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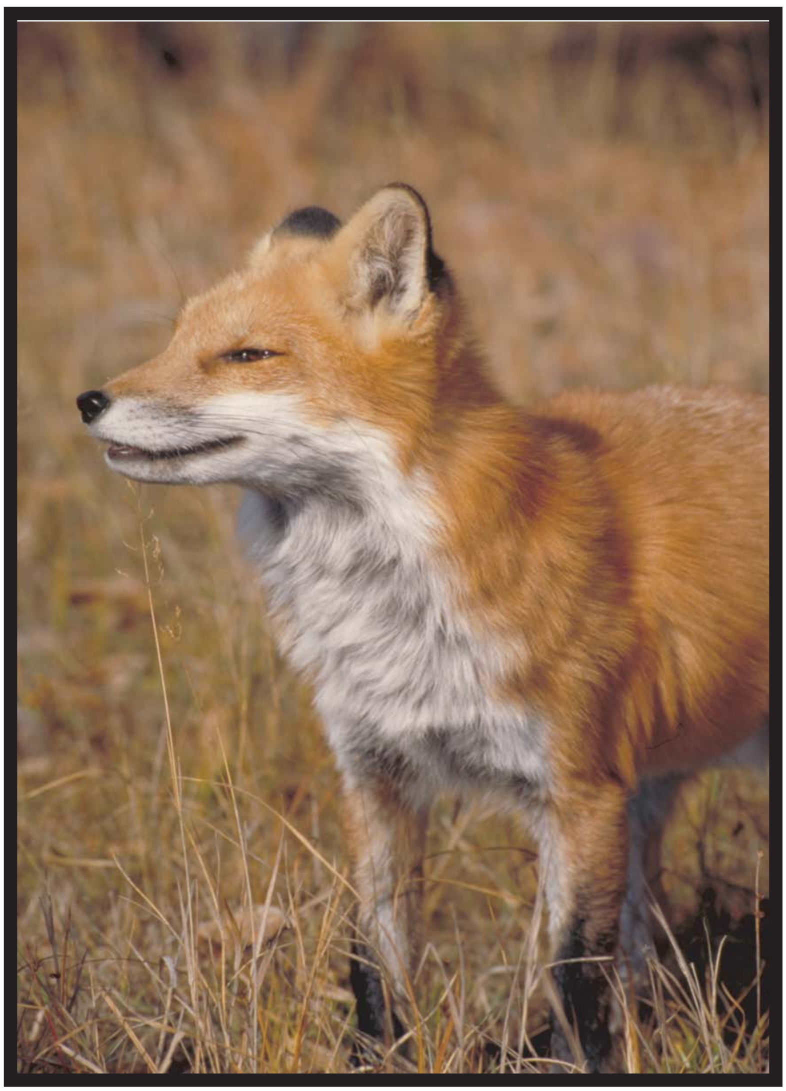
Volume I

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Site Environmental Report for 2005
Volume I

Environment, Health, and Safety Division
July 2006



Site Environmental Report for 2005

Volume I

JULY 2006

Ernest Orlando Lawrence Berkeley National Laboratory

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Preface

Each year, Ernest Orlando Lawrence Berkeley National Laboratory prepares an integrated report on its environmental programs to satisfy the requirements of United States Department of Energy Order 231.1A, *Environment, Safety, and Health Reporting*.[1] The *Site Environmental Report for 2005* summarizes Berkeley Lab's environmental management performance, presents environmental monitoring results, and describes significant programs for calendar year 2005. (Throughout this report, Ernest Orlando Lawrence Berkeley National Laboratory is referred to as "Berkeley Lab," "the Laboratory," "Lawrence Berkeley National Laboratory," and "LBNL.")

The report is separated into two volumes. Volume I contains an overview of the Laboratory, the status of environmental programs, and summarized results from surveillance and monitoring activities. This year's Volume I text body is organized into an executive summary followed by six chapters. The report's structure has been reorganized this year, and it now includes a chapter devoted to environmental management system topics. Volume II contains individual data results from surveillance and monitoring activities.

The *Site Environmental Report* is distributed by releasing it on the Web from the Berkeley Lab Environmental Services Group (ESG) home page, which is located at http://www.lbl.gov/ehs/esg/. Many of the documents cited in this report also are accessible from the ESG Web page. CD and printed copies of this *Site Environmental Report* are available upon request.

The report follows the Laboratory'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: the first defines the prefixes used with SI units of measurement, and the second provides conversions to non-SI units.

Readers are encouraged to comment on this report by completing the survey form in the Web version of the report. Questions regarding this report can be directed to Michael Ruggieri (by telephone at 510-486-5440; or by e-mail at mrruggieri@lbl.gov). This report was prepared under the direction of Michael Ruggieri of ESG. The primary authors are Robert Fox, Iraj Javandel, John Jelinski, Ron Pauer, Michael Ruggieri, Patrick Thorson, and Linnea Wahl. Other key contributors include Steve Wyrick (Volume II and illustration support), Teresa Grossman (word processing and illustration support), Netty Kahan (technical editing), and John Jelinski (photography).

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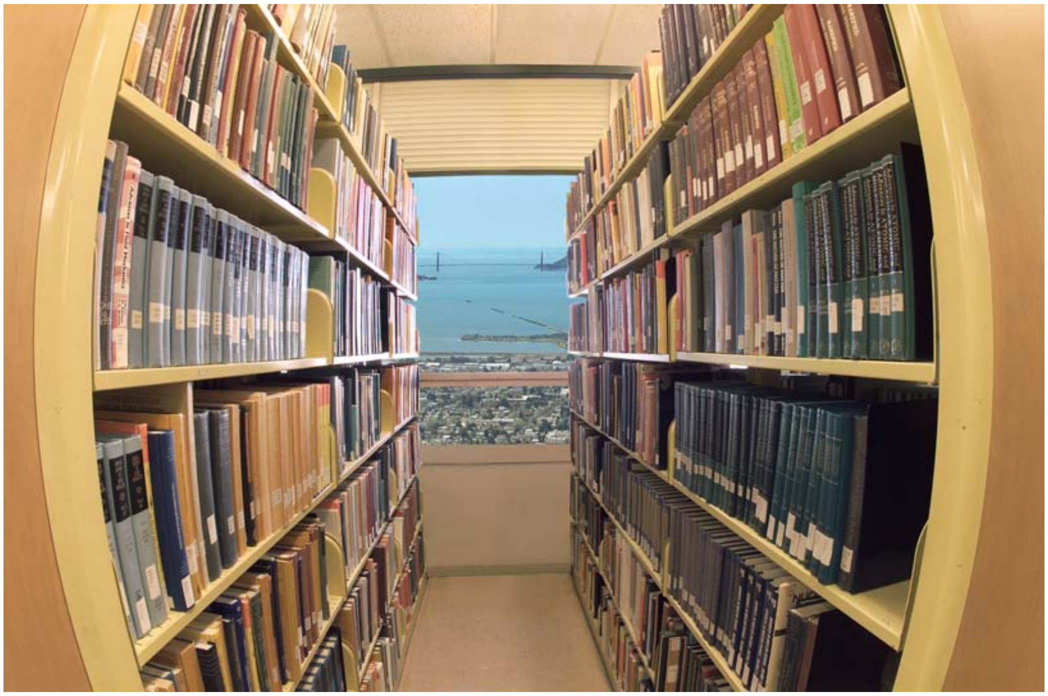
Executive Summary



Looking out from the main Berkeley Lab library

Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multiprogram scientific facility operated by the University of California for the United States Department of Energy (DOE). The Laboratory's research is directed toward the physical, biological, environmental, and computational sciences—in order to deliver the scientific knowledge and discoveries pertinent to DOE's missions.

This annual *Site Environmental Report* covers activities conducted in calendar year (CY) 2005. 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 the University of California Office of the President (UCOP) and DOE.[2]

INTEGRATED SAFETY MANAGEMENT AND ENVIRONMENTAL MANAGEMENT SYSTEM

Berkeley Lab employs Integrated Safety Management (ISM), which is a DOE management system that applies the following core EH&S functions to all Laboratory 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

Laboratory activities are planned and conducted with full regard to protecting the public and the environment and complying with appropriate environmental laws and regulations.

In 2005, Berkeley Lab completed development of a performance-based Environmental Management System (EMS), which is integrated with the Laboratory's ISM System. When practical, the existing processes used for ISM were used to support and implement environmental performance improvement and compliance management. New processes were developed to support the EMS where needed.

OPERATING PERMITS, INSPECTIONS, AND INCIDENTS IN 2005

- At the end of the year, Berkeley Lab held 49 environmental operating permits from various regulatory agencies for air and water quality protection and hazardous waste handling.
- Eighteen inspections of Berkeley Lab's environmental programs occurred during the year. One minor violation related to the chemical inventory was received following an inspection by the City of Berkeley on August 2-4.*
- Two environmental incidents were reportable during the year under the DOE occurrence-reporting program,[3] which is used to track incidents across the DOE complex.
    1. As a result of an inspection by the City of Berkeley on August 2-4,* the Laboratory received a minor violation on August 30 for a 300% increase in argon gas cylinders that was not reflected in the chemical inventory of Building 70A.
    2. On September 29, metallic mercury was discovered encased in a hard layer of sediment at the bottom of a catch basin while it was being cleaned out using a vacuum extractor. The amount of mercury found in the catch basin was calculated to be 1.32 kilograms (kg) (2.9 pounds [lb]), which exceeded the federal reportable quantity for mercury of 0.45 kg (1 lb).

For additional information on operating permits, inspections, and incidents, see Chapter 3.

PERFORMANCE EVALUATION

Each year, UCOP and DOE perform an assessment of Berkeley Lab's environmental program, using measures developed jointly by Berkeley Lab, UCOP, and DOE. For fiscal year 2005 (October 1, 2004–September 30, 2005), environmental protection was included in the performance measure for overall Integrated Safety Management System effectiveness.[4] Berkeley Lab achieved an "excellent" rating in this measure and the maximum score possible on the environmental protection portion.

* Error in the inspection date was corrected on August 2, 2006.

ENVIRONMENTAL MONITORING AND DOSE ASSESSMENT

Berkeley Lab's environmental monitoring program serves several purposes:

- To demonstrate that Laboratory activities operate within regulatory and DOE requirements
- To provide a historical record of any Laboratory impacts on the environment
- To support environmental management decisions
- To provide information on the effectiveness of emission control programs

Environmental radiological measurements are performed to assess the maximum potential dose to members of the public. In addition, both radiological and nonradiological constituents are monitored in the environment and compared to regulatory and DOE limits.

To assess dose to the public resulting from Laboratory operations, three types of environmental radiation are measured:

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

In 2005, the maximum dose to a member of the public from penetration radiation was below detection limits and indistinguishable from the average United States background, 3.6 millisieverts (mSv) (360 millirem [mrem]).[5] The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in CY 2005 was 0.00019 mSv (0.019 mrem). This is 0.2% of the United States Environmental Protection Agency dose limit for dispersible radionuclide emissions (0.10 mSv [10 mrem]).[6]

Berkeley Lab also estimates the cumulative dose impact (population dose) from its dispersible radionuclide emissions 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 80 km of the Laboratory. The population dose for CY 2005 from dispersible radionuclide emissions was estimated at 0.0017 person-sievert (0.17 person-rem). No regulatory standard exists for this measure.

During the year, monitoring results for wastewater, stormwater, creek water, rainwater, soil, sediment, vegetation, and groundwater were within regulatory limits.

- Monitoring results for metals, chlorinated hydrocarbons, radionuclides, and other specified parameters in sanitary sewer discharges were well within compliance limits for wastewater discharge permits[7] issued to the Laboratory by the East Bay Municipal Utility District.

- Berkeley Lab stormwater, regulated under a general permit[8] issued by the State Water Resources Control Board, was monitored for pH, oil and grease, total suspended solids, radionuclides, and metals; and all results were below or near analytical detection limits, or within urban background levels.
- Creeks and rainwater were monitored for radionuclides, and results were below or near detection limits. In addition, creeks were monitored for metals, volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs). Metal results were consistent with regional background levels. Results for VOCs and PCBs were all below detection limits.
- Soil samples were analyzed for radionuclides, metals and pH. Sediment samples were analyzed for radionuclides, metals, petroleum hydrocarbons, and PCBs. Most results were below or near analytical detection limits, or at natural background levels for the Berkeley Lab site.[9] Petroleum hydrocarbons in sediment samples were slightly elevated, but typical for an urban setting. The level of mercury in soil at one location was slightly above established background values at the Berkeley lab site, but below regulatory limits.
- Vegetation results for tritium decreased from previous levels or were below detection limits, confirming that vegetation tritium levels have continued to decrease since the closure of the National Tritium Labeling Facility.
- Extensive groundwater monitoring has been conducted by Berkeley Lab since the early 1990s; nine principal groundwater contamination plumes have been identified, all of which are on-site. The groundwater in the vicinity of the Laboratory is not used as a source for public drinking water. Conducted under the requirements of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program, an evaluation of potential cleanup measures has been performed. The Department of Toxic Substances Control (DTSC) issued its *Notice of Final Decision for the Approval of the Corrective Measures Study Report and Remedy Selection* on August 31, 2005.[10] The *RCRA Corrective Measures Implementation Workplan*[11] was subsequently submitted to DTSC on November 10, 2005. The Laboratory continues to monitor these plumes while it develops long-term strategies to address the contamination. Berkeley Lab has initiated several interim corrective-action measures to remediate the contaminated media or prevent movement of contamination until the Laboratory can implement the long-term strategies. Concentrations of groundwater contaminants, along with other program developments and planned activities, are reported quarterly to regulatory agencies.

For more details on environmental monitoring conducted in 2005, see Chapter 4.

1

Introduction

LBNL (outlined) is located next to a university campus

1.1 HISTORY

Lawrence Berkeley National Laboratory 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 the Laboratory, leading to the awarding of Nobel Prizes to eight more Berkeley Lab scientists.

The Laboratory supports work in such diverse fields as genomics, physical biosciences, 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. Its research embraces the following concepts to align with the United States Department of Energy (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 the University of California (UC) Office of the President. 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 the Laboratory. High school students and teachers, as well as college and graduate students, participate in many Berkeley Lab programs designed to enhance science education.

1.2 LABORATORY

The following sections describe the physical location, population, space distribution, and water supply at Berkeley Lab.

1.2.1 Location

Berkeley Lab is located about 5 kilometers (km) (3 miles [mi]) east of San Francisco Bay (see Figure 1-1) on land owned by the University of California. The Laboratory's main site is situated on approximately 82 hectares (203 acres) of this land. University of California provides long-term land leases to the DOE for the buildings at the Laboratory.

The main site lies in the hills above the UC Berkeley campus, on the ridges and draws of Blackberry Canyon (which forms the western part of the site) and adjacent Strawberry Canyon

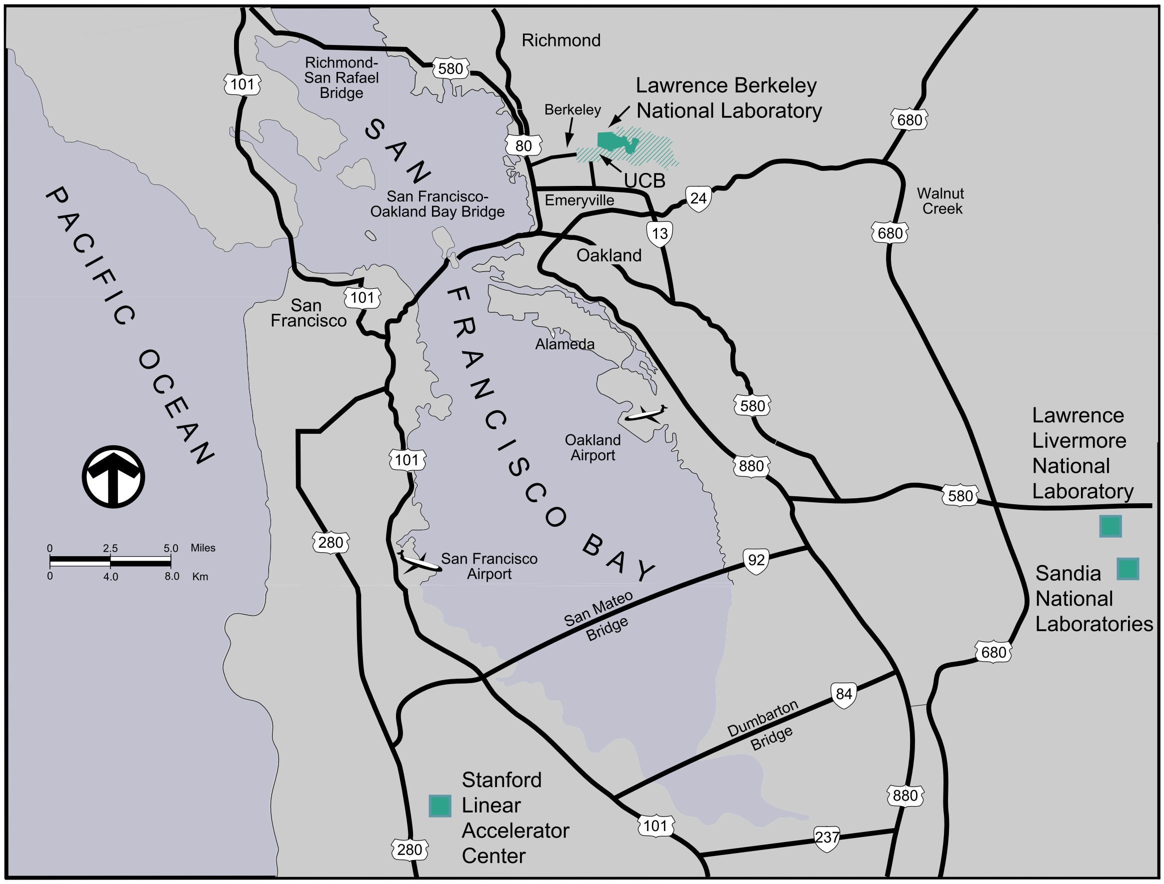


Figure 1-1 San Francisco Bay Area Map

(which forms the eastern part of the site), with elevations ranging 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 population of Berkeley is estimated at 102,743, and that of Oakland at 370,736.[1]

Adjacent land use consists of residential, institutional, and recreation areas (see Figure 1-2). The area to the south and east of the Laboratory, which is University land, is maintained largely in a natural state but includes UC Berkeley's Strawberry Canyon Recreational Area and Botanical Garden. Northeast of the Laboratory are the University's Lawrence Hall of Science, Space Sciences Laboratory, and Mathematical Sciences Research Institute. Berkeley Lab is bordered on the north by single-family homes and on the west by the UC Berkeley campus, as well as by multiunit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.

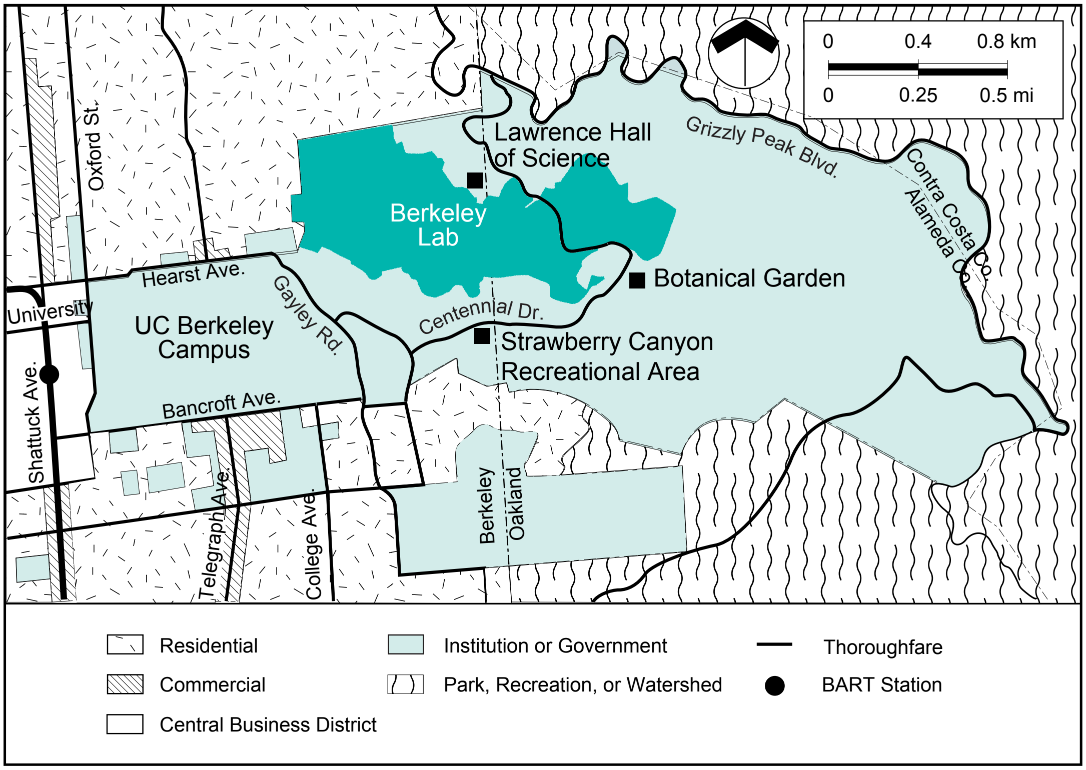


Figure 1-2 Adjacent Land Use

1.2.2 Population and Space Distribution

Approximately 3,000 scientists and support personnel and 1,400 students work at Berkeley Lab. In addition, the Laboratory hosts 3,200 participating guests each year, who use its unique scientific facilities for varying lengths of time. Berkeley Lab also supports 300 scientists and staff at off-site locations, including Walnut Creek, Oakland, Berkeley, and Washington, D.C. Approximately 300 of the Laboratory's scientists serve as faculty members at UC Berkeley and UC San Francisco.[2]

Berkeley Lab research and support activities are conducted in structures having a total area of 201,000 gross square meters (gsm) (2.17 million gross square feet [gsf]). About 79% of the total space is at the main site, about 4% is on the UC Berkeley campus (i.e., Donner and Calvin Laboratories), and the remaining approximate 17% is located in the various other off-site leased buildings. Figure 1-3 shows the Berkeley Lab space distribution.[2]

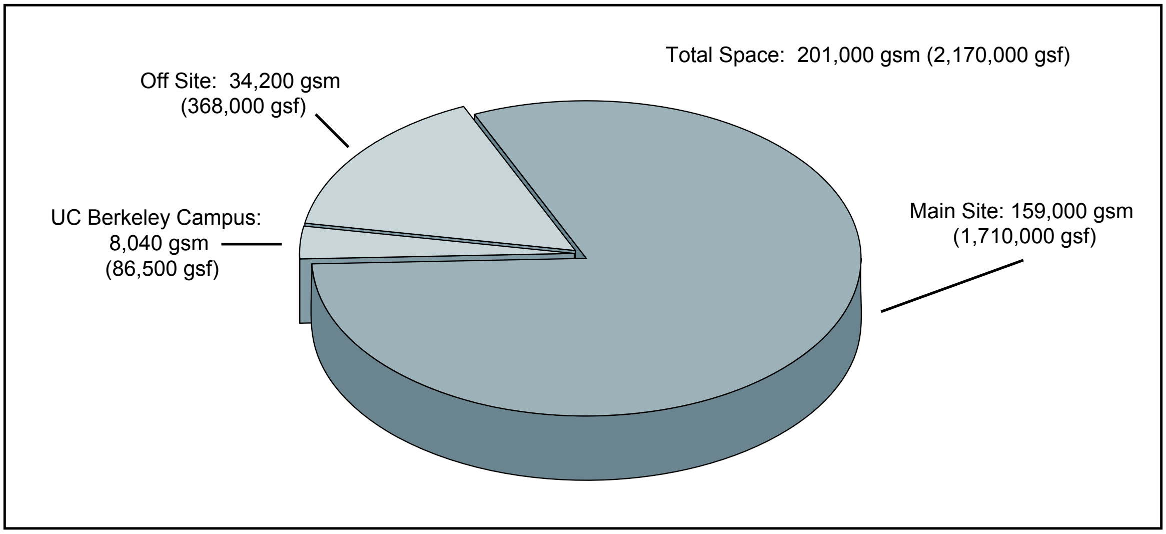


Figure 1-3 Space Distribution

1.2.3 Water Supply

All domestic water for the Laboratory'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 for contaminants and meets disinfection standards required by the Safe Drinking Water Act.[3]

1.3 ENVIRONMENTAL SETTING

The following sections describe the meteorology, vegetation, wildlife, geology, and hydrogeology at Berkeley Lab.

1.3.1 Meteorology

The climate of the site 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 from more than 30 years of records at Berkeley Lab is more than 77 centimeters (cm) (30.5 inches [in]) of rain for 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.

On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the bay, followed by lighter nighttime southeasterly winds originating in 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, a graphical summary of the annual wind patterns (called a "wind rose"), illustrates the frequency of the two predominant wind patterns.

