the 2018/2019 season. In comparison, few industrial facilities were able to return to Baseline from Level 2 in the same time period.

In May, RWQCB representatives conducted a routine site inspection that focused on recently installed minimum and advanced stormwater treatment controls such as asphaltic curbs/berms, compost socks, weirs, small settling areas, and inlet filters. The controls helped reduce stormwater pollutant concentrations to below Numeric Action Levels, which changed Berkeley Lab's discharger status from Level 2 to Baseline. RWQCB representatives described the additional controls as innovative, and recognized Berkely Lab's ongoing commitment to water quality objectives. The sampling results 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 2018, two projects at Berkeley Lab required coverage under the Construction General Permit program:

1. Old Town Demolition Project
2. Integrative Genomics Building (IGB) and Modular Utility Plant (MUP) Project within the Bayview area

Similar to the Industrial General Permit, each of these projects required a SWPPP and an annual report. Unlike the Industrial General Permit, no stormwater sampling was required, but project site inspections were required (i.e., prior to predicted rain event on a business day, during extended rain events, post rain events, and quarterly non-stormwater discharge). Inspection logs were included in the annual report. Both projects were compliant with their permit requirements for 2018.

Construction General Permit coverage for the Old Town Demolition Project has been in place since May 2015, while coverage for the IGB/MUP Project became effective in July 2016.

3.4.6 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.

PCBs are the principal substances at Berkeley Lab currently subject to TSCA regulations. The only remaining equipment containing TSCA-regulated PCBs is 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 annual reporting threshold to the U.S. EPA for this substance.

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. Efforts to characterize the extent of PCB contamination continued into 2017 under the regulatory authority of U.S. EPA Region 9. Cleanup efforts of this contamination began in early 2017 under a cleanup plan approved by the U.S. EPA. More information on the Old Town Demolition Project is provided in Section 3.5.1 of this report. In addition, characterization and cleanup efforts are documented in the LBNL Environmental Restoration Program's progress reports, which are available at the main branch of the Berkeley Public Library and on the program's website at https://ehs.lbl.gov/resource/environmental-restoration-program/.

3.4.7 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. At Berkeley Lab, environmental staff provide information and technical support to DOE and UC to assist with NEPA and CEQA requirements.

In 2018, DOE determined that eight proposed federally supported activities at Berkeley Lab met the criteria for categorical exclusion under NEPA. Review documents for each are available online at the DOE website for the Office of NEPA Policy and Compliance. One categorical exclusion (CatEx) was for installation and operation of Berkeley Lab's Advanced Light Source Upgrade project. Another addressed installation of DOE's Energy Sciences Network Six system. Berkeley Lab issued another CatEx to expand its engineering fabrication operation at Building 77A. Finally, Berkeley Lab issued five additional CatExs for leases of office, research, and other business-related space in South Dakota, Illinois, and California.

No environmental assessments under NEPA were prepared for LBNL activities. Approximately eight activities were determined to be either categorically exempt under CEQA or covered under CEQA's programmatic environmental impact report.

A final environmental impact report was prepared under CEQA and certified under delegated authority by the Berkeley Lab Director. The report, which examined the Building 59 upgrade and the installation and operation of the NERSC-9 Project for a high-performance computing system, is available online at http://www.lbl.gov/community/nersc-9-project/. Four additional activities were determined to be categorically exempt under CEQA.

3.5 SPECIAL PROJECTS

In 2018, Berkeley Lab continued two projects that involved significant environmental activities: the Old Town Demolition Project and the IGB/MUP Project.

3.5.1 Old Town Demolition Project

To support modernization of its research facilities, in 2014, Berkeley Lab began demolishing buildings constructed in the 1940s and 1950s in the central portion of the site known as Old Town. By the end of 2018, six Old Town buildings along with their foundation slabs (Buildings 5, 16, 16A, 41, 52, and 52A) and a concrete pad that previously held electrical transformers (Bank 16) were demolished. Post-demolition cleanup comprised removal

and off-site disposal of concrete building slabs, retaining walls, sediment in concrete trenches, soil, and subsurface utilities impacted by PCBs and/or radionuclides.

A completion report for cleanup of PCBs at the Old Town Demolition Project will be submitted to DTSC in 2019. A separate report for other non-radiological contaminants in post-excavation soil will be submitted to DTSC in late 2019 or early 2020. Together these documents, which will be available to the public at the main branch of the Berkeley Public Library and on the program's website at https://ehs.lbl.gov/resource/environmental-restoration-program/, will comply with DTSC's 2014 request to submit a report documenting Old Town Project post-excavation conditions.

3.5.1.1 PCB Cleanup at Old Town

PCB cleanup of Old Town was conducted as specified in Berkeley Lab's *Application for Cleanup of Polychlorinated Biphenyls, Old Town Demolition Phase I Project* ("Cleanup Application"; DMS, 2016), and conditions of approval issued by EPA Region 9 on May 10, 2016, and in subsequent amendments to this application approved by the U.S. EPA (2016a). A risk-based cleanup goal of 0.94 mg/kg of total PCBs was developed for the cleanup of PCBs in soil. In approving the Cleanup Application, the EPA approved the risk-based cleanup goal as protective of human health and the environment consistent with the research and academic land use anticipated for the Old Town area.

For investigation purposes, the Old Town Demolition Project area was divided into 10 decision units. A decision unit is an area where a decision is to be made regarding the extent and magnitude of contaminants in relation to potential environmental hazards and associated risks to human health and the environment. Between July 2017 and August 2018, Berkeley Lab submitted summaries of the cleanup activities to the EPA for each decision unit, along with verification sample results, as cleanup at each decision unit was determined to be complete. In accordance with the EPA's conditions of approval of the Cleanup Application, the PCB cleanup completion was determined using the following criteria:

- Direct comparison of each cleanup verification result to the risk-based cleanup goal.
- When one or more verification sample results exceeded the cleanup goal, comparison to the cleanup goal of the concentration corresponding to the 95 percent upper confidence limit of the arithmetic mean (95% UCL) within each decision unit, as long as hot spots (defined as adjacent verification samples with PCBs concentrations exceeding the cleanup goal) were not present.

EPA concurred with Berkeley Lab's determination that no additional cleanup was required at any of the decision units.

Other areas of PCB-impacted soil were investigated besides the defined decision units. PCBs remain in soil at concentrations greater than the cleanup goal in the following areas near the perimeter of the Old Town Demolition Project boundary. Cleanup of PCBs in soil was not planned in these areas at the time the Cleanup Application was submitted.

- **Northeast Corner of Building 52.** The northeastern corner of former Building 52 was subject to cleanup that began within the project boundary and was later expanded to the northeast based on PCB verification results. The cleanup was suspended in the winter of 2017-2018 when heavy rains caused the excavation to begin to collapse, threatening to undermine a roadway and parking area. After discussion

with the EPA, controlled-density fill (low-strength concrete) was placed in the excavation to protect the roadway. Additional soil characterization was conducted in this area in May and September 2018 to determine the extent of the remaining PCB-impacted soil. Sample results indicate that PCBs remain in the soil at concentrations exceeding the cleanup goal to the north of the backfilled excavation, but PCBs do not extend to the south beyond the edge of the excavation. Northeast of the backfilled excavation, PCB concentrations that exceed the cleanup goal range from 2.3 mg/kg to 580 mg/kg.

- **Self-Implementing Cleanup East of Building 5.** In early 2018, Berkeley Lab removed PCB-impacted soil to the east of Building 5 as a self-implementing cleanup approved by the EPA. On April 9, Berkeley Lab requested the EPA's concurrence that the cleanup was complete based on verification sampling data. EPA concurred on July 9 that the cleanup was complete in the cleanup area, but incomplete to the south, where sample results indicate that PCBs remain in the soil at concentrations exceeding the cleanup goal, with a maximum detected concentration of 3.3 mg/kg.

3.5.1.2 Assessment of Other Non-radiological Contaminants at Old Town

In conjunction with the excavation and disposal of PCB-contaminated soil and the removal of belowground structures and utilities, Berkeley Lab assessed the presence of other potential Old Town soil contaminants, including metals, petroleum hydrocarbons, and VOCs. Following is a brief summary of the activities conducted in 2018 related to the assessment of these other contaminants.

To evaluate potential risk, analytical results were compared to DTSC screening levels for commercial and industrial soil or EPA Region 9 screening levels for industrial soil for analytes where a DTSC screening level had not been established.

