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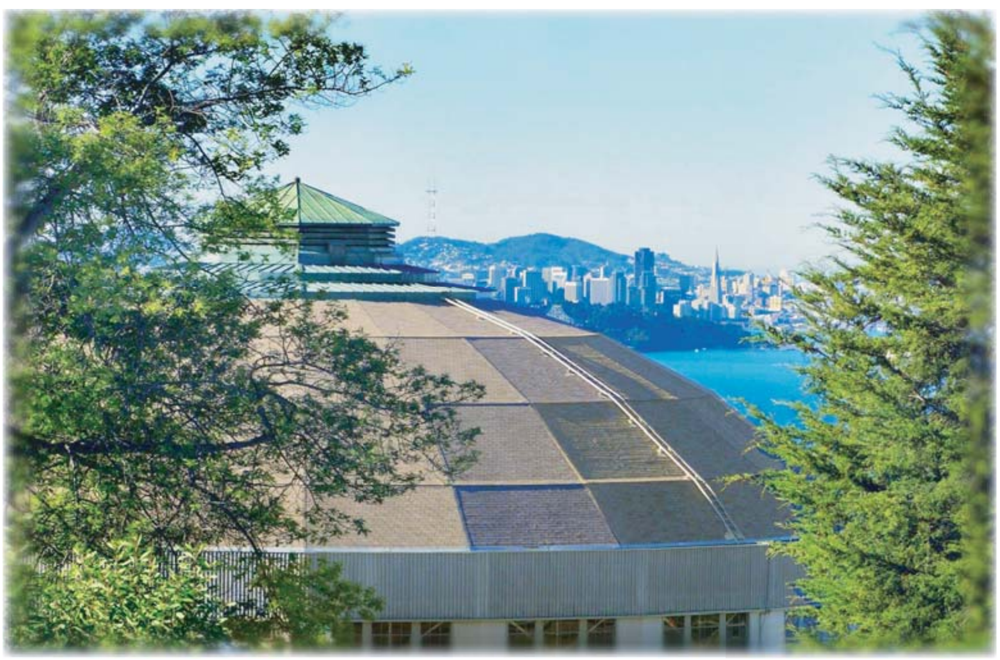
Volume 1

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Site Environmental Report for 2004

Volume 1

Environment, Health, and Safety Division
September 2005



DISCLAIMER

Site Environmental Report for 2004

Volume I

SEPTEMBER 2005

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 2004* summarizes Berkeley Lab's environmental management performance, presents environmental monitoring results, and describes significant programs for calendar year 2004. (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. Volume II contains individual data results from these activities. This year, the *Site Environmental Report* was 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 (telephone: 510-486-5440; e-mail: mrruggieri@lbl.gov).

This report was prepared under the direction of Michael Ruggieri of ESG. The primary authors are Robert Fox, Iraj Javandel, Ginny Lackner, 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 Roy Kaltschmidt (photography).

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1

Executive Summary

Sunset from Berkeley Lab

1.1 INTRODUCTION

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 (for more details, see Section 2.1).

This annual *Site Environmental Report* covers activities conducted in CY 2004. 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]

1.2 INTEGRATED SAFETY MANAGEMENT AND ENVIRONMENTAL MANAGEMENT SYSTEM

To provide the highest degree of protection for its workers, the public, and the environment, Berkeley Lab employs a system called Integrated Safety Management (ISM). ISM is a comprehensive DOE management system that involves five core functions: work planning, hazard and risk analysis, establishment of controls, work performance in accordance with the controls, and feedback and improvement. These five core functions are applied to all activities at Berkeley Lab. (For further information, see Section 3.2.) Laboratory activities are planned and conducted with full regard to protecting the public and the environment and complying with appropriate environmental laws and regulations. Both radiological and nonradiological activities are thoroughly monitored to assess their impacts on public health and the environment.

Berkeley Lab is developing a focused Environmental Management System (EMS), which will be integrated with the Laboratory's ISM System. When practical, ISM processes will be used to support environmental performance improvement and compliance management. In CY 2004, Berkeley Lab completed all scheduled EMS development milestones (see Section 3.2.1) and is on track to have a fully implemented and validated EMS by the end of 2005.

1.3 OPERATING PERMITS

At the end of CY 2004, Berkeley Lab held the following 49 environmental operating permits from various regulatory agencies:

- Air emission sources (35)
- Hazardous waste handling and treatment operations (2)
- Stormwater discharges (2)
- Underground storage tanks (6)
- Wastewater discharges (4)

(For further discussion of these permits, see Chapter 3.)

1.4 INSPECTIONS

Twenty-six inspections of Berkeley Lab's environmental programs occurred in CY 2004. Following one of these inspections, the California Department of Toxic Substances Control (DTSC) issued an inspection report identifying seven violations and a subsequent report identifying two additional violations.[3] (For details, see Sections 3.3.3 and 3.4.4.1.) In addition, Central Contra Costa Sanitary District issued a notice of violation (NOV) pertaining to a small stain found underneath an uncovered sanitary waste dumpster. (For more information on that NOV, see Section 3.3.3.)

1.5 INCIDENT TRACKING

In CY 2004, the following four environmental incidents occurred, which were reportable under the DOE occurrence-reporting program used to track incidents across the DOE complex:

- Nine violations were identified by the DTSC related to a hazardous waste inspection in March.
- An NOV was received from the Central Contra Costa Sanitary District as a result of an inspection of the Joint Genome Institute in September, which identified an uncovered dumpster with a small stain below the dumpster.
- Capacitor oil containing polychlorinated biphenyls was released from a dumpster near Building 71 in November.
- A routine inspection of trash dumpsters by Berkeley Lab staff in November identified improper disposal of California-regulated hazardous waste between Buildings 70 and 70A.

(For additional information on these incidents, see Section 3.3.3.)

1.6 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.[4] In 2004, there were three environmental performance measures. Table 1-1 summarizes these measures and shows the ratings received from both UCOP and DOE.

Table 1-1 Environmental Performance Measure Ratings for 2004

Performance measure	UCOP rating	DOE rating
Tracking of environmental incidents	Excellent	Excellent
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Completion of milestones for an Environmental Management System	Outstanding	Outstanding

(For additional information on the performance review program, see Section 3.6.)

1.7 ENVIRONMENTAL MONITORING

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

Both radiological and nonradiological contaminants are monitored in the local environment.[5] Sections 1.7.1 and 1.7.2 briefly summarize environmental monitoring results from CY 2004.

1.7.1 Radiological Monitoring

A significant portion of the environmental monitoring program measures radiological impacts from Laboratory activities. The Laboratory monitors and assesses two types of radiation: (1) direct penetrating radiation (gamma and neutron) from sources such as accelerators and (2) dispersible radionuclides from a wide range of Laboratory research activities. Specially designed shielding reduces the release of penetrating radiation into the environment, and capture systems minimize releases of dispersible radionuclides to the atmosphere. Discharges to the sanitary sewer are minimized by using strict administrative controls and the sewer outflows are continuously monitored.