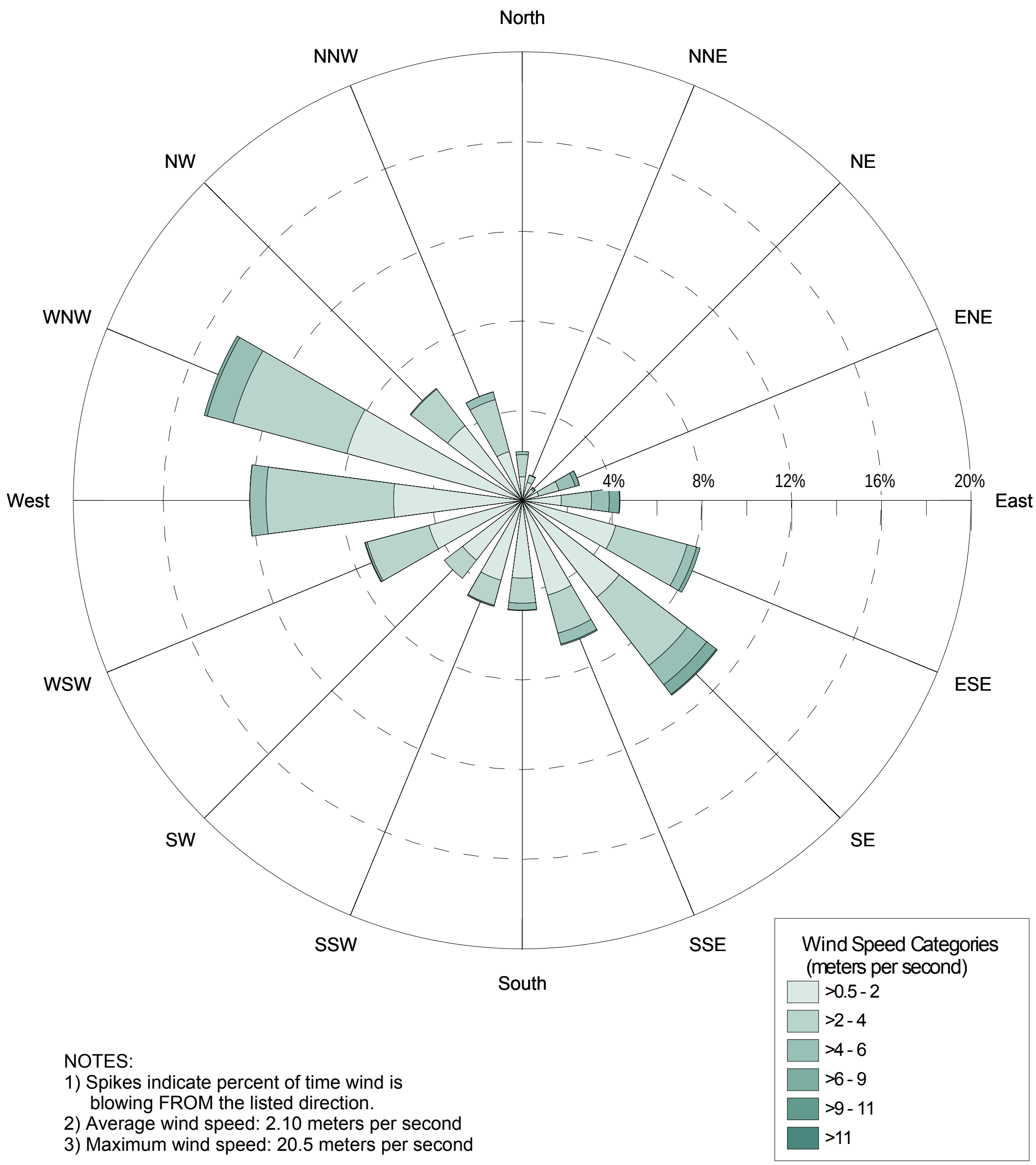


Figure 1-4 Annual Wind Patterns

1.3.2 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 the Laboratory at this site in the late 1930s. At the main site, the Laboratory manages on-site vegetation so that it is coordinated 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 does not have any rare, threatened, or endangered species of plants present. Figure 1-5 shows the vegetation types and locations on-site.

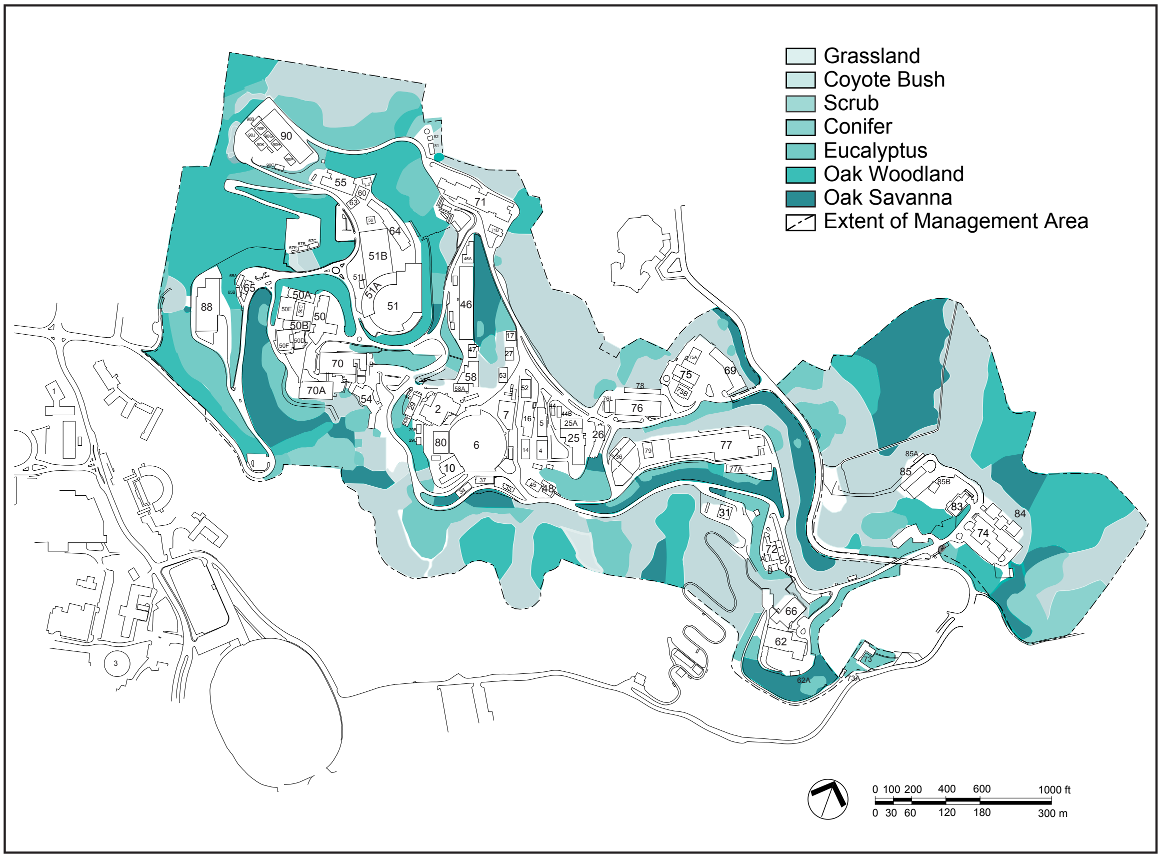


Figure 1-5 Vegetation Types (Map Revised 1999)

The Lab's main site is managed to minimize wildland fire damage to structures. The vegetation management program is designed to reduce the potential flame heights of groundcover 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 annual vegetation management area

These vegetation management (fuel reduction) efforts will substantially reduce the intensity of any future fire storm. Not only would Laboratory buildings more likely survive such a fire, but the lower-intensity fire conditions at the Laboratory would allow regional fire fighters to suppress the flame front before it would proceed to the west of the Laboratory.

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 the larger area.

1.3.3 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 the University of California. Wildlife that frequents the Laboratory 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, and reptiles/amphibians are thought to exist on the site. The most abundant large mammal is the Columbian black-tailed deer.

A portion of the site is on the periphery of a 165,000-hectare (407,000-acre) zone designated by the United States Fish and Wildlife Service (USF&WS) in 2000 as critical habitat for the Alameda whipsnake, which previously was designated as “threatened” pursuant to the Federal Endangered Species Act (FESA).[4] However, a recent federal court decision has vacated the USF&WS rule regarding the habitat designation. Consequently, currently there is no critical habitat for the Alameda whipsnake. Even so, the Laboratory continues to take appropriate precautions during its construction projects.

1.3.4 Geology and Hydrogeology

Three geologic formations underlie the majority of the site. These formations and their properties are described below:

- The western and southern parts of Berkeley Lab are underlain by marine siltstones and shales of the Great Valley Group. It consists primarily of low-permeability rock with moderately spaced open fractures that allow for groundwater movement. The hydraulic conductivity (measure of the rate at which water can move through a permeable medium) ranges between approximately 10^{-5} and 10^{-8} meters per second (m/s) (3.3 x 10^{-5} and 3.3 x 10^{-8} feet per second [ft/s]).
- River-deposited sediments of the Orinda Formation overlie the Great Valley Group and underlie most of the developed area of the site. The Orinda Formation consists primarily of low-permeability rock with closed fractures that inhibit groundwater movement. The hydraulic conductivity generally ranges between approximately 10^{-7} and 10^{-12} m/s (3.3 x 10^{-7} and 3.3 x 10^{-12} ft/s); although, the hydraulic conductivity may be greater where coarser materials are present. The Orinda Formation typically has lower values of hydraulic conductivity than the underlying Great Valley Group or overlying Moraga Formation, and therefore impedes the horizontal and vertical flow of groundwater.

- Ancient landslide deposits from the Moraga Formation underlie most of the higher elevations of Berkeley Lab, as well as much of the central developed area ("Old Town"). These deposits constitute the main water-bearing unit at Berkeley Lab. The hydraulic conductivity of the Moraga Formation is relatively high, generally ranging between 10^{-4} and 10^{-6} m/s (3.3 x 10^{-4} and 3.3 x 10^{-6} ft/s). Although the permeability of the rock matrix is low, groundwater flows readily through the numerous open fractures. The presence of low-permeability interbeds of fine-grained sediments, as well as zones with little fracturing, creates perched water conditions at many locations.

The Claremont Formation and San Pablo Group underlie the easternmost area of the site. The Claremont Formation consists of chert and shale. The San Pablo Group consists of marine sandstones.

The surficial geology consists primarily of colluvium and fill. Weathered detritus from the bedrock units has accumulated as soil deposits, generally from one to several meters thick. Because of the hilly terrain, up to tens of meters of cuts and fills have been necessary to provide suitable building sites.

The active Hayward Fault, a branch of the San Andreas Fault System, trends northwest to southeast along the base of the hills at Berkeley Lab's western edge. The inactive Wildcat Fault traverses the site north to south along the canyon at the Laboratory's eastern edge. In addition to the faulting, landsliding and tilting of the rock units underlying the site have helped to develop a complex geological structure.

Groundwater is a concern at the Laboratory because of its potential effect on slope stability and on the underground movement of contaminants (see Section 4.4). The water table depths vary from approximately 0 to 30 m (98 ft) below the surface across the site. During the past 20 years, the Laboratory 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.

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2

Performance-Based Environmental Management System

The recently constructed Molecular Foundry building for nanoscale research, which was built to Leadership in Energy and Environmental Design silver criteria

2.1 SUMMARY

To continually improve environmental stewardship, Berkeley Lab has established a performance-based Environmental Management System (EMS)—a systematic approach to ensuring that environmental activities are well managed and provide business value. This approach includes those components of the ISO 14001 EMS[1] standard that provide real and tangible business value— which allows the Laboratory to focus resources on those activities that have important environmental benefits, while maintaining and building on the strengths of the current environmental compliance programs. The goals of the Laboratory's EMS are the following:

- Compliance with applicable environmental and public health laws and regulations
- Prevention of pollution and conservation of natural resources
- Continual improvement of the Laboratory's environmental performance

In addition, United States Executive Order 13148, *Greening the Government through Leadership in Environmental Management,*[2] required all federal agencies to implement an EMS by December 31, 2005. DOE Order 450.1, *Environmental Protection Program,*[3] established the EMS requirement for all DOE facilities and mandated that the EMS be integrated with existing Integrated Safety Management (ISM) systems.

In 2005, an EMS Core Team—composed of representatives from Berkeley Lab's Environment, Health, and Safety (EH&S), Facilities, and Procurement organizations— worked on the following implementation tasks:

- **Identification of aspects and impacts.** Environmental aspects (activities or services that may produce a change to the environment) resulting from Laboratory operations were identified. The impacts associated with each aspect also were determined, and each aspect was then ranked according to its environmental significance.
- **Development of objectives and targets.** The seven activities with the most significant impacts were selected, and objectives and targets were developed for reducing their environmental impacts:
    1. Commute traffic to and from Laboratory
    2. Diesel particulate matter
    3. Electronic waste
    4. Energy-efficient buildings
    5. Low-level radioactive waste
    6. Procurement of environmentally friendly products
    7. Vehicle fleet petroleum use
- **Preparation of Environmental Management Programs (EMPs).** Seven EMPs were prepared that summarize how the objectives and targets will be achieved, including time scales and personnel responsible for implementing the appropriate actions.
- **Assessments.** The EMS program was reviewed by Berkeley Lab's Office of Assessment and Assurance (OAA), and then by NSF International Strategic Registrations, Ltd., to determine (1) whether all programmatic activities were completed and (2) the level of

effectiveness of the program. On November 16, 2005, NSF issued a Citation of Conformance that validated Berkeley Lab's implementation of an EMS.

Based on the strength of the Laboratory's EMS and the results of these assessments, on December 28, 2005, the DOE Berkeley site manager, Aundra Richards, sent a letter to DOE's Office of Science director, Raymond Orbach, confirming that the EMS fully conforms to EMS requirements in DOE Order 450.1.

2.2 BACKGROUND

Neither Executive Order 13148 nor DOE Order 450.1 required that the organization's EMS meet a recognized standard, such as the ISO 14001 standard for EMSs. Robert Card, former undersecretary of Energy, Science, and Environment, had established operating principles for improving contractor performance. These principles allow for the use of alternative approaches, processes, standards, and methodologies in lieu of those otherwise set forth in a DOE order. They permit customized approaches that would accomplish DOE objectives in a manner more appropriate to the particular conditions and circumstances at a contractor-managed site.

In 2002, before Berkeley Lab had developed its EMS approach, an analysis was performed to identify whether gaps existed between then-current programs and systems and each element required by an ISO 14001 EMS. Relevant Berkeley Lab documents were reviewed, and appropriate program managers were interviewed. The results from the analysis indicated where deficiencies existed for each element. Potential actions required to address each gap were identified, and each element was evaluated for its significance in assuring environmental compliance and improving environmental performance.

Consistent with the Card principles for improving contractor performance, Berkeley Lab developed and implemented a performance-based EMS—a systematic approach to ensuring that environmental stewardship activities are not only well managed but also provide business value. Accordingly, the EMS was based on the work, the environment in which the work is performed, and the hazards or risks associated with the work at the Laboratory. The performance-based approach includes those components of ISO 14001 that provide real and tangible business value— rather than simply all the components of an ISO 14001–type of EMS, regardless of value. This approach allows Berkeley Lab to focus resources on those activities that have a more valuable and stronger environmental benefit and to maintain the current strengths of the environmental compliance programs.

A system was established that incorporated an annual cycle of planning, implementing, evaluating, and improving processes and actions to achieve the EMS goals (see Figure 2-1).

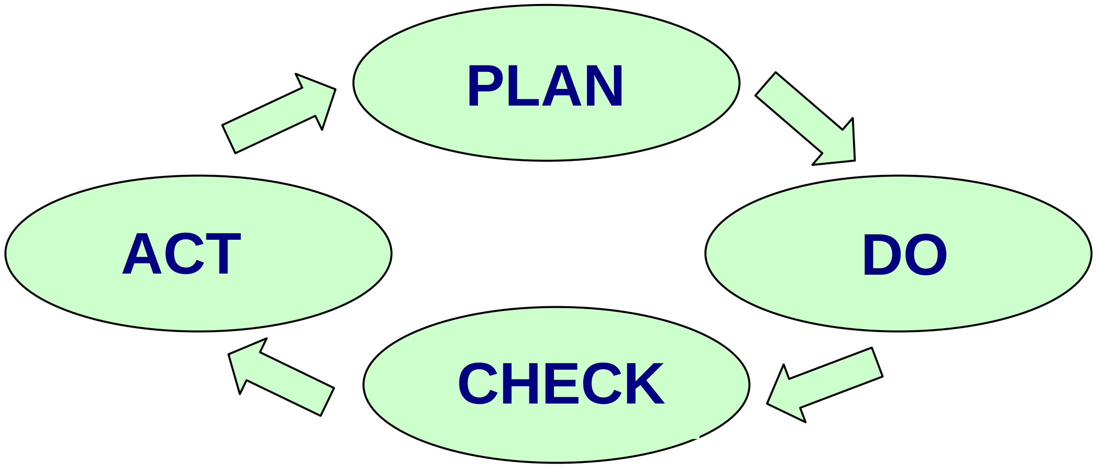


Figure 2-1 Cycle of Activities That Are Performed to Achieve EMS Goals

Berkeley Lab's EMS program was documented in the *Performance-Based Environmental Management System Plan.*[4] This document, as well as other EMS-related documentation, is available at the following Web site: http://www.lbl.gov/ehs/esg/emsplan/emsplan.htm.

2.3 INTEGRATION OF EMS INTO ISM

The EMS has been integrated with the Laboratory's ISM system. To the extent that it has been practical, ISM processes have been used to support environmental performance improvement and compliance management. Where it has been impractical, new processes were developed to support the EMS and were integrated with the ISM.

Both the EMS and ISM strive for continual improvement, through a plan-do-check-act cycle. 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.

The major elements of an EMS consist of the following: an environmental policy statement (part of Berkeley Lab's EH&S policy statement); planning; implementation and operation; checking and corrective action; and management review. Table 2-1 shows the parallels between the major elements of the EMS and the core functions of the ISM.

Table 2-1 EMS and ISM Comparison

	Environmental Management System	Integrated Safety Management System
PLAN	Planning	Analyze hazards
DO	Implementation and operation	Development and implementation of hazard controls
CHECK	Checking and corrective action	Providing of feedback and continuous improvement
ACT	Management review	Annual ISM review

2.4 IMPLEMENTATION

The keys to the implementation of the Laboratory's performance-based EMS program are in the following six areas:

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

Each of these key areas is described below.

2.4.1 EMS Core Team

The Core Team has been established to design, implement, and maintain an EMS to manage environmental compliance matters and to reduce environmental impacts over time. It consists of key representatives from the EH&S, Facilities, and Procurement organizations that are most knowledgeable of environmental management concerns; and the team is led by a representative of the EH&S organization. As issues arise, other organizations are consulted or brought into the team; similarly, input from other groups (e.g., the Laboratory's Safety Review Committee or Division Safety Coordinators) is solicited through designated Core Team representatives. A representative from the DOE Berkeley Site Office also attends the meetings, to maintain an operational awareness of the EMS Core Team activities. The following are some of the key functions of the Core Team:

- Identification of environmental aspects
- Identification of significant impacts
- Development of objectives and targets for the selected significant aspects
- Preparation and implementation of the EMPs
- Evaluation of all EMPs annually
- Coordination of internal assessments of the EMS
- Review of performance results
- Preparation of recommendations to management on improvements to the EMS
- Coordination of the annual management review of the EMS

2.4.2 Environmental Aspects

Each year the Core Team identifies environmental aspects: activities or services that may produce a change to the environment—whether adverse or beneficial—resulting wholly or partially, immediately or gradually, from Berkeley Lab operations. Consideration is given to activities that involve waste generation and recycling, emissions and discharges to the environment, materials/resources use, and land/building development and use. A worksheet of these aspects and associated impacts is created and maintained. In addition, the Core Team determines the significance of each aspect's potential impact, using the following factors of the impact to shape its decisions:

- Severity
- Duration
- Probability of occurrence
- Scale
- Cost of addressing
- Effect on public image
- Effect on other activities
- Potential legal exposure
- Potential for improvement

Each impact is 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 impact are determined and used to provide a starting point for the significance determination. Before this list is finalized, the Core Team and other related employees perform further evaluations of these identified aspects/impacts, which affect the significance determination.

2.4.3 Environmental Management Programs

Each significant aspect selected by the Core Team has objectives and targets assigned to reduce or improve the associated environmental impacts. These are formally documented in an EMP. An EMP establishes goals and strategies, actions to achieve goals, and resource needs; develops procedures, metrics, or techniques; and sets up schedules. An EMP leader is selected from the Core Team members to monitor the performance of each EMP. A program schedule may be prepared to help the EMP leader track the status of various EMP-related actions.

2.4.4 Training

In Berkeley Lab's EMS approach, training is targeted and graded, commensurate with the EMS activity. There are four types of training:

1. General EMS awareness
2. Comprehensive EMS awareness
3. EMS implementation
4. EMS auditor

2.4.5 Appraisals

The EMS program and activities will have an annual internal assessment performed. The review will determine whether the EMS activities conform to the requirements of the Laboratory's EMS program plan and whether it has been properly implemented and maintained. Suggestions will be made for corrective action and opportunities for improvement. Additionally, the assessors may review the performance of the EMPs. The results of the internal review will be discussed with the EMS Core Team, and the Team will determine what actions are necessary to address the assessment findings. The results of the internal assessment will also be presented to a Berkeley Lab senior management team during the annual management review meeting. On a three-year cycle, a third-party audit team will be retained to determine whether the Laboratory's EMS activities conform to the requirements of the EMS Plan and it has been properly implemented and maintained. The team will consist of a subject–matter expert, or team of experts, that are knowledgeable of EMS requirements and have experience with the implementation of EMSs in research facilities. Representatives from DOE will be invited to participate as observers on the team. The findings will be presented to the EMS Core Team, and the Team will determine the appropriate set of corrective actions. The results of the validation audit will also be presented to a Berkeley Lab management team at the next normally scheduled management review session. A special management review may be convened if the validation audit determines that significant weaknesses in the program require their attention. All significant findings will be tracked using the Laboratory's Corrective Action Tracking System.

2.4.6 Management Review

The status of the EMS is reviewed annually by a Berkeley Lab senior management team as appropriate for the activities involved. The review will include progress in achieving EMS objectives and targets as well as the results of EMS internal and external reviews. Based on this review, the Laboratory's management may determine changes 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 to make changes to the program.

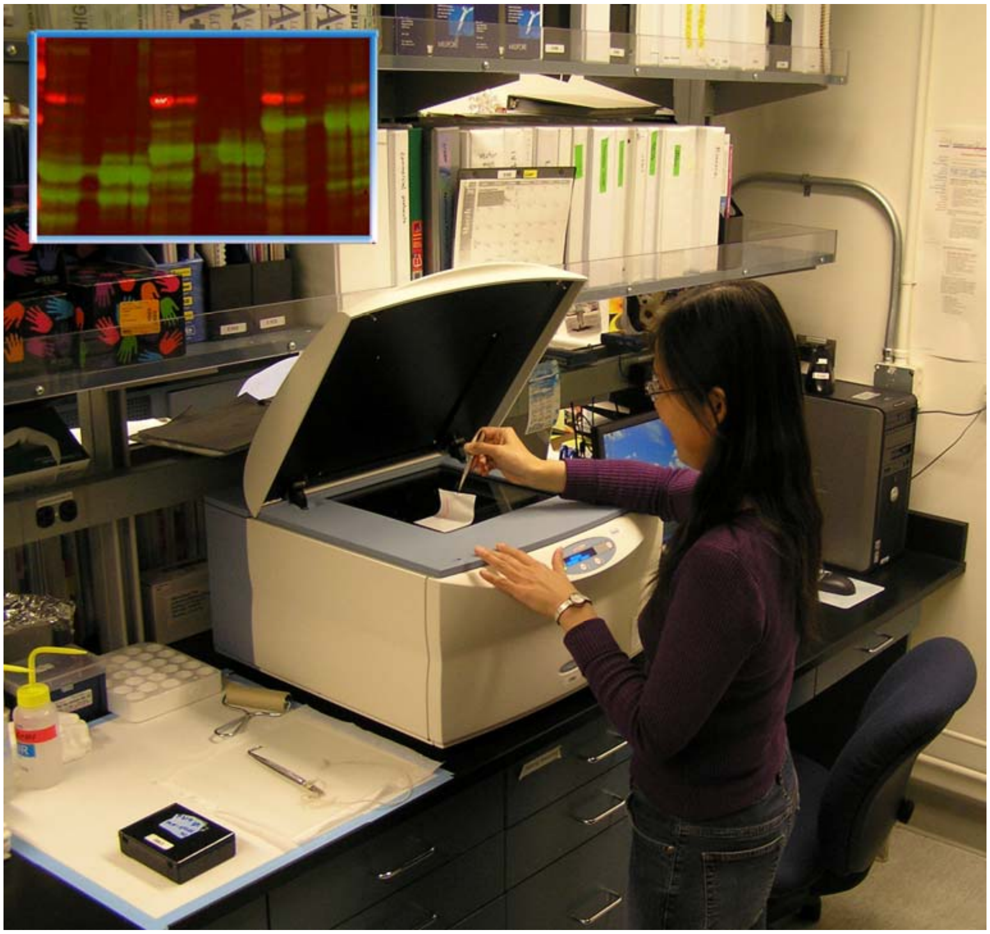
2.5 2005 ENVIRONMENTAL MANAGEMENT PROGRAMS

Based on the EMS Core Team's review of environmental aspects and impacts, seven areas were identified for potential improvement. In each case, objectives and targets were developed and an EMP established to improve the Laboratory's environmental performance in the specific area. Table 2-2 summarizes the projects that were undertaken in 2005.

Table 2-2 Environmental Management System Projects Undertaken in 2005

PROJECT	OBJECTIVE	ACCOMPLISHMENT(S)
Diesel Particulate Matter (DPM)	Study DPM emission reduction measures–DPM currently accounts for about 95% of the projected maximum off-site risk from air emissions	Prepared an inventory of stationary and mobile DPM sources; collected and compiled relevant information; determined alternatives and costs for reducing emissions
Electronic Waste	Minimize the generation of electronic waste, primarily computer equipment that contains lead, silver, mercury, and other hazardous materials	Investigated the viability of a computer take-back program; determined that current recycling program is effective and efficient
Energy-Efficient Buildings	Demonstrate leadership in energy-efficiency and environmentally sustainable building design	Incorporated Leadership in Energy and Environmental Design (LEED) standards into the Project Design Requirement document
Fleet Petroleum Use	Reduce vehicle fleet petroleum consumption	Compiled and analyzed fuel (gasoline, diesel, biodiesel) usage data and vehicle usage data; developed vehicle acquisition strategy that includes switching light trucks to sedans, switching high-mileage vehicles to alternative fuel vehicles (AFV), and acquisition of AFV or fuel-efficient vehicles
Green Purchasing	Increase procurement of energy-efficient products and products made with recycled material	Trained buyers on “green” purchasing; modified procurement software to highlight and track green products; and tabulated purchases of Energy Star products and products with recycled content
Low-Level Radioactive Waste	Continue to minimize the generation of low-level radioactive waste	Assessed opportunities for reducing low-level radioactive waste; selected digital imaging equipment; completed a Return on Investment analysis; prepared funding request and received approval
Traffic	Reduce Laboratory commute traffic by optimizing mass transit opportunities	Conducted a readership survey to identify improvements for the bus system; began reviewing options to increase use of mass transit

One of the most notable accomplishments was the acquisition of two filmless digital imagers used in research applications by the Life Science Division at Berkeley Lab. Previous research methods used to assay DNA, RNA, and proteins generated significant quantities of photochemical and low-level-radioactive waste at a considerable disposal cost. A Return on Investment analysis had determined that the use of newer, filmless digital imaging methods would result in a payback period of between two to three years. As a result, funding for the equipment was requested and eventually approved. One of the two imagers is shown below.



