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Volume I

BERKELEY LAB

Lawrence Berkeley
National Laboratory

Site Environmental Report for 2011
Volume I

Environment, Health, and Safety Division

September 2012

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Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 90-1023
Berkeley, California 94720

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DISTRIBUTION

Subject: 2011 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 2011. 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 2011 environmental monitoring, compliance, and restoration programs at LBNL. This assurance can be made based on the reviews conducted by DOE/BSO, Oak Ridge Operations Office, 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@bso.science.doe.gov .

Sincerely,

Aundra Richards
Site Office Manager

Site Environmental Report for 2011

Volume I

September 2012

Ernest Orlando Lawrence Berkeley National Laboratory

Cover photo by John Turner of the Material Sciences Division

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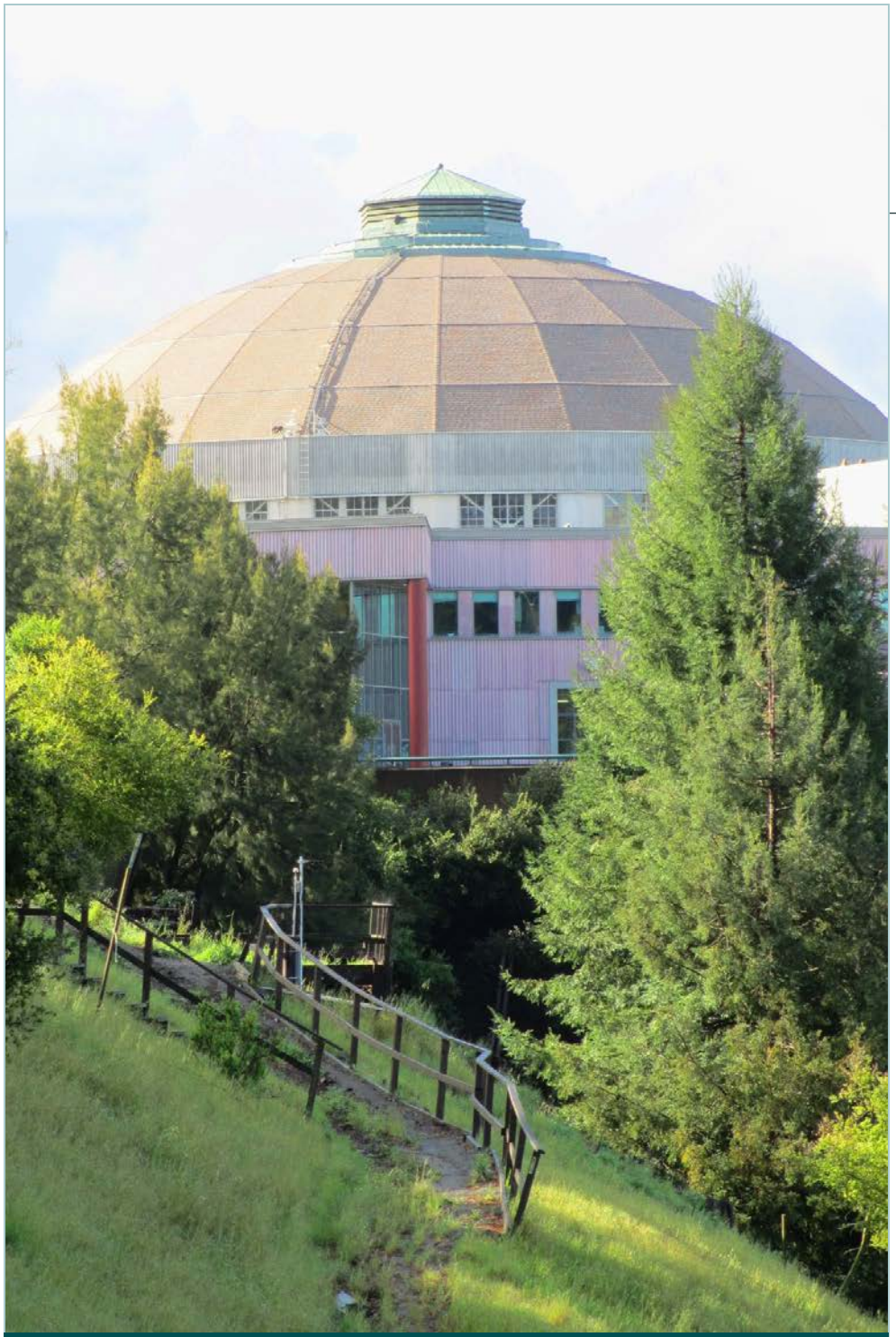

Scientists from around the world use the Advanced Light Source in Building 6.

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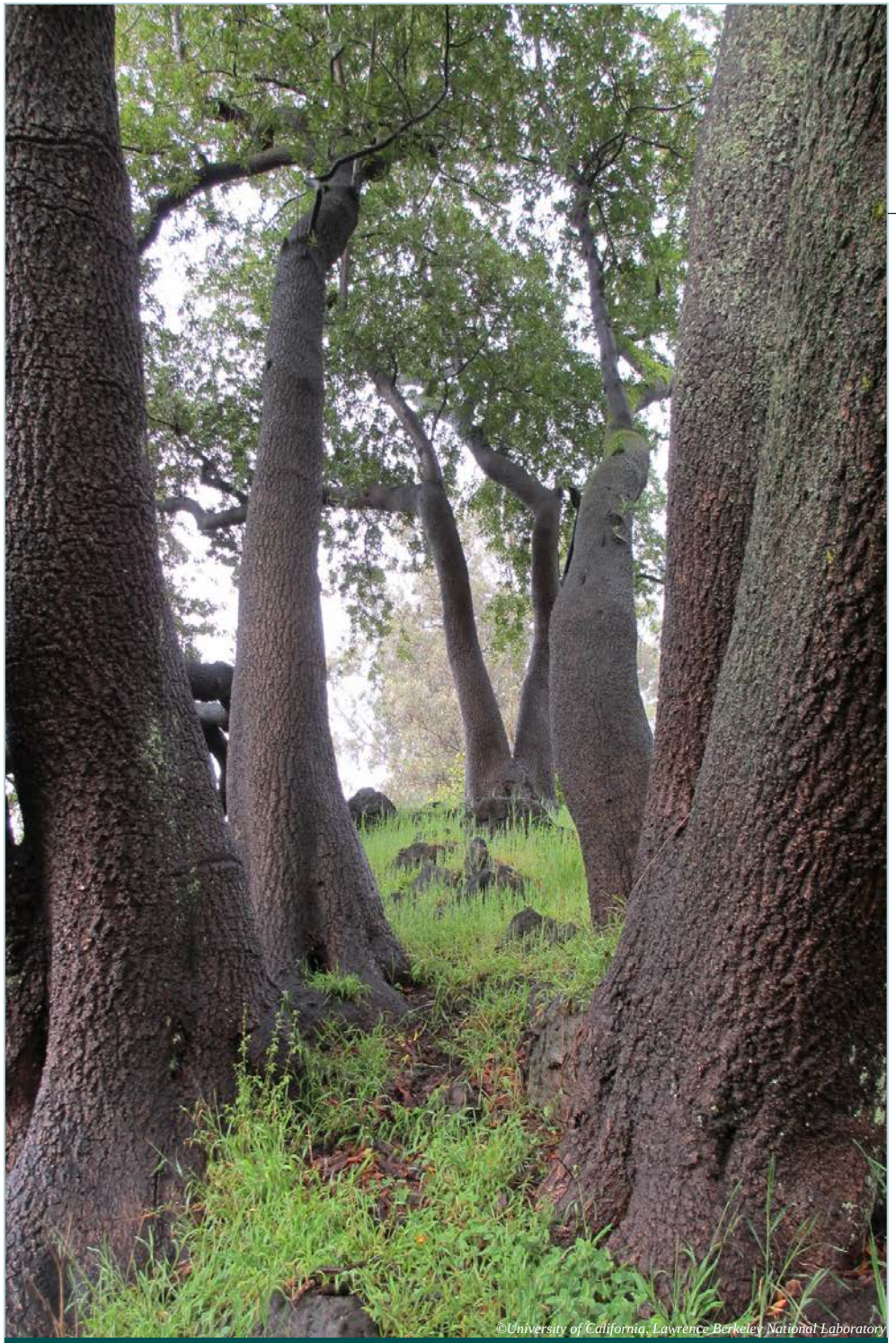


Mature Bay Laurel (*Laurus nobilis*) trees behind Building 85.

Preface

Each year, the University of California (UC), as the managing and operating contractor of the Ernest Orlando Lawrence Berkeley National Laboratory, prepares an integrated report regarding its environmental programs to satisfy the requirements of United States Department of Energy (DOE) Order 231.1B, *Environment, Safety, and Health Reporting*.[1] The *Site Environmental Report for 2011* summarizes Berkeley Lab's environmental management performance, presents environmental monitoring results, and describes significant programs for calendar year (CY) 2011. Throughout this report, "Berkeley Lab" or "LBNL" refers both to (1) the multiprogram scientific facility the UC manages and operates on the 202-acre university-owned site located in the hills above the UC Berkeley campus, and the site itself, and (2) the UC as managing and operating contractor for Ernest Orlando Lawrence Berkeley National Laboratory.

The report is separated into two volumes. Volume I is organized into an executive summary followed by six chapters that include an overview of LBNL, a discussion of its Environmental Management System (EMS), the status of environmental programs, summarized results from surveillance and monitoring activities, and quality assurance (QA) measures. Volume II contains individual data results from surveillance and monitoring activities.

The *Site Environmental Report* is distributed online from the Berkeley Lab Environmental Services Group (ESG) home web page, located at www.lbl.gov/ehs/esg/. Many of the documents cited in this report also are accessible from the ESG web page. Links to documents available online are

cited in the References section. Compact disc and printed copies of this *Site Environmental Report* are available upon request.

The report follows Berkeley Lab's policy of using the International System of Units (SI), also known as the metric system of measurements. Whenever possible, results are also reported using the more conventional (non-SI) system of measurements, because the non-SI system is referenced by several current regulatory standards and is more familiar to some readers. Two tables are provided at the end of the Glossary to help readers: Table G-1 defines the prefixes used with SI units of measurement, and Table G-2 provides conversions to non-SI units.

Years mentioned in this report refer to calendar years unless specified as fiscal year(s). Berkeley Lab's fiscal year (FY) is October 1 to September 30, and begins in the year previous to its name, i.e., FY 2011 was from October 1, 2010, to September 30, 2011. For ease of reference, a key to acronyms and abbreviations used in this report can be found directly after the text, at the end of Chapter 6. A glossary is also provided for readers who may be unfamiliar with some of the terms used in this report.

This report was prepared under the direction of Ron Pauer of ESG. Please address any questions regarding this report to him by telephone at 510-486-7614, or by e-mail at ropauer@lbl.gov. The primary contributors were David Baskin, Tim Bauters, Ned Borglin, Robert Fox, Blair Horst, John Jelinski, Ginny Lackner, Jeff Philliber, Nancy Rothermich, Patrick Thorson, Linnea Wahl, and Suying Xu (Volume II).

Readers are encouraged to comment on this report by completing the survey form found at www.lbl.gov/ehs/esg/Reports/tableforreports.shtml.

Researchers at Berkeley Lab helped develop the first energy-efficient dual-paned windows, now used in buildings and homes world-wide for billions of dollars in energy savings. This Berkeley Lab building is a windows testing facility.

Executive Summary

LBNL is a multiprogram scientific facility operated by the UC for the DOE. LBNL's research is directed toward the physical, biological, environmental, and computational sciences, in order to deliver scientific knowledge and discoveries pertinent to DOE's mission.

This annual *Site Environmental Report* covers activities conducted in CY 2011. The format and content of this report satisfy the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*,[1] and the operating contract between UC and DOE.[2]

INTEGRATED SAFETY MANAGEMENT AND ENVIRONMENTAL MANAGEMENT SYSTEMS

Berkeley Lab employs an Integrated Safety Management System (ISMS), which is a management approach that applies the following core environmental, safety, and health functions to all LBNL work:

1. Work planning
2. Hazard and risk analysis
3. Establishment of controls
4. Work performance in accordance with the controls
5. Feedback and improvement

LBNL activities are planned and conducted with full regard to protecting employees, the public, and the environment and complying with all applicable environmental, safety, and health laws and regulations.

In 2011, Berkeley Lab continued to implement its Environmental Management System (EMS) and integrate it with LBNL's ISMS. When practical, the existing processes used for integrated safety management were used to support and implement environmental performance improvement and compliance management. New processes were developed to support the EMS where needed.

The EMS itself promoted activities for reducing Berkeley Lab's environmental impacts in areas such as energy, fuel, water use, toxic air emissions, and landfill waste, while improving performance in acquiring more environmentally sustainable and preferable products, such as computers and monitors that meet international environmental performance criteria.

For more information, see Chapter 2.

OPERATING PERMITS, INSPECTIONS, AND INCIDENTS IN 2011

At the end of the year, Berkeley Lab held 52 environmental operating permits from various regulatory agencies for air and water quality protection and hazardous waste handling.

During the year, 27 inspections of Berkeley Lab's environmental programs occurred, including both regulatory agency inspections and internal LBNL inspections. Two violations resulted from these inspections. Both violations have been corrected.

For additional information on operating permits, inspections, and violations, please see Sections 3.2.1 and 3.2.2. For details of DOE-reportable environmental incidents, see Section 3.2.3.

PERFORMANCE EVALUATION

Each year, UC and DOE assess the performance of Berkeley Lab's environmental program using measures and a rating system developed jointly by Berkeley Lab, UC, and DOE. The rating system includes possible letter grades ranging from A+ to F. In FY11, the Lab's EMS was evaluated and given a performance rating of A-. The EMS was successful in many areas including:

- Reducing radioactive waste and nuclear material
- Increasing water recycling
- Increasing electric vehicle use
- Diverting demolition waste
- Installing cool roofs

ENVIRONMENTAL MONITORING AND DOSE ASSESSMENT

Berkeley Lab's environmental monitoring program serves several purposes:

- Demonstrate that LBNL activities operate within regulatory and DOE requirements
- Provide a historical record of LBNL impacts on the environment
- Support environmental management decisions
- Provide information on the effectiveness of emission control programs
- Assess the maximum potential radiological dose to members of the public and to biota (plants and animals)

To assess potential doses to the public resulting from Berkeley Lab operations, three types of environmental radiation are measured:

1. Penetrating radiation (gamma and neutron) from sources such as accelerators
2. Discharges of dispersible radionuclides to stack air and sanitary sewer water
3. Concentrations of radionuclides in the ambient environment (air, surface water, vegetation, soil, sediment, and groundwater)

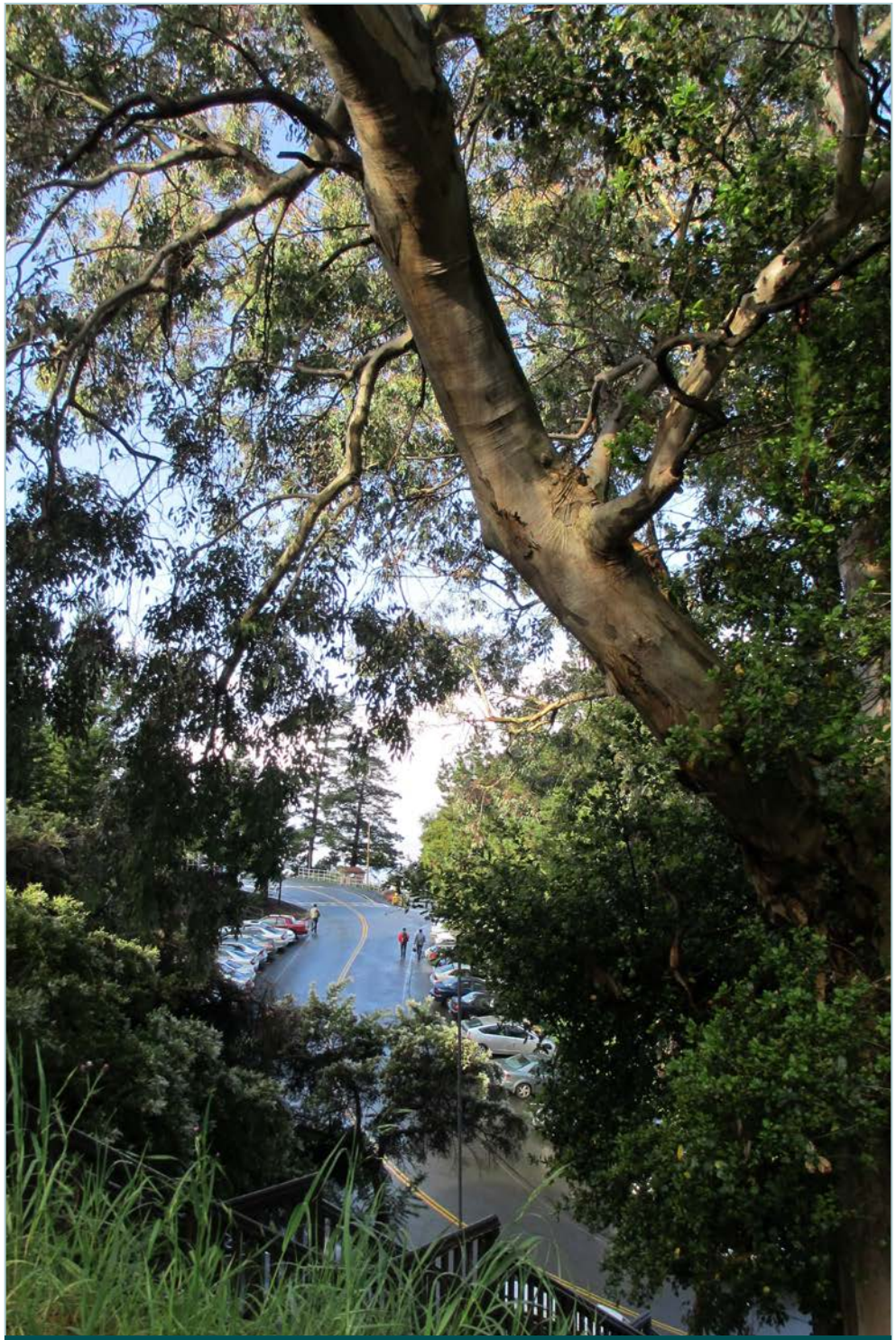
Of these three, penetrating radiation and dispersible airborne radionuclides are the only significant contributors to dose to the public. In 2011, the maximum dose to an individual member of the public residing near Berkeley Lab from penetrating radiation and dispersible airborne radionuclides was about 2.0 × 10-4 millisievert (mSv) (0.02 millirem [mrem]).

This is approximately 0.007% of the average United States natural background radiation dose (3.1 mSv [310 mrem])[3] and about 0.02% of the DOE annual limit for the public from all sources (1.0 mSv [100 mrem]).[4] The estimated maximum potential dose from airborne radionuclides released from Berkeley Lab in 2011 was 5.0×10^{-5} mSv (0.005 mrem). This is approximately 0.05% of the United States Environmental Protection Agency (U.S. EPA) annual dose limit for the public from dispersible radionuclide emissions (0.10 mSv/year [yr] [10 mrem/yr]).[5]

Berkeley Lab also estimates the cumulative dose impact (population dose) from penetrating radiation and dispersible airborne radionuclides to the entire population found within an 80-kilometer (km) (50-mile [mi]) radius of Berkeley Lab. This measure is the sum of all individual doses to the population residing or working within this radius. The population dose for 2011 from penetrating radiation and airborne radionuclides was estimated at 1.8×10^{-3} person-sievert (person-Sv) (0.18 person-rem). From natural background radionuclides alone, this same population receives an estimated dose of 12,000 person-Sv (1,200,000 person-rem).[6] No regulatory standard exists for this measure.

During the year, ambient air, creek water, groundwater, sediment, soil, stormwater, and wastewater were monitored for radiological and nonradiological constituents to comply with environmental regulations, permits, and DOE requirements. Most results were below or near analytical detection limits, or within urban background levels and below regulatory limits.

Investigations conducted as part of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program (CAP) since the early 1990s have identified and characterized eleven areas of groundwater contamination at Berkeley Lab. Berkeley Lab is currently in the Corrective Measures Implementation (CMI) phase of the RCRA CAP. The purpose of the CMI phase is to operate, maintain, and monitor the corrective measures (clean-up activities) approved by the State of California Department of Toxic Substances Control (DTSC) for cleanup of the contaminated groundwater. Groundwater monitoring data indicate that the corrective measures have been effective in reducing concentrations of contaminants in the groundwater, the groundwater plumes are stable or attenuating, and contaminants are not migrating offsite in the groundwater. Although the groundwater at Berkeley Lab is not used for domestic, irrigation, or industrial purposes, the long-term goal is to restore all groundwater at LBNL to drinking water standards, if practicable. For more details on environmental monitoring conducted in 2011, see Chapter 4. For more details on radiological dose assessments conducted in 2011, see Chapter 5.



View of Lawrence Road between Buildings 54 and 23.

1. Introduction

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1.1 HISTORY

Lawrence Berkeley National Laboratory, also known as Berkeley Lab, was founded by Ernest O. Lawrence in 1931. Lawrence invented a unique particle accelerator, called a cyclotron, which ushered in a new era in the study of subatomic particles. In 1939, he was awarded the Nobel Prize in physics. Through his work, Lawrence launched the modern era of multidisciplinary team science. Today, Berkeley Lab continues the tradition of multidisciplinary scientific teams working together to solve global problems in human health, technology, energy, and the environment. Twelve Nobelists have worked here, and countless other researchers have contributed to LBNL's success as an institution for furthering our nation's scientific endeavors.

Berkeley Lab supports work in such diverse fields as genomics, physical biosciences, alternative fuels, nanoscience, life sciences, fundamental physics, accelerator physics and engineering, energy conservation technology, and materials science. Through its fundamental research in these fields, Berkeley Lab has achieved international recognition for its leadership and has made numerous contributions to national programs. Berkeley Lab's research embraces the following concepts to align with the DOE mission:

- Explore the complexity of energy and matter
- Advance the science needed to attain abundant clean energy
- Understand energy impacts on our living planet
- Provide extraordinary tools for multidisciplinary research

Since its beginning, Berkeley Lab has been managed by UC. Numerous Berkeley Lab scientists are faculty members on the campuses of either UC Berkeley or UC San Francisco. They and other Berkeley Lab researchers guide the work of graduate students pursuing advanced degrees through research at LBNL. High school students and teachers, as well as college students, also participate in many Berkeley Lab programs designed to enhance science education, which is part of LBNL's mission.

1.2 LOCATION

Berkeley Lab is located about five kilometers (km) (three mi) east of San Francisco Bay (see Figure 1-1) on land owned by UC. The main site is situated on approximately 82 hectares (202 acres) of land. UC provides long-term land leases to the DOE for many of the facilities and buildings at LBNL.

The main site lies in the hills above the UC Berkeley campus, on the ridges and draws of Blackberry Canyon (which forms much of the western part of the site) and adjacent Strawberry Canyon (which forms much of the southern part of the site). Elevations across the site range from 135 to 350 meters (m) (450 to 1,150 feet [ft]) above sea level. The western portion of the site is in Berkeley, while the eastern portion is in Oakland; the entire site is located within Alameda County. The population of Berkeley is estimated at approximately 113,000, and that of Oakland at 391,000.[1]

Adjacent land use consists of residential, institutional, and recreational areas (see Figure 1-2). The area to the south and east of LBNL, which is University land, is maintained largely in a natural or undeveloped state, but includes UC

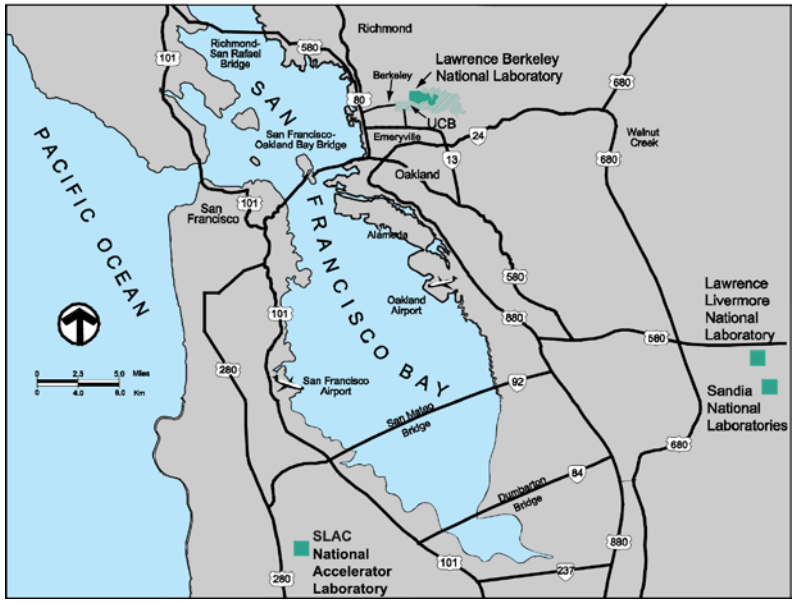

Figure 1-1 Map of National Laboratories in the San Francisco Bay Area

Berkeley's Strawberry Canyon Recreational Area and Botanical Garden. To the northeast are the University's Lawrence Hall of Science, Space Sciences Laboratory, and Mathematical Sciences Research Institute. Berkeley Lab is bordered on the north by a residential neighborhood of low-density, single-family homes and on the west by the UC Berkeley campus, as well as by multi-unit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.

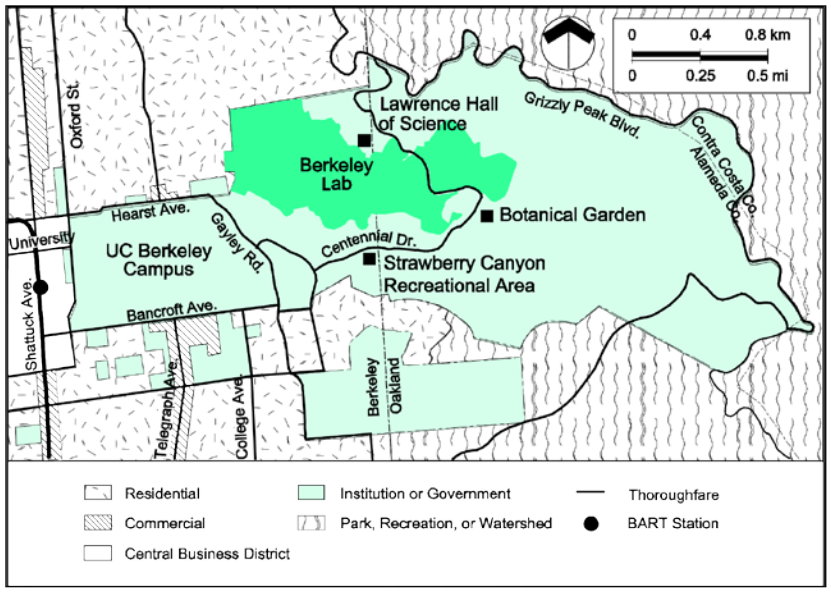

Figure 1-2 Adjacent Land Use

1.3 POPULATION AND SPACE DISTRIBUTION

Approximately 3,500 scientists and support personnel, plus approximately 1,000 faculty and students, work at Berkeley Lab. In addition, LBNL hosts over 5,000 participating guests who use its unique scientific facilities each year for varying lengths of time. Berkeley Lab also supports over 700 scientists and staff at off-site locations including Walnut Creek, Oakland, Berkeley, Emeryville, and Washington, D.C. Approximately 1,400 of LBNL's scientists and guests are jointly affiliated with some university campus.