In 2018 after the cleanup of PCB-contaminated soil to the west of Building 16 was completed, in preparation for demolition of the retaining wall west of the building, the soil behind the retaining wall was characterized for soil disposal purposes. Mercury was detected in a localized area near the retaining wall at a concentration exceeding the DTSC screening level. No other constituents were detected at a concentration exceeding the screening level. The mercury-impacted soil was excavated. Post-excavation sample results indicated that concentrations of mercury in the remaining soil were less than the screening level.

Soil with petroleum hydrocarbon contamination was removed during demolition of subsurface pits and trenches at Building 16 and from the east side of Building 52 after the demolition of the building slab. Post-demolition sample results from Building 52 area indicated that petroleum hydrocarbons in the remaining soil are at concentrations less than the screening levels. These results at Building 16 indicated that petroleum hydrocarbons in the diesel range continued to be present in soil at concentrations exceeding the screening level.

A limited investigation was conducted in September 2018 to assess the extent of the petroleum hydrocarbon contamination at Building 16. Six borings were advanced to 25 feet below ground surface around the completed excavation. The results of soil sample analysis indicated that diesel-range petroleum hydrocarbons remain in the soil at concentrations greater than the screening level beyond the excavated area to the north. It is anticipated that the residual diesel concentrations will be further evaluated under DTSC direction.

In 2018, five groundwater samples were collected in the Building 16 area to help delineate the extent of diesel-range petroleum hydrocarbons previously detected in the groundwater. Diesel-range petroleum hydrocarbons were detected in all five samples at concentrations ranging from 110 to 42,000 µg/L. All detections exceeded the RWQCB's odor nuisance screening level.

3.5.1.3 Final Status Surveys for Radiological Soil Cleanup

Two soil survey units (SUs) (SU-06 and SU-07) and four concrete structure SUs (SU-W1, SU-W2, SU-W3, and SU-W4) were radiologically surveyed and sampled during 2018. SU-06 contained the former Perkins Pad (area between former Buildings 16 and 5) and Building 16A areas. The final status survey of SU-07 was performed in two stages to facilitate excavation and backfill operations. SU-07A contained the southeast corner of the Building 52 area and the southern half of the concrete masonry unit wall that was removed. SU-07B contained the former Electrical Pad and Building 52A areas. SU-W1 made up the western face of the northeast retaining wall on Building 5, and SU-W2 and SU-W3 were the northern and southern portions of the western face of the Building 5 east retaining wall. SU-W4 was the exposed eastern face of the retaining wall between Building 16 and Building 7. Final status survey release reports were developed by the project integration contractor and submitted to Berkeley Lab and DOE for approval.

3.5.1.4 Disposal

In 2018, a total of 1,657 tons of waste – 813 tons of soil and 844 tons of debris –from the Old Town Demolition Project was excavated, packaged, and shipped for disposal. A detailed breakdown of waste shipments is presented in Table 3-8. No concrete or soil waste generated during the cleanup in 2018 was reused or recycled.

Table 3-8 Old Town Waste Shipment Breakdown

Waste Stream	Disposal Facility	No. of Shipments
LLW with PCB <50 parts per million (ppm) or no PCBs	Nevada National Security Site	80
LLW with PCB >50 ppm	Nevada National Security Site	8
PCB >50 ppm with TSCA Lead Debris	Waste Management Kettleman Hills	2
TSCA Lead Debris	Waste Control Specialists	1
PCB Debris Waste <50 ppm	Potrero Hills Landfill	1
RCRA Mercury Debris	Perma-Fix Northwest	1
	Total	93

Waste packages used for transportation and disposal include industrial package IP-1 and IP-2 nine-cubic-yard Super Sacks, SeaLand containers, poly containers, metal drums, and end dump trucks. All waste transporters used were on the DOE Motor Carrier Evaluation Program approved carrier list.

All waste generated from the Old Town Demolition Project was sent to different disposal facilities based on waste stream analytical criteria and cost considerations. The Nevada National Security Site, Waste Management's Kettleman Hills facility, Potrero Hills Landfill, Perma-Fix Northwest, and Waste Control Specialists accepted waste

from the project. Transport trucks were escorted on and off site and loaded by a trained team that included crane operators, riggers, spotters, and traffic controllers.

3.5.2 Integrative Genomics Building and Modular Utility Plant Project

Site preparation activities continued for construction of the IGB and MUP at the southeastern portion of the Bayview Area, which is the former Bevatron site. The IGB/MUP Project is shown as "Building under Construction" on figures used in this report, such as Figure 3-1. In preparing the construction site, Berkeley Lab conducted characterization, demolition or excavation, and off-site disposal of soil and concrete from the following areas:

- Soil from the IGB and MUP building footprints.
- Soil from excavations associated with new utilities.
- Concrete from the top of the existing retaining wall to meet project elevation requirements.
- Concrete from pre-existing subsurface features encountered during construction activities.

Characterization and off-site disposal activities in 2018 were performed in conformance with both the *Sampling and Analysis Plan for Characterization of Soil and Concrete Building 91 Integrative Genomics Building and Building 91U Modular Utility Plant* (Northgate, 2017b) and the *Soil Management Plan, Building 91 Integrative Genomics Building and Building 91U Modular Utility Plant* (LBNL, 2016b).

3.5.2.1 Characterization

Samples of concrete and soil were collected and analyzed for both radiological and non-radiological constituents. The analytical results for non-radiological constituents indicated that the materials were all nonhazardous; the radiological data indicated that the material was indistinguishable from background. These analytical data, which are summarized in the *Characterization Report for Excavated Soil and Concrete Building 91 Integrative Genomics Building and Building 91U Modular Utility Plant* (Northgate, 2017a), were used to characterize materials for final off-site disposition.

3.5.2.2 Disposal

Using the characterization data, special waste applications were submitted to Waste Connections for approval. In 2018, approximately 900 cubic yards of materials were shipped in covered trucks under nonhazardous waste manifests to Waste Connections' Potrero Hills Landfill in Suisun City, California, bringing the total amount of waste generated from the IGB/MUP Project and transported for off-site disposal to approximately 12,000 tons.

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. The comprehensive *Environmental Monitoring Plan* (LBNL, 2013b) provides the basis and current scope for each program. This chapter presents summaries of 2018 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 measure the impacts from radiological air emissions. The program consists of emissions sampling and monitoring to measure contaminants in building exhaust systems. The program meets the U.S. EPA and DOE requirements discussed in Section 3.4.1.1.

Various 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 through 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, and *monitoring* is the continuous measurement of radionuclides in real time.

Each year, all locations using radionuclides are evaluated for their potential to emit radionuclides, then compared with the thresholds listed in Table 4-1. In 2018, the dose to the maximally exposed individual was found to be less than 0.004 mrem/yr, indicating that applicable sampling requirements were met or exceeded for both Category 3 sources, which require periodic sampling, and Category 4 sources, which require a dose evaluation but no sampling or monitoring. At some locations, Berkeley Lab follows a more conservative approach that may include either real-time monitoring to better characterize emissions, or more frequent sampling than required. In 2018,

sampling was performed on a total of 17 stacks, and real-time monitoring was performed on 4 others. Sampling and monitoring locations are shown on Figure 4-1.