The Li-Cor Image Station 4000MM and a typical image (inset) produced during a protein assay

2.6 ENVIRONMENTAL MANAGEMENT PROGRAMS FOR 2006

Consistent with the goal of continual progress, Berkeley Lab's environmental aspects and impacts are reviewed annually. Areas for environmental improvement are also reassessed annually based on this review. As a result, the set of EMPs will likely change as existing ones are completed, discontinued, or modified, and as new ones are added. For 2006, nine areas for advancement were identified as summarized in Table 2-3.

Table 2-3 Environmental Management Programs for 2006

PROJECT	OBJECTIVE
Building Retro-Commissioning	Prepare study to reduce electrical and natural gas use at Building 6
Commute Traffic	Prepare study to reduce Laboratory commute traffic
Diesel Particulate Matter	Reduce diesel particulate matter emissions from mobile and stationary sources
Dolphin System	Reduce water and chemical use in cooling tower at Building 37
Electricity Use	Reduce electricity use throughout site
Fleet Petroleum Use	Maintain vehicle fleet's petroleum consumption below 20% of 1999 levels
Green Purchasing	Increase procurement of Energy Star Products and Recycled Content Products
Natural Gas Use	Reduce natural gas use throughout site
Sealing HVAC Ducts	Reduce electrical and natural gas use at Buildings 50 and 70 complexes

3

Environmental Program Summary

Vapor Extraction System, near Building 53, used by the Environmental Restoration Program

3.1 INTRODUCTION

This chapter provides an overview of Lawrence Berkeley National Laboratory's environmental protection program, reviews the status of various compliance programs and activities, and presents measures of the Laboratory's environmental performance in key areas for calendar year (CY) 2005.

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 ISM. Applying ISM to the Laboratory activities involves the performance of five core functions (http://www.lbl.gov/ehs/pub811/principles.html):[1]

- 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 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 Laboratory. The organizational structure of EH&S as of the end of CY 2005 is shown in Figure 3-1.

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

1. The Environmental Services Group (ESG) oversees sitewide air and water quality compliance activities, provides technical assistance to Laboratory 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.)
2. The Waste Management Group manages hazardous, medical, radioactive, mixed (hazardous and radioactive) and universal waste generated at the Laboratory.

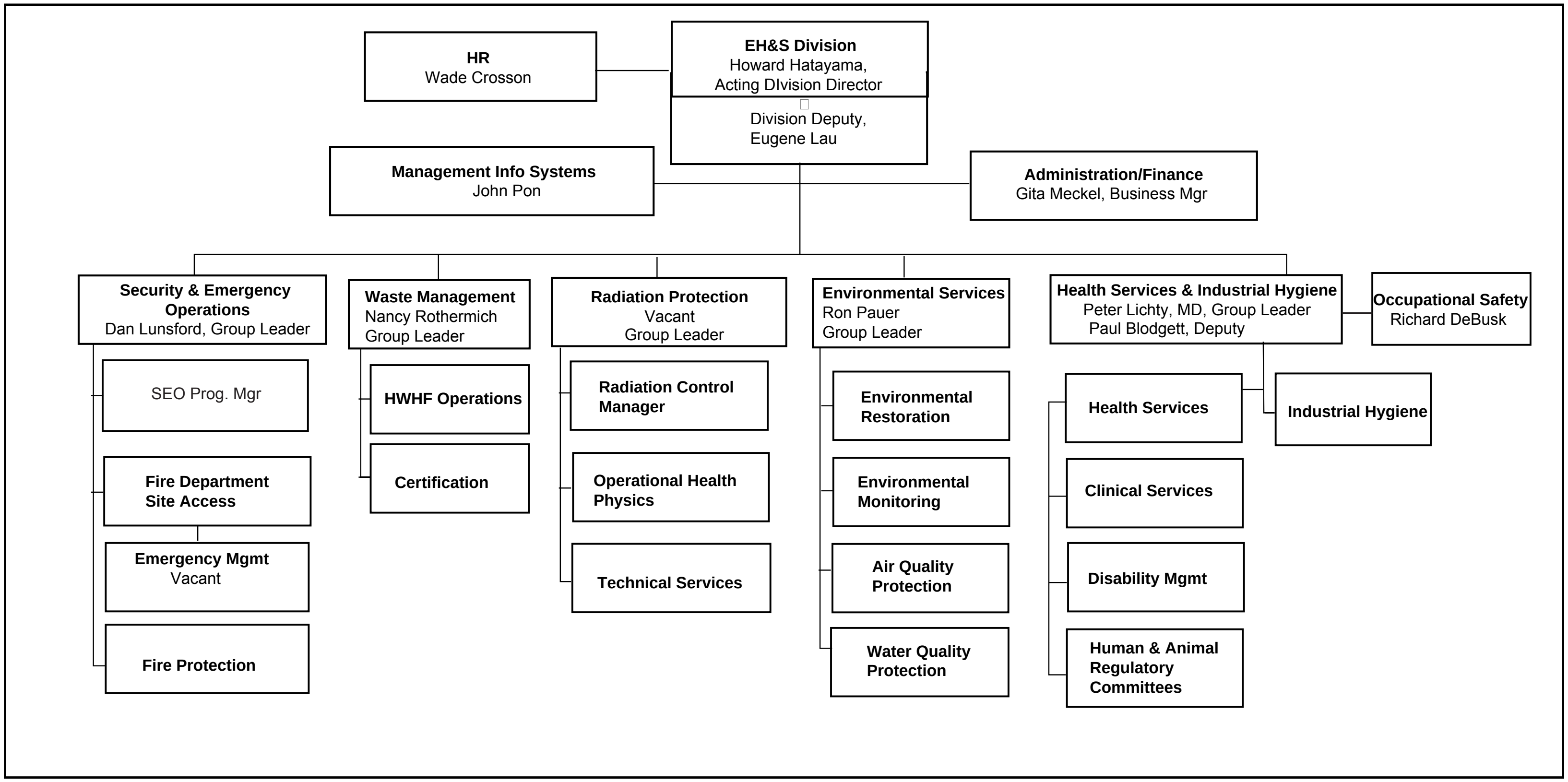


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization in 2005

3.2.1 Environmental Management System

To continually improve environmental performance, Executive Order 13148[2] required all federal agencies to implement an EMS by December 31, 2005. An EMS is a systematic approach to achieving environmental goals. DOE Order 450.1,[3] established the EMS requirement for all DOE facilities and, in addition, mandated that the EMS be integrated with existing ISM systems.

Berkeley Lab has established a performance-based EMS—a systematic approach to ensuring that environmental stewardship activities are well managed and provide business value. In 2005, seven areas were targeted for improvement:

1. Commute traffic to and from the Laboratory
2. Diesel emissions
3. Electronic waste
4. Energy-efficient building design
5. Fleet petroleum use
6. Green purchasing
7. Low-level radioactive waste

For details on the performance-based EMS, see Chapter 2.

3.3 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, inspections, and DOE-reportable environmental incidents at Berkeley Lab for CY 2005.

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 49 active permits held by the Laboratory 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 inspect the Laboratory. Table 3-2 lists the inspections by these agencies that occurred at Berkeley Lab during the year. The list includes self-monitoring inspections conducted by Berkeley Lab that are required by EBMUD wastewater discharge permits because these activities expose the Laboratory to potential regulatory violations.

Table 3-1 Environmental Permits Held by Berkeley Lab at the End of 2005

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD[a]	Various activities with emissions to air	35	3.4.1.2
Hazardous waste	DTSC[b]	Hazardous Waste Handling Facility operations	1	3.4.4.1
	City of Berkeley	Fixed treatment units (5)	1	3.4.4.1
Stormwater	SWRCB[c]	Sitewide stormwater discharges	1	3.4.6.2
		Construction activity stormwater discharges	1	3.4.6.2
Underground storage tanks	City of Berkeley	Underground storage tanks containing petroleum products	6	3.4.6.4
Wastewater	EBMUD[d]	Sitewide and operation-specific wastewater discharges to sanitary sewer	3	3.4.6.1
	CCCSD[e]	Wastewater discharges to sanitary sewer at Joint Genome Institute in Walnut Creek	1	3.4.6.1

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

Table 3-2 Environmental Audits, Inspections, and Appraisals in Calendar Year 2005

Organization	Inspection title	Start date	Length[a] (days)	Violations
CCCSD	Wastewater/Stormwater	December 15*	1	0*
City of Berkeley	Underground storage tanks	September 27	1	0
	Hazardous Material, Waste Storage Areas and Fixed Treatment Units*	August 2	3	1*
DTSC	Inspection of Hazardous Waste Handling Facility	June 29	2	0 [b]
EBMUD	Wastewater monitoring inspection at Hearst and Strawberry outfalls	November 17	1	0
	Wastewater monitoring inspection at B25 treatment unit	February 17	1	0
	Wastewater monitoring inspection at B77 treatment unit	March 22	1	0
	Wastewater monitoring inspection at groundwater treatment units	September 8	1	0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	March 1 April 13	1 1	0 0
	EBMUD self-monitoring inspections at B77 treatment unit	March 15 April 13 October 10	1 1 1	0 0 0
	EBMUD self-monitoring inspections at B25 treatment unit	March 15 September 13	1 1	0 0
	EBMUD self-monitoring inspections at groundwater treatment units	March 18 September 28	1 1	0 0
US/EPA [c]	Evaluation of protocol for periodic confirmation under 40 CFR 61, Subpart H	September 22	1	0

[a] A portion of a day is tabulated as one day.
[b] No inspection report has been received.
[c] United States Environmental Protection Agency

3.3.3 Summary of DOE-Reportable Environmental Incidents

Two environmental incidents were reportable under the DOE occurrence-reporting program,[4] which is used to track incidents across the DOE complex:

1. On August 2-4, the City of Berkeley conducted a routine inspection of hazardous materials, waste storage areas and fixed treatment units at Berkeley Lab.* As a result, the City of Berkeley issued a minor violation on August 30 for a 300% increase in argon gas cylinders that was not reflected in the chemical inventory of Building 70A. The situation had been corrected on August 16, after receipt of the preliminary findings, by updating the chemical inventory.
2. On September 29, metallic mercury was discovered encased in a hard layer of sediment at the bottom of a catch basin while it was being cleaned out using a vacuum extractor. The

* Errors in Table 3-2 and Section 3.3.3 text were corrected on August 2, 2006.

asphalt area around the catch basin and also the vacuum truck were assessed for mercury and decontaminated. After completion of the cleanup response planning and investigation, the remainder of the contaminated sediment was removed from the catch basin on October 12. A video surveillance of both influent and effluent pipes to the catch basin showed no visible sign of mercury in either pipe. Six sediment samples were collected from a concrete structure at the outfall of the storm drain line to the North Fork of Strawberry Creek, and results indicated it was unlikely that any mercury had been released into the creek. From samples taken of the collected sediment and decontamination efforts, the amount of mercury found in the catch basin was calculated to be 1.32 kilograms (kg) (2.9 pounds [lb]). This exceeds the federal reportable quantity for mercury of 0.45 kg (1 lb). Accordingly, on October 24, Berkeley Lab notified the California Office of Emergency Services, City of Berkeley, Regional Water Quality Control Board (RWQCB), and Department of Toxic Substances Control (DTSC); the DTSC had previously been informally notified.

3.4 PROGRAM REVIEW

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

3.4.1 Air Quality (Clean Air Act)

The Clean Air Act[5] 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[6] 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 Laboratory research activities must adhere to NESHAP regulations (40 CFR 61, Subpart H *[National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities* [7]*]),* as well as sections of DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.[8] The United States Environmental Protection Agency (US/EPA) administers the NESHAP regulations, which limit the dose to the public from the Laboratory's airborne radionuclide emissions to 0.10 millisievert per year (mSv/yr) (10 millirem per year [10 mrem/yr]. The Laboratory documents its NESHAP review and compliance at http://www.lbl.gov/ehs/esg/.

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 2005, Berkeley Lab held operating permits issued by BAAQMD for 35 activities.[9] Two of these 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. One new operating permit was issued during the year, for an emergency generator to support the new Molecular Foundry (Building 67) that was under construction. For a list of active operating permits, see Table 3-3.

Table 3-3 Air Emission Sources Permitted by BAAQMD[a] at the End of 2005

BAAQMD category	Description	Building	Abatement type
Combustion equipment	Standby emergency generators	64, 70	Catalytic converter
	Standby emergency generators	67	Diesel particulate filter
	Standby emergency generators	Various [b]	None
	Standby emergency generators	JGI [c]	None
Gasoline dispensing	Unleaded and E85 fueling stations	76	Vapor recovery
Surface coating and painting	Paint spray booth	76, 77	Dry filter
	Epoxy-mixing hood	53	None
Surface preparation and cleaning	Sandblast booth	77	Baghouse
	Vapor degreaser	25	Chiller
	Wipe-cleaning	Sitewide	None
Miscellaneous	Soil-vapor extraction systems	7, 7E, 58	Activated carbon

[a] Bay Area Air Quality Management District
[b] Individual generators located at Buildings 2, 37, 48, 50A, 50B, 55, 62, 64, 66, 70A, 72, 74, 75, 77, 84B, and 85, plus four mobile locations
[c] Two generators located at the Joint Genome Institute in Walnut Creek, California

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.[10] Activities covered by permits are subject to periodic inspection. BAAQMD did not conduct any such inspections during this reporting period.

One of the current air quality issues in California is particulate matter (PM) emissions from diesel-fueled vehicles and engines. In 2000, the California Air Resources Board (CARB) prepared a comprehensive *Diesel Risk Reduction Plan*[11] to significantly reduce diesel PM emissions. The plan has the following two objectives:

1. To require all new diesel-fueled vehicles and engines to use state-of-the-art catalyzed diesel particulate filters (DPFs) and ultra-low-sulfur diesel fuel
2. To require that all existing vehicles and engines be retrofitted with DPFs, wherever technically feasible and cost-effective

These objectives are achieved through a series of airborne toxic control measures, which are then implemented by local agencies such as BAAQMD. One of these control measures, which targets stationary diesel-fueled compression ignition engines such as emergency generators, was approved in November 2004. To satisfy requirements of this control measure, BAAQMD requested additional information from Berkeley Lab on all of its permitted emergency generators by July 1. Using this information, BAAQMD is expected to reissue operating permits in 2006 that will reduce the number of hours allowed for maintenance and testing of the Laboratory's generators.

In other fuel-related air quality activities, Berkeley Lab continued operating its E85-fuel dispensing facility at the Building 76 Motor Pool under a research and development test site authorization and permit from CARB and BAAQMD, respectively. E85 fuel is a mixture of 85% ethanol and 15% unleaded gasoline. Federal mandates require that Berkeley Lab increase the percentage of vehicles using alternative fuels according to a given time schedule. Both BAAQMD and CARB have placed an operating condition upon this fueling station that the Laboratory perform quarterly testing of the system's vapor recovery components. Such aggressive testing is needed to provide data that will speed up the availability of CARB-certified E85-fuel dispensing equipment to the entire California marketplace. Berkeley Lab remains one of only five sites in all of California authorized to use this alternative fuel.

3.4.2 Environmental Restoration (Comprehensive Environmental Response, Compensation, and Liability Act of 1980; Resource Conservation and Recovery Act Corrective Action Program)

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)[12] authorizes the US/EPA to manage the cleanup of abandoned or uncontrolled hazardous waste sites. In 2005 no releases occurred that were reportable under CERCLA, and Berkeley Lab conducted no remedial activities related to CERCLA. Berkeley Lab continued, however, to investigate and remediate areas of concern at the site under the requirements of the Corrective Action Program (CAP) of the Resource Conservation and Recovery Act of 1976 (RCRA).[13] Because these actions relate primarily to the protection of groundwater, they are described in Section 4.4.

3.4.3 Hazardous Materials Regulations

The following sections discuss programs related to the Emergency Planning and Community Right-to-Know Act (EPCRA); Toxic Release Inventory (TRI); Hazardous Material Business Plan; Risk

Management and Prevention Plan (RMPP); Federal Insecticide, Fungicide, and Rodenticide Act; and Toxic Substances Control Act (TSCA).

3.4.3.1 Emergency Planning and Community Right-to-Know Act

The EPCRA was passed in 1986 as Title III of the Superfund Amendments and Reauthorization Act (SARA).[14] 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 3.4.3.1.1 through 3.4.3.1.3.

3.4.3.1.1 Toxic Release Inventory

Under Executive Order 13148,[2] DOE is required to evaluate its facilities against the TRI reporting requirements of EPCRA without regard to SIC code. TRI reporting consists of two steps: Berkeley Lab determines chemical usage; and if threshold quantities are exceeded, DOE submits US/EPA Form R.

Berkeley Lab determined that no chemical usage in CY 2005 exceeded the TRI criterion of 4,536 kg (10,000 lb) for a listed substance and that DOE was not required to submit a Form R on behalf of the Laboratory. Table 3-4 shows the highest usage levels of the chemicals from the Laboratory's assessments over the past several years.

Table 3-4 Trends in Highest Quantities of EPCRA[a] Toxic Release Inventory Reporting (in Kilograms[b])

Substance	2001	2002	2003	2004	2005
Chlorofluorocarbons	280	164	61	72	126
Methanol	593	322	228	206	129[c]
Nitric acid	861	778	582	511	466
1,1,1-trichloroethane	2	<1	7	<1	0

[a] Emergency Planning and Community Right-to-Know Act
[b] 1 kg = 2.2 lb
[c] Estimated

In 2002, US/EPA lowered reporting thresholds for 18 chemicals and chemical categories that meet the EPCRA Section 313 criteria for persistence, bioaccumulation, and toxicity (PBT). The thresholds were lowered to 45.5 kg (100 lb) for PBT chemicals and 4.5 kg (10 lb) for highly PBT chemicals. In June 2005, Berkeley Lab performed a sitewide survey on all 18 PBT chemicals and chemical categories for which reporting thresholds had been lowered. It was found that the PBT chemicals either were not present at the Berkeley Lab or they were used in research experiments. Hence the use of the PBT chemicals was exempt from reporting. It should be noted that even though the research exemption applies, the total inventory of PBT chemicals is below the usage thresholds by two orders of magnitude.

3.4.3.1.2 Hazardous Materials Business Plan

The City of Berkeley is the local administering agency for certain hazardous materials regulations falling under state law. Berkeley Lab voluntarily submits an annual *Hazardous Materials Business Plan* (HMBP)[16] to the City of Berkeley, although the Laboratory as a federal facility is exempt from such regulations.

The 2005 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 the underground storage tanks (USTs) and fixed treatment units (FTUs). Furthermore, due to occupancy of the Berkeley West Biocenter (leased building) at 717 Potter Street, in April 2005, an additional HMBP was submitted to the City of Berkeley for this research facility; the plan contained the same elements, where applicable, as the HMBP for the main Berkeley Lab site.

3.4.3.1.3 Risk Management and Prevention Plan

The City of Berkeley requires an RMPP[17] 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 RMPP is required for the site.

3.4.3.2 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 Berkeley Lab site by licensed contractors only. The Laboratory operates a composting program to minimize the use of herbicides and to reduce solid waste. The mulch generated from composting is used on-site for weed screening and landscaping where herbicides previously were applied. The end products from the chipper and mulcher program are also used to control erosion.

3.4.3.3 Toxic Substances Control Act

The objective of the 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 US/EPA.

Polychlorinated biphenyls (PCBs) are one of the principal substances at Berkeley Lab currently affected by the TSCA regulations. Since the TSCA program began, the Laboratory has removed all TSCA-regulated PCB transformers (PCB concentrations greater than 500 parts per million). The remaining equipment containing TSCA-regulated PCBs are 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 Laboratory is not required to prepare an annual PCB report for the US/EPA.

3.4.4 Hazardous Waste (Resource Conservation and Recovery Act)

The primary goal of the RCRA[20] is to ensure that hazardous waste management practices are conducted in a manner that protects human health and the environment. RCRA affects waste treatment, storage, and disposal activities at Berkeley Lab in two areas: hazardous waste (including the hazardous portion of mixed waste) and USTs.

3.4.4.1 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 continues to oversee the "full permit" and the "standardized permit" tiers; 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 Hazardous Waste Handling Facility (HWHF) operates under the "full permit" tier of the program. A full permit is also known as an RCRA Part B permit. The current permit for the HWHF[22] was approved by DTSC on May 4, 1993. Berkeley Lab submitted a timely permit-renewal application for operation of its HWHF and is continuing to operate under the existing permit conditions until the new permit is issued. The permit authorizes storage and treatment of certain hazardous and mixed wastes at the HWHF. Authorized treatments include 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.

Berkeley Lab's waste management program sends hazardous, universal, mixed, medical, and radioactive waste generated at the Laboratory off-site for disposal. Disposal of medical waste is managed in accordance with the state's Medical Waste Management Act[23] (see Section 3.4.4.2). Low-level radioactive waste is managed in accordance with DOE orders. Mixed waste is managed in accordance with the *Site Treatment Plan* compliance order.[24]

Berkeley Lab has an additional hazardous waste permit[25] to operate five fixed treatment unites (FTUs). 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 two 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. In March 2005, the Laboratory submitted the 2005 FTU renewal package to the City of Berkeley.

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

FTU	Building	Description of treatment	Permit tier	Volume of Wastewater treated (gallons)
002	25	Metals precipitation and acid neutralization	Permit-by-rule	8,535
003	76	Oil/water separation	Conditional authorization	7,261
004	70A/70F	Acid neutralization	Conditional authorization	596,450
005	2	Acid neutralization	Conditional authorization	52,140
006	77	Metals precipitation and acid neutralization	Permit-by-rule	36,482

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

- The *Biennial 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 a detailed analysis of waste minimization efforts made by waste generators during the reporting year.
- Quarterly reports on the inventory of mixed waste more than one year old were submitted to meet a DTSC operating-permit requirement.

In October 1995, DTSC approved the Laboratory's *Mixed Waste Site Treatment Plan*,[28] which documents the procedures and conditions used by Berkeley Lab to manage its mixed-waste streams. The Laboratory 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 (FY) (October 1 to September 30).

3.4.4.2 Medical Waste

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

In California, the state's Medical Waste Management Act[23] contains requirements designed to ensure the proper storage, treatment, and disposal of medical waste. The state program is administered by the Department of Health Services (DHS).

The Laboratory generates medical waste at about 150 different locations distributed over 15 buildings, including 3 off-site buildings. Berkeley Lab does not treat any medical waste: It is treated at off-site vendor facilities, using either incineration or steam sterilization.

Berkeley Lab produced 14,657 kg (32,245 lb) of medical waste in CY 2005. Under the state's program, the Laboratory 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 DHS and are subject to periodic inspections. DHS did not inspect the medical waste program at Berkeley Lab during the year.

3.4.4.3 RCRA Corrective Actions Program (Site Environmental Restoration Program)

Berkeley Lab's Environmental Restoration Program is conducted under the requirements of the RCRA CAP and it is intended to satisfy three criteria:

1. Identification of areas of contamination that may have resulted from past releases of contaminants into the environment
2. Determination of the sources and extent of contamination
3. Development and implementation of plans to remediate contaminated areas

The Laboratory maintains a proactive interaction with stakeholders in the RCRA CAP, including the DTSC, the RWQCB, and the City of Berkeley. The Environmental Restoration Program holds regularly scheduled meetings with these agencies, at which planned and completed activities are discussed.

The *RCRA Facility Investigation Work Plan,*[29] which outlined environmental investigations necessary to characterize the site, was submitted to DTSC in October 1992. Between 1992 and 2000, Berkeley Lab submitted a series of work plans for detailed site investigations. After each of these submittals, the Laboratory carried out the investigations described in the work plans and reported results in Quarterly Progress Reports. In addition, results of the investigations were reported in the *RCRA Facility Investigation Phase I Progress Report*[30] and *Phase II Progress Report*,[31] and in the *Draft Final RCRA Facility Investigation Report*,[32] submitted to DTSC on September 29, 2000. DTSC approved the *Draft Final RCRA Facility Investigation Report* on July 27, 2001. Throughout all phases of the corrective action process, Berkeley Lab has implemented interim measures to protect human health and the environment.

A *Corrective Measure Study (CMS) Plan*[33] was subsequently submitted to DTSC on May 24, 2002, and was approved on June 18, 2002. As part of the CMS, *Human Health Risk Assessment*[34] and *Ecological Risk Assessment*[35] reports were submitted to DTSC. The *Ecological Risk Assessment* concluded that there are no adverse impacts to ecological receptors from exposure to chemicals in soil, groundwater, sediment, or surface water at Berkeley Lab. This report was approved by DTSC on April 14, 2003. DTSC accepted the *Human Health Risk Assessment* on August 19, 2003.

The *Draft Corrective Measures Study Report*[36] was submitted to DTSC on July 19, 2004. The primary purpose of the report is to provide the information necessary for DTSC to select the remedies to be implemented at Berkeley Lab, so that risks to human health and the environment are eliminated, reduced, or controlled. DTSC issued its *Notice of Final Decision for the Approval of the Corrective Measures Study Report and Remedy Selection* on August 31, 2005.[37] The *RCRA Corrective Measures Implementation (CMI) Workplan*[38] was subsequently submitted to DTSC on November 10, 2005. The CMS Report and the CMI Workplan, as well as the other documents listed, are available for public review at the City of Berkeley main public library and at www.lbl.gov/ehs/erp.

3.4.5 Pollution Prevention and Waste Minimization

The following sections discuss programs related to pollution prevention and waste minimization.

