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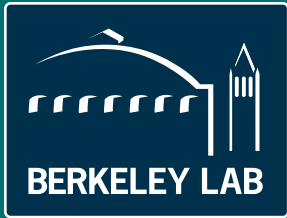
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Lawrence Berkeley
National Laboratory

Site Environmental Report for 2015

Environment/Health/Safety Division

September 2016



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Subject: 2015 Site Environmental Report (SER) for the Ernest Orlando Lawrence Berkeley National Laboratory (LBNL)

This report, prepared by LBNL for the U.S. Department of Energy, Berkeley Site Office (DOE/BSO), provides a comprehensive summary of the environmental program activities at LBNL for calendar year 2015. 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 2015 environmental monitoring, compliance, and restoration programs at LBNL. This assurance can be made based on the reviews conducted by DOE/BSO, and LBNL, as well as quality assurance protocols applied to monitoring and data analyses at LBNL.

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

Questions or comments regarding this report may also be made directly to DOE/BSO, by contacting Mr. Kim Abbott of the Berkeley Site Office at (510) 486-7909, or by mail to the address above, or by email kim.abbott@science.doe.gov.

Sincerely,

A handwritten signature in blue ink that reads "Paul Golan".

Paul Golan
Site Office Manager

Site Environmental Report for 2015

September 2016

Cover photo: To the right of the dome of the ALS (Building 6) is Chu Hall (Building 30), a LEED Gold Certified building that houses research laboratories and offices devoted to nanoscale photovoltaic and electrochemical solar energy systems. The grassy area shown represents a green roof designed to reduce and filter stormwater runoff. © 2016 The Regents of the University of California, through the Lawrence Berkeley National Laboratory.

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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). LBNL's research is directed toward 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 Berkeley Lab operations conducted in 2015. The format and content of this report satisfy the requirements of both DOE Order 231.1B Admin Chg 1, *Environment, Safety, and Health Reporting*, and the operating contract between UC and DOE.

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. Berkeley Lab implements an environmental management system (EMS) to oversee these compliance activities and improve overall environmental performance while maintaining operational capability and sustaining the overall mission.

The effectiveness of the EMS and environmental programs is reviewed annually as part of the operating contract's performance evaluation process. For fiscal year (FY) 2015, which began October 1, 2014, and ended September 30, 2015, the EMS was given a performance rating of B+ for its management of environmental activities (A+ is the highest grade, F is the lowest). The measures and rating system is developed jointly by Berkeley Lab, UC, and DOE, and the rating is based both on how the EMS successfully implemented elements of the International Organization for Standardization's (ISO) International Standard 14001:2004, *Environmental Management Systems—Requirements with Guidance for Use*, and on how well Berkeley Lab performed in completing numerous projects that reduced environmental impacts.

The EMS was also graded through the federal Office of Management and Budget's EMS Annual Report Data, in which elements of the ISO 14001 standard were rated and the degree of integration between the EMS and Berkeley Lab's sustainable practices was measured. Overall scores fall into one of three ranges: green (highest), yellow (middle), or red (lowest). For FY 2015, Berkeley Lab received a score of green, as described in more detail in Chapter 2.

An overview of environmental protection and restoration programs is provided (Chapter 3), including information about compliance activities, operating permits, and regulatory agency inspections that occurred during 2015. Six minor violations issued during these inspections are also discussed in Chapter 3. This report also includes information on environmental monitoring performed in 2015 (Chapter 4). The results of these monitoring activities confirmed that environmental restoration actions continue to show improving conditions, and all emissions and discharges from Berkeley Lab operations were within environmental compliance release limits with the exception of some stormwater discharges. While most stormwater discharges measured throughout the LBNL site fall within acceptable levels established by the state's stormwater permit, iron and aluminum exceeded permitted levels. LBNL is aggressively implementing controls to reduce iron and aluminum discharge levels including construction of asphaltic berms to control and filter runoff to stormdrains and installation of filtration units in stormdrain basins to absorb metal contaminants.

The radiation dose assessments (Chapter 5) performed in 2015 found that the maximum dose to an individual from LBNL's airborne radionuclide releases was approximately 0.08% of the DOE and U.S. Environmental Protection Agency annual limit of 10 millirem per year (mrem/year), and the dose from all radiation sources at LBNL was approximately 0.1% of the average natural background radiation dose (310 mrem/yr) in the United States, and about 0.4% of the DOE annual limit from all sources (100 mrem/yr).

Preface

Each year the University of California 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 meets the reporting requirements of U.S. Department of Energy Order 231.1B Admin Chg 1, *Environment, Safety, and Health Reporting*, and includes the following information:

- Site environmental management performance
- Environmental occurrences and responses
- Environmental compliance
- Significant programs and efforts
- Property clearance activities

The report is organized into six chapters that provide an overview of LBNL, a discussion of its environmental management system, the status of environmental compliance programs, summarized results from surveillance and monitoring activities, radiological dose assessment results, and quality assurance measures. The Site Environmental Report can be viewed or downloaded from the Berkeley Lab Environmental Services Group's (ESG's) web page (<http://www2.lbl.gov/ehs/esg/>), where many of the documents cited in this report can also be found.

This report was prepared under the direction of ESG's environmental manager, Ron Pauer. Primary contributors include David Baskin, Ned Borglin, Robert Fox, Zachary Harvey, John Jelinski, Maram Kassis, Brendan Mulholland, Nancy Sutherland, Patrick Thorson, Petra Wehle, and Suying Xu. If you have comments or questions, contact Ron Pauer at ropauer@lbl.gov or 510-486-7614. To provide feedback on the report, complete a reader survey form, available on ESG's Publications page: <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>.

1. Site Overview

1.1 INTRODUCTION

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 where unclassified research is conducted across a wide range of scientific disciplines by nearly 4,000 scientists, engineers, support staff, and students who work there year round, and by several thousand national facility users and visiting researchers whom Berkeley Lab hosts each year. This chapter provides an overview of the location and physical features of the main site.

1.2 LOCATION

Figure 1-1 shows the location of LBNL's main site and nearby satellite facilities in the East Bay of the San Francisco Bay Area. The main site is located about three miles east of San Francisco Bay on land owned by UC. It is situated on the ridges and in the draws of Blackberry and Strawberry Canyons in the East Bay Hills on approximately 200 acres of land east of the UC Berkeley campus, straddling the border between the cities of Berkeley and Oakland in Alameda County. Satellite facilities in Berkeley, Emeryville, Oakland, and Walnut Creek consist of leased buildings in developed urban areas. Research activities at the Joint Center for Artificial Photosynthesis relocated to the main site in mid-2015 to occupy the newly constructed Building 30.

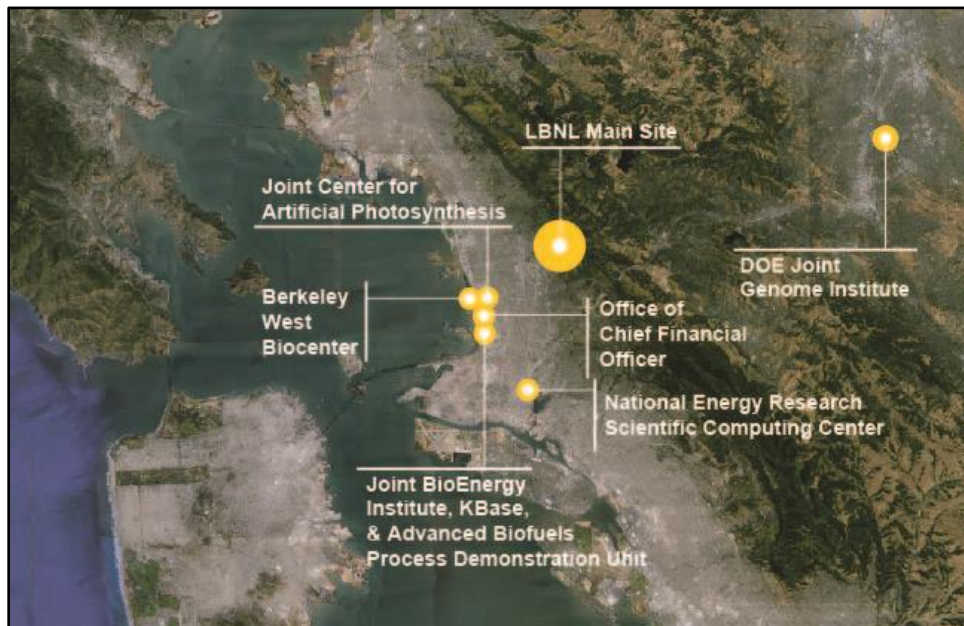


Figure 1-1 LBNL Main Site and Satellite Facility Locations in the East Bay

As shown on Figure 1-2, Berkeley Lab is located within a large area owned by UC. Within this area most of the land to the south and east of the Lab is maintained in its natural state and adjoins park and recreation areas. Nearby points of interest include UC Berkeley’s Strawberry Canyon Recreational Area, Botanical Garden, and Lawrence Hall of Science. To the north of the Lab is a residential neighborhood of low-density single-family homes, and to the west is a highly urbanized area that includes the UC Berkeley campus, commercial zones, and residential areas.

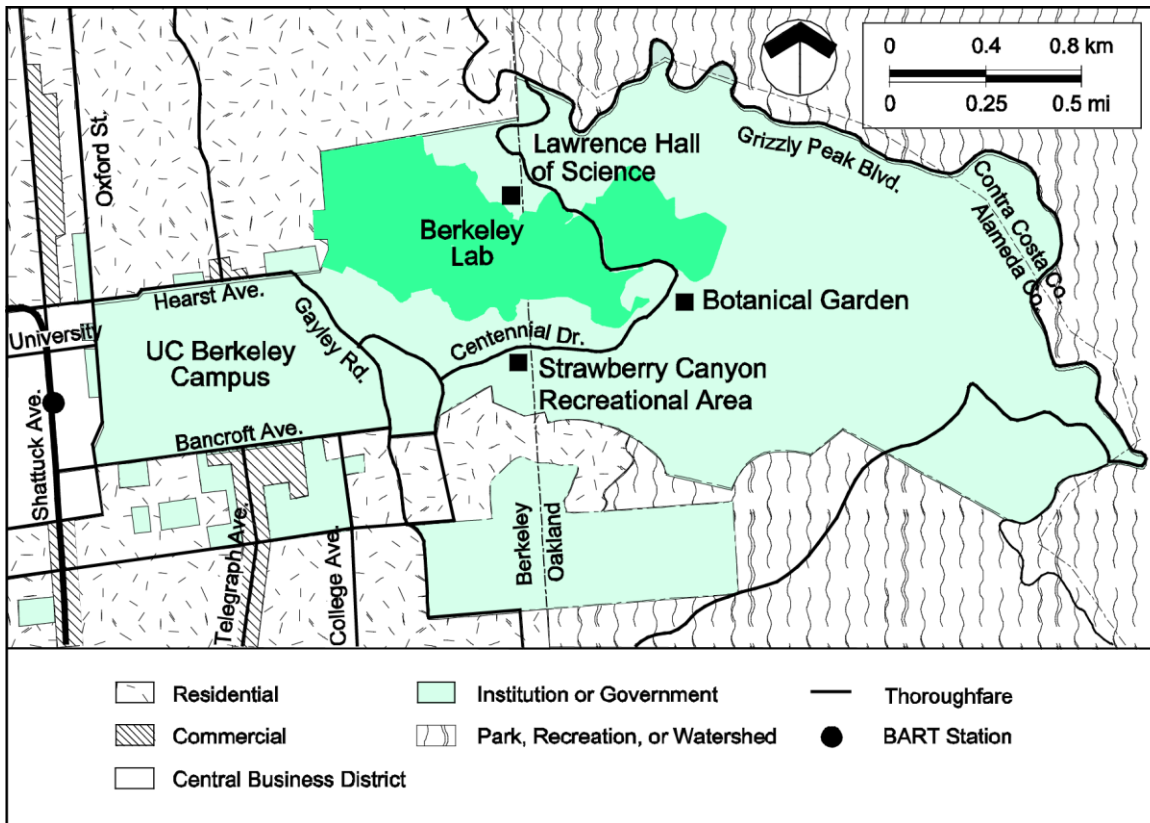


Figure 1-2 Adjacent Land Use

1.3 ENERGY SUPPLY

All electric power for the site is provided by the Western Area Power Administration. Power purchases are arranged through DOE’s Northern California Power Purchase Consortium, which serves the electric power needs of DOE facilities in the San Francisco Bay Area, namely, Berkeley Lab, Lawrence Livermore National Laboratory, and the SLAC National Accelerator Laboratory. Natural gas is provided by the Defense Logistics Agency and is transported through infrastructure belonging to Pacific Gas and Electric Company.

1.4 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 the 1974 Safe Drinking Water Act. Three large tanks store water for emergencies. No drinking water wells are located on site.

1.5 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. The annual average temperature is 55 degrees Fahrenheit (°F), with temperatures between 40°F and 70°F over 95% of the time. The temperature seldom exceeds 90°F or drops below 32°F. The maximum and minimum temperatures in 2015 were 87°F and 35°F, respectively.

Based on more than 40 years of measurements on site, the precipitation total for a “water year” averages 30.1 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 better characterizes California’s seasonal rainfall cycle than rainfall occurring during a calendar year. The precipitation total for the 2014/2015 water year – at 22.8 inches – shows rainfall below average for the fifth consecutive year, continuing the extraordinary drought affecting California.

Wind patterns recorded at the on-site meteorological station change little from year to year, as shown by the “wind rose” comparison on Figure 1-3. The graphic on the left shows the distribution of wind patterns for 2015, while the one on the right summarizes the wind patterns at the site since 1994. The most common wind pattern

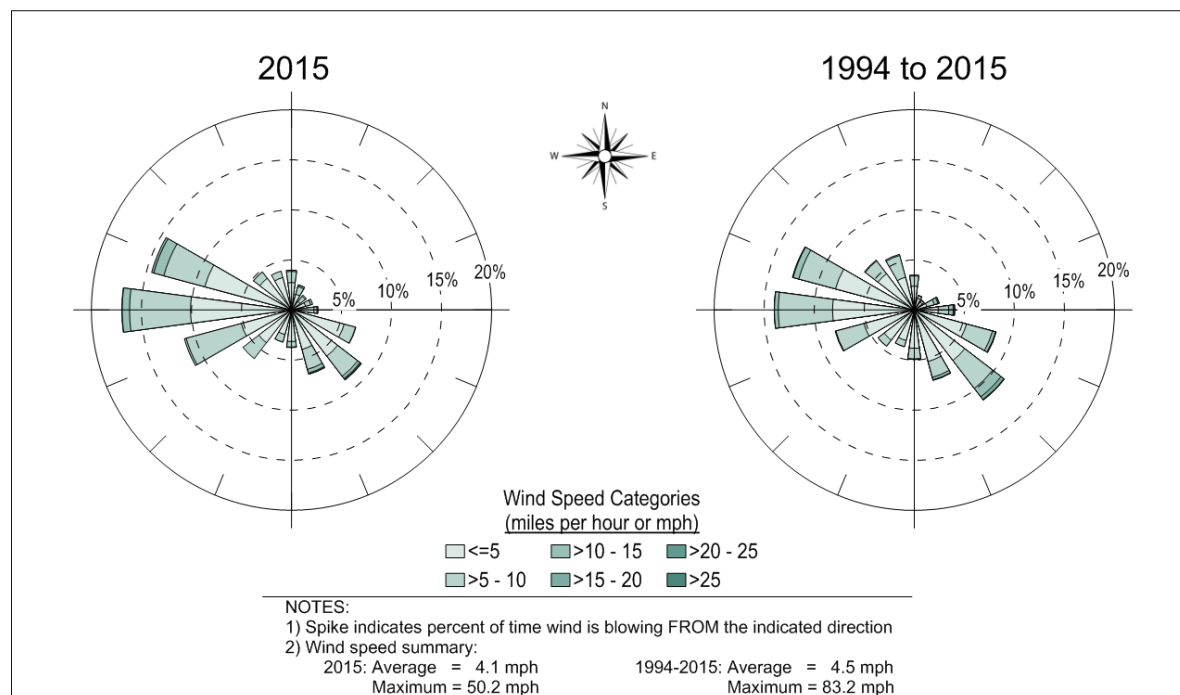


Figure 1-3 Annual Wind Patterns from 1994 to 2015

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 blow in advance of each system, followed by a shift to west or northwest winds after its passage.