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

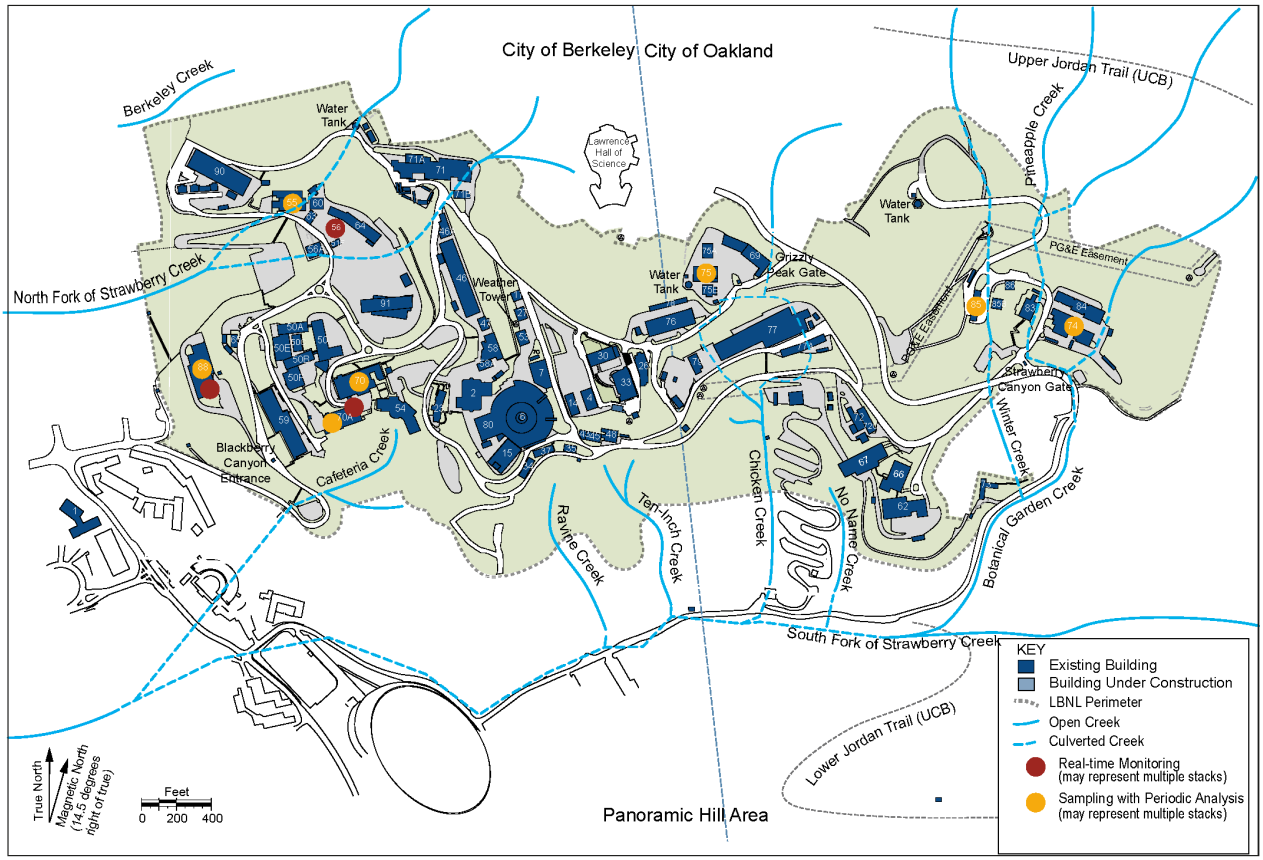

Figure 4-1 Building Exhaust Sampling and Monitoring Locations

Stack exhaust samples were analyzed for five radiological parameters: gross alpha, gross beta, carbon-14, iodine-125, and tritium. Real-time stack air monitoring systems measured alpha emitters and positron emitters. The positron emitter fluorine-18 (half-life of 1.8 hours) was the predominant radionuclide emitted, accounting for

nearly 92.5% of the emitted activity. The Building 56 glove box was the main source of fluorine-18 emissions, at 0.924 curies (Ci). Additional details on stack emissions are available in Berkeley Lab's *Radionuclide Air Emission Report for 2018* (LBNL, 2019), which was submitted to the U.S. EPA, and is available on the Environmental Publications page of ESG's website (https://ehs.lbl.gov/service/environmental-services/). 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 on 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

To establish background water quality values for the region, samples were also collected semiannually 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 Regional Park and flows in a northwest direction away from Berkeley Lab.

Samples from the following subset of creeks were collected semiannually and analyzed for gross alpha, gross beta, and for tritium in accordance with DOE Order 458.1 requirements: Chicken Creek, the North Fork of Strawberry Creek, Wildcat Creek, and Winter Creek (inflow and outflow points). Samples from these locations were also analyzed for the following specific radionuclides using gamma emission spectroscopy: actinium-228, americium-241, antimony-124, bismuth-214, cesium-137, europium-152, lead-214, potassium-40, radium-226, thorium-234, uranium-235, and uranium-238.

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

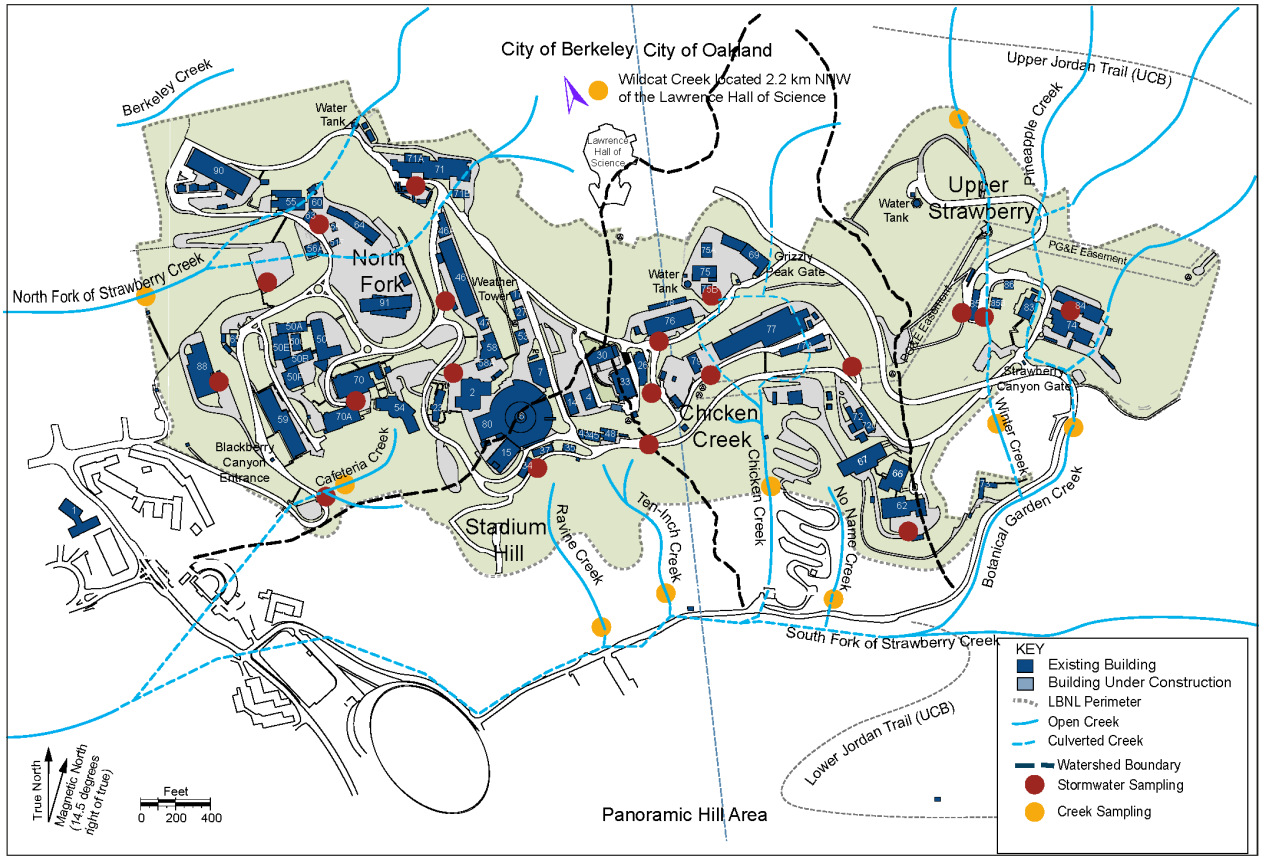

Figure 4-2 Surface Water Sampling Locations

Laboratory analysis reported 23 of the 27 sample results (85%) as below detectable levels. As shown in Table 4-2, four samples had detectable levels of gross beta, although these were less than 6% of the federal and state MCL values for drinking water. Naturally occurring radioactive materials, such as potassium-40, uranium-238, thorium-232, and their daughter products, are believed to contribute the majority, if not all, of the detectable and gross beta results. Tritium was not detected in any of the samples.

Table 4-2 Detectable Radiological Results from 2018 Creek Sampling

Activity	MCL[a] (pCi/L)	Creek	Sample (pCi/L)	% of MCL
gross beta	50	Chicken Creek	2.34	4.7
gross beta	50	North Fork Strawberry Creek	2.1	4.2
gross beta	50	Wildcat	2.6	5.2
gross beta	50	Wildcat	1.47	2.9

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

Using gamma spectroscopy for specific radionuclides, the laboratory analytical results indicated that 67 of the 79 analyses (85%) were below detectable levels. Radiological activities for the remaining samples with detectable results were consistently low and within historical environmental levels monitored by Berkeley Lab.