3.4.5.1 Executive Order 13101 *(Greening the Government through Waste Prevention, Recycling, and Federal Acquisition)*

Executive Order 13101[39] replaced Executive Order 12873 *(Federal Acquisition, Recycling, and Waste Prevention)*. Like its predecessor, Executive Order 13101 seeks to integrate recycled materials into the procurement and acquisition process. Identified categories of products include the following:

- Paper and paper products
- Vehicular products
- Construction products

- Transportation products
- Park and recreation products
- Landscaping products
- Miscellaneous products
- Nonpaper office products

All federal agencies must procure only US/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.

Berkeley Lab has had an affirmative procurement program since 1992. The Laboratory's Procurement staff has an ongoing program to search for products made from recycled materials and to work with other federal facilities to enhance their power to purchase environmentally sound products. The Laboratory has implemented a "stepped" program to ensure that only US/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 the Laboratory's operating needs.

3.4.5.2 Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the Hazardous Waste Source Reduction and Management Review Act[40] 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*[41] and the *Hazardous Waste Management Report Summary*.[42] The last report was compiled in 2003 and submitted to DOE Oakland Operations Office as part of the DOE-wide report. In both 2004 and 2005 the Laboratory was not required to update this report.

3.4.5.3 Pollution Prevention Act of 1990

The Pollution Prevention Act of 1990[43] declares that source reduction is a national policy, and the Act directs US/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 the Laboratory is not subject to its reporting requirements.

3.4.6 Water Quality (Clean Water Act)

The Clean Water Act (CWA)[44] 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 US/EPA to administer the principal components of the federal water quality management program.

Additionally, the California Porter-Cologne Water Quality Control Act[45] 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 Regional Water Quality Control Boards (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 both wastewater and stormwater discharges from the JGI, which is in Walnut Creek.

3.4.6.1 Wastewater

The Laboratory has three wastewater discharge permits[46] issued by EBMUD for the following activities:

1. General sitewide wastewater discharge
2. Treatment unit discharge of rinse water from the metal finishing operations in Buildings 25 and 77
3. Treatment unit discharge of groundwater from hydraugers and groundwater monitoring wells

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 2005. (For more information regarding the results of the Laboratory's annual wastewater self-monitoring program, see Chapter 4.)

In 2003, EBMUD renewed the permits and increased the renewal term from one to four years, so that the current permits do not expire until 2007. EBMUD also elected to combine the permits from Buildings 25 and 77 into one permit.

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

The wastewater discharge permit for Buildings 25 and 77 requires that each facility maintain a *Toxic Organics Management Plan* (TOMP).[47] Each TOMP outlines facility management practices designed to minimize the release of toxic organics to the sanitary sewers or external environment.

The terms of the wastewater discharge permits also require an *Accidental Spill Prevention and Containment Plan* (ASPCP).[48] Specifically, Berkeley Lab must maintain this plan for areas where spills are most likely to occur. Berkeley Lab has prepared operation-specific plans for the following activities: sitewide photoprocessing, Buildings 25 and 77 metal finishing, Building 76 vehicle services, and Buildings 2 and 70A rinse water treatment. EBMUD requires that plan documents be maintained on file in the relevant areas and that essential emergency information be posted. These plans are not required to be submitted to the agency. The TOMP and ASPCP for Building 77 have been combined.[49]

The Laboratory now holds a Class III Industrial User Permit[50] issued by CCCSD for general wastewater discharged at the JGI. It was issued on December 3, 2004, and it contains requirements for inspecting and reporting on operations, but no monitoring requirements.

3.4.6.2 Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide *Industrial Activities Storm Water General Permit (or General Permit)*.[51] The General Permit is issued by the SWRCB but administered and enforced by the RWQCB and the City of Berkeley. Under this permit, the Laboratory has implemented a *Storm Water Pollution Prevention Plan* (SWPPP) [52] and a *Storm Water Monitoring Program* (SWMP).[53] Together, these documents represent the Laboratory's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

The General Permit requires submission of an annual report on stormwater activities by July 1. Berkeley Lab transmitted its annual report to the RWQCB and the City of Berkeley in June.[54] No regulatory concerns were raised by either agency regarding the annual report. (For a summary of the stormwater monitoring results, see Chapter 4.) No inspections of this program took place during the year.

The State of California has also issued a *General Permit for Stormwaters Discharge Associated with Construction Activity*[55] to the Laboratory for the construction of its new Molecular Foundry building. Such a permit was needed because the construction site for the project exceeded 0.4 hectare (one acre) in size. During 2005, the third year of this project, the Laboratory submitted an annual report and continued to implement Best Management Practices as appropriate in accordance with permitting requirements. When the construction of the Molecular Foundry is completed, Berkeley Lab will submit the required Notice of Termination to the RWQCB at the end of the project. The Molecular Foundry site will then be under the sitewide Industrial Activities General Permit.

3.4.6.3 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the CWA.[42] The CWA and the state's Aboveground Petroleum Storage Act[56] outline the regulatory requirements for ASTs. Under the authority of the CWA, a *Spill Prevention, Control, and Countermeasures (SPCC) Plan*[57] is required for petroleum-containing tanks—aboveground and underground tanks. Berkeley Lab maintains an SPCC Plan with the goal of preventing and, if needed, mitigating potential spills or leaks from petroleum-containing tanks. ASTs are provided with secondary containment or spill kits to capture any potential leaks. The locations of ASTs are shown in Figure 3-2. In addition, in December 1999, a 15,142 L (4,000 gal) AST was installed at the JGI to support an engine generator. The JGI maintains an SPCC for this AST.

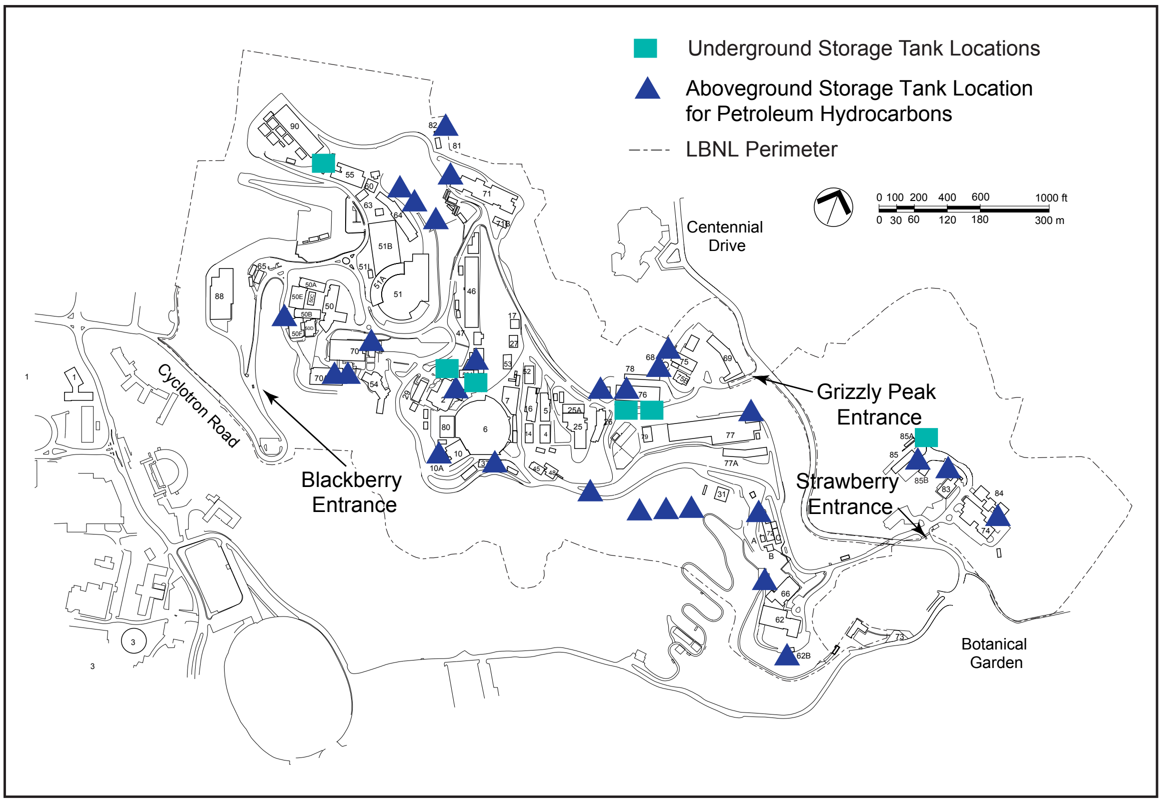


Figure 3-2 Aboveground and Underground Storage Tank Locations at the End of Calendar Year 2005

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. Product distribution areas, containing petroleum and nonpetroleum drums, are inspected by the Fire Department during routine inspections.

The E85-fuel dispensing station (located at Building 76) provides a fuel mixture of 85% ethanol and 15% gasoline. The station supports approximately 60 alternative-fuel vehicles. The use of 85%-ethanol fuel is one of the Laboratory's strategies for reducing petroleum usage by its fleet of vehicles. In FY 2005, Berkeley Lab was able to reduce its petroleum usage for fleet vehicles by more than 20% as compared to the 1999 baseline year. The National Ethanol Vehicle Coalition has commended the Laboratory for installing the E85-fuel dispensing station and for supporting the use of a clean, domestic, renewable fuel.

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.[58] 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.[59] The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab.

Two LBNL employees have passed the State of California exam to become UST Designated Operators. The two UST Designated Operators are responsible for conducting monthly inspections of the UST systems, which supplement the daily inspections conducted by other facility employees. The UST Designated Operator provides annual training to the employees that conduct the daily UST inspections.

At the end of 2005, six permitted USTs were in operation at the Laboratory (see Table 3-6 and Figure 3-2). The tanks contain either diesel fuel or unleaded gasoline. The Laboratory has removed nine USTs since 1993 and properly closed each 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					
2-1	2	Diesel	15,200 (4,000)	Fiberglass	1988
2-2	2	Diesel	3,800 (1,000)	Fiberglass	1988
85-1	85	Diesel	9,500 (2,500)	Fiberglass	1995
Steel tanks, double-walled, with fiberglass plastic corrosion protection					
55-1	55	Diesel	3,800 (1,000)	Glasteel	1986
76-1	76	Unleaded gasoline	38,000 (10,000)	Glasteel	1990
76-2	76	Diesel	38,000 (10,000)	Glasteel	1990

On September 27 and October 25, leak-detection monitors were tested and recertified for all UST systems. During the recertification of the leak-detection monitors, the City of Berkeley inspected all six USTs and found no violations. In September 2005, all product piping (pressure and suction) was pressure-tested for the UST systems. All piping passed the pressure tests. Also in September, every spill bucket at the fill port of each UST was tested for leaks. All spill buckets were found free of leaks.

3.4.7 Safe Drinking Water Act

The Safe Drinking Water Act[60] 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 now 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 the Laboratory’s 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.

3.4.8 National Environmental Policy Act and California Environmental Quality Act

The National Environmental Policy Act of 1969 (NEPA)[61] established national policy for assessing federal actions that have the potential to impact the environment. The NEPA process is intended to help officials of the federal government make decisions that are based on an understanding of environmental consequences and take actions that protect, restore, and enhance the environment. The California Environmental Quality Act of 1970 (CEQA)[62] is similar to NEPA. The California legislature established CEQA with the following intentions:

- To inform both state and local governmental decision makers and the public of potential significant environmental effects of proposed activities
- To identify ways to avoid or reduce environmental impacts
- To disclose to the public the reasons why a project is approved if significant environmental effects are involved

Lawrence Berkeley National Laboratory, as a federal facility located on land leased from the Regents of the University of California, complies with the provisions of both NEPA and CEQA. Since the DOE and the UC Regents have the ultimate decision-making authority on Berkeley Lab activities under NEPA and CEQA, respectively, Laboratory staff provides information to enable both entities to determine whether Berkeley Lab's proposed actions will have a significant effect on the environment.

Berkeley Lab issued a CEQA Notice of Preparation on March 15, 2005, stating that an Environmental Impact Report (EIR) would be prepared for a project to demolish the Laboratory's Bevatron and Building 51. The Notice of Preparation, which was accompanied by a CEQA Initial Study, was circulated to federal, state, regional, and local agencies as well as to community organizations and individuals. A public scoping meeting was held on March 31 at the North Berkeley Senior Center, at 1901 Hearst Street in Berkeley. A public notice announcing the preparation of a NEPA Environmental Assessment for this project was issued on May 5 and was circulated.

A Draft EIR (*Demolition of Building 51 and the Bevatron Draft Environmental Impact Report*, SCH #2005032095) was issued by the Laboratory on October 21. The Draft EIR was circulated for review and comment by governmental agencies and the public for a 47-day period, extending from October 21 through December 7, 2005; and a public hearing on the Draft EIR was held on November 16, 2005.

3.4.9 Federal Endangered Species Act (FESA)

Under FESA,[63] the Secretary of the Interior and the Secretary of Commerce have joint authority to list a species as threatened or endangered (16 United States Code [USC] Section 1533[c]). As a federal agency, the DOE is subject to the FESA, which 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. If so, DOE and Berkeley Lab would consult with the USF&WS as appropriate and required under the FESA.

3.4.10 California Endangered Species Act (CESA)

Under CESA,[64] the California Department of Fish and Game (CDFG) has the responsibility for maintaining a list of threatened and endangered species (California Fish and Game Code Section 2070). The CDFG also maintains a list of "candidate species," which are species formally under review for addition to either the list of endangered species or the list of threatened species. Also, the CDFG maintains lists of "species of special concern"; these lists serve as watch lists. As a state agency, the University of California is subject to the CESA, which 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. If so, DOE and Berkeley Lab would consult with the CDFG as appropriate and required under the CESA.

3.4.11 National Historic Preservation Act

Under the National Historic Preservation Act,[65] the National Register of Historic Places is the nation's master inventory of known historic resources. The National Register is administered by the National Park Service and includes listings of buildings, structures, sites, objects, and districts that possess historic, architectural, engineering, archaeological, or cultural significance at the national, state, or local level. Berkeley Lab currently is undergoing a sitewide inventory with a qualified historian in consultation with the State Historic Preservation Officer to determine which assets at Berkeley Lab are eligible for listing on the National Register and to comply with the National Historic Preservation Act.

3.4.12 Migratory Bird Treaty Act

The federal Migratory Bird Treaty Act (16 USC Section 703, Supplement I, 1989)[66] prohibits killing, possessing, or trading in migratory birds, except in accordance with regulations prescribed by the Secretary of the Interior. This act encompasses whole birds, parts of birds, and bird nests and eggs.

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.

3.5 WATER AND ENERGY USAGE AND CONSERVATION

Berkeley Lab conserves water by practices such as installing low-flow faucets and toilets. In addition, during FY 2005, a nonchemical water treatment system was installed in the Building 62 cooling tower, which resulted in water consumption for the cooling tower being reduced by 87 %. Berkeley Lab has purchased two more nonchemical water treatment units for Building 37 cooling towers; they are expected to be installed in FY 2006. Berkeley Lab water consumption for 2005 was 29% lower than consumption for FY 2004.

Energy conservation practices include upgrading building automation; installing premium-efficiency motors, high-efficiency chillers and boilers, energy-efficient lamps/electronic ballasts, light-emitting diode (LED) exit lights; and using high-value insulation for buildings.

In FY 2005, 72,000 megawatt-hours of electrical energy were used. With the high level of energy use reductions employed at Berkeley Lab in the past fifteen years, it is increasingly difficult to reduce energy consumption per area of building space. Electrical British thermal units (BTU) per gsf in FY 1990 was 188,811; in FY 2005, electrical BTU/gsf was 124,746, for a reduction of 33.93%.

In addition to the water- and energy-conservation retrofits that are noted above, Berkeley Lab also incorporates water- and energy-efficient systems into new building design and construction. A current example is provided by the Molecular Foundry, completed in early 2006. Below are some of the efficient systems included in that new building:

- Double-pane windows with low solar heat gain coefficient
- Wall panels insulated to R-11 and roofs to R-19
- Sun shades that reduce undesirable solar heat gains and lower peak cooling load
- Variable air-volume systems for office and lab areas where constant volume is not required
- High-efficiency water heaters
- Flow restrictors on lavatory faucets
- Motion sensing/control for lighting in storage rooms, conference rooms, bathrooms, private offices, main corridors, main lobby
- High-efficiency electrical transformers

3.6 PROGRAM PERFORMANCE

Since 1994, Berkeley Lab, DOE, and DOE's managing contractor, the University of California Office of the President (UCOP), have used a system to annually measure the effectiveness of the Laboratory'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 "unsatisfactory," "marginal," "good," "excellent," and "outstanding."

Berkeley Lab has consistently received performance ratings of "outstanding" or "excellent" from both DOE and UCOP since the inception of environmental performance measures ten years ago.

For FY 2005 (October 1–September 30), environmental protection was included in the overall ISM effectiveness performance measure. Berkeley Lab achieved an "excellent" rating in this measure, and the maximum score possible on the environmental protection portion. To achieve the maximum score, Notices of Violation (NOV) issued to the Laboratory could not exceed two; the Laboratory received two during the fiscal year. In October 2004, the Laboratory received a stormwater NOV for waste released from a dumpster at the Production Sequencing Facility in Walnut Creek (as reported in the 2004 SER). The other was a minor NOV issued for an increase in argon gas not reported in the chemical inventory (see Section 3.3.3). For more information on environmental performance measures, go to Berkeley Lab's Office of Institutional Assurance home page at http://www.lbl.gov/DIR/OIA/.

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4

Environmental Monitoring

Ambient-air sampling system near Building 44

4.1 INTRODUCTION

The Berkeley Lab environmental monitoring program assesses whether the Laboratory's emissions are impacting the quality of the local environs. 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 2005 monitoring results for the following categories:

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

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

Lawrence Berkeley National Laboratory's air monitoring program is designed to measure the impacts from radiological air emissions. The program meets the US/EPA and DOE requirements, which are contained in the following references:

- 40 CFR Part 61, Subpart H (*National Emission Standards for Hazardous Air Pollutants,* or NESHAP) [1]
- DOE Order 5400.5 *(Radiation Protection of the Public and the Environment)*[2]

The comprehensive *Environmental Monitoring Plan*[3] prepared by Berkeley Lab includes the basis and current scope of the overall air monitoring program at the Laboratory.

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 data for both stack air and ambient air is reported in Volume II. The number and placement of monitoring stations, as well as the substances collected and their collection frequencies, are routinely reviewed to address changes in Laboratory 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 radiouclides are used. If the potential emissions exceed the US/EPA-approved threshold, the Laboratory 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.

In 2005, the Laboratory worked with US/EPA Region 9 to revise the thresholds for measuring airborne emissions from Berkeley Lab's stacks. The revised approach, shown in Table 4-1, was based on data acquired over more than 10 years, showing that radionuclide emissions from the vast majority of Berkeley Lab stacks have negligible dose impacts. The revised approach allows the Laboratory to focus its resources on airborne emissions that have the highest potential public health impacts. The revised approach was approved by US/EPA Region 9 on April 5, 2005.

Table 4-1 US/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] Abbreviated as AEDE
[b] 1 mSv = 100 mrem

Based on this approach, only quarterly sampling is required because all sources have potential doses that are less than 0.001 mSv/yr (0.1 mrem/yr). However, Berkeley Lab may choose to monitor or sample some stacks more frequently. Exercising this choice, Berkeley Lab collected quarterly samples from five stacks, collected monthly samples from four stacks, and monitored in real-time at four stacks (one of which was also sampled monthly). Sampling and monitoring locations are shown in Figure 4-1.

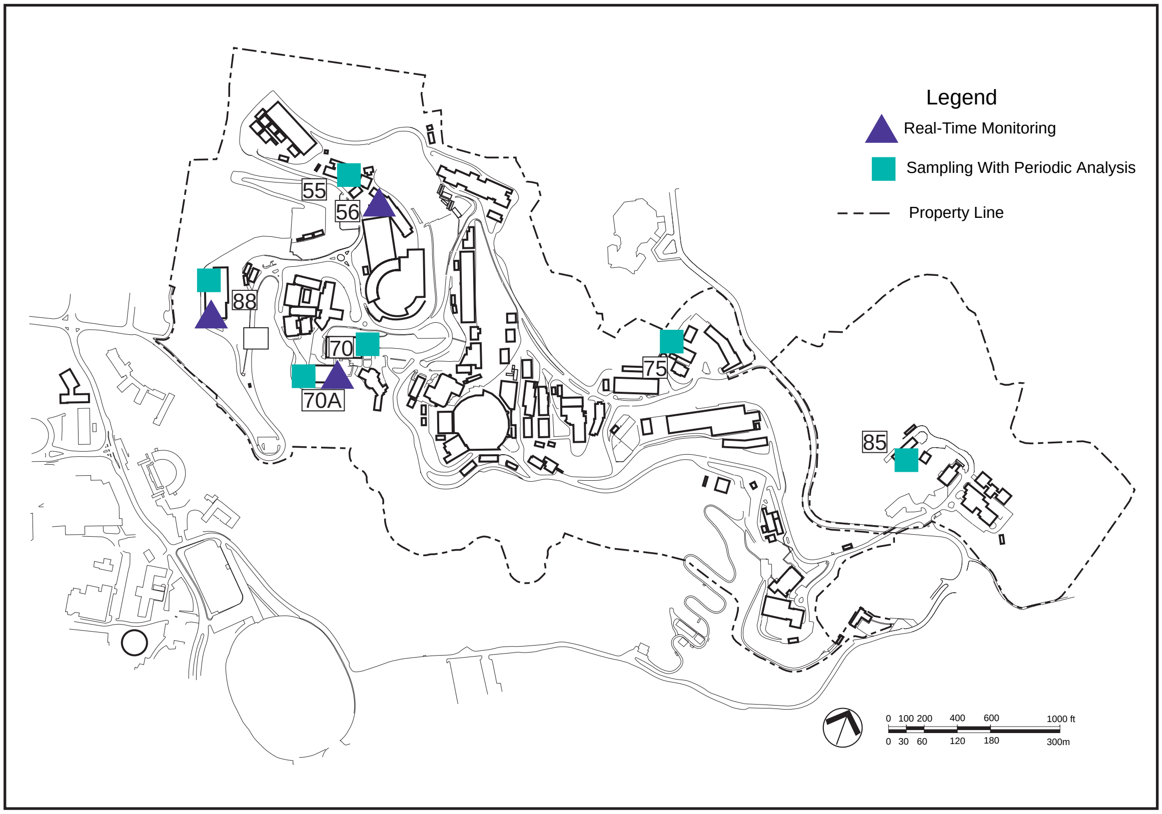


Figure 4-1 Locations of Building Exhaust Sampling and Monitoring

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 2005, positron emitters fluorine-18 (half-life of 1.8 hours) and carbon-11 (half-life of about 20 minutes) were the predominant radionuclides emitted. The Building 56 accelerator was the main source of fluorine-18 emissions (1.45×10^{11} Bq [3.93 Ci]; the Building 88 accelerator was the primary source of carbon-11 (9.0×10^{11} Bq [2.42 Ci]). Stack measurement results are provided in Volume II. Additional details on stack emissions are available in the Laboratory's annual *Radionuclide Air Emission Report*, submitted to US/EPA (at http://www.lbl.gov/ehs/esg, under "Available Documents"). (For information on the projected dose from all radionuclide emissions, see Chapter 5.)

In addition to air emissions from exhaust systems, Berkeley Lab also collects and analyzes (for tritium) rainwater that drains down the inside of stacks associated with the former National Tritium Labeling Facility (NTLF). The average concentration of tritium in drain water collected and analyzed during the year was 9.36×10^3 Bq/L (2.53×10^5 picocuries per liter [pCi/L]) and the maximum was 1.21×10^4 Bq/L (3.28×10^5 pCi/L). In accordance with an internal authorization for this low-activity source, the stack drain water was disposed of in the sanitary sewer. The total activity of tritium in the stack drain water released to the sanitary sewer was 7.66×10^5 Bq (2.07×10^7 pCi), which is 0.0004% of the EBMUD annual limit of 1.9×10^{11} Bq (5×10^{12} pCi) for tritium disposal in the sewer.

4.2.2 Ambient-Air Monitoring Results

Historically, the focal points of the ambient-air monitoring program were the specific radionuclide of tritium and the general classes of alpha and beta emitters.

4.2.2.1 Tritium

With the closure of the former NTLF at the end of 2002 and the subsequent lack of detectable tritium across the ambient-air network in the ensuing years, tritium sampling was eliminated at all five monitoring locations after March 2005. This action was taken after receiving prior approval from DOE. Figure 4-2 indicates where monitoring occurred prior to shutdown.

While operational, instrumentation at each site continuously drew outdoor air through sampling media (i.e., silica gel) at a constant rate. Sampling media was replaced monthly and submitted to a certified laboratory for analysis. All sample results except one were below the analytical detection limit. The one detectable result for 2005, at 0.13 Bq/m^3 (3.5 pCi/m^3), was only marginally above the detection limit.