1.6 VEGETATION

Figure 1-4 shows the vegetation and ground cover at and around the Berkeley Lab site, which includes native plants, naturalized exotics, and ornamental species. This region was intensively grazed and farmed for about 150 years before Berkeley Lab development began in the 1930s. Vegetation is now managed in harmony with the local natural succession of native plant communities, as is evident in the less developed areas, where the wooded and savanna character is being maintained. Ornamental species are generally restricted to courtyards and areas adjacent to buildings. There are no known rare, threatened, or endangered plant species on site.



Figure 1-4 Vegetation at and Surrounding LBNL Site

1.7 WILDLIFE

Wildlife is abundant at Berkeley Lab because the site is adjacent to open space land owned by the East Bay Regional Park District and UC. The wildlife that lives on site or traverses it is typical of that found in disturbed (previously grazed) areas of mid-latitude California with a temperate climate, and is thought to include more than 120 species of birds, mammals, reptiles, and amphibians. The most abundant large mammal is the Columbian black-tailed deer.

The following habitats on site are protected by environmental laws:

- A small area of about one acre on the south-facing slope of LBNL's Blackberry Canyon has been identified as a site where an arachnid called Lee's Micro-Blind Harvestman (*Microcina leei*) occurs. *Microcina leei* is listed as a "special animal" by the California Department of Fish and Wildlife.
- An approximately five-acre area at the eastern boundary is included in the U.S. Fish and Wildlife Service's designated critical habitat for the Alameda whipsnake (*Masticophis lateralis euryxanthus*). This snake species is listed as threatened under both federal and state law.

1.8 GEOLOGY

The three principal bedrock units underlying the site are described below:

1. The western and southern portions of the site are underlain by marine siltstones and shales of the Great Valley Group. The permeability of these rocks is relatively low, with groundwater flow controlled through open fractures rather than through pore spaces.
2. Non-marine sedimentary rocks of the Orinda Formation overlie the Great Valley Group and constitute the exposed bedrock over most of the site's developed area. The Orinda Formation consists primarily of sandstones, mudstones, and conglomerates deposited in fluvial and alluvial environments. Groundwater typically moves at a lower rate in this formation than in the underlying Great Valley Group or overlying Moraga Formation; therefore, this formation impedes the horizontal and vertical flow of groundwater.
3. The Moraga Formation 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, and although the rock's permeability is low, groundwater flows readily through the numerous open fractures.

In addition to the three main units described above, the Claremont Formation (primarily marine chert and shale) and the San Pablo Group (primarily marine sandstones) underlie the easternmost area of the site.

Surface materials consist primarily of soil, colluvium (soil accumulated at the foot of a slope), and artificial fill. Soil derived primarily from the bedrock units has accumulated to typical thicknesses of three or more feet across much of the site. Cutting and filling of the hilly terrain has been necessary to provide suitable building sites, resulting in up to tens of feet of engineered cuts and fills at some locations.

1.9 SURFACE WATERS

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

1.10 GROUNDWATER

Groundwater elevation contours are also shown on Figure 1-5. The water table approximately mirrors surface topography, flowing from higher to lower elevation. Groundwater flow in the western portion is generally

westward toward Blackberry Canyon, while flow in the remainder 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.

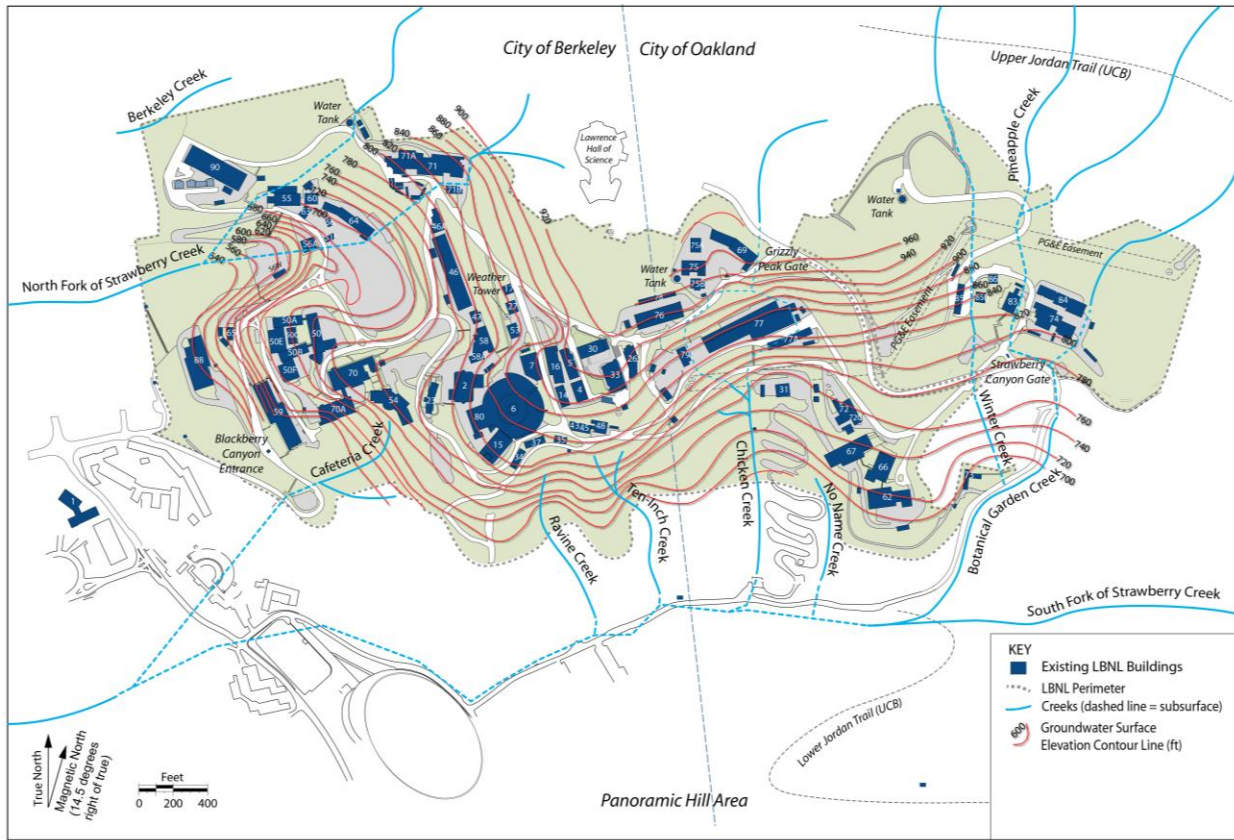


Figure 1-5 Map Showing Surface Water and Groundwater Elevation at Berkeley Lab

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, 2004). This standard was revised in September 2015 and includes a provision for a three-year transition period to implement new requirements. A DOE order citing the revised standard is anticipated in 2016.

As required, Berkeley Lab has an established EMS that ensures that environmental activities are well managed and cost-effective while reducing environmental impacts. The EMS also strives for continual improvement through the four-step “Plan-Do-Check-Act” framework for management systems.

Berkeley Lab’s EMS-based environmental policy commits to the following 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

The framework for implementing this policy incorporates the elements of the ISO 14001 standard into Berkeley Lab’s *Environmental Management System Plan* (LBNL, 2012a). This plan and related documents are available online at <https://commons.lbl.gov/display/SBL/Environmental+Management+System>.

DOE Order 436.1 also requires that a site’s sustainability goals be integrated into the EMS. Berkeley Lab’s *Site Sustainability Plan for FY2016* (LBNL, 2015a) 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)
- Electronic stewardship (life-cycle management)
- Climate change resilience

In total, more than 30 sustainability goals are set forth in these areas by federal legislation and formalized by executive order, primarily Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, issued in 2015. The new executive order, issued in March 2015, significantly raises and expands sustainability goals that have been in place since 2009 under Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*. The new executive order also creates an “opportunity to reduce agency direct greenhouse gas emission by at least 40 percent over the next decade while at the same time fostering innovation, reducing spending, and strengthening the communities in which our Federal facilities operate.” Berkeley Lab updates its sustainability plan each year and publishes it online at <http://sbl.lbl.gov/results/reports.html>.

2.2 EMS IMPLEMENTATION

Berkeley Lab addresses elements of the ISO standard through its *Environmental Management System Plan* (LBNL, 2012a) and implementing procedures as described in the following sections.

2.2.1 EMS Core Team

The Core Team is tasked with implementing and maintaining LBNL’s EMS. The team includes representatives from organizations essential to meeting the site’s environmental objectives, namely, Environment/Health/Safety (EHS), Facilities, Procurement and Property Management, and Sustainable Berkeley Lab. An EHS representative leads the team, and a DOE Berkeley Site Office representative attends scheduled meetings to maintain awareness. A formal meeting was held in August, but efforts to achieve environmental and sustainability performance goals continued throughout the year.

The Core Team has the following primary responsibilities:

- Identifying environmental aspects and determining their significance
- Developing objectives and targets for significant aspects
- Preparing and implementing environmental management programs (EMPs)
- Coordinating internal and external audits of the EMS
- Reviewing performance results
- Preparing materials for management reviews

2.2.2 Environmental Aspects

As part of the “plan” step for a management system, the Core Team routinely reviews environmental aspects (i.e., any activity, product, or service that interacts, whether adversely or beneficially, with the environment) associated with Berkeley Lab research and operations. The approximately 40 environmental aspects, with no new aspects added in 2015, are grouped into the following categories:

- Emissions and discharges
- Waste generation and recycling
- Materials and resources
- Land and building development and use

The Core Team's review includes scoring each aspect with a risk grade (low, medium, high) on each of the following factors:

- Cost
- Duration
- Effect on Berkeley Lab's mission
- Effect on public image
- Potential for improvement
- Potential legal exposure
- Probability of occurrence
- Severity of impacts

2.2.3 Environmental Management Programs

As part of the "do" step for a management system, the Core Team's scoring described above determines which of Berkeley Lab's environmental aspects are significant. Aspects deemed significant then require development and maintenance of an EMP document to define the objective, target, strategy, and actions for reducing impacts to the environment. The 2015 annual review identified no change from the previous year to the seven significant aspects.

The current set of EMPs remains as follows:

1. Energy use
2. Greenhouse gas (GHG) emissions
3. Petroleum use
4. Solid waste diversion
5. Sustainable acquisition
6. Traffic congestion
7. Water use

This set of EMPs managed under Berkeley Lab's EMS is also part of more than 30 sustainability goals mentioned in Section 2.1. The objective, target, and status of each EMP are summarized in Table 2-1. Berkeley Lab's *Site Sustainability Plan for FY2016* (LBNL, 2015a) contains more details on changes, strategy, and actions for all sustainability goals.

2.2.4 Training

Training is targeted and graded, commensurate with EMS roles and responsibilities. Training is provided at three levels of increasing rigor, as follows:

- **General EMS awareness.** Content is integrated into course LBNL0010, Safety, Emergency Preparedness, and Trafficking Persons, training that is required for all personnel new to LBNL.
- **Comprehensive EMS awareness.** Intended for EMS Core Team members, content covers the basics of the ISO 14001 standard and applicability to Berkeley Lab.

- **EMS implementation and EMS auditor.** Intended for EMS professionals, training includes multi-day courses taught by specialized organizations.

Table 2-1 Environmental Management Programs

Aspect/Activity	Objective(s)	Target(s)	Status at End of FY 2015
Energy Use	Implement sustainable practices to achieve energy efficiency	Reduce energy use intensity 30% by end of FY 2015	Consumption was 5% above baseline and 1% higher than previous FY (did not attain target).
Greenhouse Gas (GHG) Emissions	Track, report, and reduce GHG emissions from LBNL activities	Reduce Scope 1 ^(a) and 2 GHG emissions by 28% and selected Scope 3 ^(b) emissions 13% by end of FY 2020 (baseline: FY 2008)	Scope 1 and 2 emissions were 13% below baseline and 6% higher than previous FY Scope 3 emissions were 14% below baseline and 9% lower than previous FY.
Petroleum Use	Reduce vehicle fleet petroleum consumption	Reduce fleet's annual petroleum consumption by 2% annually (baseline: FY 2005 fleet fuel consumption)	Consumption was 78% below baseline and 6% lower than previous FY.
Solid Waste Diversion	Increase solid waste diversion	Divert at least 75% of non-hazardous solid waste, excluding construction and demolition debris, by end of FY 2015. Divert at least 75% of construction and demolition debris by end of FY 2015.	45% diversion for non-hazardous solid waste and 9% lower than previous FY (did not attain target). 84% diversion for construction and demolition debris, the same as previous FY.
Sustainable Acquisition	Increase procurement opportunities for environmentally sustainable products	Increase the percentage of priority sustainable products purchased (baseline: FY 2012).	Where applicable, in FY 2015, 87% of new applicable subcontract actions, which included all construction contract actions, were reviewed to ensure they included applicable sustainable acquisition provisions and clauses.
Traffic Congestion	Reduce commute traffic through transportation demand management; report Scope 3 GHG emissions	Optimize parking. Facilitate/promote non-single-occupant vehicle commuting. Enhance shuttle bus operations. Plan for off-site construction truck trips within the limits of the LBNL <i>Long Range Development Plan's Environmental Impact Report</i> .	No metrics in place at present.
Water Use	Implement sustainable practices to reduce water use intensity	Reduce potable water use consumption intensity 26% by end of FY 2020 (baseline: FY 2007). Reduce industrial/landscaping/agricultural water use 20% by end of FY 2020 (baseline: FY 2010). Update and execute annual Water Metering Plan.	Consumption was 25% below baseline (did not attain target for potable water). Berkeley Lab did not use external sources for industrial/landscaping/agricultural water use in baseline year FY 2010 (no metric possible).

^a Scope 1 and 2 emissions are direct and indirect GHG emissions from sources owned or controlled by LBNL. Scope 1 can include emissions from fossil fuels burned on site or entity-leased vehicles. Scope 2 can include emissions resulting from the generation of purchased electricity.

^b Scope 3 emissions include indirect GHG emissions from sources not owned or directly controlled by LBNL, but related to LBNL's activities. The most common activity is GHG emissions associated with employee travel and commuting.

2.2.5 Audit

As part of the “check” step for a management system, Berkeley Lab is required by DOE to conduct a formal audit of its EMS once every three years, by a qualified party outside of the control or scope of the EMS. The purpose of the audit is to verify that Berkeley Lab’s EMS conforms to the ISO 14001 standard, as required by the Contractor Requirements Document of DOE Order 436.1, *Departmental Sustainability*. An external audit in May met these requirements. The auditors conducted a desktop review of program documents and a weeklong series of interviews and site visits and noted the following conclusions:

- One strength of the EMS was noted for collaboration on a new sitewide waste diversion program.
- No major nonconformances.
- Three minor nonconformances, as follows: Neither a management review nor an internal audit were held within the frequencies stated in Berkeley Lab procedures. Also, the new Berkeley Lab Work Planning and Control process did not include environmental hazards and controls as part of authorizing work activities at Berkeley Lab, which represents an operational control nonconformance.

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, contingent on Berkeley Lab preparing a corrective action plan to address the three findings. The DOE Berkeley Site Office declared the EMS in conformance with the ISO standard in late June.

