Site Environmental Report for 2009

Volume I

September 2010

Ernest Orlando Lawrence Berkeley National Laboratory

Cover photo by John Turner of the Material Sciences Division

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

Table of Contents

VOLUME I

Figures

Tables

VOLUME II

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 231.1A, *Environment, Safety, and Health Reporting.*[1] The *Site Environmental Report for 2009* summarizes Berkeley Lab's environmental management performance, presents environmental monitoring results, and describes significant programs for calendar year (CY) 2009. 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 contain 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 by releasing it on the World Wide Web (Web) from the Berkeley Lab Environmental Services Group (ESG) home page, which is 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 on the Web are given with the citations in the References section. CD 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 2009 was from October 1, 2008, to September 30, 2009. 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. Following that is also a glossary 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, John Jelinski, Ginny Lackner, Patrick Thorson, Linnea Wahl, and Suying Xu (Volume II).

Readers are encouraged to comment on this report by completing the survey form found at the ESG Web page where this report is available.

Executive Summary

Building 50 Complex

LBNL is a multiprogram scientific facility operated by the University of California (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 missions.

This annual *Site Environmental Report* covers activities conducted in CY 2009. The format and content of this report satisfy the requirements of DOE Order 231.1A, *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, health, and safety laws and regulations.

In 2009, 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 most notable achievement during the year for this management system was validation by DOE that the system conforms to the EMS requirements established by DOE Order 450.1A, *Environmental Protection Program*[3] in 2009. The EMS itself continues to set targets for reducing Berkeley Lab's environmental impacts in areas such as energy, fuel, and water use, toxic air emissions, and landfill waste, while improving performance in acquiring more environmentally sustainable and preferable products. For more information, see Chapter 2.

OPERATING PERMITS, INSPECTIONS, AND INCIDENTS IN 2009

At the end of the year, Berkeley Lab held 44 environmental operating permits from various regulatory agencies for air and water quality protection and hazardous waste handling.

Nineteen inspections of Berkeley Lab's environmental programs occurred during the year. Three violations were received and were reported in two Occurrence Reports under the DOE occurrence-reporting program,[4] which is used to track incidents across the DOE complex.

For additional information on operating permits and inspections, please see Sections 3.3.1 and 3.3.2. For details of DOE-reportable environmental incidents, see Section 3.3.3.

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. For FY09 there were two environmental measures: implement an EMS and complete EMS projects.

The first measure addressed the effectiveness of developing, implementing, and maintaining an EMS that is based on the eighteen elements and framework found in the International Organization for Standardization's (ISO) 14001:2004 International Standard. In the spring of 2009, Berkeley Lab commissioned an independent assessment of its revised EMS. Based on the favorable outcome of this assessment, DOE's Berkeley Site Office declared the EMS as fully implemented.

The second measure considered the number and significance of projects completed under the EMS that lessen Berkeley Lab's impact on the environment. Eighteen such projects were completed during the fiscal year. These projects ranged from in-house energy conservation activities to updating subcontract terms to include language on sustainable acquisition

measures to installing diesel emissions control units on several emergency generators.

Berkeley Lab received a combined grade of A- for both of these measures for FY09. The rating system includes possible letter grades ranging from A+ to F. For more information on environmental performance measures, go to Berkeley Lab's Office of Institutional Assurance home page at www.lbl.gov/DIR/OIA/OCA/contract-performance/index.html.

ENVIRONMENTAL MONITORING AND DOSE ASSESSMENT

Berkeley Lab's environmental monitoring program serves several purposes:

- To demonstrate that LBNL activities operate within regulatory and DOE requirements
- To provide a historical record of LBNL impacts on the environment
- To support environmental management decisions
- To provide information on the effectiveness of emission control programs
- To assess the maximum potential radiological dose to members of the public

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

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

In 2009, the maximum dose to an individual member of the public residing near Berkeley Lab from penetrating radiation and dispersible airborne radionuclides was about 1.8×10^{-3} mSv (0.18 mrem). This is approximately 0.06% of the average United States natural background radiation dose (3.1 mSv [310 mrem])[5] and about 0.2 % of the DOE annual limit from all sources (1.0 mSv [100 mrem]).[6] The estimated maximum potential dose from airborne radionuclides released from Berkeley Lab in 2009 was 7.0×10^{-5} mSv (0.0070 mrem). This is approximately 0.07% of the United States Environmental Protection Agency (U.S. EPA) annual dose limit for dispersible radionuclide emissions (0.10 mSv/yr [10 mrem/yr]).[7]

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) 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 2009 from penetrating radiation and airborne radionuclides was estimated at 2.2×10^{-3} person-sievert (person-Sv) (0.22 person-rem). From natural background radionuclides alone, this same population receives an estimated dose of 12,000 person-Sv (1,200,000 person-rem).[8] 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 operational 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 nine principal groundwater contamination plumes 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 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 2009, see Chapter 4. For more details on radiological dose assessments conducted in 2009, see Chapter 5.

All Berkeley Lab activities, in particular environmental activities, are carried out within the framework of its *2006 Long Range Development Plan* (LRDP)[9] and the accompanying Final Environmental Impact Report (FEIR).[10] These documents constitute LBNL's basic planning and land-use documents, and are intended to guide future growth and change through 2025. For further information on the LRDP and FEIR, please see www.lbl.gov/LRDP/.

1 Introduction

Lawrence Berkeley National Laboratory (outlined) is located east of the University of California Berkeley campus

1.1 HISTORY

Berkeley Lab was founded by Ernest O. Lawrence in 1931. Lawrence received the 1939 Nobel Prize in physics for his invention of the cyclotron (particle accelerator), and he is generally credited with the modern concept of interdisciplinary science, in which scientists, engineers, and technicians from different fields work together on complex scientific projects addressing national needs and programs. Lawrence's pioneering work established a great tradition of scientific inquiry and discovery at LBNL. Eleven Nobelists have been associated with Berkeley Lab. Seventy-eight of its current researchers are members of the National Academies,[1] which forms committees to advise the federal government and public.

Berkeley Lab supports work in such diverse fields as genomics, physical biosciences, 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 miles [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 the buildings at LBNL.

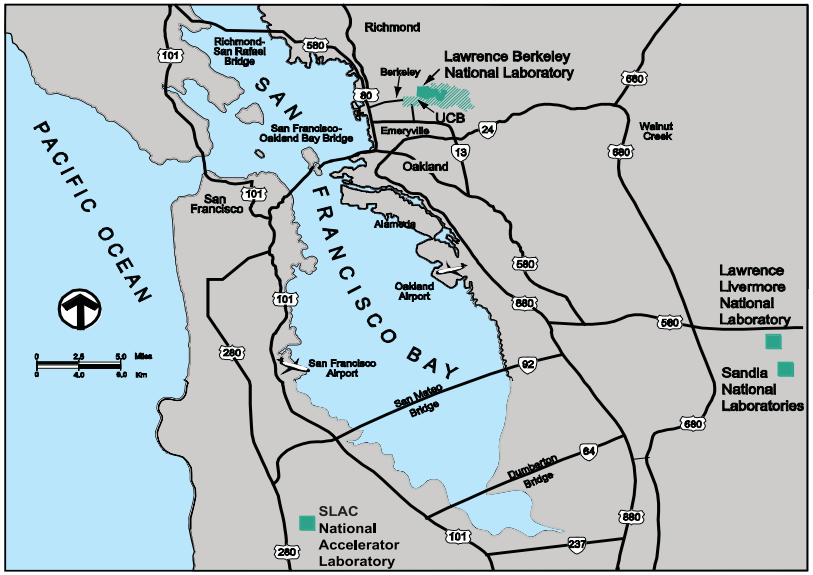


Figure 1-1 Map of National Laboratories in the San Francisco Bay Area

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 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, with the eastern portion in Oakland; the entire site is located within Alameda County. The population of Berkeley is estimated at approximately 103,000, and that of Oakland at 400,000.[2]

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

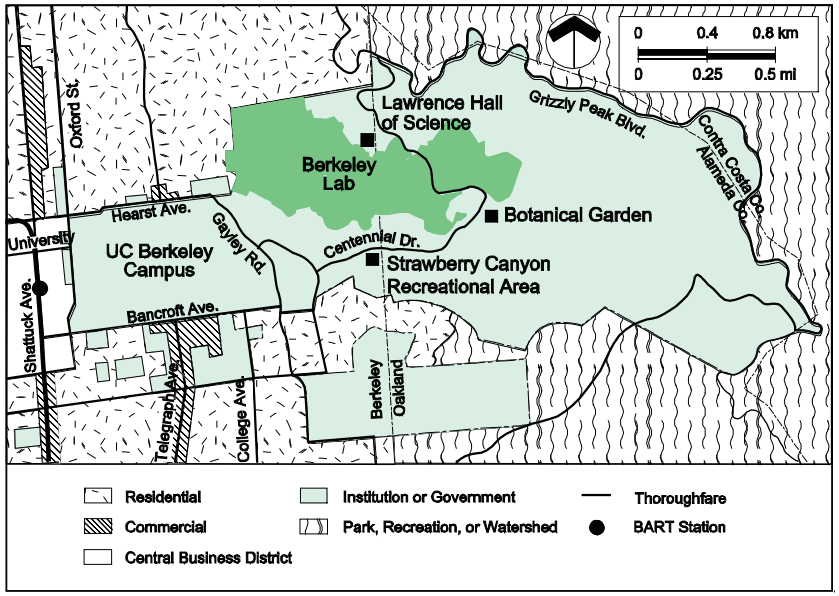


Figure 1-2 Adjacent Land Use

land, is maintained largely in a natural or undeveloped state, but includes UC Berkeley's Strawberry Canyon Recreational Area and Botanical Garden. To the northeast are the University's Lawrence Hall of Science (LHS), 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.

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, in 2009, LBNL hosted over 5,500 participating guests who used its unique scientific facilities 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 185,725 gross square meters (approximately 2.0 million gross square feet). 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.

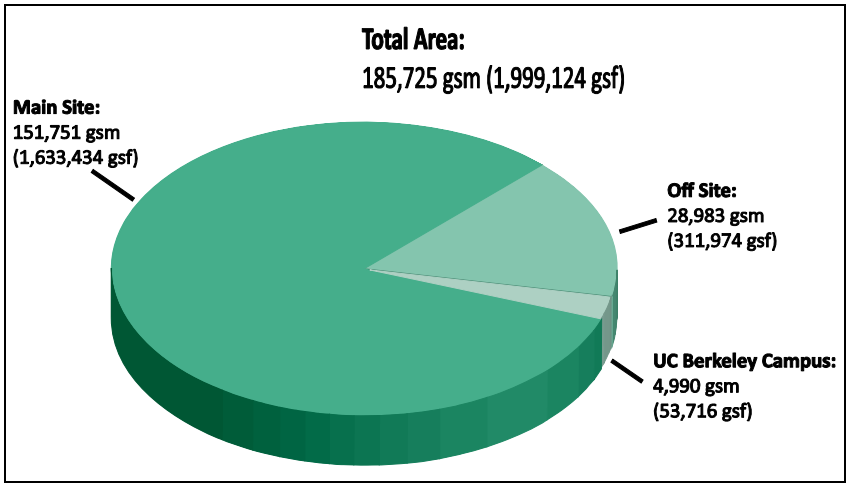


Figure 1-3 Space Distribution

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.[3]

In response to Executive Order (EO) 13423, *Strengthening Federal Environmental, Energy, and Transportation Management,*[4] signed by the President on January 26, 2007, DOE is required to reduce the intensity of water use (i.e., consumption per square foot of building space) by 16% of 2007 levels by October 2015. LBNL has implemented measures to reduce water consumption, and continues to work toward this goal. During FY09 LBNL achieved a savings of almost 18% due to these actions, but predicts difficulty in achieving the FY15 savings goal due to high process cooling needs of planned new facilities.

An adjustment to the water use reduction goal is expected in the coming year as EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*,[5] was signed in October by the President. Among other things, this new EO extends the water use intensity goal by two percent each year until 2020, resulting in an overall 26% reduction target.

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 San Francisco Bay Area DOE facilities including LBNL, Lawrence Livermore National Laboratory, and the SLAC National Accelerator Laboratory. Natural gas is provided from the Defense Fuel Supply Center and is transported through Pacific Gas and Electric transmission piping. Berkeley Lab has arranged to offset five percent of its overall electric power needs, including power to off-site facilities, through the purchase of renewable energy credits. Starting in FY13, these credits will represent 7.5 percent of overall electric power.

LBNL has committed to achieving an energy use intensity reduction of 30% from 2003 levels by October 2015 in response to EO 13423. The new EO 13514 does not directly change this energy savings goal. However, the order calls for significant reductions in greenhouse gas emissions by 2020, which will indirectly continue to lower energy use at Berkeley Lab. DOE is expected to set a system-wide reduction target for these emissions and provide guidance to its contractors on meeting this objective in FY10.

1.5 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 more than 30 years of Berkeley Lab records, is slightly more than 77 centimeters (cm) (30.4 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 2008/2009 rainfall season closed with 66.4 cm (26.1 in) of precipitation, or about 86% of the normal amount.

On-site wind patterns change little from one year to the next. Figure 1-4, a graphical summary of the annual wind patterns called a "wind rose," illustrates 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 of 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.

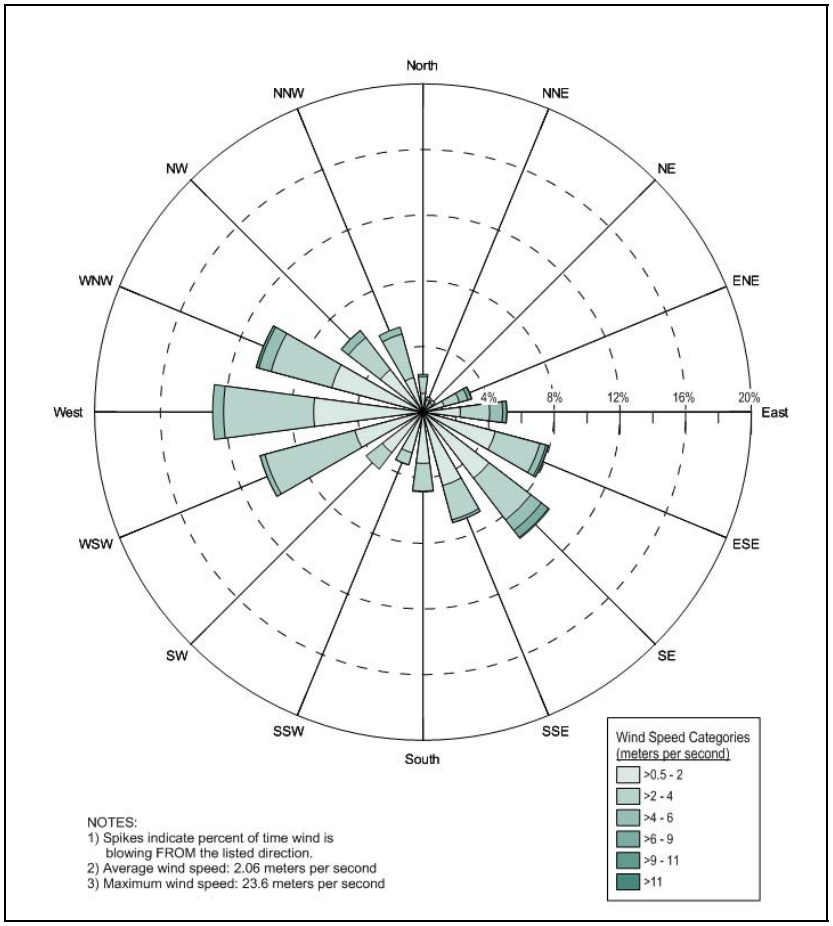


Figure 1-4 Annual Wind Patterns

1.6 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 approximately 150 years before the development of Berkeley Lab on it in the 1930s. Current vegetation is managed in harmony with the local natural succession of native plant communities. Berkeley Lab also works to maintain a wooded and savanna character in the areas surrounding buildings and roads. Ornamental species are generally restricted to public spaces and courtyards and to areas adjacent to buildings. The site has no rare, threatened, or endangered species of plants present. Figure 1-5 shows the vegetation types and locations on-site.

The site is also managed to minimize wildland fire damage to structures. The vegetation management program is designed to reduce 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 of 7.6 cm (3 in)
- Removing brush, except ornamental bushes, throughout the vegetation management area

The purpose of these vegetation management efforts is to minimize the amount of available fuel and consequently 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.

Berkeley Lab also works with the Hills Emergency Forum (comprised of representatives from the neighboring cities of Berkeley and Oakland, the East Bay Regional Park District, EBMUD, and UC Berkeley) to improve vegetation management of the urban-wildland interface in adjacent areas.