Berkeley Lab research and support activities are conducted in structures having a total area of about 190,000 gross square meters (gsm) (approximately 2.0 million gross square feet [gsf]). About 82% of the total space is at the main site, about 3% is on the UC Berkeley campus (e.g., Donner Laboratory), and the remaining 15% is located in various other off-site leased buildings. Figure 1-3 shows the Berkeley Lab space distribution.

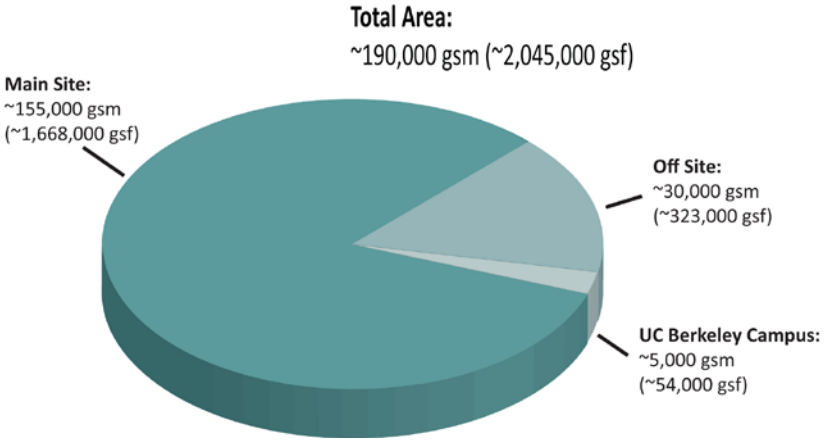

Figure 1-3 Approximate Space Distribution

1.4 WATER SUPPLY

All domestic water for LBNL's main site is supplied by the East Bay Municipal Utility District (EBMUD). The site has no drinking water wells. The domestic water originates in Sierra Nevada watershed lands and is transported to the Bay Area and ultimately to Berkeley Lab through a system of lakes, aqueducts, treatment plants, and pumping stations. EBMUD tests the water for contaminants and treats it to meet disinfection standards required by the Safe Drinking Water Act.[2]

Wisely managing water use in a region prone to periodic drought is a critical issue for LBNL. Additionally, federal requirements help create incentives for

reducing water consumption. Most recently, Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,*[3] extended the earlier goal of EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*[4] for DOE to reduce water use intensity (i.e., consumption per square foot of building space). The new goal increases the water use intensity reduction from the previous goal of 16% reduction by October 2015, relative to 2007, to 26% by October 2020, also relative to 2007. DOE established the water use intensity goal at contractor sites in DOE Order 436.1, *Departmental Sustainability*[5] (approved May 2011).

LBNL has been actively implementing measures to reduce potable water consumption, as it works toward achieving this goal. During FY09 LBNL achieved a water use intensity savings of almost 18%. During FY10, savings dropped to 8% from baseline largely due to new leaks in LBNL's water distribution piping. The leaks were repaired, restoring the earlier savings; during FY11, savings of 18.5% from baseline were observed. However, over the long term, even with a well-maintained, efficient system in place, it will be very challenging to meet October 2020 potable water savings goals. This is because planned new facilities are designed to use water-based cooling systems instead of high-energy-consuming, air-based cooling systems to meet their cooling needs.

1.5 ENERGY USE

All electric power for Berkeley Lab's main site is provided by the Western Area Power Administration. Power purchases are arranged through DOE's Northern California Power Purchase Consortium. This consortium 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 from the Defense Logistics Agency - Energy, and is transported through Pacific Gas and Electric piping. In response to DOE's accelerated renewable energy acquisition goals, Berkeley Lab set a goal to offset at least 7.5 % of its overall electric power needs (including off-site facilities) through purchasing renewable energy credits (RECs), starting in FY10. In FY11, these credits represented 8.8% of overall electric power used, exceeding the 7.5% goal.

LBNL has committed to achieving an energy use intensity (energy use per facility floor square feet) reduction of 30% from 2003 levels by October 2015 in response to EO 13423. By the end of FY11, Berkeley Lab used about 1% more than the baseline. The increase is attributed to both expanded scientific missions and demolition of the Bevatron facility, which removed significant square footage from the denominator of the intensity calculation. EO 13514 indirectly addressed energy use reductions by adding requirements to reduce greenhouse gas (GHG) emissions (see next section).

1.6 GREENHOUSE GAS EMISSIONS

DOE Order 436.1, incorporating EO 13514 requirements, established goals to significantly reduce GHG emissions from federal facilities by October 2020. DOE has prescribed department-wide GHG reduction goals as described in Table 1-1.

Unlike the energy use intensity reduction goal addressed in Section 1.5, the GHG savings goals do not allow exclusion of emissions attributed to High Energy Mission Specific Facilities (HEMSFs), nor are adjustments allowed for new construction or related expanding scientific missions. The effects of future increases in Berkeley Lab's scientific projects, primarily those requiring enormous computing power, overwhelm all efforts to achieve the goals via energy savings efforts. If HEMSFs were not considered, LBNL would far exceed the GHG reduction goals by FY 2020.

Table 1-1 DOE Greenhouse Gas Reduction Goals by Type of Emission

DOE Reduction Goal	Scope Number	Definition of Scope
28%	1	Emissions from sources of greenhouse gases that are owned or controlled by the reporting entity (LBNL)
	2	Indirect emissions that are a consequence of consuming purchased electricity, heat, or steam by the reporting entity (LBNL), but occur at sources owned or controlled by another entity
13%	3	Other indirect emissions attributable to activities such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity (LBNL) not covered in Scope 2 (e.g., business travel, employee commuting, electricity-related activities), outsourced activities, and waste disposal

1.7 METEOROLOGY

The climate at LBNL is temperate, influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west, and on the east by the East Bay hills paralleling the eastern shore of this same bay. These physical barriers contribute significantly to the relatively warm, wet winters and cool, dry summers of the site. The average annual temperature at the site is about 13° Celsius (C) (55° Fahrenheit [F]). More than 90% of the time the temperature is in the range of 5° to 20°C (41° to 68°F). Seldom does the maximum temperature exceed 32°C (90°F) or the minimum temperature drop below 0°C (32°F).

The average annual precipitation, based on nearly 40 years of Berkeley Lab measuring records, is slightly more than 77.5 centimeters (cm) (30.5 inches [in]) of rain during the season (October 1 to September 30). Measurable snow does not fall at Berkeley Lab. About 95% of the annual rainfall occurs between October and April; typically the wettest of these months are December through February. The 2010/2011 rainfall season closed with 94 cm (37.02 in) of precipitation, or about 20% above the normal amount.

On-site wind patterns change little from one year to the next. Figure 1-4 is a graphical summary of the annual wind patterns called a "wind rose," illustrating the frequency of the predominant wind patterns. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the bay, followed by lighter nighttime southeasterly drainage winds off the East Bay hills. The other predominant wind pattern is associated with storm systems passing through the region, which usually occur during the winter months. South-to-southeast winds in advance of each storm are followed by a shift to west or northwest winds after passage of the system.

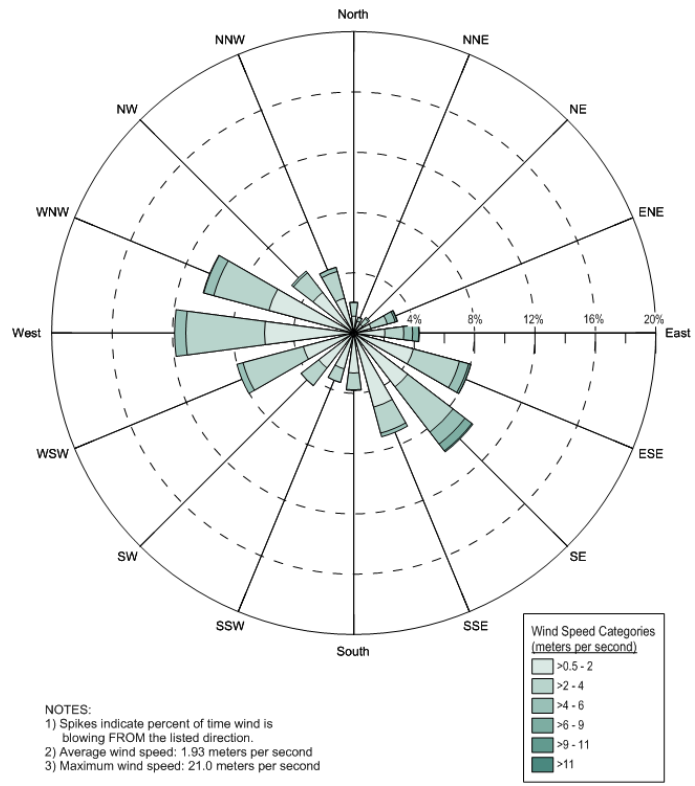

Figure 1-4 Annual Wind Patterns

1.8 VEGETATION

Vegetation on the Berkeley Lab site is a mixture of native plants, naturalized exotics, and ornamental species. The site was intensively grazed and farmed for about 150 years before Berkeley Lab development began in the 1930s. Current vegetation is managed in harmony with the local natural succession of native plant communities and the wooded and savanna character of the areas surrounding buildings and roads is maintained. Ornamental species are generally restricted to public spaces, courtyards, and areas adjacent to buildings. The site has no known rare, threatened, or endangered plant species. Figure 1-5 shows the vegetation types on-site.

The vegetation management program is designed to minimize wildland fire damage to structures by limiting the potential flame heights of ground cover vegetation to no more than 0.9 m (3 ft).

The following vegetation management is conducted annually:

- Cutting off tree limbs below a minimum of 1.8 to 2.4 m (6 to 8 ft) from the ground (depending on species)
- Cutting grasses to a maximum height of 7.6 cm (3 in)
- Removing brush, except ornamental bushes, in the area

The purpose of these vegetation management efforts is to minimize the amount of available fuel and the intensity of any future wildland fire. As a result, buildings at the site would more likely survive such a fire, and the lower-intensity fire conditions would allow regional fire fighters to suppress the flame front so that it would not proceed to the west of LBNL.

As a member of the Hills Emergency Forum, Berkeley Lab collaborates with other members (representatives from the neighboring cities of Berkeley and Oakland, EBMUD, and UC Berkeley), to improve vegetation management of the urban-wildland interface in adjacent areas.

1.9 WILDLIFE

Wildlife is abundant at Berkeley Lab because the site is adjacent to East Bay Regional Park District and UC open spaces. Wildlife is typical of that found in disturbed (e.g., previously grazed) areas of midlatitude California featuring a Mediterranean climate. More than 120 species of birds, mammals, reptiles, and amphibians are thought to traverse or exist on the site. The most abundant large mammal is the Columbian black-tailed deer. Habitat protected by various environmental laws exists on site. These are:

- An area 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. This area consists of a dense canopy of oak-bay woodland with undisturbed sandstone rocks that are embedded in the soil and have moist conditions underneath.[6] *Microcina leei* is listed as a "special animal" by the California Department of Fish and Game; however, it is not considered by the state to be a special-status species. It was first identified on the main site in the 1960s and again in the 1980s.
- An approximately five-acre area at the eastern boundary of LBNL is included in the U.S. Fish and Wildlife Service's (USFWS) designated critical habitat for the Alameda whipsnake. This snake species (*Masticophis lateralis euryxanthus*) is listed as threatened under both federal and state law and is found in open-canopied shrub communities, including coastal scrub and chaparral, and adjacent habitats including oak woodland, savanna, and grassland areas. The entire LBNL site was surveyed for whipsnake suitability in 2006. Several undeveloped areas were identified as having high and moderate "potential" or suitability for habitation by the Alameda whipsnake. In 2008, a three-month trapping survey was commissioned by LBNL and conducted by a licensed, permitted biologist. A single juvenile Alameda whipsnake was trapped in the undeveloped southeastern areas of the site.

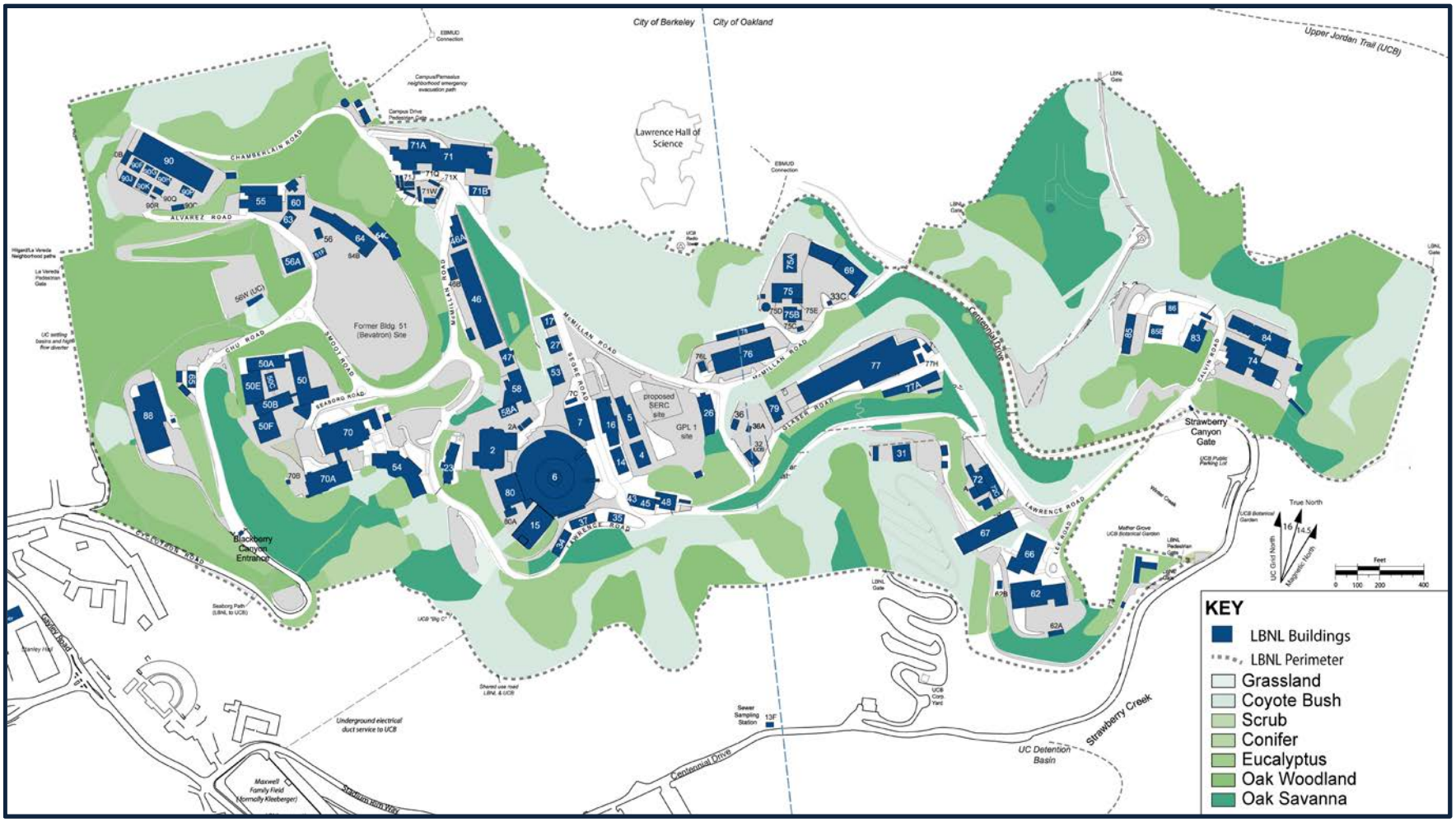

Figure 1-5 Vegetation Types

- A number of drainages, including potentially "jurisdictional" drainages as defined under the Clean Water Act (CWA), exist on the main site. Some are ephemeral or intermittent, and others (the North Fork of Strawberry Creek and Chicken Creek) are perennial. All jurisdictional waterways warrant special protection under the CWA. These jurisdictional drainages, along with four freshwater seeps, appear to support riparian habitat.

1.10 SOILS

The Moraga Formation, the Orinda Formation, and the Great Valley Group are the three principal bedrock units underlying the site as described below:

1. The western and southern parts of Berkeley Lab 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 developed area of the site. The Orinda Formation consists primarily of sandstones, mudstones, and conglomerates deposited in fluvial and alluvial environments. It typically has lower values of hydraulic conductivity (measure of the rate at which water can move through a permeable medium) than the underlying Great Valley Group or overlying Moraga Formation, and therefore it impedes the horizontal and vertical flow of groundwater.
3. The Moraga Formation consists of volcanic rocks that underlie most of the higher elevations of Berkeley Lab, as well as much of the central developed area ("Old Town"), and constitutes the main water-bearing unit at Berkeley Lab. Although the permeability of the rock 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 San Pablo Group (primarily marine sandstones) underlie the easternmost area of the site.

Surface materials at Berkeley Lab 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 one to several meters 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 meters of engineered cuts and fills at some locations.

1.11 GROUNDWATER

The groundwater elevation map of Berkeley Lab (Figure 1-6) shows that the water table approximately mirrors surface topography. The groundwater flow in the western portion of Berkeley Lab is generally westwards, and flow in the remainder of the site is generally southwards. The depth to groundwater varies from approximately 0 to 30 m (98 ft) below the surface. In some areas, due to the subsurface geometry and physical characteristics of various geologic units, groundwater flow directions vary from the general trends presented on the groundwater elevation map.

Groundwater at LBNL has a potential effect on slope stability and on the underground movement of contaminants (see Section 4.4). Berkeley Lab has a successful program of slope stabilization that reduces the risk of property damage caused by soil movement. This program includes construction of subsurface drain lines (hydraugers), vegetation cover, and soil retention structures.

1.12 SEISMICITY

The active Hayward Fault, a branch of the San Andreas Fault System, runs from northwest to southeast along the base of the hills at the western boundary of Berkeley Lab. The inactive Wildcat Fault traverses the site from north to south along the canyon at LBNL's eastern edge.

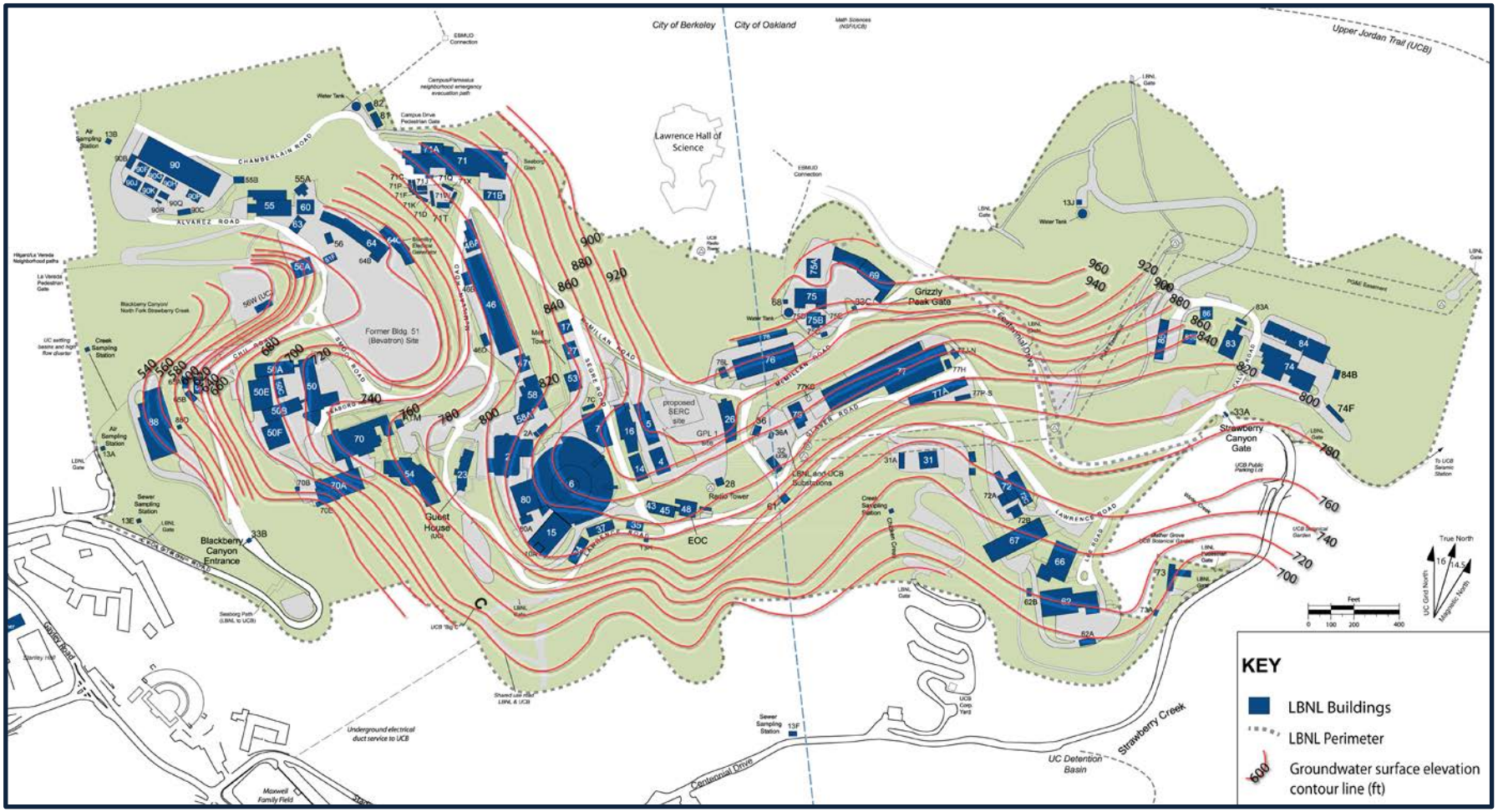

Figure 1-6 Groundwater Elevation Map

Flowering ice plant (Carpobrotus edulis) is found on Berkeley Lab's hillsides.

2. Environmental Management System

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2.1 SUMMARY

To continually improve environmental stewardship at Berkeley Lab, an environmental management system (EMS) provides a systematic approach to ensuring that environmental activities are both well-managed and provide business value by addressing regulatory compliance, program performance, and cost-effectiveness of activities.

LBNL's EMS begins with a broad-based environmental policy that commits Berkeley Lab to:

- Complying with applicable environmental, public health, and resource conservation laws and regulations
- Preventing pollution, minimizing waste, and conserving natural resources
- Correcting environmental hazards and cleaning up existing environmental problems
- Continually improving LBNL's environmental performance while maintaining operational capability
- Sustaining Berkeley Lab's overall mission

LBNL's approach is built around a framework that includes all eighteen elements of the International Organization for Standardization's (ISO) International Standard 14001:2004(E) *Environmental Management Systems-Requirements with Guidance for Use,*[1] though it does not include ISO 14001 certification of the EMS. Certification is not required and does not provide sufficient business value to Berkeley Lab. However, an external audit of the EMS by a qualified party is required every three years, with the most recent audit completed in June 2012.

The EMS Core Team, comprising representatives from the Environment, Health, and Safety (EH&S), Facilities, and the Office of the Chief Financial Officer (i.e., Procurement) organizations, is tasked with completing the annual cycle of planning, implementing, evaluating, and improving processes that help LBNL carry out its environmental policy. In 2011, environmental aspects (activities or services that may produce a change to the environment) were identified and their impacts to the environment were evaluated. Objectives and targets were developed or updated for each aspect that was determined to have a significant impact. Environmental Management Programs (EMPs) were prepared or updated to document actions necessary for reducing identified environmental impacts. A review of the EMS by senior management representatives for each of the Core Team organizations was conducted to provide feedback needed for continual improvement of the system.

2.2 BACKGROUND

In early 2007, EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*,[2] established the policy that federal agencies:

- Use EMS as the primary management approach for addressing environmental aspects of internal agency operations and activities, especially energy and transportation functions
- Establish agency objectives and targets to ensure implementation of this order
- Collect, analyze, and report information to measure performance with implementation of this Executive Order

In the fall of 2009, EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,*[3] expanded the policy by establishing greenhouse gas (GHG) emission reductions as a top priority, while leaving the goals and requirements of EO 13423 either in place or extending them to the end of FY20.

In response to EO 13423, DOE approved Order 430.2B, *Departmental Energy, Renewable Energy, and Transportation Management,*[4] and Order 450.1A, *Environmental Protection Program*[5] as the primary means of achieving the provisions of the Executive Order.

DOE Order 430.2B mandated an energy management program that considers energy use and renewable energy, water, new and renovated buildings, and vehicle fleet activities. The Order also incorporated the provisions of the *Energy Policy Act of 2005*[6] and the *Energy Independence and Security Act of 2007.*[7]

DOE Order 450.1A mandated the development of an EMS to implement sustainable environmental stewardship practices that:

- Protect the air, water, land, and other natural and cultural resources potentially impacted by facility operations
- Meet or exceed applicable environmental, public health, and resource protection laws and regulations
- Implement cost-effective business practices

Furthermore, the Order required that the environmental management system reflect the elements and framework found in ISO 14001:2004(E). This led to a significant update of Berkeley Lab's *Environmental Management System Plan*[8] in 2009. The EMS Plan and related documentation are found on LBNL's A-Z Index (www.lbl.gov/lab-index/) as *Environmental Management System* under "E."

In response to EO 13514, in May of 2011, DOE approved new Order 436.1, *Departmental Sustainability.*[9] This action consolidated and eliminated Orders 430.2B and 450.1A. It is also less prescriptive than Order 450.1, which set requirements for a site's EMS. However, Order 436.1 retained the requirement that a site must develop and maintain an environmental management system that conforms to ISO 14001:2004(E) standards. The new Order also states that the site sustainability goals must be integrated into the EMS.

The new Order established a requirement that Berkeley Lab develop a site sustainability plan. This plan must identify site contribution to the DOE sustainability goals defined in its agency-level *Strategic Sustainability Performance Plan.*[10] In December 2011, Berkeley Lab prepared the *FY2012 LBNL Site Sustainability Plan.*[11] This plan sets performance goals in such areas as:

- Scope 1 & 2 GHG emissions reduction
- Scope 3 GHG emissions reduction
- Energy use intensity reduction
- Renewable energy
- Fleet fuel consumption and vehicle inventory reduction
- High-performance sustainable design
- Regional and local planning
- Water use efficiency and management
- Pollution prevention
- Waste diversion
- Sustainable acquisition
- Electronic stewardship and data centers
- Site innovation

This plan can be found on the "sustainLBL" website (www.lbl.gov/sustainlbl/) under the "What the Lab is Doing" tab.

2.3 CONTINUAL IMPROVEMENT

Both the EMS and ISMS strive for continual improvement through a four-step plan-do-check cycle (see Figure 2-1). For that reason, Berkeley Lab keeps the programs integrated. To the extent that it is practical, existing ISMS

processes are used to support environmental performance improvement. In other cases, new processes have been developed to support the EMS. This approach allows LBNL to develop an EMS that is cost-effective and to focus resources on those activities with the highest potential environmental benefits.