2.2.6 Management Review

As part of the “act” step for a management system, senior management of organizations involved in implementing the EMS must meet periodically meet the EMS Program Manager to review program status. At a minimum, the following topics cited in the ISO 14001 standard are covered:

- Results of internal audits and evaluations of compliance with legal and other requirements
- Communications from external interested parties
- Berkeley Lab’s environmental performance
- The extent to which objectives and targets have been met
- Status of corrective and preventive actions
- Follow-up actions from previous management reviews
- Changing circumstances, including developments in legal and other requirements
- Recommendations for improvement

A management review held in September focused on the status of the corrective actions stemming from the external audit of the EMS held in May and included a discussion on options for hosting future management review meetings that will foster greater involvement from the entire Berkeley Lab community. A detailed document was prepared and distributed in advance of the meeting. This document provided in-depth information on the status of each topical area and allowed the meeting to focus on critical issues.

2.2.7 Environmental Management Performance and Highlights

At the end of each fiscal year (FY), which begins October 1 of one year and ends September 30 of the following year, Berkeley Lab is required to report on the performance of its EMS. One reporting is through the operating contract between DOE and UC. The second reporting is broader and is required of all federal agencies and their contractors.

2.2.7.1 DOE's EMS Performance Evaluation

On a scale ranging from A+ (best) to F (worst), Berkeley Lab received a score of "B+" for providing an effective and efficient EMS in DOE Berkeley Site Office's Performance Evaluation Report for FY 2015 (DOE Berkeley Site Office, 2015). This evaluation is based on objectives in DOE's FY 2015 *Performance Evaluation and Measurement Plan*; both the plan and report are required by the operating contract between DOE and UC. The following activities contributed to earning a high performance score:

- Preparing for compliance with the new California Industrial General Permit for stormwater discharges that became effective July 1, 2015. Compliance involved updating the program's key document (Stormwater Pollution Prevention Plan) for the main site, determining appropriate sampling locations, and briefing LBNL management on pending regulatory changes.
- Reducing the risk of noncompliance with stormwater regulations by ensuring that outdoor collection bins for metal materials are securely covered, and collaborating with Property Management staff to implement a system for tracking metal hopper use around the site.
- Streamlining the regulatory process for cleanup of polychlorinated biphenyls (PCBs) associated with the Old Town Demolition Project – Phase I site by conducting monthly meetings with the U.S. Environmental Protection Agency (EPA).
- Diligently supporting the Old Town Demolition Project – Phase I by recommending compliance strategies and assisting with preparation of essential project documents required of the subcontractor.
- Preparing a technical basis document for the radionuclide compliance program, as required under National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations, that justifies a shift from modeling numerous emission sources scattered around the site to modeling the annual dose assessment using a single virtual source to represent the radionuclide emissions from the entire site. This reduces the time needed to generate information for the annual report with no loss in accuracy.
- Siting the Integrative Genomics Building at a location that will minimize soil-vapor building intrusion, based on a sampling study.
- Retrofitting the main site with new waste collection bins to support an expanded waste diversion program.

2.2.7.2 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. The federal Office of Management and Budget collects annual performance information online to measure performance against goals established in this Executive Order for eight categories, as follows:

1. Environmental aspects
2. Sustainable practices (e.g., use of renewable energy, electronics stewardship, sustainable acquisition)
3. Objectives, targets, and programs
4. Environmental training
5. Operational controls
6. Contracts and concessionaire agreements
7. Evaluation of compliance with regulatory requirements
8. Management review

For FY 2015, Berkeley Lab's EMS program earned the highest score of "green" (green is best, followed by yellow, then red) based on collective ratings in the above categories. Each category is scored from D (best) to A (worst). Berkeley Lab received five D and three C scores for FY 2015.

3. Environmental Program Summary

3.1 INTRODUCTION

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.

3.2 ENVIRONMENTAL PERMITS

Certain activities require operating permits issued by government agencies. Table 3-1 summarizes, by area of environmental activity, the 62 active permits held by LBNL at the end of 2015.

Table 3-1 Environmental Permits

Permit Type	Issuing Agency	Description (Section with Details)	Location
Air quality	BAAQMD ^a	Various activities with emissions to atmosphere (3.5.1)	Main Site
		Standby emergency generators (3.5.1)	Joint Genome Institute
CUPA ^b (permit and registration)	ACEH ^c	Hazardous Materials Business Plan and hazardous waste generator areas (3.5.2)	Joint BioEnergy Institute & Advanced Biofuels Process Demonstration Unit
	CCHS ^d	Aboveground storage tanks (3.5.4.1) Hazardous Materials Business Plan and hazardous waste generator areas (3.5.2)	Joint Genome Institute
	COB ^e	Aboveground storage tanks (3.5.4.1) Fixed treatment units (3.5.3.1) Hazardous Materials Business Plan and hazardous waste generator areas (3.5.2) Underground storage tanks (3.5.3.3)	Main Site
		Hazardous Materials Business Plan and hazardous waste generator areas (3.5.2)	Berkeley West Biocenter
Hazardous waste	DTSC ^f	Hazardous Waste Handling Facility operations and hazardous waste generator areas (3.5.3.1)	Main Site
Stormwater	SWRCB ^g	Sitewide and construction stormwater discharges (3.5.4.3)	Main Site
Surface water and sediment	EBRPD ^h	Surface water and sediment sampling (4.3.1, 4.6.2)	Tilden Park
Wastewater	CCCSD ⁱ	Wastewater discharges to sanitary sewer (3.5.4.1)	Joint Genome Institute
	EBMUD ^j	Sitewide and operation-specific wastewater discharges to sanitary sewer (3.5.4.1)	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

3.3 AUDITS AND INSPECTIONS

The regulatory agencies that enforce environmental requirements conduct periodic on-site inspections. Information about the 18 inspections conducted in 2015 is summarized in Table 3-2. The table includes the self-monitoring inspections conducted by Berkeley Lab as required by EBMUD wastewater discharge permits, since the self-monitoring results expose LBNL to potential regulatory actions. Six minor violation notices resulted from the 18 inspections; these are discussed in Section 3.5.3.1.

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 generator areas at Joint BioEnergy Institute & Advanced Biofuels Process Demonstration Unit	Jan 29	2
CCHS ^b	Hazardous Materials Business Plan, aboveground storage tanks, and hazardous waste generator areas at Joint Genome Institute	Apr 27	2
CCCSD ^c	Wastewater inspection of Joint Genome Institute	Feb 10	0
		Nov 18	0
COB ^d	Hazardous Materials Business Plan, aboveground storage tanks, fixed treatment units, and hazardous waste generator areas at main site	June 8	1
	Hazardous Materials Business Plan and hazardous waste generator areas at Berkeley West Biocenter	May 20	1
	Closure walkthrough of Joint Center for Artificial Photosynthesis (Hazardous Materials Business Plan and hazardous waste generator areas)	June 18	0
	Tiered permitting of fixed treatment units	June 25	0
	Underground storage tanks	Oct 22	0
		Dec 11	0
	Groundwater well destruction	Dec 22	0
EBMUD ^e	Wastewater monitoring inspection at Hearst and Strawberry sanitary sewer outfalls	Jan 7 & 8	0
		June 11, 12 & 16	0
LBNL	Self-monitoring inspections required by EBMUD for groundwater treatment units	Feb 15	0
		July 30	0
	Self-monitoring inspections required by EBMUD for Building 77 fixed treatment unit	Oct 17	0
	Self-monitoring inspections required by EBMUD for Hearst and Strawberry sanitary sewer outfalls	March 4 Sep 22	0 0

^a Alameda County Environmental Health

^d City of Berkeley (under California's Certified Unified Program Agency)

^b Contra Costa Health Services

^e East Bay Municipal Utility District

^c Central Contra Costa Sanitary District

3.4 DOE-REPORTABLE ENVIRONMENTAL INCIDENTS

One environmental incident prompted submittal of a report under the DOE Occurrence Reporting Program, which tracks incidents across the DOE complex. Occurrence Report #SC-BSO-LBL-GN-2015-0001 documents the Notice to

Comply issued by the Contra Costa Health Services at the completion of a regulatory inspection at the Joint Genome Institute (JGI) in Walnut Creek on April 27. Two violations were cited, as follows:

- Failure to complete the annual aboveground tank inspection as called for in the Spill Prevention, Control, and Countermeasure Plan (SPCC)
- Failure to complete refresher training on the SPCC for personnel who conduct inspections of the aboveground petroleum storage tank

These findings are discussed in Section 3.5.3.1.

3.5 COMPLIANCE PROGRAMS

The primary federal laws driving Berkeley Lab 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, and the Clean Water Act. The federal and state laws that impact Berkeley Lab's environmental planning for future activities are the National Environmental Policy Act (NEPA) of 1969 and the California Environmental Quality Act (CEQA) of 1970. The following sections briefly describe these environmental laws and associated regulations, as well as how Berkeley Lab activities are impacted.

3.5.1 Clean Air Act

The Clean Air Act of 1970 is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into three main categories:

- Hazardous air pollutants (e.g., radionuclides, air toxics)
- Criteria air pollutants (e.g., carbon monoxide, nitrogen oxides, particulate matter)
- Ozone-depleting substances (e.g., chlorofluorocarbons, halons)

3.5.1.1 Radiological Emissions

Radionuclide emissions to the atmosphere from LBNL research activities must adhere to the following regulations:

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

The U.S. EPA administers the NESHAP regulations (40 Code of Federal Regulations [CFR] Part 61), which limit the dose to the public from a facility's airborne radionuclide emissions to 10 millirem per year (mrem/yr). The potential dose from LBNL activities in 2015 was about 0.08% of this limit.

Berkeley Lab documents its NESHAP review and compliance annually; the *Radionuclide Air Emission Report for 2015* (LBNL, 2016b) was submitted to the U.S. EPA and is available on ESG's publications web page at <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>.

3.5.1.2 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). The Bay Area Air Quality

Management District (BAAQMD) is responsible for implementing federal and state air quality requirements for most non-radiological air emission activities that affect Berkeley Lab. CARB administers regulations on mobile sources such as vehicles, as well as regulations on certain toxic chemicals.

At the end of 2015, Berkeley Lab held 35 operating permits issued by the BAAQMD (2014); 33 of these cover activities and equipment at the main site, and the remaining two cover standby emergency diesel generators at the JGI in Walnut Creek. Three new permits for combustion equipment were issued in 2015: one standby emergency diesel generator installed at the recently constructed Building 59, and two portable standby diesel generators for general use. All permits issued by BAAQMD are listed in Table 3-3.

BAAQMD operating permits must be renewed annually. The 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. The process also satisfies submittal of information required by the state’s Air Toxics “Hot Spots” Information and Assessment Act of 1987.

Table 3-3 BAAQMD Permitted Air Emission Sources

BAAQMD 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, two portable units	Diesel particulate filter
	Standby emergency generators (17)	2, 33, 37 (2), 50B, 55, 62, 64, 68, 70A, 74, 77, 84B, 85, three portable units	None
	Standby emergency generators (2)	JGI	None
Gasoline dispensing	Fueling stations: unleaded and E85	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 systems (1)	58	Activated carbon

Beginning in 2013, CARB prohibited the use of the potent greenhouse gas sulfur hexafluoride (SF₆) as a tracer gas except under specified exemptions such as military operations. SF₆ is targeted because its global warming potential is 23,900, making it the highest global warming potential value for any substance currently identified. For comparison, carbon dioxide has a global warming potential of 1. Since the prohibition, LBNL requested – and was granted – a one-year exemption in both 2014 and 2015 for ongoing research in which SF₆ was used as a tracer gas in very small quantities for building ventilation and air movement studies by Berkeley Lab’s Environmental Energy Technologies Division. Since no research was conducted in 2015 by this group, no SF₆ was released under the

granted exemption. No further exemption requests will be made for SF₆ research conducted by Berkeley Lab in California.

Additionally, CARB regulates SF₆ emissions from gas-insulated switchgear by setting a maximum annual emission rate and requiring an annual usage report. Berkeley Lab had 15 active switches and breakers in service in 2015, and reported zero emissions for this type of equipment in 2015.

CARB's Refrigerant Management Program regulates stationary non-residential 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 66 refrigeration systems affected by this program are on the main site (50 units) and at the Oakland Scientific Facility (16 units), which housed the National Energy Research Scientific Computing Center until November 2015. This computing center is now located on site in Building 59, where all equipment is cooled with high-efficiency cooling tower technology.

A federal mandate set in 2005 requires that Berkeley Lab decrease petroleum fuel use by 2% each year through strategies such as switching to alternative fuels, increasing the fleet's fuel efficiency, and reducing the number of vehicles in the fleet in order to reduce dependence on petroleum and to lower greenhouse gas emissions. The reduction of petroleum fuel use is incorporated into LBNL's EMS aspect "Petroleum Use" (see Table 2-1), and to comply with the mandate, Berkeley Lab is implementing the following practices:

- Operating an E85 fuel (85% ethanol, 15% unleaded gasoline) dispensing facility that serves more than 120 fleet vehicles
- Maintaining a fleet that includes 13 hybrid vehicles and one electric vehicle, bringing the percentage of LBNL's alternative-fueled fleet vehicles to nearly 80% (135 of 170)
- Maintaining 69 electric carts, which reduces the size of the petroleum fuel-consuming fleet (Note: The U.S. Department of Transportation categorizes electric carts as a "neighborhood electric vehicle," so they are not counted as alternative-fueled vehicles in the LBNL fleet.)

Since 2010, Berkeley Lab has reported its annual greenhouse gas emissions to DOE at the end of each fiscal year. Initially this reporting was required by Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*. As of March 2015, Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, superseded Executive Order 13514 and significantly raises and expands more than 30 sustainability goals, including those for greenhouse gas emissions and fleet activities, as discussed in Section 2.2.3.

Berkeley Lab facilities do not emit greenhouse gases 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, California Global Warming Solutions Act of 2006.

3.5.2 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, Chapter 6.95, Section 25500–25547.8). Berkeley Lab addresses these requirements as summarized below in Table 3-4.

As a federal facility, LBNL is subject to EPCRA Toxic Release Inventory reporting requirements. If threshold usage quantities are exceeded, a U.S. EPA Form R must be submitted. LBNL determined in 2015, as in recent years, that no chemical usage exceeded the chemical-specific Toxic Release Inventory criterion for a listed substance, and that DOE was therefore not required to submit a Form R on behalf of LBNL. Table 3-4 summarizes LBNL'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 (pounds)								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Chlorofluorocarbons	1140	209	172	150	319	202	70	193	322
Methanol	139	152	180	147	88	103	172	127	87
Nitric acid	198	667	614	592	634	631	633	556	78
1,1,1-trichloroethane	<2.2	<2.2	<2.2	<2.2	0	0	0	0	0

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 federal EPCRA and corresponding state law. Berkeley Lab complies with applicable federal hazardous materials reporting requirements and even though it is not subject to state hazardous materials regulations, each year it voluntarily submits Hazardous Materials Business Plans (HMBPs) meeting state requirements, as follows:

- 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. The plans are also available on ESG's publications web page at <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>. An HMBP is prepared for each of the following facilities:

- Berkeley Lab Main Site
- Berkeley West Biocenter
- Joint BioEnergy Institute and the Advance Biofuels Process Demonstration Unit
- Joint Genome Institute

3.5.3 Resource Conservation and Recovery Act

The 1976 Resource Conservation and Recovery Act (RCRA) is an amendment to the earlier Solid Waste Disposal Act of 1965 that was enacted to create a management system to regulate waste from "cradle to grave." In 1984 the Hazardous and Solid Wastes Amendments were added to the Solid Waste Disposal Act to reduce or eliminate the

generation and disposal of hazardous wastes, and 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, clean up spilled or improperly stored wastes, and encourage reuse, reduction, and recycling. RCRA primarily impacts Berkeley Lab operations in these three areas:

- 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

3.5.3.1 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 permitting and enforcement elements.