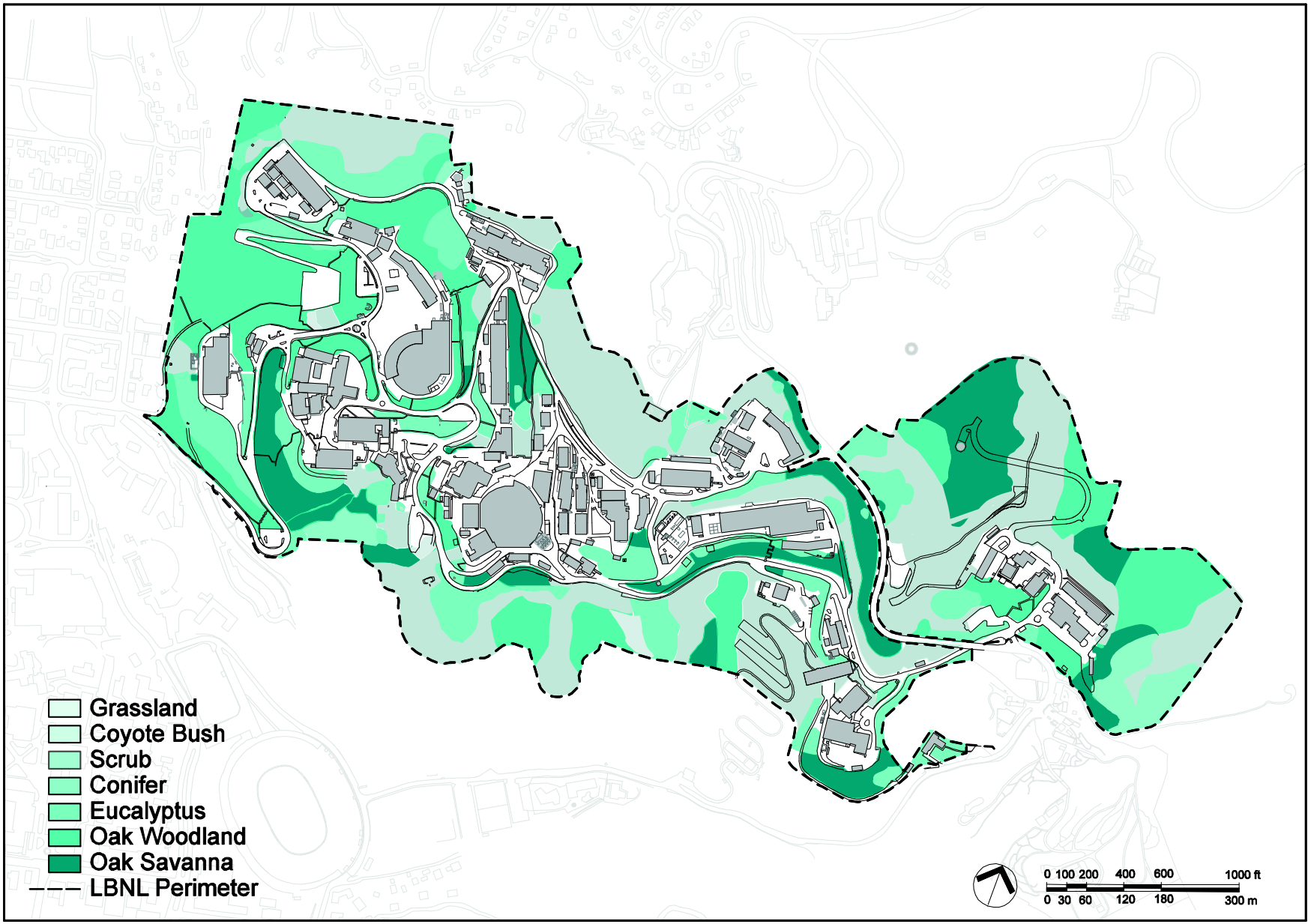


Figure 1-5 Vegetation Types

1.7 WILDLIFE

Wildlife is abundant in the area surrounding Berkeley Lab because the site is adjacent to open spaces managed by the East Bay Regional Park District and UC. Wildlife that frequents the site is typical of wildlife in disturbed (e.g., previously grazed) areas that have a Mediterranean climate and are located in midlatitude California. More than 120 species of birds, mammals, reptiles, and amphibians are thought to exist on the site. The most abundant large mammal is the Columbian black-tailed deer.

1.7.1 Protected Habitats

Specific instances of habitat protected by various environmental laws exist on-site. These are:

- An area of LBNL on the south-facing slope of Blackberry Canyon has been identified as the type of locality where *Microcina Leei* (Lee's Micro-Blind Harvestman) 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 once proposed to be a federal "candidate" species under the Endangered Species Act, but it has not been so designated by the U.S. Fish and Wildlife Service (USFWS) and is no longer proposed for federal listing. This arachnid 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 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.[7] 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.
- 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, such as the North Fork of Strawberry Creek and Chicken Creek, are perennial. All jurisdictional waterways warrant special attention and protection under the CWA. These jurisdictional drainages, along with four freshwater seeps, appear to support riparian habitat.[8]

1.8 SOILS

The Moraga Formation, the Orinda Formation, and the Great Valley Group constitute the principal bedrock units underlying the site. These formations and their properties are 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 the movement of groundwater primarily controlled by flow 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. The Orinda Formation 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 and San Pablo Group underlie the easternmost area of the site. The Claremont Formation consists of marine chert and shale. The San Pablo Group consists of marine sandstones.

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.

1.9 GROUNDWATER

The groundwater elevation map of Berkeley Lab (Figure 1-6) shows that the water table approximately mirrors surface topography, such that groundwater flow in the western portion of Berkeley Lab is generally westwards, whereas 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 the different geologic units, groundwater flow directions vary from the general trends presented on the groundwater elevation map.

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

1.10 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.

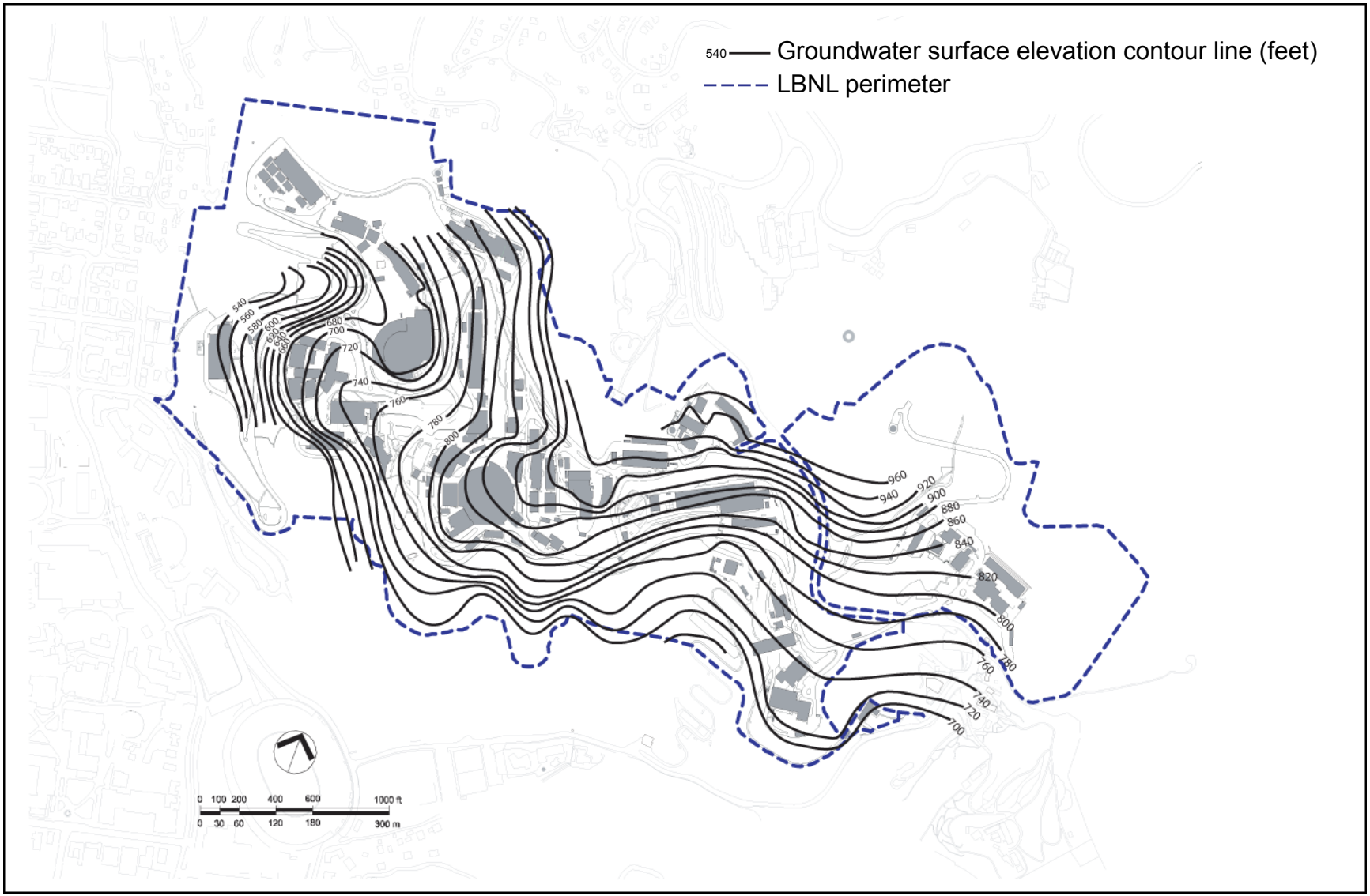


Figure 1-6 Groundwater Elevation Map

2 Environmental Management System

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

2.1 SUMMARY

To continually improve environmental stewardship at Berkeley Lab, an environmental management system 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 the following:

- 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: 2004E *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, since certification under this standard is most beneficial to facilities that provide a product or service intended directly for the global marketplace.

Berkeley Lab has established what it refers to as the EMS Core Team, comprised of representatives from the Environment, Health, and Safety (EH&S), Facilities, and Procurement organizations, whose task is to complete the annual cycle of planning, implementing, evaluating, and improving processes that help LBNL carry out its environmental policy. In 2009, 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 these organizations was conducted to provide feedback needed for continual improvement of the system.

Lastly, an external audit of the EMS was conducted in the spring of 2009. The audit was a necessary step before DOE's Berkeley Site Office could declare that LBNL's EMS conformed to DOE requirements for an EMS, which is further described in the following section.

2.2 BACKGROUND

EO 13423[2] establishes the policy that federal agencies:

- Use EMS as the primary management approach for addressing environmental aspects of internal agency operations and activities, including environmental aspects of energy and transportation functions
- Establish agency objectives and targets to ensure implementation of this order
- Collect, analyze, and report information to measure performance in the implementation of EO 13423

In 2008, DOE approved DOE Order 450.1A, *Environmental Protection Program,*[3] and DOE Order 430.2B*, Departmental Energy, Renewable Energy and*

Transportation Management,[4] as the means of achieving the provisions of EO 13423.

DOE Order 450.1A mandates 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

Berkeley Lab's EMS program is documented in the *Environmental Management System Plan.*[5] This plan was revised in early 2009 to address the new requirements of recently-approved DOE Order 450.1A. The revision preceded an external review of the EMS that was needed before the DOE Berkeley Site Office could declare that the EMS satisfied the requirements of the order. The EMS Plan, as well as other EMS-related documentation, is available at www.lbl.gov/ehs/esg/emsplan/emsplan.htm.

DOE Order 430.2B mandates an energy management program that considers energy use and renewable energy, water, new and renovated buildings, and vehicle fleet activities. The Order incorporates the provisions of the *Energy Policy Act of 2005*[6] and the *Energy Independence and Security Act of 2007*,[7] and includes the DOE's Transformational Energy Action Management initiative, which implements a compliance program by requiring a Sustainability Executable Plan. For LBNL, this plan is approved by the DOE Berkeley Site Office. The current plan is the *FY2010 Sustainability Executable Plan.*[8]

These DOE Orders and associated policies establish goals and sustainable stewardship practices that are protective of environmental, natural, and cultural resources, and take a life cycle approach that considers aspects such as:

- Acquisition and use of environmentally preferable products
- Electronics stewardship
- Energy conservation, energy efficiency, and renewable energy
- Pollution prevention, with emphasis on toxic and hazardous chemical and material reduction
- Procurement of efficient energy- and water-consuming materials and equipment
- Recycling and reuse
- Sustainable and high-performance building design
- Transportation and fleet management
- Water conservation

Changes in requirements for the EMS are expected in the coming year in response to the signing of EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,*[9] in 2009. The present requirements are largely untouched, though the new EO augments this list with the addition of the reporting and reducing of greenhouse gas emissions.

2.3 INTEGRATION OF EMS INTO ISMS

As mandated in DOE Order 450.1A, Berkeley Lab's EMS is integrated into the facility's existing Integrated Safety Management System (ISMS), which is described in the LBNL *Integrated Environment, Health and Safety Management Plan.*[10] 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, and these are integrated with the ISMS. 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.

Both the EMS and ISMS strive for continual improvement through a four-step plan-do-check-act cycle (see Figure 2-1). This 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 the five ISMS core functions.

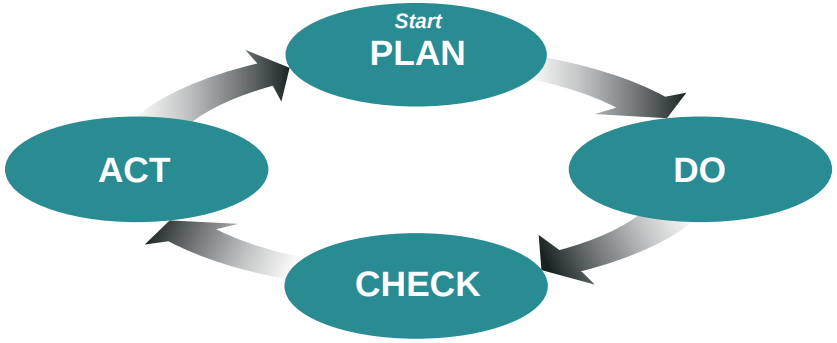


Figure 2-1 Cycle of Activities That Are Performed to Achieve EMS Goals

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

The following six key areas form the fundamental building blocks for the implementation of LBNL's EMS program:

4. EMS Core Team
5. Environmental aspects
6. EMPs
7. Training
8. Appraisals
9. Management review

Activities that occurred during 2009 for each of these key areas are described below.

2.4.1 EMS Core Team

The Core Team is tasked with implementing and maintaining LBNL's EMS, with its primary objectives of managing environmental compliance matters and to 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 the DOE Berkeley Site Office also attended the meetings to maintain an 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 or activities that result in an environmental impact, whether adverse or beneficial. This review included a significance determination of each aspect's potential impact, using the following factors to shape its decisions:

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

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. No new activities were determined to be significant in 2009, keeping the number of EMPs at seven. Objectives and targets for reducing environmental impacts were reevaluated for each of the following activities:

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

The objectives and targets were formally documented in an EMP for each significant impact. Each EMP also established strategies and actions needed to achieve the objectives and targets; developed procedures, metrics, or techniques; and set up schedules. A member of the Core Team was selected as the leader to coordinate actions and monitor the performance of each EMP.

2.4.4 Training

In Berkeley Lab's EMS approach, 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, such as senior management or staff involved in implementing the EMS. 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 newcomers 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.

2.4.5 Appraisals

When DOE Order 450.1A[11] was approved in June 2008, it required that a site's environmental management system be "fully implemented" by June 30, 2009. This included having the management system subjected to a formal audit by a qualified external party, addressing any findings, and having DOE then recognize that the system conformed to requirements.

Berkeley Lab's EMS underwent a two-stage EMS implementation audit in the spring of 2009 by an assessor who also performs audits for the ISO 14001 standard. For the first stage in March, documents related to the EMS were reviewed by the auditor. No major non-conformances were found, so the auditor's recommendation was to proceed with the on-site review, which took place over a three-day period in late April. During this onsite visit, the auditor interviewed both management and staff to determine the range and depth of implementation of Berkeley Lab's EMS relative to the eighteen elements that comprise the ISO 14001 standard.

The second stage of the audit resulted in zero non-conformances and eight opportunities for improvement. Opportunities for improvement do not require corrective action. The successful completion of the external audit allowed the site manager for the DOE Berkeley Site Office to declare to DOE Headquarters on June 10th that Berkeley Lab's EMS was fully implemented. To retain this status, Berkeley Lab must repeat this process at least every three years.

Details on the audit and DOE's declaration can be found on LBNL's EMS website at http://www.lbl.gov/ehs/esg/EMS%20Plan/emsplan.shtml.

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 changes that 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 review in 2009 included senior management representatives from EH&S, Facilities, and the Office of Chief Financial Officer divisions, including the division directors for the EH&S and Facilities divisions. Topics of discussion included a review of the environmental policy, performance of the various EMP activities and accomplishments, UC contract and DOE annual EMS scorecard performance metrics, and the result of the external assessment of the program. Recommendations from senior management included:

- Coordinate EMS-related funding activities across divisions in future years
- Continue to replace petroleum-based vehicles with alternatively-fueled vehicles
- Continue implementing sustainable practices into design requirements
- Expand the 3R recycling program to other buildings on site
- Capture EMS training requirements within the Job Hazards Analysis system

- Invite a representative from Berkeley Lab's Public Affairs to Core Team meetings to improve awareness of various environmental activities
- Consider hosting several management review sessions each year

2.4.7 2009 Environmental Management Programs

As part of its annual rating of the effectiveness of LBNL's performance, DOE evaluates Berkeley Lab's progress in completing projects designed to minimize waste, reduce emissions, and/or conserve resources.

In FY09, Berkeley Lab was given an A- rating for its performance of environmental measures. This included achieving the highest or "green" rating within DOE's seven EMS scorecard metrics for:

1. Identification and evaluation of environmental aspects
2. Identification, review, and update of goals, objectives, and targets
3. Establishment of effective operational controls
4. Establishment of environmental training requirements and implementation of training
5. Inclusion of EMS requirements in appropriate contracts
6. Establishment of a formal audit process and conduct of an audit
7. Performance of a senior management review of the EMS program

In addition, LBNL completed eighteen environmental improvement projects. Most notable was a petroleum fuel reduction project which continued to reduce fuel use by Berkeley Lab fleet vehicles. Since this program began, petroleum fuel use has dropped nearly 30% since FY99, with 7% of the reduction coming since FY05. Core to this effort has been the ongoing addition of alternatively fueled (i.e., E85) and electric cart vehicles to the fleet. The slowing in the pace of the reduction is attributable to a significant increase in LBNL's shuttle bus route in FY08. Other environmental projects include updating subcontract terms to specify sustainable acquisition measures in applicable subcontracts, installing diesel particulate filters on two emergency generators, performing a detailed energy use study on the site, and having 95% of all new computers and monitors achieve a minimum rating of EPEAT (Electronic Product Environmental Assessment Tool) Bronze. In fact, almost 85% of the acquisitions met the EPEAT Gold standard. The EPEAT rating system is used worldwide and is based on 51 criteria found in the Institute of Electrical and Electronic Engineers 1680 family of standards. For more information on environmental performance measures, go to Berkeley Lab's Office of Institutional Assurance home page at www.lbl.gov/DIR/OIA/OCA/contract-performance/index.html.

Table 2-2 summarizes the EMPs for 2009. For further information on performance measures and LBNL's ratings for this year, please see Section 3.5, Performance Measures.