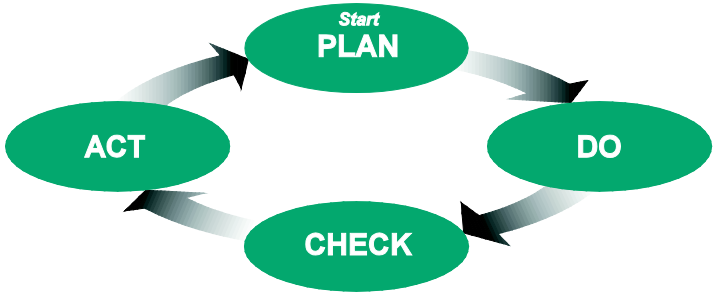


Figure 2-1 Cycle of Activities That Are Performed to Achieve EMS Goals

The plan-do-check-act cycle calls for defining the scope and purpose of the system, followed by a planning *(plan)* step to develop programs and procedures that must then be implemented *(do)*. Once implemented, programs must be assessed *(check)* and any problems corrected *(act)* to improve the effectiveness of the management system and to achieve improved environment, safety, and health performance. Table 2-1 shows the parallels between the four EMS top-level elements and ISMS core functions.

Table 2-1 EMS Top-Level Elements and Corresponding ISMS Core Functions

Environmental Management System		Integrated Safety Management System
PLAN	Planning	Define Work and Analyze Hazards
DO	Implementation and Operation	Develop & Implement Hazard Controls
CHECK	Checking and Corrective Action	Provide Feedback and Continuous Improvement
ACT	Management Review	Annual ISMS Review

2.4 IMPLEMENTATION

Six areas form the fundamental building blocks for implementing the EMS program:

1. EMS Core Team
2. Environmental aspects
3. Environmental Management Programs
4. Training
5. Appraisals
6. Management review

2.4.1 EMS Core Team

The Core Team is tasked with implementing and maintaining LBNL's EMS. The team's primary objective is reducing environmental impacts over time. As in the previous year, the Core Team consisted of key representatives from the EH&S, Facilities, and Procurement organizations that were most knowledgeable of environmental management concerns. The team was led by a representative of the EH&S organization. A representative from Berkeley Lab's Public Affairs Office and one from the DOE Berkeley Site Office were also invited to meetings to maintain operational awareness of activities. The primary functions of the Core Team were the following:

- Identify environmental aspects
- Determine significant impacts
- Develop objectives and targets for the significant aspects
- Prepare and implement the EMPs
- Evaluate all EMPs annually
- Coordinate internal assessments of the EMS
- Review performance results
- Prepare recommendations to management to improve the EMS

- Coordinate the annual management review of the EMS
- Coordinate internal communications about the EMS

2.4.2 Environmental Aspects

The Core Team reviewed the list of identified environmental aspects, whether adverse or beneficial. This review included a significance determination of each aspect's potential impact, using the following factors to shape its decisions:

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

Each aspect was given a numeric rating based on a three-tiered scoring system: high (3), medium (2), and low (1). Average scores and overall ratings for each aspect provided a starting point for the significance determination. Before a final significance determination was made, the Core Team members discussed and evaluated each activity and associated impacts.

2.4.3 Environmental Management Programs

EMPs are prepared for each significant aspect. There are currently eight activities determined to be significant. Objectives and targets for reducing environmental impacts were re-evaluated for each of the following activities:

- Diesel particulate matter air emissions
- Energy use
- GHG emissions
- Petroleum use
- Procurement of goods and services
- Solid waste diversion
- Traffic congestion
- Water use

Each EMP also established strategies and actions needed to achieve the objectives and targets; developed procedures, metrics, or techniques; and set up schedules. Each EMP is typically led by a member of the Core Team to coordinate actions and monitor the performance of each EMP, though a subject matter expert can also perform this role. Table 2-2 summarizes the EMPs active during 2011.

2.4.4 Training

Training is targeted and graded, commensurate with EMS roles and responsibilities. In order of increasing rigor, the following four levels of training were maintained during the year:

- General EMS awareness
- Comprehensive EMS awareness
- EMS implementation
- EMS auditor

General EMS awareness training lasts approximately one hour and is often tailored to the individual. General EMS awareness and its integration with safety and ISMS principles is also included in course EHS 0010, *Introduction to EH&S at LBNL*, which is a requirement for all new employees to LBNL. In contrast, EMS implementation and auditor training are multi-day courses taught by professional organizations and are generally reserved for the EMS professional. In between these levels is comprehensive EMS awareness training, which targets the EMS core team members to assist them in carrying out the responsibilities of their role in the EMS.

Table 2-2 Environmental Management Programs for 2011

Aspect/Activity	Objective(s)	Target(s)
Diesel Particulate Matter (DPM) Air Emissions	Implement alternatives for reducing DPM emissions from mobile and stationary sources.	Reduce DPM emissions 5% per year relative to a 2005 baseline year.
Energy Use	Implement sustainable practices to achieve energy efficiency.	Reduce energy use intensity 30% by the end of FY15, including a minimum cumulative reduction of 18% by the end of FY11 relative to the FY03 baseline year.
GHG Emissions	Reduce GHG emissions from broad range of activities.	Reduce Scopes 1 and 2 GHG emissions 28% and selected Scope 3 emissions 13% by end of FY20, relative to FY08 baseline.
Petroleum Use	Reduce vehicle fleet petroleum consumption.	Reduce fleet's annual petroleum consumption by 2% annually using FY05 fleet fuel consumption as a baseline.
Procurement of Goods and Services	Increase procurement of Energy Star Products and Recycled Content Products.	Increase procurements of Recycled Content Products 5% each year using FY05 as the baseline year.
Solid Waste Generation (Diversion)	Increase diversion of solid waste.	Increase solid waste diversion by 5% by the end of FY11 relative to the previous fiscal year.
Traffic Congestion	Reduce LBNL commute traffic through Transportation Demand Management and 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 Long Range Development Plan's Environmental Impact Report.
Water Use	Implement sustainable practices to reduce water use intensity.	Reduce potable water use consumption intensity 26% by the end of FY20 from FY07 base: reduce industrial/agricultural water use 20% by FY20 year end from FY10 base. Update and execute annual Water Metering Plan.

2.4.5 Appraisals

Under DOE Order 436.1, the most recent external audit of the Berkeley Lab EMS was completed in June 2012. A formal external audit includes the following elements:

1. An audit plan that reflects the scope and schedule of the audit
2. A review of background documents before the audit site visit
3. A physical audit site visit of the Lab to evaluate ISO standard conformity, consistency among EMS element implementations, and continual improvement of the EMS
4. Preparation of an audit report outlining audit findings
5. A briefing with senior managers from the Lab to review audit findings

The most recent internal review of the EMS, in September 2010, satisfied periodic program assessment requirements of the Technical Assurance Program that is administered by the Lab's Office of Contractor Assurance. The next internal review is set for 2013.

2.4.6 Management Review

The status of the EMS is reviewed annually by Berkeley Lab's senior management. Based on this review, senior management may determine that changes are needed in the EMS program. Factors such as improved assessment methodologies or major changes to the facility's mission, products, and processes are considered in determining the need for changes. The management review in 2011 included senior management representatives from EH&S, Facilities, and the Office of Chief Financial Officer divisions. Topics of discussion included a review of the recommendations from the previous year, a summary of events from the past year, including activities and accomplishments affecting EMP performance, and a look ahead to the projected emphasis of the management system for the upcoming year.

2.4.7 Environmental Management Performance

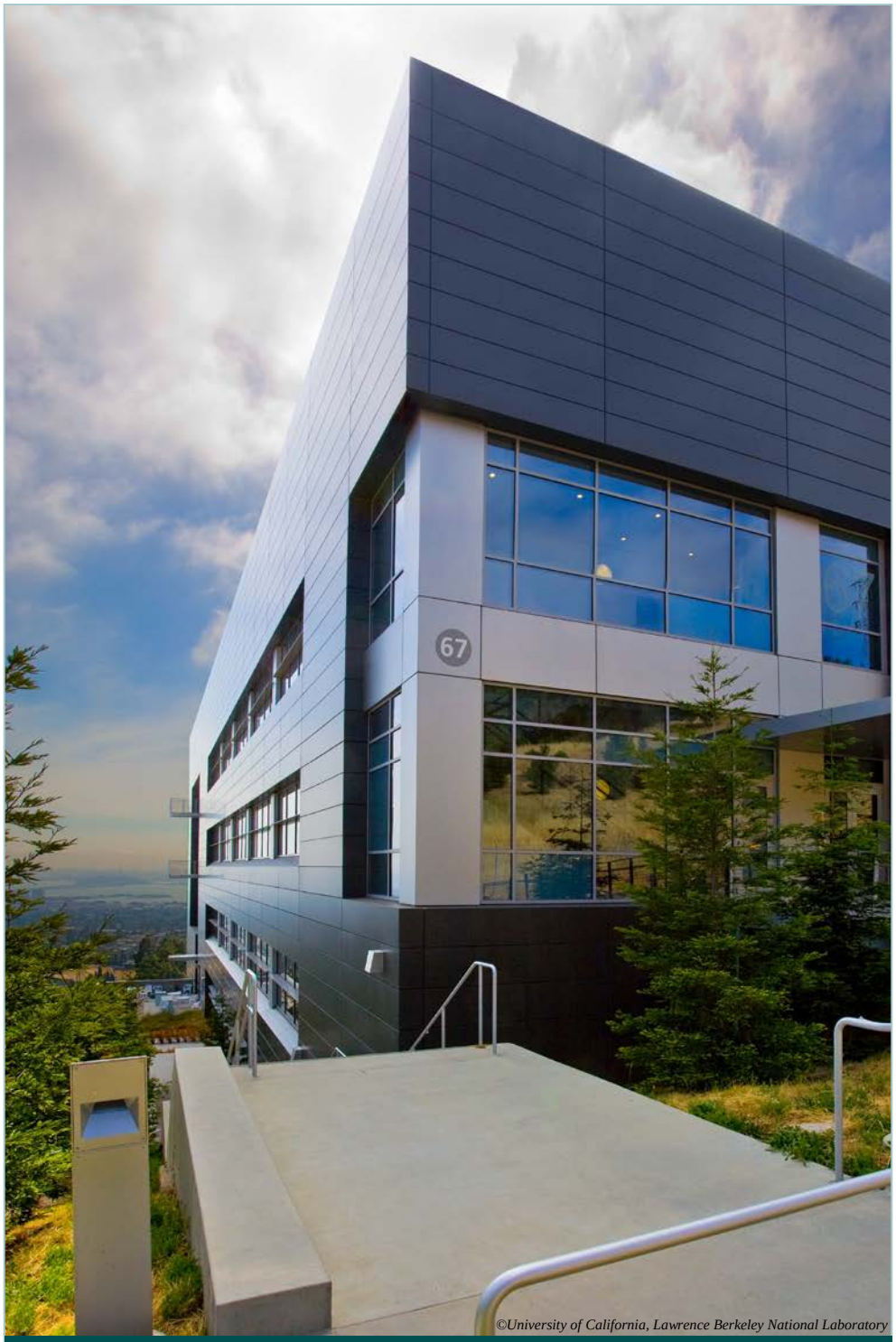
In the *FY2011 Performance Evaluation Report*[12], prepared by the DOE Berkeley Site Office, Berkeley Lab was given an A- rating for its management of environmental measures. This is, in part, based on achieving the highest or "green" rating within DOE's eight EMS scorecard metrics for:

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

Another significant achievement contributing to the A- rating was successful reduction of radioactive waste and nuclear material inventory at LBNL. Through an American Recovery and Reinvestment Act-funded Waste Isolation Pilot Plant Transuranic (TRU) waste campaign, LBNL was able to remove legacy mixed TRU Hazardous Waste Handling Facility waste. Nuclear material inventory was further reduced with shipments made through the Los Alamos Off-Site Source Recovery Program.

Other environmental performance highlights for 2011 included:

- Recycling approximately 500,000 gal/year (1,892,706 L/yr)of water from the Building 70A treatment unit to a nearby cooling tower
- Continuing expansion of GEM electric vehicle use
- Diverting demolition waste out of landfills from the Old Town and Building 51 demolition projects
- Installing energy-efficient "cool roofs" on additional site buildings



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Berkeley Lab's Molecular Foundry Building has been awarded a U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) gold certification.

3. Environmental Program Summary

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3.1 INTRODUCTION

This chapter provides an overview of Berkeley Lab's environmental protection program and reviews the status of various compliance programs and activities for 2011.

To continually improve environmental performance, LBNL implements a systematic approach to achieving environmental performance goals at the site via an EMS. For details on the EMS, see Chapter 2.

3.1.1 Overview of Environmental Responsibilities

To provide the highest degree of protection for the public and the environment, Berkeley Lab applies the principles of integrated safety management to LBNL's activities. This involves the performance of five core functions.[1]

- **Work Planning.** Clearly define the tasks that are to be accomplished as part of any given activity.
- **Hazard and Risk Analysis.** Finalize and determine the hazards and risks associated with any activity; in particular, risks to employees, the public, and the environment.
- **Establishment of Controls.** Controls must be sufficient to reduce the risks associated with any activity to acceptable levels as determined by responsible line management, but are always in conformance with all applicable laws and the relevant set of environment, safety, and health standards.
- **Work Performance.** Conduct tasks to accomplish the activity in accordance with the established controls.
- **Feedback and Improvement.** Implement a continuous improvement cycle for the activity, including incorporation of employee suggestions, lessons learned, and employee and community outreach, as appropriate.

The EH&S Division at Berkeley Lab is responsible for administering environmental protection and compliance programs at the site. The organizational structure of EH&S in 2011 is shown in Figure 3-1.

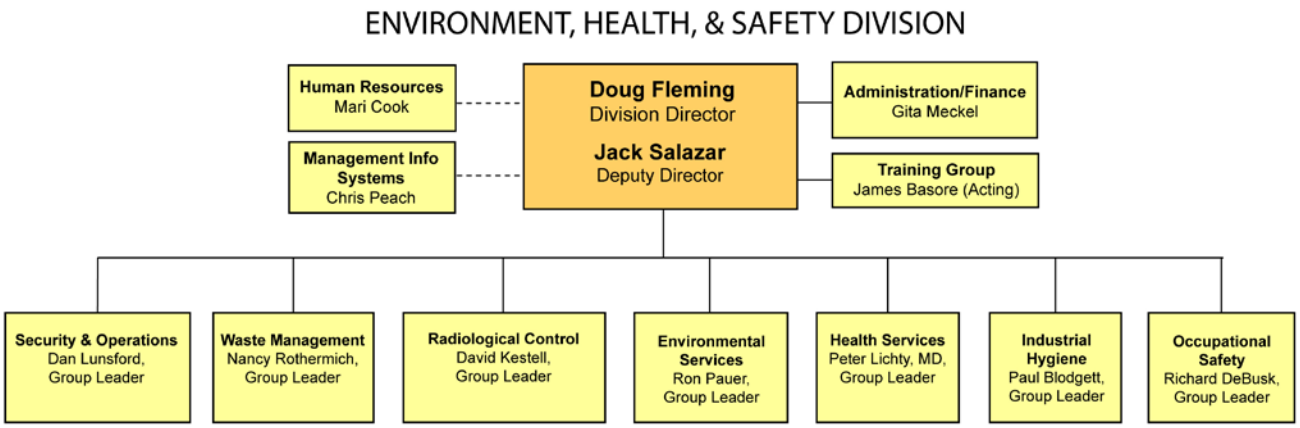

Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization in 2011

Environmental protection programs are largely administered by two EH&S organizations:

- **The Environmental Services Group (ESG)** oversees site-wide air and water quality compliance activities, provides technical assistance to LBNL staff, and manages environmental remediation activities, including groundwater sampling. These programs include environmental monitoring activities that provide information critical to demonstrating compliance and making programmatic decisions. (For monitoring result summaries, see Chapter 4.)
- The **Waste Management Group (WMG)** manages hazardous, medical, radioactive, mixed (hazardous and radioactive), and universal waste generated at Berkeley Lab.

3.2 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, inspections, and DOE-reportable environmental incidents at Berkeley Lab for 2011.

3.2.1 Summary of Environmental Permits

Some Berkeley Lab activities require operating permits from environmental regulatory agencies. Table 3-1 summarizes, by area of environmental activity, the 52 active permits held by LBNL at the end of 2011.

3.2.2 Summary of Audits and Inspections

The regulatory agencies that enforce the environmental requirements at Berkeley Lab periodically conduct inspections. Table 3-2 lists the inspections by these agencies that occurred at Berkeley Lab during 2011. Table 3-2 includes self-monitoring inspections conducted by Berkeley Lab that are required by EBMUD wastewater discharge permits because these activities expose LBNL to potential regulatory violations. A total of 27 inspections were conducted during 2011. Two violation notices resulted from these inspections.

Table 3-1 Environmental Permits Held by Berkeley Lab at the End of 2011

Type of Permit	Issuing Agency	Description	Number of Permits	Section for More Information
Air quality	BAAQMD[a]	Various activities with emissions to air	32	3.4.1.2
Hazardous waste	DTSC[b]	Hazardous Waste Handling Facility operations, waste generation areas	1	3.4.6.1
	COB[c]	Hazardous waste SAAs[g] and WAAs[h], fixed treatment units (5)	1	3.4.6.1
Underground storage tanks	COB[c]	Underground storage tanks containing petroleum products	6	3.4.6.4
Wastewater	EBMUD[d]	Sitewide and operation-specific wastewater discharges to sanitary sewer	5	3.4.9.1
	CCCSD[e]	Wastewater discharges to sanitary sewer at Joint Genome Institute in Walnut Creek	1	3.4.9.1
Stormwater	SWRCB[f]	Sitewide & construction stormwater discharges	6	3.4.9.2

[a] Bay Area Air Quality Management District
[b] Department of Toxic Substances Control
[c] City of Berkeley
[d] East Bay Municipal Utility District
[e] Central Contra Costa Sanitary District
[f] State Water Resources Control Board
[g] Satellite Accumulation Areas
[h] Waste Accumulation Area

Table 3-2 Environmental Audits, Inspections, and Appraisals in 2011

Organization	Inspection Title	Start Date	Violations
BAAQMD	Air emission sources	January 18	0
COB	Tiered permit units and hazardous waste generator areas	June 22	0
	Underground storage tanks	November 9[a]	2
U.S. EPA (with COB)	Hazardous materials/hazardous waste	September 27	0
EBMUD	Wastewater monitoring inspection at Hearst and Strawberry outfalls	April 22 April 26	0 0
	Wastewater monitoring inspection at B77 Fixed Treatment Unit	August 26	0
	Wastewater monitoring inspection at groundwater treatment units	February 7	0
DFG	Water/Mud Slurry Release into Strawberry Creek	January 11	0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	March 22 September 20	0 0
	EBMUD self-monitoring inspections at B77 Fixed Treatment Unit	March 15 August 26 September 14	0 0 0
	EBMUD self-monitoring inspections at groundwater treatment units	February 10 March 1 September 8 September 9	0 0 0 0
	EBMUD self-monitoring inspections for PCB congeners at the Bevatron demolition area	January 13 March 2 April 14 December 22	0 0 0 0
	EBMUD self-monitoring inspections for tritium at the Bevatron demolition area	May 18 July 25 August 4 September 20 October 17	0 0 0 0 0

[a] Inspection in 2011. Report received in 2012.

On November 9, 2011 the City of Berkeley inspected six underground storage tanks and identified two minor violations on two of the diesel tanks. On both tanks, the containment systems for the fill pipes had failed leak tests. The issue on one tank was resolved by tightening the containment system gaskets. The containment system on the second tank was eventually replaced. Both tanks have passed the subsequent leak testing.

3.2.3 Summary of DOE-Reportable Environmental Incidents

In 2011, five environmental incidents resulted in submittal of occurrence reports under the DOE occurrence-reporting program used to track incidents across the DOE complex. Brief descriptions of these five incidents are given below:

1. On 1/08/2011, a subcontractor discharged a water/mud material that had been generated as a result of storm drain cleaning activities. Due to the amount of material and the rate of release, an earthen berm was breached and the material flowed down a hillside and onto a road. Eventually it entered the storm drain system, which discharges into a creek below the site. Appropriate state and local agencies were notified. A warden for the California Department of Fish and Game (DFG) inspected the creek for adverse environmental impacts and none were found.
2. On 3/18/2011, a significant accumulation of concrete dust slurry was found on an electrical substation pad and in a concrete V-ditch below the pad. The source of the concrete slurry was traced to a demolition site at Building 51. Follow-up inspections found evidence of the concrete slurry in the storm drain system that discharged to the North Fork of Strawberry Creek. Based on the height of slurry residue on the wall of the storm drain inlet, it is believed that as much as 200 gallons (gal) (757 L) may have been discharged to the creek. Inspection of the creek did not find

evidence of the concrete slurry; however, the heavy rainfall that had occurred at the time may have removed evidence of the discharge. The appropriate state and local regulatory agencies were notified of the possible discharge to the North Fork of Strawberry Creek.

3. On 4/06/2011, water sample results were received that indicated an ongoing release of PCB contamination. Since the water eventually flowed into the creek below the site, appropriate state and local regulatory agencies were notified. An investigation determined that an overflow line from a dewatering sump was the most likely source and the line was plugged. Follow-up sampling of creek water showed the PCB levels were below detection levels.
4. On 8/19/2011, a vehicle hit a fire hydrant in the Building 88 parking lot, sheared the pipe at the base of the hydrant, and created a major water release. Approximately 200,000 gal (757,082 L) of water were released at a rate of approximately 6,000 gallons per minute (22,712 L/min). The water flowed down a hillside and onto a road below the site. It eventually flowed into a storm drain system which discharged into a creek that flows through the University of California at Berkeley campus. The release was reported to state and local environmental agencies and to University of California representatives. Although there were significant accumulations of sediment in the creek, subsequent surveys determined that there was no apparent environmental damage from this incident.
5. On 11/09/2011, the City of Berkeley conducted an underground tank inspection and identified two minor violations for two diesel tanks. On both tanks, the containment systems for the fill pipes failed their leak tests. One was corrected immediately by tightening the gaskets. A retest demonstrated that the leak had been repaired. On the second tank, the containment system was eventually replaced. It has also passed subsequent leak testing.

3.3 COMPLIANCE PROGRAMS

The following sections provide individual summaries of the more significant environmental compliance programs at Berkeley Lab.

3.3.1 Clean Air Act

The Clean Air Act[2] is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into these main categories:

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

The State of California's air pollution control program[3] gives it additional powers to regulate sources of air emissions.

Berkeley Lab divides its air quality protection and compliance activities into two categories: radiological (see Section 3.3.1.1) and nonradiological (see Section 3.3.1.2).

3.3.1.1 Radiological

Radionuclides released to the atmosphere from LBNL research activities must adhere to *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities* regulations,[4] as well as sections of DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*[5] U.S. EPA administers the National Emission Standards for Hazardous Air

Pollutants (NESHAP) regulations (under 40 CFR Part 61), which limit the dose to the public from LBNL's airborne radionuclide emissions to 0.10 mSv/yr (10 mrem/yr). Berkeley Lab documents its NESHAP review and compliance in its annual *Radionuclide Air Emission Report*.[6]

3.3.1.2 Nonradiological

The BAAQMD implements federal and state air quality requirements for most air emission activities that are not addressed by NESHAP regulations.

At the end of 2011, Berkeley Lab held 3 operating permits issued by the BAAQMD covering 32 emission sources.[7] Two of these operating permits cover activities located at the LBNL site, for 28 and 2 emission sources, respectively. The other operating permit covers two emission sources at the Production Genomics Facility in Walnut Creek, California. This facility is part of the Joint Genome Institute (JGI), a collaboration involving Berkeley Lab, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory research groups.

No other new emission sources were permitted during the year at Berkeley Lab or the Walnut Creek site.

For a list of active operating permits, see Table 3-3. Operating permits are renewed annually, at which time the BAAQMD also requests information required by the state's *Air Toxics "Hot Spots" Information and Assessment Act of 1987*.[8] While submitting annual update information for the BAAQMD operating permits, Berkeley Lab also submits its site-wide adhesive and sealant usage under the BAAQMD-approved alternative recordkeeping agreement for compliance with Regulation 8, Rule 51: Adhesive and Sealant Products. Activities covered by permits are subject to periodic inspection. BAAQMD performed one on-site inspection this year inspecting the following sources:

Table 3-3 Air Emission Sources Permitted by BAAQMD at the End of 2011

BAAQMD Category	Description (# of emission sources)	Building	Abatement Type
Combustion equipment	Standby emergency generators (4)	64, 66, 67, 70	Catalytic converter
	Standby emergency generators (3)	48, 50A, 72	Diesel particulate filter
	Standby emergency generators (17)	Various[a]	None
	Standby emergency generators (2)	JGI [b]	None
Gasoline dispensing	Fueling stations (2): 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

[a] Individual generators located at Buildings 2, 37 (2), 50B, 55, 62, 64, 70A, 74, 75, 77, 84B, and 85, plus four portable units

[b] Two generators located at the Joint Genome Institute in Walnut Creek, California

- Paint Spray Booth (S96)
- Sandblast Shop (S97)
- Facility-wide Solvent Wipe Cleaning (S188)
- Soil Vapor Extraction System (S110)
- Five Emergency Diesel Generators (S216, S218, S220, S221, S222)

No findings or violations were noted, and the facility was found to be in compliance with all BAAQMD regulations.

Berkeley Lab continues to operate its E85-fuel dispensing facility at the Building 76 Motor Pool. E85 fuel is a mixture of 85% ethanol and 15% unleaded gasoline. Federal mandates require that Berkeley Lab decrease the use of petroleum fuel.

Berkeley Lab facilities do not emit GHG in quantities exceeding either U.S. EPA or California reporting levels. However, EO 13514 requires Berkeley Lab to report its GHG emissions through DOE, which Berkeley Lab did in FY11 and will continue to do annually.

3.3.2 Comprehensive Environmental Response, Compensation, and Liability Act

The *Comprehensive Environmental Response, Compensation, and Liability Act* of 1980 (CERCLA),[9] popularly called "Superfund," authorizes the U.S. EPA to manage the cleanup of abandoned or uncontrolled hazardous waste sites. According to CERCLA, the National Response Center must receive immediate notification of releases of hazardous substances in quantities that are equal to or greater than the reportable quantities of designated chemicals in the CERCLA regulation. In 2011, no releases occurred that were reportable under CERCLA, and Berkeley Lab conducted no remedial activities covered by CERCLA.

3.3.3 Emergency Planning and Community Right-to-Know Act

The *Emergency Planning and Community Right-to-Know Act* (EPCRA)[10] was passed in 1986 as Title III of the *Superfund Amendments and Reauthorization Act* (SARA). The Act 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*.[11] Berkeley Lab activities addressing these requirements are summarized in Sections 3.4.3.1 through 3.4.3.3.

3.3.3.1 Toxic Release Inventory

Toxic Release Inventory (TRI) reporting at LBNL consists of two steps. First, Berkeley Lab determines chemical usage, and then, if threshold quantities are exceeded, DOE submits U.S. EPA Form R.

Berkeley Lab determined that no chemical usage in 2011 exceeded the TRI criterion of 4,536 kilograms (kg) (10,000 pounds [lb]) for a listed substance and that DOE was therefore not required to submit a Form R on behalf of LBNL. Table 3-4 shows the highest usage quantities of the chemicals from LBNL's assessments over the past several years.