The state's permitting program for hazardous waste treatment and storage facilities consists of five tiers, as listed in Table 3-5 in order of decreasing regulatory complexity. Berkeley Lab has activities that fall under three of these tiers. The Hazardous Waste Handling Facility operates under a full permit issued by DTSC that authorizes storage and treatment of certain hazardous and mixed wastes at the facility. The renewal of this 10-year permit is due in 2016. Administration and enforcement for the three lowest tiers is delegated to the City of Berkeley under California's Certified Unified Program Agency (CUPA) program. Four fixed treatment units (FTUs) operate under a hazardous wastewater treatment permit issued by the City of Berkeley at the permit-by-rule and conditional authorization tiers (City of Berkeley, 2014). This permit is renewed annually as part of the HMBP submission process for the main site.

Table 3-5 California's Tiered Permitting Program Overview

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	—

FTU treatment types and operational throughput are summarized in Table 3-6. The FTU serving Buildings 70A and 70F treats over 75% of all FTU wastewater generated at the site, and most of this amount is recycled by diverting it to a nearby cooling tower to replace the water consumed by the cooling process. The amount of water recycled in this manner in 2015 is estimated to be approximately 464,750 gallons. Since the recycling system was installed in 2011, the total volume recycled as of the end of 2015 is close to 2.2 million gallons.

Table 3-6 Fixed Treatment Unit Operations Summary

FTU	Building No.	Treatment Types	Gallons of Wastewater Treated in 2015
004	70A/70F	Acid neutralization	552,161 (464,750 estimated recycled)
005	2	Acid neutralization	94,570
006	77	Metals precipitation and acid neutralization	11,846
007	67	Acid and alkaline neutralization	47,355

Berkeley Lab also sends hazardous, universal, mixed, medical, and radioactive waste generated at LBNL to permitted off-site facilities for disposal. Disposal of medical waste is managed in accordance with the state's Medical Waste Management Act (California Health and Safety Code, 1991). Low-level radioactive waste is managed in accordance with DOE orders. Mixed waste is managed in accordance with the *Mixed Waste Site Treatment Plan* (DOE, 1995) and is subject to both California regulations and DOE orders.

In January, Alameda County Environmental Health inspected two Berkeley Lab satellite facilities in Emeryville: the Joint BioEnergy Institute and the Advanced Biofuels Process Demonstration Unit. Of the two minor violations issued, one was for a fire extinguisher that was not properly certified (this was corrected during the inspection), and the other was for incomplete information on hazardous waste labeling of waste accumulation containers. Corrective actions, including providing the county with documentation of changes made, were completed within two months. The county agency approved the changes in April.

In April, Contra Costa Health Services conducted a CUPA inspection of the JGI in Walnut Creek. No violations were found for the areas of hazardous waste management or the site's HMBP. Two minor violations were issued for aboveground storage tank (AST) deficiencies; one for failure to complete the annual inspection and testing specified in the site's Spill Prevention, Control, and Countermeasure Plan. The annual inspection was overdue by two months. The other minor violation was for the lack of refresher training as required by this plan for the person who operates and maintains the AST. Both deficiencies were corrected and reported to Contra Costa Health Services.

In May, the City of Berkeley conducted a one-day CUPA inspection of the Berkeley West Biocenter. No violations were found with the site's HMBP. One minor violation was issued for incomplete labeling on two small hazardous waste containers. The labels were corrected during the inspection, resulting in no further action needed.

In June, the City of Berkeley conducted an inspection of ASTs, FTUs, and waste generator areas, including satellite accumulation areas, around the main site. The City also inspected Berkeley Lab's HMBP. One minor violation was issued for incomplete information on the hazardous waste labels of three containers in a satellite accumulation area located in Building 62. The missing information was placed on the label during the inspection, which corrected the violation immediately.

3.5.3.2 Corrective Action Program

Berkeley Lab is currently in the Corrective Measures Implementation phase of the RCRA Corrective Action Program, which consists of operating, maintaining, and monitoring the environmental restoration activities approved by DTSC in the *Corrective Measures Study Report* (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 contaminant areas to enhance the natural biodegradation of volatile organic compounds (VOCs).
- *Monitored natural attenuation* (i.e., reliance on natural processes) has also been used within the context of a controlled and monitored site cleanup approach to achieve site-specific cleanup objectives.

In March 2006, LBNL prepared a *Soil Management Plan* and a *Groundwater Monitoring and Management Plan*. These plans describe the nature and extent of contamination, the controls used to reduce potential risk from exposure to the contaminants, and the requirements for ongoing groundwater and surface water monitoring. These documents, as well as other RCRA Corrective Action Program documents prepared by LBNL, are available to the public at the main branch of the Berkeley Public Library and on the program's publications web page at <http://www2.lbl.gov/ehs/erp/html/documents.shtml>.

3.5.3.3 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. There are six permitted USTs on site containing either diesel or unleaded gasoline, as shown in Table 3-7 and on Figure 3-1. LBNL has removed nine USTs since 1993 following the regulatory closure process; no USTs were removed in 2015.

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
Glaesteel 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

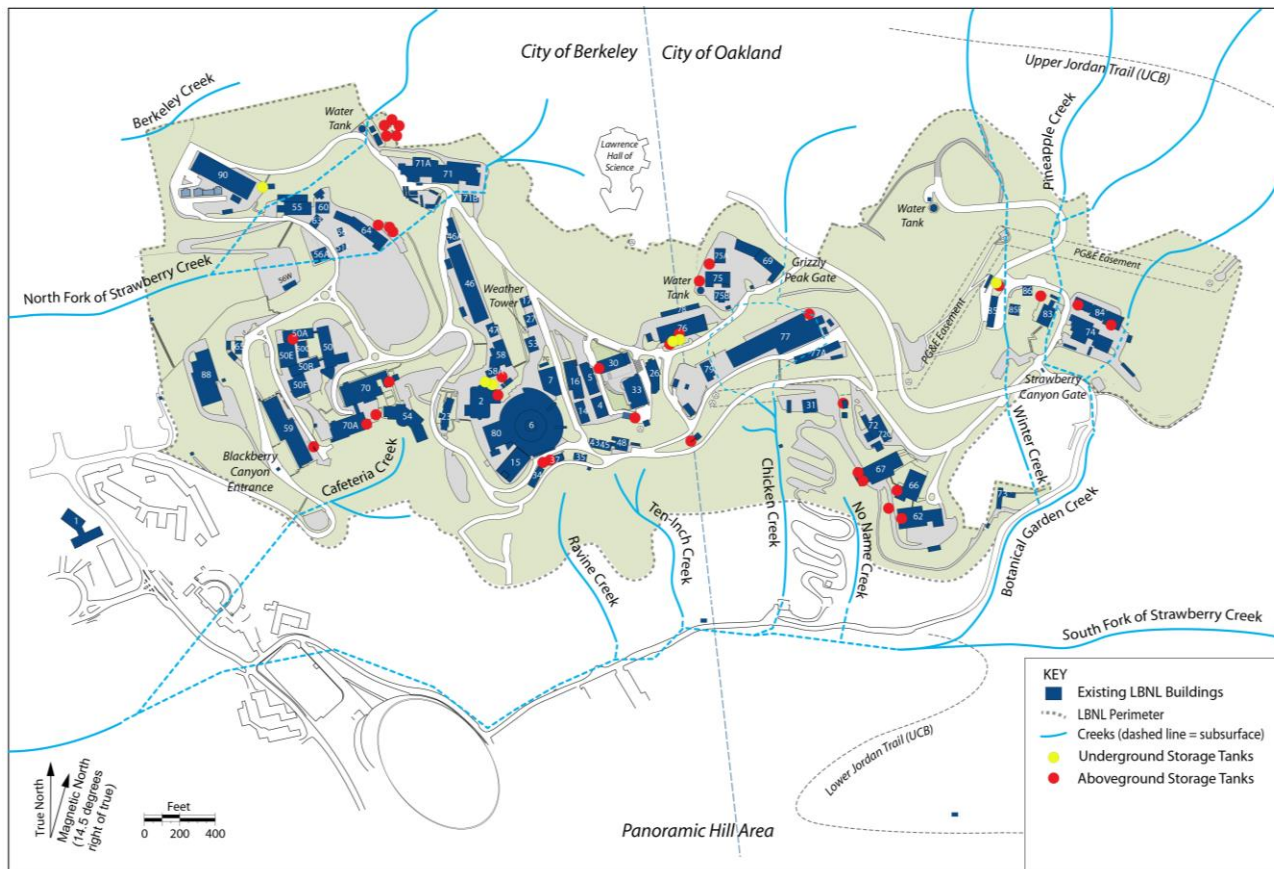


Figure 3-1 Locations of Aboveground and Underground Storage Tanks

On October 22, all product piping for all UST systems passed pressure tests during annual testing and recertification of system leak-detection monitors. Also on this date, City of Berkeley representatives conducted their annual inspection, and all USTs were found to be compliant with regulations.

3.5.4 Clean Water Act

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

The 1969 California Porter-Cologne Water Quality Control Act established a comprehensive statewide system for regulating water use and provided for a three-tiered system of regulatory administration and enforcement:

- State Water Resources Control Board (SWRCB)
- Nine Regional Water Quality Control Boards
- Local governments

For the Berkeley Lab main site, the agencies responsible for regulatory programs are the San Francisco Bay Regional Water Quality Control Board (hereafter referred to as RWQCB) for stormwater discharges, and EBMUD for drinking water supply and wastewater discharges. For JGI, which is located in Walnut Creek, the responsible agency for both wastewater and stormwater discharges is the Central Contra Costa Sanitary District.

3.5.4.1 Aboveground Storage Tanks

ASTs fall under the authority of the Clean Water Act, which, together with the state's Aboveground Petroleum Storage Act (California Health and Safety Code, 1989), outlines the applicable regulatory requirements for ASTs containing chemicals or hazardous materials. At Berkeley Lab, these requirements apply to petroleum storage tanks for standby emergency diesel generators, storage drums at waste accumulation areas, and storage drums at product distribution areas.

Under the authority of the Clean Water Act, a Spill Prevention, Control, and Countermeasure (SPCC) Plan is required 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, 2014a). These ASTs are provided with secondary containment or spill kits to capture any potential leaks. Their locations are shown on Figure 3-1. A 4,000-gallon AST at the JGI facility supports two standby emergency generators, and the JGI maintains a separate SPCC Plan for this AST (LBNL, 2014b).

In January, a 2,300-gallon belly tank associated with a new standby emergency diesel generator was installed and filled to provide backup support for computational research activities at the recently completed Building 59.

3.5.4.2 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, 2013a)
- Treated groundwater from hydraugers and groundwater monitoring wells (EBMUD, 2013b)
- Treated rinse water from the metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77 (EBMUD, 2012)

The sitewide wastewater and groundwater treatment system permits were last approved in 2013. The sitewide wastewater permit expires in July 2017, and there is no expiration date for the groundwater treatment system permit. 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 2015 no wastewater discharge limits were exceeded. The monitoring results are provided in [Chapter 4](#).

EBMUD periodically inspects the site's sanitary sewer discharge without prior notice, and in 2015 this occurred on two occasions, as listed in Table 3-2. The sample collection results for all discharges indicated no violations.

The wastewater discharge permit for the Building 77 Ultra-High Vacuum Cleaning Facility requires that the facility maintain a Toxic Organics Management Plan and a Slug Discharge Plan. The requirements for these two plans are incorporated into the Berkeley Lab's work authorization activity for metal finishing operations. These two plans outline facility management practices designed to eliminate the accidental release of toxic organics, or any other pollutant, to the sanitary sewers or external environment by emphasizing secondary containment and other appropriate spill prevention practices. It also includes emergency response procedures.

Berkeley Lab also holds a Class III Industrial User Permit for general wastewater discharged from the JGI facility in Walnut Creek. The permit, re-issued by the Central Contra Costa Sanitary District in December 2014, specifies requirements for inspections and reporting. No monitoring is required.

3.5.4.3 Stormwater

Berkeley Lab's stormwater releases are permitted under the state's *General Permit of Stormwater Discharges Associated with Industrial Activities*, commonly referred to as the Industrial General Permit or IGP (SWRCB, 2014). While the IGP is issued by the SWRCB, it is administered and enforced locally by the RWQCB. Under this permit, LBNL has implemented a Stormwater Pollution Prevention Plan (SWPPP) (LBNL, 2015e), which includes the site's Stormwater Monitoring Implementation Plan (LBNL, 2015d).

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 assuring the quality and reporting of the results. Together, these documents represent LBNL's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

A significant revision to the IGP became effective on July 1 for the 2015/2016 rainfall season. The previous revision of the IGP was in 1997. The new permit doubled the required number of sampling events from two to four. In addition, to meet new requirements to fully characterize the discharge from on-site activities, Berkeley Lab increased the number of locations (from 6 to 15) from which samples are collected during stormwater sampling events. The results from the new sampling program under the new permit are discussed in Section 4.3.2.

The annual report covering stormwater activities for the 2014/2015 season under the previous IGP was submitted in hardcopy to the RWQCB by the July 1 deadline. This report is available on the ESG Publications web page at <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>. With the new permit, submittal of the annual report and all sampling event data uses SWRCB's online Stormwater Multiple Application and Report Tracking System.

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). During 2015, three construction projects at Berkeley Lab required a stormwater construction permit:

- Solar Energy Research Center (Building 30)
- Computational Research and Theory Facility (Building 59)
- Old Town Demolition Project

As the construction phase of two of these projects ended, the SWRCB approved a Notice of Termination for the construction permit for Buildings 30 (in March) and for Building 59 (in August). A construction permit for the Old Town Demolition Project became active in May.

3.5.5 Toxic Substances Control Act

The objective of the 1976 Toxic Substances Control Act (TSCA) 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, as well as controlling their use once they are approved for manufacturing. TSCA regulations are administered by the U.S. EPA.

Polychlorinated biphenyls (PCBs) are the principal substances at Berkeley Lab currently subject to the 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. This quantity 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 fully characterize the extent of PCB contamination continued in 2015 under the regulatory authority of the U.S. EPA. Characterization and cleanup efforts are documented in the Environmental Restoration Program's periodic progress reports, which are available at the main branch of the Berkeley Public Library and on the program's web page at <http://www2.lbl.gov/ehs/erp/html/documents.shtml>.

3.5.6 National Environmental Policy Act and California Environmental Quality Act

The National Environmental Policy Act of 1969 and the California Environmental Quality Act of 1970 require that potential environmental impacts of proposed actions are considered in the decision making process by the designated lead agency. At Berkeley Lab, environmental staff provide information and technical support to assist DOE and UC in complying with NEPA and CEQA requirements.

In 2015, five proposed federally supported activities were determined by DOE to meet the criteria for a categorical exclusion under NEPA. Review documents for each are posted at the following DOE website:

<http://science.energy.gov/bsa/nepa-documents/>. No Environmental Assessments or Environmental Impact Statements were prepared for Berkeley Lab activities.

4. Environmental Monitoring

4.1 INTRODUCTION

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. A comprehensive *Environmental Monitoring Plan* (LBNL, 2013b) provides the basis and current scope for each program. This chapter presents summaries of 2015 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

4.2 STACK AIR

Berkeley Lab's air monitoring program, which consists of emissions sampling and monitoring to measure contaminants in building exhaust systems, is designed to measure the impacts from radiological air emissions. The air monitoring program meets the U.S. EPA and DOE requirements discussed in Section 3.5.1.1.

Various radionuclides are used in Berkeley Lab's radiochemical and biomedical research programs, and particle accelerators generate radioactive materials. These research and accelerator operations may produce very small amounts of airborne radionuclides, which are typically emitted through building exhaust systems. Berkeley Lab is required to evaluate the potential for 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, LBNL 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 and subsequent analysis of the filters at an analytical laboratory, and *monitoring* is the continuous measurement of radionuclides in real time.