Table 2-2 Environmental Management Programs for 2009

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 for energy efficiency	Reduce energy use intensity 30% by the end of FY15, including a minimum cumulative reduction of 6.6% by the end of FY09 relative to the FY03 baseline year.
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 (ESP) and Recycled Content Products (RCP)	Increase RCP procurements 5% each year using FY05 as the baseline year; ESP procurements will be tracked starting with FY07 procurements.
Solid Waste Generation (Diversion)	Increase diversion of solid waste	Increase solid waste diversion by 5% by the end of FY09 relative to the FY06 baseline year.
Traffic Congestion	Reduce LBNL commute traffic through Transportation Demand Management	Optimize parking; facilitate/promote non-single-occupant vehicle commuting; 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 for water consumption intensity	Reduce water consumption intensity 16% by the end of FY15, including a minimum cumulative reduction of 1% by the end of FY09, relative to the FY07 baseline year.

3 Environmental Program Summary

Lawn area between Building 25 and Building 4

3.1 INTRODUCTION

This chapter provides an overview of Berkeley Lab's environmental protection program, reviews the status of various compliance programs and activities, and presents environmental performance measures in key areas for 2009.

To continually improve environmental performance, LBNL implements a systematic approach to achieving environmental performance goals at the site via an EMS, as required by EO 13423[1] and EO 13514.[2] The EMS is integrated with Berkeley Lab's existing ISMS per DOE Order 450.1A.[3] For details on the EMS, see Chapter 2.

3.2 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.[4]

- **Work Planning.** Clear definition of the tasks that are to be accomplished as part of any given activity.
- **Hazard and Risk Analysis.** Analysis and determination of the hazards and risks associated with any activity; in particular, risks to employees, the public, and the environment.
- **Establishment of Controls.** Controls that are sufficient to reduce the risks associated with any activity to acceptable levels. Acceptable levels are determined by responsible line management, but are always in conformance with all applicable laws and the set of ES&H Standards (formerly Work Smart Standards).
- **Work Performance.** Conduct of the tasks to accomplish the activity in accordance with the established controls.
- **Feedback and Improvement.** Implementation of 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 as of the end of 2009 is shown in Figure 3-1.

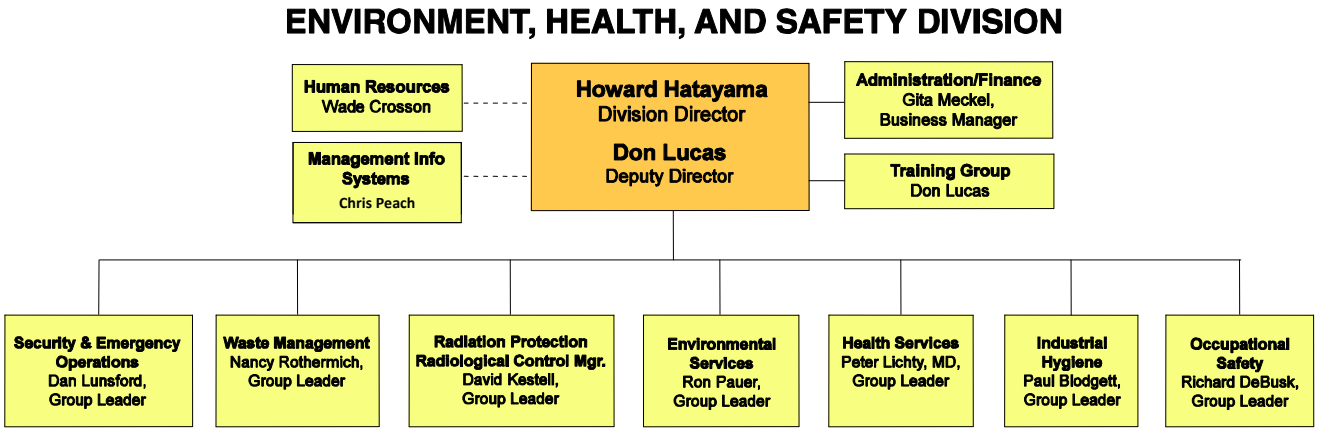


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization in 2009

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 characterization and cleanup. 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 manages hazardous, medical, radioactive, mixed (hazardous and radioactive), and universal waste generated at Berkeley Lab.

3.3 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, inspections, and DOE-reportable environmental incidents at Berkeley Lab for 2009.

3.3.1 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 44 active permits held by LBNL at the end of the year.

3.3.2 Summary of Audits and Inspections

The agencies that regulate the environmental programs at Berkeley Lab periodically conduct inspections. Table 3-2 lists the inspections by these agencies that occurred at Berkeley Lab during 2009. 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.

Table 3-1 Environmental Permits Held by Berkeley Lab at the End of 2009

Type of Permit	Issuing Agency	Description	Number of Permits	Section for More Information
Air quality	BAAQMD[a]	Various activities with emissions to air	31	3.4.1.2
Hazardous waste	DTSC[b]	Hazardous Waste Handling Facility operations	1	3.4.6.1
	COB[c]	Fixed treatment units (6)	1	3.4.6.1
Stormwater	SWRCB[d]	Sitewide stormwater discharges	1	3.4.10.2
Underground storage tanks	COB[c]	Underground storage tanks containing petroleum products	6	3.4.6.4
Wastewater	EBMUD[e]	Sitewide and operation-specific wastewater discharges to sanitary sewer	3	3.4.10.1
	CCCSD[f]	Wastewater discharges to sanitary sewer at Joint Genome Institute in Walnut Creek	1	3.4.10.1

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

Table 3-2 Environmental Audits, Inspections, and Appraisals in 2009

Organization	Inspection Title	Start Date	Violations
BAAQMD	Vehicle Fueling	April 21	1
COB	Underground storage tanks	November 6	0
[with U.S. EPA]	Hazardous materials/hazardous waste	May 26	2
CCCSD	Sanitary District inspection at JGI	May 21	0
CDPH[a]	Medical Waste Management Program	November 10	0
EBMUD	Wastewater monitoring inspection at Hearst and Strawberry outfalls	May 1 August 19	0 0
	Wastewater monitoring inspection at B77 Fixed Treatment Unit	April 22	0
	Wastewater monitoring inspection at B25 Fixed Treatment Unit	December 14	0
	Wastewater monitoring inspection at groundwater treatment units	January 22	0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	March 24 September 22	0 0
	EBMUD self-monitoring inspections at B77 Fixed Treatment Unit	March 19 June 16 November 30	0 0 0
	EBMUD self-monitoring inspections at B25 Fixed Treatment Unit	November 16	0
	EBMUD self-monitoring inspections at groundwater treatment units	January 13 April 14 July 15 October 13	0 0 0 0

[a] California Department of Public Health

In 2009, agency inspections resulted in only two violations, both of which were corrected on the spot. Additionally, one violation for non-compliance with a regulation was self-reported.

On May 26th, the EPA and the City of Berkeley (COB) completed a joint one-day inspection of various hazardous materials/hazardous waste activities. This inspection resulted in two violations noted by the COB, and generated a DOE Occurrence Report. Additionally, LBNL self-reported a failure to modify vehicle fueling vapor recovery equipment by the BAAQMD-imposed deadline, which resulted in a violation and an Occurrence Report.

See Section 3.3.3 below for further details of these violations.

3.3.3 Summary of DOE-Reportable Environmental Incidents

In 2009, two environmental incidents were reportable under the DOE occurrence-reporting program[5] used to track incidents across the DOE complex. In June, LBNL received written notification from the COB on the results of the on-site inspection conducted on May 26. The notification cited two violations: (1) the phone number of the secondary emergency contact was not listed in the Hazardous Materials Business Plan; and (2) two fluorescent light bulb storage containers were not closed. Both conditions were corrected immediately. No injuries or fines from an outside agency resulted from the incident. A written report of the inspection was received from EPA in April of 2010. Further details can be found at https://ehswprod.lbl.gov/orps/reports/2010/EHS-10-3.asp.

In April, LBNL received a notice from the BAAQMD for violating their regulations by failing to modify vehicle fueling vapor recovery equipment by the April 1, 2009 deadline. The notice included a $300 monetary civil penalty. As required by the District, LBNL entered into a Compliance and Settlement Agreement and installed the appropriate vapor recovery equipment by

September 1, 2009. Further details can be found at https://ehswprod.lbl.gov/orps/reports/2009/OPER-09-5.asp.

3.4 COMPLIANCE PROGRAMS

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

3.4.1 Clean Air Act

The Clean Air Act[6] 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[7] 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 3.4.1.1) and nonradiological (see Section 3.4.1.2).

3.4.1.1 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,[8] as well as sections of DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*[9] U.S. EPA administers the NESHAP regulations (National Emission Standards for Hazardous Air Pollutants, the title for all of 40 Code of Federal Regulations [CFR] Part 61), which limit the dose to the public from LBNL's airborne radionuclide emissions to 0.10 millisieverts (mSv)/year (yr) (10 millirems [mrem]/yr). Berkeley Lab documents its NESHAP review and compliance in its annual *Radionuclide Air Emission Report.*[10]

3.4.1.2 Nonradiological

The Bay Area Air Quality Management District (BAAQMD) implements federal and state air quality requirements for most air emission activities that are not addressed by NESHAP regulations.

At the end of 2009, Berkeley Lab held operating permits issued by BAAQMD for 31 emission sources.[11] Two of these operating permits cover activities located 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 new activities were permitted during the year at either the main or Walnut Creek sites; however, permit modifications were approved by BAAQMD and diesel particulate filters were added to two existing emergency generators. Also, a BAAQMD permit modification was made to the Gasoline Dispensing Facility providing exemption to the new Enhanced Vapor Recovery regulation. Berkeley Lab qualified for this exemption because over 92% of its fleet vehicles are equipped with on-board refueling vapor recovery.

Efforts to install a new emergency generator, replace an existing emergency generator with a modern, California Air Resources Board (CARB)-certified type, and to install another diesel particulate filter are expected to begin in 2010.

For a list of active operating permits, see Table 3-3. Operating permits are renewed annually, at which time BAAQMD also requests information required by the state's *Air Toxics "Hot Spots" Information and Assessment Act of 1987.*[12] Activities covered by permits are subject to periodic inspection.

Table 3-3 Air Emission Sources Permitted by BAAQMD at the End of 2009

BAAQMD Category	Description	Building	Abatement Type
Combustion equipment	Standby emergency generators	64, 70	Catalytic converter
	Standby emergency generators	48, 50A, 67	Diesel particulate filter
	Standby emergency generators	Various[a]	None
	Standby emergency generators	JGI[b]	None
Gasoline dispensing	Unleaded and E85 fueling stations	76	Vapor recovery
Surface coating and painting	Paint spray booth	76, 77	Dry filter
Surface preparation and cleaning	Sandblast booth	77	Baghouse
	Wipe-cleaning	Sitewide	None
Miscellaneous	Soil-vapor extraction systems	7E, 58	Activated carbon

[a] Individual generators located at Buildings 2, 37, 50B, 55, 62, 64, 66, 67, 70A, 72, 74, 75, 77, 84B, and 85, plus four mobile locations

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

BAAQMD did not conduct any inspections of permitted activities during the reporting year.

Berkeley Lab requested and obtained another 2-year extension under a research-and-development test-site authorization and permit from CARB and BAAQMD, respectively, to continue operating 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 both increase the percentage of vehicles using alternative fuels and decrease the amount of petroleum used according to a given time schedule. Originally both BAAQMD and CARB placed an operating condition upon this fueling station that LBNL conduct quarterly testing of the system's vapor recovery components. In 2009, both agencies approved reduction of this testing frequency from quarterly to annual. Berkeley Lab remains one of a limited number of sites in all of California authorized to dispense this alternative fuel.

Regarding greenhouse gas emissions, Berkeley Lab facilities do not emit quantities in excess of either U.S. EPA or California reporting levels. However, the signing of EO 13514 by the President in October of 2009 will require Berkeley Lab to report its greenhouse gas emissions through DOE beginning in FY10.

3.4.2 Comprehensive Environmental Response, Compensation, and Liability Act

The *Comprehensive Environmental Response, Compensation, and Liability Act* of 1980 (CERCLA),[13] 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 2009 no releases occurred that were reportable under CERCLA, and Berkeley Lab conducted no remedial activities covered by CERCLA.

3.4.3 Emergency Planning and Community Right-to-Know Act

The *Emergency Planning and Community Right-to-Know Act* (EPCRA)[14] 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*.[15] Berkeley Lab activities addressing these requirements are summarized in Sections 3.4.3.1 through 3.4.3.3.

3.4.3.1 Toxic Release Inventory

Under EO 13148,[16] DOE is required to evaluate its facilities against the Toxic Release Inventory (TRI) reporting requirements of EPCRA without regard to Standard Industrial Classification (SIC) code. TRI reporting consists of two steps: Berkeley Lab determines chemical usage, and if threshold quantities are exceeded, DOE submits U.S. EPA Form R.

Berkeley Lab determined that no chemical usage in 2009 exceeded the TRI criterion of 4,536 kilograms (kg) (10,000 pounds [lb]) for a listed substance and that DOE was not required to submit a Form R on behalf of LBNL. Table 3-4 shows the highest usage levels 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])					
	2004	2005	2006	2007	2008	2009
Chlorofluorocarbons	72	126	123	518	95	78
Methanol	206	129	165	63	69	82
Nitric acid	511	466	403	90	303	279
1,1,1-trichloroethane	<1	0	<1	<1	<1	<1

[a] 1 kg = 2.2 lb

3.4.3.2 Hazardous Materials Business Plan

The City of Berkeley is the local administering agency for certain hazardous materials regulations that fall under state law. Berkeley Lab voluntarily submits an annual *Hazardous Materials Business Plan* (HMBP)[17] to the City of Berkeley, although as a federal facility it is exempt from such regulations.

The 2009 HMBP included a list of all hazardous materials present in amounts exceeding the state's aggregate threshold quantities (i.e., 208 liters [L] [55 gallons (gal)] for liquids, 227 kg [500 lb] for solids, and 5.7 cubic meters [m^3] [200 cubic feet] for compressed gases) per building. The plan included a site map as well as summaries of emergency plans, procedures, and training. In addition, the HMBP included permit renewals for fixed treatment units (FTUs). For 2009, an HMBP was also filed with Alameda County pertaining to the research activities associated with the Joint BioEnergy Institute located in Emeryville. The level of information submitted for this HMBP was consistent with that provided in the HMBP for the main site.

3.4.3.3 Risk Management and Prevention Plan

The City of Berkeley requires a Risk Management and Prevention Plan for operations using acutely hazardous materials above certain thresholds established in 40 CFR Part 355. Berkeley Lab does not have any operations that contain acutely hazardous materials above the threshold quantities, and therefore no such plan is required for the site.

3.4.4 Federal Insecticide, Fungicide, and Rodenticide Act

Passed by Congress in 1972, the *Federal Insecticide, Fungicide, and Rodenticide Act* [18] restricts the registration, sale, use, and disposal of pesticides. Pesticides, including insecticides and herbicides, are applied at the site by licensed contractors only. 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 Grounds

Keepers occasionally apply very small amounts of herbicides (for example, Roundup) to weeds, such as poison oak, that are otherwise difficult to control.

3.4.5 Toxic Substances Control Act

The objective of the *Toxic Substances Control Act* (TSCA)[19] 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.

3.4.6 Resource Conservation and Recovery Act

The *Resource Conservation and Recovery Act* (RCRA)[20] 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 creation and disposal of hazardous wastes, and between 1984 and 1988, RCRA was expanded further to regulate 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.

3.4.6.1 Hazardous Waste

In California, DTSC administers the RCRA hazardous waste program. The California program incorporates the provisions of both the federal and state hazardous waste laws.[21] 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:

- Full permit
- Standardized permit
- Permit-by-rule
- Conditional authorization
- 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 City of Berkeley for oversight under California's Certified Unified Program Agency program.

Berkeley Lab's 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[22] 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. Of these, only neutralization of mixed waste was performed in 2009.

Berkeley Lab has an additional hazardous waste permit to operate six FTUs.[23] The type and location of each unit are listed in Table 3-5. These treatment units operate independently of the HWHF. Three of these FTUs are authorized to operate under the "conditional authorization" tier, while the remaining three are authorized to operate under the "permit-by-rule" tier. The type of treatment determines which tier applies. The City of Berkeley requests renewal of this permit each year. The FTU permit was renewed in April 2009.

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*[24] (see Section 3.4.6.2). Low-level radioactive waste is managed in accordance with DOE Orders. Mixed waste is managed in accordance with the *Mixed Waste Site Treatment Plan*[25] and is subject to both California EPA regulations and DOE Orders.

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

- *The Annual Hazardous Waste Report*,[26] prepared for 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*,[27] prepared for DOE, contains information on waste generated during the reporting year.

In October 1995, DTSC approved LBNL's *Mixed Waste Site Treatment Plan,*[28] 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.

Table 3-5 Fixed Treatment Units Subject to the State's Tiered Permitting Program

FTU	Building	Treatment Description	Permit Tier	Wastewater Volume Treated (Gallons/Year)
002	25	Metals precipitation and acid neutralization	Permit-by-rule	3,284
003	76	Oil/water separation	Conditional authorization	12,106
004	70A/70F	Acid neutralization	Conditional authorization	1,711,810
005	2	Acid neutralization	Conditional authorization	101,430
006	77	Metals precipitation and acid neutralization	Permit-by-rule	21,461
007	67	Acid and alkaline neutralization	Permit-by-rule	4,364

3.4.6.2 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* [29] 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 19,025 kg (41,853 lb) of solid medical and biohazardous waste in 2009. 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 inspected the Berkeley Lab in 2009 and found no violations.

3.4.6.3 Corrective Action Program

Berkeley Lab is currently in the final phase of the RCRA Corrective Action Program (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*. [30] These measures were approved by the DTSC,[31] 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 nine areas of groundwater contamination have been constructed and are operational. These consist of in situ soil flushing, groundwater capture, subsurface injection of Hydrogen Release Compound® (HRC), and monitored natural attenuation (MNA).

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 cleaned 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* [32] and a *Groundwater Monitoring and Management Plan*.[33] 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 the City of Berkeley Main Public Library and at www.lbl.gov/ehs/erp/html/documents.shtml.

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

3.4.6.4 Underground Storage Tanks

In the early 1980s, California addressed the problem of groundwater contamination from leaking USTs through a rigorous regulatory and remediation program.[34] 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.[35] The City of Berkeley 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 employees are responsible for conducting monthly inspections of the UST systems; these inspections supplement the daily inspections conducted by other facility employees. The UST Designated Operators also provide annual training to the employees that conduct the daily UST inspections.

At the end of 2009, six permitted USTs were in operation at Berkeley Lab (see Table 3-6 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.