Creek samples were also analyzed for PCBs, VOCs, and metals. No PCBs or VOCs were detected, but the following metals were detected: aluminum, antimony, arsenic, barium, chromium, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc. Metals concentrations 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.

In addition, the first samples of the year collected from Chicken Creek, the North Fork Strawberry Creek, Wildcat Creek, and Winter Creek were analyzed for the following general indicator parameters: pH, chemical oxygen demand, oil and grease, total suspended solids, and nitrate plus nitrite. The results were within historical levels for the site.

4.2.2 Stormwater Sampling

Berkeley Lab's *Stormwater Monitoring Implementation Plan* (LBNL, 2016c) describes the sampling rationale, sampling locations (see Figure 4-2), and analytical parameters for each specific industrial activity. The Industrial General Permit also requires visual observation of the surface water runoff from each qualifying storm event, dry weather visual observations of non-stormwater discharges once per month, 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), and the remaining two occur during the second half (January 1–June 30). Because the Site Environmental Report is based on the calendar year, the sampling events discussed here are based on results from two stormwater reporting years: the second half of 2017/2018 and the first half of 2018/2019.

As identified by industrial activities listed in Berkeley Lab's SWPPP, samples collected during the second half of 2017/2018 were analyzed for the following nine parameters:

1. aluminum
2. chemical oxygen demand
3. copper
4. iron
5. pH
6. nitrate plus nitrite
7. oil and grease
8. total suspended solids
9. zinc

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 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 level, the least stringent of three compliance levels. To remain at the Baseline level, 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 of the nine 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 status to change again to compliance Level 2.

The change in compliance level prompted Berkeley Lab to identify additional stormwater controls to implement in order to prevent future exceedances of NALs. These additional controls fell into the two categories of administrative and structural/treatment controls. Administrative controls were in the areas of updated procedures and expanding stormwater training for LBNL staff, vendors, and contractors. Structural/treatment controls included additional asphaltic berms and check dams, and enhanced filtration for metal treatment. This also meant updating 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 level for the 2018/2019 reporting year. In comparison, few industrial facilities in compliance Level 2 were able to return to baseline in the 2018/2019 reporting year.

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 in order to upgrade to a recycling system.

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 treated groundwater operations at eight locations. As discussed above, Berkeley Lab requested termination of the wastewater discharge permit for the metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77 in May 2018.

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. The 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. The 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.

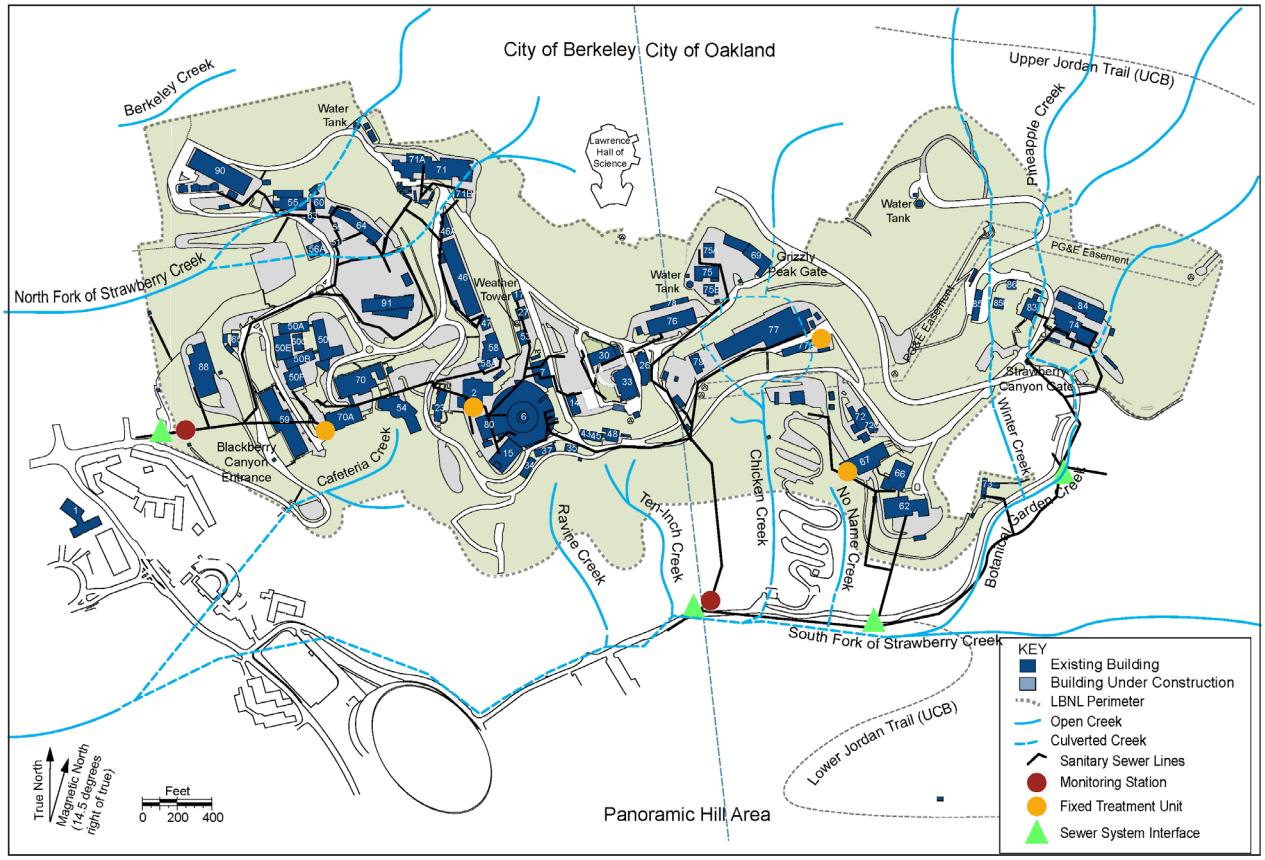

Figure 4-3 Sanitary Sewer System (Main Lines)

4.3.2 Hearst and Strawberry Sewer Outfalls

In 2018, Berkeley Lab discharged approximately 29.8 million gallons through the Hearst branch of the sewer system and 25.8 million gallons through the Strawberry branch, as measured by total volumetric flow. 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, 2013) and corresponding guidance (DOE, 2015). Monitoring verifies compliance with radiological limits established by the Nuclear Regulatory Commission to regulate the use of radioactive materials.
- Non-radiological 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, time-interval (every hour) composite samples are collected every month at the Hearst and Strawberry outfalls and analyzed by a state-certified laboratory for gross alpha, gross beta, iodine-125, tritium, and carbon-14. All samples taken at the Hearst or Strawberry sanitary sewer outfalls in 2018 were below the minimum detectable activity levels for carbon-14, iodine-125, and tritium. One positive result for gross alpha was detected at 3.33 pCi/L, which is below the federal and state MCL for drinking water of 15 pCi/L. 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 monthly gross beta concentration was 21.95 pCi/L, which is below the federal and state MCL for drinking water of 50 pCi/L.

In accordance with DOE guidance (DOE, 2015), annual discharges are estimated by multiplying the sample result's activity by the volume discharged during the monitoring period, even when the activity level is below the minimum detection limits. Since carbon-14, iodine-125, and tritium were below minimum detectable activity 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 2.22×10^{-2} Ci, or 0.44% of the tritium discharge limit of 5 Ci. The annual discharge estimated from carbon-14 values totaled 3.49×10^{-2} Ci, or 3.5% of the carbon-14 discharge limit of 1 Ci. Both estimates use the maximum concentration for each sample result, even if this value is below the minimum detection limit. For example, all sample results for carbon-14 were below the detection limit, yet the discharge estimate is still a positive number. The estimated annual discharge for all other radioisotopes (gross alpha, gross beta, and iodine-125) was 5.82×10^{-3} Ci, or 0.58%% 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-1196-2011, *Derived Concentration Technical Standard* (DOE, 2011b). Compliance is demonstrated when the fraction of each DCS value is calculated, based on consecutive 12-month average concentrations, and totaled. Applying 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 0.0082 (0.82%) and 0.016 (1.6%) of the allowable fractional DCS values in the Strawberry and Hearst sanitary sewer systems, respectively.

4.3.2.2 Non-radiological Monitoring

Berkeley Lab collected two non-radiological 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 either below EBMUD permit limits or not detected. All pH results were well above 5.5, as required by the permit. Total suspended solids and chemical oxygen demand also 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 PCBs in wastewater.