Annually, all locations using radionuclides are evaluated for their potential to emit radionuclides and compared with the thresholds listed in Table 4-1. In 2015, all potential doses were found to be less than 0.1 mrem/yr, indicating that the applicable requirements are Category 3, which requires periodic sampling, or Category 4, which requires 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 2015, a total of 17 stacks were sampled, and real-time monitoring was performed on four of them. 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

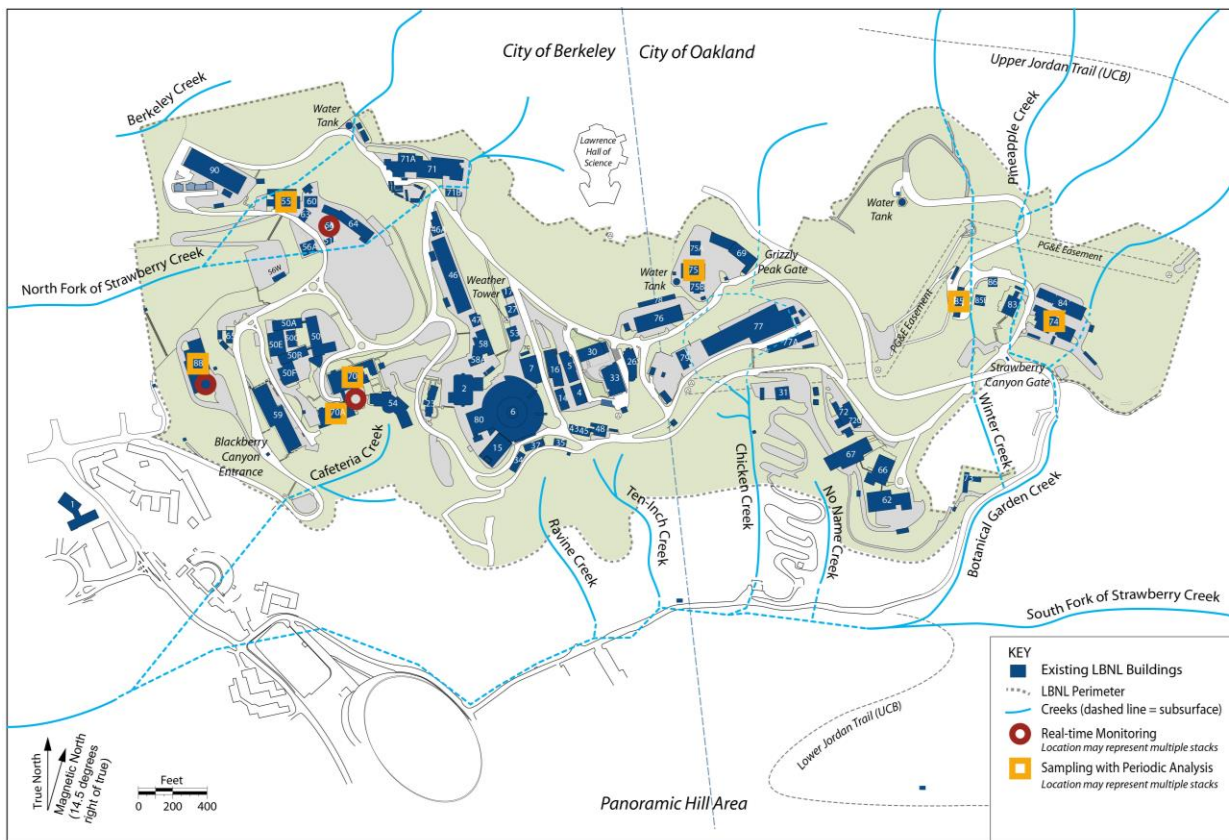


Figure 4-1 Building Exhaust Sampling and Monitoring Locations

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 99% of the emitted activity. The Building 56 accelerator was the main source of fluorine-18 emissions at

2.75 curies (Ci). Additional details on stack emissions are available in LBNL's *Radionuclide Air Emission Report for FY 2015* (LBNL, 2016b), which was submitted to the U.S. EPA and also published on ESG's publications web page at <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>.

For information on the estimated dose from radionuclide emissions, see Chapter 5.

4.3 SURFACE WATER

Sampling of surface waters at and around Berkeley Lab comprises creek water and stormwater.

4.3.1 Creek Sampling

Surface water quality is checked by sampling creeks within the Strawberry Creek watershed. As shown on Figure 4-2, the sampled creeks flow through – or originate within – the Berkeley Lab site. They include the North Fork of Strawberry Creek, Chicken Creek, Upper Botanical Garden Creek, No Name Creek, Ravine Creek, and Winter Creek, which is sampled at two locations (inflow and outflow points to the site). Because seasonal changes affect the flow volume and water quality in most creeks, samples are collected semiannually – once during the wet season and once during the dry season. In 2015, sampling was conducted in March and September.

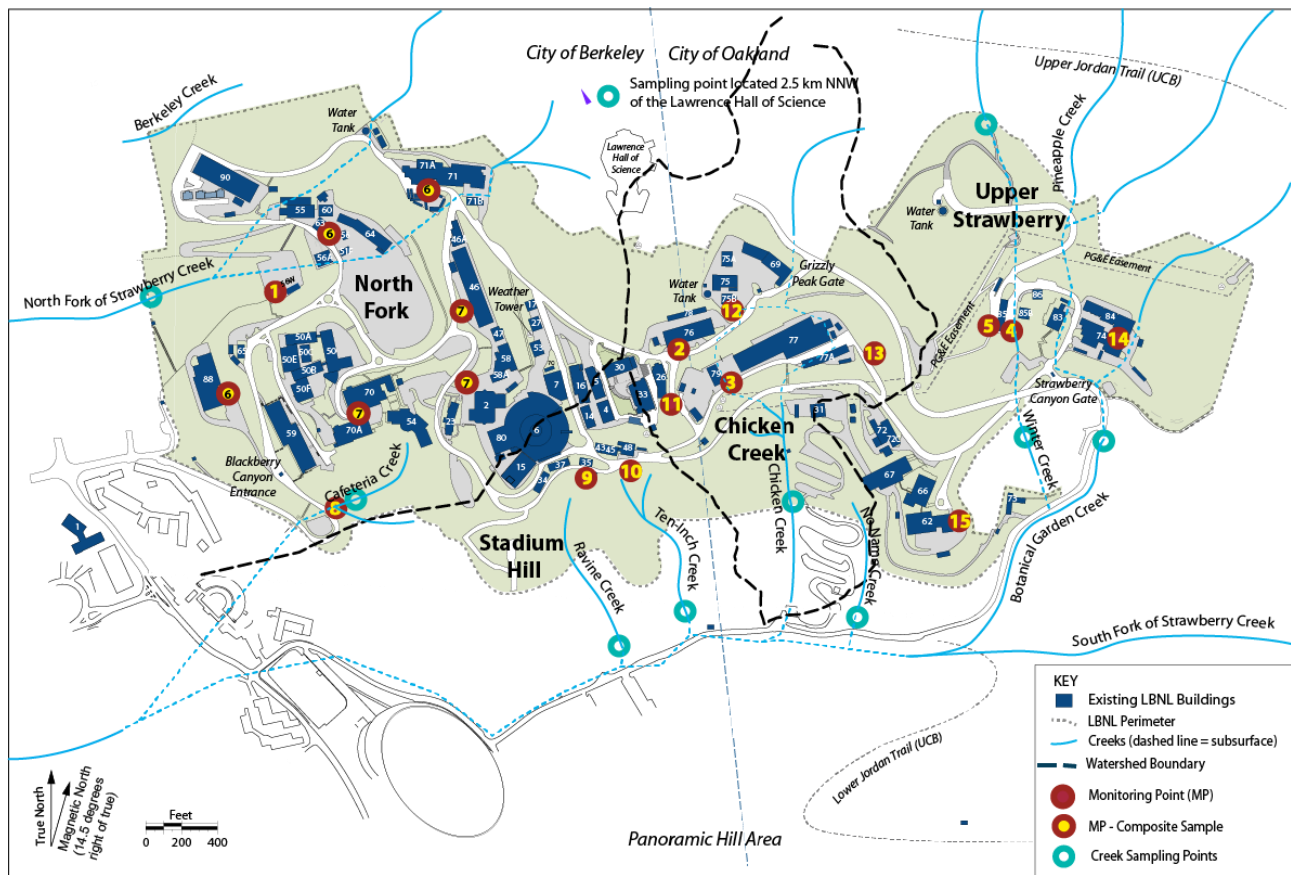


Figure 4-2 Surface Water Sampling Locations

To establish baseline water quality values, samples were also collected semiannually from Wildcat Creek, which is located in Tilden Regional Park approximately 1.4 miles north-northwest of UC's Lawrence Hall of Science and which flows away from Berkeley Lab. Sampling results confirm that Wildcat Creek is not impacted by Berkeley Lab operations.

Samples from the following subset of creeks were analyzed for gross alpha, gross beta, and tritium in accordance with DOE Order 458.1 requirements: Chicken Creek, the North Fork of Strawberry Creek, Wildcat Creek, and Winter Creek (inflow and outflow points). 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 referred to as the Basin Plan (RWQCB, 2015). The federal and state MCL values for drinking water are as follows: alpha is 15 picocuries/liter (pCi/L); beta is 50 pCi/L; and tritium is 20,000 pCi/L (U.S. EPA, 1976; CDPH, 1984).

Laboratory analysis reported 19 of the 24 sample results as non-detectable. As shown in Table 4-2, none of the detectable results from the semiannual samples collected exceeded 10% of the federal and state MCL values for drinking water.

Creek samples were also analyzed for VOCs and metals. No VOCs were detected, but the following metals were detected: aluminum, antimony, barium, copper, iron, lead, magnesium, mercury, selenium, and zinc. Metals concentrations were within historical levels for LBNL, well below the water quality objectives listed in the *Basin Plan*, and well below the drinking water standard.

In addition, the March samples 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 (COD), specific conductance, total suspended solids (TSS), and nitrate plus nitrite. The results indicate that concentrations in all samples analyzed for these indicator parameters were within historical levels for the site.

Table 4-2 Detectable Radiological Results from 2015 Creek Sampling

Activity	MCL ^a (pCi/L)	Creek	% of MCL
alpha	15	Winter Creek	10.0%
beta	50	Chicken Creek	7.8%
		Wildcat Creek ^b	3.8%
		Winter Creek	5.0%
tritium	20,000	Chicken Creek	0.85%

^a MCL = Maximum Contaminant Level, in picocuries per liter (pCi/L)

^b Wildcat Creek does not flow through the Berkeley Lab site.

4.3.2 Stormwater Sampling

Under the terms of the new IGP, stormwater sampling must take place during four qualifying storm events that meet permit-specific conditions. Sampling for two qualifying storm events is required during the first half of the 2015/2016 reporting year (July 1 to December 31), which Berkeley Lab successfully performed. The remaining two

events are required during the second half of the reporting year (January 1 to June 30) and will be reported in next year's Site Environmental Report.

Berkeley Lab's *Stormwater Monitoring Implementation Plan* describes the sampling rationale, sampling locations (see Figure 4-2), and analytical parameters for each specific industrial activity (LBNL, 2015c). The IGP also requires visual observation of the surface water runoff from each qualifying storm event, and dry weather visual observations of non-stormwater discharges once per month.

The sampling results from 2015, covering portions of two reporting years, show that Berkeley Lab's best management practices provide adequate control for stormwater discharges at most locations. At locations where results exceed regional benchmark levels, best management practices were improved, as noted in the annual report. The current and recent reports are available on ESG's publications page at <http://www2.lbl.gov/ehs/esg/Reports/tableforreports.shtml>.

4.4 WASTEWATER

4.4.1 Wastewater Monitoring Locations

As discussed in Section 3.5.4.1, Berkeley Lab holds EBMUD wastewater discharge permits for general sitewide activities, metal finishing operations in the Ultra-High Vacuum Cleaning Facility at Building 77, and treated groundwater operations at seven locations. Each permit specifies periodic monitoring and reporting requirements.

Berkeley Lab's sanitary sewer system, shown on Figure 4-3, includes a monitoring station located near the outfall of each of the two main sewer system branches:

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

As a permit requirement, Berkeley Lab samples wastewater discharges at these two monitoring stations. Wastewater sampling is also conducted to assess discharges from hydraugers, extraction wells, and treated groundwater sites, as well as the Building 77 Ultra-High Vacuum Cleaning Facility. In addition, EBMUD conducts unannounced wastewater discharge monitoring. For the current reporting year, all monitoring results were below EBMUD discharge limits.

4.4.2 Hearst and Strawberry Sewer Outfalls

In 2015, Berkeley Lab discharged approximately 15.6 million gallons through the Hearst branch of the sewer system and 19.7 million gallons through the Strawberry branch, as measured by total volumetric flow. Sampling and monitoring is conducted at these sewer outfalls as described briefly below; additional details are given in Sections 4.4.2.1 and 4.4.2.2.

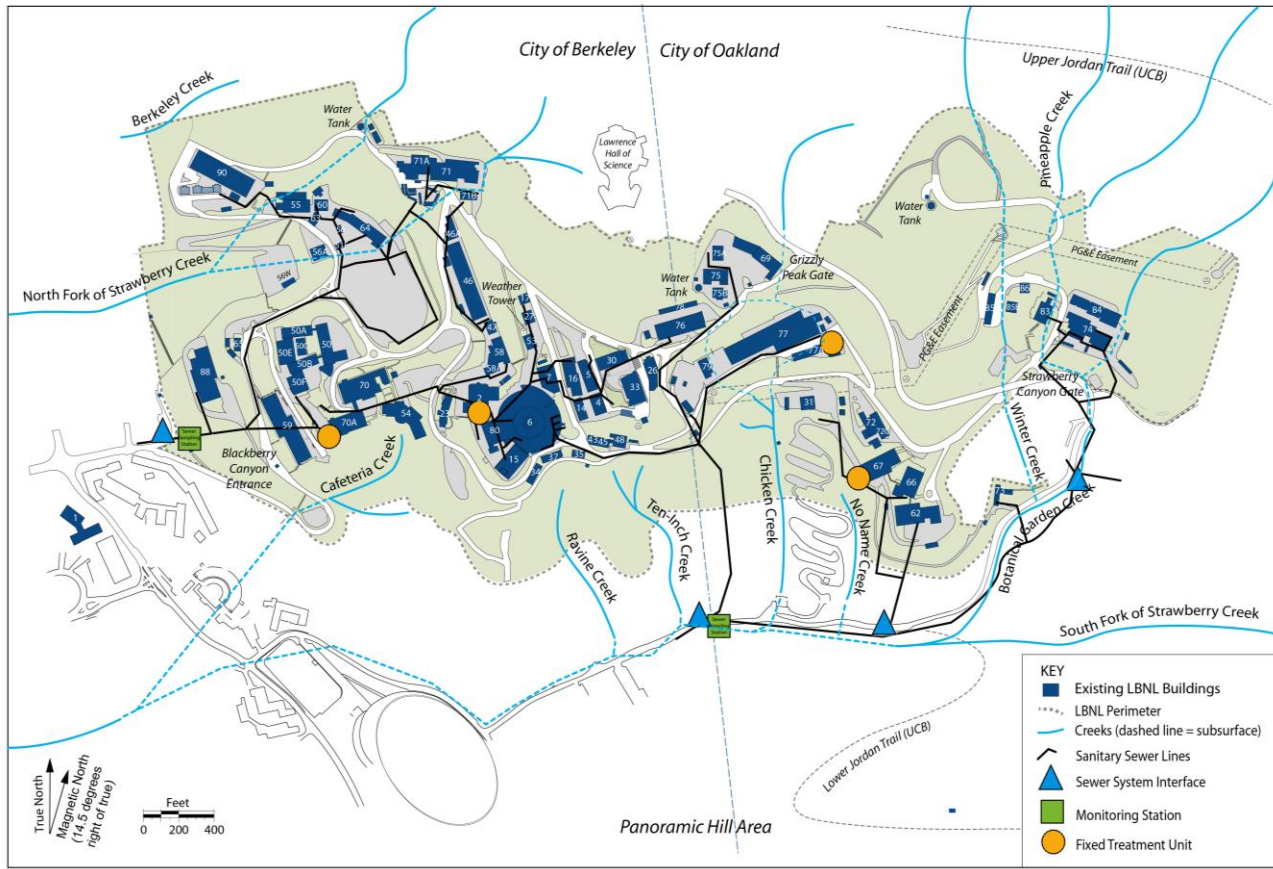


Figure 4-3 Sanitary Sewer System (Main Lines)

- Non-radiological samples collected at the Hearst and Strawberry outfalls are analyzed for pH, total identifiable chlorinated hydrocarbons, TSS, COD, and specified metals.
- Radiological monitoring is required by DOE Order 458.1 (DOE, 2013) and corresponding guidance (DOE, 2015b), and verifies compliance with radiological limits under the Nuclear Regulatory Commission or other governmental agency empowered to regulate the use of radioactive materials.