Table 3-6 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

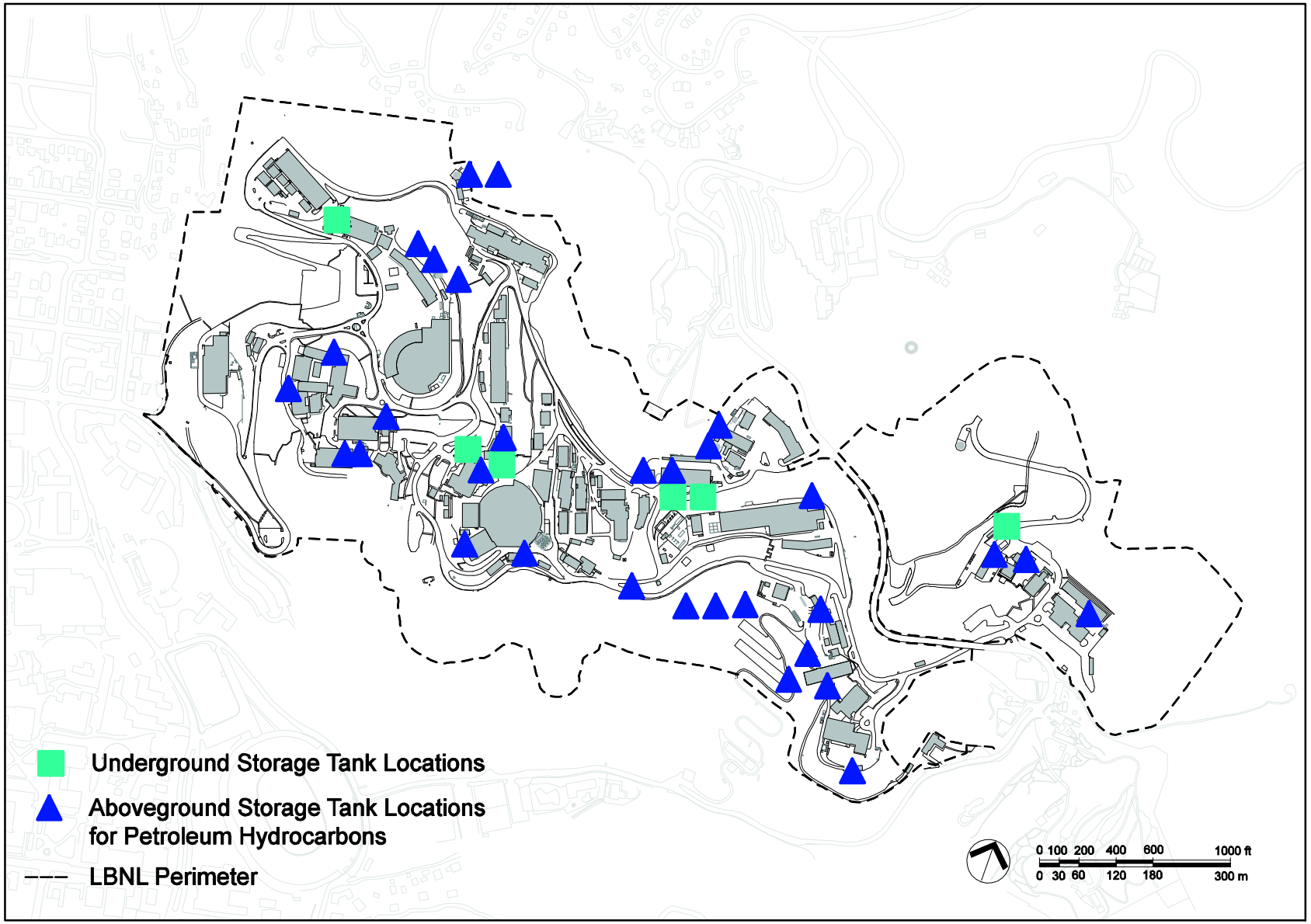


Figure 3-2 Aboveground and Underground Storage Tank Locations at the End of Calendar Year 2009

On November 6, 2009, leak-detection monitors were tested and recertified for all UST systems. On the same date, all product piping (pressure and suction) was pressure-tested for the UST systems. All piping passed the pressure tests. In addition, every spill bucket at the fill port of each UST was tested for leaks. All spill buckets were found free of leaks. During the November 6th testing, the City of Berkeley conducted its annual inspection of Berkeley Lab's USTs. No violations resulted from this inspection.

3.4.7 Executive Order 13423 (Strengthening Federal Environmental, Energy, and Transportation Management)

In January 2007, EO 13423[36] replaced EO 13101 (*Greening the Government through Waste Prevention, Recycling, and Federal Acquisition*). Like its predecessor, EO 13423 seeks to integrate recycled materials into the procurement and acquisition process. Identified categories of products include the following:

- Electronic equipment
- Construction materials
- Landscape products
- Non-paper office products
- Paper products
- Park and recreation products
- Transportation products
- Vehicular products
- Miscellaneous products
- Bio-based content

All federal agencies must procure only U.S. EPA-listed items with specified contents of recycled materials, unless a product is not available competitively within a reasonable time frame, does not meet appropriate performance standards, or is only available at an unreasonable price.

EO 13423 established environmental, energy, and transportation requirements for federal agencies. DOE passed on these requirements to its contractors by adopting its DOE Order 450.1A, *Environmental Protection Program.*[37] As a DOE contractor, Berkeley Lab has had an ongoing affirmative procurement program since 1992. LBNL's Procurement staff searches for products made from recycled materials and works with other federal facilities to purchase environmentally preferable products. LBNL has implemented a "stepped" program to ensure that only U.S. EPA-listed products manufactured from recycled materials will be purchased, as long as these materials are available at a reasonable cost and are compatible with Berkeley Lab's operating needs.

3.4.8 Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the *Hazardous Waste Source Reduction and Management Review Act*[38] 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*[39] and the *Hazardous Waste Management Report Summary*.[40] The last report was compiled in 2007 and submitted to the DOE Livermore Site Office as part of the DOE-wide report.

3.4.9 Pollution Prevention Act of 1990

The *Pollution Prevention Act of 1990*[41] declares that source reduction is a national policy and directs U.S. EPA to study and encourage source reduction policies. Berkeley Lab's levels of pollution are below the de minimis thresholds identified in the Act, and therefore it is not subject to the Act's reporting requirements.

3.4.10 Clean Water Act

The CWA[42] 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.

Additionally, the *California Porter-Cologne Water Quality Control Act*[43] established a comprehensive statewide system for regulating water use. This 1969 act provides for a three-tiered system of regulatory oversight and enforcement: the State Water Resources Control Board (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. 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.

3.4.10.1 Wastewater

Berkeley Lab has three wastewater discharge permits[44] issued by EBMUD for the following activities:

- General sitewide wastewater discharge
- Treatment unit discharge of rinse water from the metal finishing operations in Buildings 25 and 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 2009. (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 five separate occasions throughout the year. Table 3-2 lists these inspections, which were routine sample collections. No violations resulted from these inspections.

The EBMUD wastewater discharge permit for Buildings 25 and 77 requires that each facility maintain a *Toxic Organics Management Plan* and a *Slug Discharge Plan*. In 2007, the requirements of these two EBMUD plans were incorporated into each facility's *Activity Hazard Document* (AHD) for

operations. Each 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 AHDs for metal finishing areas at Buildings 25 and 77 also include 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: Buildings 25 and 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* [45] 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.

3.4.10.2 Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide *General Permit for Storm Water Associated with Industrial Activity* (or General Permit).[46] The General Permit is issued by the SWRCB, but administered and enforced by the RWQCB and the City of Berkeley. Under this permit, Berkeley Lab has implemented a *Storm Water Pollution Prevention Plan* (SWPPP)[47] and an *Alternative Storm Water Monitoring Program* (ASWMP).[48] 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 and COB, as well as to the California Sportfishing Protection Alliance and Strawberry Canyon Stewardship Group, in late June.[49] No regulatory concerns were raised by either agency regarding the annual report. The latter two entities received the report under the terms of a settlement agreement following a lawsuit in April of 2008 regarding previous annual report monitoring data, which showed that certain pollutants during certain sampling events were above established water quality benchmarks, and the timely implementation of effective best management practices after validation of that data. According to the General Permit, the water quality benchmarks in question are guideline values, not effluent permit limits. LBNL started monitoring at the agreed-upon specific industrial locations in early 2009. (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.*[50] During 2009, Berkeley Lab did not undertake any construction projects which disturbed more than one acre of soil, and thus held no stormwater construction permits.

During the summer of 2009, an external audit of this program was conducted by CE^2 Corporation, in cooperation with Wreco. The audit found that the stormwater program met or exceeded the compliance requirements. The audit noted the importance of LBNL's continued implementation of best available technology economically achievable and best conventional pollutant control technology to help prevent and reduce pollutants, as well as the continued

liaison with the Facilities Division, which is tasked with implementing best management practices.

3.4.10.3 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the CWA.[51] The CWA and the state's *Aboveground Petroleum Storage Act* [52] outline the regulatory requirements for ASTs. Under the authority of the CWA, a *Spill Prevention, Control, and Countermeasure* (SPCC) *Plan* [53] 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 31 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 an SPCC Plan [54] 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.

3.4.11 Safe Drinking Water Act

The *Safe Drinking Water Act* [55] and amendments established requirements to protect underground sources of drinking water and set primary drinking-water standards for public water systems. Berkeley Lab has no drinking-water wells on-site. The drinking water provided to the site comes from the EBMUD supply and distribution system. EBMUD water is tested for compliance with state and federal drinking-water standards. Berkeley Lab has taken measures to protect its distribution system for its drinking-water supply by installing backflow-prevention devices on main supply lines throughout the site.

EBMUD currently uses chloramine for disinfection of the drinking-water supply. Although chloramine improves the water supply for human consumption, it is toxic to fish and other aquatic organisms. To prevent toxic effects to organisms involved in laboratory research, researchers have instituted measures to neutralize the chloramine to provide water in which these organisms can safely exist.

Additionally, to prevent toxic effects to organisms living in neighboring creeks, Berkeley Lab has programs to prevent drinking water from being discharged to its storm drains. When responding to waterline breaks and when testing and flushing fire hydrants, the Facilities Division and Fire Department neutralize the chloramine before the water reaches a storm drain to the extent possible.

3.4.12 National Environmental Policy Act and California Environmental Quality Act

LBNL staff provides information and technical support to enable DOE and UC to determine, as required by the *National Environmental Policy Act of 1969* (NEPA)[56] and the *California Environmental Quality Act of 1970* (CEQA),[57] whether proposed actions at Berkeley Lab will have a significant effect on the environment.

In 2009, DOE conducted the following NEPA review of a proposed major Federal Action at Berkeley Lab:

- Environmental Assessment and FONSI for Berkeley Laboratory Laser Accelerator (BELLA) Project.

In 2009, several projects were categorically excluded from further NEPA review, and approximately 1,000 projects -- mostly research activities and proposals -- were found to be covered under existing categorical exclusions.

3.4.13 Federal Endangered Species Act

The *Federal Endangered Species Act* [58] 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 2009. However, in accordance with 2006 Long Range Development Plan EIR mitigation measures, several project-specific bat and raptor surveys were carried out prior to tree removals or disturbance in 2009, and Alameda whipsnake (identification and avoidance) training was carried out for numerous project construction teams.

3.4.14 California Endangered Species Act

The *California Endangered Species Act* [59] 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 2009. (See Section 3.4.13 above regarding bird, raptor, and Alameda whipsnake mitigation activities carried out in 2009).

3.4.15 National Historic Preservation Act

The *National Historic Preservation Act* [60] 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 by 2010.

3.4.16 Migratory Bird Treaty Act

The *Migratory Bird Treaty Act* [61] 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 2009.

3.5 PERFORMANCE MEASURES

Since 1994, Berkeley Lab, DOE, and the University of California Office of the President (UCOP) have annually used a rating system to measure the effectiveness of LBNL's performance, including the performance of its environmental programs. These performance measures have been integrated directly into the operating contract for Berkeley Lab. Possible ratings include letter grades ranging from A+ to F. Berkeley Lab has consistently received high marks from both DOE and UCOP since the inception of environmental performance measures 16 years ago. For FY09 there were two environmental measures. Berkeley Lab achieved a combined rating of A- for these two measures (the measures are not scored individually).

For the measure of Environmental Management System implementation, Berkeley Lab achieved the highest or "green" rating within DOE's seven EMS scorecard metrics for:

10. Identification and evaluation of environmental aspects
11. Identification, review, and update of goals, objectives, and targets
12. Establishment of effective operational controls
13. Establishment of environmental training requirements and implementation of training

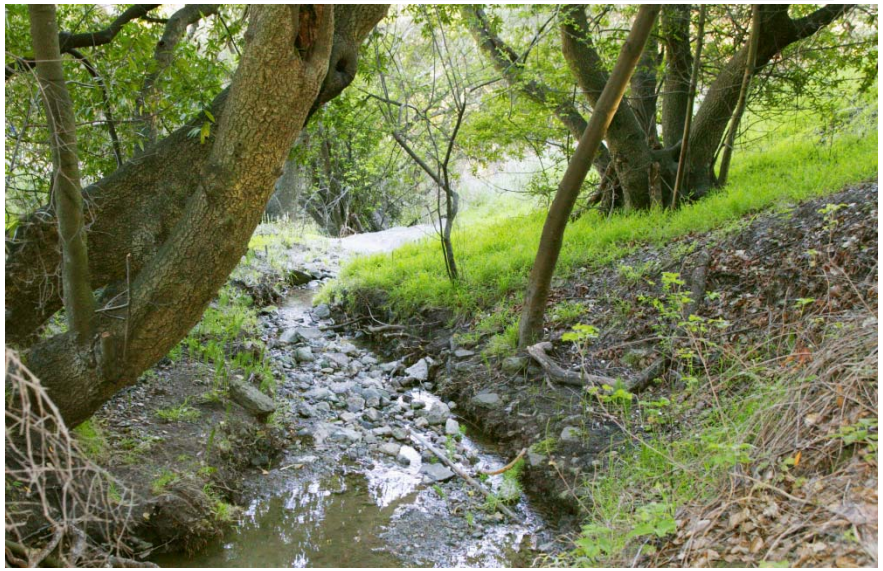
14. Inclusion of EMS requirements in appropriate contracts
15. Establishment of a formal audit process and conduct of an audit
16. Performance of a senior management review of the EMS program

The second performance measure evaluates Berkeley Lab's progress in completing projects designed to minimize waste, reduce emissions, and/or conserve resources. During FY10, Berkeley Lab completed 18 such projects. The most noteworthy of these included:

- Reducing petroleum fuel use by nearly 30% since FY99, with 7% of the reduction coming since FY05
- Installing diesel particulate filters on two emergency generators, reducing diesel particulate in emissions by 90%
- Meeting the Electronic Product Environmental Assessment Tool—a worldwide environmental performance rating system—Bronze standard in 95% of all new computers and monitors purchased

For further details on environmental improvement projects, see Section 2.4.7. For more information on environmental performance measures, go to Berkeley Lab's Office of Institutional Assurance home page at www.lbl.gov/DIR/OIA/OCA/contract-performance/index.html.

4 Environmental Monitoring



Chicken Creek below the Berkeley Lab site

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 2009 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. This plan is updated periodically; the most recent revision was completed in September 2009.

All of the individual sample results, except for groundwater, 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 City of Berkeley 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. The number and placement of monitoring stations, as well as the substances collected and their collection frequencies, are routinely reviewed to address changes in LBNL operations or external requirements.

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.

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 five stacks and performed real-time monitoring at four stacks (one of which was also sampled monthly) in addition to collecting samples quarterly from four 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 2009, the positron emitter fluorine-18 (half-life of 1.8 hrs) was the predominant radionuclide emitted and accounted for more than 99% of the emitted activity. The Building 56 accelerator was the main source of fluorine-18 emissions (1.01×10^{11} becquerels [Bq] [2.74 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[a] (mSv/yr)[b]	Requirements
Noncompliant	AEDE ≥ 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] AEDE – annual effective dose equivalent
[b] 1 mSv = 100 mrem

4.2.2 Ambient-Air Monitoring Results

The objective of the ambient-air monitoring program is to determine the environmental levels of two general classes of radionuclides, alpha and beta emitters.

The network consists 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 includes a second sampler for quality control (QC) purposes. Figure 4-2 shows the sampling locations.

Table 4-2 summarizes gross alpha and beta sample results from the sampling network. While DOE Order 5400.5[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.