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

Substance	Quantity (in kilograms[a])						
	2005	2006	2007	2008	2009	2010	2011
Chlorofluorocarbons	126	123	518	95	78	68	145
Methanol	129	165	63	69	82	67	40
Nitric acid	466	403	90	303	279	269	288
1,1,1-trichloroethane	0	<1	<1	<1	<1	<1	0

[a] 1 kilogram = 2.2 lb

3.3.3.2 Hazardous Materials Business Plan

The COB, Alameda County, and Contra Costa County are the local administering agencies for certain hazardous materials regulations that fall under state law. Each year, Berkeley Lab voluntarily submits *Hazardous Materials Business Plan*s (HMBP)[12] to these local agencies, even though as a federal facility it is not subject to these regulations.

The HMBPs include a list of all hazardous materials present in amounts exceeding the state's aggregate threshold quantities per building (i.e., 208 L [55 gal)] for liquids, 227 kg [500 lb] for solids, and 5.7 cubic meters [m^3] [200 cubic feet] for compressed gases). Also included is a site map and information regarding emergency plans, procedures, and training. In addition, the LBNL Main Site HMBP includes permit renewals for fixed treatment units (FTUs). In 2011, five HMBPs were submitted as detailed in Table 3-5.

Table 3-5 Hazardous Materials Business Plans (HMBPs) Submitted in 2011

Location	Agency
LBNL Main Site (Berkeley)	City of Berkeley
Joint Center for Advanced Photosynthesis (Berkeley)	City of Berkeley
Berkeley West Biocenter (Berkeley)	City of Berkeley
Joint BioEnergy Institute (Emeryville)	Alameda County
Joint Genome Institute (Walnut Creek)	Contra Costa County

3.3.4 Federal Insecticide, Fungicide, and Rodenticide Act

Passed by Congress in 1972, the *Federal Insecticide, Fungicide, and Rodenticide Act*[13] restricts the registration, sale, use, and disposal of pesticides. Pesticides, including insecticides and herbicides, are applied at the site by licensed contractors. LBNL chips and mulches green waste to minimize the use of herbicides and to reduce solid waste. The mulch generated is used on-site for weed screening and landscaping, and to control erosion. LBNL staff may occasionally apply very small amounts of herbicides (for example, Roundup) to weeds, such as poison oak, that are otherwise difficult to control.

3.3.5 Toxic Substances Control Act

The objective of the *Toxic Substances Control Act* (TSCA)[14] is to minimize the exposure of humans and the environment to chemicals found in manufacturing, processing, commercial distribution, and disposal activities. TSCA establishes a protocol for evaluating chemicals before they are introduced into the marketplace and 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 affected by the TSCA regulations. Since the TSCA program began, LBNL has removed all TSCA-regulated PCB transformers (PCB concentrations greater than 500 parts per million). The remaining equipment containing TSCA-regulated PCBs consists of four large low-voltage capacitors. These capacitors remain in use, containing an estimated 170 kg (375 lb) of regulated PCB dielectric fluid. Because the small amount of PCBs is below reporting thresholds, the site is not required to prepare an annual PCB report for the U.S. EPA.

3.3.6 Resource Conservation and Recovery Act

The *Resource Conservation and Recovery Act* (RCRA)[15] is an amendment to the earlier Solid Waste Disposal Act (SWDA) of 1965, and was enacted to create a management system that would regulate waste from "cradle to grave." In 1984, the Hazardous and Solid Wastes Amendments were added to the SWDA to reduce or eliminate the generation and disposal of hazardous wastes, and between 1984 and 1988 RCRA was expanded further to regulate underground storage tanks (USTs) and other leaking waste-storage facilities. The primary goals of RCRA are:

- To protect the public from harm caused by waste disposal
- To encourage reuse, reduction, and recycling
- To clean up spilled or improperly stored wastes

RCRA applies in three primary areas of Berkeley Lab operations: treatment and storage of hazardous waste (including the hazardous portion of mixed

waste), cleanup of historical releases of chemicals to the environment, and operation of USTs.

3.3.6.1 Hazardous Waste

In California, the DTSC administers the RCRA hazardous waste program. The California program incorporates the provisions of both the federal and state hazardous waste laws.[16] The state program includes both permitting and enforcement elements.

The state's permitting program for hazardous waste treatment and storage facilities consists of five tiers, shown in the following list in decreasing order of regulatory complexity:

1. Full permit
2. Standardized permit
3. Permit-by-rule
4. Conditional authorization
5. Conditional exemption

The state oversees the "full permit" and the "standardized permit" tiers; at Berkeley Lab, the other three tiers have been delegated to the COB for oversight under California's CUPA program.

Berkeley Lab's Hazardous Waste Handling Facility (HWHF) operates under the "full permit" tier of the state's program. A full permit is also known as a RCRA Part B permit. The current permit for the HWHF[17] became effective on July 31, 2007. The permit authorizes storage and treatment of certain hazardous and mixed wastes at the HWHF. Authorized treatment includes neutralization, consolidation, solidification, filtration, precipitation, phase separation, ultraviolet (UV) ozone and UV peroxide oxidation, reduction of Class 1–3 oxidizers, air or steam stripping, absorption, adsorption, ion exchange, metallic exchange, evaporation, distillation electrowinning, rinsing of empty containers, mixing of multicomponent resins, and desensitization.

Berkeley Lab has an additional hazardous waste permit to operate four fixed treatment units (FTUs).[18] The type and location of each unit are listed in Table 3-6. These treatment units operate independently of the HWHF. Two of these FTUs are authorized to operate under the "conditional authorization" tier and the remaining two are authorized to operate under the "permit-by-rule" tier. The type of treatment determines which tier applies. The COB requests renewal of this permit each year. The FTU permit was renewed in March 2011. With permit renewal, the conditionally authorized FTU at

Table 3-6 Fixed Treatment Units Subject to the State's Tiered Permitting Program

FTU	Building	Treatment Description	Permit Tier	Wastewater Volume Treated (Gallons/Year)
004	70A/70F	Acid neutralization	Conditional authorization	661,860 (502,670 recycled)
005	2	Acid neutralization	Conditional authorization	114,350
006	77	Metals precipitation and acid neutralization	Permit-by-rule	20,230
007	67	Acid and alkaline neutralization	Permit-by-rule	12,868

Building 76 was removed since it did not treat hazardous waste.

In 2011, Berkeley Lab installed a system to recycle treated wastewater from the Building 70A fixed treatment unit to the Building 70A cooling tower. In 2011, this recycling system recycled 502,670 gal (1,902,813 L) of water (approximately 76% of all water treated in that unit) to the cooling tower, effectively fulfilling all cooling tower water needs for the year.

Berkeley Lab's waste management program also sends hazardous, universal, mixed, medical, and radioactive waste generated at LBNL off-site for disposal. Disposal of medical waste is managed in accordance with the state's *Medical Waste Management Act* [19] (see Section 3.3.6.2). Low-level radioactive waste is managed in accordance with DOE Orders. Mixed waste is managed in accordance with the *Mixed Waste Site Treatment Plan*[20] and is subject to both California Environmental Protection Agency regulations and DOE Orders.

Waste management permits and regulations require Berkeley Lab to prepare several reports for the year:

- *The Hazardous Waste Annual Facility Report*,[21] prepared for the DTSC, contains facility treatment and disposal information for all hazardous waste activities (including the hazardous waste portion of mixed waste) at the HWHF during the reporting year.
- *The Annual Report of Waste Generation and Pollution Prevention Progress*,[22] prepared for DOE, contains information on waste generated during the reporting year.

In October 1995, DTSC approved LBNL's *Mixed Waste Site Treatment Plan,*[23] which documents the procedures and conditions used by Berkeley Lab to manage its mixed-waste streams. LBNL prepares an annual report that quantifies the amount of mixed waste in storage at the end of the reporting period. This update is prepared in October for the previous fiscal year, October 1 to September 30.

3.3.6.2 Medical Waste

Although not regulated under RCRA, medical waste is included here as hazardous waste which is also administered under the Berkeley Lab Waste Management Program.

In California, the state's *Medical Waste Management Act* [24] contains requirements designed to ensure the proper storage, treatment, and disposal of medical waste. The state program is administered by the California Department of Public Health (CDPH).

Medical waste includes biohazardous waste (e.g., blood and blood-contaminated materials) and "sharps" waste (e.g., needles) produced in the following activities:

- Research relevant to the diagnosis, treatment, or immunization of human beings or animals
- Diagnosis, treatment, or immunization of humans or animals
- Production of biological products used in medicine

LBNL generates medical waste and biohazardous waste at about 150 different locations distributed over 15 buildings, including three off-site buildings. Berkeley Lab does not treat any solid medical or biohazardous waste; it is treated at off-site vendor facilities, using either incineration or steam sterilization.

Berkeley Lab produced 18,469 kg (40,717 lb) of solid medical and biohazardous waste in 2011. Under the state's program, LBNL is considered a large-quantity generator because it generates more than 91 kg (200 lb) of medical waste each month. All large-quantity generators must register with the CDPH and are subject to periodic inspections. CDPH did not inspect Berkeley Lab in 2011.

3.3.6.3 Corrective Action Program

Berkeley Lab is currently in the final phase of the RCRA CAP, the Corrective Measures Implementation (CMI) phase. The purpose of the CMI phase is to design, construct, operate, maintain, and monitor the corrective measures (cleanup activities) recommended by LBNL in the *Corrective Measures Study Report.*[25] These measures were approved by the DTSC[26] and 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 corrective measures required for contaminated soil have been completed. The corrective measures required for eleven areas of groundwater contamination have been constructed and are operational. These consist of *in situ* soil flushing, groundwater capture and treatment, subsurface injection of Hydrogen Release Compound® (HRC), and monitored natural attenuation (MNA). The corrective measures are described below.

- *In situ* soil flushing is the injection of clean water into, and concurrent extraction of contaminated groundwater from, the subsurface.
- Groundwater capture involves extraction of groundwater in the downgradient portions of groundwater contaminant plumes to minimize further migration of the plumes. The extracted water from soil flushing and groundwater capture is treated on-site using granular activated carbon (GAC) treatment systems before being either reinjected for flushing or discharged to the sanitary sewer system.
- HRC is an environmentally safe polylactate ester formulate that is used to enhance the natural biodegradation of volatile organic compounds (VOCs) (enhanced bioremediation), and has been injected at regular intervals into some contaminant plume source areas.
- MNA refers to the reliance on natural attenuation processes within the context of a carefully controlled and monitored site cleanup approach to achieve site-specific remediation objectives. A more detailed description of the specific corrective measures pertaining to each of the groundwater contaminant plumes is given in Section 4.4.

As part of the CMI phase, LBNL has prepared a *Soil Management Plan* [27] and a *Groundwater Monitoring and Management Plan.*[28] These management plans describe the nature and extent of the contamination and the institutional controls required to reduce potential risk from exposure to the contaminants. The *Groundwater Monitoring and Management Plan* also provides the requirements for ongoing groundwater and surface water monitoring. These documents, as well as other RCRA CAP documents prepared by Berkeley Lab, are available for public review at www.lbl.gov/ehs/erp/html/documents.shtml and at the main branch of the Berkeley Public Library.

Berkeley Lab maintains a proactive approach in interacting with stakeholders in the RCRA CAP, including the DTSC, the RWQCB, and the COB.

3.3.6.4 Underground Storage Tanks

In the early 1980s, California addressed the problem of groundwater contamination from leaking USTs through a rigorous regulatory and remediation program.[29] The state program for USTs that contain hazardous materials addresses permitting, construction, design, monitoring, record-keeping, inspection, accidental releases, financial responsibility, and tank closure. The state's program satisfies the provisions of the federal RCRA requirements.[30] The COB is the local administering agency for UST regulations that apply to Berkeley Lab.

Two Berkeley Lab employees have passed the State of California exam to become a UST Designated Operator. These two Designated Operators annually train other facility employees to conduct daily inspections of the UST systems. Designated Operators also ensure the quality of daily inspections by conducting monthly inspections of the systems.

At the end of 2011, six permitted USTs were in operation at Berkeley Lab (see Table 3-7 and Figure 3-2). The tanks contain either diesel fuel or unleaded gasoline. LBNL has removed nine USTs since 1993 and properly closed each UST site.

On November 9, 2011 leak-detection monitors were tested and recertified for all UST systems. On the same date, all product piping (pressure and suction) for the UST systems passed pressure testing. In addition, every spill bucket at the fill port of each UST was tested for leaks. The spill buckets for the diesel tanks at Building 76 and Building 85 failed the leak test. The Building 76 diesel spill bucket was repaired the same day. The Building 85 diesel spill bucket was removed and replaced with a new spill bucket.

Table 3-7 Underground Storage Tank Operating Permits from the City of Berkeley

Registration Tank ID Number	Building	Stored Material	Capacity in Liters (Gallons)		Construction	Year Installed
Fiberglass tanks, double-walled						
TK-3-2	2	Diesel	15,200	(4,000)	Fiberglass	1988
TK-4-2	2	Diesel	3,800	(1,000)	Fiberglass	1988
TK-1-85	85	Diesel	9,500	(2,500)	Fiberglass	1995
Steel tanks, double-walled, with fiberglass-reinforced plastic corrosion protection						
TK-1-55	55	Diesel	3,800	(1,000)	Glasteel	1986
TK-5-76	76	Unleaded gasoline	38,000	(10,000)	Glasteel	1990
TK-6-76	76	Diesel	38,000	(10,000)	Glasteel	1990

During the November 9th testing, the COB conducted its annual inspection of Berkeley Lab's USTs and cited Berkeley Lab with two minor violations for the two failed spill buckets. Both repaired buckets later passed retesting.

3.3.7 Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the *Hazardous Waste Source Reduction and Management Review Act* [31] in 1989. With an emphasis on minimizing waste and preventing pollution, the Act has the following goals:

- Reduce hazardous waste at its source
- Encourage recycling wherever source reduction is infeasible or impractical
- Manage hazardous waste in an environmentally safe manner and minimize present and future threats to health and the environment if it is infeasible to reduce or recycle
- Document hazardous waste management information and make that information available to state and local governments

Every four years, Berkeley Lab prepares a two-part report in compliance with this Act: the *Source Reduction Evaluation Review Plan and Plan Summary.* [32] The last report was compiled in 2011 and submitted to the DOE Livermore Site Office as part of the DOE-wide report.

The *Clean Water Act* (CWA)[33] regulates the discharge of pollutants from both point and nonpoint sources to the waters of the United States, using various means; these include development of pollutant discharge standards and limitations, and also a permit and licensing system to enforce the standards. California is authorized by U.S. EPA to administer the principal components of the federal water quality management program.

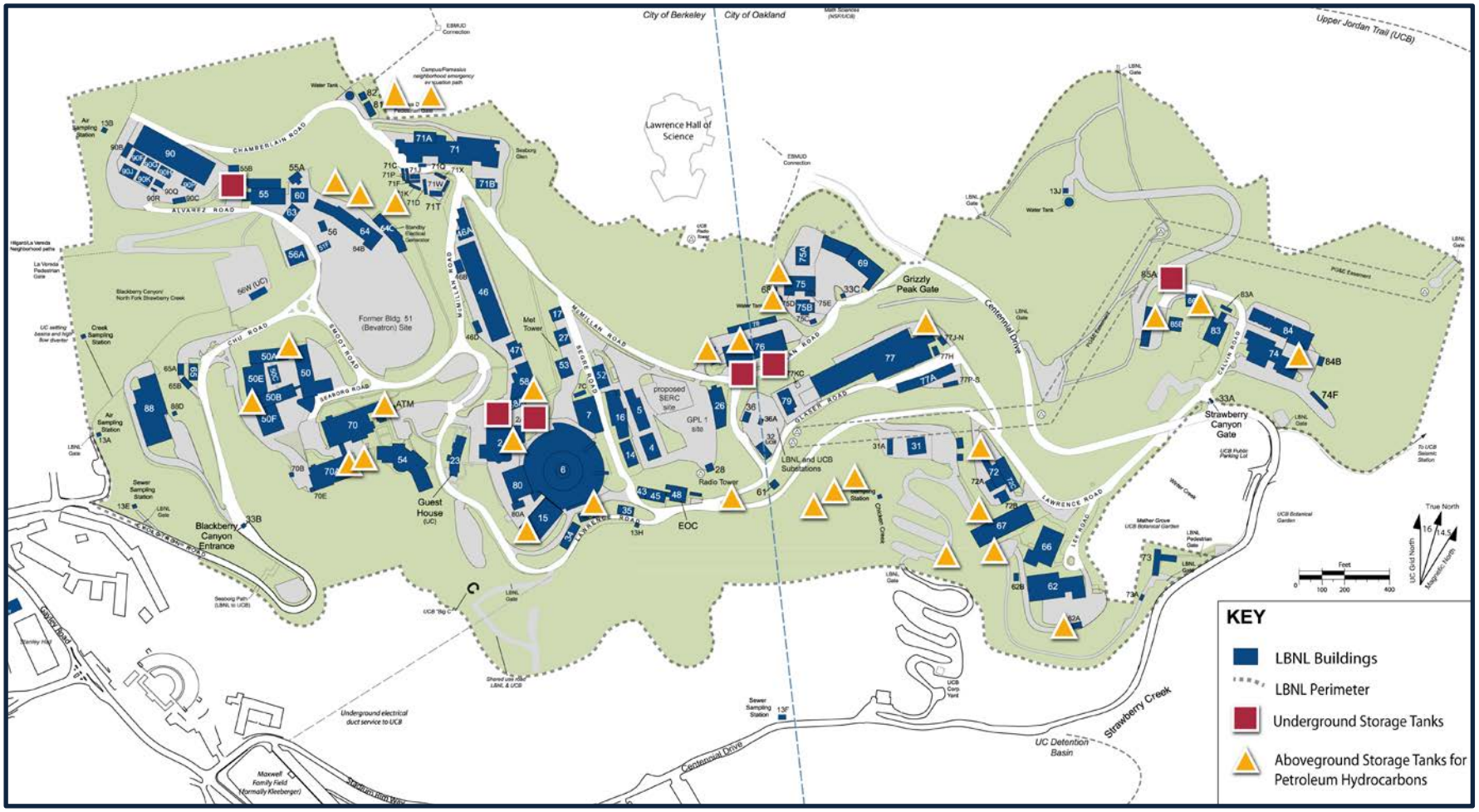

Figure 3-2 Aboveground and Underground Storage Tank Locations at the End of Calendar Year 2011

3.3.8 Clean Water Act

Additionally, the *California Porter-Cologne Water Quality Control Act* [34] established a comprehensive statewide system for regulating water use. This 1969 act provides for a three-tiered system of regulatory oversight and enforcement: the SWRCB, the nine RWQCBs, and local governments.

For the Berkeley Lab main site, the regional regulatory agency is the San Francisco Bay RWQCB. The local agencies are (1) the cities of Berkeley and Oakland for stormwater and (2) EBMUD for drinking water supply and wastewater discharges. The Central Contra Costa Sanitary District (CCCSD) is responsible for regulatory oversight of both wastewater and stormwater discharges from the JGI, which is in Walnut Creek.

3.3.8.1 Wastewater

Berkeley Lab has three wastewater discharge permits[35] issued by EBMUD for the following activities:

- General sitewide wastewater discharge
- Treatment unit discharge of rinse water from the metal finishing operations in Building 77
- Treatment system discharge of groundwater from hydraugers and groundwater monitoring wells

In 2007, EBMUD renewed the wastewater discharge permits through 2012. The permits incorporate standard terms and conditions, individual discharge limits, and provisions, as well as monitoring and reporting requirements. Under each permit, Berkeley Lab submits periodic self-monitoring reports. The number of reports and their timing depend on the individual permit. No wastewater discharge limits were exceeded in 2011 for these three permits. (For more information regarding the results of LBNL's annual wastewater self-monitoring program, see Chapter 4.)

EBMUD inspects the site's sanitary sewer discharge activities without prior notice; the inspections include the collection and analysis of wastewater samples. The agency conducted inspections on four separate occasions throughout the year. Table 3-2 lists these inspections, which were routine sample collections. No violations resulted from these inspections.

Berkeley Lab held two special wastewater discharge permits with EBMUD in 2011. One permit was for the Bevatron Demolition Project located at Building 51. This special wastewater discharge permit allowed for the discharge of treated rainwater and dust suppression water into the sanitary sewer system. Under this permit, 977,500 gal (3,700,240 L) were discharged to the sanitary sewer between January 7, 2011 and December 29, 2011. For the Bevatron Demolition Project special discharge permit, EBMUD set a PCB congener benchmark for discharge at 0.017 μg/L. On the first sampling event for PCB congeners (January 13, 2011), a minimum of 0.0647 μg/L (based on 48 PCB congeners) was found. To address the exceedance of congeners in the January 13, 2011 test, Berkeley Lab installed a second 500-gallon GAC canister to treat Bevatron Demolition site wastewater. Further sampling to test the effectiveness of the added GAC canister was done on March 2, 2011. This sampling showed a minimum of 0.000033 μg/L (based on 48 PCB congeners). While awaiting results of the March 2 sampling (which were well under the benchmark limit), Berkeley Lab further augmented the treatment system by adding a 25-micron and 5-micron filter bag ahead of the GAC canisters and a 0.5-micron filter bag after the GAC canisters. Sampling on April 14, 2011 showed 0.00323 μg/L (based on 66 PCB congeners) for this final treatment configuration.

The second special discharge EBMUD permit was issued for a fault line study to be completed by the Earth Sciences Division near Building 85. Under this special permit, 121,500 gal (459,927 L) of wastewater were discharged to the sanitary sewer. The permit required analysis of VOCs, metals, total petroleum

hydrocarbons, oil, and grease before any new fault line study borehole discharge. All fault line study discharges were in compliance with EBMUD permit limits for 2011.

The EBMUD wastewater discharge permit for Building 77 requires that the facility maintain a *Toxic Organics Management Plan* and a *Slug Discharge Plan*. In 2007, the requirements of these two EBMUD plans were incorporated into the facility's activity hazard document (AHD) for operations. The AHD outlines 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. The AHD for the metal finishing area at Building 77 also includes emergency response procedures.

To meet the requirements of EBMUD's *Slug Discharge Plan,* Berkeley Lab maintains emergency response procedures for areas where spills are most likely to occur. Berkeley Lab has prepared operation-specific response procedures for the following activities: Building 77 metal finishing, Building 76 vehicle fueling, and Buildings 2, 67, and 70A research projects.

Berkeley Lab also holds a *Class III Industrial User Permit* [36] issued on January 1, 2006 by CCCSD for general wastewater discharged at the JGI in Walnut Creek. The permit remained in effect through December 31, 2008, and was reissued on January 1, 2009, with validity through December 31, 2011. It contains requirements for inspecting and reporting on operations, but no monitoring requirements.

3.3.8.2 Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide *General Permit for Storm Water Associated with Industrial Activity* (or General Permit).[37] The General Permit is issued by the SWRCB, but administered and enforced by the RWQCB. Under this permit, Berkeley Lab has implemented a *Storm Water Pollution Prevention Plan* (SWPPP)[38] and an *Alternative Storm Water Monitoring Program* (ASWMP).[39] The purpose of the SWPPP is to identify sources of pollution that could affect the quality of stormwater discharges, and to describe and ensure the implementation of practices to reduce pollutants in these discharges. The ASWMP describes the rationale for sampling, sampling locations, and analytical parameters (radiological and nonradiological). Together, these documents represent LBNL's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

The General Permit requires submittal of an annual report on stormwater activities by July 1 of each year. Berkeley Lab transmitted its annual report to the RWQCB in June.[40] No regulatory concerns were raised by the agency regarding the annual report. The report was also issued to the California Sportfishing Protection Alliance and the Strawberry Canyon Stewardship Council under the terms of a settlement agreement following a lawsuit in April of 2008 regarding prior stormwater monitoring data. The lawsuit had raised issues regarding detections of certain pollutants above established water quality benchmarks during some sampling events, and claimed that best management practices installed after data validation were not effective. According to the General Permit, the water quality benchmarks are guideline values, not effluent permit limits. LBNL started monitoring at specific industrial locations in early 2009 under the terms of the settlement agreement. (For a summary of sampling locations and stormwater monitoring results, see Chapter 4).

Stormwater releases from construction activity disturbing one or more acres of soil are regulated under the California-wide *General Permit for Stormwater Discharges Associated with Construction and Land-Disturbance Activities.*[41] During 2011, Berkeley Lab had five construction projects which disturbed more than

one acre of soil, and thus held five stormwater construction permits during portions of 2011.

- *Building 51 and Bevatron Demolition Project.* The purpose of this project was to clear the site to make it available for future construction. To accomplish this, the building, its contents, and the shallow foundation were removed, and the subsurface soil was characterized.
- *Seismic Life Safety, Modernization, and Replacement of General Purpose Buildings, Phase II Project (a.k.a. Seismic Phase II project).* This project aims to provide seismically safe facilities for scientific research and involves demolishing several older buildings (Buildings 25/25B, 55, and three trailers associated with Building 90) and replacing the Building 25/25B demolished space with a new facility that would be built to higher seismic safety standards. In addition, modernization of Building 74 and slope stabilization at Building 85 are part of the Seismic Phase II project.
- *Old Town Demolition and Environmental Restoration Project.* Up to 14 buildings were designated for decontamination and demolition, including Buildings 4, 5, 7, 7C, 14, 16, 25A, 40, 41, 44, 44A, 44B, 52, and 52A. Beyond the demolition, subsurface investigation would be carried out to identify past releases of contamination and would be remediated where required. A notice of termination of the stormwater construction permit was approved on December 21, 2011 since the funding was not available at that time to complete the project. In total, three buildings were decontaminated and demolished as part of the project, including buildings 44, 44A, and 44B. As stated above, Buildings 25A, 40, 41, 52 and 52A were demolished under the Seismic Phase II Project. The slabs for buildings 40, 41, 52 and 52A will be removed under Old Town at a later date, along with sub-slab soil remediation where required.
- *Computational Research and Theory Facility (CRT).* The University of California is constructing this new facility near LBNL's main entry point, Blackberry Gate. CRT will provide approximately 300 office spaces and 28,000 square feet of computer floor space in 32,000 total square feet. About 20,000 square feet is slated for initial use, with an additional 12,000 square feet for growth to house current and forecasted National Energy Research Scientific Computing Center (NERSC) systems.
- *Erosivity Waiver Soil Borrow Area.* Clean soil from a number of laboratory construction projects has been placed in a small area in the easternmost area of the laboratory. Typically the soil was stored temporarily, and then reused on-site or hauled off-site to an approved landfill. The erosivity waiver automatically expired on November 30, 2011. The entire site was stabilized with adequate grass growth prior to the wet season, and sediment control best management practices (BMPs) remained in place.

3.3.8.3 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the CWA.[42] The CWA and the state's *Aboveground Petroleum Storage Act* [43] outline the regulatory requirements for ASTs. Under the authority of the CWA, a *Spill Prevention, Control, and Countermeasure* (SPCC) *Plan* [44] is required for petroleum-containing tanks, both aboveground and underground. Berkeley Lab maintains an SPCC Plan with the goal of preventing and, if needed, mitigating spills or leaks from petroleum-containing tanks. ASTs are provided with secondary containment or spill kits to capture any potential leaks. The locations of the 32 ASTs are shown in Figure 3-2. In addition, at the JGI, a

15,142-L (4,000-gal) AST supports an engine generator. The JGI maintains a separate SPCC Plan [45] for this AST.

Nonpetroleum (i.e., chemical or hazardous) ASTs consist of FTU tanks, storage drums at Waste Accumulation Areas (WAAs), and storage drums at product distribution areas. FTU operators inspect FTU tanks each operating day. EH&S staff inspect WAAs weekly.