EBMUD visited both outfalls in May and November to collect grab samples and 24-hour composite samples. All results were within EBMUD permit discharge limits.

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 (subsurface drains), groundwater extraction wells, and well sampling and development activities. The treatment process consists of first filtering the groundwater to remove sediment and then passing the contaminated groundwater through a carbon adsorption (i.e., 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, which can treat approximately 60 gallons of wastewater per minute. As noted earlier, this FTU was shut down in April 2018 to upgrade to a recycling system.

The permit also requires that Berkeley Lab submit an annual report certifying that Building 77 is not discharging chlorinated hydrocarbons or other toxic organic compounds to the FTU or the sanitary sewer. The Total Toxic Organics Compliance Report was submitted to EBMUD in November.

4.3.5 Sewer System Management Plan

Berkeley Lab's *Sewer System Management Plan* (LBNL, 2015) addresses the State Water Board's requirements for maintaining Berkeley Lab's sanitary sewer systems and preventing and reporting overflows. SWRCB 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 (SSMP) 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. The most recent review and update was completed in April 2015. In addition, the plan must be audited by an independent party every two years.

A third-party auditor performed an internal audit of Berkeley Lab's SSMP occurred in August and September 2018, concluding that although the SSMP document contained adequate descriptions of most of the required plan elements, the results of the actual implementation of the programs indicated that few of the activities and frequencies described were being followed. The SSMP outlined a comprehensive maintenance program, yet program elements in the SSMP were not being met due to either insufficient funding or attention. The SSMP lacked sufficient information to renew and replace sewer collection system programs while related forms and procedures were not effectively designed. Finally, the auditor observed that regular internal audits of the sewer program were not conducted at the required frequency.

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 during the year.

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 respective corrective measures. More detailed information on RCRA Corrective Action Program activities is provided in the Environmental Restoration Program's progress reports, which contain the site groundwater monitoring data, maps showing monitoring well locations and contaminant concentrations, and graphs showing variations in contaminant concentrations over time. These reports, currently produced annually, are available at the main branch of the Berkeley Public Library and 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 175 wells, including 17 that are used to monitor for potential 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, irrigation, or industrial purposes.)

The groundwater monitoring data continue to indicate that corrective measures have been effective in reducing VOC concentrations in 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 (i.e., 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.

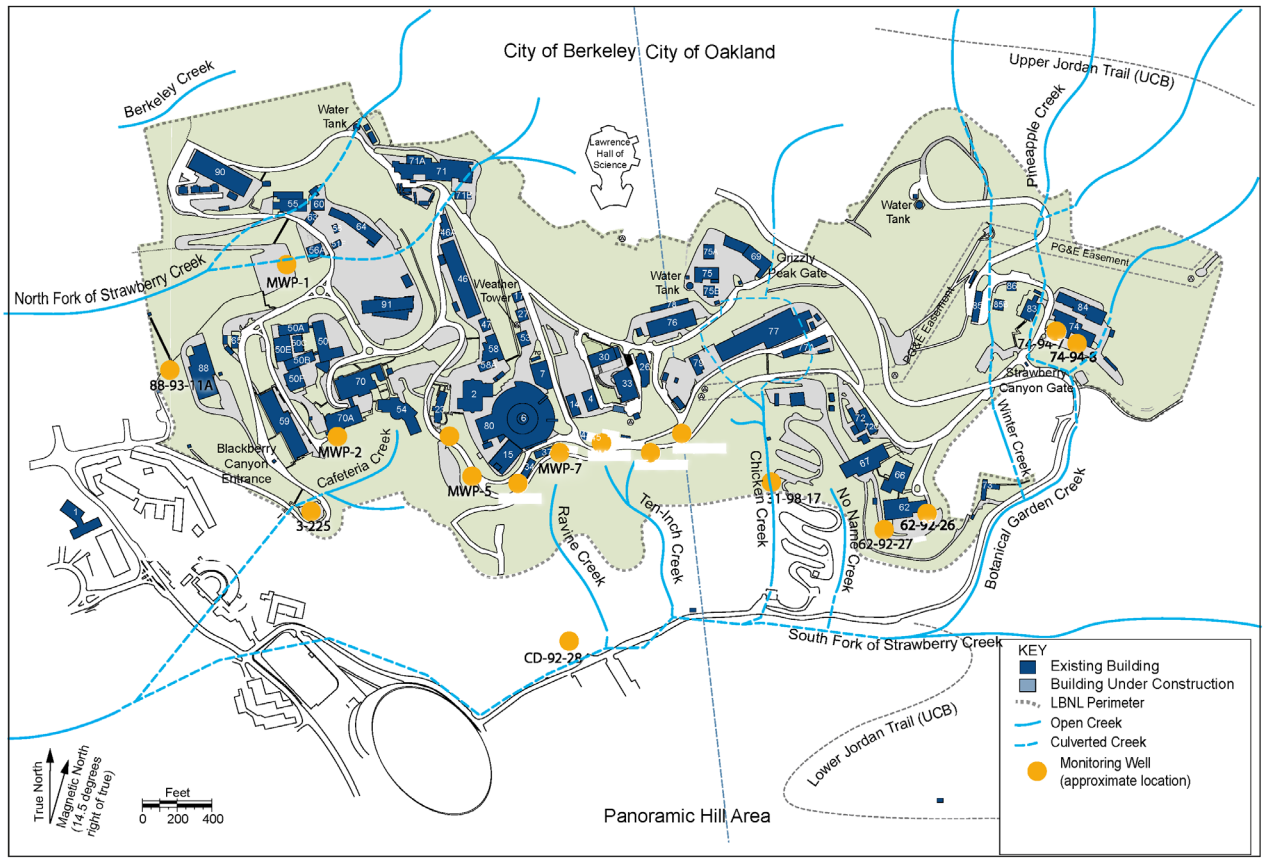

Figure 4-4 Groundwater Monitoring Wells Closest to the Site Boundary

The primary VOCs detected in the groundwater are chlorinated VOCs (e.g., tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and 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 decreased significantly, primarily from the implemented corrective measures. However, VOC concentrations remain above MCLs in a number of areas. The areas where VOC concentrations in the groundwater exceed MCLs are shown on Figure 4-5.

Metals: Twelve groundwater monitoring wells at the site were previously monitored annually for a specific metal (i.e., arsenic, mercury, molybdenum, or selenium) that historically had exceeded the upper estimate of LBNL background (LBNL, 2002) and any established MCL. In May 2017, DTSC approved Berkeley Lab's request to eliminate the requirement to sample those wells for metals. The request was based primarily on evidence indicating that the exceedances of statistically estimated background levels and MCLs were likely the result of naturally occurring metal concentrations.