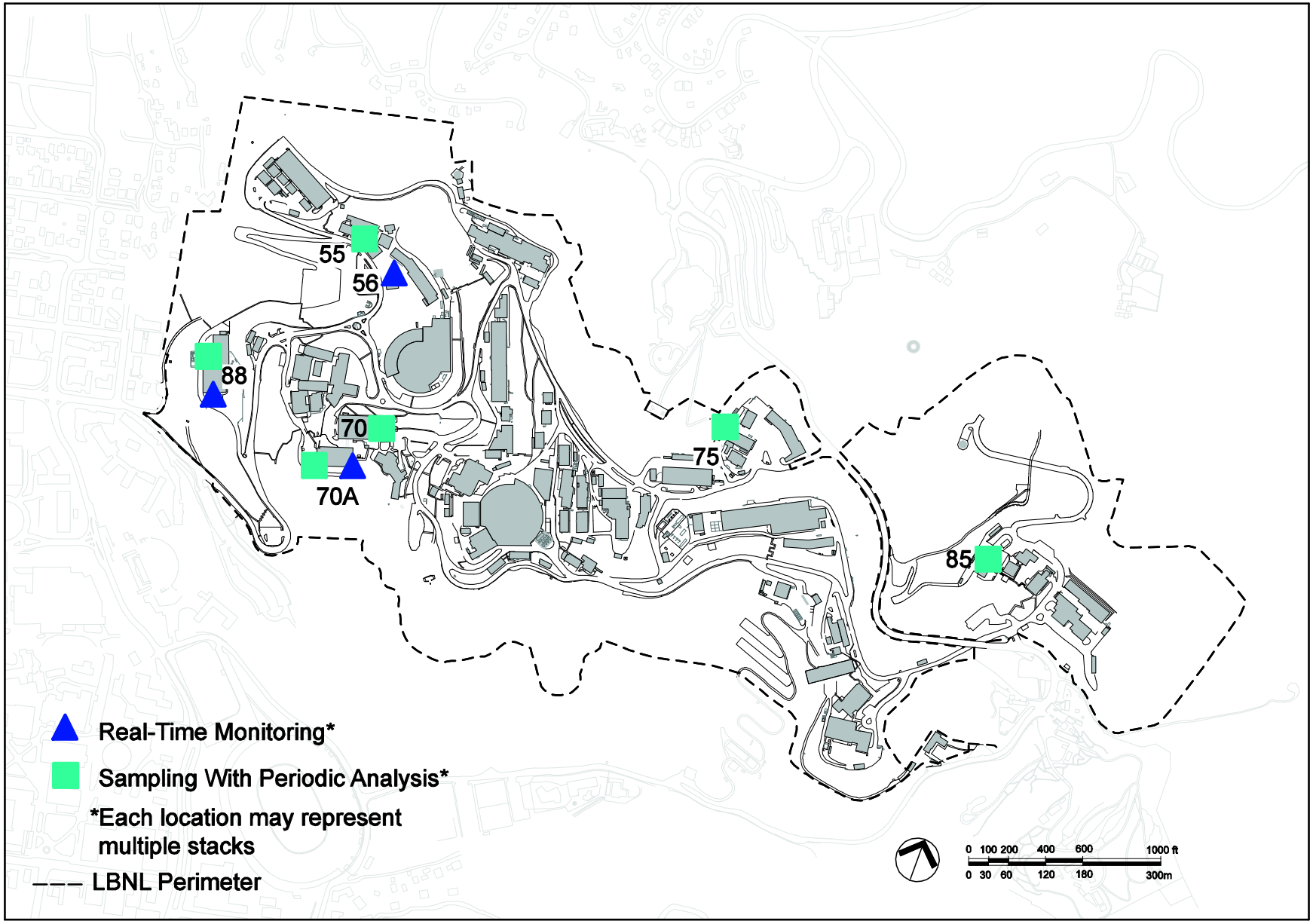


Figure 4-1 Locations of Building Exhaust Sampling and Monitoring

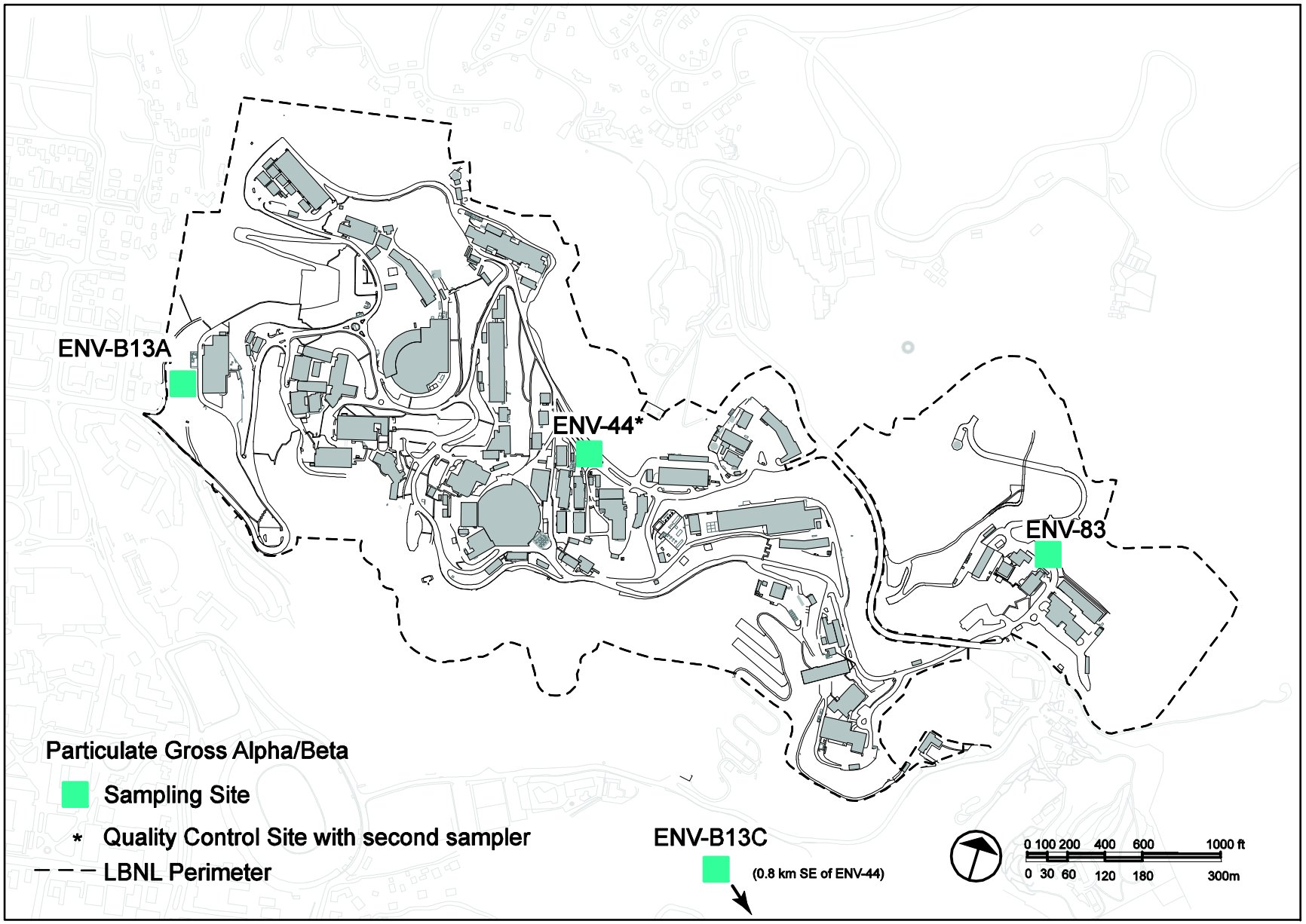


Figure 4-2 Ambient-Air Monitoring Network Sampling Locations

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

Analyte	Station ID	Number of Samples[a]	Mean (Bq/m^3)[b]	Median (Bq/m^3)	Maximum (Bq/m^3)
Alpha	ENV-B13A	13	7.1×10^{-5}	5.1×10^{-5}	2.0×10^{-4}
	ENV- B13C[c]	13	6.6×10^{-5}	5.2×10^{-5}	1.7×10^{-4}
	ENV-44	13	6.3×10^{-5}	4.8×10^{-5}	1.7×10^{-4}
	ENV-83	13	6.8×10^{-5}	5.1×10^{-5}	2.0×10^{-4}
Beta	ENV-B13A	13	4.9×10^{-4}	3.7×10^{-4}	1.1×10^{-3}
	ENV-B13C[c]	13	5.0×10^{-4}	3.3×10^{-4}	1.1×10^{-3}
	ENV-44	13	4.8×10^{-4}	3.7×10^{-4}	1.0×10^{-3}
	ENV-83	13	5.2×10^{-4}	3.9×10^{-4}	1.2×10^{-3}

[a] Due to unusually heavy filter loading at all sites from wildland fires in the region, one month was divided into two sample collection periods.

[b] 1 Bq = 27 pCi.

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

Surface water monitoring for 2009 included rainwater, creeks, and stormwater. Rainwater and creeks are monitored primarily for alpha and beta emitters and tritium, based on DOE Order 5400.5,[6] 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[7] 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)[8, 9] The federal and state limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L)[10, 11] LBNL also uses the water quality objectives stated in the *Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan)*[12] for comparison purposes.

4.3.1.1 Rainwater Sampling Results

Measurable rainfall occurred during January through May and October through December. Sampling is performed at the site of the meteorological tower and the ENV-44 ambient air sampling stations near Building 44 (see Figure 4-3), with monthly composite samples analyzed for gross alpha, gross beta, and tritium activity.

Monthly composite sample results from this location were consistent with historical values and were below drinking-water standards. All sample results for alpha and beta were below or near detection limits. 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 sample is collected quarterly from each of three creeks: Chicken Creek, the North Fork of Strawberry Creek, and Strawberry Creek (UC). Samples are analyzed for gross alpha, gross beta, and tritium radiological activity, as well as for mercury.

Samples are also collected at a lesser frequency from a second set of creeks. Two sets of samples were collected in 2009 from Chicken Creek, North Fork of Strawberry Creek, Botanical Garden Creek, and No Name Creek, and one set of samples from Cafeteria Creek, Ravine Creek, and Ten-Inch Creek. All samples were analyzed for metals and VOCs. In addition, the samples from Chicken Creek and North Fork of Strawberry Creek were analyzed for tritium. Figure 4-3 shows all creek sampling locations. No VOCs were detected in any of the creek samples. The only metals detected were arsenic,

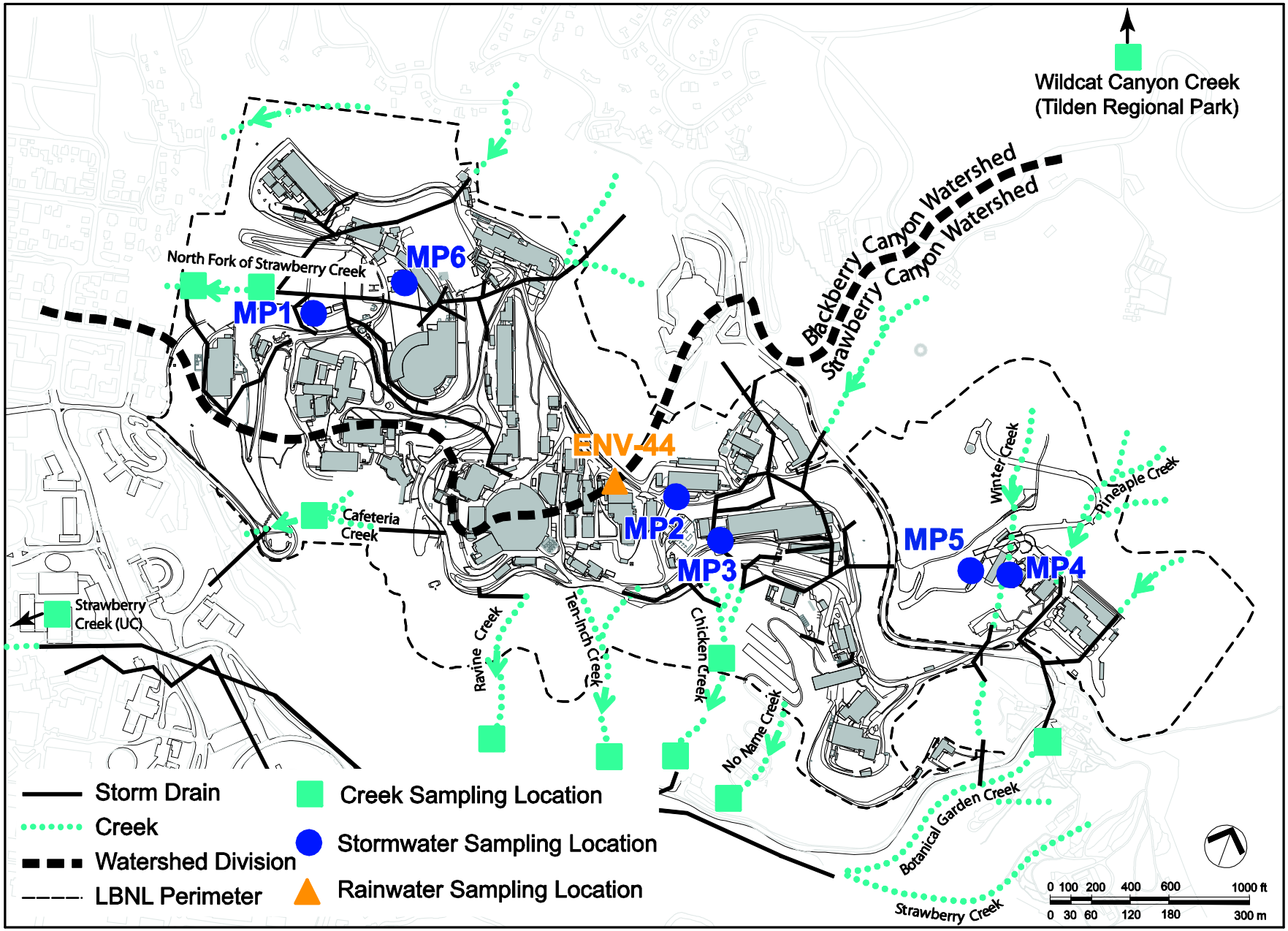


Figure 4-3 Creek, Rainwater, and Stormwater Sampling Locations

barium, selenium, vanadium, and zinc. Their concentrations were within historical levels for LBNL, well below the water quality objectives listed in the *Basin Plan*,[13] and well below the drinking-water standard.

For the approximately 30% of the time that gross alpha, gross beta, or tritium activity was detected, the majority of results were only slightly above analytical detection limits and all were well below the drinking-water standard. Of the thirteen samples taken for gross alpha, three samples were found positive above the MDA. The highest result for gross alpha, 0.69 Bq (18.6 pCi/L), was found in the North Fork of Strawberry Creek from an August 31, 2009 collection, and was about 1.5 times the MDA. For gross beta, the highest result was 0.64 Bq (17 pCi/L), which is well below the federal and state requirements for drinking water. For the twenty-one samples taken for tritium, two samples at 8.1 Bq (220 pCi/L) were found slightly above the MDA, and again significantly below federal and state requirements.

4.3.1.3 Stormwater Sampling Results

Under the terms of California's General Permit, sampling must take place at least twice each stormwater year (i.e., October to September) under specific conditions. Berkeley Lab's ASWMP[14] 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 provide an indicator of pollutant contributions from regulated activities at LBNL more specific to industrial activity, and thus a more reliable basis for evaluating the performance and effectiveness of Best Management Practices (BMPs), as described in LBNL's SWPPP. The monitoring program that has historically been implemented at LBNL focused on larger drainage areas within the site, so that monitoring results have reflected the combined runoff from regulated and non-regulated areas. The ASWMP is specifically designed to focus on the areas of industrial activity, which represent the only potential sources of pollutants that are specifically regulated under the General Permit. Berkeley Lab is regulated by the General Permit for industrial activities that fall under the following Standard Industrial Classifications (SIC):

- 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

Stormwater sampling in 2009, which spans the 2008-2009 and the 2009-2010 wet seasons, 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. Building 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. Total Suspended Solids
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, since 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.

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

SIC	Sampling Location	Parameters
3499 – Fabricated Metal Products	MP 3	Nitrite and nitrate as nitrogen Aluminum, iron, and 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 and MP 5	Ammonia Chemical oxygen demand (COD) Magnesium Arsenic, cadmium, lead, selenium, and silver Mercury Cyanide
5093 – Scrap Recycling Facility	MP 3	COD Aluminum, copper, iron, lead, and zinc

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.

COD was observed at elevated levels during the May 1 storm event at the lower and upper yard (MP 4 and MP 5) of the HWHF; follow-up investigative studies pointed to aerial deposition of soil particles on the concrete surface at the yards as the source of the COD. Cyanide results are below detectable limits. pH at all the locations and sampling events has been within the acceptable 6 to 9 standard pH units, except for one collection at the upper yard (MP 5); a follow-up investigative study during the subsequent rain events did not duplicate that result. 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 2009 were below this guideline.

The MSGP benchmark for Total Suspended Solids (TSS) is 100 mg/L, and the Blackberry parking lot (MP 1) had some results greater than that. The probable source was significant sediments which were deposited on the parking lot due to a water line break on the neighboring hillsides. While the majority of those sediments were quickly removed from the parking lot, small amounts continued to be discharged. In March of 2010 an asphaltic berm was constructed which surrounds the entire parking lot, eliminating run-on from the surrounding hillsides. In the duplicate samples at the metal fabrication and salvage yard (MP 3), TSS was measured above the benchmark as well, but was below the benchmark in the primary samples. This serves as a good example that duplicate samples taken as discrete samples sometimes may have significant variations between them. Aluminum was seen above the

benchmark at the metal fabrication and salvage yard (MP 3). While continuing improvements have been made at the yard to reduce and temporarily cover the amount of stored material present, as well as increasing cleaning of the yard, further improvements are needed to reduce aluminum in stormwater runoff at this location. Again, the duplicate sample taken during the October 13 storm had results below the benchmark, while the primary sample showed results above the benchmark. Given the discrete sampling, this could be due to variations between samples taken.

Arsenic and cadmium were not detected in stormwater runoff. Copper was detected at the metal fabrication and salvage yard (MP 3), and studies were undertaken to pinpoint the source. 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 runoff at the metal fabrication and salvage yard; further BMPs will be implemented to reduce these values to below guidelines. While lead has been detected, all results have been below MSGP benchmarks. Magnesium was detected at the upper and lower yard of the HWHF (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. Zinc was detected at the metal fabrication and salvage yard (MP 3), despite the temporary covering of galvanized fabricated materials. Studies to determine the source of the zinc indicated that it is largely in the dissolved phase and galvanized roofing materials are used that contain zinc.

Ammonia as nitrogen was not above MSGP benchmark values. Nitrate plus nitrite was below MSGP benchmark guidelines except during the May 1 storm water sampling.

Oil and grease results have been below detection limits for the majority of the sampling sites, except for the fuel dispensing facility (MP 2). Additional oil absorbent pads were inserted in the drain inlet, and oil and grease values have dropped below detectable limits at this location in the subsequent storm sampling events. Oil and grease was also detected above the benchmark guidelines at the metal fabrication and salvage yard (MP 3) during the first storm event, after which additional oil filters were placed in the drain. Sampling during subsequent storm events did not detect any oil and grease at that location.

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 Figure 4-4).