The E85-fuel dispensing-station tank (located at Building 76) supports approximately 70 alternative-fuel vehicles. The use of 85%-ethanol fuel is one of LBNL's strategies for reducing petroleum usage by its fleet of vehicles.

3.3.9 National Environmental Policy Act and California Environmental Quality Act

LBNL staff provides information and technical support to enable DOE and UC to determine whether proposed actions at Berkeley Lab will have a significant effect on the environment, as required by the *National Environmental Policy Act of 1969* (NEPA)[46] and the *California Environmental Quality Act of 1970* (CEQA).[47]

In 2011, DOE conducted a NEPA Environmental Assessment and Finding of No Significant Impact (FONSI) for the Computational Theory and Research Facility project. Also in 2011, UC conducted the following major CEQA reviews:

- Environmental Impact Report Addendum for the Seismic Life Safety, Modernization, and Replacement of General Purpose Buildings, Phase 2 Project
- The Final Environmental Impact Report for the Solar Energy Research Center was certified by the UC Regents

In 2011, several projects were categorically excluded from further NEPA and CEQA review, and approximately 1,000 projects (mostly research activities and proposals) were found to be covered under existing categorical exclusions and exemptions. NEPA categorical exclusions are posted at www.bso.sc.doe.gov/html/NEPA_categorical_exclusion_documents.html.

3.3.10 Federal Endangered Species Act

The *Federal Endangered Species Act*[48] requires that activities taking place at Berkeley Lab on federally controlled property, or using federal permission or funding, undergo a screening process or the NEPA process to determine whether federally listed or proposed species may be present or affected by the action. No compliance activities were required in 2011, although the U.S. Fish and Wildlife Service (USFWS) conducted a site visit and informal consultation regarding the proposed Computational Research and Theory Facility project site to assess any potential impact to the Alameda whipsnake. In accordance with the 2006 *Long Range Development Plan Environmental Impact Report* mitigation measures, several project-specific bat and raptor surveys were carried out prior to tree removals or disturbance in 2011. Also, Alameda whipsnake (identification and avoidance) training was carried out for numerous project construction teams.

3.3.11 California Endangered Species Act

The *California Endangered Species Act*[49] requires that activities taking place at Berkeley Lab on UC Regents land, or using UC Regents or state permission or funding, undergo a screening process or the CEQA process to determine whether state-listed or proposed species may be present or affected by the action. No compliance activities were required in 2011. (See Section 3.3.10 above regarding bird, raptor, and Alameda whipsnake mitigation activities carried out in 2011.)

3.3.12 National Historic Preservation Act

The *National Historic Preservation Act*[50] provides for a National Register of Historic Places, which lists buildings, structures, sites, objects, and districts

that possess historic, architectural, engineering, archaeological, or cultural significance. In the past few years, Berkeley Lab has inventoried most of its buildings using qualified historians in consultation with the State Historic Preservation Officer to determine whether those assets at Berkeley Lab are eligible for listing on the National Register. In 2009, Berkeley Lab began a process to develop a Cultural Resources Management Program (CRMP) to further comply with the National Historical Preservation Act and DOE policy. The CRMP is expected to be completed in 2012.

3.3.13 Migratory Bird Treaty Act

The *Migratory Bird Treaty Act* [51] legislates that actions and projects undertaken at Berkeley Lab must undergo appropriate NEPA and CEQA review, which includes assessment of biological impacts, to determine whether species subject to the provisions of the *Migratory Bird Treaty Act* would be affected. No compliance activities were required in 2011 with the exception of pre-construction bird surveys taken during breeding season.

Tom Donovan of the Environmental Services Group at Berkeley Lab collects soil samples as part of the Environmental Monitoring Program.

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4.1 INTRODUCTION

The Berkeley Lab environmental monitoring program assesses whether LBNL's emissions are impacting the health of the public or the environment. The program is important for environmental stewardship and for demonstrating compliance with requirements imposed by federal, state, and local agencies. The program also confirms adherence to DOE environmental protection policies and supports environmental management decisions.

This chapter presents summaries of the 2011 monitoring results for the following categories:

- Stack and ambient air
- Surface water and wastewater
- Groundwater
- Soil and sediment
- Vegetation and foodstuffs
- Penetrating radiation

A comprehensive *Environmental Monitoring Plan*[1] prepared by Berkeley Lab provides the basis and current scope for each of these monitoring programs. The most recent periodic revision of the plan was completed in September 2009.

All of the individual sample results are presented in Volume II of this *Site Environmental Report*. Additional details on groundwater investigations and results are included in Environmental Restoration Program reports, which are available at the COB main public library and at www.lbl.gov/ehs/erp.

4.2 AIR QUALITY

Berkeley Lab's air monitoring program is designed to measure the impacts from radiological air emissions. The program meets the U.S. EPA and DOE requirements, which are contained in the following references:

- 40 CFR Part 61, Subpart H (*National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*)[2]
- DOE Order 5400.5 (*Radiation Protection of the Public and the Environment*)[3]

This program consists of two elements: exhaust emissions monitoring and ambient air surveillance. Exhaust emissions monitoring measures contaminants in building exhaust systems (e.g., stacks). Ambient air surveillance measures contaminants in the outdoor environment. Due to budget considerations, ambient air surveillance was terminated in June 2011 because surveillance information provided only limited value and was not required by environmental regulations. The ambient air samplers were removed from service.

4.2.1 Exhaust Emissions Monitoring Results

Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. Charged particle accelerators also generate radioactive materials. These operations result in small amounts of airborne radionuclides, which are typically emitted through building exhaust systems.

Berkeley Lab must evaluate the potential for radionuclide emissions from laboratories where radionuclides are used. If the potential emissions exceed the U.S. EPA-approved threshold, LBNL must measure emissions by sampling or monitoring stacks through which emissions are released. *Sampling* means collecting radionuclides on a filter and analyzing the filters at an analytical laboratory; *monitoring* means continuously measuring radionuclides in real time.

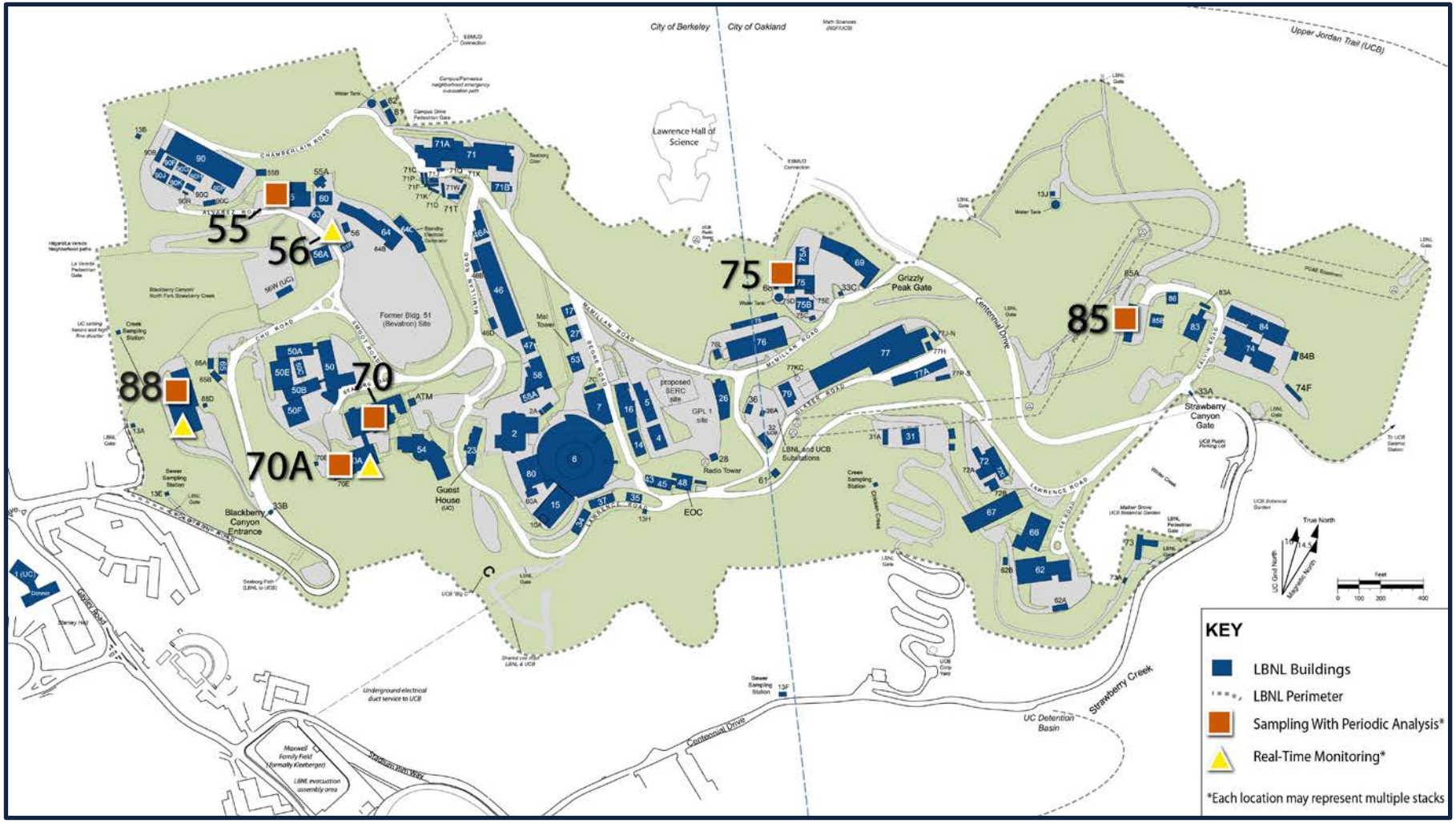

Figure 4-1 Locations of Building Exhaust Sampling and Monitoring

LBNL measures stack emissions in accordance with an approach approved by U.S. EPA Region 9 (Table 4-1). Based on this approval, only Category 3 and 4 measurements are required because all sources have potential doses that are less than 0.001 mSv/yr (0.1 mrem/yr). However, Berkeley Lab may monitor or sample some stacks more frequently than required by U.S. EPA. Exercising this option, Berkeley Lab collected monthly samples from four stacks and performed real-time monitoring at four stacks (one of which was also sampled monthly) in addition to collecting samples quarterly from nine stacks. Sampling and monitoring locations are shown in Figure 4-1.

Stack exhaust samples were analyzed for five radiological parameters: gross alpha, gross beta, carbon-14, iodine-125, and tritium. Real-time stack monitoring systems measured for alpha emitters and positron emitters. In 2011, the positron emitter fluorine-18 (half-life of 1.8 hrs) was the predominant radionuclide emitted and accounted for more than 93% of the emitted activity. The Building 56 accelerator was the main source of fluorine-18 emissions (6.25×10^{10} becquerels [Bq] [1.69 curies (Ci)]). Additional details on stack emissions are available in LBNL's annual *Radionuclide Air Emission Report*,[4] which is submitted to U.S. EPA. For information on the projected dose from all radionuclide emissions, see Chapter 5.

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

Category	Annual Effective Dose Equivalent (mSv/yr)[a]	Requirements
Noncompliant	AEDE[b] ≥ 0.1	Reduction or relocation of the source and reevaluation before authorization
1	0.1 > AEDE ≥ 0. 01	Continuous sampling with weekly collection and real-time monitoring for short-lived radionuclides
2	0.01 > AEDE ≥ 0.001	Continuous sampling with monthly collection or real-time monitoring for short-lived radionuclides
3	0.001 > AEDE ≥ 0.0001	Periodic sampling 25% of the year
4	0.0001 > AEDE	Potential dose evaluation before project starts and when project changes; no sampling or monitoring required

[a] 1 mSv = 100 mrem

[b] AEDE – annual effective dose equivalent

4.2.2 Ambient Air Monitoring Results

The goal of ambient air monitoring was to determine the environmental levels of two general classes of radionuclides, alpha and beta emitters.

The ambient air monitoring network once consisted of three sites on the main grounds of LBNL and a fourth off-site location. All locations were chosen based on historical wind patterns and current site activities. One of the sites also included a second sampler for quality control (QC) purposes. Figure 4-2 shows the sampling locations. The program was suspended in June 2011 and sampling systems were removed.

Table 4-2 Summary of Sampling Results for Alpha and Beta Radiation in Ambient Air

Analyte	Station ID	Number of Samples	Mean (Bq/m^3)[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
Alpha	ENV-B13A	12	5.0×10^{-5}	3.9×10^{-5}	1.2×10^{-4}
	ENV- B13C[b]	12	5.2×10^{-5}	4.8×10^{-5}	1.2×10^{-4}
	ENV-44	12	4.8×10^{-5}	3.4×10^{-5}	1.1×10^{-4}
	ENV-83	12	4.9×10^{-5}	3.6×10^{-5}	1.1×10^{-4}
Beta	ENV-B13A	12	4.0×10^{-4}	3.3×10^{-4}	6.7×10^{-4}
	ENV-B13C[b]	12	4.3×10^{-4}	3.2×10^{-4}	8.3×10^{-4}
	ENV-44	12	3.9×10^{-4}	3.1×10^{-4}	6.9×10^{-4}
	ENV-83	12	4.0×10^{-4}	3.2×10^{-4}	6.9×10^{-4}

[a] 1 Bq = 27 pCi.

[b] Station ENV-B13C provides local background data for alpha and beta radiation in ambient air particulates.

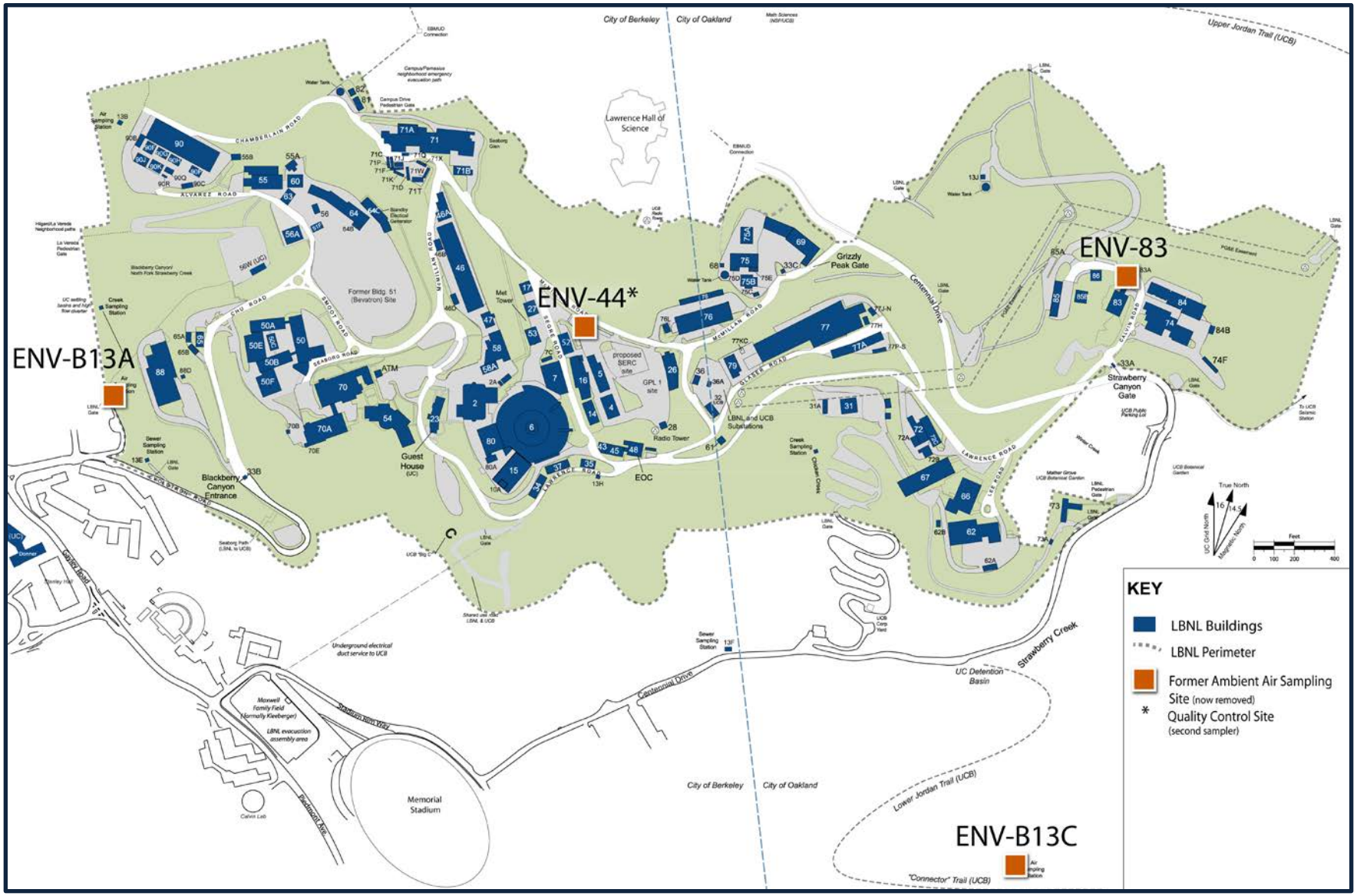

Figure 4-2 Ambient Air Monitoring Network Sampling Locations (program closed in June 2011)

Table 4-2 summarizes gross alpha and beta results from the sampling network through May 2011 and the termination of the program. While DOE Order 5400.5 does not provide ambient air thresholds for either parameter, all results were near or below the analytical detection limits. This observation is consistent with results from prior years across the network.

4.3 SURFACE WATER AND WASTEWATER

This section summarizes the monitoring results for surface water (rainwater, creeks, and stormwater) and wastewater.

4.3.1 Surface Water Program

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon subwatersheds of the Strawberry Creek watershed. There are two main creeks in these watersheds, the South Fork of Strawberry Creek (in Strawberry Canyon) and the North Fork of Strawberry Creek (in Blackberry Canyon). Both creeks join below Berkeley Lab on the UC Berkeley campus.

Surface water monitoring for 2011 included rainwater, creeks, and stormwater. Rainwater and creeks are monitored primarily for alpha and beta emitters and tritium, based on DOE Order 5400.5,[5] which prescribes monitoring requirements for radioisotopes. Creek water is also monitored for nonradiological analytes in an ongoing effort to characterize and manage LBNL's overall impact on the environment. Stormwater monitoring is a condition of the California-wide General Permit[6] and includes monitoring for metals and other constituents.

Although LBNL surface waters are not used as a public drinking water supply, Berkeley Lab takes the conservative approach of evaluating creek water results against drinking water standards. The federal and state maximum contaminant levels for alpha and beta radioactivity in drinking water are 0.6 Bq/L (15 picocuries per liter [pCi/L] and 1.9 Bq/L [50 pCi/L], respectively).[7, 8] The federal and state limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).[9, 10] LBNL also uses the water quality objectives stated in the *Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan)*[11] for comparison purposes.

4.3.1.1 Rainwater Sampling Results

Sampling of rainfall occurred during January through June and October through December. Sampling was performed at the site of the meteorological tower (ENV-44) ambient air sampling station near Building 44 (see Figure 4-3), with monthly composite samples analyzed for gross alpha, gross beta, and tritium activity. Due to budget concerns, the Rainwater Sampling Program was discontinued in June 2011 because sample results provided limited value and were not required by environmental regulations. Rainwater is no longer collected for analysis.

Monthly composite sample results from this location were consistent with historical values and were below drinking water standards. The majority of the sample results for gross alpha and gross beta were below or near detection limits; however, gross beta during the months of April and May had values above detection limits, but still within historical values. No tritium activity was detected in any of the samples.

4.3.1.2 Creeks Sampling Results

The flow in many of the creeks of the Strawberry Creek watershed varies in intensity throughout the year. To track any seasonal variation in water quality, a set of creek samples is collected semi-annually from the following creeks: North Fork Strawberry Creek, Chicken Creek (two locations), Botanical Garden Creek, Cafeteria Creek, No-Name Creek, Ravine Creek, Ten-Inch Creek, Winter Creek (two locations). Two off-site sampling locations include Wildcat Creek, located in Tilden Regional Park, and the South Fork of Strawberry Creek on the UC campus. All samples were analyzed for metals and VOCs. Figure 4-3 shows all creek sampling locations. No VOCs were detected in any of the creek samples. Metals detected were aluminum,

antimony, arsenic, barium, copper, iron, lead, magnesium, selenium, vanadium, and zinc. Their concentrations were within historical levels for LBNL, well below the water quality objectives listed in the *Basin Plan*,[12] and well below the drinking water standard.

Samples with a different set of parameters are also collected from a subset of the above-mentioned creeks. Two sets of samples were collected in 2011 from Chicken Creek, the North Fork of Strawberry Creek, and Wildcat Creek. All samples were analyzed for gross alpha, gross beta, gamma by spectroscopy, and tritium. To provide additional data about the identity of the alpha- and beta-emitting radionuclides measured, the samples were analyzed by gamma spectroscopy for actinium-228, cesium-137, lead-214, potassium-40, radium-226 (by two methods), and uranium-238. In addition, samples were analyzed for chemical oxygen demand (COD), pH, specific conductance, total suspended solids (TSS), and nitrate plus nitrite.

Results indicate that low levels of naturally occurring alpha- and beta-emitting radionuclides were detected in Chicken Creek and the North Fork of Strawberry Creek, and low levels of beta-emitting radionuclides were also detected at the Winter Creek influent. At Winter Creek, radium-226, a naturally occurring radionuclide whose decay products emit both alpha and beta radiation, was the only detected radionuclide. Radium-226 was measured at Winter Creek at levels consistent with the gross alpha and gross beta measurements, which were less than the federal and state maximum contaminant levels. Radium-226 was also detected at low levels at the off-site location of Wildcat Creek.

Of the nineteen samples taken for tritium analysis, four creek samples, one at 7.3 Bq (200 pCi/L), one at 8.2 Bq (220 pCi/L), one at 5.5 Bq (150 pCi/L), and one at 6.1 Bq (160 pCi/L), were found slightly above the minimum detectable activity (MDA), but significantly below federal and state limits for drinking water. It should be noted that one control equipment blank also registered above the MDA at 5.1 Bq (140 pCi/L).

Results indicate that concentrations in all samples analyzed for COD, pH, specific conductance, TSS, and nitrate plus nitrite were within historical levels for LBNL.

4.3.1.3 Stormwater Sampling Results

Under the terms of California's Industrial General Permit, sampling must take place during rain events at least twice each stormwater year (i.e., October through the following September) under specific conditions. Berkeley Lab's ASWMP[13] describes the rationale for sampling, sampling locations (see Figure 4-3 for the six sampling locations), and analytical parameters for each specific industrial activity. The General Permit also requires visual observation of one storm each month and visual observation of authorized and unauthorized non-stormwater discharges once each quarter.

The ASWMP has been prepared to determine pollutant contributions from specific industrial regulated activities at LBNL, and is thus a reliable basis for evaluating the performance and effectiveness of the BMPs described in LBNL's SWPPP. The ASWMP is designed to focus on the specific areas of industrial activity which represent the only potential sources of pollutants that are regulated under the General Permit.

Berkeley Lab is regulated by the General Permit for industrial activities that fall under the following Standard Industrial Classification (SIC) Codes:

- 3499 - Fabricated Metal Products, Not Elsewhere Classified
- 4173 - Terminal and Service Facilities for Motor Vehicle Passenger Transportation
- 4953 - Hazardous Waste Treatment Storage or Disposal
- 5093 - Scrap Recycling Facility

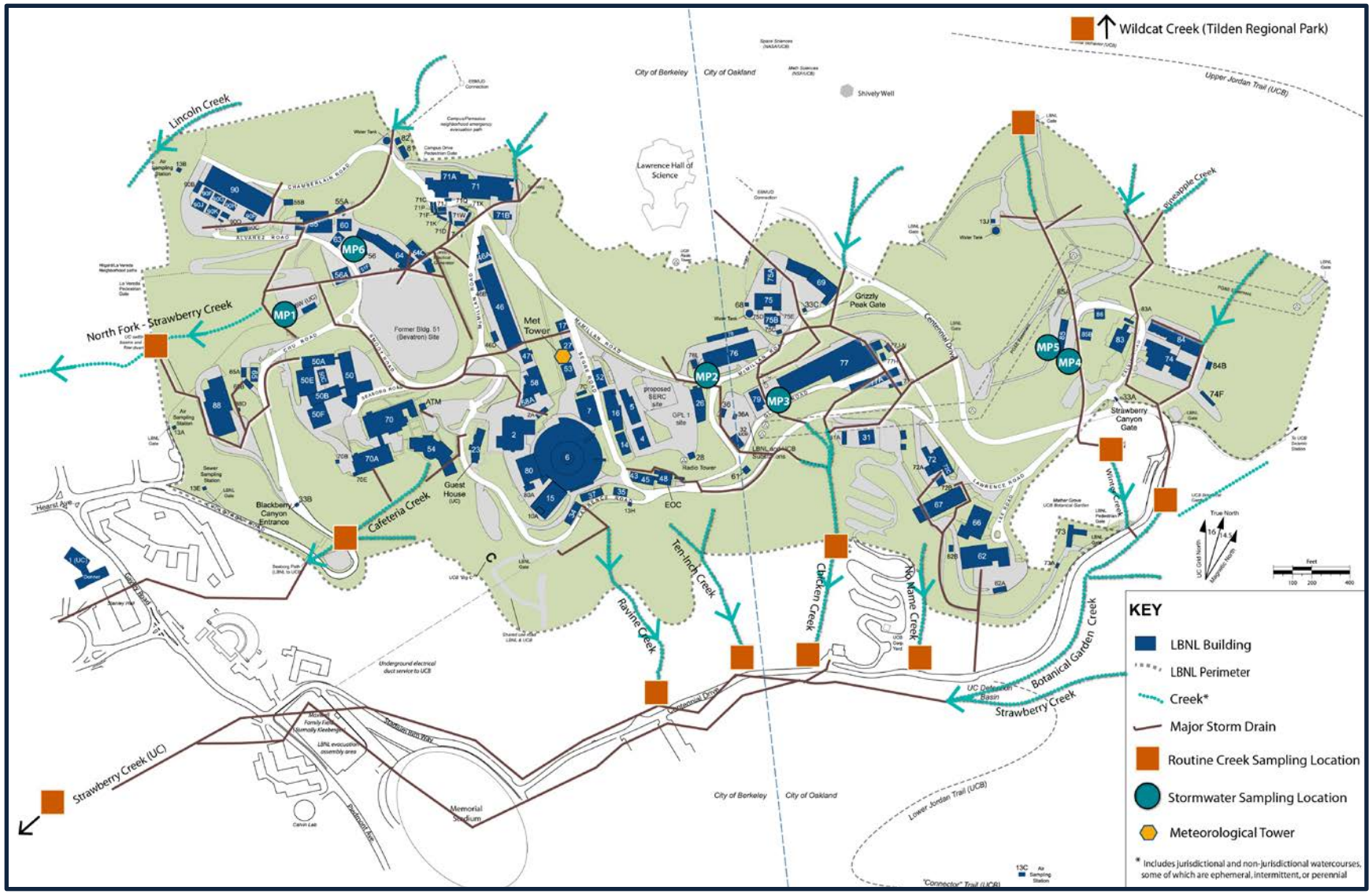

Figure 4-3 Creek, Rainwater, and Stormwater Sampling Locations

Stormwater sampling in 2011 was performed at the following five areas with regulated industrial activities (as shown in Figure 4-3). Note that one area, the HWHF, has two sampling locations.