The primary radiological compliance standards affecting the Laboratory are based on the maximum potential dose that a member of the public would receive from both direct penetrating radiation and dispersible radionuclides from the site.[6] In 2004, the maximum dose to a member of the public from direct radiation was indistinguishable from natural background.

Dispersible radionuclide emission sources are regulated by the United States Environmental Protection Agency (US/EPA). US/EPA has set 0.1 millisieverts per year (mSv/yr) (10 millirem per year [mrem/yr])[7] as the maximum allowable dose to the public from all exposure pathways (e.g., inhalation, ingestion, and skin absorption) resulting from airborne releases of radionuclides from a site. The maximum potential dose is based on a hypothetical member of the public who resides at the location of the Lawrence Hall of Science, which is consistent with the US/EPA regulations. The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in CY 2004 was 0.0001 mSv (0.01 mrem). This is 0.1% of the US/EPA dose limit for dispersible radionuclide emissions. (See Figure 1-1.)

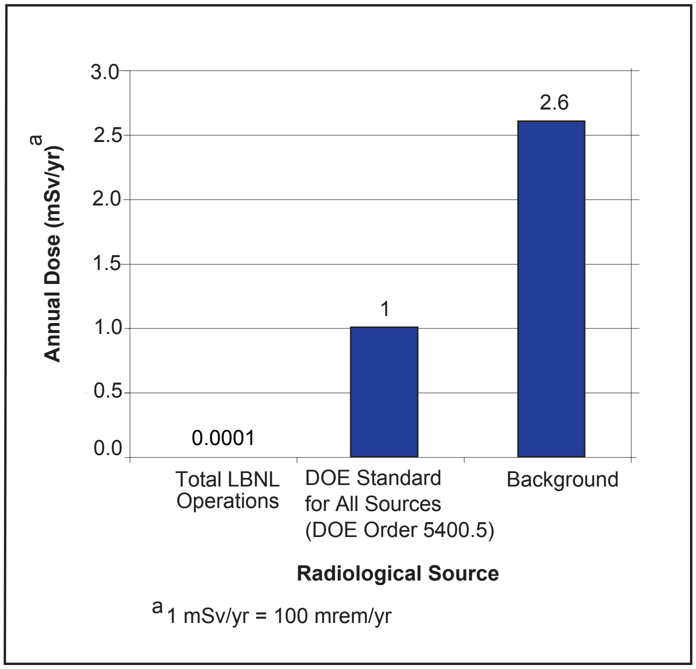

Figure 1-1 Comparison of Maximum Dose to Public from Berkeley Lab with DOE Radiological Standard and with Background Radiation Dose Received by the Public

Berkeley Lab also estimates the cumulative dose impact (collective effective dose equivalent [CEDE]) from its dispersible radionuclide emissions to the entire population found within an 80-kilometer (km) (50-mile) radius of the Laboratory. This measure is the sum of all individual doses to the population residing or working within 80 km of the Laboratory. The CEDE for CY 2004 from dispersible radionuclide emissions was estimated at 0.001 person-sieverts (0.1 person-rem) (see Glossary). No regulatory standard exists for this measure.

(For further discussion of the estimated dose impacts to the neighboring community from both direct and dispersible radiation, see Chapter 9.)

1.7.2 Nonradiological Monitoring

Berkeley Lab's nonradiological monitoring program focuses primarily on water, soil, and sediment. (These environmental media types are also analyzed for radiological components.)

In compliance with the three wastewater discharge permits[8] issued to the Laboratory by the East Bay Municipal Utility District, Berkeley Lab samples for metals, chlorinated hydrocarbons, and other specified parameters in sanitary sewer discharges. All results were well within compliance limits in 2004. (For details on the wastewater discharge sampling program, see Chapter 5.)

Stormwater discharges at Berkeley Lab are regulated under a general permit[9] issued by the State Water Resources Control Board. Stormwater discharges are treated differently from wastewater in that no specific discharge limits are established in the permit. References in the permit to the limits set by the Water Quality Control Plan[10] for the San Francisco Bay Basin are intended as guidelines rather than measures of compliance for stormwater discharges. Berkeley Lab analyzes stormwater samples for a wide set of potential contaminants, including pH, oil and grease, total suspended solids, and some metals. All results for the year were below or near sample detection limits. (For the results from stormwater sampling efforts throughout the year, along with the results from the routine sampling of rainwater and creeks, see Chapter 5.)

Extensive groundwater monitoring has been conducted by Berkeley Lab since the early 1990s, and nine principal groundwater plumes have been identified. All these plumes are on-site. The groundwater in the vicinity of the Laboratory is not used for public drinking water. Three types of contaminant plumes exist on-site:

- Volatile organic compounds (six plumes)
- Petroleum hydrocarbon (two plumes)
- Tritium (one plume)

Berkeley Lab's Environmental Restoration Program is conducted under the requirements of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program (see Chapter 6). An RCRA Facility Investigation was performed that evaluated 166 chemical release locations. Based on the results of the RCRA Facility Investigation, the DTSC determined that at 121 of the 166 locations there were either no chemical releases or the chemical concentration levels were low enough that no further action was needed. At the remaining 45 locations, human health and ecological risk assessments were performed. The risk assessments identified four areas of soil contamination and eleven areas of groundwater contamination that may require cleanup. An evaluation of potential cleanup measures has been performed; and in 2004, Berkeley Lab submitted to DTSC, for its review and approval, a *Draft Corrective Measures Study Report*[11] that identifies proposed final remedies.

The Laboratory continues to monitor these plumes while it develops long-term strategies to address the contamination. Until the Laboratory can implement these strategies, it has initiated several interim corrective-action measures to remediate the contaminated media or prevent movement of contamination. Concentrations of groundwater contaminants, along with other program developments and planned activities, are reported quarterly to regulatory agencies. (For further information, see Chapter 6.)

The soil and sediment monitoring program analyzes samples for metals, pH, and organic compounds at locations that complement sampling in other media such as air and surface water. Similar to results reported for other programs, most samples were below or near analytical detection limits, or at natural background levels for the Berkeley Lab site. In all instances, levels of contaminants were within regulatory limits. The levels of oil and grease in sediment measured at Berkeley Lab are 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.[12] Berkeley Lab will continue to monitor these locations. (For more information on Berkeley Lab's soil and sediment monitoring, see Chapter 7.)

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2

Introduction

Flowers planted by the Green Team with Building 2 in the background

2.1 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 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.