- 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 City of Berkeley'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 City of Berkeley 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 LHS, 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 Buildings 25 and 77, and one for the discharge of treated groundwater at

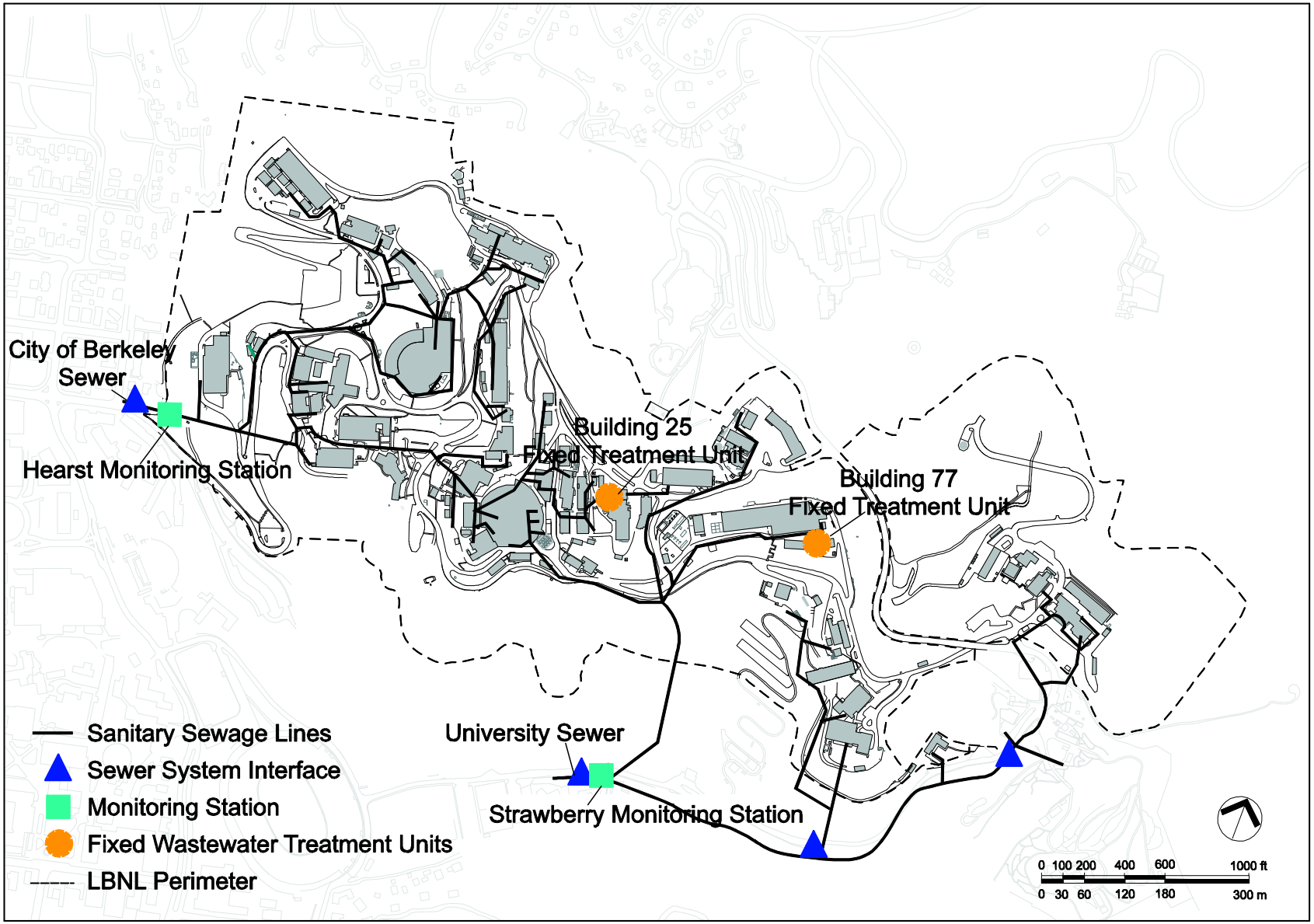


Figure 4-4 Sanitary Sewer System

seven locations. EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

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 Buildings 25 and 77 and at groundwater treatment systems, according to the terms of their respective EBMUD permits.[15] In addition, EBMUD performs unannounced monitoring of wastewater discharges. For 2009, no changes in permit requirements occurred, and all sampling results for the three permits were below discharge limits.

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 (TICH), TSS, and COD, with additional analyses for metals. Also, total flow is measured and recorded. In 2009, Berkeley Lab discharged approximately 58,295 m^3 (15.4 million gal) through Hearst Sewer and 118,483 m^3 (31.3 million gal) through Strawberry Sewer.

Radiological monitoring is required by DOE Order 5400.5[16] and guidance,[17] and verifies compliance with radiological limits under the California Code of Regulations (CCR),[18] cited in the EBMUD wastewater discharge permit.[19] California regulations now incorporate by reference the applicable federal Nuclear Regulatory Commission regulations[20] 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 2009. All results were well within discharge limits, as were all measurements made by EBMUD in its two independent sampling events.

No chlorinated hydrocarbons were detected except chloroform (which is present in EBMUD supply water). 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[21] and state[22] regulatory limits for radioisotopes are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (five 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 carbon-14, iodine-125, and tritium samples collected at the Hearst and Strawberry Monitoring Stations were below minimum detectable activity (MDA).

Positive results for gross alpha and gross beta, phosphorus-32, and sulfur-35 were found. Of the twenty-six samples taken for gross alpha, three samples were found positive slightly above the MDA. The highest result for gross

alpha, 0.11 Bq (3.1 pCi/L), found in the sanitary sewer was about two times the MDA. As a comparison, the federally allowed amount of gross alpha activity in bottled drinking water is 15 pCi/L. For gross beta results, the highest result was 0.58 Bq (16 pCi/L), which is below the federal and state requirements for drinking water. For the twenty-six samples taken for phosphorus-32, one sample at 0.96 Bq (29 pCi/L) was found positive, although significantly less than two times the MDA. For the twenty-six samples taken for sulfur-35, one sample at 0.35 Bq (9.3 pCi/L) was found positive and significantly less than two times the MDA.

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 1.96×10^{8} Bq (5.28×10^{-3} Ci) or 0.11% of the discharge limit. Activities below the MDA were also totaled for carbon-14 to give an estimated annual discharge of 1.06×10^{6} Bq (2.85×10^{-5} Ci) or 0.0029% of the discharge limit for carbon-14. The estimated annual discharge for all other radioisotopes (gross alpha, gross beta, iodine-125, phosphorus-32, sulfur-35) combined was 1.31×10^{7} Bq (3.53×10^{-4} Ci) or 0.035% of the discharge limit.

4.3.2.2 Building 25 Photo Fabrication Shop Wastewater

The Photo Fabrication Shop in Building 25 manufactures electronic circuit boards and screen-print nomenclature on panels, and the shop performs chemical milling, to support the needs of Berkeley Lab research and operations activities. Wastewater containing metals and acids from these activities is routed to an FTU before discharge to the sanitary sewer. The Building 25 FTU treats wastewater in batches rather than continuously.

The self-monitoring event performed by Berkeley Lab yielded daily maximum and monthly average results well below EBMUD discharge limits.[23] EBMUD also performed one sampling event at the Building 25 FTU in 2009. The EBMUD results were below the EBMUD discharge limits as well.

4.3.2.3 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.

The Building 77 EBMUD permit is currently combined with the Building 25 permit. Instead of monitoring for chlorinated hydrocarbons, LBNL submits a *Total Toxic Organics Compliance Report* twice per year; it certifies that Buildings 25 and 77 are not discharging chlorinated hydrocarbons or other toxic organic compounds to the FTU, which then discharges to the sanitary sewer.

4.3.2.4 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[24] 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 (emphasizing 2009 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 the City of Berkeley main public library and at www.lbl.gov/ehs/erp/html/documents.shtml.

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 drinking water is supplied by EBMUD.

4.4.1 Groundwater Monitoring Results

The groundwater monitoring network at Berkeley Lab consists of more than 180 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 approved by the RWQCB. Selected wells are also monitored for other potential contaminants.

Except for a single well, MWP-7, in which trichloroethylene (TCE) was detected at a concentration well below the drinking-water standard,[25] no tritium or VOCs were detected in any of the 17 perimeter or off-site wells in 2009. Sitewide VOC and tritium results are discussed in detail in Section 4.4.2.

The only metal detected in 2009 at a concentration above both the drinking-water standard and the statistically estimated Berkeley Lab background level[26] 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 background level in five wells.

4.4.2 Groundwater Contaminant Plumes

VOC Plumes: 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 two other localized areas (Building 75/75A and Building 77 areas). 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 unwanted releases.

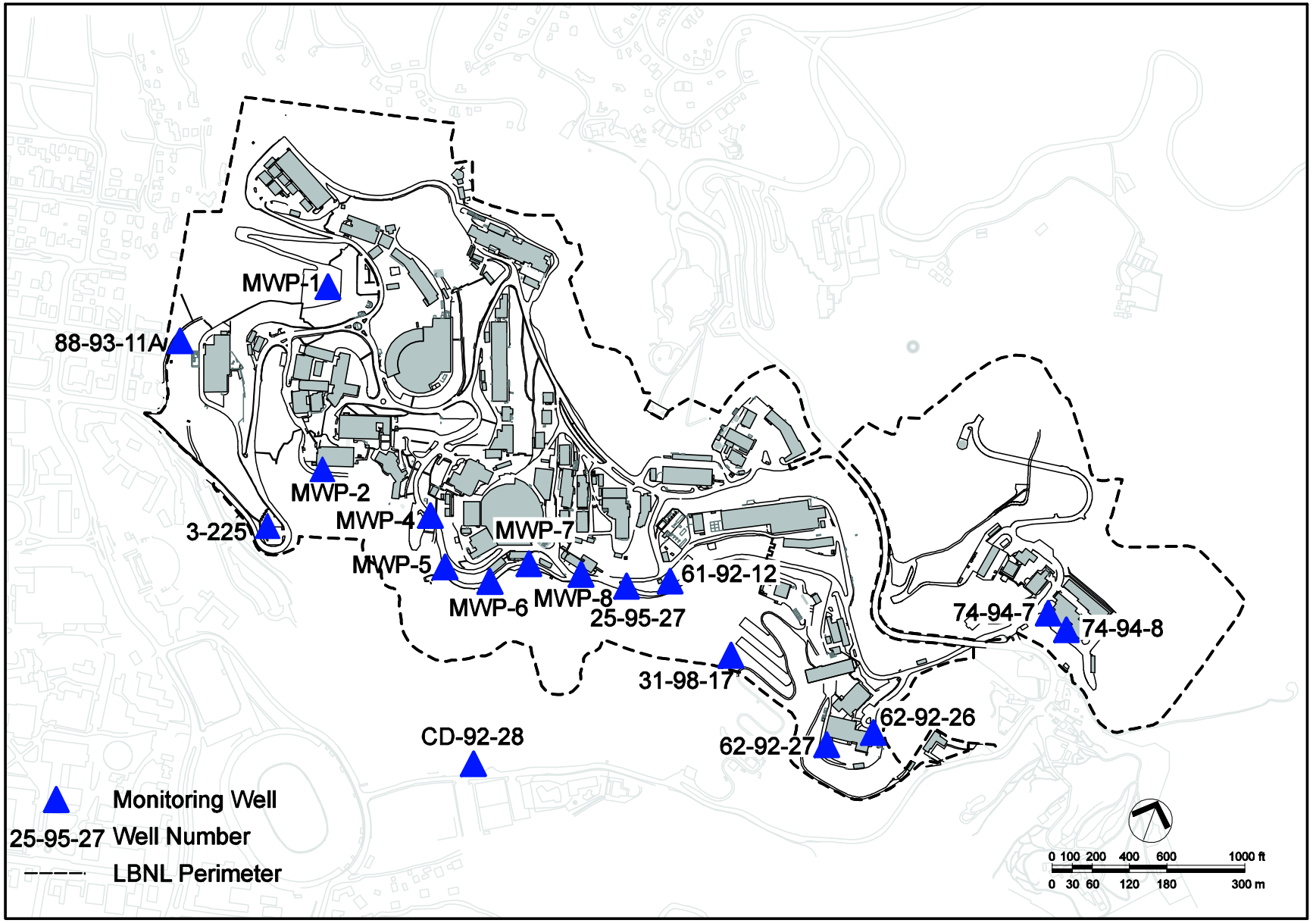


Figure 4-5 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

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 Plume: 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)[27, 28] in all wells since February 2005.

Petroleum Hydrocarbon Plumes: 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.

The locations of the plumes and the extent of groundwater with contaminant concentrations exceeding the drinking water standard in September 2009 are shown on Figure 4-6. The plumes are 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., TCE; 1,1-dichloroethylene (DCE); cis-1,2-DCE; and vinyl chloride).

A number of interim corrective measures were instituted in prior years 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 source and core area wells declining from approximately 20,000 micrograms per liter (µg/L) in 2002 to approximately 1,000 µg/L in 2009. The maximum concentration of total VOCs detected in 2009 was 18,900 µg/L, which primarily consisted of PCE (16,100 µg/L).

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.

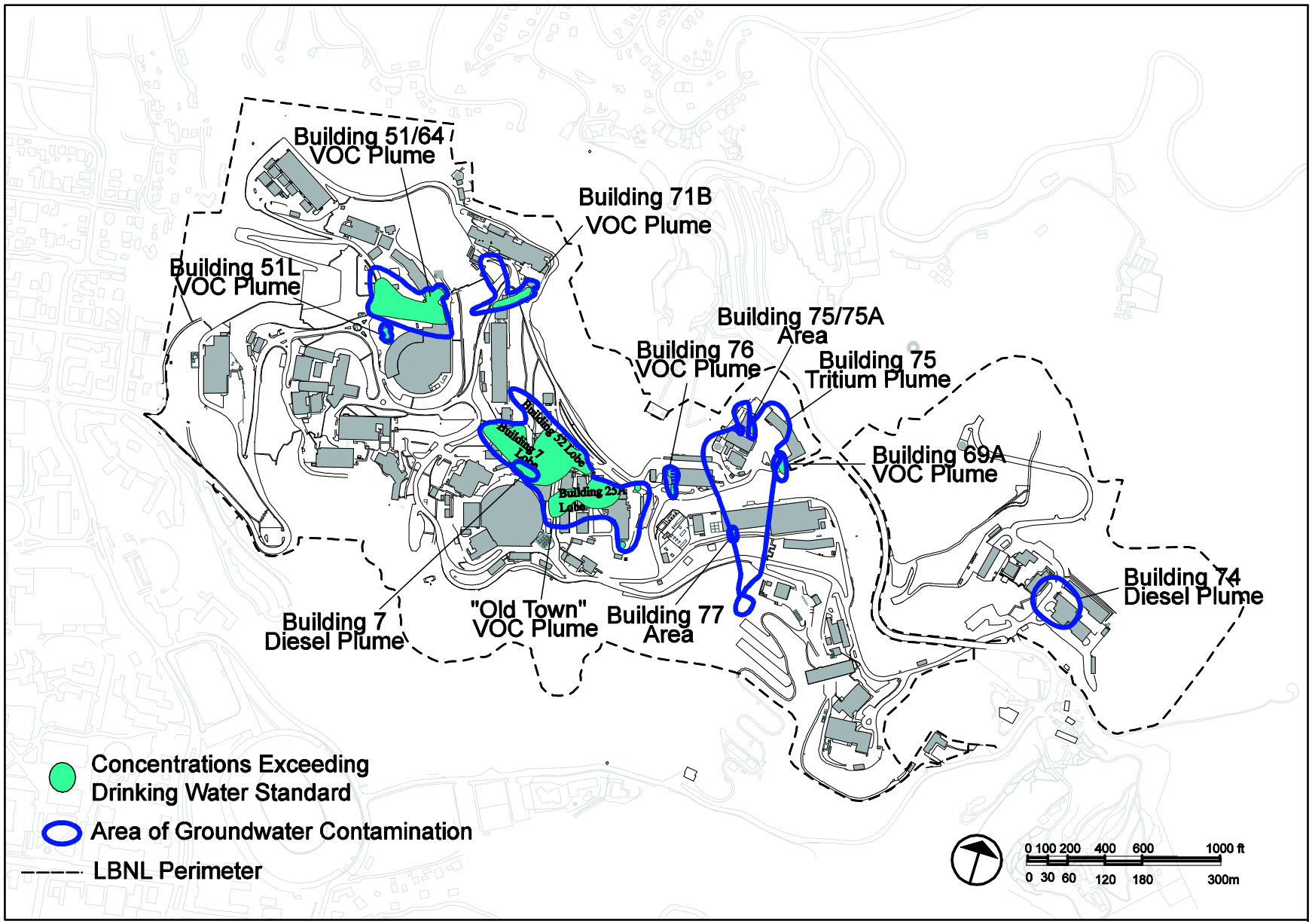


Figure 4-6 Locations of Plumes and Extent of Groundwater Contamination Above Drinking-Water Standards (September 2009)

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 in representative wells in the Building 25A subplume source and core area has declined from approximately 200 µg/L to approximately 70 µg/L in 2009. 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. Except for carbon tetrachloride (0.54 µg/L), which slightly exceeded the drinking-water standard of 0.5 µg/L in one sample, concentrations of VOCs in groundwater samples collected south of Building 25 remained below the drinking-water standard in 2009.

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).

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 source and core area wells has declined from more than 100 µg/L to less than 5 µg/L in 2009, with concentrations of individual VOCs declining to less than the drinking-water standards throughout most of the lobe area.

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. Since flushing was started in 2003, the annual average concentration of total VOCs in representative source and core area wells has declined from more than 4,000 µg/L to less than 100 µg/L in 2009. The maximum concentration of total VOCs (primarily 1,1-DCA) detected in 2009 was 2,434 µg/L in a groundwater sample from one of two multiport wells in the source area. These wells were constructed with short, approximately 1-foot, screened intervals to target specific permeable zones within the bedrock, and therefore are not representative of the water-bearing unit as a whole. Excluding the multiport wells, the maximum concentration of total VOCs in the source area has declined from more than 700,000 µg/L prior to excavation of the source area in 2000 to approximately 400 µg/L in 2009.

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 offsite 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 2009 was 18 µg/L. The maximum concentration of total VOCs (primarily TCE) detected in the Building 51L area in 2009 was 248 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 2009. The maximum concentration of total VOCs detected has declined from more than 6,000 µg/L to less than 500 µg/L in 2009.

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 maximum concentration of total VOCs (primarily cis-1,2-DCE) detected in 2009 was 39 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 2009 was 15 µg/L. No corrective measures are required for the Building 76 plume.

4.4.2.9 Tritium Plume

The Building 75 tritium plume extends southwards from Building 75 toward Chicken Creek. In addition, low concentrations of tritium have been detected in a few monitoring wells in the Building 71B area. The source of the tritium was the former NTLF at Building 75. The maximum concentration of tritium detected in Building 75 tritium plume groundwater in 2009 was 414 Bq/L (15,300 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. No tritium was detected in the Building 71B area in 2009.