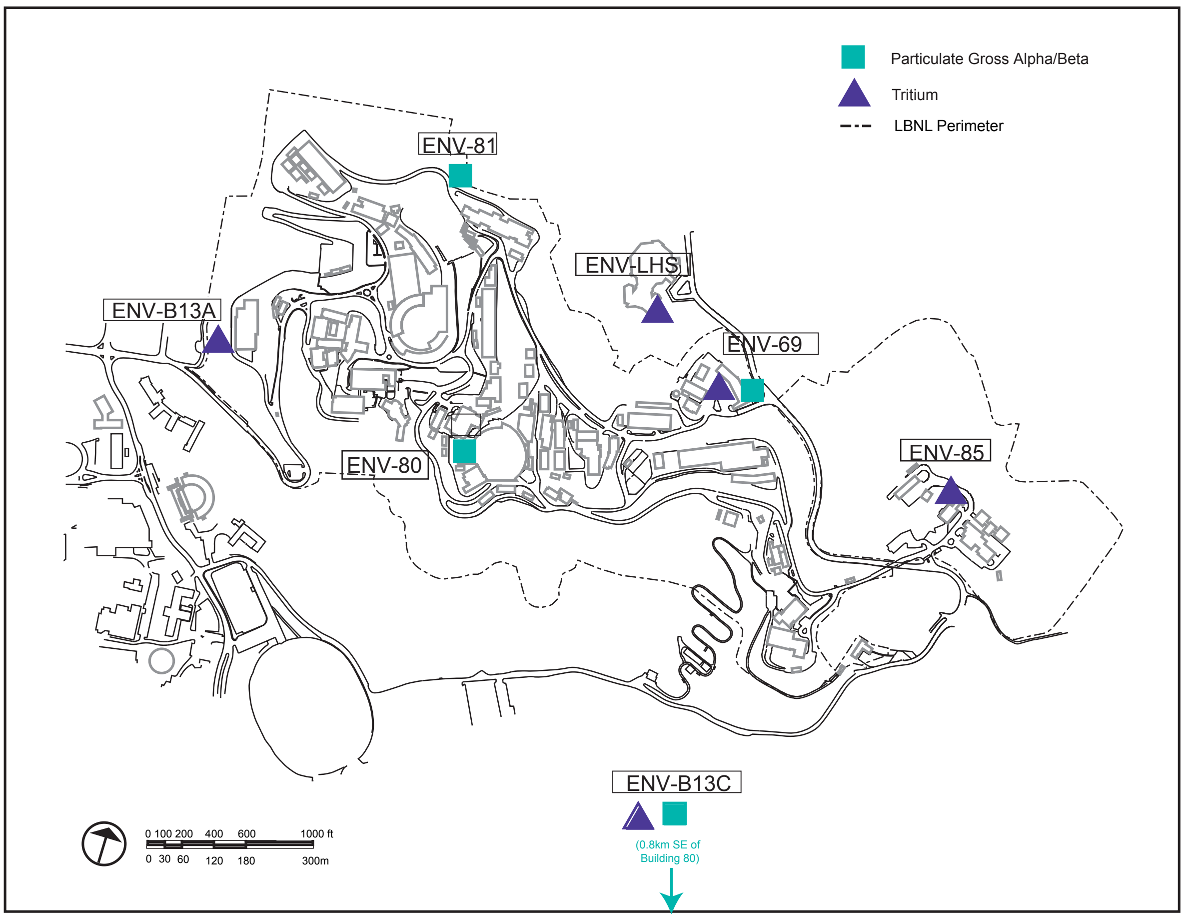


Figure 4-2 Ambient-Air Monitoring Network Sampling Locations

4.2.2.2 Particulate Gross Alpha/Beta

The network designed to collect air particulate samples for measurement of gross alpha and gross beta emitters remained unchanged from the previous year, with three sites on the main grounds of the Laboratory and a fourth off-site location, ENV-B13C (see Figure 4-2). Similar to tritium sampling, each sampler draws air past collection media (i.e., filter paper) at a constant rate, with the media replaced monthly and samples analyzed by a certified laboratory. Previous studies have found that the filter-paper media already contains a small amount of naturally occurring potassium-40.[4] Berkeley Lab's contract analytical laboratory corrects results for the presence of any naturally occurring radioactivity found in the collection media.

Table 4-2 summarizes gross alpha and beta sample results. Individual sample results are provided in Volume II.

Table 4-2 Summary of Ambient-Air Gross Alpha and Gross Beta Sampling Results

Analyte	Station ID	Number of samples	Mean (Bq/m^3)[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
Alpha	ENV-B13C[b]	12	4.9×10^{-5}	3.8×10^{-5}	1.5×10^{-4}
	ENV-69	12	5.3×10^{-5}	5.0×10^{-5}	1.5×10^{-4}
	ENV-80	12	5.3×10^{-5}	5.2×10^{-5}	1.4×10^{-4}
	ENV-81	12	5.1×10^{-5}	4.7×10^{-5}	2.0×10^{-4}
Beta	ENV-B13C[b]	12	4.5×10^{-4}	4.0×10^{-4}	1.1×10^{-3}
	ENV-69	12	3.9×10^{-4}	3.6×10^{-4}	9.7×10^{-4}
	ENV-80	12	4.7×10^{-4}	4.2×10^{-4}	9.5×10^{-4}
	ENV-81	12	5.0×10^{-4}	4.0×10^{-4}	1.5×10^{-3}

[a] 1 Bq = 27 pCi

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

While DOE Order 5400.5 does not provide a standard 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 AND WASTEWATER

This section summarizes the monitoring results for rainwater, creeks, 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 the Laboratory on the UC Berkeley campus.

Surface water monitoring for 2005 included rainwater, creeks, and stormwater. Rainwater and creeks are monitored primarily for alpha and beta emitters and tritium, based on DOE Order 5400.5,[2] which prescribes monitoring requirements for radioisotopes. Creek water is also monitored for nonradiological analytes as an ongoing effort to characterize and manage the Laboratory's overall impact on the environment. Stormwater monitoring is performed under the California-wide *Industrial Activities Storm Water General Permit* (or General Permit)[5] and includes monitoring for metals and other constituents.

Although monitored surface waters are not a source of drinking water, Berkeley Lab takes the conservative approach of evaluating surface water results against drinking-water standards. The Laboratory also used the water quality objectives stated in the Water Quality Control Plan (Basin Plan) for the San Francisco Bay Basin[6] for comparison purposes.

The federal and state maximum contaminant levels for alpha and beta radioactivity in drinking water are 0.6 Bq/L (15 pCi/L) and 1.9 Bq/L (50 pCi/L), respectively.[7] The US/EPA limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).[8]

All surface water samples were analyzed by state-certified laboratories.

4.3.1.1 Rainwater Sampling Results

Measurable rainfall occurred during January through June and October through December. During each of these months, a composite rainfall sample was collected near Building 75 at ENV-75 (see Figure 4-3) and analyzed for tritium, gross alpha, and gross beta activity. All sample results were below or near detection limits except for a rain sample collected in November, which contained 0.19 Bq/L (5.0 pCi/L) of alpha emitters and 0.78 Bq/L (21 pCi/L) of beta emitters. Those levels are consistent with historical values and below drinking water standards.

4.3.1.2 Creeks Sampling Results

Given Berkeley Lab's location in the hills of the Strawberry Creek watershed, many streams and drainages flow at varying intensities throughout the year. Each quarter, three creeks—Chicken Creek, the North Fork of Strawberry Creek, and Strawberry Creek (UC)—have a grab sample collected from them if water is flowing. The samples are analyzed for gross alpha, gross beta, and tritium radiological activity, as well as for mercury and PCBs. At five other creeks—Botanical Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek—twice each year a grab sample is collected and analyzed for tritium and numerous metals and organic compounds. Creek sampling locations are displayed in Figure 4-3.

No organic compounds were detected in any of the samples collected during the year. Most samples do not contain any detectable concentrations of metals. When metals were detected—which was limited to arsenic, barium, copper, selenium, vanadium, and zinc—the concentrations were consistent with regional background levels and well below the water quality objectives listed

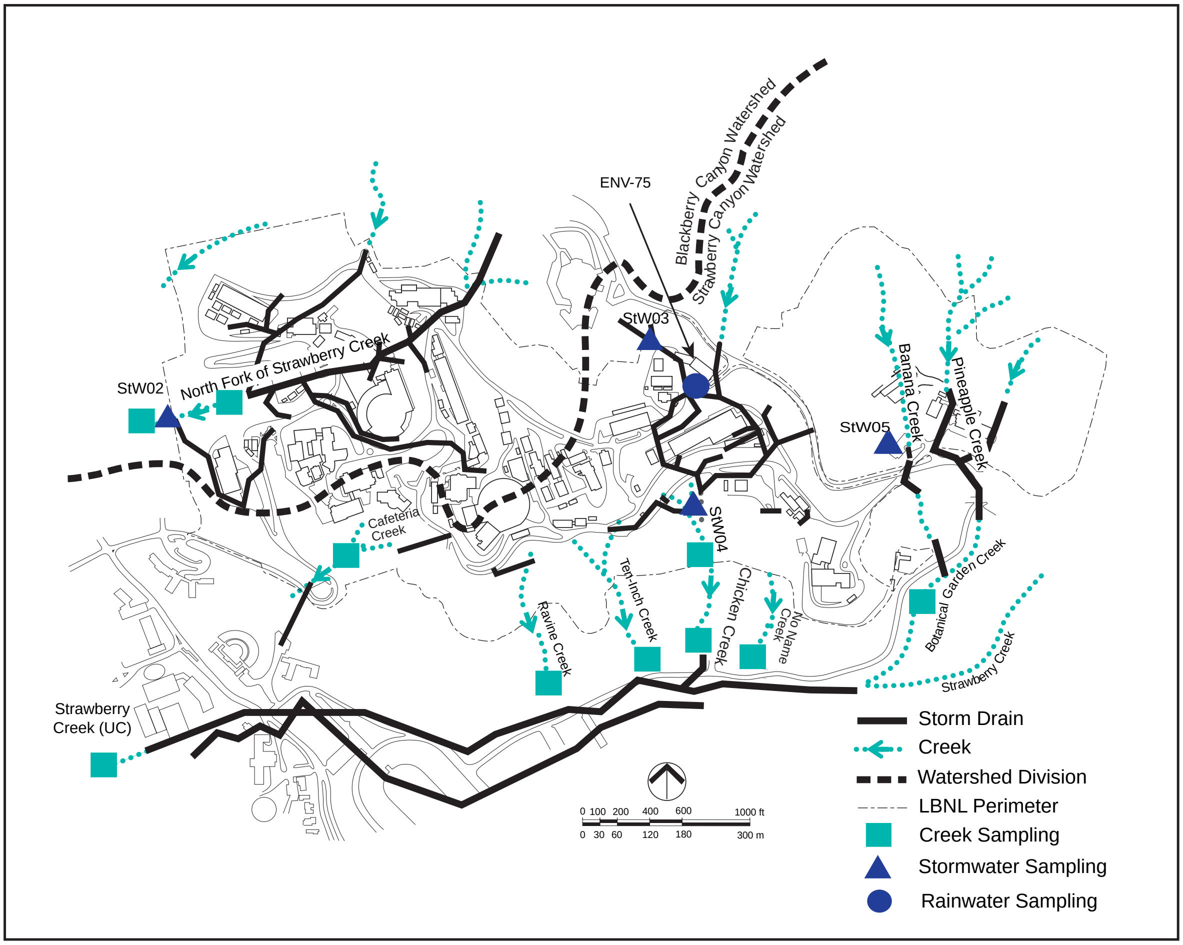


Figure 4-3 Creek, Rainwater, and Stormwater Sampling Locations

in the Basin Plan.[6] Radioactive analytes were not detected in about 80% of the samples. When radioactivity was detected, the results were only slightly above analytical detection limits and well below the drinking-water standard. Individual sample results for the creek-sampling program are presented in Volume II.

4.3.1.3 Stormwater Sampling Results

Surface runoff from Berkeley Lab can be substantial because of the site's hillside location, the amount of paved or covered surface, the moderate annual rainfall, and the intensity of some rainfall events. All stormwater runoff from the site drains through its stormwater drainage system to either the South Fork or the North Fork of Strawberry Creek.

Under California's General Permit program, Berkeley Lab maintains an SWMP[9] and an SWPPP.[10] These are the guiding documents for the Laboratory's compliance with stormwater regulations. Berkeley Lab's SWMP describes the rationale for sampling, sampling locations, and analytical parameters (radiological and nonradiological). The SWMP was updated in the last quarter of 2005.

Under the terms of the General Permit, sampling must take place at least twice each stormwater year (i.e., October to September) under specific conditions. See Figure 4-3 for the locations of the four sampling sites. This permit also requires visual observation of one storm each month and visual observation of authorized and nonauthorized nonstormwater discharges once each quarter. The 2005 stormwater sampling, which actually spanned the 2004–2005 and 2005–2006 stormwater years, included the following parameters (Oil and grease, pH, specific conductance and total suspended solids were explicitly required by the General Permit):

- Chemical oxygen demand (COD)
- Nitrogen and nitrate
- Metals
    - Aluminum
    - Iron
    - Magnesium
    - Mercury
    - Zinc
- Oil and grease (in lieu of total organic carbon)
- PCBs
- pH
- Radioactivity
    - Gross alpha
    - Gross beta
    - Tritium
- Specific conductance
- Total petroleum hydrocarbons (TPH) (as diesel range organics)
- Total Suspended Solids (TSS)

The list of parameters sampled is only a partial listing of potential surface water quality objectives considered by the Basin Plan, yet one that is appropriate for the activities at the Berkeley Lab site. This list assesses the overall state of water quality using a broad range of measures. Effluent limitations in the General Permit refer to 40 CFR Subchapter N standards for industrial source categories, 40 CFR Part 117 and 40 CFR Part 302 regulations for reportable quantities of hazardous substances, and the Basin Plan for the San Francisco Bay Basin.

Sampling results for the year were below detectable concentrations for mercury, oil and grease, and PCBs, across the network. Sampling for PCB measurements was discontinued after the 2004–2005 stormwater year, based on a history of results below detection limits. When detectable results for other parameters were observed, the concentrations varied by location and by stormwater sampling event. But in all cases the results were (1) within historical levels for the Laboratory, (2) consistent with urban background levels, (3) within the objectives of the Basin Plan, and (4) well below drinking-water standards. Individual sample results for all parameters are reported in Volume II.

4.3.2 Wastewater Discharge Program

The Laboratory's sanitary sewer system is based on gravity flow and discharges through one of two monitoring stations, Hearst or Strawberry (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 the Laboratory'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 the Laboratory. 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 the Laboratory and are separate from the main UC Berkeley campus: Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden.

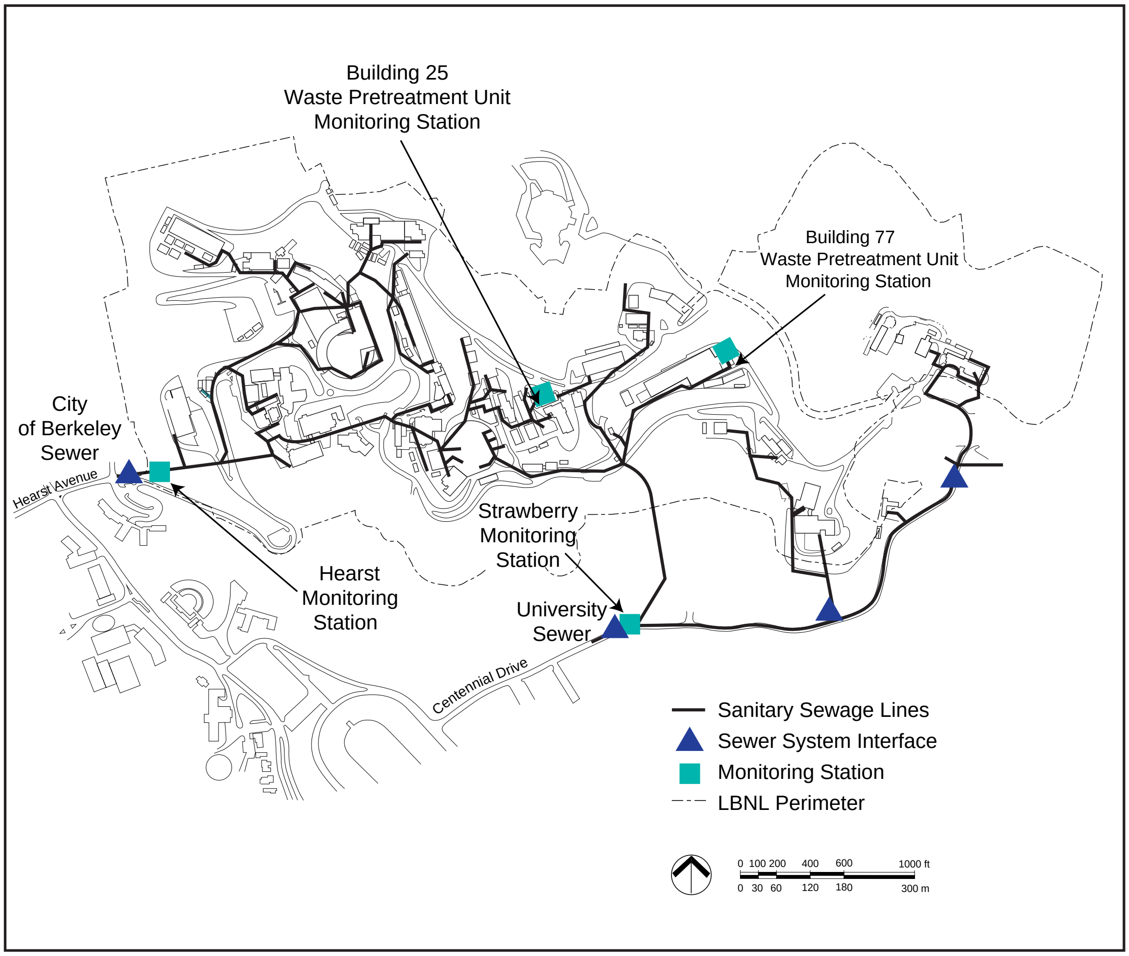


Figure 4-4 Sanitary Sewer System

Self-monitoring of wastewater discharges within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units, according to the terms of their respective EBMUD permits.[11] EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

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 from hydraugers. The permit for treated groundwater is valid until September 2006, while the first two permits are valid until July 2007. The Laboratory's sitewide permit requires periodic monitoring of wastewater discharges for various parameters twice per year, with metals analysis once per year at times specified by EBMUD. In addition, the sitewide permit states that EBMUD will perform unannounced monitoring of wastewater discharges four times per year. For 2005, no changes in permit requirements have occurred, and all sampling results were below discharge limits.

4.3.2.1 Hearst and Strawberry Sewer Outfalls

Nonradiological monitoring of sitewide samples includes analyses for pH, total identifiable chlorinated hydrocarbons, TSS, and COD, with additional analyses for metals. Also, total flow is measured and recorded. In 2005, Berkeley Lab discharged approximately 20 million gallons through Hearst Sewer and 26 million gallons through Strawberry Sewer. In comparison, the discharge volumes in 2004 for Hearst and Strawberry Sewers were 21 million gallons and 31 million gallons, respectively.

Radiological monitoring is required by DOE Order 5400.5[5] and guidance,[12] but the monitoring also ensures compliance with radiological limits under the California Code of Regulations,[13] cited in the EBMUD wastewater discharge permit. California regulations now incorporate by reference the applicable federal regulations[10] and associated discharge limits.

Analyses are performed by both a state-certified external laboratory and, for certain radiological analyses, an accredited in-house 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 the Laboratory's discharge is in compliance with the permit's radioactive limits.

4.3.2.1.1 Nonradiological Monitoring Results

Two self-monitoring samples were taken from the Hearst and Strawberry outfalls during CY 2005 by Berkeley Lab staff. All results were well within discharge limits, as were all measurements made by EBMUD in its independent sampling. For the one-time sampling of metals, some metals were below detection limits in both the Hearst and Strawberry outfalls; however, small amounts of chromium, copper, nickel, silver, and zinc were measured in both outfalls.

No chlorinated hydrocarbons were detected, except for chloroform (which is present in EBMUD supply water) and a very small concentration of 1,4-dichlorobenzene (in Strawberry outfall). 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 the Laboratory for wastewater treatment.

4.3.2.1.2 Radiological Monitoring Results

The Hearst and Strawberry sewer outfalls are continuously sampled at half-hour intervals using automatic equipment. Every four weeks, composite samples are collected 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 additional quality control (QC) purposes.

The federal[14] and state[13] regulatory limits for radioisotopes are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (5 curies [Ci]) per year; and for carbon-14 the limit is 3.7×10^{10} Bq (1 Ci) per year. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 Ci) per year.

All results for samples collected at the Hearst Monitoring Station and the Strawberry Monitoring Station except gross beta were below minimum detectable activity. The highest gross beta result was 18.4 pCi/L, which is below the Federal and State requirements for drinking water. Because most of the results were below the minimum detectable activity, the total annual discharge is a conservative upper- limit estimate. The estimate for the annual discharge of tritium in wastewater was 8.7×10^7 Bq (0.0023 curies [Ci]); discharge of carbon-14 was 1.7×10^8 Bq (0.0045 Ci); and the total discharge of other radioisotopes was 9.7×10^7 Bq (0.0026 Ci).

All estimates for the annual discharge of radioisotopes are orders of magnitude below allowable limits. Tritium was 0.05% of the allowable federal and state limit; carbon-14 was 0.45% of its limit; and all other radioisotopes together were approximately 0.26% of their 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 activities. Wastewater containing metals and acids from these operations is routed to an FTU before discharge to the sanitary sewer. The Building 25 FTU treats wastewater in batch mode.

All sampling performed by Berkeley Lab and EBMUD—two self-monitorings and one sampling event by EBMUD—yielded daily maximum and monthly average results well below EBMUD discharge limits.[12]

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 operations at Berkeley Lab. Cleaning operations include passivating, acid and alkaline cleaning, and ultrasonic cleaning. Acid and alkaline rinse waters containing metals from UHVCF operations are routed to a nearby 227-liter-per-minute (60-gallon-per-minute) FTU.

All sampling performed by Berkeley Lab and EBMUD—three self-monitorings and one sampling event by EBMUD—yielded results well within permitted limits.

The Building 77 permit is currently combined with the Building 25 permit. According to the current permit, at Building 77, Berkeley Lab samples three times per year for pH and metals; at Building 25, the Laboratory samples twice per year. Instead of monitoring for chlorinated hydrocarbons, the Laboratory now submits a *Total Toxic Organics Compliance Report*[16] twice per year, certifying that Buildings 25 and 77 are implementing the applicable solvent management plan and that no dumping of concentrated toxic organics into wastewaters has occurred.

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. The treatment process consists of passing the contaminated groundwater through a two-stage carbon-drum adsorption system.

The EBMUD permit allows for discharge of treated groundwater from certain hydrauger (subsurface drain) treatment systems and extraction wells, and also from well sampling and development activities (related to the Environmental Restoration Program). All treated groundwater discharged under the permit is routed through the Hearst Sewer. One of the conditions for this discharge is the submission of a semiannual report that provides information on the volumes treated and discharged, as well as any contaminants found.

Tests using US/EPA-approved methodologies are performed monthly on treated groundwater to determine levels of VOCs. Most results were below detection limits.

Occasional low levels of some chlorinated hydrocarbons have been measured (parts per billion) that do not exceed allowable limits. As a precautionary measure, a sample is collected from the outflow of the first drum of carbon in each system to assist in determining when it should be changed out. This prevents contaminated groundwater from being discharged to the sanitary sewer because there is always a second drum in the system to treat the outflow from the first drum. (For further discussion of groundwater monitoring and treatment, see Section 4.4.)

4.4 GROUNDWATER

This section reviews the groundwater monitoring program at Berkeley Lab, emphasizing CY 2005 results. Additional details on the program can be obtained from Environmental Restoration Program reports, which contain all the groundwater monitoring data, site maps that show monitoring well locations and contaminant concentrations, and graphs that show 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.

Berkeley Lab's groundwater monitoring program began in 1991 to serve the following purposes:

- Characterize the magnitude and extent of groundwater contamination
- Evaluate the potential for future contaminant migration
- Monitor groundwater quality near the site perimeter
- Monitor groundwater quality where hazardous materials or hazardous waste storage units, including USTs, are present and also the areas where they were removed

The Laboratory has installed an extensive system of wells to monitor groundwater quality. Four categories of contaminants are monitored under the program: volatile organic compounds (VOCs), petroleum hydrocarbons, metals, and tritium. Selected wells are also monitored for other potential contaminants.

Under the RCRA CAP,[16] the Laboratory first identified areas of soil and groundwater contamination that were the result of past releases of contaminants to the environment, and then determined the sources and extent of the contamination. Based on assessments of potential risks to human health and the environment, the Laboratory identified the areas where corrective measures were necessary. Subsequently, corrective measures were proposed to clean up contaminated areas. The proposed measures have been approved by the regulatory agencies that are overseeing the CAP at Berkeley Lab.

Activities are closely coordinated with the regulatory oversight agencies, including the lead agency, the California Environmental Protection Agency DTSC; the San Francisco Bay RWQCB; the City of Berkeley; and the DOE. Berkeley Lab meets with these agencies regularly to discuss current and planned activities.

4.4.1 Hydrogeologic Characterization

Moraga Formation volcanic rocks, Orinda Formation sediments, and Great Valley Group sediments constitute the principal bedrock units underlying the site. The geologic structure and physical characteristics of these three units are the principal factors controlling the movement of groundwater and groundwater contaminants at the Laboratory. (The geology and hydrogeology of these three units are described in more detail in Section 1.3.4.)

Depth to groundwater is measured monthly in site monitoring wells. The depth to groundwater ranges from approximately 0 to 30 meters (0 to 98 feet). Figure 4-5 shows groundwater elevations at Berkeley Lab. This map shows that the groundwater surface generally mirrors the surface topography.