1. Blackberry Parking Lot, (previous bus parking and storage industrial area (MP 1)
2. Building 76, Fuel Dispensing (MP 2)
3. Buildings 77 & 79, Metal Fabrication, Storage, and Scrap Recycling (MP 3)
4. Building 85, HWHF (MP 4, lower yard, and MP 5, upper yard)
5. Building 64, Bus Parking Lot (MP 6)

The General Permit requires the analysis of at least four parameters for stormwater samples at each monitoring location.

1. TSS
2. pH
3. Specific conductivity
4. Total oil and grease

Based on the SIC codes for specific industrial activities conducted at LBNL, additional sector-required analyses are specified in the General Permit monitoring program, as shown in Table 4-3. Note that MP 1 and MP 6 do not fall under a specific SIC code that requires sampling for additional parameters; however, because they are areas of former transportation activities, it was deemed appropriate to include them in the ASWMP as areas to be sampled for the standard four parameters.

Sampling results for stormwater are compared to the Multi-Sector General Permit (MSGP) benchmark guidelines for industrial activities. It should be noted that the current General Permit does not include benchmark values; however, the draft version of the future General Permit does include very similar benchmark guidelines, hence the use of those particular benchmarks.

TSS, COD, oil and grease, cyanide, ammonia, and nitrate plus nitrite results were all below benchmark guidelines. The pH was within the acceptable range of 6 to 9 standard pH units at all the locations. While the MSGP does not list a benchmark value for specific conductance, other sources set this value at less than 200 μmhos/cm; all stormwater samples collected in 2011 were below this guideline.

Aluminum was below the MSGP benchmark at the metal fabrication and salvage yard (MP 3); however, the duplicate sample was above that benchmark. Zinc was also detected above MSGP benchmarks at the metal fabrication and salvage yard (MP 3), despite the removal and/or covering of all galvanized fabricated materials present in the metal yard. Investigations to determine the source of the zinc indicated that it is largely in the dissolved phase, and that wear (small particles) from forklift truck tires used on the yard contain significant quantities of zinc.

Table 4-3 Additional Sector-Required Analyses from the General Permit

SIC Code	Sampling Locations	Parameters
3499 – Fabricated Metal Products	MP 3	Aluminum, iron, nitrite and nitrate as nitrogen, zinc
4173 – Terminal and Service Facilities for Motor Vehicle Passenger Transportation	MP 2	No additional parameters listed
4953 – Hazardous Waste Treatment, Storage, or Disposal	MP 4, MP 5	Ammonia, arsenic, cadmium, COD, cyanide, lead, magnesium, mercury, selenium, silver
5093 – Scrap Recycling Facility	MP 3	Aluminum, COD, copper, iron, lead, zinc

Copper was also detected at the metal fabrication and salvage yard at below the MSGP benchmark, and it was determined that the likely source was copper pipes that are used to funnel rain from the roof of neighboring buildings onto the yard. Iron was also detected in the MP 3 runoff but was below MSGP benchmarks; however, a duplicate sample was above the benchmark. While lead has been detected, all results have been below MSGP benchmarks.

Magnesium was detected at the upper and lower yard of the HWHF (locations MP 4 and MP 5, respectively). This was traced to aerial deposition of soil particles on the concrete surface. The surrounding soils have been found to contain a significant amount of magnesium. Mercury, selenium, and silver were all below detection limits.

4.3.2 Wastewater Discharge Program

Berkeley Lab's sanitary sewer system is based on gravity flow. The point of water discharge is from either Hearst or Strawberry Monitoring Station, and depends on which part of LBNL the water is coming from (see)

- Hearst Station, located at the head of Hearst Avenue below the western edge of Berkeley Lab, monitors discharges from the western and northern portions of the site. The monitoring site is located at a point immediately before the connection of LBNL's sanitary sewer system with the COB's sewer main.
- Strawberry Station is located next to Centennial Drive in Strawberry Canyon and monitors discharges from the eastern and southern parts of LBNL. Downstream from the monitoring station, the discharge system first ties into University-owned piping and then into the COB system. Because of the design of the network, the Strawberry Monitoring Station also receives effluent from several UC Berkeley campus facilities that are located above LBNL and are separate from the main UC Berkeley campus: the Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden.

Berkeley Lab has three wastewater discharge permits issued by EBMUD: one for general sitewide discharges, one for the metal finishing operations found in Building 77, and one for the discharge of treated groundwater at seven locations. EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

In June 2010, Berkeley Lab received a special discharge permit from EBMUD to discharge groundwater to the sanitary sewer in support of a research project studying the Wildcat Canyon fault line located near Building 85. 121,500 gal (459,927 L) of groundwater were discharged to the sanitary sewer under this special discharge permit during 2011. The permit expired in July 2012.

In January 2011, Berkeley Lab received a special discharge permit from EBMUD to discharge rainwater and dust suppression water to the sanitary sewer in support of the Building 51 and Bevatron Demolition project. Under this permit, 977,500 gal (3,700,240 L) were discharged to the sanitary sewer during 2011.

Berkeley Lab's wastewater discharge permits require periodic monitoring for various parameters as specified by EBMUD. Self-monitoring of wastewater discharges within Berkeley Lab occurs at the wastewater treatment systems located at Building 77 and at groundwater treatment systems, according to the terms of their respective EBMUD permits.[14] In addition, EBMUD performs unannounced monitoring of wastewater discharges. For 2011, all sampling results for the EBMUD permits were below discharge limits, with the exception of the PCB congener analysis for the Building 51 and Bevatron Demolition project, as discussed in Section 3.3.8.1.

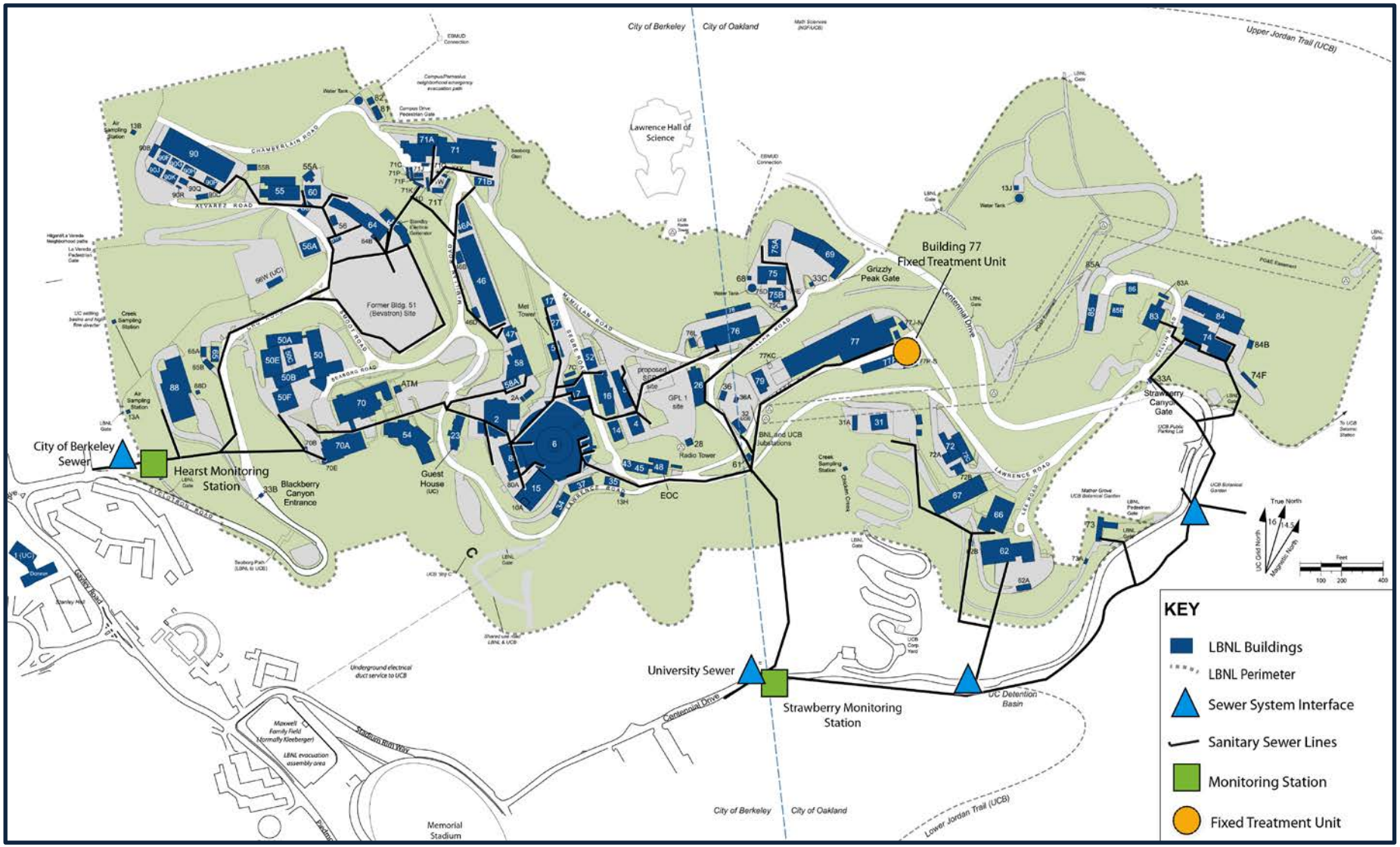

Figure 4-4 Sanitary Sewer System

4.3.2.1 Hearst and Strawberry Sewer Outfalls

Nonradiological monitoring of sitewide samples collected at the Hearst and Strawberry monitoring stations includes analyses for pH, total identifiable chlorinated hydrocarbons, TSS, and COD, with additional analyses for metals. Total flow is also measured and recorded. In 2011, Berkeley Lab discharged approximately 70,000 m^3 (18.4 million gal) through Hearst Sewer and 90,000 m^3 (23.9 million gal) through Strawberry Sewer.

Radiological monitoring is required by DOE Order 5400.5[15] and guidance,[16] and verifies compliance with radiological limits under the California Code of Regulations (CCR),[17] cited in the EBMUD wastewater discharge permit.[18] California regulations now incorporate by reference the applicable federal Nuclear Regulatory Commission regulations[19] and associated discharge limits.

Analyses are performed by a state-certified external laboratory. Results are compared against the discharge limits for each parameter given in the permits, and self-monitoring reports are submitted to EBMUD in compliance with permit requirements. Annually, Berkeley Lab submits a certification to EBMUD that its discharge is in compliance with the permit's radioactive limits.

4.3.2.1.1 Nonradiological Monitoring Results

Berkeley Lab collected two nonradiological samples from both the Hearst and Strawberry outfalls as part of self-monitoring during 2011. All results were well within discharge limits, as were all measurements made by EBMUD in its two independent sampling events.

All metals and chlorinated hydrocarbon results were below EBMUD permit limits or not detected. According to the permit, the pH level must be equal to or greater than 5.5; all results were well above this value. TSS and COD have no discharge limits and are measured to determine wastewater strength, which forms the basis for the costs charged by EBMUD to LBNL for wastewater treatment.

4.3.2.1.2 Radiological Monitoring Results

The Hearst and Strawberry sewer outfalls are sampled every half-hour using automatic equipment. Every four weeks, composite samples are collected at both locations and submitted to a state-certified laboratory for analysis of gross alpha radiation, gross beta radiation, iodine-125, tritium, phosphorus-32, sulfur-35, and carbon-14. Periodically, split samples are analyzed for QC purposes.

The federal[20] and state[21] regulatory limits for radioisotopes in wastewater are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (5 Ci), and for carbon-14 the limit is 3.7×10^{10} Bq (1 Ci). The annual limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 Ci).

All results for gross alpha, carbon-14, iodine-125, phosphorus-32, sulfur-35, and tritium samples collected at the Hearst and Strawberry Monitoring Stations were below the MDA.

Positive results for gross beta were found. The highest result was 0.60 Bq (16.3 pCi/L), which is below the federal and state requirements for drinking water and far below the EBMUD discharge limit for all radioisotopes.

Annual discharges are estimated by multiplying the activity found by the volume discharged during the monitoring period. In the case of tritium, activities below the MDA were totaled to give an estimated annual discharge of zero Bq (zero Ci) or 0% of the discharge limit. Activities below the MDA were also totaled for carbon-14 to give an estimated annual discharge of zero Bq (zero Ci) or 0% of the discharge limit. The estimated annual discharge for all other radioisotopes (gross alpha, gross beta, iodine-125, phosphorus-32, sulfur-35) combined was 7.17×10^{7} Bq (1.94×10^{-3} Ci) or 0.19% of the discharge limit.

4.3.2.2 Building 77 Ultra-High Vacuum Cleaning Facility Wastewater

The Ultra-High Vacuum Cleaning Facility (UHVCF) at Building 77 cleans various types of metal parts used in research and support activities at Berkeley Lab. Cleaning activities include passivating, acid and alkaline cleaning, and ultrasonic cleaning. Acid and alkaline rinse waters that contain metals from UHVCF operations are routed to an approximately 230 L/minute (L/min) (60 gal/min) FTU.

All sampling performed by Berkeley Lab and EBMUD (three self-monitoring events and one sampling event by EBMUD) yielded results well within permitted limits.

Instead of monitoring for chlorinated hydrocarbons, LBNL submits a *Total Toxic Organics Compliance Report* twice per year which certifies that Building 77 is not discharging chlorinated hydrocarbons or other toxic organic compounds to the FTU and to the sanitary sewer.

4.3.2.3 Treated Hydrauger and Extraction Well Discharge

Since 1993, EBMUD has permitted Berkeley Lab to discharge treated groundwater to the sanitary sewer at seven locations. The EBMUD permit[22] allows for discharge of treated groundwater from certain hydraugers (subsurface drains) and extraction wells, and also from well sampling and development activities.

The treatment process consists of passing the contaminated groundwater through a two-stage carbon-drum adsorption system. Samples of the treated water are collected bi-monthly and analyzed for VOCs using U.S. EPA-approved methods to document that discharge limits have not been exceeded. All treated groundwater discharged under the permit is routed through the Hearst Sewer. One of the conditions for this discharge is the submittal of a semiannual report that provides information on the volumes treated and discharged, as well as analytical results for samples collected each quarter from the treated water. (For further discussion of groundwater monitoring and treatment, see Section 4.4).

4.4 GROUNDWATER

This section reviews the Berkeley Lab groundwater monitoring program with emphasis on the 2011 results and provides a summary discussion of site groundwater contaminant plumes and the corrective measures applied to each of those plumes. More detailed information on the program is provided in the Environmental Restoration Program Quarterly Progress Reports, which contain all site groundwater monitoring data, site maps showing monitoring well locations and contaminant concentrations, and graphs showing changes in contaminant concentrations over time. These reports are available for public review at www.lbl.gov/ehs/erp/html/documents.shtml and at the main branch of the Berkeley Public Library.

Berkeley Lab is currently in the CMI phase of the RCRA CAP. The objectives of groundwater monitoring during this phase are to: (1) evaluate the continued effectiveness of the corrective measures that have been implemented for cleanup of contaminated groundwater; (2) document that site groundwater plumes are stable or attenuating and are not migrating offsite; and (3) monitor progress toward attaining the long-term goal of restoring all groundwater at the site to drinking water standards, if practicable. Although drinking water standards are a long-term goal, it should be noted that groundwater at Berkeley Lab is not used for domestic, irrigation, or industrial purposes, and that drinking water is supplied by EBMUD.

4.4.1 Groundwater Monitoring Results

The groundwater monitoring network at Berkeley Lab consists of more than 230 wells, with 16 of the wells located close to the site boundary and one well located offsite (see Figure 4-5). LBNL's groundwater monitoring wells are sampled for VOCs, metals, and/or tritium in accordance with a schedule

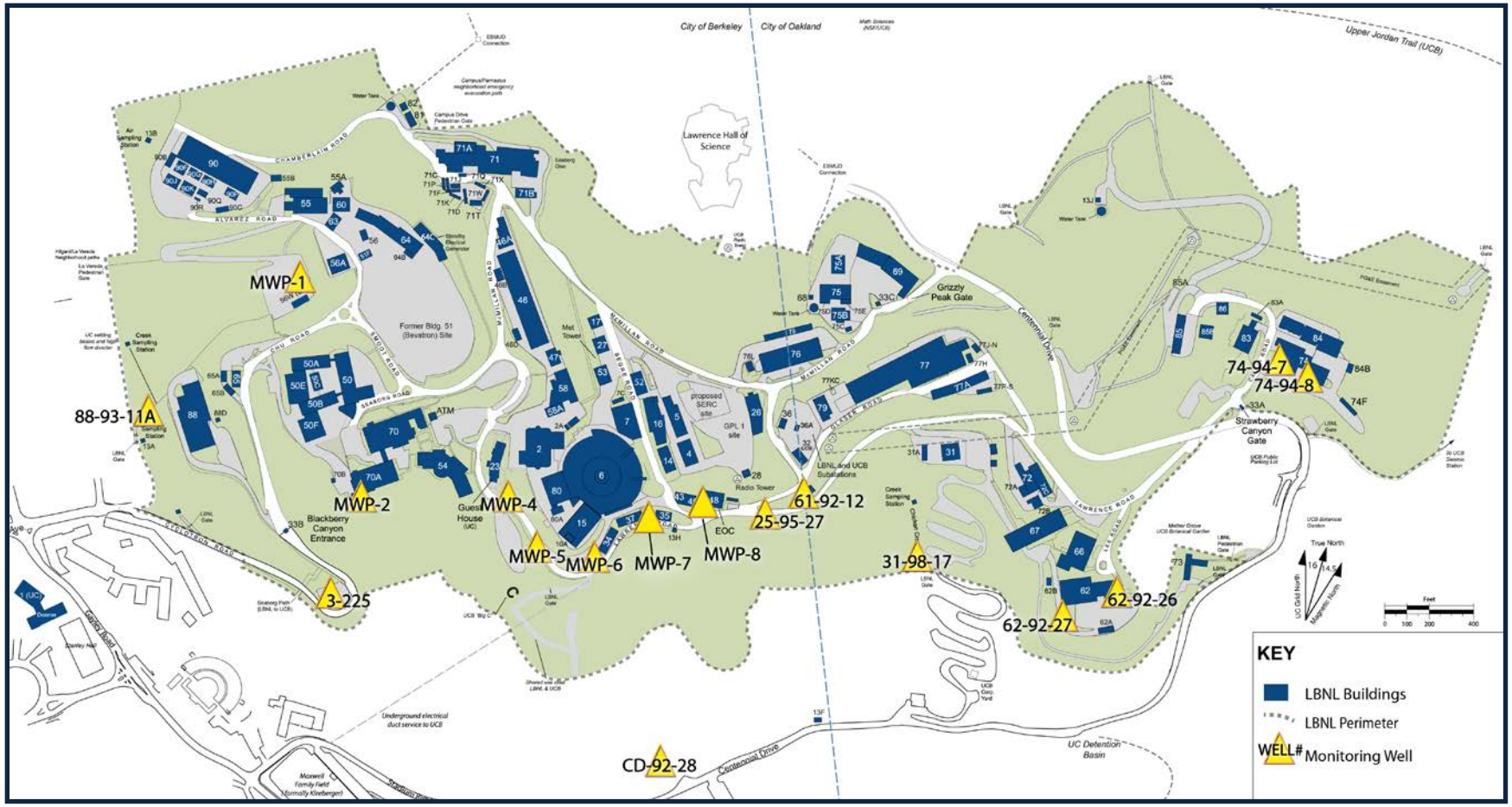

Figure 4-5 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

approved by the RWQCB. Selected wells are also monitored for other potential contaminants.

No tritium or VOCs were detected in any of the perimeter or off-site wells in 2011. Sitewide VOC and tritium results are discussed in detail in Section 4.4.2. The only metal detected in 2011 at a concentration above both the drinking water standard and the statistically estimated Berkeley Lab background level[23] was arsenic in one well. No plumes are associated with this metal, and it is likely to be naturally occurring. The elevated arsenic concentration is attributed to the relatively high natural concentration of this metal in certain sedimentary rock types at Berkeley Lab. In addition, molybdenum, which has no drinking water standard, was detected above the upper estimate of background in five wells. The 2011 results are consistent with previously detected metals concentrations in the groundwater.

4.4.2 Groundwater Contamination

VOC-Contaminated Groundwater: Based on groundwater monitoring results, six principal VOC groundwater contaminant plumes have been identified at Berkeley Lab (Old Town, Building 51/64, Building 51L, Building 71B, Building 69A, and Building 76 plumes). In addition, VOC-contaminated groundwater is present in five other localized areas (former Building 51A, former Building 51 Vacuum Pump Room, Building 64, Building 75/75A, and Building 77). The Building 51A and Building 51 Vacuum Pump Room contaminant areas were discovered in 2011 during the subsurface characterization investigations conducted for the Building 51 and Bevatron Demolition Project.

The primary contaminants associated with the plumes and localized areas of groundwater contamination are halogenated VOCs (that were used as cleaning solvents) and their associated degradation products. Past releases associated with the use of these solvents were the source of the groundwater contamination. Over the past several decades, LBNL has improved control systems and practices to prevent spills and accidental releases.

Concentrations of VOCs in most of the plume locations and in the Building 77 area have been decreasing; however, except for the Building 77 area, VOC concentrations still remain above the drinking water standard.

Tritium-Contaminated Groundwater: A plume of tritium-contaminated groundwater extends southward from the Building 75 area. The source of the contamination was the former National Tritium Labeling Facility (NTLF), which ceased operation in 2001. The magnitude and lateral extent of the tritium plume have been decreasing since closure of the NTLF, with concentrations of tritium below the drinking water standard of 740 Bq/L (20,000 pCi/L)[24, 25] in all wells since February 2005. Low concentrations of tritium (below the drinking water standard) have also been detected in groundwater samples collected in the Building 71B area and beneath the central area of the former Bevatron site.

Petroleum-Hydrocarbon Contaminated Groundwater: Two petroleum hydrocarbon plumes associated with former USTs are present at the site. One is located at Building 74, and the other near Building 6. Petroleum hydrocarbons have also been detected in the groundwater at a former UST site south of Building 76.

The locations of the plumes and the extent of groundwater with contaminant concentrations exceeding the drinking water standard in September 2011 are shown on Figure 4-6.

The groundwater contamination is discussed in more detail in the following subsections.

4.4.2.1 Old Town VOC Plume - Building 7 Lobe

The Old Town VOC plume is a broad, multi-lobed plume that underlies much of the central portion of Berkeley Lab known as "Old Town." The geometry and distribution of chemicals in the plume indicate that it consists of

three coalescing lobes (Building 7, Building 25A, and Building 52 lobes) that were originally discrete plumes derived from distinct sources.

The Building 7 lobe extends northwestward from the northwest corner of Building 7 to the parking area downslope from Building 58. The principal constituents of the Building 7 lobe are tetrachloroethylene (PCE) and carbon tetrachloride, and their associated degradation products (e.g., trichloroethylene (TCE); 1,1-dichloroethylene (DCE); cis-1,2-DCE; and vinyl chloride).

A number of interim corrective measures were instituted prior to 2007 for the Building 7 lobe, including excavation of contaminated soil from the source area, removal of a sump that was the source of the groundwater contamination, and installation of several groundwater extraction trenches to control plume migration.

The final corrective measures for the Building 7 lobe consisted of excavation and off-site disposal of contaminated soil remaining in the source area, *in situ* soil flushing and groundwater capture, and MNA. Excavation of the source area soil was completed in 2006. The *in situ* soil-flushing and groundwater capture system consists of three groundwater extraction trenches and numerous groundwater extraction and injection wells. This system is designed to flush contaminants from the subsurface and control the migration of contaminated groundwater.

The source removal, together with *in situ* soil flushing and groundwater capture, has significantly reduced VOC concentrations through much of the Building 7 lobe area, with the annual average concentration of total VOCs in representative wells declining from approximately 20,000 micrograms per liter (µg/L) in 2002 to less than 700 µg/L in 2011. The maximum concentration of total VOCs detected in 2011 was 5,204 µg/L, which primarily consisted of PCE and TCE.

4.4.2.2 Old Town VOC Plume - Building 25A Lobe

The Building 25A lobe of the Old Town VOC plume encompasses two subplumes of groundwater contamination. The main Building 25A subplume extends from the western portion of Building 25A westward to the eastern edge of Building 6. The Building 25 subplume is located south of Building 25. The principal constituents of the Building 25A subplume are TCE and its degradation products (e.g., 1,1-DCE and cis-1,2-DCE). The principal constituents of the Building 25 subplume are TCE and carbon tetrachloride.

The final corrective measure for the Building 25A lobe consists of *in situ* soil flushing. Since flushing was started in 2002, the annual average concentration of total VOCs detected in representative wells in the Building 25A subplume has declined from approximately 200 µg/L to less than 50 µg/L in 2011. The maximum concentration of total VOCs in the Building 25A subplume in 2011 was 159 µg/L.

Significant declines in the concentrations of VOCs have also been observed in the Building 25 subplume since the initiation of soil flushing in the subplume source area in April 2006. Concentrations of VOCs in groundwater samples collected south of Building 25 remained below the drinking water standard in 2011.

4.4.2.3 Old Town VOC Plume - Building 52 Lobe

The Building 52 lobe of the Old Town VOC plume extends northwest from the area east of Building 52 to the east edge of Building 46, where the contaminated groundwater is captured by a subdrain that was installed in the 1950s as a landslide mitigation measure. The principal lobe constituents are PCE and carbon tetrachloride, and their associated degradation products (e.g., TCE; 1,1-DCE; cis-1,2-DCE; and chloroform).