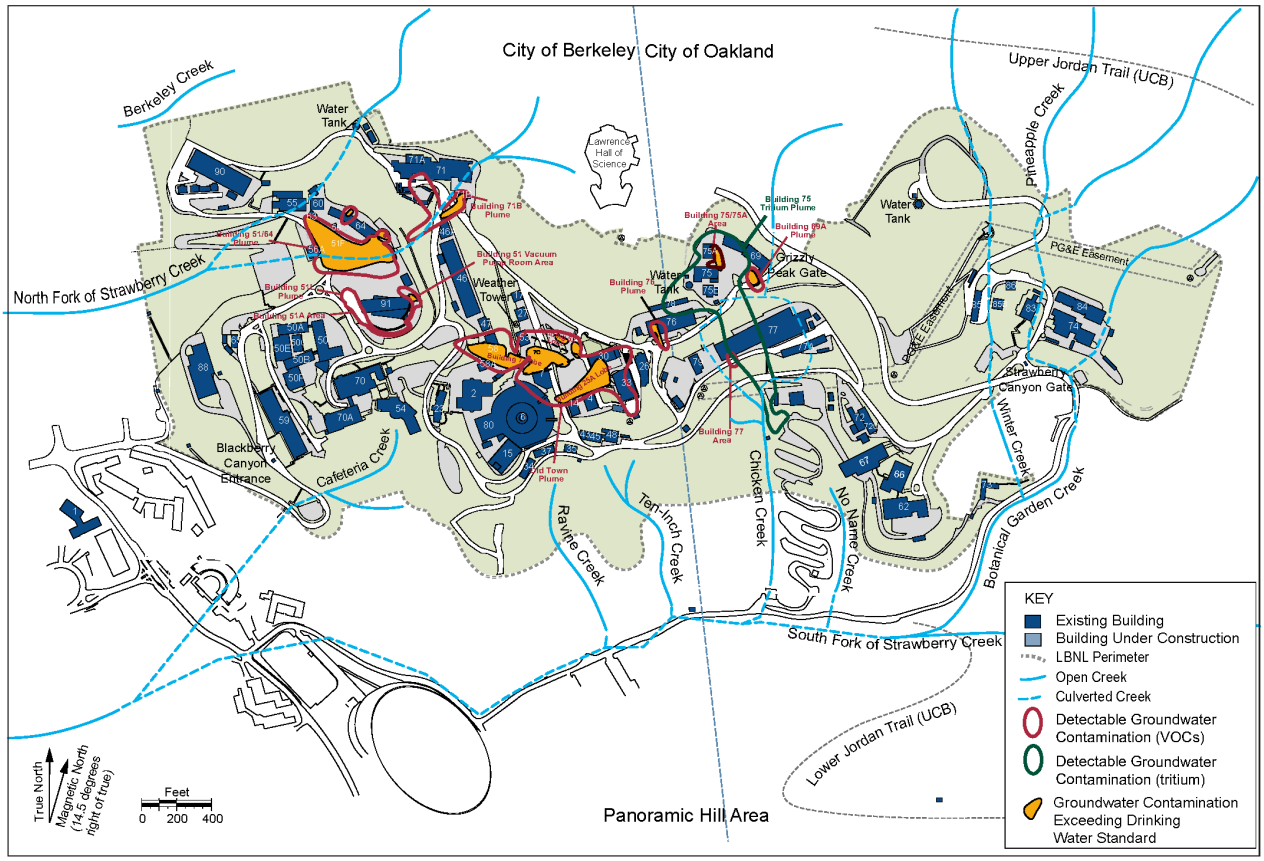

Figure 4-5 Locations of Groundwater Contamination

Tritium: A plume of tritium-contaminated groundwater extends southward from the Building 75 area. The source of the plume was the former National Tritium Labelling 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, 2016) since February 2005. The maximum concentration of tritium detected in 2018 was approximately 40% of the MCL. The location of this tritium plume is shown on Figure 4-5. Concentrations of tritium that were well below the drinking water standard were also previously detected in groundwater samples collected in the Building 71B area and beneath the central area of the former Bevatron site during demolition activities of this structure in 2010.

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 were in operation in 2018 to treat extracted groundwater, which totaled approximately 4.8 million gallons for the year. The cumulative volume of groundwater treated from 1991 through the end of 2018 exceeds 198 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 2018 and required by DOE Order 458.1 and guidance (DOE, 2015). Locations for soil and sediment sampling are shown on Figure 4-6.

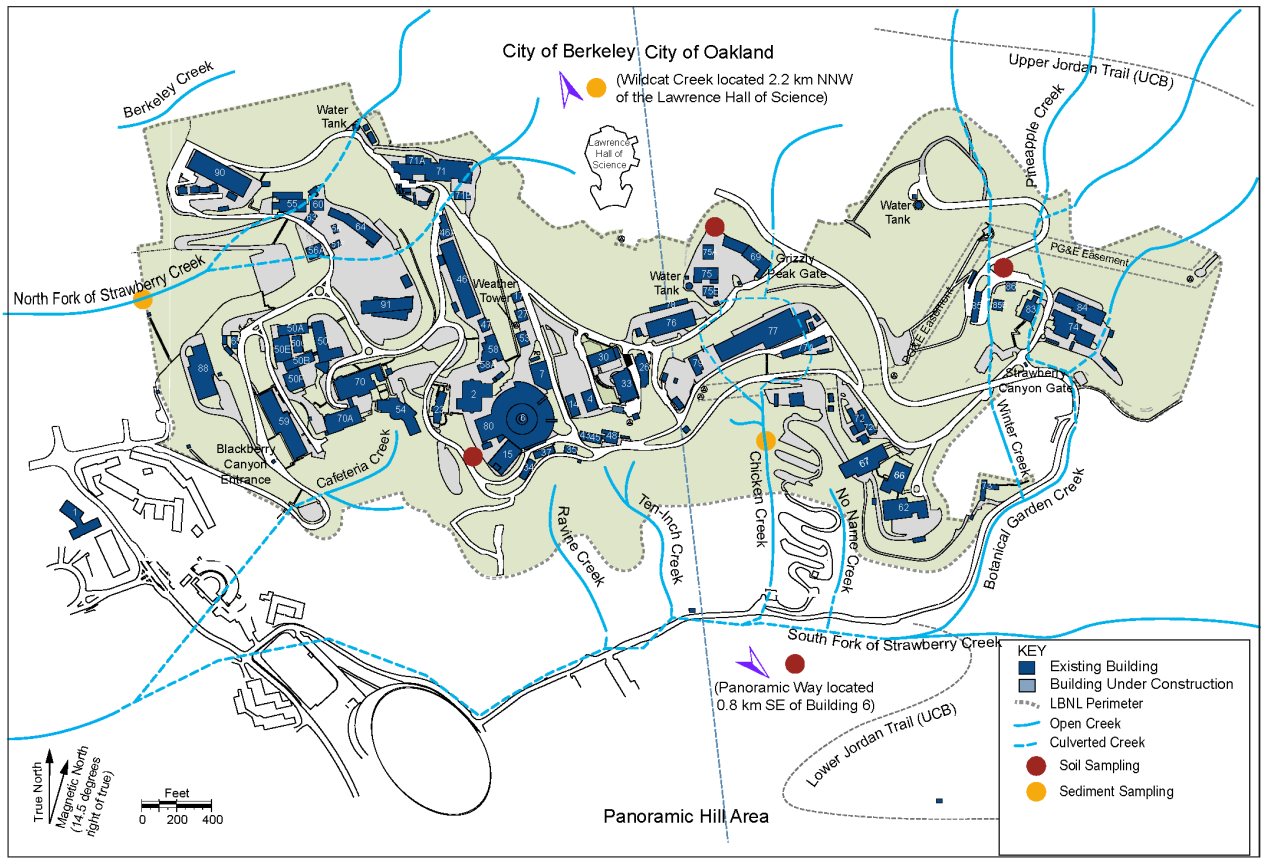

Figure 4-6 Soil and Sediment Sampling Sites

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 69, 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 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 detection limits.

Moisture content and pH levels at each of the sampling locations were within the historical range for soils at Berkeley Lab. With the exception of mercury, metals results were within both the established LBNL background levels (LBNL, 2009a) and levels commonly found in soils in the United States (Shacklette and Boerngen, 1984).

At the Building 80 sampling locations, mercury was detected at concentrations of 3.8 milligrams per kilogram (mg/kg), which is above the established LBNL soil background concentration for mercury (0.42 mg/kg) but below the RWQCB's commercial/industrial environmental screening level of 44 mg/kg (RWQCB, 2019) and DTSC's modified commercial/industrial screening level of 4.4 mg/kg (DTSC, 2019).

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, moisture content, pH, petroleum hydrocarbons (diesel and oil/grease), PCBs, and 15 metals. 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 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 non-radiological analysis for moisture content, pH, 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, 2009a) 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 2015, confirmed that although vegetation in the vicinity of the former NTLF hillside stack contains measurable tritium concentrations, the concentration continues to decrease. Concentrations in much of the area around this former stack are projected to decrease to below the detection limit by the next scheduled vegetation sampling event, which is in 2020.

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 two methods to determine the environmental radiological impact from accelerator operations:

1. Real-time monitors that continuously detect and record gamma radiation and neutron dose.
2. Passive detectors known as optically stimulated luminescence dosimeters, which provide an integrated dose over time from gamma radiation.

The real-time monitors are used to satisfy criteria in DOE Order 458.1. Passive detectors supplement the real-time monitors and confirm that the dose from LBNL 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).

4.8 RADIOLOGICAL CLEARANCE OF PROPERTY

Radiological clearance is the process by which property with the potential to contain residual radioactive material is evaluated and then transferred or disposed of. Requirements for this process are set by DOE Order 458.1, which specifies that property can be cleared only if it has been demonstrated that levels of radioactivity are indistinguishable from background. In addition, Berkeley Lab's safety principle of "as low as reasonably achievable" 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 does not contain residual radioactive material, or that residual radioactivity has been characterized sufficiently to demonstrate through process knowledge or radiological survey that it contains only levels of radioactive material indistinguishable from background. 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.