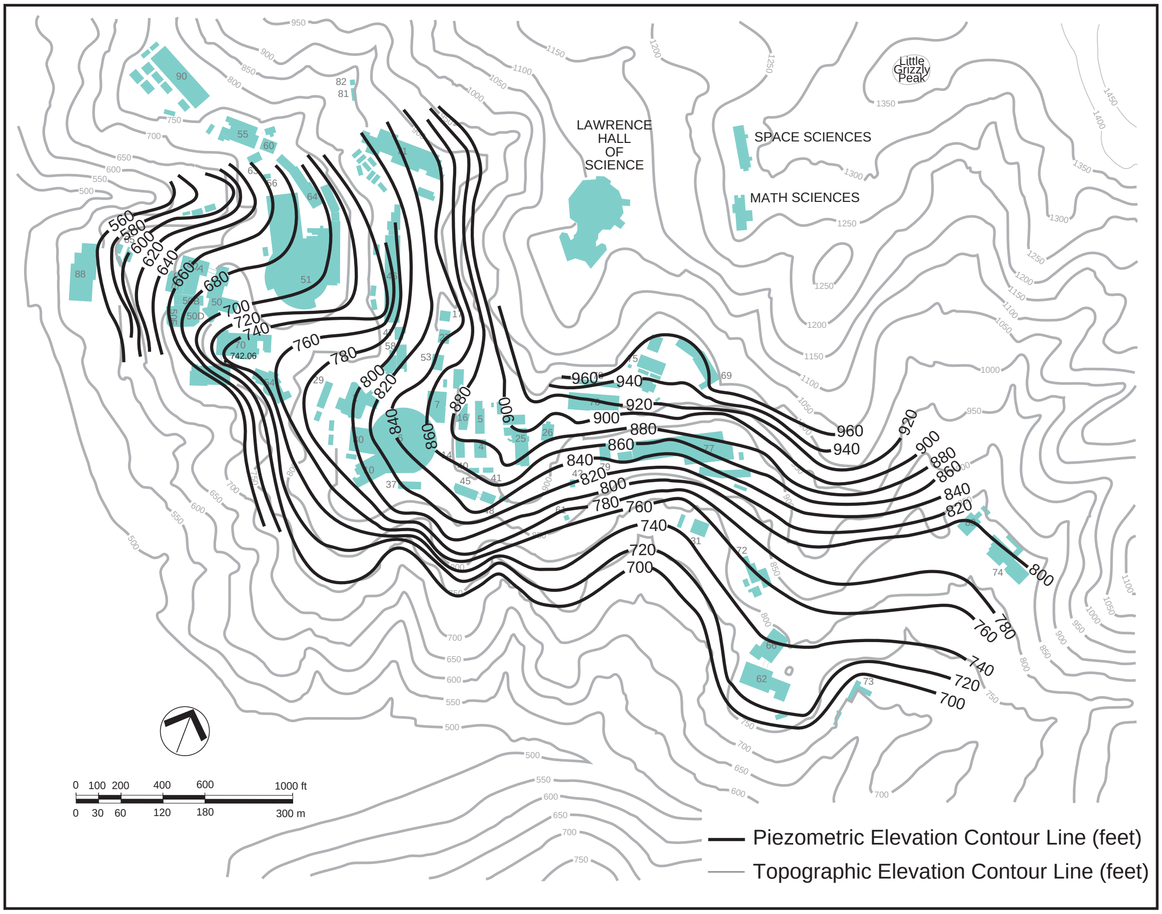


Figure 4-5 Groundwater Piezometric Map

In the western part of Berkeley Lab, groundwater generally flows toward the west; over the rest of the Laboratory, groundwater generally flows toward the south. In some areas, due to the subsurface geometry of geologic units, groundwater flow directions vary from the general trends presented on the groundwater elevation map. The velocity of the groundwater varies from approximately 0.001 meter per year (m/yr) (0.003 foot per year [ft/yr]) to about 300 m/yr (984 ft/yr).

4.4.2 Groundwater Monitoring Results

The groundwater program monitors more than 180 groundwater wells. These include 20 wells near the boundary, and 1 off-site well (see Figure 4-6).

No tritium was detected in any of the 21 wells during the year; and, except at MWP-7, no VOCs were detected. Trichlorolethylene (TCE) has been detected in MWP-7 at concentrations well below the drinking-water standard.[7]

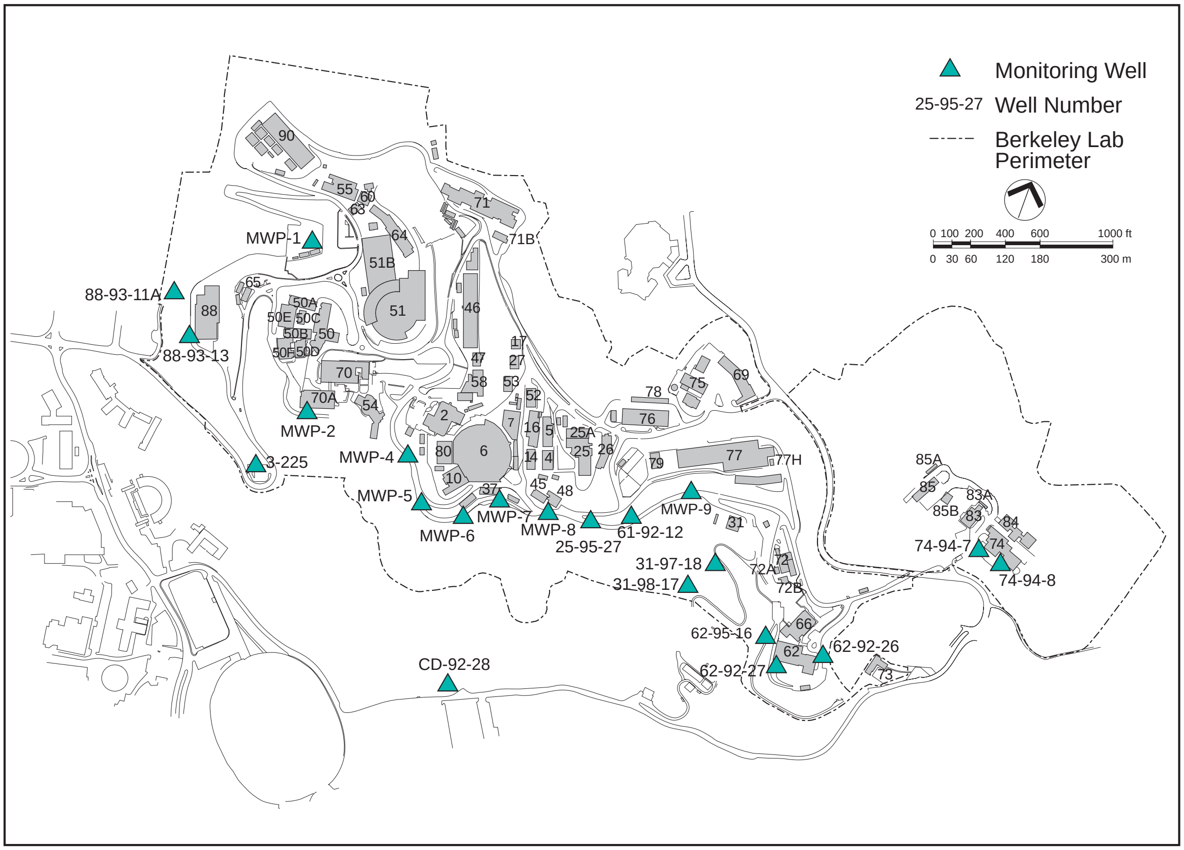


Figure 4-6 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

In 2005, of the 17 metals monitored in groundwater, three metals—arsenic, barium, and selenium—were detected at concentrations above both the corresponding drinking-water standard and Berkeley Lab background levels, while molybdenum was detected above the background level. No plume is associated with these metals, and for the most part, the metals are likely to be naturally occurring. Elevated arsenic concentrations, for example, may be attributed to the relatively high concentration of this metal in some sedimentary rocks at the Laboratory.

Concentrations of tritium in all wells were below the drinking-water standard in 2005. VOC concentrations are discussed in detail in Section 4.4.3.1.

4.4.3 Groundwater Contamination Plumes

Based on groundwater monitoring results, nine principal groundwater contamination plumes have been identified (listed below). One of these plumes, the Old Town plume, has been subdivided into multiple lobes to reflect the commingling of contaminated groundwater derived from different sources.

- *VOC plumes:* Old Town, Buildings 51/64, Building 51L, Building 69A, Building 71, and Building 76
- *Tritium plume:* Building 75
- *Petroleum hydrocarbon (diesel) plumes:* Buildings 7 and 74

Groundwater contaminated with VOCs also was detected in three other areas of the site in 2005 (Buildings 75/75A, 75B, and 77); the extent of contamination in each of these areas is limited. The extent of these plumes, and the three areas of VOC-contaminated groundwater where contaminant concentrations exceeded drinking-water standards in September 2005, are shown in Figure 4-7.

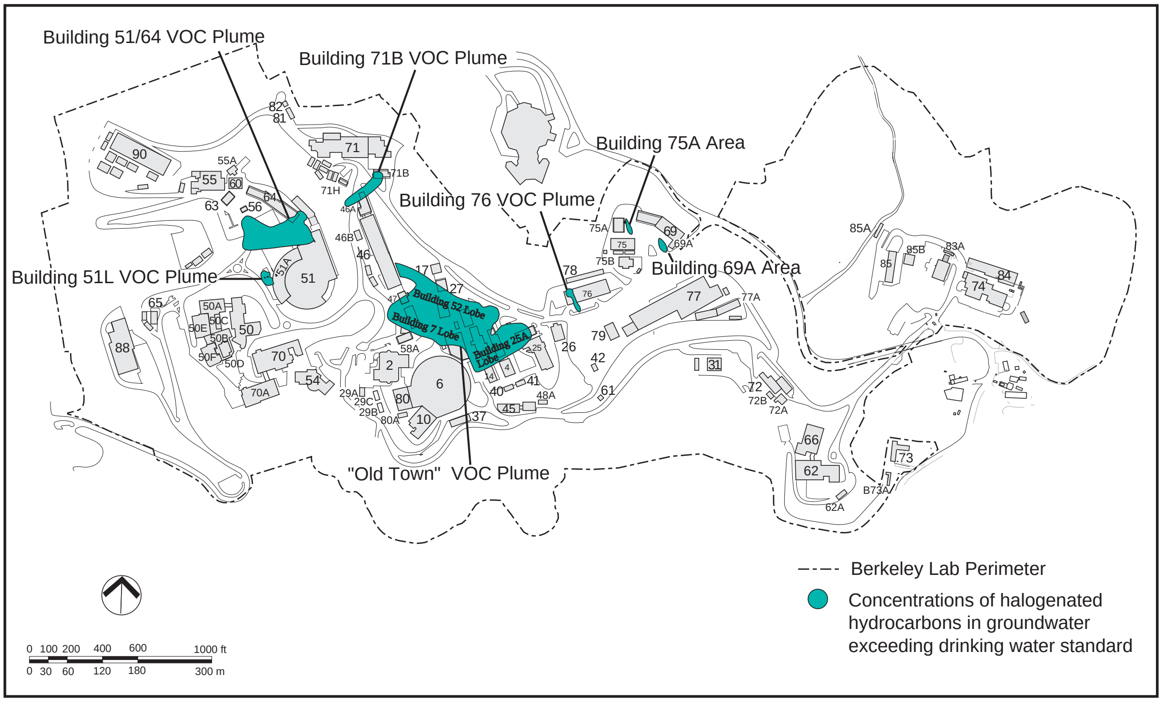


Figure 4-7 Groundwater VOC Contamination Plumes (September 2005)

4.4.3.1 Volatile Organic Compound Plumes

Covering the area of Buildings 4, 5, 7, 14, 16, 25, 27, 52, 53, and 58, and also the slope west of Building 53, the Old Town VOC plume is the most extensive plume at Berkeley Lab. This plume is defined by the presence of tetrachloroethene (PCE), TCE, carbon tetrachloride, and lower concentrations of other halogenated hydrocarbons, including 1,1-dichloroethene (1,1-DCE); cis-1,2-DCE; 1,1-dichloroethane (1,1-DCA); 1,2-DCA; and vinyl chloride; most of which are products of PCE and TCE degradation. The primary source of the Old Town VOC plume was an abandoned sump located north of Building 7.

The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume monitoring wells during the year was 77,240 micrograms per liter (µg/L), which primarily consisted of PCE (42,000 µg/L) and TCE (33,300 µg/L). It should be noted that this sample was collected from a well that is screened entirely in a very low permeability zone in the core of the plume, and as such is not representative of the overall Old Town Plume contamination.

Concentrations of VOCs detected in groundwater samples from monitoring wells east of Building 52 and west of Building 25A indicate other less significant source areas for groundwater contamination. The contaminated groundwater from these sources (designated "the Building 52 and Building 25A lobes") flows westward, where it intermixes with the main Old Town plume (designated "the Building 7 lobe").

The following interim corrective measures have been instituted to manage the Old Town VOC plume:

- The contents of the Building 7 sump were removed when the sump was discovered in 1992. The sump itself was removed in 1995 after the relocation of underground utility lines that crossed the sump.
- A groundwater collection trench was installed immediately downgradient from the former Building 7 sump to control the source of the groundwater contamination.
- A groundwater collection trench was installed west of Building 25A to control the source of the Building 25A lobe.
- A subdrain located east of Building 46 intercepts the Building 52 lobe of the plume. Water is pumped from the subdrain and treated to prevent the discharge of contaminated groundwater to the storm drain.
- A groundwater collection trench was installed west of Building 58 to intercept the Building 7 lobe of the plume and control its migration.
- Two groundwater collection trenches were installed east of Building 58, in areas of the Building 7 lobe where high VOC concentrations had been detected in the groundwater.
- Contaminated soil believed to be the source of the Building 52 lobe was removed.

Soil flushing, the corrective measure approved by the DTSC for the Old Town plume, has been implemented in all three lobe areas. Flushing has reduced the concentrations of VOCs in the Building 52 lobe source area to levels very close to drinking-water standards.

A second plume of VOC-contaminated groundwater, the Building 51/64 VOC plume, extends from the southeast corner of Building 64, under Building 64 and former Building 51B. In 2000, highly contaminated soil was excavated from the source area of the plume as an interim corrective measure (see Section 4.4.4.1). This plume is defined by the presence of 1,1-DCA; 1,1-DCE; PCE; TCE; and lower concentrations of other halogenated hydrocarbons. Halogenated hydrocarbons were detected at a maximum total concentration of 10,622 µg/L in 2005 in a groundwater sample from a multiport well close to the previously removed source area of the plume. The primary contaminant was 1,1-DCA.

Smaller VOC plumes with lower concentrations of VOCs than either the Old Town plume or the Building 51/64 plume are present south of Building 71B (Building 71B VOC plume), at the former Building 51L location (Building 51L VOC plume), near Building 69A (Building 69A VOC plume), and south of Building 76 (Building 76 VOC plume).

The Building 71B VOC plume is defined by the presence of halogenated hydrocarbons, predominantly PCE; TCE; cis-1,2-DCE; 1,1-DCA; and vinyl chloride. Halogenated hydrocarbons were detected in 2005 at a maximum total concentration of 1,550 µg/L (almost exclusively PCE) in a groundwater sample from a temporary sampling point close to the source area of the plume. Corrective actions consisting of soil flushing and application of Hydrogen Release Compounds reduced the maximum concentration of VOCs to about 110 µg/L by the end of the year. Contaminated groundwater from the front end of the plume is discharged continuously through five hydraugers. Effluent from these hydraugers is collected and treated before being released under permit to the sanitary sewer. Highly contaminated soil was excavated from the source area of the plume in 2000, 2003, and 2004 as interim corrective measures (see Section 4.4.4.1).

The Building 51L VOC plume is defined by the presence of TCE; cis-1,2-DCE; trans-1,2-DCE; and lower concentrations of other TCE degradation products. Halogenated hydrocarbons were detected in 2005 at a maximum total concentration of 1,295 µg/L in a sample from a temporary sampling point near the source area of the plume. The contaminants consisted primarily of cis-1,2-DCE; trans-1,2-DCE, TCE; and vinyl chloride.

The Building 69A VOC plume is defined by the presence of cis-1,2-DCE and vinyl chloride. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume during the year was 67 µg/L.

The Building 76 VOC plume is defined by the presence of TCE and cis-1,2-DCE. The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Building 76 VOC plume monitoring wells during the year was 17 µg/L.

4.4.3.2 Tritium Plume

The tritium plume covers the areas of Buildings 75, 76, 77, and 78. The area of tritium-contaminated groundwater extends southward from Building 75 toward Chicken Creek. Figure 4-8 shows the location of the groundwater tritium plume. In addition, low concentrations of tritium (21 Bq/L [570 pCi/L] maximum in 2005) have been detected in 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 groundwater in 2005 was at monitoring well 75-97-5 and measured 733 Bq/L (19,800 pCi/L), which is below the drinking-water standard of 740 Bq/L (20,000 pCi/L).[8] Monitoring well 75-97-5 has been the only monitoring well in which tritium has been detected above the drinking-water standard. Concentrations of tritium in 75-97-5 have been decreasing, particularly since closure of the NTLF.

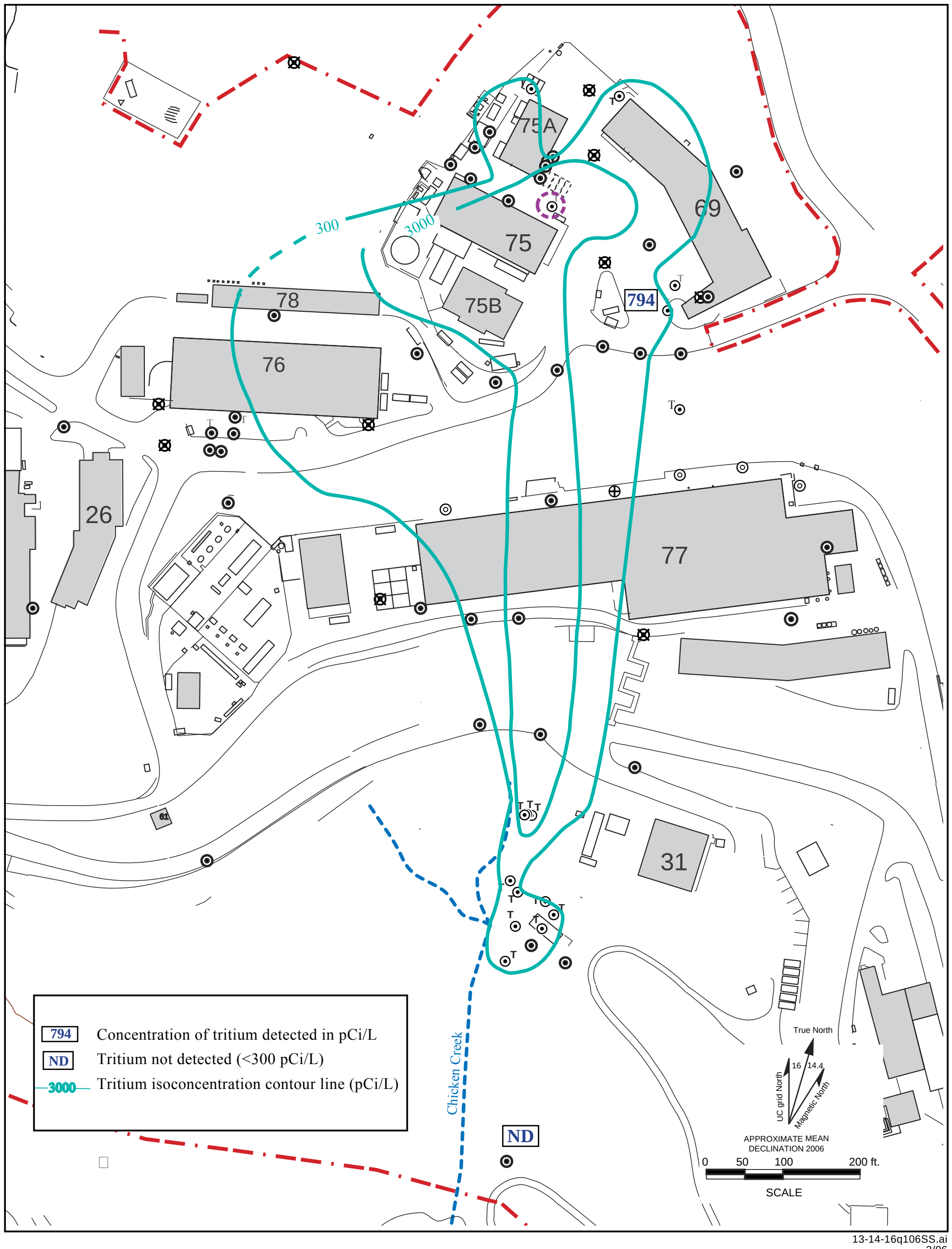


Figure 4-8 Groundwater Tritium Contamination Plume (September 2005)

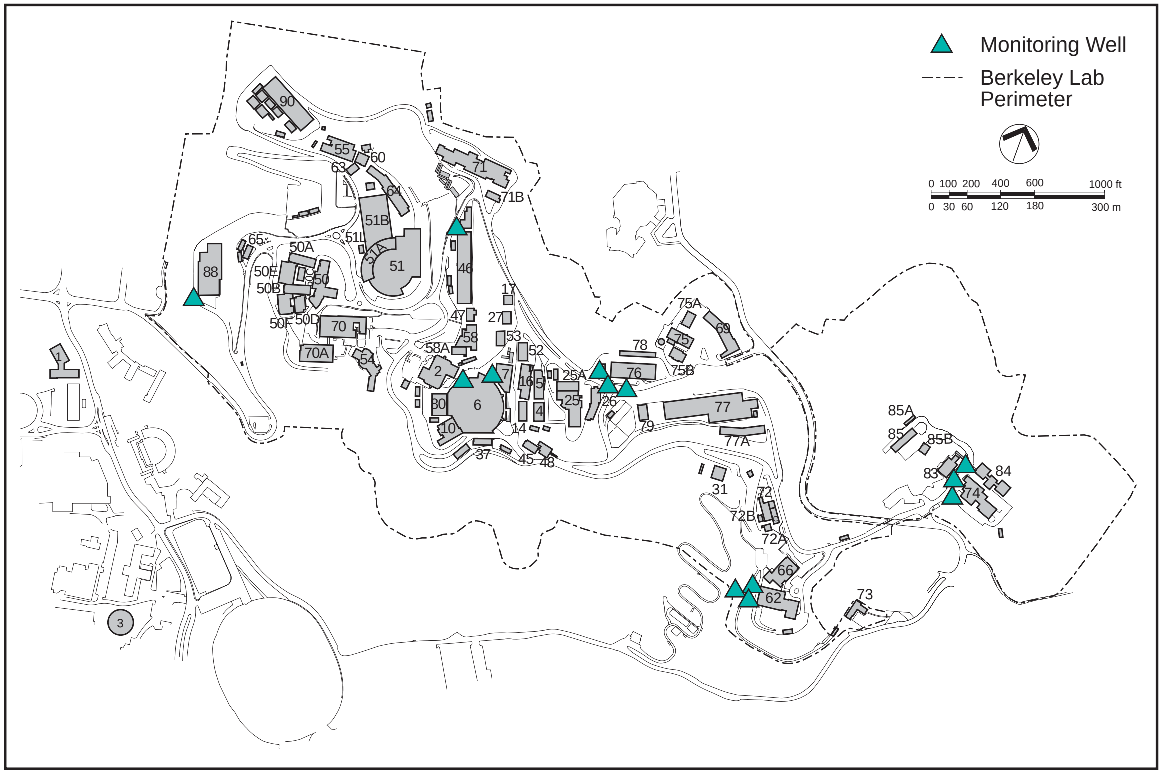


Figure 4-9 Approximate Locations of Monitoring Wells Associated with Former Underground Storage Tanks

4.4.3.3 Petroleum Hydrocarbon Plumes

Monitoring wells have been installed at, or downgradient from, two abandoned and five removed USTs. Figure 4-9 shows the approximate locations of these wells.

Petroleum hydrocarbon plumes are located in two areas: north of Building 6, and near Building 74. No aromatic hydrocarbons including BTEX components (i.e., benzene, toluene, ethyl benzene, xylenes) were detected at UST sites in 2005. A dual-phase (groundwater and soil vapor) extraction and treatment system has been installed north of Building 6 as an interim corrective measure.

4.4.4 Interim Corrective Measures

Interim corrective measures are used to remediate contaminated media or prevent movement of contamination, where the presence or movement of contamination poses a potential threat to human health or the environment. Throughout the RCRA CAP, Berkeley Lab has conducted the following interim corrective measures in consultation with regulatory agencies:

- Removed or controlled sources of contamination
- Prevented discharge of contaminated water to surface waters
- Eliminated potential pathways that could contaminate groundwater
- Prevented further migration of contaminated groundwater

4.4.4.1 Source Removal or Control

Several sources of contamination have been removed. The following is a list of such actions:

- Removed approximately 35 m^3 (46 cubic yards [yd^3]) of VOC-contaminated soil from the source area of the Building 52 lobe of the Old Town plume
- Removed approximately 53 m^3 (69 yd^3) of VOC-contaminated soil from the source location of the Building 7 lobe of the Old Town plume
- Removed most of the VOC-contaminated soil from the source area of Building 71B lobe of the Building 71 VOC plume
- Removed most of the VOC-contaminated soil from the source area of the Building 51/64 plume
- Removed more than 100 m^3 (131 yd^3) of soil contaminated with PCBs and tritium from the Building 75A area
- Removed more than 22 m^3 (29 yd^3) of PCB-contaminated soil at Building 88

4.4.4.2 Preventing Discharge of Contamination to Surface Waters

Slope stability is a concern at Berkeley Lab because of the geology and topography of the site. Free-flowing hydraugers were installed in the past to dewater and stabilize areas of potential landslides. Some of the hydraugers intercept contaminated groundwater. To prevent the contaminated groundwater (draining from the hydraugers) from discharging to the creeks, Berkeley Lab installed a system to collect and treat hydrauger effluent that is contaminated with VOCs. See Sections 4.3.2.4 and 4.4.4.5 for more information on discharge from this system. Additionally, effluent from a subdrain east of Building 46 that collects VOC-contaminated groundwater is treated.

4.4.4.3 Eliminating Potential Pathways That Could Contaminate Groundwater

Due to concerns about stability of slopes, Berkeley Lab has also installed wells to monitor for slope movement. The space around the casings of some of these wells had been backfilled to the surface with gravel, constituting potential pathways for the migration of contaminants from the surface to groundwater. To eliminate this potential migration pathway, Berkeley Lab either (1) modified the well construction with an impermeable cement seal around the well casing at the surface, or (2) destroyed the well in accordance with regulatory requirements.

4.4.4.4 Preventing Further Migration of Contaminated Groundwater

Berkeley Lab is capturing and treating contaminated groundwater using collection trenches as interim corrective measures to control the migration of groundwater plumes. Following is a list of measures that continued operation in 2005:

- In 1996, a groundwater extraction trench and treatment system was installed near Building 7 to control migration of VOC-contaminated groundwater from the Old Town plume Building 7 lobe source area.
- In 1998, a groundwater extraction trench was constructed on the slope west of Building 53 to control migration of VOC-contaminated groundwater from the Old Town plume

Building 7 lobe core area. A dual-phase groundwater and soil-vapor extraction and treatment system was installed to remove contaminants from the soil and groundwater. An additional groundwater extraction trench was installed at the southeast corner of Building 58 in 2002.

- In 1998, a groundwater extraction trench was installed west of Building 58 to control migration of VOC-contaminated groundwater at the downgradient edge of the Old Town plume Building 7 lobe.
- In 2002, a groundwater extraction trench and treatment system were installed west of Building 25A to control migration of contaminated groundwater from the Old Town plume Building 25A lobe source area.