4.4.2.1 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 2015 were below the minimum detectable activity levels for gross alpha, carbon-14, iodine-125, and tritium. Positive results for gross beta were consistently detected throughout the year at Hearst and Strawberry sewer outfalls, which are likely due to naturally occurring radioactive material such as potassium-40. The highest monthly gross beta concentration was 24.4 picoCurie/liter (pCi/L), which is below the federal and state MCL for drinking water of 50 pCi/L.

In accordance with DOE guidance (DOE, 1991), 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 detectable 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 1.44×10^{-2} Ci, or 0.29% of the tritium discharge limit of 5 Ci. The annual discharge estimated from carbon-14 values totaled 1.16×10^{-2} Ci, or 1.16% of the carbon-14 discharge limit of 1 Ci. The estimated annual discharge for all other radioisotopes (gross alpha, gross beta, and iodine-125) was 4.52×10^{-3} Ci, or 0.45% 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) and beta (strontium-90) activity, the calculated discharges were 0.010 (1.0%) and 0.050 (5.0%) of the allowable fractional DCS values in the Strawberry and Hearst sanitary sewer systems, respectively.

4.4.3 Treated Hydrauger and Extraction Well Discharge

Since 1993, Berkeley Lab has discharged treated groundwater to the sanitary sewer at seven locations, in accordance with a permit issued by EBMUD. Sources of this treated groundwater are certain hydraugers (subsurface drains), extraction wells, and well sampling and development activities. The treatment process consists of passing contaminated groundwater through a two-stage carbon-drum adsorption system. Samples of the treated water are collected and analyzed for VOCs using U.S. EPA–approved methods to document that discharge limits have not been exceeded. All sampling results since this program began have been below EBMUD discharge thresholds.

4.4.4 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 per minute. As required by the EBMUD permit, Berkeley Lab sampled effluent from the treatment unit in September. Sampling results showed that pH and metals were within the permit limits.

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

4.4.5 Sewer System Management Plan

Berkeley Lab's *Sewer System Management Plan* addresses the SWRCB's requirements for maintaining LBNL's sanitary sewer systems and preventing and reporting overflows (LBNL, 2015b). SWRCB regulations require that any public agency owning or operating a wastewater collection system with piping longer than one mile prepare a written sewer system management plan to address the proper operation, maintenance, and funding for

maintenance and capital improvements of the system. This plan must be reviewed every five years to ensure that information is current and available. The most recent review and update was completed in April.

SWRCB's Sanitary Sewer Order (WQ 2013-0058-EXEC, *Amending Monitoring and Reporting Program for Statewide General Waste Discharge Requirements for Sanitary Sewer Systems*) requires reporting of all spill activity, including monthly reporting for each month during which no sanitary sewer overflow occurred (SWRCB, 2013). Sanitary sewer overflow reporting is accomplished through the online California Integrated Water Quality System used by the SWRCB and the Regional Water Quality Control Boards to track water quality-related information. In 2015, a total of 12 monthly "No-Spill" certifications were submitted to the online system because no sanitary sewer overflows occurred during the year.

4.5 GROUNDWATER

This section reviews Berkeley Lab's groundwater monitoring program and provides a brief summary of the site's groundwater contaminant plumes and the corrective measures applied to each. More detailed information on RCRA Corrective Action Program activities is provided in the Environmental Restoration Program's progress reports, which contain all site groundwater monitoring data, site maps showing monitoring well locations and contaminant concentrations, and graphs showing decreasing contaminant concentrations over time. These reports are available at the main branch of the Berkeley Public Library and on the program's web page at <http://www2.lbl.gov/ehs/erp/html/documents.shtml>.

4.5.1 Groundwater Monitoring Overview

The three objectives of groundwater monitoring are as follows:

1. Evaluate the continued effectiveness of the corrective measures that have been implemented for cleanup of contaminated groundwater.
2. Document that groundwater plumes continue to be stable or attenuating and are not migrating off site.
3. Monitor progress toward attaining the long-term goal of restoring all groundwater at the site to drinking water standards, if practicable.

Although attaining drinking water standards is the long-term goal for all groundwater at Berkeley Lab, the groundwater is not used for domestic, irrigation, or industrial purposes.

The groundwater monitoring network consists of more than 200 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). Wells are sampled primarily for one or more of the following contaminants: VOCs, metals, and tritium.

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

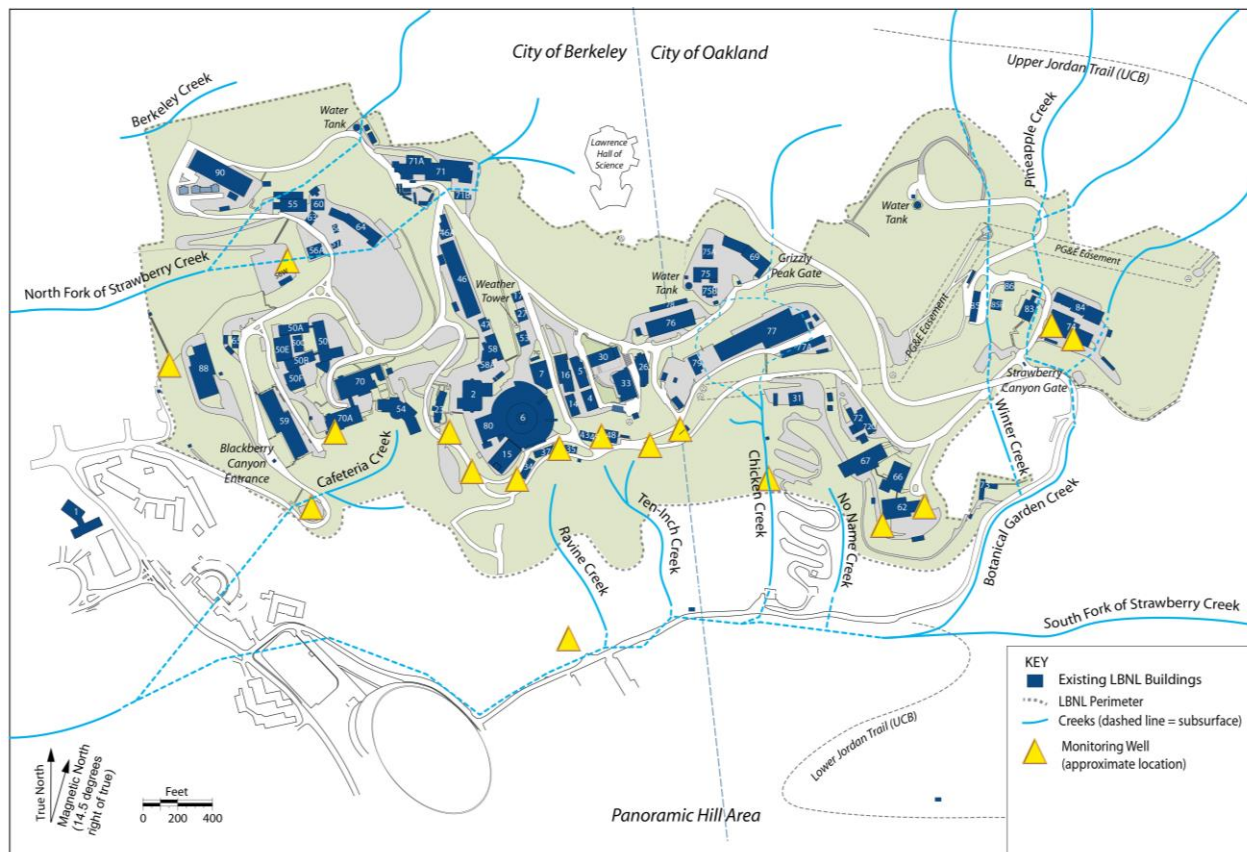


Figure 4-4 Downgradient Groundwater Monitoring Wells Closest to the Site Boundary

Metals. Concentrations of metals detected in 2015 were consistent with results from previous years. The only metal detected at a concentration above both the drinking water standard and the statistically estimated Berkeley Lab background level (LBNL, 2002) was arsenic, which was detected in three wells.

These values are attributed to the relatively high natural concentration of arsenic in certain rock types at Berkeley Lab. In addition, molybdenum, for which there is no drinking water standard, was detected above the upper estimate of background in five wells.

VOCs. Four principal plumes of VOC-contaminated groundwater have been identified at Berkeley Lab: Old Town, Building 51/64, Building 51L, and Building 71B. The geometry and distribution of chemicals in the Old Town plume indicate that it consists of three coalescing lobes (Building 7, Building 25A, and Building 52 lobes) that were originally separate plumes. In addition, Berkeley Lab monitors VOC-contaminated groundwater 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 primary VOCs detected in the groundwater have been tetrachloroethylene, trichloroethylene (TCE), 1,1-dichloroethane, and carbon tetrachloride and their associated degradation products such as 1,1-dichloroethylene (DCE), cis-1,2-DCE, 1,1,1-trichloroethane (TCA), and vinyl chloride. Concentrations of VOCs in

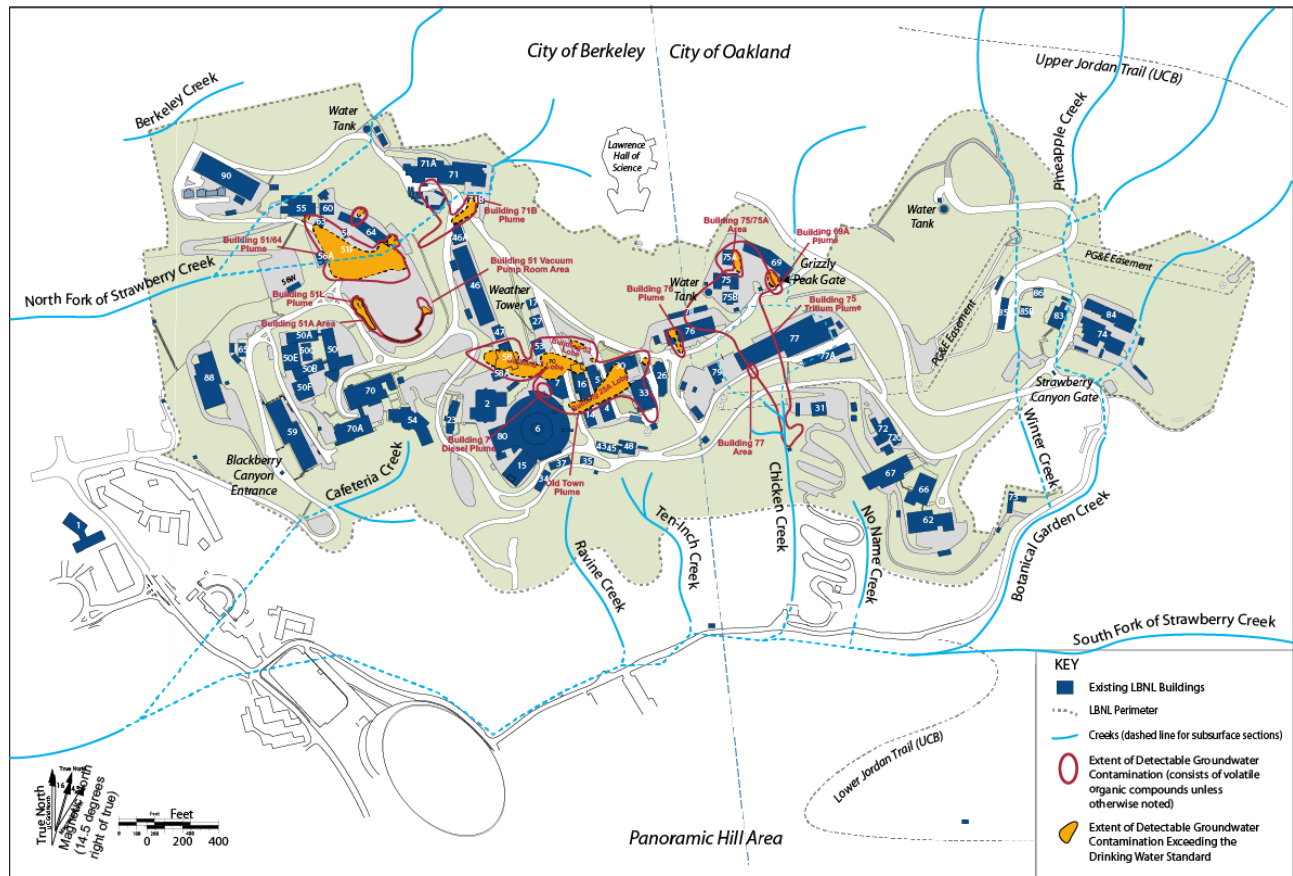


Figure 4-5 Locations of Groundwater Contamination (September 2015)

most areas have shown significant declines primarily as a result of the corrective measures that have been implemented. However, VOC concentrations remain above the drinking water standard in a number of areas.

Tritium. A plume of tritium-contaminated groundwater extends southward from the Building 75 area. The source of the plume is the former National Tritium Labeling Facility (NTLF), which ceased operation in December 2001. Since closure of the NTLF, concentrations of tritium detected in the groundwater have declined steadily, with concentrations below the drinking water standard of 20,000 pCi/L (U.S. EPA, 1976; CDPH, 1984) since February 2005. The location of the Building 75 area tritium plume is shown on Figure 4-5. Tritium in concentrations 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. In 2015, tritium was not detected in the groundwater in the Building 71B area, nor was it detected in wells immediately downgradient from the central area of the former Bevatron site.

Petroleum Hydrocarbons. Two petroleum hydrocarbon plumes associated with former USTs are present: one located at Building 74 (Building 74 diesel plume) and the other near Building 6 (Building 7 diesel plume). While not considered a plume, petroleum hydrocarbons have also been detected in the groundwater at a former UST site south of Building 76. No aromatic VOCs, including BTEX components (i.e., benzene, toluene, ethylbenzene, and xylenes), have been detected in the groundwater at any of these former UST sites since 2003.

Polychlorinated Biphenyls. PCBs were detected in early 2014 in soil samples collected as part of the characterization of the Old Town Demolition Project area. To assess whether the contaminated soil had impacted groundwater, samples were collected in 2015 from 15 wells located both in the areas where PCBs had been detected in the soil and downgradient from those areas. No PCBs were detected in these groundwater samples.