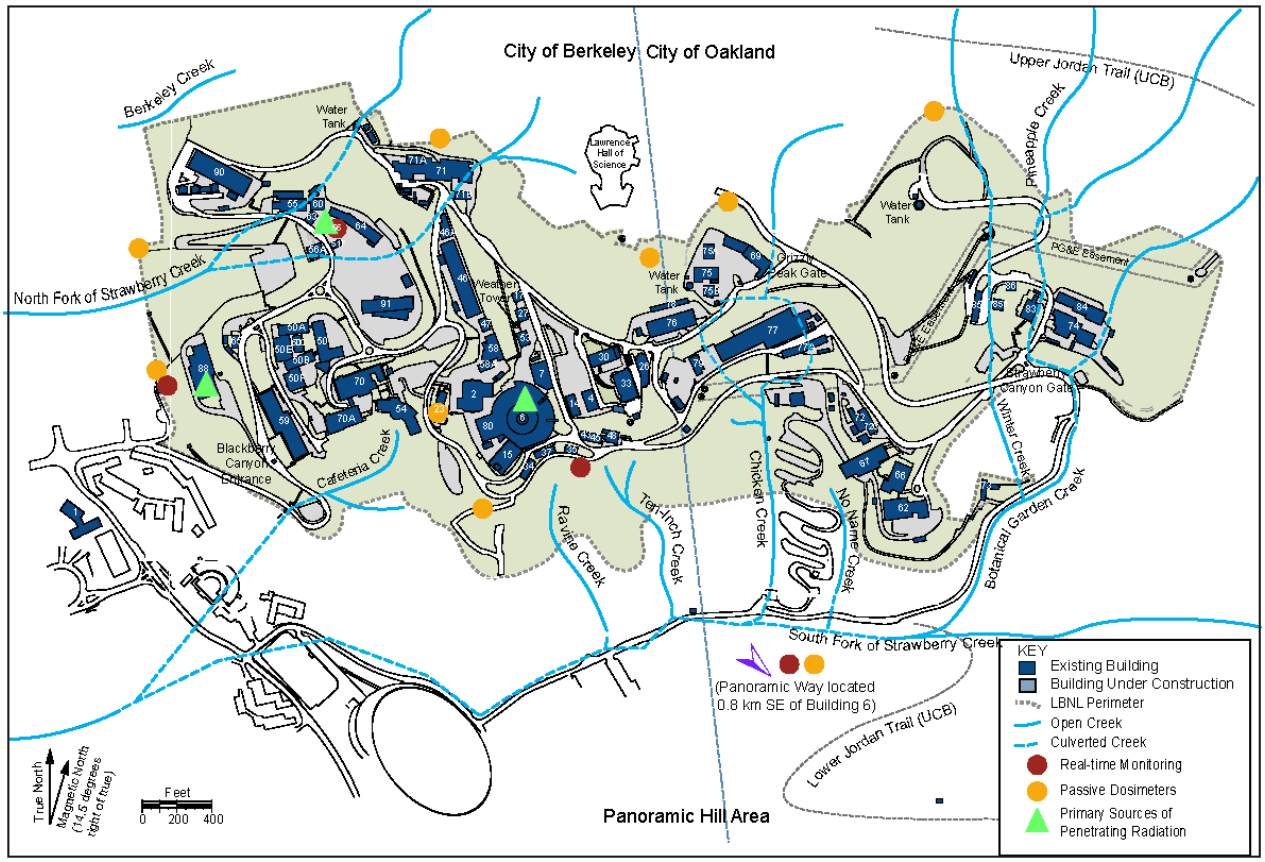

Figure 4-7 Environmental Penetrating Radiation Primary Sources and Monitoring Stations

In 2018, 143 release and clearance surveys were performed by Berkeley Lab's Radiation Protection Group, and 139 unrestricted release surveys were performed by subcontractors working at Berkeley Lab; the equipment may be subsequently reused on site or released to the public. Additionally, Berkeley Lab's radiological soil assessment program supported eight soil excavation projects during this time.

5 Radiological Dose Assessment

5.1 BACKGROUND

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).

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 then 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 as low as reasonably achievable. Berkeley Lab's environmental program ensures that a screening (qualitative) review is performed on activities that could result in a dose to the public or the environment (LBNL, 2013a). Potential dose from activities that may generate airborne radionuclides is estimated through the required National Emission Standards for Hazardous Air Pollutants (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 2018.

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 western boundary of the site was 5.42×10^{-1} mrem. This potential dose was located at the nearest residence, about 360 feet from the primary contributing source, which was the 88-Inch Cyclotron. This dose is statistically higher than the measured background for Berkeley Lab, but represents a small fraction (0.54%) 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 1.22 person-rem, based on the most recent population figure and measured dose around the perimeter of the site. A network of passive optically stimulated luminescence dosimeters located around the perimeter of Berkeley Lab 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 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 computer programs.

In late 2016, U.S. EPA Region 9 approved Berkeley Lab's request to use a streamlined approach to model dispersion of radiological air emissions through a single virtual stack to comply with NESHAP requirements. This methodology was then used to prepare the annual Radionuclide Air Emission Report submitted to the U.S. EPA. Previously, the dose assessment process was performed by collecting information and evaluating radionuclide emissions from approximately 10 grouped stack locations. Details of dose calculations from dispersible airborne radionuclide emissions are included in the *Radionuclide Air Emission Report for 2018* (LBNL, 2019).

Following 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, which is located at the northern edge of the site and downwind of the primary contributing source: fluorine-18 emissions from Buildings 55, 56, and 64. 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 2018, the calculated annual dose from airborne radionuclides was 3.71×10^{-3} mrem, which is approximately 0.04% of the DOE and U.S. EPA annual limit for airborne radionuclides of 10 mrem/yr (DOE, 2013; 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 the year was 3.99×10^{-2} 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 2018 was approximately 5.46×10^{-1} 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 0.15% of the average natural background radiation dose (310 mrem/yr) in the United States (NCRP, 2009), and approximately 0.5% of the DOE annual limit from all sources (100 mrem/yr) (DOE, 2013).

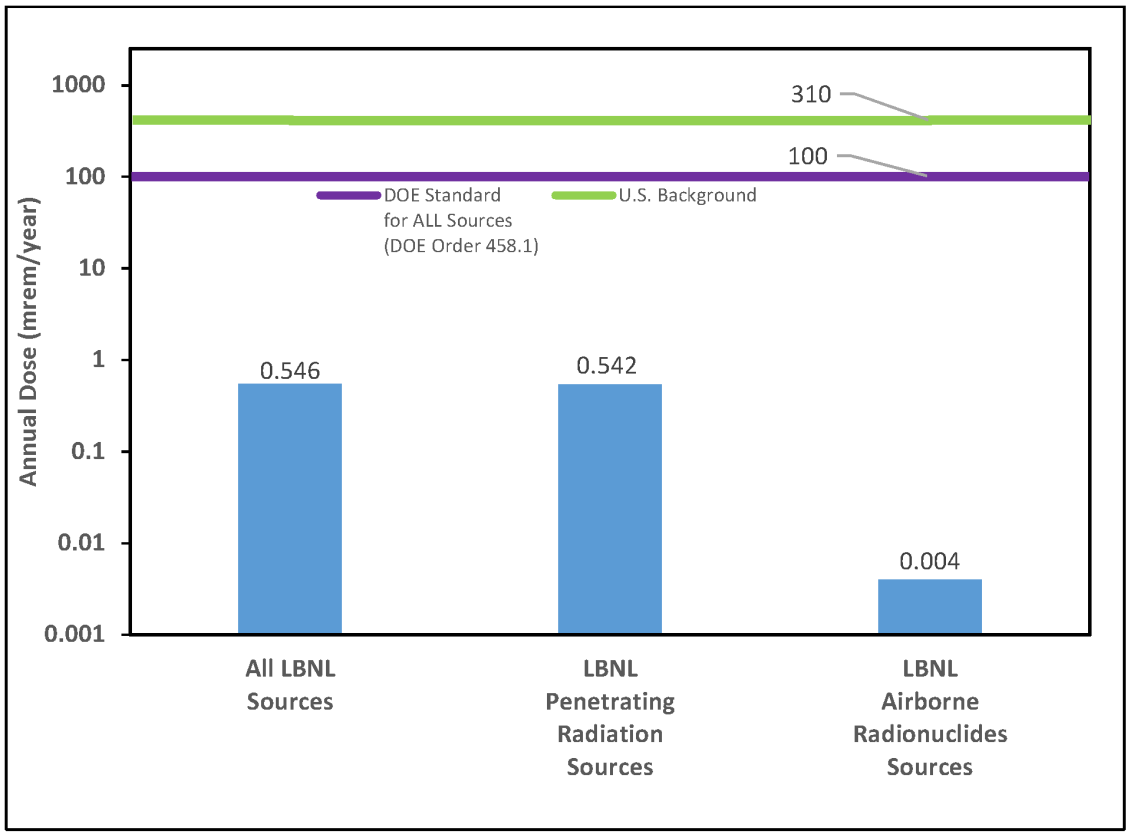

Figure 5-1 Comparative Radiological Doses for 2018

5.5 DOSE TO ANIMALS AND PLANTS

As described in DOE technical standard DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota* (DOE, 2002), 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

Creek water, soil, and sediment samples 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 process" described in the DOE technical standard (DOE, 2002) and confirmed that the calculated dose for terrestrial or aquatic systems is far below DOE dose limit requirements.