4.4.4.5 Treatment Systems

As described above, Berkeley Lab is using collection trenches and subdrains to control the migrations of groundwater plumes. Eleven granular-activated carbon systems were operated in 2005 to treat the extracted groundwater. The treated water is mainly used for on- site soil-flushing activities. Extra water is released to the sanitary sewer in accordance with Berkeley Lab's treated groundwater discharge permit from EBMUD.[17]

The total volume of contaminated groundwater treated by these systems during the year was about 44,200 m^3 (11.8 million gal).

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 centimeters (1 to 2 inches) of surface soils were collected from three locations around the site and one off-site environmental monitoring station (see Figure 4-10). Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, moisture content, and pH.

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

For non-radioisotope analysis, measurements of pH and moisture content at each of the sampling locations were within the typical range for soils. All metal concentrations measured were at or near the established background values for the Berkeley Lab site. The sample collected at the Building 80 location contained a mercury concentration of 0.71 mg/kg, which is slightly above the upper-level background value for mercury (0.60 mg/kg) in soil at Berkeley Lab but well below the

Preliminary Remediation Goal of 310 mg/kg set up by the US/EPA[18]. This location will be sampled in future years to monitor any changes in mercury concentrations.

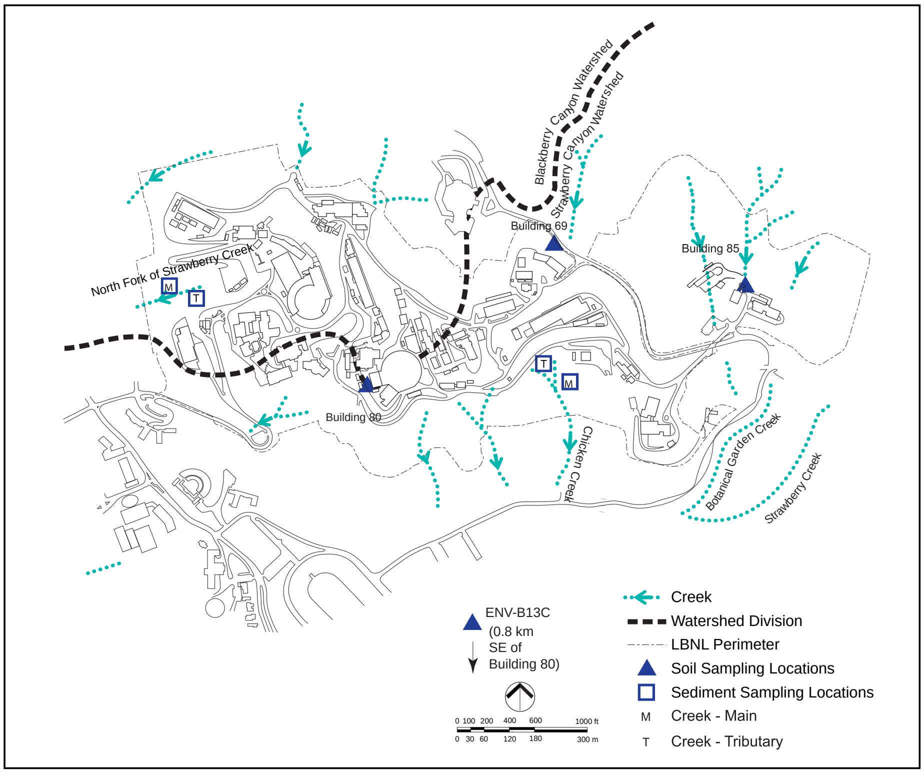


Figure 4-10 Soil and Sediment Sampling Sites

4.5.2 Sediment Sampling Results

Sediment samples were collected at the main and tributary creek beds of the North Fork of Strawberry Creek and Chicken Creek (see Figure 4-10). The samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, moisture content, petroleum hydrocarbons (diesel fuel and oil/grease), pH, and PCBs.

For radioisotope analysis, gross alpha and beta radiation and gamma emitter results were within background levels of naturally occurring radioisotopes commonly founds in sediments. Tritium measurements at the Chicken Creek Tributary were below detection limits. At all of the other sampling locations, tritium measurements were near or slightly above detection limits. These locations will be sampled in future years to monitor any changes in tritium concentrations.

For non-radioisotope analysis, metals concentrations at all of the locations were at the established background values for the Berkeley Lab site.[19] PCB measurements at all of the sampling locations were below detection limits (0.02 mg/kg). Measurements of pH, moisture content, and petroleum hydrocarbons (TPH 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.

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 the former NTLF contains measurable concentrations of tritium. Tritium in vegetation occurs in two chemical forms—tissue-free water tritium (TFWT) and organically bound tritium (OBT)—and Berkeley Lab analyzes vegetation for both forms.

Since the closure of the NTLF in 2002, tritium emissions from Berkeley Lab have decreased sharply, and concentrations in vegetation are expected to slowly decrease with time. To document changes in the concentrations of tritium in the local vegetation, Berkeley Lab routinely samples vegetation for tritium at least every five years. In 2005, routine vegetation samples were collected at 10 locations for this purpose.

In addition, Berkeley Lab samples trees for tritium for landscape management, because only trees with tritium levels indistinguishable from background are removed and released to the public. In 2005, no trees were sampled for landscape management.

4.6.1 Routine Vegetation Sampling

Berkeley Lab sampled vegetation in nine locations near the Lab and one remote background location in Tilden Park (see Figure 4-11). Of the nearby locations, four had been sampled in previous years and five were new. Samples collected at each site included tree wood, leaves, and duff (organic matter that collects and decays beneath trees). All samples were collected in accordance with internal procedure and analyzed by an off-site laboratory for TFWT and OBT. The results of vegetation sampling are listed in Volume II.

At locations where Berkeley Lab had sampled in previous years, both TFWT and OBT levels decreased in wood, leaves, and duff. At all locations that were sampled for the first time in 2005, both TFWT and OBT levels were below detection level. This was true of the background location as well. These results confirm that tritium levels in vegetation have decreased since the closure of the NTLF.

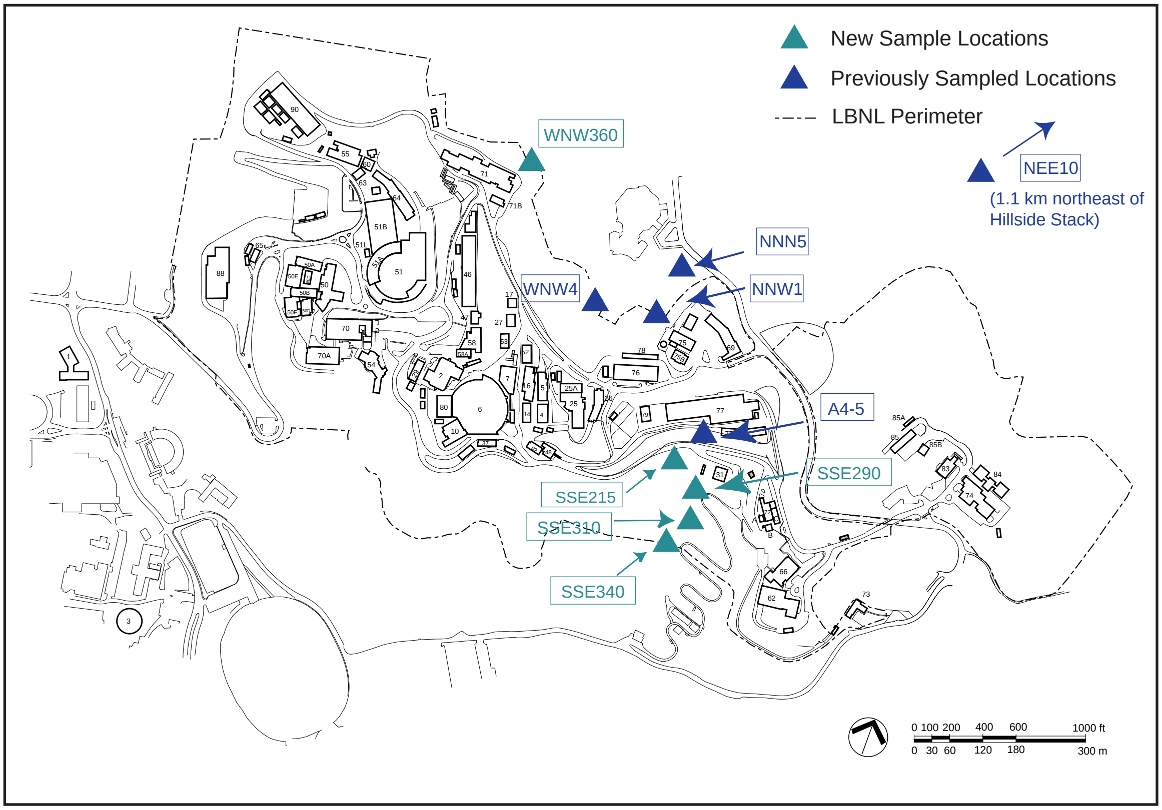


Figure 4-11 Vegetation Sample Locations

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. Penetrating radiation is primarily associated with accelerator and irradiator operations at the Laboratory.

When operating, accelerators 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 research accelerators, which include the Advanced Light Source Facility (Building 6), Biomedical Isotope Facility (Building 56), and 88-Inch Cyclotron (Building 88).

The Laboratory 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 "thermoluminescent dosimeters" (TLDs), which by laboratory analysis provide an average dose over time from gamma radiation

The locations of real-time monitors and TLDs are shown in Figure 4-12. Results of both measurement methods are given in terms of "dose" and are provided in Section 5.2.

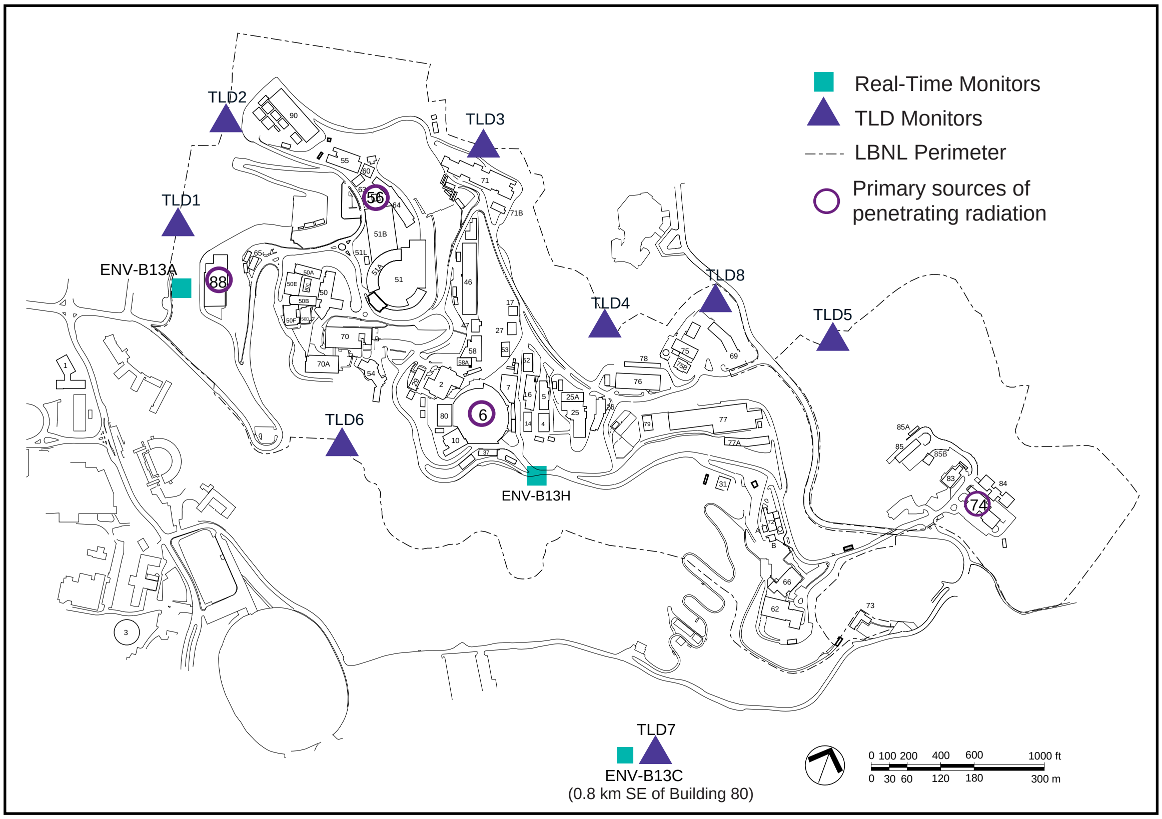


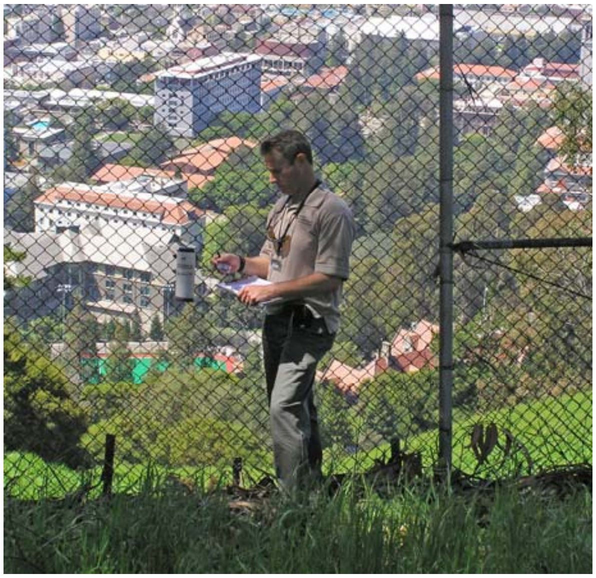
Figure 4-12 Environmental Penetrating Radiation Monitoring Stations

Irradiators at Berkeley Lab produce only gamma radiation. Used for radiobiological and radiophysics research, a gamma irradiator with a 1.5 x 10^{13} Bq (400-curie) cobalt-60 source is housed at Berkeley Lab in Building 74; the irradiator is in a massive interlocked structure that is covered with reinforced concrete. Routine surveys confirmed that the maximum gamma radiation doses at 1 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 that pose considerably less potential for environmental impact than does the Building 74 irradiator. This class of smaller irradiators does not measurably increase the dose to the public.

5

Radiological Dose Assessment



Exchanging a thermoluminescent dosimeter at the Berkeley Lab fence line, with the U.C. Berkeley campus in the background

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 Lawrence Berkeley National Laboratory's penetrating radiation and airborne radionuclide monitoring programs. These doses include all known radionuclides released in significant quantities from Berkeley Lab. The doses projected from each monitoring program are presented separately before they are cumulatively evaluated to summarize the overall impact of the Laboratory'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). The Laboratory'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[1] process (discussed in Section 4.2). If the potential for a public dose is greater than 0.01 mSv (1 mrem) to an individual or 0.1 person-sievert (person-Sv) (10 person-rem) to a population, an in-depth quantitative review is performed. No quantitative reviews were performed in 2005.

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 TLDs. Results of penetrating radiation measurements by both methods indicate that the maximum dose to a member of the public (person residing near the 88-inch Cyclotron) from penetrating radiation was indistinguishable from natural background levels.

5.3 DOSE FROM DISPERSIBLE AIRBORNE RADIONUCLIDE

Dose due to dispersible contaminants represents the time-weighted exposure to a concentration of a substance, whether the concentration 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 requires that any facility that releases airborne radionuclides assess the impact of such releases using a computer program approved by the US/EPA.[1] Berkeley Lab satisfies this requirement with the use of CAP88-PC.[2]

Details of dose calculations from dispersible airborne radionuclides are included in the Laboratory's annual NESHAP report. Based on these calculations, the location of the maximally exposed individual (MEI) to airborne emissions was determined to be at the Lawrence Hall of Science (LHS). The maximum possible dose to the MEI (a person residing at the LHS) from airborne radionuclides for 2005 was about 1.9 x 10^{-4} mSv (0.019 mrem).

The dose from airborne radionuclides to the surrounding population is estimated for a region that extends from the site for 80 km (50 mi). Within this area, the population is about 6,615,000.[3] The estimated annual population dose from all airborne radionuclides for the year was 1.7 x 10^{-3} person-Sv (0.17 person-rem).

5.4 TOTAL DOSE TO THE PUBLIC

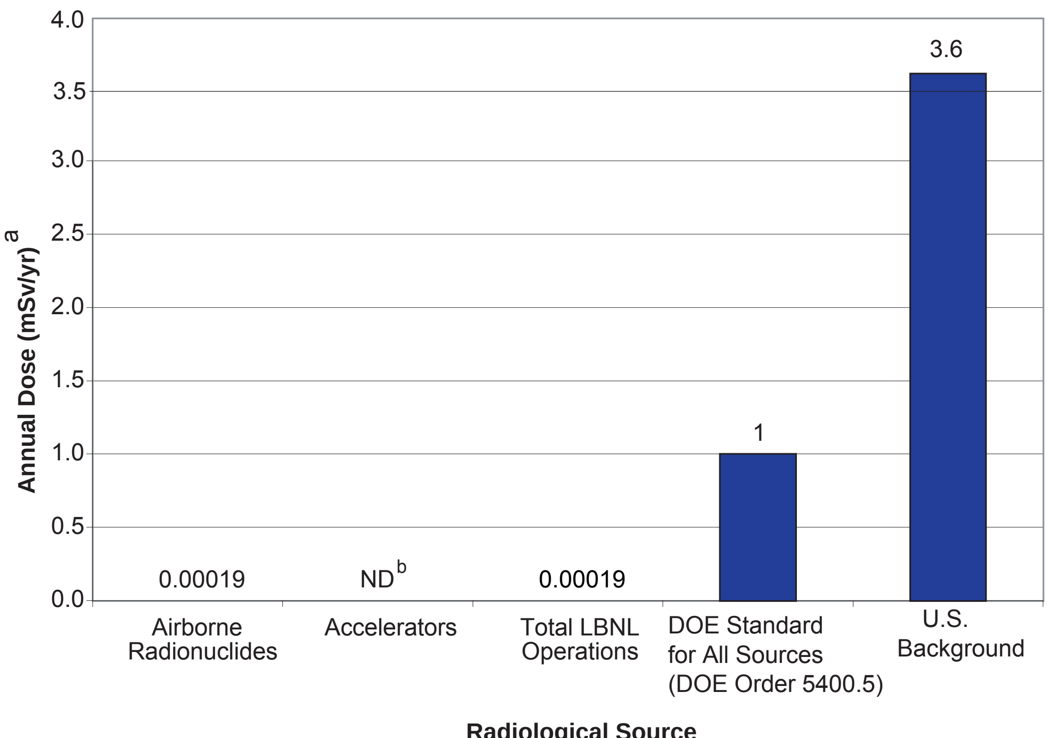
The total radiological impact to the public from accelerator operations and airborne radionuclides is well below applicable standards and nominal background radiation levels. Because the greatest possible dose from penetrating radiation was indistinguishable from background radiation levels, the 2005 total dose to the MEI from Berkeley Lab activities is due solely to exposure to airborne radiation. As presented in Figure 5-1, the maximum effective dose equivalent from Berkeley Lab operations to an individual residing at LHS in 2005 is about 1.9 x 10^{-4} mSv/yr (0.019 mrem/yr). This dose was primarily from fluorine-18 from the cyclotron at the Biomedical Isotope Facility (Building 56) and from iodine-125 used in biomedical research in Building 55. This value is approximately 0.005% of the average United States background radiation[4] (3.6 mSv/yr [360 mrem/yr]) and about 0.2% of the US/EPA annual limits (0.10 mSv/yr [10 mrem/yr]).[1]

As noted previously, the estimated dose to the population within 80 km (50 mi) of Berkeley Lab from airborne radionuclides emitted by laboratory operations was 1.7 x 10^{-3} person-Sv (0.17 person-rem) for the same period. From natural background airborne radionuclides alone, this same population receives an estimated dose of 13,000 person-Sv (1,300,000 person-rem). The dose to the population from Berkeley Lab is less than 0.000013% of the background level.

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 1 rad/day (0.01 Gray per day [Gy/day]).[5] 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 1 rad/day (0.01 Gy/day).[6]

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



[a] 1 mSv/yr = 100 mrem/yr

[b] Nondetect: Dose from penetrating radiation was indistinguishable from natural background radiation levels.

Figure 5-1 Comparison of Radiological Dose Impacts for 2005

radionuclides in water, soil, and sediment. Creek water, soil, and sediment samples were collected and analyzed for several radionuclides, including tritium, alpha-emitting radionuclides, and beta-emitting radionuclides. Alpha- and beta-emitting radionuclides in soil and sediment were further characterized by gamma spectroscopy.

These radionuclides, with the exception of tritium, were measured at levels similar to natural background levels. Sample results are provided in Volume II. Alpha- and beta-emitting radionuclides and tritium were evaluated using the DOE-endorsed computer model RESRAD-BIOTA.[7] Both terrestrial and aquatic systems passed the "general screening process," which is described in a DOE-approved technical standard.[6] These results confirm that Berkeley Lab is in compliance with DOE requirements to limit radiation doses to aquatic organisms to 1 rad/day (0.01 Gy/day). In addition, they show that the Laboratory is well within international recommendations for limiting dose to other plants and animals.

6

Quality Assurance

Calibration of a flow controller that is used for air sampling

6.1 OVERVIEW

Lawrence Berkeley National Laboratory's quality assurance (QA) policy is documented in the *Operating and Assurance Plan* (OAP).[1] The OAP consists of a set of operating principles used to support internal organizations in achieving consistent, safe, and high-quality performance in their work activities. OAP 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 OAP, 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 US/EPA[4] guidance. When special QA and quality control (QC) requirements are necessary for environmental monitoring (such as the NESHAP stack monitoring program), a Quality Assurance Project Plan is developed and implemented.

On-site and external analytical laboratories analyze samples for the environmental monitoring program. Both types of laboratories must meet demanding QA/QC specifications and certifications[5] that were established to define, monitor, and document laboratory performance. The QA/QC data provided by these laboratories are incorporated into Berkeley Lab's data quality–assessment processes. For CY 2005, seven external analytical laboratories were available for use under contract(s) coordinated with Berkeley Lab and Lawrence Livermore National Laboratory.

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.

The DOE Consolidated Audit Program (DOECAP) annually audits all 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 (NQA-1) 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 one representative to participate in DOECAP audits of Berkeley Lab's external analytical laboratory locations. The team audits each of the following six areas that pertains to the services provided by the particular external analytical laboratory:

1. QA management systems and general laboratory practices
2. Organic analyses
3. Inorganic and wet chemistry analyses
4. Radiochemical analyses
5. Laboratory information management systems and electronic deliverables
6. Hazardous and radioactive material management

Also included in the lab audits is a review of the external analytical laboratory's performance in proficiency testing required by the California Environmental Laboratory Accreditation Program. No major deficiencies were found during any of the audits of the seven external laboratories used by Berkeley Lab during the year. Any minor deficiencies identified in the audits are followed by corrective action plans and are tracked to closure.

To verify that environmental monitoring activities are adequate and effective, internal oversight is performed consisting of assessments performed by the ESG and the OAA. In 2005, an ESG subject-matter expert performed assessments on the NESHAP Monitoring Program. This assessment found the Monitoring Program to be in compliance with US/EPA and Berkeley Lab requirements.

In addition, external oversight of Berkeley Lab programs is performed through the DOE Operational Awareness Program.[6] 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 1,180 individual samples (air, sediment, soil, vegetation, and water) throughout the year; the samples generated nearly 2,850 analytical results. This represents a 30% decrease in the number of samples collected compared to the previous year. The reduction was primarily due to Berkeley Lab implementing an EPA-approved revised NESHAP stack air monitoring program (see Section 4.2.1 for more information). Figure 6-1 shows the number of samples collected by each of the major programs.

The various water monitoring programs, which require a larger number of analytical tests per sample than most other programs, accounted for 45% of the overall monitoring results from the samples. However, the stack exhaust air monitoring program remained the single largest of the monitoring programs as measured by both the number of samples collected and analytical results.

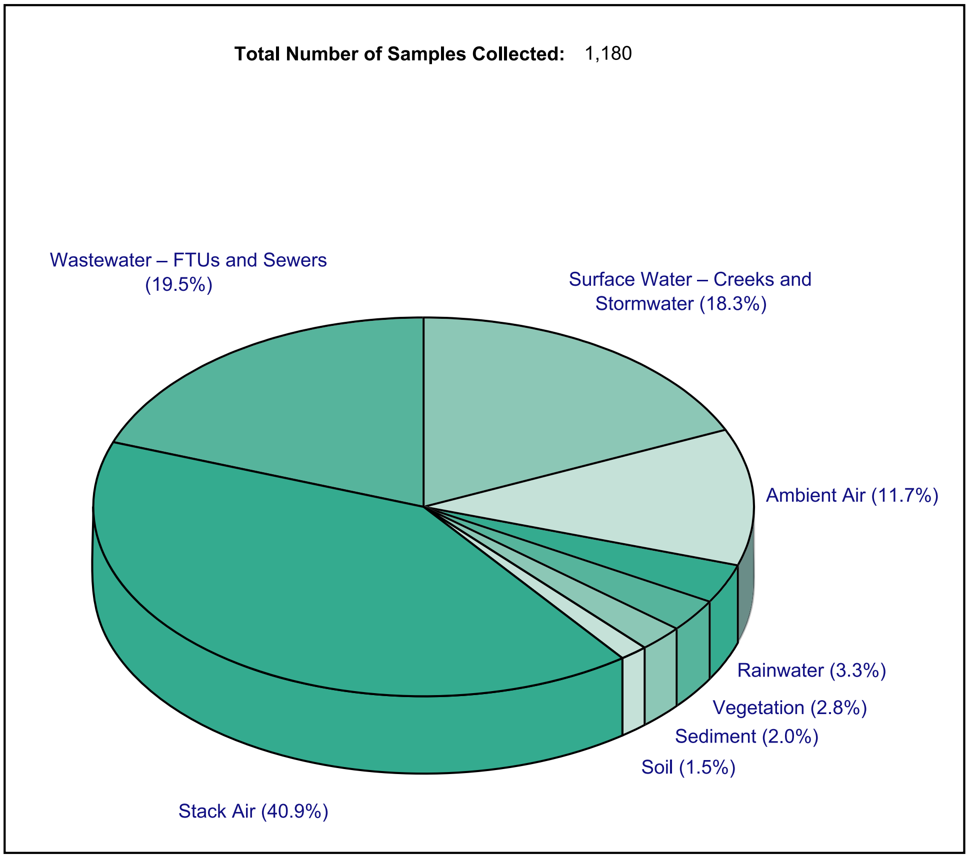


Figure 6-1 Quantity of Samples Collected per Program

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 2005, a total of 371 split and 143 duplicate samples from all programs were collected for either radiological or nonradiological (or both) analyses. This represents an increase of almost two and a half times the number of QC samples collected during the previous year and is well above Berkeley Lab's goal of analyzing one split or duplicate sample for every 10 environmental samples. The increased number of split and duplicate analyses were used to confirm the performance of new analytical laboratories that did not previously support the environmental monitoring program.