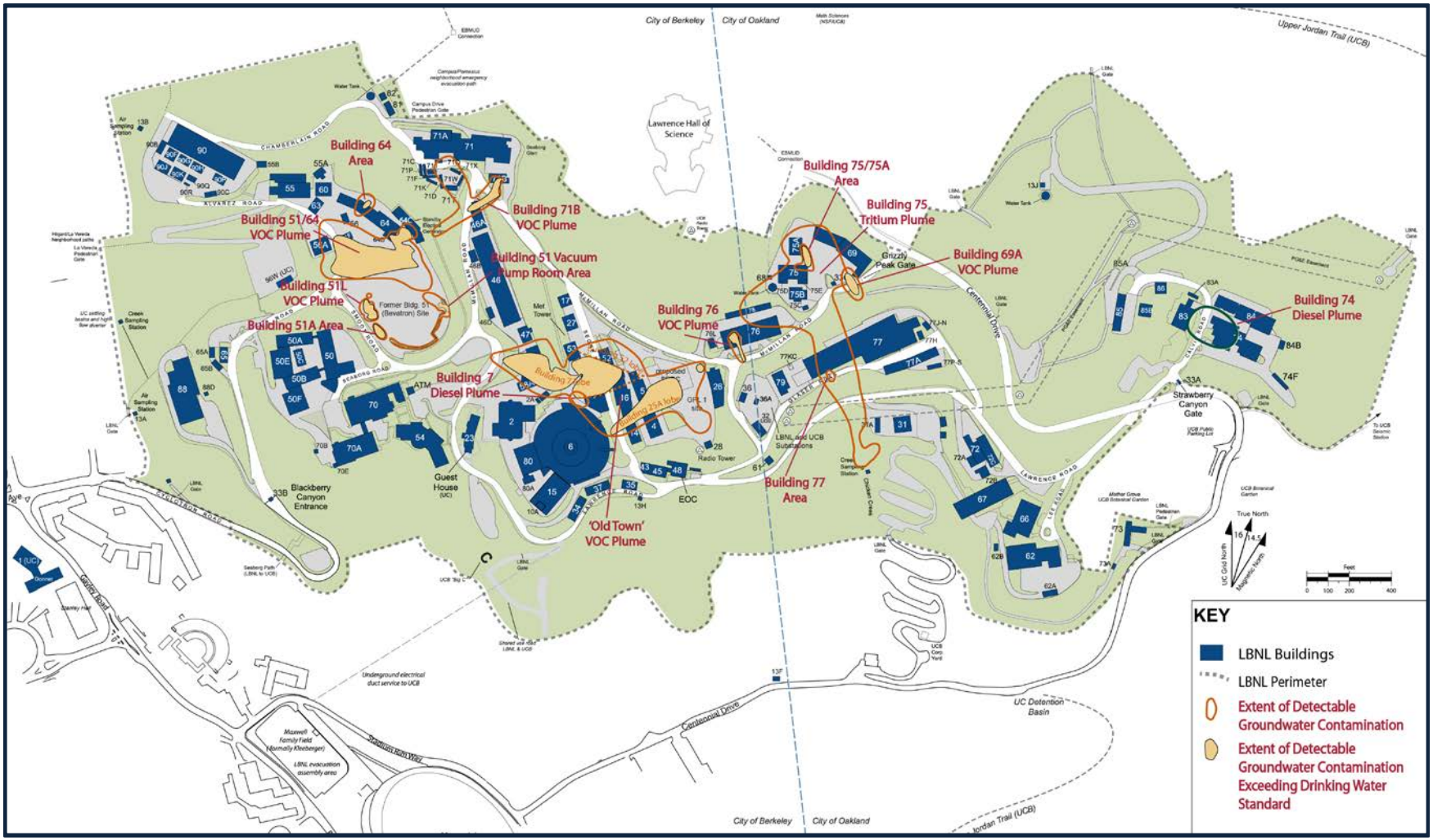

Figure 4-6 Locations of Groundwater Contamination (September 2011)

The final corrective measures for the Building 52 lobe consist of *in situ* soil flushing and the continued capture of groundwater at the Building 46 subdrain. Since flushing was started in 2003, the annual average concentration of total VOCs in representative Building 52 lobe wells has declined from more than 100 µg/L to less than 5 µg/L, with concentrations of individual VOCs declining to less than the drinking water standard throughout most of the lobe area. The maximum concentration of total VOCs detected in the Building 52 lobe in 2011 was 6.8 µg/L. Since flushing started, there has also been a significant reduction in the lateral extent of the plume.

4.4.2.4 Building 51/64 VOC Plume

The Building 51/64 VOC plume extends south and west from the southeast corner of Building 64 beneath the former location of Building 51B. The principal plume constituents are 1,1-dichloroethane (DCA), TCE, and PCE and their associated degradation products (e.g., 1,1-DCE; cis-1,2-DCE; and vinyl chloride).

In 2000, contaminated soil was excavated from the source area of the plume as an interim corrective measure. The final corrective measures for the Building 51/64 VOC plume consist of *in situ* soil flushing, MNA, and the continued collection and treatment of water from the Building 51 subdrain system. In addition, HRC has been injected into the subsurface in the downgradient plume area. As a result of these interim and final corrective measures, the maximum concentration of total VOCs in groundwater in the source area has declined from more than 700,000 µg/L to approximately 200 µg/L in 2011. Since *in situ* soil flushing was started in 2003, the annual average concentration of total VOCs detected in representative wells has declined from more than 4,000 µg/L to less than 80 µg/L. The maximum concentration of total VOCs detected in 2011 was 1,238 µg/L, which consisted primarily of 1,1-DCA.

4.4.2.5 Building 51L VOC Plume

The Building 51L VOC plume is located beneath the area where Building 51L was formerly located. The principal plume constituent is TCE and its associated degradation products (e.g., cis-1,2-DCE).

The final corrective measure for the Building 51L VOC plume was excavation and off-site disposal of contaminated source area soil. The corrective measure was completed at the end of 2006. Prior to completion of the corrective measure, halogenated VOCs were detected at concentrations above 1,000 µg/L in wells monitoring the plume. Groundwater extraction well EW51L-06-1 was installed in the backfilled corrective measure excavation. The maximum concentration of total VOCs detected in EW51L-06-1 in 2011 was 50 µg/L. The maximum concentration of total VOCs (primarily TCE) detected in the Building 51L area in 2011 was 337 µg/L.

4.4.2.6 Building 71B VOC Plume

The Building 71B VOC plume extends southwest from Building 71B towards the Building 51/64 area. The principal plume constituents are TCE and PCE, and their associated degradation products (e.g., cis-1,2-DCE). Between 2000 and 2004, highly contaminated soil was excavated from the plume source area as an interim corrective measure.

The final corrective measures for the Building 71B VOC plume consist of *in situ* soil flushing with the injection of HRC, and continued collection and treatment of contaminated effluent from the hydraugers that drain groundwater from the slope west of Building 46A. Since flushing was started in 2004, the annual average concentration of total VOCs in source area wells has declined from more than 300 µg/L to less than 50 µg/L in 2011. The maximum concentration of total VOCs detected has declined from more than 6,000 µg/L to less than 200 µg/L in 2011.

4.4.2.7 Building 69A VOC Plume

The Building 69A VOC plume is located west of Building 69A. The principal plume constituents are cis-1,2-DCE and vinyl chloride.

The final corrective measure for the Building 69A VOC plume is MNA. In addition, HRC was injected into the subsurface in 2006 and 2007 to enhance the natural degradation processes. The annual average concentration of total VOCs in representative wells has declined from approximately 100 µg/L to less than 10 µg/L in 2011. The maximum concentration of total VOCs (primarily cis-1,2-DCE) detected in 2011 was 18 µg/L.

4.4.2.8 Building 76 VOC Plume

The Building 76 VOC plume extends approximately 100 feet southwards from the motor-pool area on the south side of Building 76. The principal plume constituent is TCE and its degradation products (e.g., cis-1,2-DCE). The maximum concentration of total VOCs detected in groundwater samples collected in 2011 was 11 µg/L. No corrective measures are required for the Building 76 plume.

4.4.2.9 Former Building 51 Vacuum Pump Room and Building 51A Areas

Two additional areas of VOC-contaminated groundwater were identified in 2011 as part of the environmental investigations conducted to assess potential contamination at the Building 51 and Bevatron Demolition Project site. VOCs (primarily TCE) were detected at a total concentration of 132,960 µg/L in a predevelopment groundwater sample collected from a temporary groundwater sampling point installed in the former Vacuum Pump Room of Building 51. Groundwater samples collected within several feet of this location contained VOC concentrations orders of magnitude lower. VOCs (14,470 µg/L maximum total concentration) were also detected in grab groundwater samples collected from borings in the former Building 51A area. The contaminants in this area consisted primarily of TCE and carbon tetrachloride. These findings were reported to the DTSC.

4.4.2.10 Tritium Contaminated Groundwater

The Building 75 tritium plume extends southwards from Building 75 toward Chicken Creek. Tritium was also detected in concentrations well below the drinking water standard in groundwater samples collected from a few monitoring wells in the Building 71B area. As a result of the environmental investigations conducted during 2011 to assess potential contamination at the Building 51 and Bevatron Demolition Project site, tritium was also detected in concentrations well below the drinking water standard in groundwater samples beneath the central area of the former Bevatron site. The source of the Building 75 tritium plume and the Building 71B area of tritium-contaminated groundwater was the former NTLF at Building 75.

The maximum concentration of tritium detected in Building 75 tritium plume groundwater in 2011 was 533 Bq/L (14,400 pCi/L), which is below the drinking water standard of 740 Bq/L (20,000 pCi/L). Concentrations of tritium have been declining in almost all wells monitoring the plume since closure of the NTLF in December 2001, with a concurrent reduction in the lateral extent of the plume. Tritium was not detected (less than 11.1 Bq/L [300 pCi/L]) in 2011 in the Building 71B area groundwater. In 2011 tritium was detected at a maximum concentration of 24.9 Bq/L (673 pCi/L) in groundwater samples collected beneath the central area of the former Bevatron site. In 2011, tritium was not detected in groundwater samples collected from 29 wells downgradient and crossgradient from this area, indicating that the extent of the contamination is limited.

4.4.2.11 Petroleum Hydrocarbon Plumes

Petroleum hydrocarbon-contaminated groundwater has been historically detected in three areas where USTs formerly were located: north of Building 6, near Building 74, and south of Building 76. In 2011, petroleum

hydrocarbons were detected at a concentration of 100 µg/L in one well near Building 74. Petroleum hydrocarbons were not detected in the groundwater samples south of Building 76 or north of Building 6. No aromatic VOCs, including BTEX components (i.e., benzene, toluene, ethylbenzene, xylenes), have been detected in the groundwater at any of these UST sites since 2003.

4.4.3 Treatment Systems

Berkeley Lab is using collection trenches, groundwater extraction wells, and subdrains to control the migration of groundwater plumes. Eleven GAC treatment systems were operated in 2011 to treat the extracted groundwater. The treated water is mainly reinjected into the subsurface for *in situ* soil-flushing purposes. Excess water is released to the sanitary sewer in accordance with Berkeley Lab's treated groundwater discharge permit from EBMUD.[26]

The total volume of contaminated groundwater treated by these systems during the year was about 50,000 m^3 (13 million gal). From 1991 through the end of 2011, more than 492,000 m^3 (130 million gal) of contaminated groundwater have been extracted, treated, and mostly reinjected as clean water into the subsurface for *in situ* soil-flushing purposes.

4.5 SOIL AND SEDIMENT

This section summarizes the routine monitoring results for soil and sediment samples. Non-routine sampling conducted to investigate contamination at specific sites (e.g., the Building 51 and Building 25 demolition sites) is not reported here. Non-routine results are reported in the Environmental Restoration Program Quarterly Progress Reports. These quarterly reports are available for public review at www.lbl.gov/ehs/erp/html/documents.shtml and at the main branch of the Berkeley Public Library.

4.5.1 Soil Sampling Results

Soil samples obtained from the top 2 to 5 cm (1 to 2 in) of surface soils were collected from three locations on the LBNL site and one off-site environmental monitoring station (see Figure 4-7). Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, moisture content, pH, and 15 individual metals.

For radioisotope analysis, the alpha, beta, and gamma emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soils. Tritium measurements at each of the sampling locations were below detection limits.

For non-radioisotope analysis, measurements of pH and moisture content at each of the sampling locations were within the typical range for soils. With the exception of mercury, the metals results were within established Berkeley Lab soil background levels[27] or levels commonly found in California soils.

For mercury, the Quality Assurance/Quality Control sampling location was at 70 milligrams per kilogram (mg/kg), which is slightly above the established Berkeley Lab soil background concentration of 42 mg/kg, but well below the U.S. EPA's industrial preliminary remediation goal of 800 mg/kg.

4.5.2 Sediment Sampling Results

Sediment samples were collected in the creek beds of the North Fork of Strawberry Creek and Chicken Creek on the LBNL site and at one off-site location at Wildcat Creek in Tilden Regional Park in Berkeley (see Figure 4-7). Due to limited sediment availability, several grab samples from the general sampling area of each location were composited and analyzed. Samples were analyzed for gross alpha, gross beta, and gamma emitters, tritium, 15 individual metals, pH, moisture content, and petroleum hydrocarbons (diesel and oil/grease).

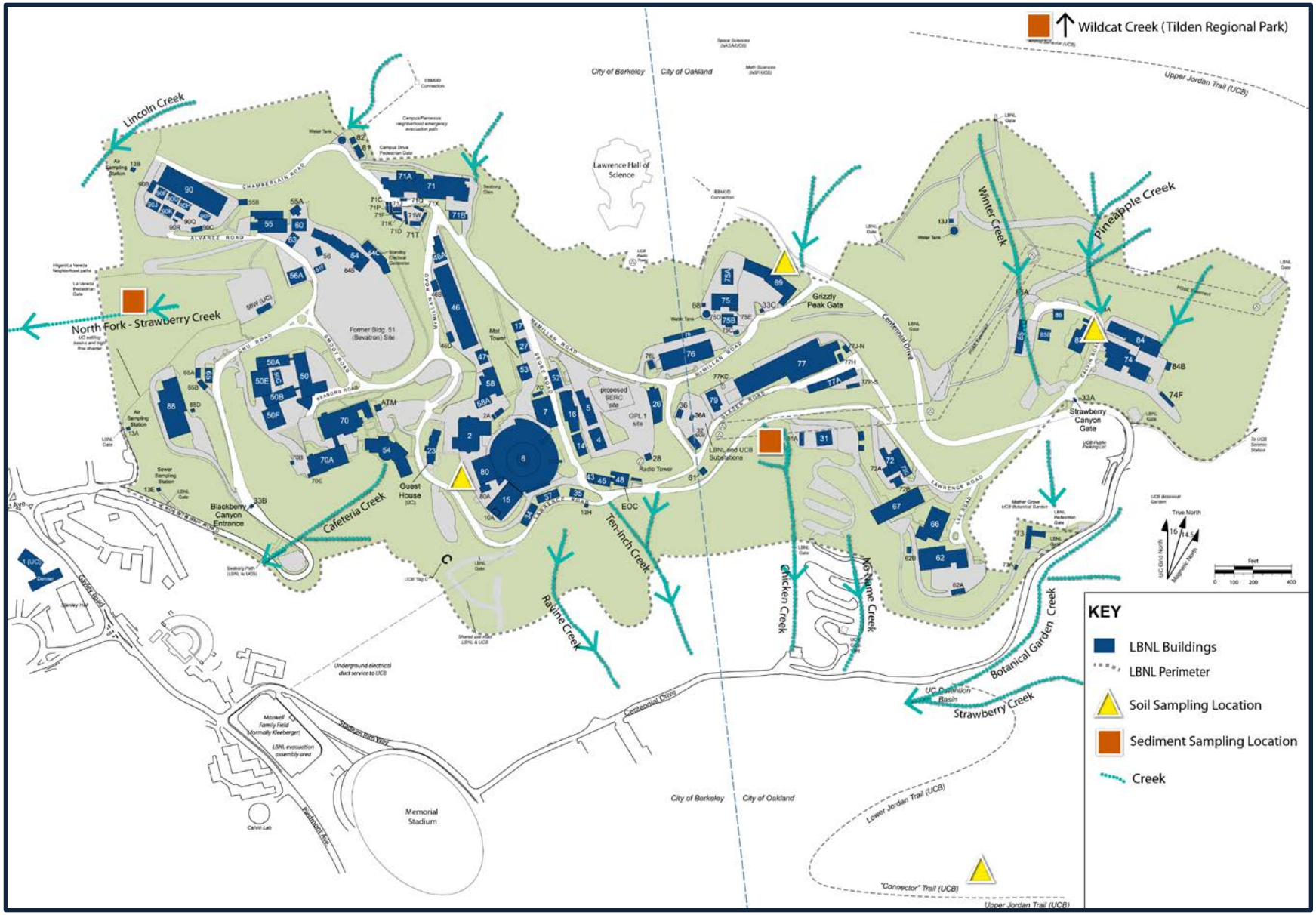

Figure 4-7 Soil and Sediment Sampling Sites

For radioisotope analysis, the levels of alpha, beta, and gamma emitters were within background levels of naturally occurring radioisotopes commonly found in sediments. Tritium measurements at each of the sampling locations were below detection limits.

For non-radioisotope analysis, measurements of pH and moisture content at each of the sampling locations were within the typical range for soils. Petroleum hydrocarbons (diesel and oil/grease) were within the historical values typically found at the Berkeley Lab site over the past five years. The metals results were within either the established Berkeley Lab soil background levels or levels commonly found in California soils.

4.6 VEGETATION AND FOODSTUFFS

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

Due to historical air emissions from the former NTLF Hillside Stack, vegetation near that site contains measurable concentrations of tritium. Tritium in vegetation occurs in two chemical forms – organically bound tritium (OBT) and tissue-free water tritium (TFWT). Berkeley Lab analyzes vegetation for both forms. Since the closure of the NTLF in December of 2001, tritium emissions from Berkeley Lab 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 routinely samples this vegetation at least every five years. In 2011, no samples were collected for this purpose.

Berkeley Lab also samples trees for tritium for landscape management, because only trees with tritium levels indistinguishable from background are removed from the LBNL site and released to the public. In 2011, two trees near Building 76L (about 135 m [443 feet] south-southwest of the former NTLF Hillside Stack) were sampled for this purpose. The samples were analyzed at a commercial laboratory for OBT and TFWT. The trees were found to have measurable organically bound tritium, as shown in Table 4-4. Based on these results, the trees were not removed from the Berkeley Lab site. Instead, they were chipped and the chips were left in place or were spread on the hillside near the location of the former NTLF stack.

Table 4-4 Results of Landscape Management Sampling

Sample Description	Result (Bq/g)	MDA (Bq/g)	Result (pCi/g)	MDA (pCi/g)
Organically Bound Tritium				
SSW135 - Chip	0.41	0.10	11	2.8
SSW137 - Chip	0.25	0.12	6.7	3.2
Tissue Free Water Tritium				
SSW135 - Chip	<0.0033	0.0033	<0.089	0.089
SSW137 - Chip	<0.0039	0.0039	<0.0106	0.106

4.7 PENETRATING RADIATION MONITORING

Radiation-producing machines (e.g., accelerators, x-ray machines, irradiators) and various radionuclides are used at Berkeley Lab for high-energy particle studies and biomedical research. Accelerator and irradiator operations at the site are the primary contributors of penetrating radiation.

When operating, accelerators may produce both gamma radiation and neutrons. To detect gamma radiation and neutrons from accelerator operations, Berkeley Lab places radiation-detection equipment at environmental monitoring stations near the site's primary research

accelerators, which include the Advanced Light Source (Building 6), Biomedical Isotope Facility (Building 56), and 88-Inch Cyclotron (Building 88). The LOASIS Project (Building 71) is an experimental, laser-driven accelerator that does not produce measurable gamma or neutron radiation outside the building; nonetheless, penetrating radiation near this accelerator is passively monitored, as discussed below.

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 doses
- Passive detectors called "optically stimulated luminescence dosimeters," which by laboratory analysis provide an average dose over time from gamma radiation

The locations of real-time monitors and dosimeters are shown in Figure 4-8. Results of both measurement methods are given in terms of dose and are provided in Section 5.2.

Irradiators at Berkeley Lab produce only gamma radiation. Used for radiobiological and radiophysics research, a gamma irradiator that uses sealed cobalt-60 sources is housed at Berkeley Lab in Building 74; the irradiator is in a massive interlocked structure that is covered with reinforced concrete. In December 2008, this irradiator was removed from service, and it is not currently authorized for use. While the irradiator was in use, routine surveys confirmed that the maximum gamma radiation doses at one m (3.3 ft) from the outside walls or ceiling of the building were indistinguishable from background levels (0.002 mSv per hour [mSv/hr]) [0.2 mrem/hr]).

Berkeley Lab also uses other, smaller, well-shielded gamma irradiators, neutron generators, and x-ray machines that pose considerably less potential for environmental impact than does the Building 74 irradiator. These smaller radiation-producing machines do not measurably increase the dose to the public.

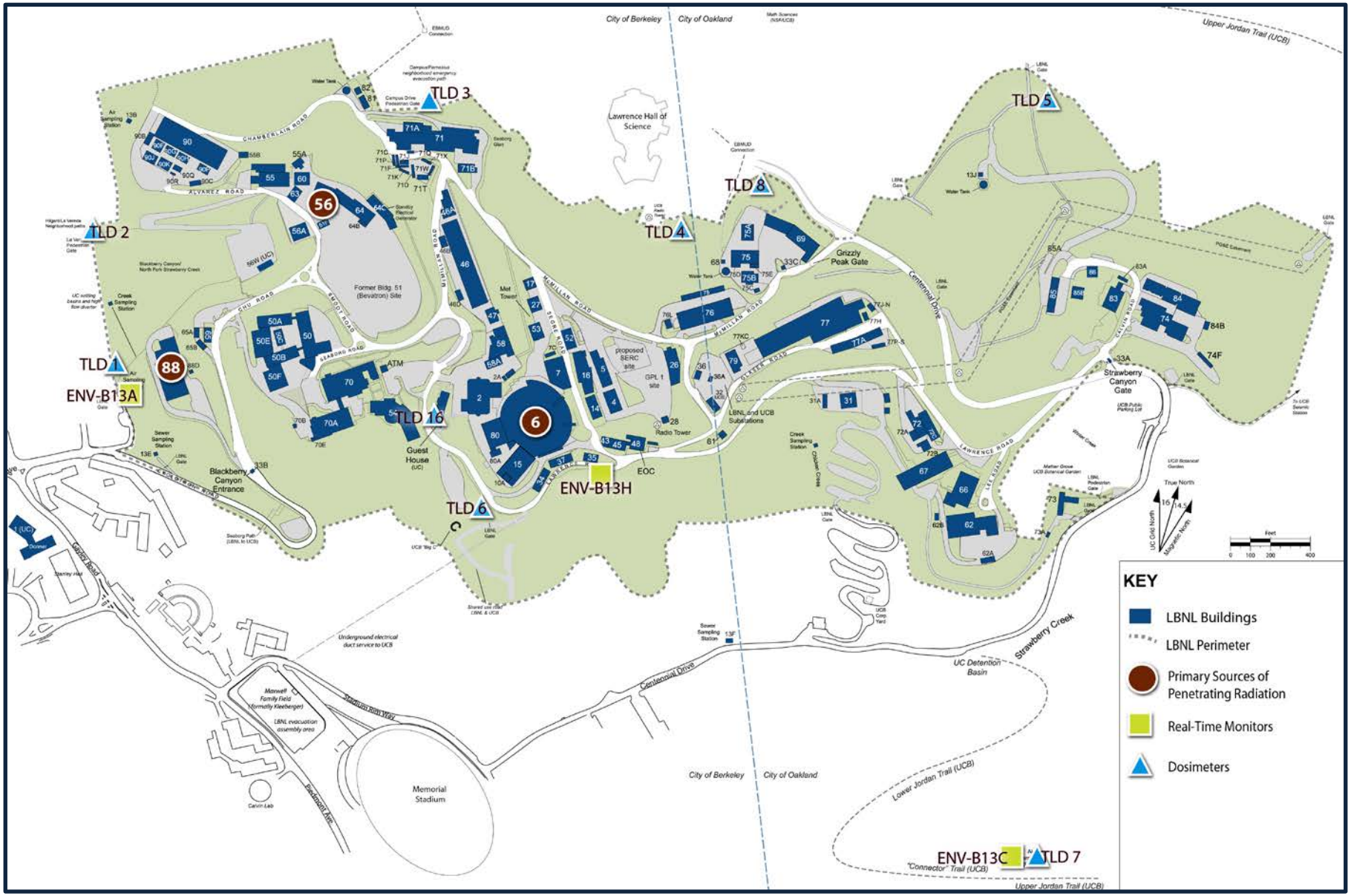

Figure 4-8 Environmental Penetrating Radiation Monitoring Stations

Flowering Flannelbush (*Fremontodendrom californicum*) at the entrance of Building 2.

5. Radiological Dose Assessment

5.1	BACKGROUND	5-2
5.2	DOSE FROM PENETRATING RADIATION	5-2
5.3	DOSE FROM DISPERSIBLE AIRBORNE RADIONUCLIDES	5-2
5.4	TOTAL DOSE TO THE PUBLIC	5-3
5.5	DOSE TO ANIMALS AND PLANTS	5-3

5.1 BACKGROUND

Earlier chapters refer to monitoring and sampling results in terms of concentrations of a substance. An exposure to concentrations of a substance over a period of time is referred to as "dose." Because doses are calculated rather than measured, they represent potential or estimated, instead of actual, doses. This chapter presents the estimated dose results from Berkeley Lab's penetrating radiation and airborne radionuclide monitoring programs. These doses include all known radionuclides released in significant quantities from Berkeley Lab. Doses to nearby individual members of the public are calculated, as well as population doses to people in the surrounding region extending 80 km (50 mi) from the site. Within this area, the population is about 6,615,000.[1] The doses projected from each monitoring program are presented separately before they are cumulatively evaluated to summarize the overall impact of LBNL's radiological activities on members of the public. Additionally, the radiological impact of Berkeley Lab's operations on local animals and plants is discussed.

To minimize radiological impacts to the environment and the public, Berkeley Lab manages its programs so that radioactive emissions and external exposures are as low as reasonably achievable (ALARA). LBNL's Environmental ALARA Program ensures that a screening (qualitative) review is performed on activities that could result in a dose to the public or the environment. Potential doses from activities that may generate airborne radionuclides are estimated through the NESHAP[2] process (discussed in Section 3.3.1.1 and Section 4.2.1). If the potential for a public dose is greater than 0.01 mSv (1 mrem) to an individual or 0.1 person-Sv (10 person-rem) to a population, an in-depth quantitative review is required. No quantitative reviews were required or performed in 2011.

5.2 DOSE FROM PENETRATING RADIATION

As discussed in Section 4.7, penetrating radiation from Berkeley Lab operations is measured by real-time monitors and dosimeters. Results of penetrating radiation measurements indicate that the maximum dose from gamma and neutron radiation (which is from the Advanced Light Source [ALS]) to a person at the nearest residence (about 350 m [1150 feet] away) was 1.7×10^{-4} mSv (1.7×10^{-2} mrem), and the population dose to people in the surrounding region that extends 80 km (50 mi) from the site was 6.7×10^{-4} person-Sv (6.7×10^{-2} person-rem).

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. Dispersible radionuclides originate as emissions from building exhaust points generally located on rooftops, as discussed in Section 4.2.1. Once emitted, these radionuclides may affect any of several environmental media: air, water, soil, plants, and animals. Each of these media represents a possible pathway of exposure affecting human dose.

Dose to an individual and the population is determined using computer dispersion models. The NESHAP regulation[3] requires that any facility that releases airborne radionuclides assess the impact of such releases using a computer program approved by the U.S. EPA. Berkeley Lab satisfies this requirement with the use of the U.S. EPA-approved programs CAP88-PC and COMPLY.[4] Details of dose calculations from dispersible airborne radionuclides are included in LBNL's annual NESHAP report,[5] available at www.lbl.gov/ehs/esg/Reports/tableforreports.shtml and at the main branch of the Berkeley Public Library. .

The maximally exposed individual (MEI) to airborne emissions from the main LBNL site was determined to be a hypothetical person residing at the Lawrence Hall of Science. The maximum possible dose to the MEI from airborne radionuclides for 2011 was about 5.0×10^{-5} mSv (0.005 mrem). This value is about 0.05% of the DOE and U.S. EPA annual limit for airborne radionuclides (0.10 mSv/yr [10 mrem/yr]).[6, 7]

As with penetrating radiation, the population dose from airborne radionuclides to the surrounding population is estimated for a region that extends from the site for 80 km (50 mi). The estimated population dose from all airborne emissions from the LBNL main site for the year was 1.1×10^{-3} person-Sv (0.11 person-rem).