6 Quality Assurance

6.1 OVERVIEW

Berkeley Lab's overarching quality assurance (QA) policy is documented in the *Requirements and Policies Manual* (LBNL, 2014a). Details on the operating principles and practices used by organizations to achieve reliable, safe, and quality performance are provided in the *Quality Assurance Program Description* (QAPD) (LBNL, 2013c), which describes the elements necessary to integrate QA, management systems, and process controls into LBNL operations. The QAPD provides the framework for LBNL administrators, managers, supervisors, and staff to plan, manage, perform, and assess their work. EHS's Environment, Waste & Radiation Protection Department implements elements of the QAPD through its *Quality Management Plan* (LBNL, 2016a), which describes a graded approach to quality and programmatic assurance based on the scope of the department's technical programs.

Berkeley Lab's *Environmental Monitoring Plan* (LBNL, 2013b) and guidance from DOE (2015) and the U.S. EPA (1989) are also part of the QA system; indeed, 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. NESHAP stack air monitoring activities (LBNL, 2012b) and the Environmental Restoration Program (LBNL, 2009b) are examples of programs with a Quality Assurance Project Plan.

In 2018, Berkeley Lab had contracts with seven commercial analytical laboratories for specific analytical services:

1. ALS (Fort Collins, Colorado)
2. BC Laboratories (Bakersfield, California)
3. Enthalpy Analytical (Berkeley, California)
4. GEL Laboratories (Charleston, South Carolina)
5. Vista Analytical Laboratory (El Dorado Hills, California)
6. Landauer, Inc. (Glenwood, Illinois)
7. PAES (Pittsburgh, Pennsylvania)

All but the Landauer laboratory 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 (CDPH, 1994). These laboratories must meet demanding QA and QC specifications and certifications that were established to define, monitor, and document laboratory performance (LBNL, 2012c; DoD/DOE, 2018), and their QA and QC data is incorporated into Berkeley Lab's data quality assessment processes. The Landauer laboratory is certified by the DOE Laboratory Accreditation Program (DOELAP).

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 2018, all five analytical laboratories were accredited to perform for DOE facilities.

Complementing the objectives of Berkeley Lab's QAPD, the DOE Berkeley Site Office's Oversight and Issues Management Program (DOE/BSO, 2014) enables its staff to participate in LBNL operational activities such as field orientations, meetings, audits, workshops, document and information system reviews, and day-to-day communications. This interaction provides an effective and efficient means of meeting contractual requirements between DOE and UC while allowing Berkeley Lab to accomplish its assigned missions. This assurance system includes attributes such as metrics and targets to assess performance, rigorous self-assessment and improvement, identification and correction of negative performance trends before they become significant issues, and timely communication with BSO on assurance-related information.

6.2 ENVIRONMENTAL MONITORING SAMPLES AND RESULTS PROFILE

In 2018, a total of 2,354 individual air, sediment, soil, and water samples were collected under Berkeley Lab's environmental monitoring programs, both routine and project-specific, generating 44,857 analytical results. These numbers represent approximately 33% fewer results than in 2017 due to the scaling back of the groundwater monitoring program, Old Town Demolition Project, and IGB/MUP Project. Samples were obtained from over 760 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 (https://ehs.lbl.gov/resource/environmental-restoration-program/) or in hard copy at the main branch of the Berkeley Public Library.

The sampling result totals include those from all activities associated the Old Town Demolition Project that were carried out by the demolition subcontractor and provided to Berkeley Lab. These projects accounted for over 64% of the environmental monitoring programs' sampling locations, almost 45% of the individual samples collected, and nearly 38% of the analytical results in 2018.

6.3 SPLIT AND DUPLICATE SAMPLING FROM ENVIRONMENTAL MONITORING

An essential activity undertaken to measure the quality of environmental monitoring results is the regular collection and analysis of split and duplicate samples. In 2018, a total of 49 split and 121 duplicate samples were collected for either radiological or non-radiological analyses, or both. These samples led to 591 split and 1,695 duplicate results. In addition, 187 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.

6.4 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.

During the year, the five analytical laboratories performed 2,730 radiological and non-radiological 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.

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Abbreviations

AEDE	annual effective dose equivalent
AST	aboveground storage tank
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan for the San Francisco Bay Basin
BTU	British thermal unit
CARB	California Air Resources Board
CatEx	categorical exclusion
CCCSD	Central Contra Costa Sanitary District
CCHS	Contra Costa Health Services
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CFATS	Chemical Facility Anti-Terrorism Standards
CFR	Code of Federal Regulations
Ci	curie
CUPA	Certified Unified Program Agency (California)
DCS	derived concentration standard
DHS	Department of Homeland Security
DOE	U.S. Department of Energy
DOECAP	Department of Energy Consolidated Audit Program
DTSC	Department of Toxic Substances Control (California)
E85	85% ethanol / 15% unleaded gasoline fuel blend
EBMUD	East Bay Municipal Utility District
EHS	Environment/Health/Safety Division at Berkeley Lab
ELAP	Environmental Laboratory Accreditation Program
EMS	Environmental Management System
EPCRA	Emergency Planning and Community Right-to-Know Act
EPEAT	Electronic Product Environmental Assessment Tool
ESG	Environmental Services Group
F	Fahrenheit
FTU	fixed treatment unit

FY	fiscal year (October 1 through September 30)
GAC	granular activated carbon
gal	gallon(s)
GHG	greenhouse gas
HMBP	Hazardous Materials Business Plan
HPSB	high-performance sustainable building
IGB	Integrative Genomics Building
ISO	International Organization for Standardization
JCAP	Joint Center for Artificial Photosynthesis
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
MUP	Modular Utility Plant
NAL	Numeric Action Level
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOD	Notice of Deficiency
NTLF	National Tritium Labelling 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
SF_6	sulfur hexafluoride
SIC	Standard Industrial Classification
SPCC	Spill Prevention, Control, and Countermeasure
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
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

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.

annual effective dose equivalent (AEDE)

The largest amount of ionizing radiation a person may receive in a given year. It combines the internal and external dose. The AEDE limit is prescribed for various organs, as well as the whole body, and various working conditions. The AEDE limit is 5,000 mrem/year.

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.

Certified Unified Program Agency (CUPA)

A local agency certified under DTSC to administer hazardous materials management and environmental protection programs. For Berkeley Lab, three different CUPAs coordinate and enforce the HMBP, AST, UST, and hazardous waste generator programs; the on-site hazardous waste tiered treatment permitting program; the SPCC Plan program; and the California Accidental Release Prevention Program.

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. *See also* effective dose equivalent.

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 (EDE)

The sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The EDE includes the committed EDE from internal deposition of radionuclides and the EDE due to penetrating radiation from sources external to the body. EDE is expressed in units of rem. *See also* dose.

effluent

A liquid waste discharged to the environment.

effluent monitoring

The collection and analysis of samples or measurements of liquid discharges for the purpose of characterizing and quantifying contaminants, assessing exposures of members of the public, and demonstrating compliance with applicable standards and permit requirements. Effluent is usually monitored at or near the point of discharge.

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 for possible contaminants. Environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance.

environmental surveillance

The collection and analysis of samples, or direct measurements, of air, water, soil, foodstuff, biota, and other media 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

The sum of the radiation doses to individuals of a population. It is expressed in units of person-rem. For example, if 1,000 people each received a radiation dose of one rem, their 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.

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.

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