2.2 LABORATORY

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

2.2.1 Location

Berkeley Lab is located about 5 kilometers (km) (3 miles [mi]) east of San Francisco Bay (see Figure 2-1) 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

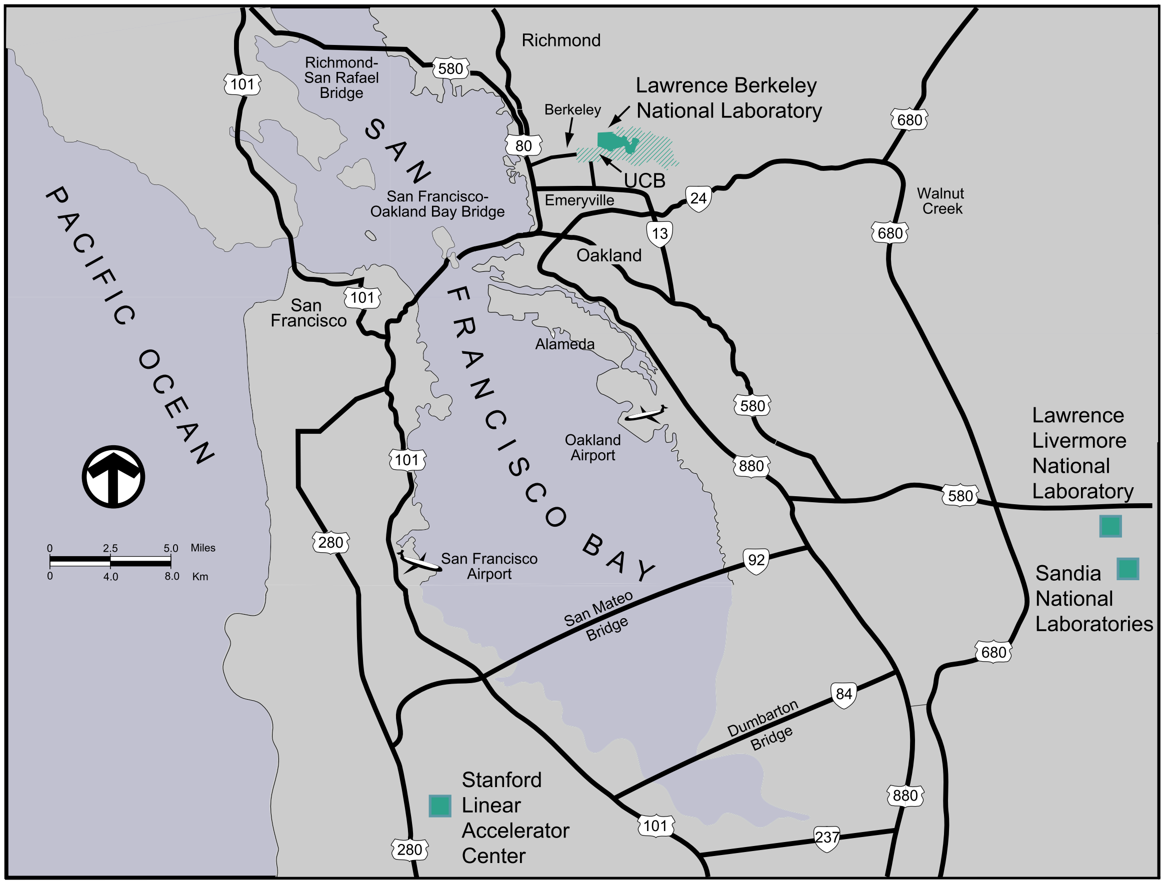

Figure 2-1 San Francisco Bay Area Map

(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 (see Figure 2-2). 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 2-3). 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.