4.5.2 Treatment Systems

Berkeley Lab is using collection trenches, groundwater 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 2015 to treat extracted groundwater, which totaled approximately 9 million gallons for the year. The cumulative volume of contaminated groundwater treated from 1991 through the end of 2015 exceeds 173 million gallons. Most of the treated water is re-injected into the subsurface for in situ soil flushing. Treated water not needed for soil flushing is discharged to the sanitary sewer in accordance with the EBMUD permit for this type of discharge (EBMUD, 2013b).

4.6 SOIL AND SEDIMENT

This section summarizes monitoring results for soil and sediment samples required by DOE Order 458.1 and guidance (DOE, 2015b). The locations for soil and sediment sampling are shown on Figure 4-6.

4.6.1 Soil Sampling

Soil samples obtained from the top two inches of surface soils were collected from three locations within the Berkeley Lab site and one off-site environmental monitoring station. Samples were analyzed for gross alpha, gross beta, gamma emitters, tritium, moisture content, pH, and 15 metals.

For radioisotope analysis, gross alpha, gross beta, and gamma emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soils (Eisenbud, 1973; NCRP, 1987). Tritium measurements at each sampling location were below detection limits.

For non-radioisotope analysis, pH and moisture content 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 Berkeley Lab background levels (LBNL, 2009a) and levels commonly found in soils in the United States (Shacklette and Boerngen (1984).

At the Building 80 sampling location, mercury was detected at a concentration of 1.10 milligrams per kilogram (mg/kg), which is above the established Berkeley Lab soil background concentration of 0.42 mg/kg but below both the RWQCB's environmental screening level of 13 mg/kg (RWQCB, 2016) and the DTSC's modified screening level of 4.5 mg/kg (DTSC, 2015).

4.6.2 Sediment Sampling

Sediment samples were collected at Chicken Creek and the North Fork of Strawberry Creek within the main site and at one off-site location at Wildcat Creek in Tilden Regional Park. Due to limited sediment availability, several composite grab samples from the general creek bed area at each location and analyzed for gross alpha, gross beta, gamma emitters, tritium, 15 metals, moisture content, pH, and petroleum hydrocarbons (diesel and oil/grease).

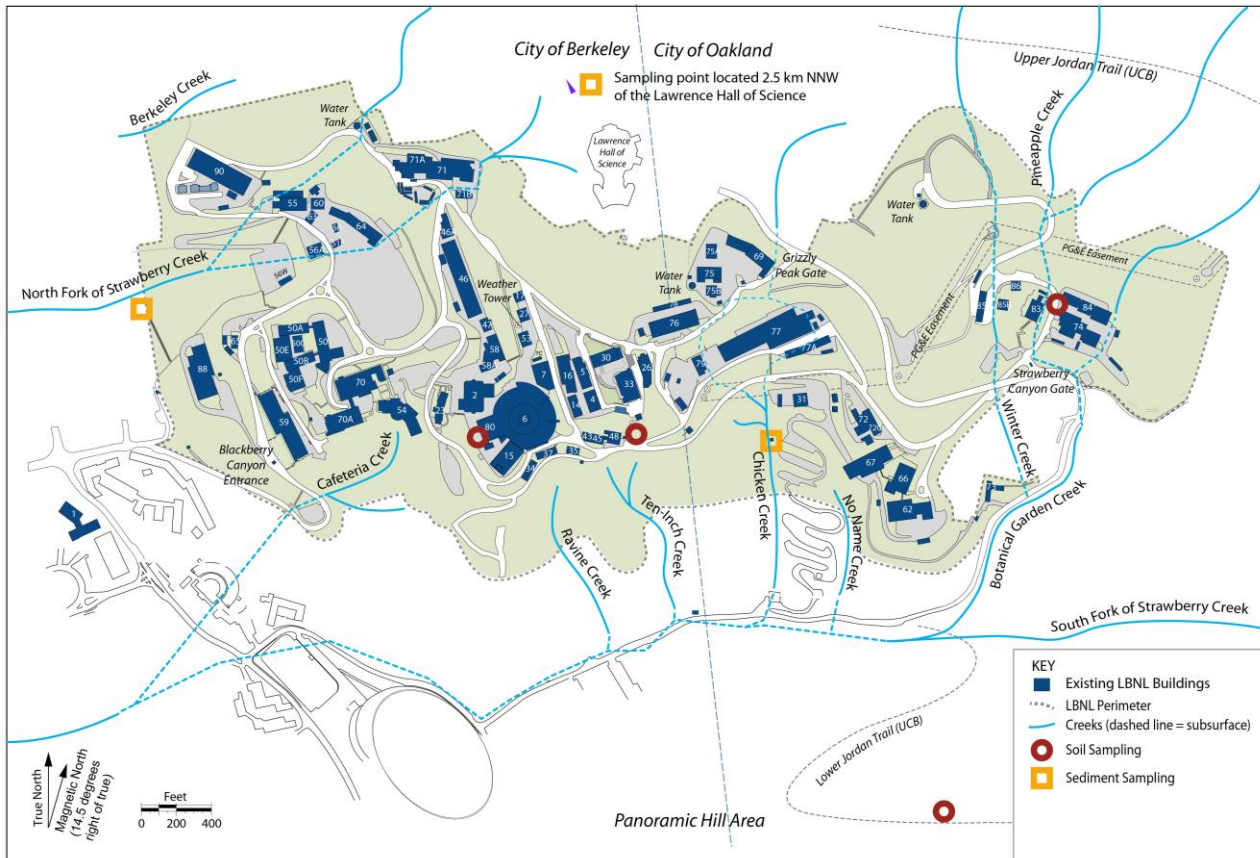


Figure 4-6 Soil and Sediment Sampling Sites

For radioisotope analysis, gross alpha, gross beta, and gamma emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soils (Eisenbud, 1973; NCRP, 1987). Tritium measurements at each sampling location were below detection limits.

For non-radioisotope analysis, pH and moisture content measurements at each of the sampling locations were within the historical range for sediments at Berkeley Lab. Values for petroleum hydrocarbons (diesel and oil/grease) were within the historical range found at Berkeley Lab and well below the RWQCB and U.S. EPA screening levels (U.S. EPA, 2015). Metals results were within both the established Berkeley Lab soil background levels and levels commonly found in soils in the United States (Shacklette and Boerngen (1984).

4.7 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 Berkeley Lab activities and to calculate the potential human dose that would occur from consuming vegetation and foodstuffs.

Due to past air emissions from the former NTLF located at Building 75, vegetation near that site contains measurable concentrations of tritium. Tritium in vegetation occurs in two chemical forms – organically bound tritium and tissue-free water tritium. Berkeley Lab analyzes vegetation for both forms. Since the closure of the

NTLF in December 2001, tritium emissions from Berkeley Lab activities have decreased sharply, and tritium concentrations in vegetation have decreased as well, albeit more slowly.

To document changes in the concentrations of tritium in the local vegetation, Berkeley Lab has sampled vegetation every five years since closure of the NTLF, most recently in the fall of 2015. The sampling confirmed that although vegetation in the vicinity of the former NTLF hillside stack contains measurable tritium concentrations, the concentration continues to decrease compared to previous sampling events. Concentrations in much of the area around this former stack are projected to decrease below the detectable limit by the next scheduled vegetation sampling event in 2020.

4.8 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 Optics and Acceleration System Integrated Studies Project (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 LBNL do not measurably increase the dose to the public.

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

- Real-time monitors that continuously detect and record gamma radiation and neutron dose
- Passive detectors called “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 Berkeley Lab operations is negligible and comparable to the measured background location. The locations of real-time monitors and dosimeters are shown on Figure 4-7. The results of both measurement methods are given in terms of dose and are provided in Section 5.2.

4.9 RADIOLOGICAL CLEARANCE

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, LBNL’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, even if the amount of radioactivity is known to be below the applicable release limit.

Berkeley Lab applies the required release and clearance criteria to all property under consideration, and property is only released when it can be demonstrated that that it does not contain residual radioactive material, or residual radioactivity has been characterized sufficiently to demonstrate through process knowledge or radiological survey

that it only contains 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. Only high-value released property worth more than \$100,000 is included in this Site Environmental Report, and in 2015 Berkeley Lab released no such property from radiological control.

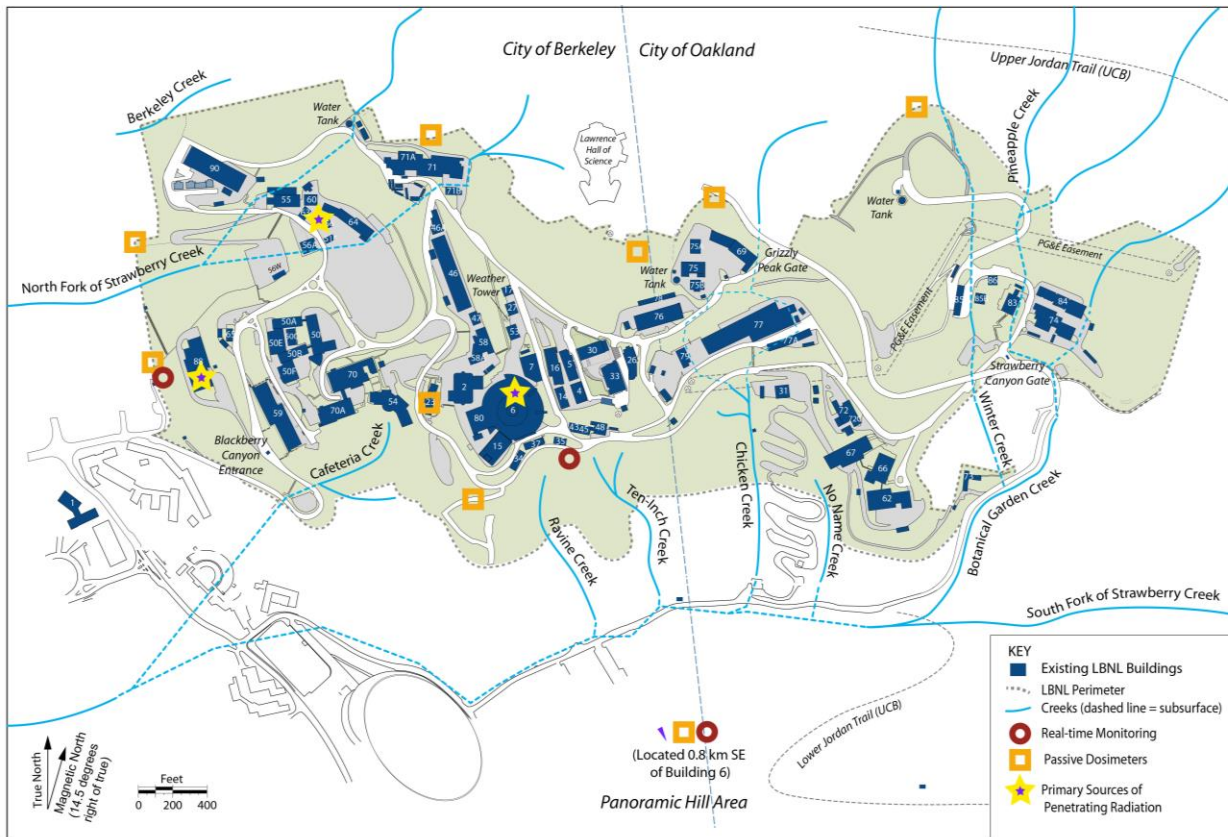


Figure 4-7 Environmental Penetrating Radiation Primary Sources and Monitoring Stations

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 dose results from Berkeley Lab's penetrating radiation and airborne radionuclide monitoring programs. This includes the annual dose to nearby individual members of the public and 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 dose to humans projected from each monitoring program is presented in Sections 5.2 and 5.3, and the results are then discussed in terms of the overall impact of LBNL's radiological activities on members of the public in the form of total dose (Section 5.4). Additionally, 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. LBNL'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 are estimated through the required National Emission Standards for Hazardous Air Pollutants (NESHAP) regulatory process (U.S. EPA, 1989), as discussed in Section 4.2. If the potential for a public dose is greater than 1 mrem to an individual or 10 person-rem to a population, an in-depth quantitative review is required. No quantitative reviews were required or performed in 2015.

5.2 DOSE FROM PENETRATING RADIATION

As discussed in Section 4.8, penetrating radiation from Berkeley Lab operations is measured by real-time monitors and passive dosimeters. The results of real-time penetrating radiation measurements, which are used to determine compliance with DOE Order 458.1, indicate that the maximum annual dose from gamma and neutron radiation to a person outside the western boundary of the site was 4.0×10^{-1} mrem, and that this maximum dose was located at the nearest residence about 360 feet from the primary contributing source, which was the 88-inch Cyclotron. The annual population dose to people in the surrounding region that extends 50 miles from the site was estimated at 4.13×10^{-1} 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 Berkeley Lab 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 4.2. Once emitted, these radionuclides may interact with such environmental media 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. Details of dose calculations from dispersible airborne radionuclide emissions are included in LBNL’s annual NESHAP report (LBNL, 2016b).

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 2015, the calculated annual dose from airborne radionuclides was 7.86×10^{-3} mrem, which is approximately 0.08% 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 1.56×10^{-1} person-rem. There is no regulatory standard for the collective dose metric.

5.4 TOTAL DOSE TO THE PUBLIC

The total radiological impact to the public from penetrating radiation and airborne radionuclides is well below applicable standards and several orders of magnitude less than local background radiation levels. As shown on Figure 5-1, the maximum effective dose equivalent from penetrating radiation and airborne radionuclides from Berkeley Lab operations to an individual residing near LBNL in 2015 was approximately 4.0×10^{-1} mrem/yr. Penetrating radiation (i.e., gamma and neutron radiation) from accelerators at LBNL 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 0.1% of the average natural background radiation dose (310 mrem/yr) in the United States (NCRP, 2009), and about 0.4% of the DOE annual limit from all sources (100 mrem/yr) (DOE, 2013).

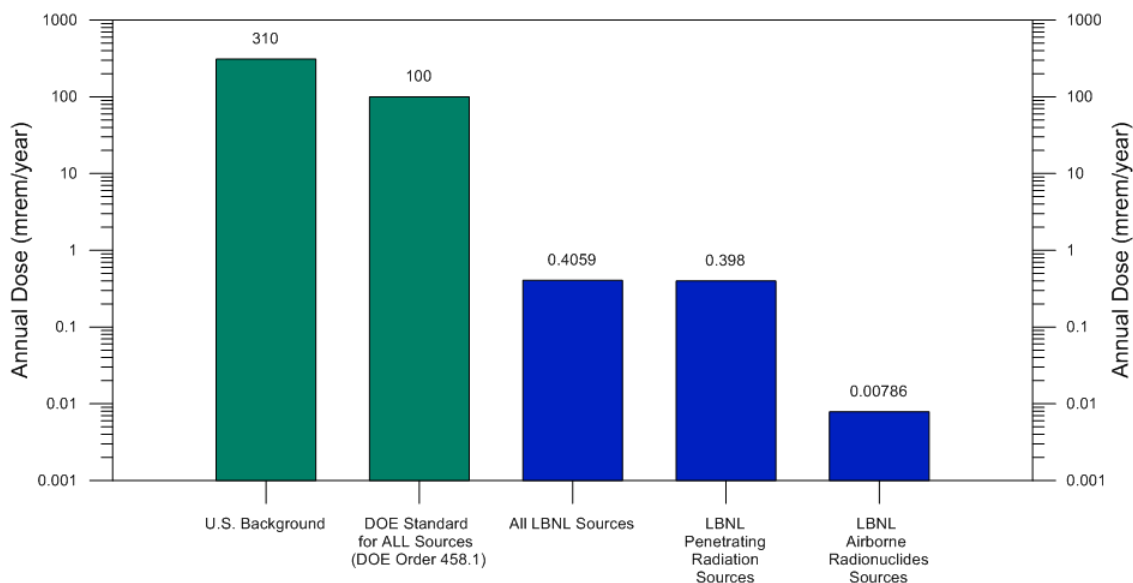


Figure 5-1 2015 Comparative Radiological Doses

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 determine 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.