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, these tests cannot be performed, although such a result is in fact confirming the validity of the primary sample. When QA pair results are outside of control limits, an investigation is performed to determine the cause of the discrepancy.

Individual data results for all environmental monitoring programs are presented in Volume II.

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 1,339 radiological and nonradiological analyses on QC samples in 2005. Table 6-1 shows the breadth and diversity of this program.

Table 6-1 Summary of Quality Control Testing Performed by Analytical Laboratories in 2005

Program	Sample batches	QC samples	Laboratories involved	Radiological	Nonradiological
Ambient air	13	48	3	X	
Rainwater	10	127	4	X	
Sediment	1	96	5	X	
Soil	1	152	5	X	
Stack air	28	135	4	X	
Rainwater and creeks	8	229	6	X	X
Vegetation	2	8	1	X	
Wastewater	21	544	6	X	X

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. In 2005, several such investigations were performed, and corrective actions were identified and implemented.

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References

Preface

1. U.S. Department of Energy, *Environment, Safety, and Health Reporting,* DOE Order 231.1A (1995, as amended).

Executive Summary

1. U.S. Department of Energy, *Environment, Safety, and Health Reporting*, DOE Order 231.1A (1995, as amended).
2. U.S. Department of Energy, *Contract Between the United States of America and the Regents of the University of California,* DE-AC02-05CH11231 (2005).
3. U.S. Department of Energy, *Occurrence Reporting and Processing of Operations Information,* DOE Order 231.1-2, (July 1997).
4. Ernest Orlando Lawrence Berkeley National Laboratory, *Contract 98 Appendix F Self-Assessment Report for Fiscal Year 2004,* LBID-2394 (September 2005).
5. Committee on the Biological Effects of Ionizing Radiations (BEIR V), *Health Effects of Exposure to Low Levels of Ionizing Radiation*, National Academy Press (1990).
6. U.S. Environmental Protection Agency, *National Emission Standard for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities,* Title 40 Code of Federal Regulations (CFR) Part 61, Subpart H (1989, as amended).
7. East Bay Municipal Utility District, *Wastewater Discharge Permits, Account Nos. 06600791, 50238911, 50238921 (April 2003) and 50347891 (September 2001)* for Lawrence Berkeley National Laboratory.
8. California State Water Resources Control Board, *General Permit for Stormwater Discharges Associated With Industrial Activity (No. 2 01I002421)*, Water Quality Order 97-03-DWQ, NPDES General Permit No. CAS 000001 (1997).
9. Ernest Orlando Lawrence Berkeley National Laboratory, *Analysis of Background Distributions of Metals in the Soil at Lawrence Berkeley National Laboratory*, Environmental Restoration Program (September 2001).
10. Department of Toxic Substances Control, *Notice of Final Decision for Approval of the Corrective Measures Study Report and Remedy Selection for Lawrence Berkeley National Laboratory,* (August 2005).
11. Ernest Orlando Lawrence Berkeley National Laboratory, *RCRA Corrective Measures Implementation Workplan,* Environmental Restoration Program (November 2005).

Chapter 1: Introduction

1. The Association of Bay Area Government's Web site: *Bay Area Census,* MTC-ABAG Library, http://www.abag.ca.gov/ (October 2003).
2. McClure, Richard, written communication to Michael Ruggieri (April 2006).
3. *Safe Drinking Water Act,* 42 USC § 300f *et seq.* (1974, as amended).
4. *Endangered Species Act,* 7 USC §136, 16 USC §460 *et seq.* (1973, as amended).

Chapter 2: Performance-Based Environmental Management System

1. International Organization for Standardization (ISO), *Environmental Management Systems—Specification with Guidance for Use,* Publication No. ISO 14001:1996(E) (Geneva, Switzerland: ISO, 196), http://www.iso.org/.
2. U.S. Executive Order 13148, *Greening the Government Through Leadership in Environmental Management* (April 22, 2000).
3. U.S. Department of Energy, Environmental Protection Program, DOE Order 450.1 (January 2005).
4. Ernest Orlando Lawrence Berkeley National Laboratory, *Performance-Based Environmental Management System Plan*, LBNL/PUB 3180, (August 2005).

Chapter 3: Environmental Program Summary

1. Ernest Orlando Lawrence Berkeley National Laboratory, *Integrated Safety Management,* "ISM Guiding Principles," http://www.lbl.gov.ehs/pub811/principles.html (2003).
2. U.S. Executive Order 13148, *Greening the Government Through Leadership in Environmental Management* (April 22, 2000).
3. U.S. Department of Energy, Environmental Protection Program, DOE Order 450.1 (January 2005).
4. U.S. Department of Energy, *Occurrence Reporting and Processing of Operations Information*, DOE Order 231.1-2 (July 1997).
5. *Clean Air Act,* 42 USC §7401 *et. seq.* (1967, as amended).
6. *Air Resources*, California Health and Safety Code §39000 *et seq.* (1967, as amended).
7. U.S. Environmental Protection Agency, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*, 40 CFR Part 61, Subpart H (1989, as amended).
8. U.S. Department of Energy, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5 (1990, as amended).
9. Bay Area Air Quality Management District, *Permit to Operate for Lawrence Berkeley National Laboratory (Plant No. 723 and G No. 6134)* (July 2003).

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

11. California Air Resources Board, *Diesel Risk Reduction Plan* (2000).

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

13. *Resource Conservation and Recovery Act of 1976*, Chapter 82, Subchapter III, *Hazardous Waste Management*, 42 USC §6921 *et seq.* (1976, 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. Ernest Orlando Lawrence Berkeley National Laboratory, *Hazardous Materials Business Plan,* Industrial Hygiene Group, EH&S Division (March 2005).

17. *Risk Management and Prevention Program*, California Health and Safety Code §25531 *et seq.* (1986, as amended).

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,* Department of Toxic Substances Control (May 4, 1993).

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

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

25. City of Berkeley, *Permit Renewal Notification for Lawrence Berkeley Laboratory (EPA ID No. CA4890008986)* (March 2003).

26. Ernest Orlando Lawrence Berkeley National Laboratory, *Biennial Hazardous Waste Report for 2004,* Waste Management Group.

27. Ernest Orlando Lawrence Berkeley National Laboratory, *Waste Minimization, Accomplishments and Goals;* http://www.eh.doe.gov/p2/wastemin/waste.htm.

28. Ernest Orlando Lawrence Berkeley National Laboratory, *Mixed Waste Site Treatment Plan,* Waste Management Group (October 1995).

29. Ernest Orlando Lawrence Berkeley National Laboratory, *RCRA Facility Investigation Work Plan,* Environmental Restoration Program (October 1992).

30. Ernest Orlando Lawrence Berkeley National Laboratory, *Draft Final RCRA Facility Investigation Phase I Progress Report*, Environmental Restoration Program (November 1994).
31. Ernest Orlando Lawrence Berkeley National Laboratory, *Draft Final RCRA Facility Investigation Phase II Progress Report*, Environmental Restoration Program (November 1995).
32. Ernest Orlando Lawrence Berkeley National Laboratory, *Draft Final RCRA Facility Investigation (RFI) Report*, Environmental Restoration Program (September 2000).
33. Ernest Orlando Lawrence Berkeley National Laboratory, *RCRA Corrective Measures Study (CMS) Plan* (CA EPA ID No. CA4890008986), Environmental Restoration Program, with *Attachment 1: Human Health and Ecological Risk Assessment Workplan and Assumptions Document* (May 2002).
34. Ernest Orlando Lawrence Berkeley National Laboratory, *Human Health Risk Assessment,* Environmental Restoration Program (May 2003).
35. Ernest Orlando Lawrence Berkeley National Laboratory, *Ecological Risk Assessment for Chemicals,* Environmental Restoration Program (December 2002).
36. Ernest Orlando Lawrence Berkeley National Laboratory, *Draft Corrective Measures Study Report*, Environmental Restoration Program (July 2004).
37. California Department of Toxic Substances Control, *Notice of Final Decision for Correction Measures Study Report and Remedy Selection for Lawrence Berkeley National Laboratory, (*August 31, 2005).
38. Ernest Orlando Lawrence Berkeley National Laboratory, *RCRA Corrective Measures Implementation (CMI) Workplan*, Environmental Restoration Program (November 2005).
39. U.S. Executive Order 13101, *Greening the Government through Waste Prevention, Recycling, and Federal Acquisition,* 63 Federal Register 49642 (September 14, 1998).
40. *Hazardous Waste Source Reduction and Management Review Act of 1989*, California Health and Safety Code §25244.12 *et seq.* (1989).
41. Ernest Orlando Lawrence Berkeley National Laboratory, *Source Reduction Evaluation Review Plan and Plan Summary* (2003).
42. Ernest Orlando Lawrence Berkeley National Laboratory, *Hazardous Waste Management Report Summary,* Waste Management Group (2003).
43. *Pollution Prevention Act of 1990*, 42 USC §13101 *et seq.* (1990).
44. *Clean Water Act*, 33 USC §1251 *et seq.* (1977, as amended).
45. *Porter-Cologne Water Quality Control Act*, California Water Code §13020 (1969, as amended).
46. East Bay Municipal Utility District, *Wastewater Discharge Permits, Account Nos. 06600791 and 50238911 (April 2003), and 503478910 (September 2001)* for Lawrence Berkeley National Laboratory.

47. Ernest Orlando Lawrence Berkeley National Laboratory, *Toxic Organics Management Plan, Building 25 Photo Fabrication Facility,* Environmental Protection Group (May 1997).

48. Ernest Orlando Lawrence Berkeley National Laboratory, *Accidental Spill Prevention and Containment Plan, Vols. I through V,* Environmental Protection Group (1994–2000).

49. Ernest Orlando Lawrence Berkeley National Laboratory, *Accidental Spill Prevention and Containment Plan/Toxic Organics Management Plan,* Environmental Protection Group (December 1997).

50. Central Contra Costa Sanitary District, *Class III Industrial User Permit for Joint Genome Institute*, (January 2006).

51. California State Water Resources Control Board, *General Permit for Stormwater Discharges Associated With Industrial Activities (No. 2 01I002421),* Water Quality Order 97-03-DWQ, NPDES General Permit No. CAS 000001 (1997).

52. Ernest Orlando Lawrence Berkeley National Laboratory, *Storm Water Pollution Prevention Plan*, Environmental Services Group (March 2006).

53. Ernest Orlando Lawrence Berkeley National Laboratory, *Storm Water Monitoring Program*, Environmental Services Group (November 2005).

54. Ernest Orlando Lawrence Berkeley National Laboratory, *2004–2005 Annual Report for Stormwater Discharges Associated with Industrial Activities*, Environmental Services Group (June 2005).

55. California State Water Resources Control Board, *General Permit for Stormwater Discharges Associated With Construction Activity,* Water Quality Order 99-08-DWQ and modifications, Permit Number CAS 000002 (1999/2001).

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

57. Ernest Orlando Lawrence Berkeley National Laboratory, *Spill Prevention, Control, and Countermeasures Plan*, Environmental Services Group (October 2002).

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

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

60. *Safe Drinking Water Act*, 42 USC §300f *et seq.* (1974, as amended).

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

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

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

64. *California Endangered Species Act*, Fish and Game Code §2050–2068 *et seq.* (1985, as amended).

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

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

Chapter 4: Environmental Monitoring

1. U.S. Environmental Protection Agency, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*, 40 CFR Part 61, Subpart H (1989, as amended).
2. U.S. Department of Energy, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5 (1990, as amended).
3. Ernest Orlando Lawrence Berkeley National Laboratory, *Environmental Monitoring Plan*, Environmental Services Group (February 2006).
4. Smith, A.R. and R. J. McDonald, *Gamma-Emitters in LBNL B70 and B70A Stack Filters: LBNL Low Background Facility Results for Calendar 2002*, Lawrence Berkeley National Laboratory, Low Background Facility (March 2003).
5. California State Water Resources Control Board, *General Permit for Stormwater Discharges Associated With Industrial Activities (No. 01I002421),* Water Quality Order 97-03-DWQ, NPDES General Permit No. CAS 000001 (1997).
6. California Regional Water Quality Control Board, *San Francisco Bay Region Basin Plan*, Table 4-3 (June 1995).
7. U.S. Environmental Protection Agency, *National Primary Drinking Water Standards,* 40 CFR Part 141, Subpart B (1976, as amended); and California Department of Health Services, *Domestic Water Quality and Monitoring Regulations,* Title 22 California Code of Regulations (CCR) §64443 (1984, as amended).
8. U.S. Environmental Protection Agency, *National Primary Drinking Water Standards,* 40 CFR Part 141, Subpart B (1976, as amended).
9. Ernest Orlando Lawrence Berkeley National Laboratory, *Storm Water Monitoring Program,* Environmental Services Group (November 2005).
10. Ernest Orlando Lawrence Berkeley National Laboratory, *Storm Water Pollution Prevention Plan,* Environmental Services Group (March 2006).
11. East Bay Municipal Utility District, *Wastewater Discharge Permits, Account Nos. 066007911 and 50238911 (April 2003), and 50347891 (September 2001)* for Lawrence Berkeley National Laboratory.
12. U.S. Department of Energy, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T (January 1991).
13. California Department of Health Services, *Standards for Protecting Against Radiation*, 17 CCR §30253 (1994, as amended).
14. U.S. Nuclear Regulatory Commission, *Standards for Protection Against Radiation*, 10 CFR 20, Subpart K (1994, as amended).

15. Ernest Orlando Lawrence Berkeley National Laboratory, *Total Toxic Organics Compliance Report*, (November, 2005).

16. *Resource Conservation and Recovery Act of 1976*, Chapter 82, Subchapter III, *Hazardous Waste Management*, 42 USC §6921 *et seq.* (1976, as amended).

17. East Bay Municipal Utility District, *Wastewater Discharge Permit (Account No. 50347891) for Lawrence Berkeley National Laboratory* (September 2001).

18. Preliminary Remediation Goals, United States Environmental Protection Agency Region 9 Table, October 2004 (http://www.epa.gov/region09/wastes/fund/prg/index.html).

19. Ernest Orlando Lawrence Berkeley National Laboratory, *Analysis of Background Distributions of Metals in the Soil at Lawrence Berkeley National Laboratory,* Environmental Restoration Program (September 2001).

Chapter 5: Radiological Dose Assessment

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

2. Chaki, S. "CAP88-PC Windows Version 2.0," memo to F. Marcionwski, U.S. Environmental Protection Agency, documenting approval of CAP88-PC Version 2.0 (October 25, 1999).

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

4. Committee on the Biological Effects of Ionizing Radiations (BEIR V), *Health Effects of Exposure to Low Levels of Ionizing Radiation*, National Academy Press (1990).

5. U.S. Department of Energy, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5 (1990, as amended).

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

7. DOE 2003. RESRAD-BIOTA for Windows, Version 1.0, developed at the Environmental Assessment Division of Argonne National Laboratory for the U.S. Department of Energy, with support from the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission, www.ead.anl.gov/resrad (September 30, 2003).

Chapter 6: Quality Assurance

1. Ernest Orlando Lawrence Berkeley National Laboratory, *Operating and Assurance Plan,* LBNL/PUB-3111, Revision 7, Office of Assessment and Assurance, EH&S Division (April 2000).

2. Ernest Orlando Lawrence Berkeley National Laboratory, *Environmental Monitoring Plan,* Environmental Services Group (February 2006).
3. U.S. Department of Energy, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance,* DOE/EH-0173T (January 1991).
4. U.S. Environmental Protection Agency, *National Emission Standard for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities,* 40 CFR Part 61, Subpart H (1989, as amended).
5. Lawrence Livermore National Laboratory/Lawrence Berkeley National Laboratory, *Quality Assurance and Quality Control Plan for Analytical Services* (February 2004).
6. U.S. Department of Energy, *ES&H Operational Awareness Guide,* Berkeley Site Office (January 1998).

Acronyms and Abbreviations

AEDE	annual effective dose equivalent
AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
ASPCP	Accidental Spill Prevention and Containment Plan
AST	aboveground storage tank
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan
Berkeley Lab	Ernest Orlando Lawrence Berkeley National Laboratory
Bq	becquerel
BTEX	benzene, toluene, ethyl benzene, and xylene
BTU	British thermal units
C	Celsius
CAP	Corrective Action Program
CARB	California Air Resources Board
CCCSD	Central Contra Costa Sanitary District
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act of 1970
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
CMI	Corrective Measures Implementation
CMS	Corrective Measure Study
COD	chemical oxygen demand
CWA	Clean Water Act

CY	calendar year
DCA	dichloroethane
DCE	dichloroethylene
DHS	Department of Health Services
DOE	United States Department of Energy
DOECAP	DOE Consolidated Audit Program
DPF	diesel particulate filter
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EH&S	Environment, Health, and Safety Division at Berkeley Lab
EIR	Environmental Impact Report
EMP	Environmental Management Program
EMS	environmental management system
EPCRA	Emergency Planning and Community Right-to-Know Act
ERP	Environmental Restoration Program
ESG	Environmental Services Group
F	Fahrenheit
FESA	Federal Endangered Species Act
ft	foot
FTU	fixed treatment unit
FY	fiscal year
gal	gallon
gsf	gross square feet
gsm	gross square meters
Gy	gray (measure of radiation in SI)
HMBP	Hazardous Materials Business Plan
hr	hour
HWHF	Hazardous Waste Handling Facility
in	inch
ISM	Integrated Safety Management
ISO	International Organization for Standardization
JGI	Joint Genome Institute
kg	kilogram

km	kilometer
kW	kilowatt
L	liter
lb	pound
LBNL	Lawrence Berkeley National Laboratory
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
m	meter
m^3	cubic meter
MCL	maximum contaminant level
MEI	maximally exposed individual
mg	milligram
mi	mile(s)
mrem	millirem
mSv	millisievert
MW	megawatt
ND	not detected
NEPA	National Environmental Policy Act of 1969
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOI	Notice of Intent
NOV	Notice of Violation
NQA	Nuclear Quality Assurance
NTLF	National Tritium Labeling Facility
OAA	Office of Assessment and Assurance
OAP	Operating and Assurance Plan
OBT	organically bound tritium
PBT	persistence, bioaccumulation, and toxicity
PCB	polychlorinated biphenyl
PCE	perchloroethylene (tetrachloroethylene)
pCi	picocurie (one trillionth of a curie)
PDF	Portable Document Format
PGF	Production Genomics Facility
PM	particulate matter

QA	quality assurance
QC	quality control
rad	radiation absorbed dose
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RFI	RCRA Facility Investigation
RMPP	Risk Management and Prevention Plan
RWQCB	Regional Water Quality Control Board
s	second
SAA	satellite accumulation area
SARA	Superfund Amendments and Reauthorization Act
SI	Système Internationale or International System of Units (the metric system)
SPCC	Spill Prevention, Control and Countermeasures
Sv	sievert
SWMP	Storm Water Monitoring Program
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCA	trichloroethane
TCE	trichloroethylene
TDS	total dissolved solids
TFWT	tissue-free water tritium
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOMP	Toxic Organics Management Plan
TPH	total petroleum hydrocarbons
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
µg	microgram(s)
UHVCF	Ultra-High Vacuum Cleaning Facility
USC	United States Code

US/EPA	United States Environmental Protection Agency
USF&WS	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

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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.

Aliquot
An exact fractional portion of a sample taken for analysis.

Alpha particle
A charged particle comprised of two protons and two neutrons, which is emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.

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

Analyte
The subject of a sample analysis.

Aquifer
A subsurface saturated layer of rock or soil that can supply usable quantities of groundwater to wells and springs. Aquifers can provide water for domestic, agricultural, and industrial uses.

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

Becquerel (Bq)
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.

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

Discharge
A release of a liquid into an area not controlled by LBNL.

Dose
The quantity of radiation energy absorbed during a given period of time.

Dose, absorbed
The energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the gray (SI unit) or rad (conventional unit).

Dose, effective
The hypothetical whole-body dose that would give a risk of cancer mortality and/or serious genetic disorder equal to a given exposure that may be limited to just a few organs. The effective dose equivalent is equal to the sum of individual organ doses, each weighted by degree of risk that the organ dose carries. For example, a 1-millisievert dose to the lung, which has a weighting factor of 0.12, gives an effective dose that is equivalent to 0.12 millisievert (1×0.12).

Dose equivalent
A term used in radiation protection that expresses all types of radiation (alpha, beta, and so on) on a common scale for calculating the effective absorbed dose. It is the product of the absorbed dose and certain modifying factors. The unit of dose equivalent is the sievert (SI unit) or rem (conventional unit).

Dose, maximum boundary
The greatest dose commitment, considering all potential routes of exposure, from a facility's operation to a hypothetical individual who is in an uncontrolled area where the highest dose rate occurs. It assumes that the individual is present 100% of the time (full occupancy), and it does not take into account shielding by obstacles such as buildings or hillsides.

Dose, maximum individual
The greatest dose commitment, considering all potential routes of exposure, from a facility's operation to a hypothetical individual at or outside the LBNL boundary where the highest dose rate occurs. It takes into account shielding and occupancy factors that would apply to a real individual.

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 1 sievert, their population dose would be 1,000 person-sievert.

Dosimeter
A portable detection device for measuring the total accumulated exposure to ionizing radiation. *See also* Thermoluminescent dosimeter.

Downgradient
Commonly used to describe the flow of groundwater from higher to lower concentration. Analogous to "downstream."

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).

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.

Environmental remediation
The process of improving a contaminated area to a noncontaminated or safe condition.

Exposure
A measure of the ionization produced in air by x-ray or gamma radiation. The unit of exposure is the coulomb per kilogram (SI unit) or roentgen (conventional unit).

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, have longer wavelengths (lower energy) and cannot cause ionization.

Groundwater
A subsurface body of water in a zone of saturated soil sediments.

Gray
The gray is the International System (SI) unit for absorbed dose, which is the energy absorbed per unit mass from any kind of ionizing radiation in any kind of matter. One gray is an absorbed radiation dose of one joule per kilogram.

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 ground-water for slope stability purposes.

Low-Level Radioactive Waste

Waste containing radioactivity that is not classified as high-level waste, TRU waste, spent nuclear fuel, by-product material (as defined in Section 11e(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material.

Millirem
A common unit for reporting radiation dose. One millirem is one thousandth (10^{-3}) of a rem. *See* Rem.

Mixed Waste
Any radioactive waste that is also an 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.

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.

Perched
Separated from another water-bearing stratum by an impermeable layer.

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.

Piezometer
Generally, a small-diameter well primarily used to measure the elevation of the water table.

Plume[1]
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.

Pollutant
Any hazardous or radioactive material present in an environmental medium such as air, water, or vegetation.

Positron[2]
A particle that is equal in mass to the electron but opposite in charge. A positively charged beta particle.

Practical Quantification Limit (PQL)
The lowest amount of a matrix analyte 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 US/EPA as indicators of environmental contamination.

Rad
A unit of absorbed dose from ionizing radiation (0.877 rad per roentgen).

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 1 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
See Environmental remediation.

Roentgen
A unit of radiation exposure that expresses exposure in terms of the amount of ionization produced by X or gamma rays in a volume of air. One roentgen is 2.58×10^{4} coulombs per kilogram of air.

Sievert
A unit of radiation dose equivalent. The sievert is the SI unit equivalent to the rem (conventional unit). 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).

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 ^{235}U, ^{233}U, or ^{232}Th; or cosmic-ray induced radionuclides in the soil.

Thermoluminescent dosimeter
A type of dosimeter. After being exposed to radiation, the material in the dosimeter (lithium fluoride) luminesces on being heated. The amount of light that the material emits is proportional to the amount of radiation absorbed (dose). *See also* Dosimeter.

Tritium
A radionuclide of hydrogen with a half-life of 12.3 years. The very low energy of its radioactive decay makes it one of the least hazardous radionuclides.

Universal Waste[3]
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.

Vadose zone
The region above the water table that is partially saturated or unsaturated and does not yield water to wells.

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

Notes

[1] Definition from Agency for Toxic Substances and Disease Registry, ATSDR Glossary of Terms (June 21, 2004). http://www.atsdr.cdc.gov/glossary.html.

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

[3] Definition from California Department of Toxic Substances Control, *Managing Universal Waste in California,* Fact Sheet, (June 2003).

Table G-1 Prefixes Used with SI (Metric) Units

Prefix	Factor	Symbol
exa	1,000,000,000,000,000,000 = 10^{18}	E
peta	1,000,000,000,000,000 = 10^{15}	P
tera	1,000,000,000,000 = 10^{12}	T
giga	1,000,000,000 = 10^{9}	G
mega	1,000,000 = 10^{6}	M
kilo	1,000 = 10^{3}	k
hecto	100 = 10^{2}	h[a]
deka	10 = 10^{1}	da[a]
deci	0.1 = 10^{-1}	d[a]
centi	0.01 = 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	2.7×10^{-11}
becquerel	picocurie	27.0
gray	rad	100
sievert	rem	100
coulomb per kilogram	roentgen	3,876
Temperature		
degrees Celsius	degrees Fahrenheit	1.8, then add 32
Velocity		
meters per second	miles per hour	2.237
Volume		
cubic meters	cubic feet	35.315
liters	gallons	0.2642

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