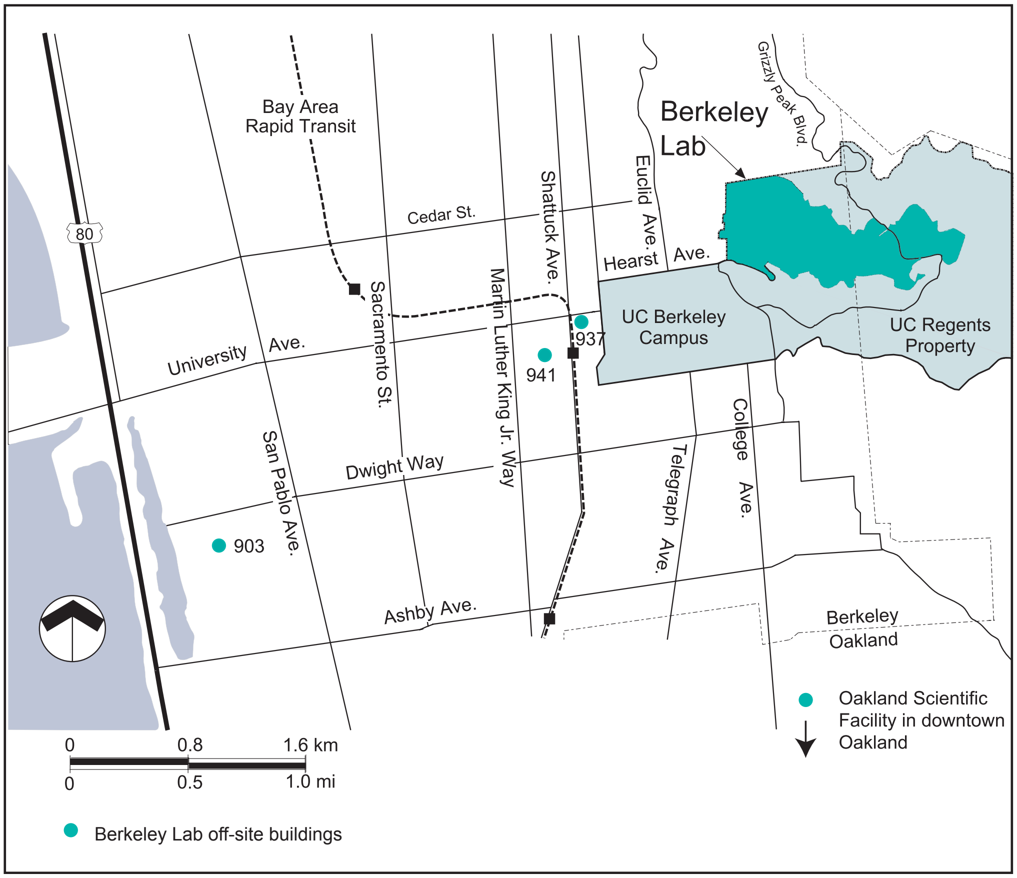

Figure 2-2 Vicinity Map

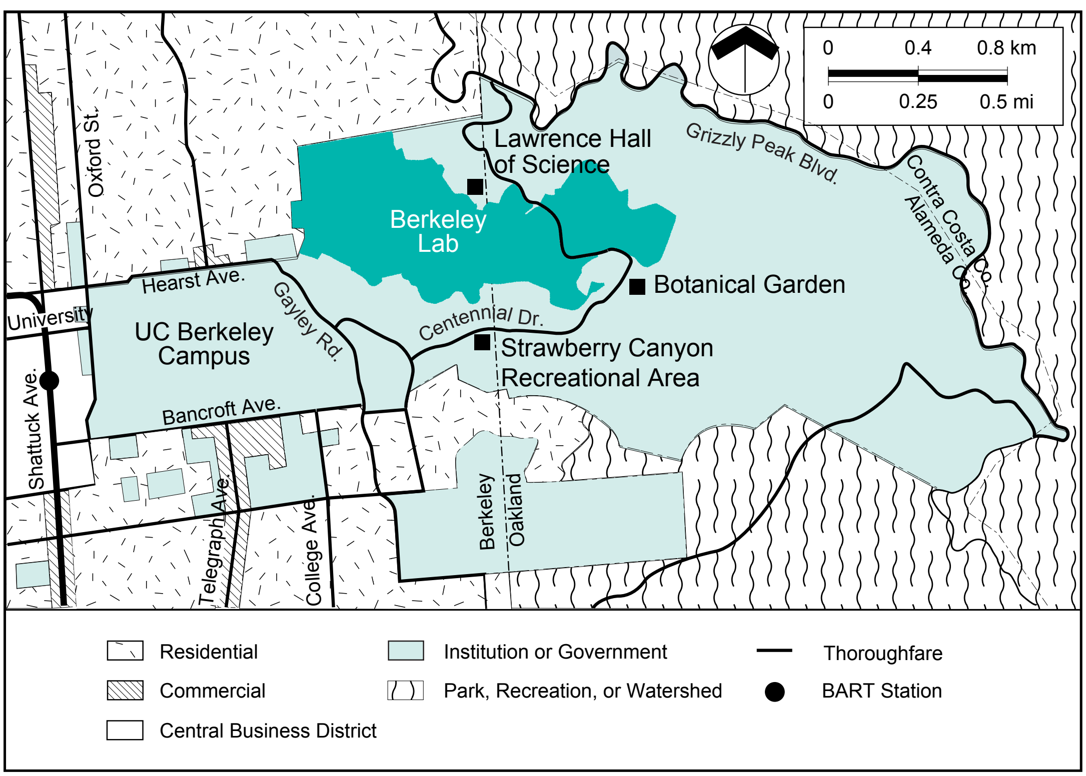

Figure 2-3 Adjacent Land Use

2.2.2 Population and Space Distribution

Approximately 3,900 scientists and support personnel work at Berkeley Lab, including about 600 students. In addition, the Laboratory hosts 2,000 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 202,000 gross square meters (2.18 million gross square feet). About 81% of the total space is at the main site, 3% is on the UC Berkeley campus (i.e., Donner and Calvin Laboratories), and the remaining 16% is located in various other off-site leased buildings in Berkeley, Oakland, and Walnut Creek. Figure 2-4 shows the Berkeley Lab space distribution.[3]

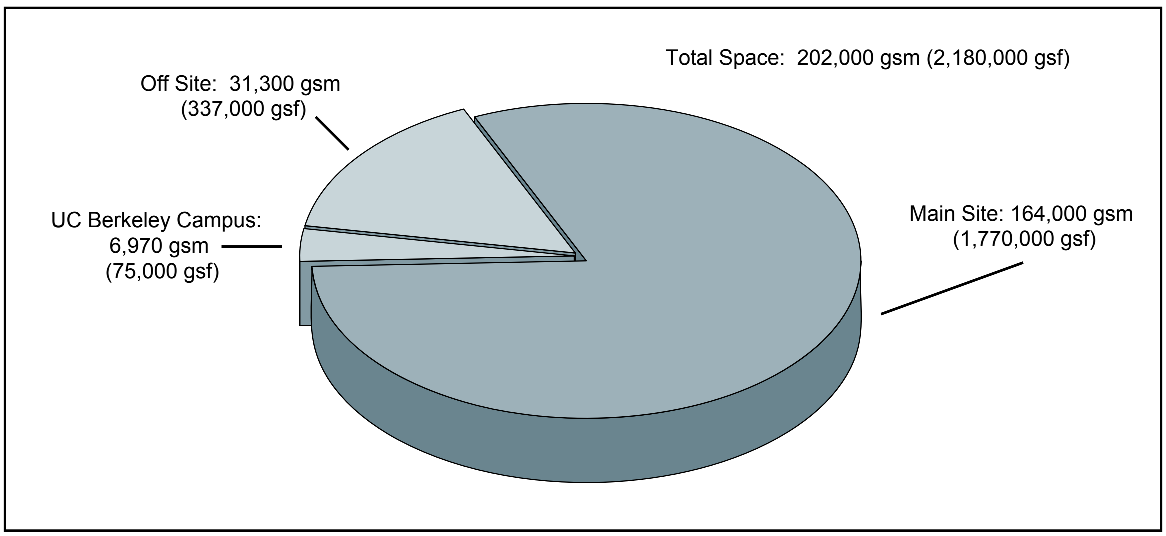

Figure 2-4 Space Distribution

2.2.3 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.

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.[4]

In 2004, Berkeley Lab completed a multiyear, sitewide upgrade of its water-supply system. The following replacements were made:

- All cast-iron water-main pipes
- Crucial system isolation valves and underground gate and butterfly valves, along with valves associated with the new pipeline

- Pressure regulators for the main line zone and main supplies at EBMUD's Shasta and Berkeley View water tanks

In addition, the following were installed:

- Dielectric isolation flanges at the connections between fire sprinkler risers and building water-supply pipes
- A cathodic protection system for the 20-centimeter (cm) and 30 cm (8-inch and 12-inch) steel mains
- Pressure relief valves at lower elevations to prevent damage to piping through overpressurization