In addition, the monitoring and sampling activities and results presented in this report were conducted in accordance with Berkeley Lab's *Environmental Monitoring Plan* (LBNL, 2013b) and applicable guidance from DOE (2015b) and the U.S. EPA (1989). Whenever extra QA and Quality Control (QC) measures are required, a Quality Assurance Project Plan is developed and implemented, such as those in place for NESHAP stack air monitoring activities (LBNL, 2012b) and the Environmental Restoration Program (LBNL, 2009b).

In 2015, LBNL had contracts with five commercial analytical laboratories for specific analytical services:

- ALS (Fort Collins, Colorado)
- BC Laboratories (Bakersfield, California)
- Curtis & Tompkins (Berkeley, California)
- GEL Laboratories (Charleston, South Carolina)
- Vista Analytical Laboratory (El Dorado Hills, California)

All of these laboratories are certified through California's Environmental Laboratory Accreditation Program (ELAP) by having demonstrated the capability to analyze samples for environmental monitoring using approved testing methods (CDPH, 1994a). These laboratories must meet demanding QA and QC specifications and certifications that were established to define, monitor, and document laboratory performance (LBNL, 2012d), and their QA and QC data is incorporated into Berkeley Lab's data quality assessment processes.

Each data set (batch) received from one of 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 periodic auditing through the DOE Consolidated Audit Program (DOECAP). A DOECAP audit generally takes three days to complete and is conducted by five or more experienced auditors from across the DOE complex. When one of the laboratories contracted to providing analytical services to Berkeley Lab is audited, Berkeley Lab strives to have at

least one LBNL representative on the audit team. A DOECAP audit also entails a review of the analytical laboratory's performance in proficiency testing, as required by the California ELAP. In 2015, three of the five analytical laboratories – ALS, BC Laboratories, and GEL Laboratories – were audited under the DOECAP. None were found to have a major deficiency during an audit, and any identified minor deficiencies were followed by corrective action plans and tracked to closure.

In addition, DOE Berkeley Site Office's Oversight and Issues Management Program (DOE, 2014) enables DOE to provide external awareness of Berkeley Lab programs by participating in operational activities such as field orientations, meetings, audits, workshops, document and information system reviews, and day-to-day communications. DOE criteria for performance evaluation include federal, state, and local regulations with general applicability to DOE facilities, and other DOE requirements.

6.2 ENVIRONMENTAL MONITORING SAMPLES AND RESULTS PROFILE

Throughout 2015, a total of 2,572 individual air, sediment, soil, vegetation, and water samples were collected under Berkeley Lab's environmental monitoring programs, generating 76,939 analytical results. Samples were obtained from nearly 970 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 the Environmental Restoration Program documents available on the program's web page (<http://www2.lbl.gov/ehs/erp/html/documents.shtml>) or in hardcopy reports at the main branch of the Berkeley Public Library.

The sampling result totals include those from activities associated with the Old Town Phase 1 Demolition Project that were carried out by the demolition subcontractor and provided to Berkeley Lab. This project accounted for over half of the environmental monitoring programs' sampling locations in 2015, over 20% of the individual samples collected, and nearly 10% of the analytical results.

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 2015, a total of 47 split and 79 duplicate samples were collected for either radiological or non-radiological analyses, or both. These samples led to 246 split and 1,739 duplicate results. Additionally, 174 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, 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 2,883 radiological and non-radiological QC analyses to validate the environmental samples submitted by Berkeley Lab. These QC analyses include various types of blank, replicate (also referred to as duplicate), matrix spike, and laboratory control samples. Table 6-1 shows the breadth and diversity of the QC activity.

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.

Table 6-1 Summary of Quality Control Testing Performed by Analytical Laboratories

Program	Number of Sample Batches	Number of QC Analyses	Number of Laboratories Involved	Radiological ^a	Non-radiological ^b
Stack Air	43	126	2	√	—
Stormwater and Creeks	89	247	4	√	√
Wastewater	138	573	5	√	√
Groundwater	149	947	5	√	√
Soil Investigation	116	480	1	—	√
Sediment	15	45	4	√	√
Soil	13	33	4	√	√
Vegetation and Foodstuffs	2	8	1	√	—
DMS Sampling	112	424	2	√	√

^a checkmark in this column indicates that the program tests for radiological substances. A dash means no testing occurred.

^b A checkmark in this column indicates that the program tests for non-radiological substances. A dash means no testing occurred.

References

- 42 United States Code (USC) §6991, 1988. *Resource Conservation and Recovery Act, Regulation of Underground Storage Tanks* (as amended).
- Bay Area Air Quality Management District (BAAQMD), 2014. *Permit to Operate for Lawrence Berkeley National Laboratory (Plant No. 723 and GDF No. 6134)* and *Permit to Operate for Joint Genome Institute (Plant No. 14549)*. July.
- California Department of Public Health (CDPH), 1984. *Domestic Water Quality and Monitoring Regulations*, 22 CCR §64443 (as amended).
- California Department of Public Health (CDPH), 1994a. *Certification and Amendment Process*, 22 CCR §64803 (as amended).
- California Department of Public Health (CDPH), 1994b. *Standards for Protecting Against Radiation*, 17 CCR §30253 (as amended).
- California Department of Toxic Substances Control, 2015. DTSC-Modified Screening Levels. September.
- California Health and Safety Code §39000 *et seq.*, 1967. *Air Resources* (as amended).
- California Health and Safety Code §25100 *et seq.*, 1972. *Hazardous Waste Control Law* (as amended).
- California Health and Safety Code §25280 *et seq.*, 1983. *Underground Storage of Hazardous Substances* (as amended).
- California Health and Safety Code §25500 *et seq.*, 1985. *Hazardous Materials Release Response Plans and Inventory Law* (as amended).
- California Health and Safety Code §44300 *et seq.*, 1987. *Air Toxics “Hot Spots” Information and Assessment Act* (as amended).
- California Health and Safety Code, §25270 *et seq.*, 1989. *Aboveground Petroleum Storage Act* (as amended).
- California Health and Safety Code §117600–118360, 1991. *Medical Waste Management Act* (as amended).
- California State Water Resources Control Board (SWRCB), 2012. *General Permit for Stormwater Discharges Associated with Construction and Land Disturbance Activities*, Order No. 2009-0009-DWQ, NPDES No. CAS000002. July.
- California State Water Resources Control Board (SWRCB), 2013. *Amending Monitoring and Reporting Program for Statewide General Waste Discharge Requirements for Sanitary Sewer Systems*, Order No. WQ 2013-0058-EXEC. August.

- California State Water Resources Control Board (SWRCB), 2014. *General Permit for Storm Water Discharges Associated with Industrial Activities* Water Quality Order 2014-0057-DWQ, NPDES General Permit No. CAS 000001. April.
- California Water Code §13000 *et seq.*, 1969. California Porter-Cologne Water Quality Control Act (as amended).
- City of Berkeley, 2014. *Certified Unified Program Agency Consolidated Permit and Registration*. May.
- Central Contra Costa Sanitary District, 2014. *Permit to Operate for Joint Genome Institute*. July.
- (U.S.) Department of Energy (DOE), 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH0173T. January.
- DOE, 1995. *Mixed Waste Site Treatment Plan for the Lawrence Berkeley National Laboratory*. October.
- DOE, 2002. *A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota*, DOE-STD-1153-2002. July.
- DOE, 2005. *Contract Between the United States of America and the Regents of the University of California, UC-DOE Prime Contract (No. DE-AC02-05CH11231)* (as amended).
- DOE, 2011a. Order 436.1, *Departmental Sustainability*. May.
- DOE, 2011b. DOE-STD-1196-2011, *Derived Concentration Technical Standard*.
- DOE, 2012. Order 231.1B Admin Chg 1, *Environment, Safety, and Health Reporting*.
- DOE, 2013. Order 458.1 Admin Chg 3, *Radiation Protection of the Public and the Environment*. January.
- DOE, 2014. *Berkeley Site Office Oversight and Issues Management Program Manual*. May.
- DOE, 2015a. *Contract Between the United States of America and the Regents of the University of California, UC-DOE Prime Contract (No. DE-AC02-05CH11231), Section J, Appendix B, FY2015 Performance Evaluation and Measurement Plan* (Modification No. 869).
- DOE, 2015b. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, DOE-HDBK-1216-2015. March.
- DOE Berkeley Site Office, 2015. *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, 2014, to September 30, 2015*. December.
- East Bay Municipal Utility District (EBMUD), 2012. *Wastewater Discharge Permit No. 5023891-1 for Lawrence Berkeley National Laboratory*. July.
- EBMUD, 2013a. *Wastewater Discharge Permit No. 0660079-1 for Lawrence Berkeley National Laboratory*. May.

- EBMUD, 2013b. *Wastewater Discharge Permit No. 5034789-1 for Lawrence Berkeley National Laboratory*. March.
- Eisenbud, M., 1973. *Environmental Radioactivity 2nd Edition*, Academic Press Inc. September.
- Executive Order 13423, 2007. *Strengthening Federal Environmental, Energy, and Transportation Management*.
- Executive Order 13514, 2009. *Federal Leadership in Environmental, Energy, and Economic Performance*.
- Executive Order 13693, 2015. *Planning for Federal Sustainability in the Next Decade*.
- Health Physics Society, 2010. *Radiation Risk in Perspective*. Position Statement of the Health Physics Society.
- International Organization for Standardization (ISO), 2004. *Environmental Management Systems: Requirements with Guidance for Use*, ISO 14001:2004. November.
- LandScan population distribution data, accessed April 14, 2014, <http://web.ornl.gov/sci/landscan/>.
- Lawrence Berkeley National Laboratory (LBNL), 2002. *Analysis of Background Distributions of Inorganic Elements in the Groundwater at Lawrence Berkeley National Laboratory*. July.
- LBNL, 2005. *Corrective Measures Study Report*. February.
- LBNL, 2006a. *Groundwater Monitoring and Management Plan*. March.
- LBNL, 2006b. *Soil Management Plan*. March.
- LBNL, 2009a. *Analysis of Background Distributions of Metals in the Soil at Lawrence Berkeley National Laboratory*. April.
- LBNL, 2009b. *Quality Assurance Project Plan for Environmental Restoration Program*. September.
- LBNL, 2012a. *Environmental Management System Plan*, LBNL-PUB-3180. May.
- LBNL, 2012b. *Quality Assurance Program Plan for NESHAP Compliance*. November.
- LBNL, 2012c. *Spill Prevention, Control, and Countermeasure Plan for Lawrence Berkeley National Laboratory*. December.
- LBNL, 2012d. *Statement of Work for Analytical Services*. April.
- LBNL, 2013a. *Environmental ALARA Program Plan, Revision 6*. March.
- LBNL, 2013b. *Environmental Monitoring Plan*. June.
- LBNL, 2013c. *Quality Assurance Program Description*, LBNL/PUB-3111, Revision 11. December.
- LBNL, 2014a. *Requirements and Policies Manual, Quality Assurance Policy*, Document Number 04.03.01.000. August.

- LBNL, 2014b. *Spill Prevention, Control, and Countermeasure Plan for Joint Genome Institute*. February.
- LBNL, 2015a. *Lawrence Berkeley National Laboratory Site Sustainability Plan for FY2016*. December 4.
- LBNL, 2015b. *Sewer System Management Plan*. April.
- LBNL, 2015c. *Stormwater Monitoring Implementation Plan*. June.
- LBNL, 2015d. *Storm Water Pollution Prevention Plan*. June.
- LBNL, 2016a. *Quality Management Plan*. Environment, Waste & Radiation Protection Department. February.
- LBNL, 2016b. *Radionuclide Air Emission Annual Report for FY 2015*. May.
- National Council on Radiation Protection and Measurements (NCRP), 1987. *Exposure of the Population of the United States and Canada from Natural Background Radiation*, NCRP Report No. 94.
- National Council on Radiation Protection and Measurements (NCRP), 2009. *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 160.
- San Francisco Bay Regional Water Quality Control Board (RWQCB), 2015. *Water Quality Control Plan for the San Francisco Bay Basin*, Chapter 3.
- San Francisco Bay Regional Water Quality Control Board (RWQCB), 2016. *Environmental Screening Levels (Interim Final)*. February.
- Shacklette, H.T., and J.G. Boerngen, 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States, U.S. Geological Survey Professional Paper 1270.
- U.S. Environmental Protection Agency (EPA), 1976. *National Primary Drinking Water Standards*, 40 CFR 141, Subpart B (amended).
- U.S. EPA, 1989. *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*, 40 CFR Part 61, Subpart H (amended).
- U.S. EPA, 2015. *Regional Screening Levels – Generic Tables*. November.

Acronyms and 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
Berkeley Lab	Lawrence Berkeley National Laboratory
CARB	California Air Resources Board
CCCSD	Central Contra Costa Sanitary District
CCHS	Contra Costa Health Services
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
Ci	curie
COD	chemical oxygen demand
CUPA	Certified Unified Program Agency (California)
DCE	dichloroethylene
DOE	United States Department of Energy
DOECAP	Department of Energy Consolidated Audit Program
DTSC	Department of Toxic Substances Control (California)
E85	85% ethanol / 15% unleaded fuel blend
EBMUD	East Bay Municipal Utility District
EHS	Environment / Health / Safety Division at Berkeley Lab
ELAP	Environmental Laboratory Accreditation Program
EMP	Environmental Management Program
EMS	Environmental Management System
EPCRA	Emergency Planning and Community Right-to-Know Act
ESG	Environmental Services Group
F	Fahrenheit
FLEXLAB	Facility for Low-Energy eXperiments in buildings LABoratory
FTU	fixed treatment unit
FY	fiscal year (October 1 – September 30)
GAC	granular activated carbon
gal	gallon(s)
GHG	greenhouse gas

HMBP	Hazardous Materials Business Plan
IGP	Industrial General Permit (for stormwater discharges associated with industrial activity)
ISO	International Organization for Standardization
JGI	Joint Genome Institute
kg	kilogram(s)
L	liter(s)
LBNL	Lawrence Berkeley National Laboratory
µg	microgram(s)
mg/kg	milligrams per kilogram
mrem	millirem (one thousandth of a rem, or 1×10^{-3} rem)
mrem/yr	millirem per year
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NTLF	National Tritium Labeling Facility
pCi	picocurie (one trillionth of a curie)
QA	quality assurance
QAPD	Quality Assurance Program Description
QC	quality control
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
SARA	Superfund Amendments and Reauthorization Act
RWQCB	San Francisco Bay Regional Water Quality Control Board
SF ₆	sulfur hexafluoride
SPCC	Spill Prevention, Control, and Countermeasure (Plan)
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCE	trichloroethylene
TPH	total petroleum hydrocarbons
TSS	total suspended solids
UC	University of California
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

Glossary

accuracy

The closeness of a measurement to its true value.

Advanced Light Source

An accelerator 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 sample analysis.

annual effective dose equivalent

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

background radiation

Ionizing radiation from sources other than LBNL. 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, water, or vegetation. *See also* pollutant.

cosmic radiation

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

curie

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

detection limit

The lowest concentration of an analyte that can reliably be distinguished from a zero concentration.

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.

dose, population

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.

dosimeter

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

duplicate sample

A sample that is equivalent to a routine sample and is analyzed to evaluate sampling or analytical precision.

effective dose equivalent

Abbreviated EDE, it is 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 of 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 ($1/2 \times 1/2$); after three half-lives, one-eighth of the original activity remains ($1/2 \times 1/2 \times 1/2$); 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 11e(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* dose, population.

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.

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 protection standard

Limits on radiation exposure regarded as necessary for protection of public health. These standards are based on acceptable levels of risk to individuals.

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* nuclide and radioactivity.

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.

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.