4.4.2.10 Petroleum Hydrocarbon Plumes

Petroleum hydrocarbon-contaminated groundwater is present in two areas where USTs formerly were located: north of Building 6 and near Building 74. In 2009, kerosene-range hydrocarbons were detected at a maximum concentration of 780 µg/L in the groundwater north of Building 6 and diesel-range hydrocarbons were detected at a maximum concentration of 110 µg/L in the groundwater near Building 74. No aromatic VOCs, including BTEX components (i.e., benzene, toluene, ethylbenzene, xylenes), have been detected at either of the UST sites since 2003.

4.4.3 Treatment Systems

As described above, Berkeley Lab is using collection trenches and subdrains to control the migration of groundwater plumes. Eleven GAC systems were operated in 2009 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.[29]

The total volume of contaminated groundwater treated by these systems during the year was about 47,300 m^3 (12.5 million gal). From 1991 through the end of 2009, more than 380,000 m^3 (100,000,000 gal) of contaminated groundwater have been extracted, treated, and mostly reinjected into the subsurface for in situ soil-flushing purposes.

4.5 SOIL AND SEDIMENT

This section summarizes the monitoring results for soil and sediment samples.

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 at or 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 lead, the 10 metals with established Berkeley Lab soil background levels[30] were within those levels. For lead, one sampling location was above the upper estimate of background metals concentrations at LBNL (57 milligrams per kilogram [mg/kg]); however, the result was well below the U.S. EPA's industrial preliminary remediation goal of 800 mg/kg. For the other five metals, concentrations were within levels commonly found in California soils.

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 Canyon 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, fifteen individual metals, pH, moisture content, and petroleum hydrocarbons (diesel and oil/grease).

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, concentrations of the ten metals with established Berkeley Lab soil background levels[31] were within those levels. Concentrations of the other five metals were within levels commonly found in California soils. Measurements of pH, moisture content, and petroleum hydrocarbons (diesel and oil/grease) at all of the locations were within the historical values typically found at the Berkeley Lab site over the past five years.

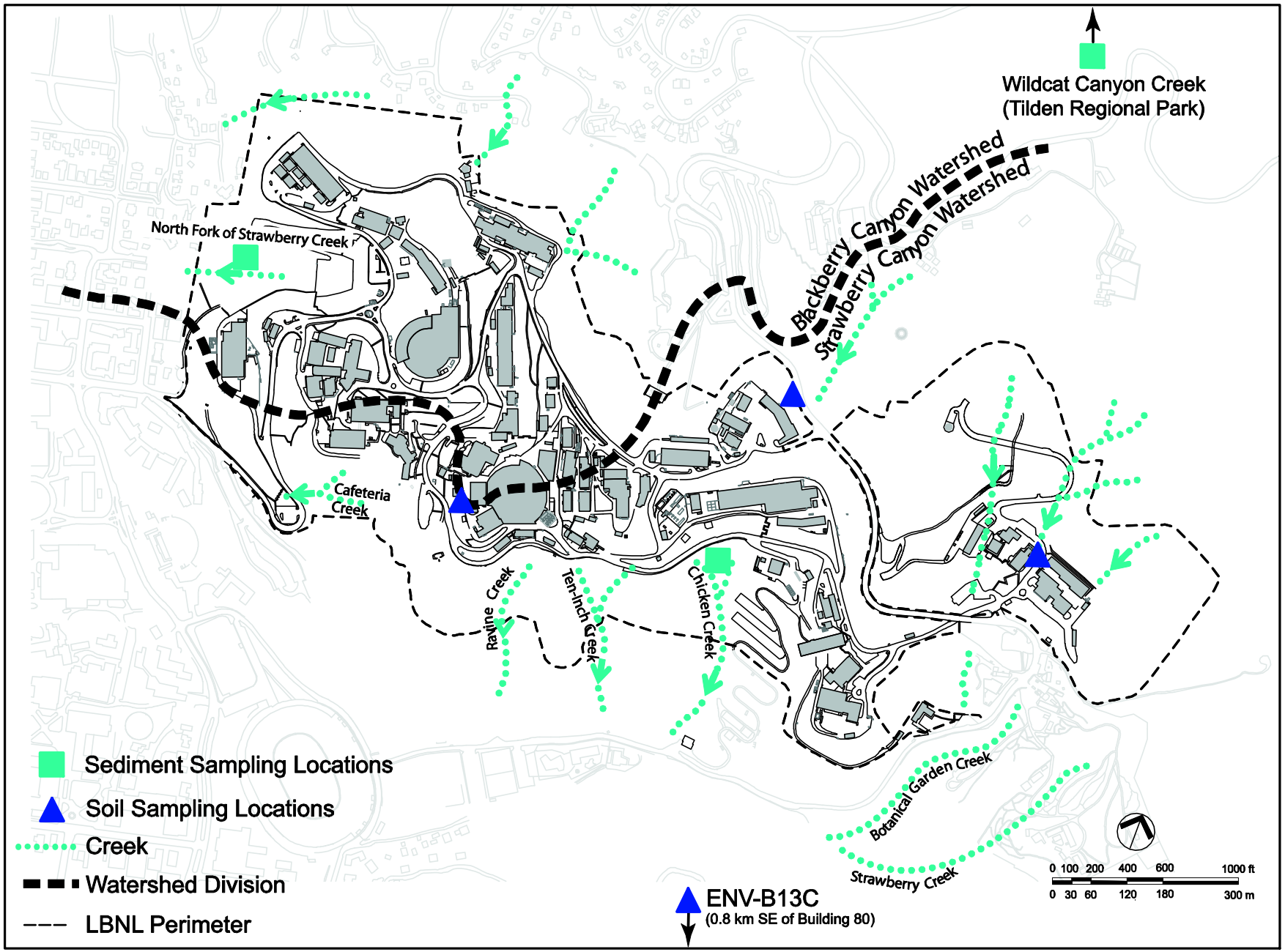


Figure 4-7 Soil and Sediment Sampling Sites

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 -- tissue-free water tritium (TFWT) and organically bound tritium (OBT). 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. Tritium concentrations in vegetation will decrease more slowly over time, as indicated by the results from the last sampling in 2005. To document changes in the concentrations of tritium in the local vegetation, Berkeley Lab routinely samples this vegetation at least every five years. In 2009, no routine vegetation 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 2009, three trees near Building 77 (about 200 m [660 feet] south-southeast of the former NTLF Hillside Stack) were sampled for this purpose. The samples were analyzed at a commercial laboratory for TFWT and OBT, and the trees were found to have no measurable tritium, as shown in Table 4-4. Based on these results, the trees were removed from the Berkeley Lab site.

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.

Table 4-4 Results of Landscape Management Sampling

Sample Description	Result (Bq/g)	MDA (Bq/g)	Result (pCi/g)	MDA (pCi/g)
Tissue Free Water Tritium				
SSE196—Chip	< 0.017	0.017	< 0.45	0.45
SSE198—Chip	< 0.16	0.016	< 0.44	0.44
SSE200—Chip	< 0.017	0.017	< 0.47	0.47
SSE200—Chip duplicate	< 0.017	0.017	< 0.46	0.46
Organically Bound Tritium				
SSE196—Chip	< 0.13	0.13	< 3.5	3.5
SSE198—Chip	< 0.13	0.13	< 3.4	3.4
SSE200—Chip	< 0.13	0.13	< 3.6	3.6
SSE200—Chip duplicate	< 0.13	0.13	< 3.6	3.6

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 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.

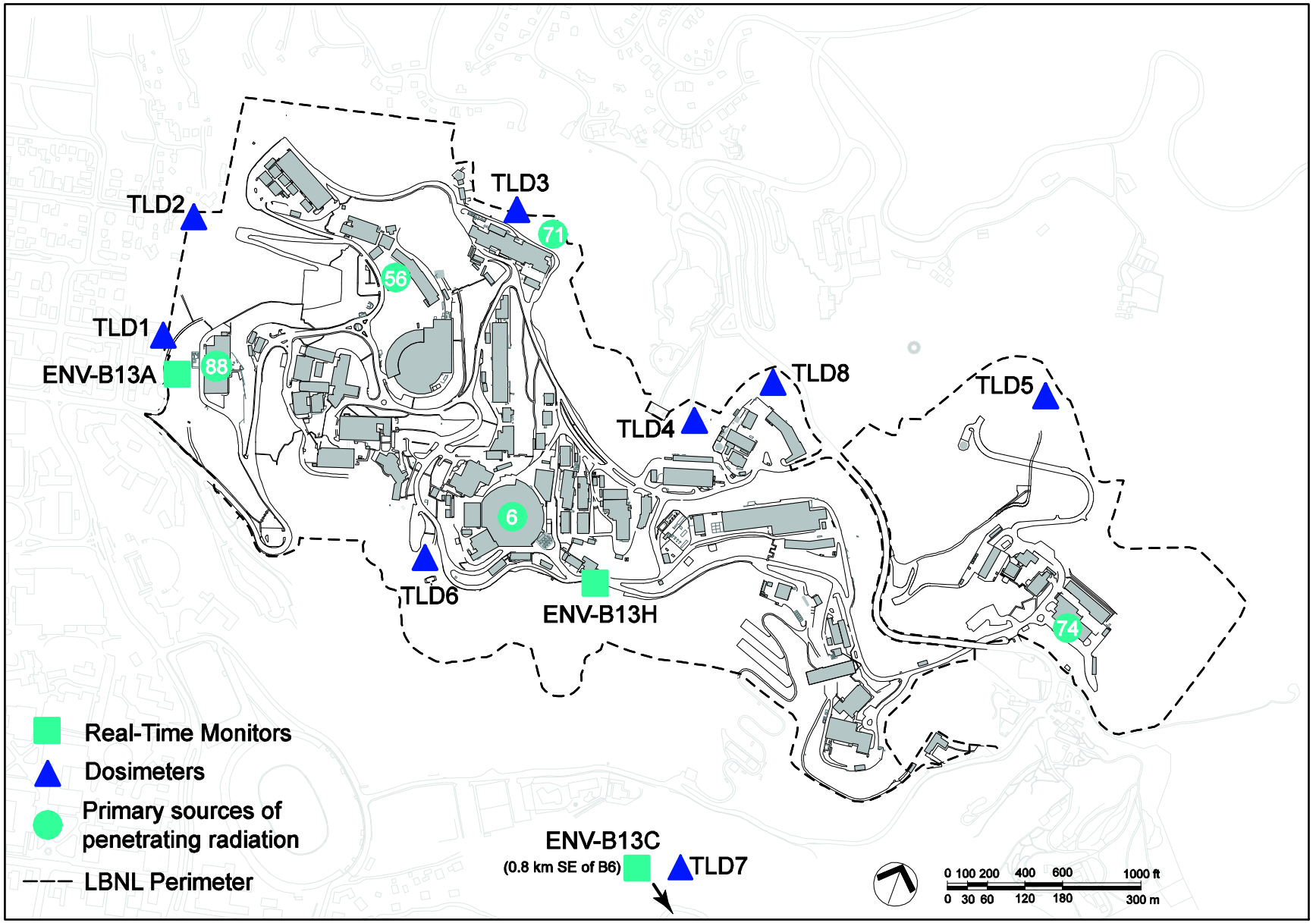


Figure 4-8 Environmental Penetrating Radiation Monitoring Stations

5 Radiological Dose Assessment

West side of the Advanced Light Source Facility

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 that extends from the site for 80 km (50 mi). 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 3.4.1.1 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 2009.

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 from the 88-Inch Cyclotron to a person at the nearest residence (about 110 m [360 feet] away) was 1.7×10^{-3} mSv (0.17 mrem), and the population dose to the surrounding area was 6.6×10^{-4} person-Sv (6.6×10^{-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 the Berkeley Public Library and online at www.lbl.gov/ehs/esg/Reports/tableforreports.shtml.

The maximally exposed individual (MEI) to airborne emissions 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 2009 was about 7.0×10^{-5} mSv (0.0070 mrem). This value is about 0.07% 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 radionuclides for the year was 1.5×10^{-3} person-Sv (0.15 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 2009 was about 1.8×10^{-3} mSv/yr (0.18 mrem/yr), primarily from gamma radiation from the 88-Inch Cyclotron. This value is approximately 0.06% of the average United States natural background radiation dose[8] (3.1 mSv/yr [310 mrem/yr]) and about 0.2% 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 2.2×10^{-3} person-Sv (0.22 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 five million times lower than background level.

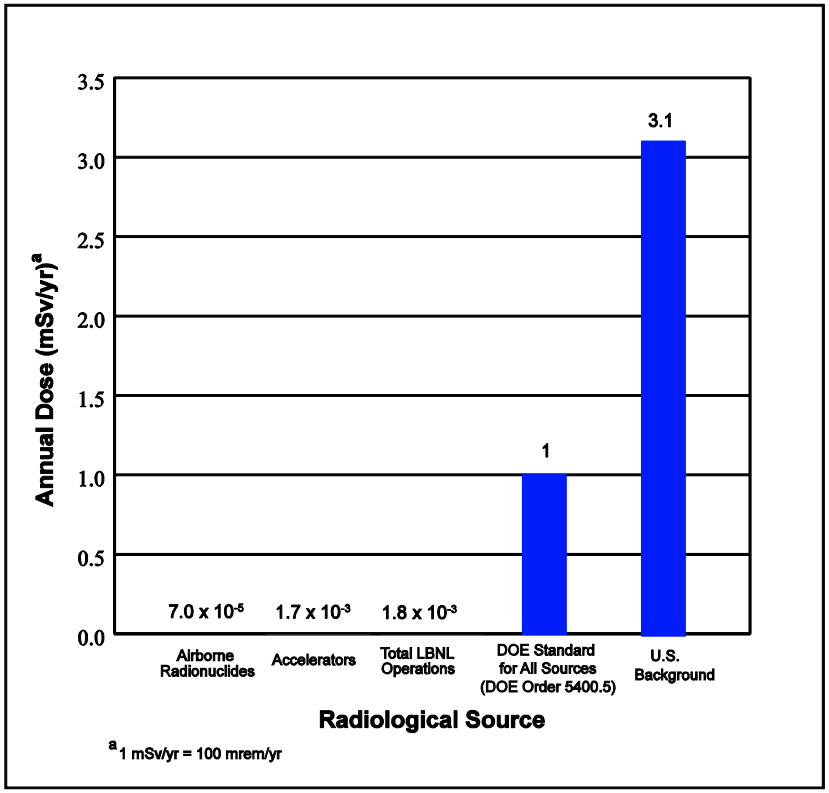


Figure 5-1 Comparison of Radiological Dose Impacts for 2009

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 organisms be protected by limiting their radiation doses to one rad/day (0.01 gray per day [Gy/day]).[11] In addition, international recommendations suggest that doses to

terrestrial animals should be limited to less than 0.1 rad/day (0.001 Gy/day), and doses to terrestrial plants should be limited to one rad/day (0.01 Gy/day).[12]

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.[13] Both terrestrial and aquatic systems passed the "general screening process" (described in a DOE-approved technical standard),[14] which confirms that Berkeley Lab is in compliance with DOE requirements to limit radiation doses to aquatic organisms to one rad/day (0.01 Gy/day). It also shows that LBNL is well within international recommendations for limiting dose to terrestrial plants and animals.

6 Quality Assurance

View of Berkeley Lab from the hills above

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. When special QA and QC requirements are necessary for environmental monitoring (such as the NESHAP stack monitoring program), a Quality Assurance Project Plan is developed and implemented.

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 2009, six 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 material management

The DOECAP laboratory audits also include a review of the external analytical laboratory's performance in proficiency testing required by ELAP. 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 2,760 individual samples (air, sediment, soil, and water) throughout the year; the samples generated approximately 105,570 analytical results.

Samples collected by these programs were obtained from 607 different locations on or surrounding the Berkeley Lab site. Individual data results for all environmental monitoring programs, except the Environmental Restoration Program, 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 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 2009, a total of 55 split and 107 duplicate samples from all programs were collected for either radiological or nonradiological (or both) analyses, leading to 218 and 2,600 analytical results, respectively. Additionally, there were 298 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.

Six analytical laboratories performed 2,265 radiological and nonradiological QC analyses to coincide with batches of samples submitted to 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.

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.

Table 6-1 Summary of Quality Control Testing Performed by Analytical Laboratories in 2009

Program	Sample Batches	QC Analyses	Laboratories Involved	Radiological[a]	Non-Radiological[b]
Ambient air	27	68	2	X	
Groundwater	177	989	4	X	X
Rainwater	22	88	3	X	
Sediment	13	44	5	X	X
Soil	10	32	5	X	X
Soil water	4	18	1	X	
Stack air	69	184	3	X	
Stormwater and creeks	70	216	6	X	X
Wastewater	136	582	6	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 nonradiological substances.

Acronyms and Abbreviations

AEDE	annual effective dose equivalent
AHD	Activity Hazard Document
ALARA	as low as reasonably achievable
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
C	Celsius
CAP	Corrective Action Program
CARB	California Air Resources Board
CCCSD	Central Contra Costa Sanitary District
CCR	California Code of Regulations
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
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
DPH	Department of Public Health
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EH&S	Environment, Health, and Safety Division at Berkeley Lab
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
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
Gy	gray (measure of radiation in SI)
HMBP	Hazardous Materials Business Plan
hr	hour
HRC	Hydrogen Release Compound
HWHF	Hazardous Waste Handling Facility
in	inch
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
JGI	Joint Genome Institute
kg	kilogram
km	kilometer
L	liter
lb	pound
LBNL	Lawrence Berkeley National Laboratory
LHS	Lawrence Hall of Science
LRDP	Long Range Development Plan
m	meter
m^3	cubic meter
MEI	maximally exposed individual
µg	microgram
mg/kg	milligrams per kilogram
mi	mile
MNA	monitored natural attenuation
mrem	millirem
mSv	millisievert
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NTLF	National Tritium Labeling Facility
OQMP	Operating and Quality Management Plan

PBT	persistence, bioaccumulation, and toxicity
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
rem	roentgen equivalent man
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 Code
SPCC	Spill Prevention, Control, and Countermeasure
Sv	sievert
SWDA	Solid Waste Disposal Act
SWMP	Storm Water Monitoring Program
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCA	trichloroethane
TCE	trichloroethylene
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
USC	United States Code
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
yr	year

Glossary

accuracy

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

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 cms 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 Svs 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.