2.3 ENVIRONMENTAL SETTING

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

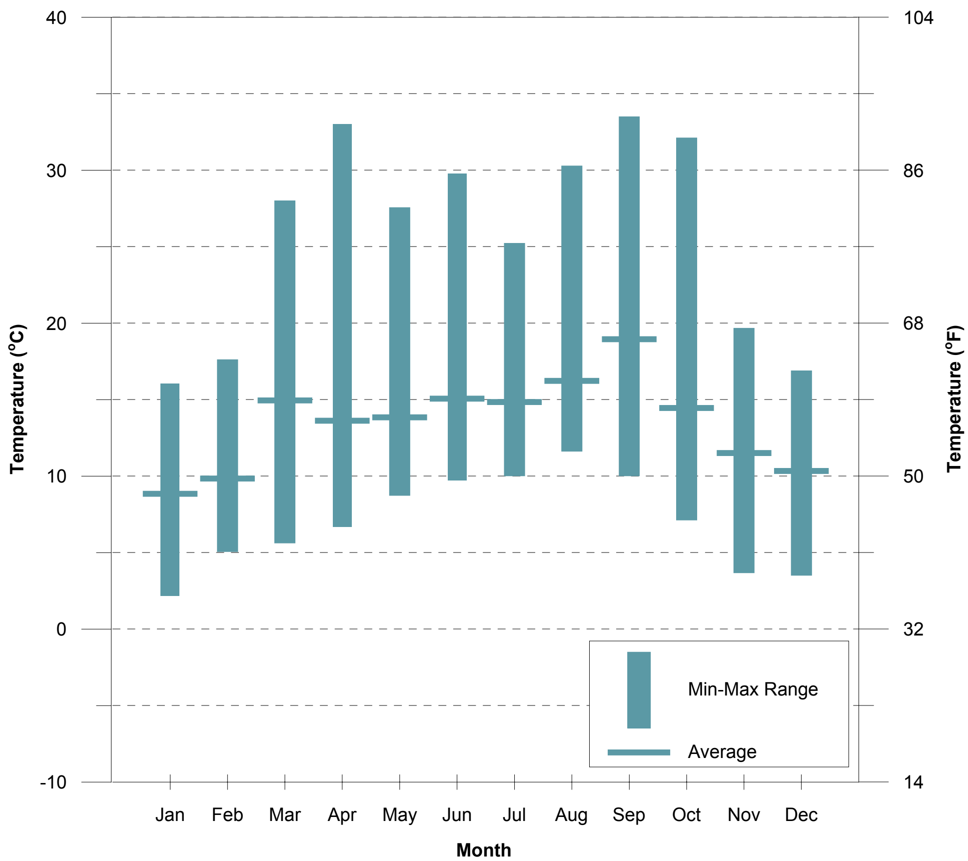

Figure 2-5 Temperature Summary by Month

2.3.1 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. Figure 2-5 traces the monthly temperature average and extremes for the year, recorded at the on-site weather station.

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 2-6, a graphical summary of the annual wind patterns (wind rose), illustrates the frequency of the two predominant wind patterns.

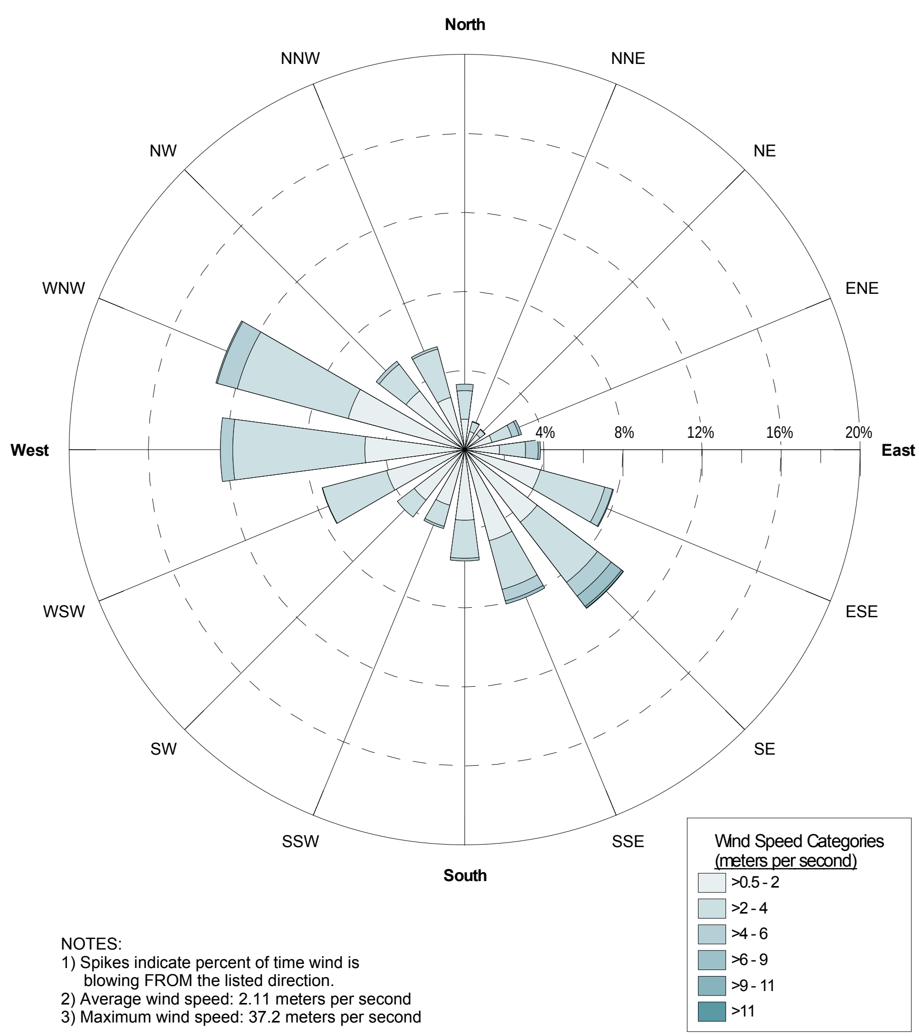

Figure 2-6 Annual Wind Patterns

Precipitation data are provided in Figure 2-7, which compares 2004 monthly precipitation totals to the average since 1974.