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 local background radiation levels. As presented in 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 2011 was about 2.2×10^{-4} mSv/yr (0.022 mrem/yr), primarily from gamma radiation from the LBNL accelerators. This value is approximately 0.007% of the average United States natural background radiation dose[8] (3.1 mSv/yr [310 mrem/yr]) and about 0.02% of the DOE annual limit from all sources (1.0 mSv/yr [100 mrem/yr]).[9]

The total estimated dose to the population within 80 km (50 mi) of Berkeley Lab from penetrating radiation and airborne radionuclides emitted by laboratory operations was 1.8×10^{-3} person-Sv (0.18 person-rem) for the same period. From natural background airborne radionuclides alone, this same population receives an estimated dose of 12,000 person-Sv (1,200,000 person-rem) each year.[10] The dose to the population from Berkeley Lab is about 0.00002% of the background level, or about six million times less than background level.

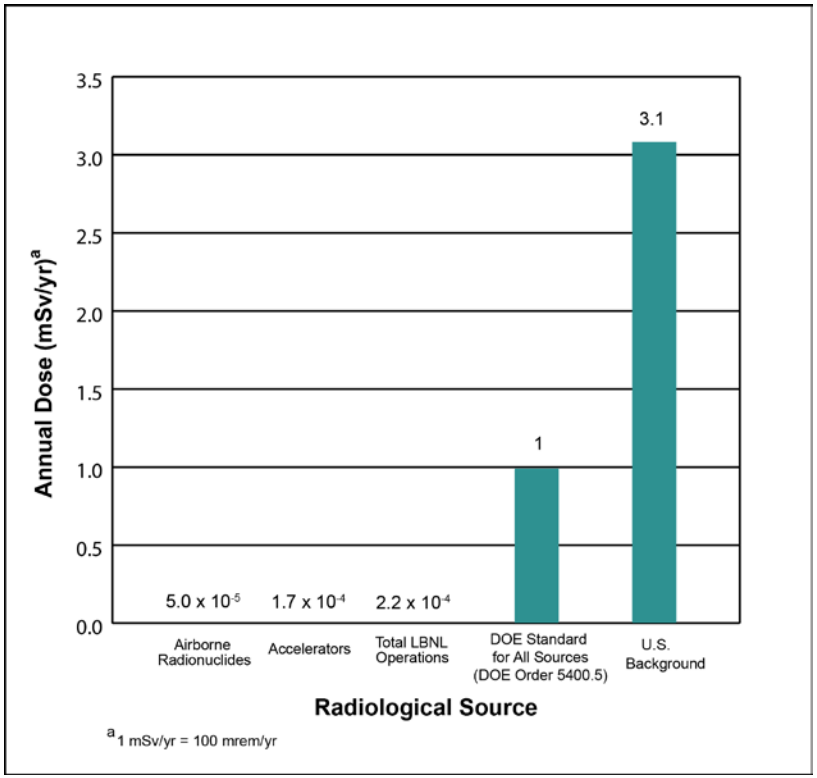

Figure 5-1 Comparison of Radiological Dose Impacts for 2011

5.5 DOSE TO ANIMALS AND PLANTS

Liquid and airborne emissions may have pathways to animals and plants in addition to their pathways to humans. DOE requires that aquatic animals and terrestrial plants be protected by limiting their radiation doses to 1 (one) rad/day (0.01 gray per day [Gy/day]) and doses to riparian and terrestrial animals must be limited to less than 0.1 rad/day (0.001 Gy/day).[11, 12]

To determine dose to animals and plants, several sources of exposure were considered, including animal ingestion of vegetation, water, and soil; animal inhalation of soil; plant uptake of water; and 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 alpha-emitting radionuclides, tritium and other beta-emitting radionuclides, and gamma-emitting radionuclides.

These radionuclides were measured at levels similar to natural background levels, or well below standards. Sample results are provided in Volume II and were evaluated using the DOE-endorsed computer model RESRAD-BIOTA. Both terrestrial and aquatic systems passed the "general screening process" (described in a DOE-approved technical standard),[13] which means that doses calculated are less than biota dose limits. This confirms that Berkeley Lab is in compliance with DOE requirements to limit radiation doses to aquatic organisms and terrestrial plants to 1 rad/day (0.01 Gy/day) and to limit radiation doses to riparian and terrestrial animals to 0.1 rad/day (0.0001 Gy/day).

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John Jelinski of LBNL's Environmental Services Group collects vegetation samples.

6. Quality Assurance

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6.2	PROFILE OF ENVIRONMENTAL MONITORING SAMPLES AND RESULTS	6-3
6.3	SPLIT AND DUPLICATE RESULTS FROM ENVIRONMENTAL MONITORING	6-3
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6.1 OVERVIEW

Berkeley Lab's QA policy is documented in the *Operating and Quality Management Plan* (OQMP).[1] The OQMP consists of a set of operating principles used to support internal organizations in achieving consistent, safe, and high-quality performance in their work activities. OQMP principles are applied to individual programs through a graded approach, with consideration given to factors such as environmental, health, and safety consequences.

In addition to the OQMP, the monitoring and sampling activities and results presented in this report were conducted in accordance with Berkeley Lab's *Environmental Monitoring Plan*[2] and applicable DOE[3] and U.S. EPA[4] guidance. A Quality Assurance Project Plan is developed and implemented when special QA and QC requirements are necessary for environmental monitoring (such as for the NESHAP stack monitoring program).

The on-site and external analytical laboratories are all certified through California's Environmental Laboratory Accreditation Program (ELAP)[5] by having demonstrated the capability to analyze samples for environmental monitoring using approved testing methods. Both types of laboratories must meet demanding QA and QC specifications and certifications[6] that were established to define, monitor, and document laboratory performance. The QA and QC data provided by these laboratories are incorporated into Berkeley Lab's processes performed to assess data quality. For 2011, eleven external analytical laboratories were available for use.

Each set of data (batch) received from the analytical laboratory 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, the DOE Consolidated Audit Program (DOECAP) annually audits external analytical laboratories supporting DOE facilities, including those working with Berkeley Lab. In general, DOECAP audits are two to three days in length, with five or more auditors participating in the audit. A member of DOE or a DOE contractor representative, trained as a Nuclear Quality Assurance lead auditor, heads the DOECAP audit team. Other team members come from across the DOE complex and add a wealth of experience. Typically, Berkeley Lab sends two representatives to participate in DOECAP audits of Berkeley Lab's external analytical laboratory locations. The team audits each of the following six areas that pertain to the services provided by the particular external analytical laboratory:

- QA management systems and general laboratory practices
- Organic analyses
- Inorganic and wet chemistry analyses
- Radiochemical analyses
- Laboratory information management systems and electronic deliverables
- Hazardous and radioactive materials management

The DOECAP laboratory audits also include a review of the external analytical laboratory's performance in proficiency testing required by California ELAP. In 2011, none of the external laboratories had a major deficiency found during an audit. Any minor deficiencies identified in the audits were followed by corrective action plans and were tracked to closure.

In addition, external oversight of Berkeley Lab programs is performed through the DOE *Operational Awareness Program*.[7] Operational awareness activities are ongoing and include field orientation, meetings, audits, workshops, document and information system reviews, and day-to-day communications. DOE criteria for performance evaluation include (1) federal,

state, and local regulations with general applicability to DOE facilities and (2) applicable DOE requirements. This program enables DOE to directly oversee Berkeley Lab programs and assess performance.

6.2 PROFILE OF ENVIRONMENTAL MONITORING SAMPLES AND RESULTS

Berkeley Lab's environmental monitoring program collected approximately 3,369 individual samples (air, sediment, soil, and water) throughout the year; the samples generated approximately 119,294 analytical results.

Samples collected by these programs were obtained from 442 different locations on or surrounding the Berkeley Lab site. Individual data results for all environmental monitoring programs are presented in Volume II. Detailed discussion of sampling conducted by the Environmental Restoration Program can be found at www.lbl.gov/ehs/erp/html/documents.shtml and at the main branch of the Berkeley Public Library.

6.3 SPLIT AND DUPLICATE RESULTS 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 collected in the field. In 2011, a total of 55 split and 106 duplicate samples from all programs were collected for either radiological or nonradiological (or both) analyses, leading to 862 and 2,651 analytical results, respectively. Additionally, there were 242 blank samples submitted for QA purposes. Blank samples are useful because they can identify contamination that was obtained outside of the sampling period.

Berkeley Lab uses the metrics of relative percent difference and relative error ratio to determine whether paired results (split-sample; duplicate-sample) 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 where analytical error is determined.

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 are outside of control limits, an investigation is performed to determine the cause of the discrepancy.

6.4 QUALITY CONTROL RESULTS FROM ANALYTICAL LABORATORIES

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.

Eleven analytical laboratories performed 3,710 radiological and nonradiological QC analyses to coincide with batches of 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 this program.

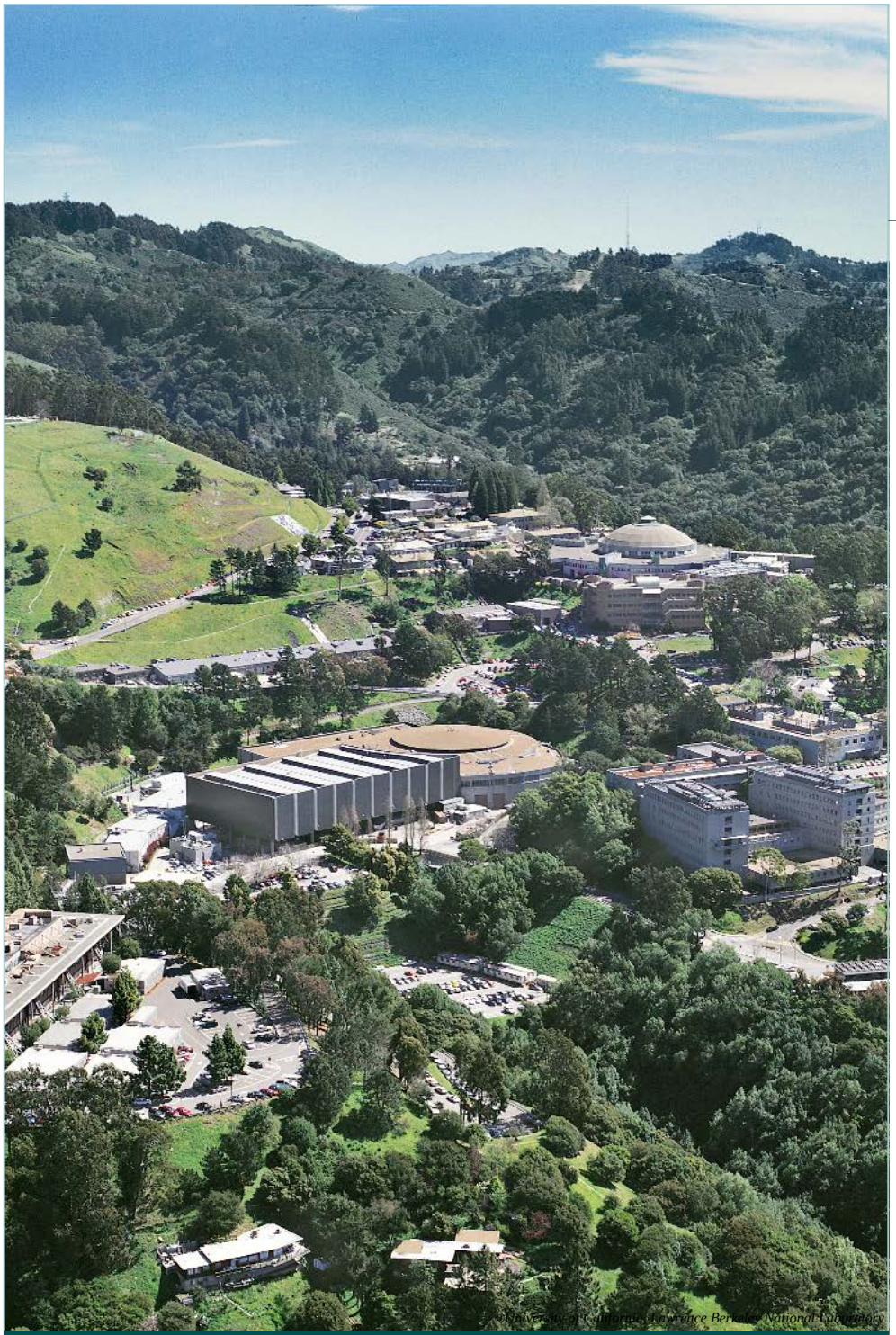
Table 6-1 Summary of Quality Control Testing Performed by Analytical Laboratories in 2011

Program	Sample Batches	QC Analysis	Laboratories Involved	Radiological[a]	Non-radiological[b]
Ambient air	23	57	2	X	
Stack air	93	270	3	X	
Rainwater	20	80	3	X	
Stormwater and creeks	86	244	6	X	X
Wastewater	133	569	6	X	X
Groundwater	172	956	4	X	X
Sediment	14	46	5	X	X
Soil	12	37	5	X	X

[a] An "X" in this column denotes that the program tests for radiological substances.

[b] An "X" in this column denotes that the program tests for non-radiological substances.

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 are outside of established criteria, an investigation is performed to determine the cause of the discrepancy.



Aerial view of Berkeley Lab (2010).

Acronyms and Abbreviations

AEDE	annual effective dose equivalent
AHD	Activity Hazard Document
ALARA	as low as reasonably achievable
ALS	Advanced Light Source
AST	aboveground storage tank
ASWMP	Alternative Stormwater Monitoring Plan
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan for the San Francisco Bay Basin
Berkeley Lab	Ernest Orlando Lawrence Berkeley National Laboratory
BMP	Best Management Practice
Bq	becquerel
BTEX	benzene, toluene, ethylbenzene, xylenes
C	Celsius
CAP	Corrective Action Program
CCCHS	Contra Costa County Health Services
CCCSD	Central Contra Costa Sanitary District
CCR	California Code of Regulations
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
CMI	Corrective Measures Implementation

COB	City of Berkeley
COD	chemical oxygen demand
CRMP	Cultural Resources Management Program
CUPA	Certified Unified Program Agency
CWA	Clean Water Act
CY	calendar year (January 1–December 31)
DCA	dichloroethane
DCE	dichloroethylene
DOE	United States Department of Energy
DOECAP	DOE Consolidated Audit Program
DFG	California Department of Fish and Game
DPH	Department of Public Health
DPM	diesel particulate matter
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EH&S	Environment, Health, and Safety Division at Berkeley Lab
ELAP	Environmental Laboratory Accreditation Program
EMP	Environmental Management Program
EMS	Environmental Management System
EO	Executive Order
EPCRA	Emergency Planning and Community Right-to-Know Act
ESG	Environmental Services Group
F	Fahrenheit
FEIR	Final Environmental Impact Report
FONSI	Finding of No Significant Impact
ft	foot/feet
FTU	fixed treatment unit
FY	fiscal year (October 1 – September 30)
GAC	granular activated carbon
gal	gallon(s)
General Permit	General Permit for Storm Water Discharges Associated with Industrial Activity
GHG	greenhouse gas
Gy	gray (measure of radiation in SI)
HMBP	Hazardous Materials Business Plan
hr	hour
HRC	Hydrogen Release Compound
HWHF	Hazardous Waste Handling Facility
ILA	industrial, landscaping, and agricultural
in	inch
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
JBEI	Joint BioEnergy Institute
JGI	Joint Genome Institute
kg	kilogram
km	kilometer
L	liter
lb	pound
LBNL	Lawrence Berkeley National Laboratory
LRDP	Long Range Development Plan
m	meter
m^3	cubic meter
mi	miles
MDA	minimum detectable activity
MEI	maximally exposed individual

µg	microgram
mg/kg	milligrams per kilogram
mi	mile
MNA	monitored natural attenuation
mrem	millirem
MSGP	Multi-Sector General Permit
mSv	millisievert
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NTLF	National Tritium Labeling Facility
OBT	organically bound tritium
OQMP	Operating and Quality Management Plan
PCB	polychlorinated biphenyl
PCE	perchloroethylene (tetrachloroethylene)
pCi	picocurie (one trillionth of a curie)
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
REC	renewable energy credits
rem	roentgen equivalent man (mrem = 1×10^{-3} rem)
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SI	Système Internationale or International System of Units (the metric system)
SIC	Standard Industrial Classification
SPCC	Spill Prevention, Control, and Countermeasure
Sv	sievert (mSv = 1×10^{-3} Sv)
SWDA	Solid Waste Disposal Act
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCE	trichloroethylene
TFWT	tissue-free water tritium
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UC	University of California
UCOP	University of California Office of the President
UHVCF	Ultra-High Vacuum Cleaning Facility
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
UST	underground storage tank
UV	ultraviolet
VOC	volatile organic compound
WAA	Waste Accumulation Area
Web	World Wide Web
WMG	Waste Management Group
yr	year

Cherry blossoms (*Prunus serrulata*) in the rain in front of Building 2.

Glossary

accuracy

The degree of agreement between a measurement and the true value of the quantity measured.

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.

air particulates

Airborne particles that include dust, dirt, and other pollutants occurring as particles, as well as any pollutants associated with or carried on the dust or dirt.

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.

ambient air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It does not include the air next to emission sources.

analyte

The subject of a sample analysis.

background radiation

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

becquerel

The International System (SI) unit of radioactive decay equal to one disintegration per second.

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 0.6 centimeter of aluminum.

contaminant

Any hazardous or radioactive material present 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 (conventional units).

de minimis

A level that is considered to be insignificant and does not need to be addressed or controlled.

detection limit

The lowest concentration of an analyte that can reliably be distinguished from a zero concentration.[1]

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 the SI units of sieverts or conventional 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 the SI units of grays or conventional 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-sievert (SI unit) or person-rem (conventional unit). For example, if 1,000 people each received a radiation dose of one sievert, their population dose would be 1,000 person-sievert.

dosimeter

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

downgradient

In the direction of groundwater flow.

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 sievert (SI unit) or rem (conventional unit). See dose.

effluent

A liquid waste discharged to the environment.

emission

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

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.

gray

The gray is the International System (SI) unit for absorbed dose. One gray is an absorbed radiation dose of one joule per kilogram.

greenhouse gas

Any of the atmospheric gases that contribute to the greenhouse effect. The greenhouse effect is a phenomenon whereby the earth's atmosphere traps solar radiation, caused by the presence in the atmosphere of gases such as carbon dioxide, water vapor, and methane that allow incoming sunlight to pass through but absorb heat radiated back from the earth's surface.

groundwater

Water below the land 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 on.

hazardous waste

Waste exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-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 subhorizontal 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 (TRU) waste, spent nuclear fuel, by-product material (as defined in Section 1 1e(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 rem.

mixed waste

Any radioactive waste that is also a U.S. EPA-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. After being exposed to radiation, the material in the dosimeter luminesces on 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.

Part B permit

The second, narrative section submitted by generators in the RCRA permitting process. It details the procedures followed at a facility to protect human health and the environment.

person-rem

See dose, population.

person-sievert

See 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 they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.[2]

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.[3]

practical quantification limit

The lowest concentration that can be reliably and consistently measured within specified limits of precision and accuracy.

precision

The degree of agreement between measurements of the same quantity.

priority pollutants

A set of organic and inorganic chemicals identified by U.S. EPA as indicators of environmental contamination.

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 a noncontaminated or safe condition.

sievert

The SI unit of effective dose equivalent in humans. 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 to produce biological effects. One sievert equals 100 rem.

source

Any operation or equipment that produces, discharges, and/or emits pollutants (e.g., pipe, ditch, well, or stack), 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, such as potassium-40; the natural decay chains of uranium-235, uranium-238, thorium-232, or cosmic ray-induced radionuclides in the soil.

tritium

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

universal waste

Hazardous wastes that are more common and pose a lower risk to people and the environment than other hazardous wastes. Some examples of universal waste are mercury thermostats, batteries, fluorescent lamps, cathode ray tubes, and consumer electronic devices.[4]

wind rose

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

Table G-1 Prefixes used with SI (metric) units

Prefix	Factor	Symbol
exa	1,000,000,000,000,000,000 $=10^{18}$	E
peta	1,000,000,000,000,000 $=10^{15}$	P
tera	1,000,000,000,000 = 10^{12}	T
giga	1,000,000,000 $=10^{9}$	G
mega	1,000,000 $=10^{6}$	M
kilo	1,000 $=10^{3}$	k
hecto	100 = 10^{2}	h
deka	10 $=10^{1}$	da[a]
deci	0.1 $=10^{-1}$	d[a]
centi	.01 = 10^{-2}	c
milli	0.001 $=10^{-3}$	m
micro	0.000001 $=10^{-6}$	µ
nano	0.000000001 $=10^{-9}$	n
pico	0.000000000001 $=10^{-12}$	p
femto	0.000000000000001 $=10^{-15}$	f
atto	0.000000000000000001 $=10^{-18}$	a

[a] Avoid where practical.

Table G-2 Conversion Factors for Selected SI (Metric) Units

To Convert SI Unit	To U.S. Conventional Unit	Multiply By
Area		
square centimeters	square inches	0.155
square meters	square feet	10.764
square kilometers	square miles	0.3861
hectares	acres	2.471
Concentration		
milligrams per kilogram	parts per million	1
milligrams per liter	parts per million	1
Length		
centimeters	inches	0.3937
meters	feet	3.281
kilometers	miles	0.6214
Mass		
grams	ounces	0.03527
kilograms	pounds	2.2046
kilograms	ton	0.00110
Pressure		
pascal	pounds per square foot	0.000145
Radiation		
becquerel	curie	2.7×10^{-11}
becquerel	picocurie	27.0
gray	rad	100
sievert	rem	100
coulomb per kilogram	roentgen	3,876
Temperature		
degrees Celsius	degrees Fahrenheit	1.8, then add 32
Velocity		
meters per second	miles per hour	2.237
Volume		
cubic meters	cubic feet	35.315
liters	gallons	0.2642

Jim Chiu of the Environmental Services Group completes on-site environmental water testing.

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Committee to Minimize Toxic Waste
Gene Bernardi
Pam Sihvola

East Bay Municipal Utility District
Source Control Division
Chandra Johannesson

Fermi National Accelerator Laboratory
Environment, Safety, and Health Section
Teri Dykhuis
Eric Mieland

Idaho National Laboratory
Environmental Management Program
Jo Anna Stenzel

Lawrence Livermore National Laboratory
Operations and Regulatory Affairs Division
Gretchen Gallegos

Los Alamos National Laboratory
Environment, Health, and Safety Division
Michael McNaughton
Steve Reneau
Douglas Stavert

National Renewable Energy Laboratory
Environment, Safety, and Health
Maureen Jordan

Oak Ridge National Laboratory
Operations, Environment, Safety, and Health
Kelly Beierschmitt

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Pacific Northwest Laboratory
Joanne Duncan
Kami Lowry

Sandia National Laboratories, Albuquerque
Environment, Safety, and Health
Stephanie Salinas

Sandia National Laboratories/California
Environmental Protection Division
Barbara Larsen

Stanford Linear Accelerator Center
Environment, Safety and Health Division
Helen Nuckolls

United States Congress, 9th Congressional District of California
Congresswoman Barbara Lee

United States Senate
Senator Barbara Boxer
Senator Dianne Feinstein

U.S. Department of Energy
Berkeley Site Office
Aundra Richards
Mary Gross
Kim Abbott

Oak Ridge Office
David R. Allen
Richard Martin

Headquarters, SC-82, Bldg: GTN
Caryle Miller

EH-412, Bldg: FORS
Ross Natoli

U.S. Department of Energy
Office of Scientific and Technical Information

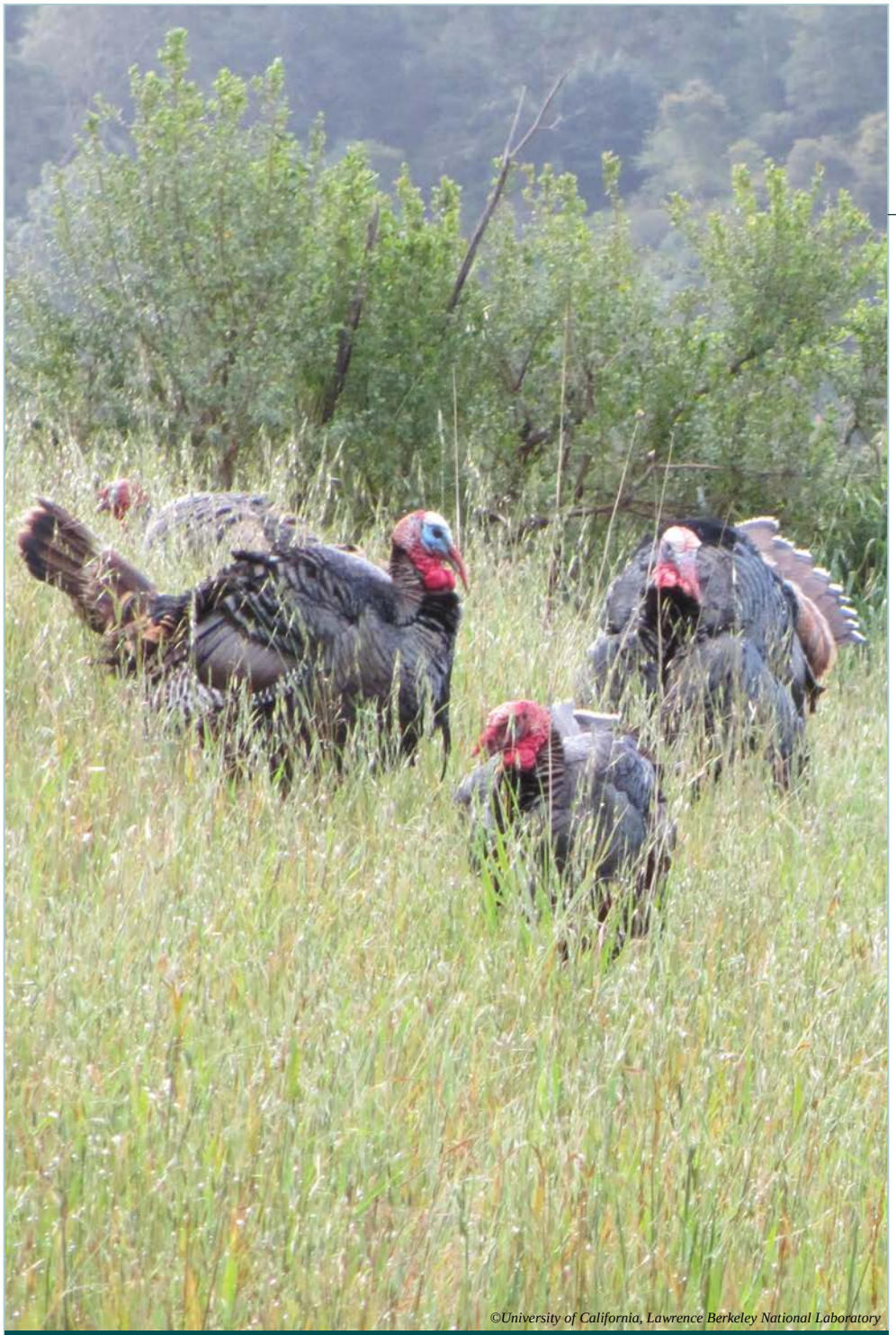
U.S. Environmental Protection Agency (Region 9)
Air and Toxics Division
Shelly Rosenblum

University of California, Office of the President
Anita Gursahani

University of California at Berkeley
Lawrence Hall of Science
Sue Guevara

University of California at Berkeley
Environment, Health, and Safety
Mark Freiberg
Greg Haet

University of California at San Francisco
Environment, Health, and Safety
Clifford Roberts



Wild turkeys (*Meleagris gallopavo*) roam Berkeley Lab.

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