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 ^{40}K; the natural decay chains of ^{235}U, ^{238}U, ^{232}Th; 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 SL (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}	
deka	10 =10^{1}	da[a]
deci	0.1 =10^{-1}	d[a]
centi	.01 = 10^{-2}	c[a]
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		
micrograms per gram	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		
pounds per square foot	pascal	0.000145
Radiation		
becquerel	curie	2.7 × 1 0–11
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

Distribution List

INTERNAL DISTRIBUTION

Chief Operating Officer
Jim Krupnick

EH&S Division

David Baskin	Robert Fox	Ron Pauer
Tim Bauters	John Jelinski	Nancy Rothermich
Paul Blodgett	David Kestell	Patrick Thorson
Ned Borglin	Peter Lichty	Linnea Wahl
Richard DeBusk	Don Lucas	Suying Xu
Doug Fleming	Dan Lunsford	

Facilities Division

Steve Black	Ken Fletcher	Jerry Ohearn
Laura Chen	Jeff Philliber	Jennifer Ridgeway

Laboratory Counsel
Nancy Ware

Public Affairs
Jeff Miller
Don Medley
Sam Chapman

88-Inch Cyclotron
Claude Lyneis

Radiation Safety Committee
David Shuh

Safety Advisory Committee
Jim Floyd

Berkeley Lab Library
Building 50

EXTERNAL DISTRIBUTION

Alameda County
Susan Hugo

Argonne National Laboratory
Environment, Safety, and Health
Norbert Golchert

Argonne National Laboratory (West)
Nuclear Program Services
Gary Marshall

Bay Area Air Quality Management District
Jack Broadbent, Executive Officer

Berkeley Public Library
Reference Desk

Brookhaven National Laboratory
Environmental and Waste Management Services Division
Karen Ratel

California Department of Public Health
Radiological Health Branch
Steve Hsu
Kent Prendergast

California Department of Toxic Substances Control
Facility Permitting Branch
Jacinto Soto
Mark Prios

California Regional Water Quality Control Board,
San Francisco Bay Region
David Elias
Cecil Felix

California State Assembly, 14th District
Assemblymember Nancy Skinner

California State Senate, Senate District 09
Senator Loni Hancock

Central Contra Costa Sanitary District
Tim Potter

City of Berkeley
Office of Emergency and Toxics Management
Nabil Al-Hadithy

Community Environmental Advisory Commission
Greg Leventis, Chair

City of Oakland
Leroy Griffin

Committee to Minimize Toxic Waste
Gene Bernardi
Pam Sihvola

East Bay Municipal Utility District
Source Control Division
Audrey Comeaux

Fermi National Accelerator Laboratory
Environment, Safety, and Health Section
Bill Griffing

Idaho National Laboratory
Environmental Management Program
Susan Stiger

Lawrence Livermore National Laboratory
Operations and Regulatory Affairs Division
Gretchen Gallegos

Los Alamos National Laboratory
Environment, Health, and Safety Division
Douglas Stavert

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

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

Oakland Main Library
Reference Desk

Pacific Northwest Laboratory
R. W. Hanf

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

Sandia National Laboratories/California
Environmental Protection Division
Barbara Larsen

Savannah River Site (Westinghouse Savannah River Company)
Environmental Sampling and Reporting
James Heffner

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
George Campbell

University of California at Berkeley
Lawrence Hall of Science
Steve Mullin

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

University of California at San Francisco
Environment, Health, and Safety
Ara Tahmassian

References

Preface

1. DOE, Order 231.1A, *Environment, Safety, and Health Reporting* (1995, as amended).

Executive Summary

1. See Preface, Note 1.
2. DOE, *Contract between the United States of America and the Regents of the University of California*, DE-AC02-05CH11231 (2005).
3. DOE, Order 450.1A, *Environmental Protection Program* (June 4, 2008).
4. DOE, Manual 231.1-2, *Occurrence Reporting and Processing of Operations Information* (August 2003).
5. National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States,* NCRP Report No. 160 (2009).
6. DOE, Order 5400.5, *Radiation Protection of the Public and the Environment* (1990, as amended).
7. U.S. EPA, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities,* Title 40 CFR Part 61, Subpart H (1989, as amended).
8. Mauro, J., and N.M. Briggs, *Assessment of Variations in Radiation Exposure in the United States*, U.S. Environmental Protection Agency (2005).

9. LBNL, *2006 Long Range Development Plan* (no date). http://www.lbl.gov/Community/pdf/env-rev-docs/LRDP-final/LBNL-2006-LRDP-Final-Small.pdf.

10. LBNL, *Berkeley Lab Long Range Development Plan Final Environmental Impact Report* (July 6, 2007). http://www.lbl.gov/Community/pdf/env-rev-docs/LRDP-final/LBNL-2006-LRDP-Final-EIR.pdf.

Chapter 1: Introduction

1. The National Academies' Web site, (May 21, 2009). www.nationalacademies.org/about.

2. Association of Bay Area Governments-Metropolitan Transportation Commission's Web site, *Bay Area Census,* 2000 census data. www.bayareacensus.ca.gov/cities/cities.htm.

3. *Safe Drinking Water Act*, 42 United States Code (USC) §300f *et seq.* (1974, as amended).

4. EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, Federal Register, Vol. 72, No. 17, Friday, January 26, 2007, page 3919.

5. EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, Federal Register, Vol. 74, No. 194, Thursday, October 8, 2009, page 52117.

6. See Executive Summary, Note 10.

7. Ibid.

8. Ibid.

Chapter 2: Performance-Based Environmental Management System

1. ISO 14001: 2004(E), *Environmental Management Systems—Requirements with Guidance for Use,* (November 2004). www.iso.org/iso/catalogue_detail?csnumber=31807.

2. See Chapter 1, Note 4.

3. See Executive Summary, Note 3.

4. DOE Order 430.2B, *Departmental Energy, Renewable Energy and Transportation Management* (February 27, 2008).

5. LBNL, *Environmental Management System Plan,* LBNL-PUB-3180 (March 2009). http://www.lbl.gov/ehs/esg/EMS%20Plan/assets/EMS%20Plan0309.pdf.

6 Public Law 109-58, *Energy Policy Act of 2005* (August 8, 2005).

7. Public Law 110-140, *Energy Independence and Security Act of 2007* (December 19, 2007).

8. LBNL, *FY2010 LBNL Sustainability Executable Plan* (December 2009).

9. See Chapter 1, Note 5.

10. LBNL, *Integrated Environment, Safety & Health Management Plan,* PUB-3140, (October 2009). www.lbl.gov/ehs/ism/assets/docs/LBNL-ISM.pdf.

11. See Executive Summary, Note 3.

Chapter 3: Environmental Program Summary

1. See Chapter 1, Note 4.

2. See Chapter 1, Note 5.

3. See Executive Summary, Note 3.

4. LBNL, "ISM Guiding Principles," *Integrated Safety Management.* http://www.lbl.gov/ehs/ism/assets/docs/LBNL-ISM.pdf.

5. See Executive Summary, Note 4.

6. *Clean Air Act,* 42 USC §7401 *et seq.* (1967, as amended).

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

8. See Executive Summary, Note 7.

9. See Executive Summary, Note 6.

10. LBNL, *Radionuclide Air Emission Report for 2009*, ESG (June 2010). www.lbl.gov/ehs/esg/Reports/assets/NESHAP2009.pdf.

11. BAAQMD, *Permit to Operate for Lawrence Berkeley National Laboratory* (Plant No. 723 and GDF No. 6134) (July 2009) and BAAQMD *Permit to Operate for Joint Genome Institute in Walnut Creek,* (Plant No. 14549).

12. *Air Toxics "Hot Spots" Information and Assessment,* California Health and Safety Code §44300 *et seq.* (1987, as amended).

13. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC §9601 *et seq.* (1980, as amended).

14. *Emergency Planning and Community Right-to-Know Act of 1986*, 42 USC §11001 *et seq.* (1986, as amended).

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

16. EO 13148 of April 21, 2000, *Greening the Government Through Leadership in Environmental Management*, Federal Register, Volume 65, Number 81, April 26, 2000, Page 24593.

17. LBNL, *Hazardous Materials Business Plan,* EH&S Division (March 2010). http://www.lbl.gov/ehs/ih/assets/docs/HazMatBusPlan.pdf.

18. *Federal Insecticide, Fungicide, and Rodenticide Act*, 7 USC §136 *et seq.* (1972, as amended).

19. *Toxic Substances Control Act*, 15 USC §2601 *et seq.* (1976, as amended).

20. *Resource Conservation and Recovery Act of 1976*, 42 USC §6901 *et seq.* (1976, as amended).

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

22. California Environmental Protection Agency, *Hazardous Waste Facility Permit, EPA ID No. CA 4890008986,* DTSC (December 22, 2006).

23. City of Berkeley, Certified Unified Program Agency Consolidated Permit and Registration, No. 800488 (January 26, 2009). http://www.lbl.gov/ehs/esg/Permit%20for%20Table/pdf/CUPA1210.pdf.

24. *Medical Waste Management Act*, California Health and Safety Code §§117600–118360 (1991, as amended).

25. DOE, *Mixed Waste Site Treatment Plan for the Lawrence Berkeley National Laboratory* (October 1995).

26. LBNL, *Annual Hazardous Waste Report for 2009,* Waste Management Group.

27. LBNL, *Annual Report of Waste Generation and Pollution Prevention Progress,* Waste Management Group (December 2008).

28. See Note 25 above.

29. See Note 24 above.

30. LBNL, *Corrective Measures Study Report,* Environmental Restoration Program (February 2005).

31. DTSC, *Notice of Final Decision for Corrective Measures Study Report and Remedy Selection for Lawrence Berkeley National Laboratory* (August 31, 2005). http://www.lbl.gov/ehs/erp/assets/pdfs/CMI%20Approval_Aug05.pdf.

32. LBNL, *Soil Management Plan,* Environmental Restoration Program (September 2006). http://www.lbl.gov/ehs/erp/assets/pdfs/Soil%20Management%20Plan.pdf.

33. LBNL, *Groundwater Monitoring and Management Plan,* Environmental Restoration Program (September 2006). http://www.lbl.gov/ehs/erp/assets/pdfs/Groundwater%20Management%20Plan.pdf.

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

35. *Resource Conservation and Recovery Act of 1976,* Subchapter IX, Regulation of Underground Storage Tanks, 42 USC §6991 (1988, as amended).

36. See Chapter 1, Note 4.

37. See Executive Summary, Note 3.

38. *Hazardous Waste Source Reduction and Management Review Act of 1989,* California Health and Safety Code §25244.12 *et seq.* (1989).

39. LBNL, *Source Reduction Evaluation Review Plan and Plan Summary,* Waste Management Group (2007).

40. LBNL, *Hazardous Waste Management Report Summary,* Waste Management Group (2007).

41. *Pollution Prevention Act of 1990*, 42 USC §13101 *et seq.* (1990).

42. *Clean Water Act,* 33 USC §1251 *et seq.* (1977, as amended).

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

44. EBMUD, *Wastewater Discharge Permit 06600791* (Sitewide) 7/8/07. www.lbl.gov/ehs/esg/Permit for Table/pdf/SITEWIDE.pdf; 50347891 (Groundwater Treatment System) 11/7/07. www.lbl.gov/ehs/esg/Permit for Table/pdf/Groundwater.pdf; 50238911 (Buildings 25 and 77 FTUs) 4/8/07. www.lbl.gov/ehs/esg/Permit for Table/pdf/B25 and B77.pdf.

45. CCCSD, *Class III Industrial User Permit for Joint Genome Institute* (January 2006, reissued January 2009). www.lbl.gov/ehs/esg/Permit for Table/pdf/JGI CCCSD Permit 010109.pdf.

46. California State Water Resources Control Board, *General Permit for Storm Water Discharges Associated With Industrial Activity (No. 2011002421)*, Water Quality Order 97-03-DWQ, NPDES General Permit No. CAS 000001 (1997). www.swrcb.ca.gov/water_issues/programs/stormwater/docs/indus pmt.pdf.

47. LBNL, *Storm Water Pollution Prevention Plan*, ESG, (February 2010). www.lbl.gov/ehs/esg/Reports/assets/SWPPP2010.pdf.

48. LBNL, *Alternative Storm Water Monitoring Program,* ESG, (September 2009). http://www.lbl.gov/ehs/esg/Reports/assets/ASWMP2009.pdf.

49. LBNL, *2008-2009 Annual Report for Stormwater Discharges Associated with Industrial Activity*, ESG, (June 2009). www.lbl.gov/ehs/esg/Reports/assets/AnnualReport20082009.pdf.

50. California State Water Resources Control Board, *General Permit for Stormwater Discharges Associated with Construction and Land Disturbance Activities*, Order No. 2009-0009-DWQ, NPDES No. CAS000002 (September 2, 2009). www.swrcb.ca.gov/water_issues/programs/stormwater/constpermi ts.shtml.

51. See Note 42 above.

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

53. LBNL, *Spill Prevention, Control, and Countermeasure Plan*, ESG (October 2007). www.lbl.gov/ehs/esg/Reports/assets/SPCC2007.pdf.

54. JGI, Production Sequencing Facility, *Spill Prevention, Control, and Countermeasure Plan*, LBNL ESG, (January 2009). www.lbl.gov/ehs/esg/Reports/assets/JGISPCCPlan2009.pdf.

55. See Chapter 1, Note 3.

56. *National Environmental Policy Act of 1969*, 42 USC §4321 *et seq.* (1970, as amended).

57. *California Environmental Quality Act of 1970*, Public Resources Code §21000 et seq. (1970, as amended).

58. *Federal Endangered Species Act of 1973*, 16 USC §1531 *et seq.* (1973, as amended).

59. *California Endangered Species Act,* Fish and Game Code §2050 *et seq.* (1985, as amended).

60. *National Historic Preservation Act of 1966*, 16 USC §470 *et seq*. (1966, as amended).

61. *Migratory Bird Treaty Act*, 16 USC §703 (Supp. I 1989) (1918, as amended).

Chapter 4: Environmental Monitoring

1. LBNL, *Environmental Monitoring Plan,* ESG, (September 2009). www.lbl.gov/ehs/esg/Reports/assets/EMP2009.pdf.

2. See Executive Summary, Note 7.

3. See Executive Summary, Note 6.

4. See Chapter 3, Note 10.

5. See Executive Summary, Note 6.

6. Ibid.

7. See Chapter 3, Note 46.

8. U.S. EPA, *National Primary Drinking Water Standards*, 40 CFR 141, Subpart B (1976, as amended).

9. California DPH, *Domestic Water Quality and Monitoring Regulations*, 22 CCR §64443 (1984, as amended).

10. See Note 8 above.

11. See Note 9 above.

12. California RWQCB, *San Francisco Bay Basin Plan*, Chapter 3 (January 2007). http://www.waterboards.ca.gov/sanfranciscobay/basin_planning.shtml.

13. Ibid.

14. See Chapter 3, Note 48.

15. See Chapter 3, Note 44.

16. See Executive Summary, Note 6.

17. DOE, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T (January 1991).

18. California DPH, *Standards for Protecting Against Radiation,* 17 CCR §30253 (1994, as amended).

19. See Chapter 3, Note 44.

20. U.S. Nuclear Regulatory Commission, *Standards for Protection Against Radiation,* 10 CFR 20, Subpart K (1994, as amended).

21. Ibid.

22. See Note 18 above.

23. See Chapter 3, Note 44.

24. Ibid.

25. See Notes 8 and 9 above.

26. LBNL, *Analysis of Background Distributions of Inorganic Elements in the Groundwater at Lawrence Berkeley National Laboratory*, Environmental Restoration Program (July 2002).

27. See Note 8 above.

28. See Note 9 above.

29. See Chapter 3, Note 44.

30. LBNL, *Analysis of Background Distributions of Metals in the Soil at Lawrence Berkeley National Laboratory*, Environmental Restoration Program (June 2002).

31. Ibid.

Chapter 5: Radiological Dose Assessment

1. Dobson, J.E., and E. A. Bright, *Landscan Global Population 1998 Database* (August 2002). www.ornl.gov/gist/projects/LandScan/landscandoc.htm.

2. See Executive Summary, Note 7.

3. Ibid.

4. U.S. EPA, *National Emissions Standards for Hazardous Air Pollutants (Radionuclides), Availability of Updated Compliance Model*, Federal Register, Vol. 71, No. 34, p. 8854 (February 21, 2006).

5. See Chapter 3, Note 10

6. See Executive Summary, Note 6.

7. See Executive Summary, Note 7.

8. See Executive Summary, Note 5.

9. See Executive Summary, Note 6.

10. See Executive Summary, Note 8.

11. See Executive Summary, Note 6.

12. U.S. DOE, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE Technical Standard DOE-STD-1153-2002 (August 2002).

13. U.S. DOE, RESRAD-BIOTA for Windows, Version 1.5, developed at the Environmental Assessment Division of Argonne National Laboratory for the DOE, with support from the U.S. EPA and the U.S. Nuclear Regulatory Commission, (November 18, 2009). http://web.ead.anl.gov/resrad/home2/biota.cfm.

14. See Note 12 above.

Chapter 6: Quality Assurance

1. LBNL, *Operating and Quality Management Plan*, LBNL/PUB-3111, Revision 10 (October 2008). http://www.lbl.gov/DIR/OIA/assets/docs/OCA/About%20OCA/OQMP%20Rev10-7.pdf.

2. See Chapter 4, Note 1.

3. See Chapter 4, Note 17.

4. See Executive Summary, Note 7.

5. California Code of Regulations, Title 22, Division 4, Chapter 19, *Certification of Environmental Laboratories*.

6. Lawrence Livermore National Laboratory/LBNL, *Quality Assurance and Quality Control Plan for Analytical Services* (February 2004).

7. DOE, *ES&H Operational Awareness Guide*, Berkeley Site Office (January 1998).

Glossary

1. Agency for Toxic Substances and Disease Registry, *ATSDR Glossary of Terms,* (June 21, 2004). www.atsdr.cdc.gov/glossary.html.

2. Ibid.

3. Shlein, Bernard, Lester A. Slaback, Jr., and Brian Kent Birdy, editors, *Handbook of Health Physics and Radiological Health* (Lippincott Williams and Wilkins, 1998).

4. DTSC, *Managing Universal Waste in California*, Fact Sheet, (June 2003).