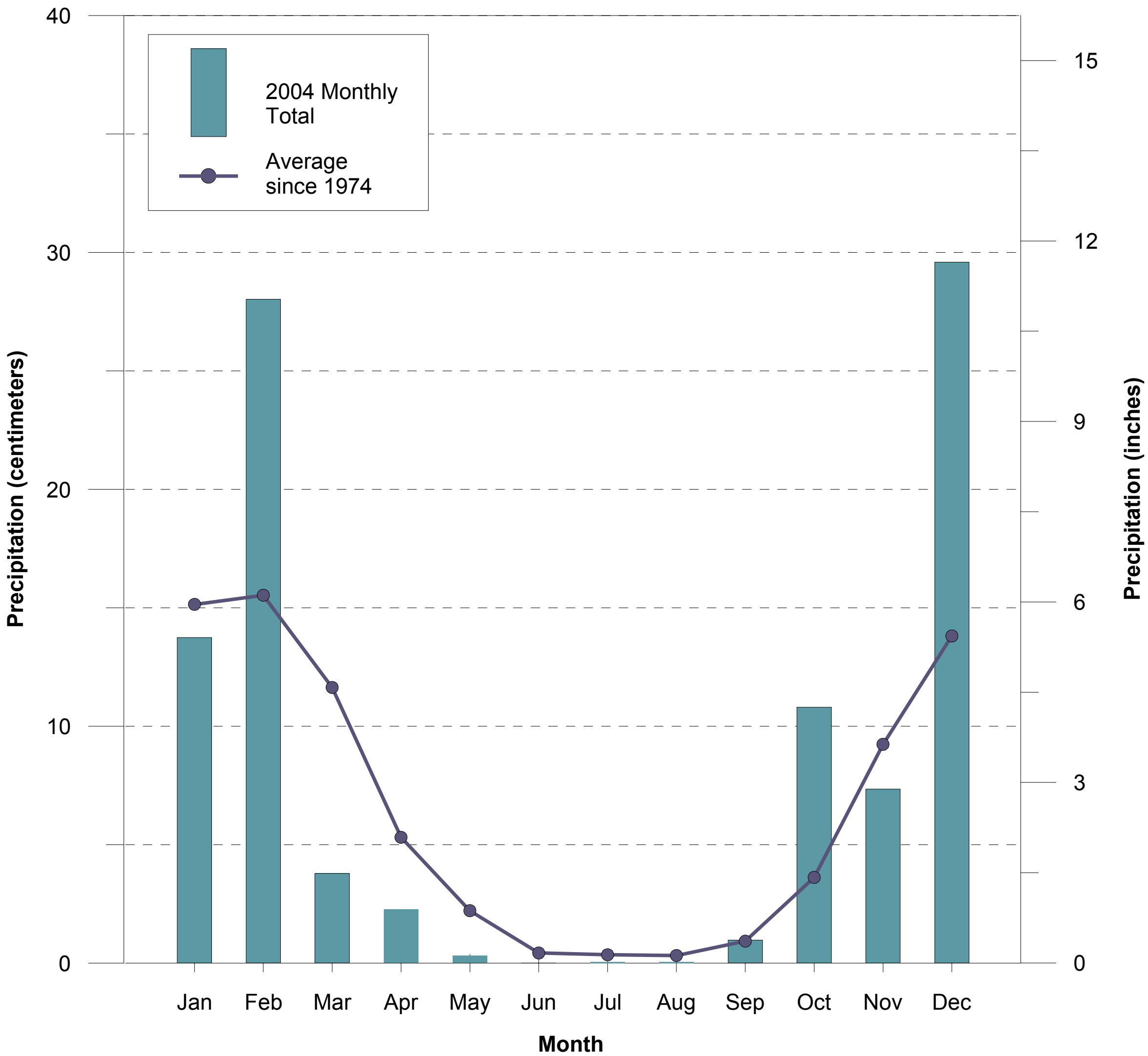

Figure 2-7 Precipitation Summary by Month

2.3.2 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 2-8 shows the vegetation types and locations on-site.

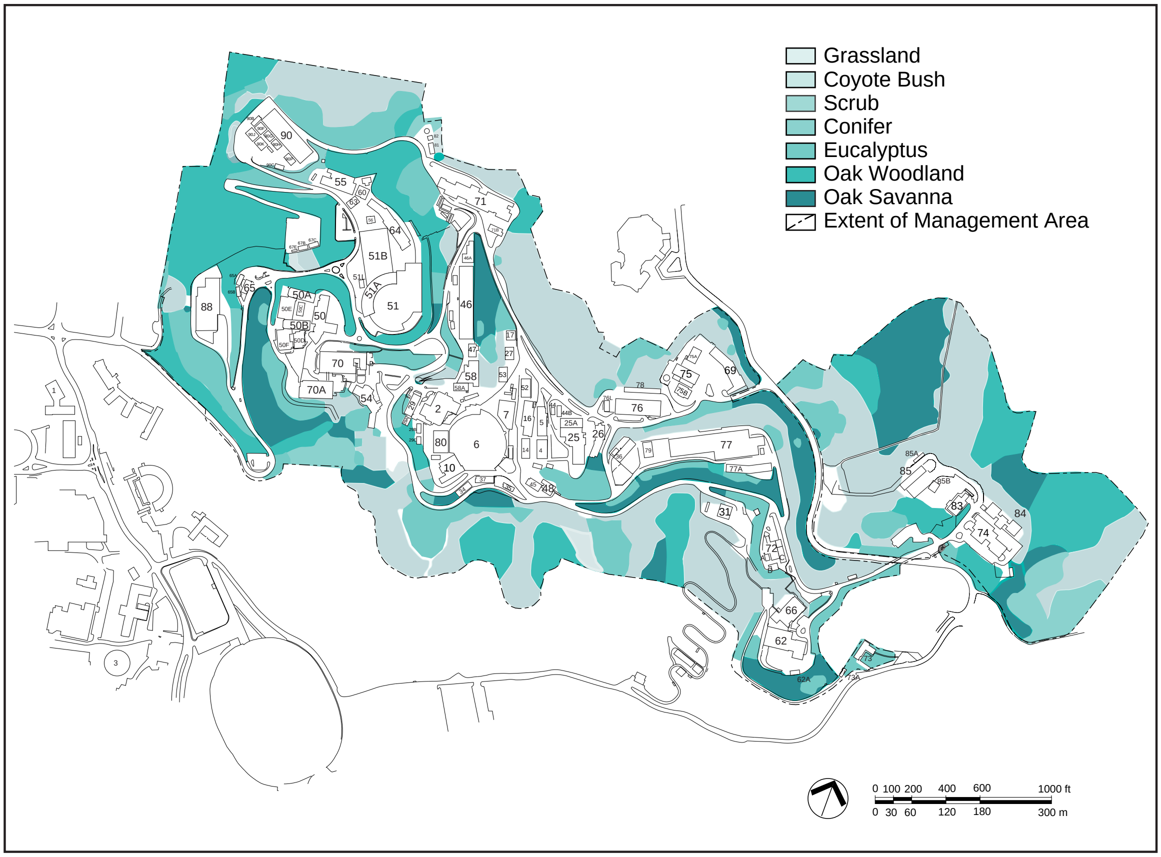

Figure 2-8 Vegetation Types (Map Revised 1999)

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 3 feet.

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 centimeters (3 inches)
- Removing brush, except ornamental bushes—throughout the annual vegetation management area

Approximately 69 hectares (170 acres) of grass and vegetation were either grazed or mechanically cut in 2004. This included grasses, shrubs, and the "limbing up" of approximately 60% of the trees.

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 proceeds 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.

2.3.3 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 whip snake, which previously was designated as "threatened" pursuant to the Endangered Species Act.[5] 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 whip snake. Even so, the Laboratory continues to take appropriate precautions during its construction projects.

2.3.4 Geology and Hydrogeology

Three geologic formations underlie the majority of the site:

- The western and southern parts of Berkeley Lab are underlain by marine siltstones and shales of the Great Valley Group.
- River-deposited sediments of the Orinda Formation overly the Great Valley Group and underlie most of the developed area of the site. The Orinda Formation consists primarily of fine-grained sediments (claystones, siltstones, and sandstones), with coarser-grained sandstone and conglomerate present in some areas.
- Ancient landslide deposits underlie most of the higher elevations of Berkeley Lab, as well as much of the central developed area ("Old Town"). These deposits consist primarily of basalt and andesite, agglomerates, and pyroclastic tuffs derived from the volcanic Moraga Formation.

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. The water table depths vary from approximately 0 to 30 m (98 ft) below the surface across the site. The hydrogeologic properties, including the hydraulic conductivity, of the three primary geologic formations at the Laboratory are described below. Hydraulic conductivity, which is a measure of the rate at which water can move through a permeable medium, is a principal factor controlling groundwater flow.

- The Great Valley Group consists primarily of low-permeability rock with moderately spaced open fractures that allow for groundwater movement. The hydraulic conductivity ranges between approximately 10^{-5} and 10^{-8} meters per second (m/s) (3.3×10^{-5} and 3.3×10^{-8} feet per second [ft/s]).
- 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 (3.3×10^{-7} and 3.3×10^{-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.
- The ancient landslide deposits of the Moraga Formation 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 (3.3×10^{-4} and 3.3×10^{-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.

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 subhorizontal drains (hydraugers), vegetation cover, and soil retention structures.

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3

Environmental Program Summary

The Berkeley Lab E85-fuel (85% ethanol and 15% gasoline) dispensing station

3.1 INTRODUCTION

This chapter provides an overview of Lawrence Berkeley National Laboratory's environmental management 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) 2004.

3.2 OVERVIEW OF ENVIRONMENTAL RESPONSIBILITIES

To provide the highest degree of protection for the public and the environment, Berkeley Lab applies the principles of Integrated Safety Management (ISM). Applying ISM to the Laboratory activities involves the performance of five core functions:[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 to acceptable levels the risks associated with any activity. Acceptable levels are determined by responsible line management but are always in conformance with all applicable laws.
- Work Performance. Conduct that accomplishes the tasks 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 Environment, Health, and Safety (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 CY 2004 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 site characterization and cleanup. Environmental monitoring programs provide information critical to demonstrating compliance and making programmatic decisions. (For monitoring result summaries, see Chapters 4 through 10.)
2. The Waste Management Group manages hazardous, medical, radioactive, and mixed (hazardous and radioactive) waste generated at the Laboratory.

3.2.1 Environmental Management System

To continually improve environmental performance, United States Executive Order 13148, *Greening the Government through Leadership in Environmental Management,*[2] required all federal agencies to implement an Environmental Management System (EMS) by December 31,

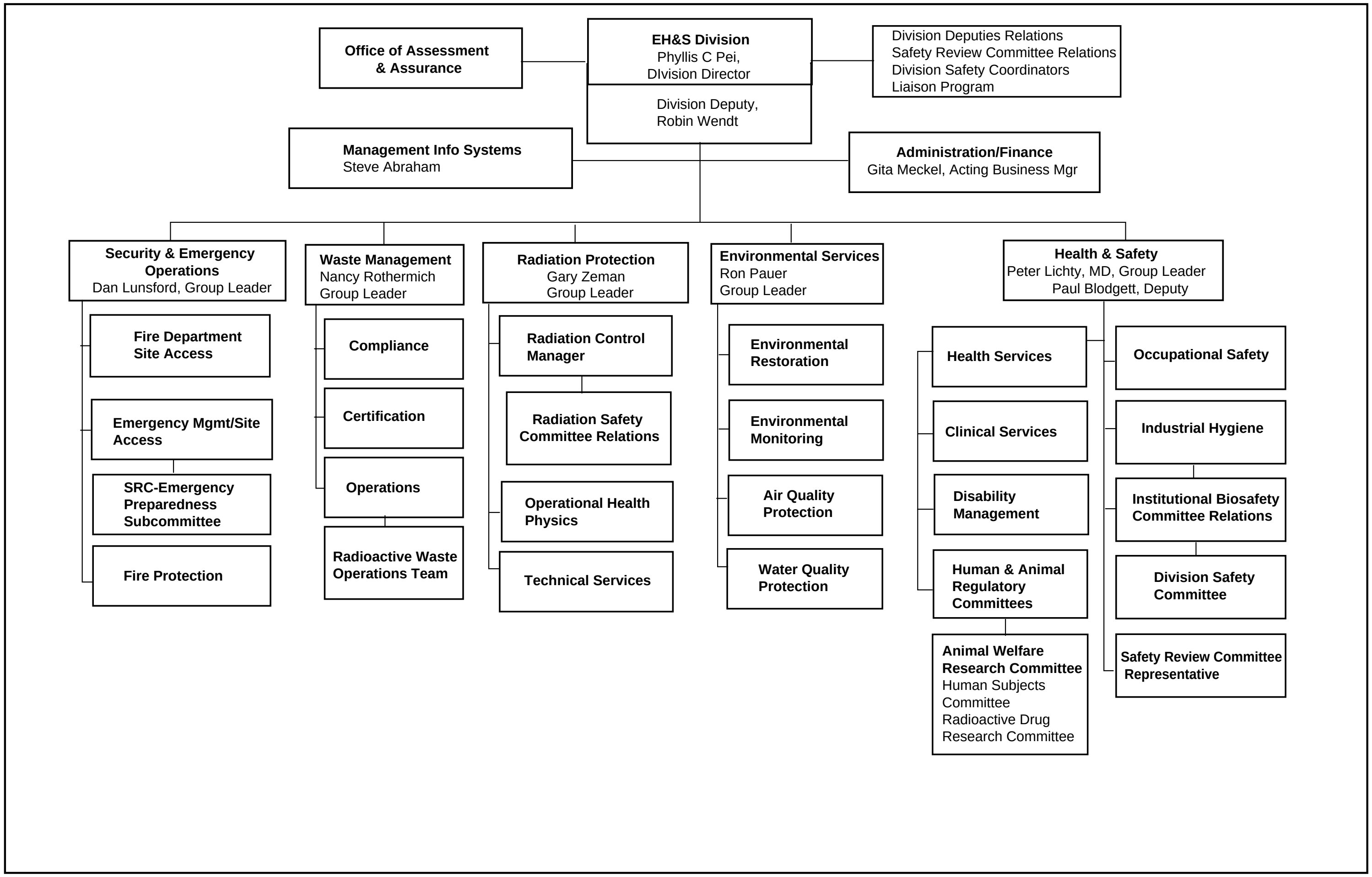


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization in 2004

2005. An EMS is a systematic approach to achieving environmental goals. United States Department of Energy (DOE) Order 450.1, *Environmental Protection Program,*[3] established the EMS requirement for all DOE facilities and, in addition, mandated that the EMS be integrated with existing ISM systems.

Berkeley Lab is developing and implementing a performance-based EMS—a systematic approach to ensuring that environmental stewardship activities are well managed and provide business value. The performance-based approach will include those components of the ISO 14001 EMS[4] standard that provide real and tangible business value; this approach will allow the Laboratory to focus resources on those activities that have environmental benefit, while maintaining and building on the strengths of the current environmental compliance programs.

The Berkeley Lab EMS approach addresses the following goals:

- 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 2004, an EMS Core Team, composed of representatives from EH&S, the Facilities Division, and the Procurement Group (Business Services Division), 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 have been identified. The impacts associated with each aspect also were identified, and these aspects were then ranked according to 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.
- 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:
    1. Diesel Particulate Matter
    2. Low-Level Radioactive Waste
    3. Electronic Waste
    4. Procurement of Environmentally Friendly Products
    5. Vehicle Fleet Petroleum Use
    6. Energy Efficient Buildings
    7. On-site Traffic Reduction

In CY 2005, the EMS program will be reviewed by Berkeley Lab's Office of Assessment and Assurance (OAA), as well as a third party, to determine whether all programmatic activities were completed and the level of effectiveness of the program. A Laboratory executive-management team also will review the progress in achieving EMS objectives and targets and the results of EMS internal and external reviews.

3.3 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, inspections, and DOE-reportable environmental incidents at Berkeley Lab for CY 2004.

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.

Table 3-1 Environmental Permits Held by Berkeley Lab at the End of 2004

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD[a]	Various activities with emissions to air	35[b]	3.4.1.2
Hazardous waste	DTSC[c]	Hazardous Waste Handling Facility operations	1	3.4.4.1
Hazardous waste	City of Berkeley	Fixed treatment units (5)	1	3.4.4.1
Stormwater	SWRCB[d]	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[e]	Sitewide and operation-specific wastewater discharges to sanitary sewer	3	3.4.6.1
	CCCSD[f]	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] One of these permit applications, submitted in December, remained under review for approval by BAAQMD at the end of the year.
[c] Department of Toxic Substances Control
[d] State Water Resources Control Board
[e] East Bay Municipal Utility District
[f] Central Contra Costa Sanitary District

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 CY 2004. The list includes self-monitoring inspections conducted by Berkeley Lab that are required by East Bay Municipal Utility District (EBMUD) wastewater discharge permits because these activities expose the Laboratory to potential regulatory violations.

The Department of Toxic Substances Control (DTSC) identified nine violations during the March 16 inspection of the Hazardous Waste Handling Facility (HWHF) and Building 903. More information on these violations is contained in Section 3.4.4.1.

On October 28, a Notice of Violation (NOV) was received from the Central Contra Costa Sanitary District (CCCSD) as a result of an inspection of the Joint Genome Institute (JGI), conducted on September 9. During this inspection, the District inspector noticed an uncovered dumpster with a small stain below it where autoclave waste apparently had leaked onto the ground from the dumpster. All corrective actions were completed before the NOV was issued. (For more information, see Section 3.3.3.)

Table 3-2 Environmental Audits, Inspections, and Appraisals in Calendar Year 2004

Organization	Inspection title	Start date	Length[a] (days)	Violations
BAAQMD	Permitted air emission sources	May 25	1	0
CCCSD	Wastewater/Stormwater	September 9	1	1
City of Berkeley	Underground storage tanks	September 3	2	0
DTSC	Inspection of Hazardous Waste Handling Facility	March 16	2	7
DTSC	Complaint Investigation Report	March 16	1	2
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry outfalls	January 21 February 9 March 2 May 26 November 3	1 1 1 1 1	0 0 0 0 0
	Wastewater monitoring inspections at B25 treatment unit	January 22 October 15	1 1	0 0
	Wastewater monitoring inspections at B77 treatment unit	January 22 October 15	1 1	0 0
	Wastewater monitoring inspections at groundwater treatment units	January 13 May 7	1 1	0 0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	February 9 July 12	1 1	0 0
	EBMUD self-monitoring inspections at B77 treatment unit	February 26 July 19 October 11	1 1 1	0 0 0
	EBMUD self-monitoring inspections at B25 treatment unit	February 26 July 20	1 1	0 0
	EBMUD self-monitoring inspections at groundwater treatment units	March 29 September 20	1 1	0 0
US/EPA	Evaluation of compliance with Clean Air Act	August 11	1	0

[a] A portion of a day is tabulated as one day.

3.3.3 Summary of DOE-Reportable Environmental Incidents

Four environmental incidents were reportable under the DOE occurrence-reporting program,[5] which is used to track incidents across the DOE complex (see Table 3-3).

Table 3-3 Summary of Environmental Incidents During 2004

Incident date	Report number	Description	Section for more information
March 16	EHS-2004-0001	Notices of Violation at B85 (HWHF)	3.4.4.1
September 9	PSF-2004-0001	Residual waste on ground	3.3.2
November 1	OPS-2004-0004	PCB spill at Building 71	3.4.3.3
November 4	EED-2004-0001	Improper disposal of California-regulated hazardous waste	3.3.3

On March 16 and 17, DTSC conducted a routine inspection of the HWHF at Building 85. As a result of the inspection, an inspection report that was issued on July 13 and a subsequent report issued on August 13, 2004, identified violations based on the following findings:

- LBNL received hazardous wastes at its permitted HWHF from its off-site warehouse/ salvage facility (Building 903).
- LBNL shipped unmanifested hazardous wastes to, and received such hazardous waste at, an unauthorized off-site warehouse.
- Wastes were stored in satellite accumulation areas (SAAs) for greater than the 275 days specified in the permit application.
- The accumulation and receival dates on a waste drum were inconsistent with the dates in the HWHF operating records.
- Certain operating records for the HWHF were internally inconsistent.
- Inspection records failed to record the time of certain inspections.

(For more information, see Section 3.4.4.1.)

On September 9, during a wastewater/stormwater inspection of the JGI performed by the CCCSD, the inspector noticed that a dumpster was uncovered and found a small stain on the ground where autoclave waste from the dumpster apparently had leaked onto the ground. The inspector required that the stain be cleaned up, so that stormwater discharges to the nearest inlet would not be impacted, and that the dumpster be kept closed in the future. The facility contracted with a mobile cleaner to remove the stain and wash the surrounding parking lot. New dumpsters with lids were ordered, and a sign has been posted at all dumpster locations reminding staff to close the lids. All corrective actions were completed before the NOV was issued on October 28, 2004.

Capacitor oil containing polychlorinated biphenyls (PCBs) was released from a dumpster near Building 71 on November 1. Immediately following the spill, the oil leak from the dumpster was stopped and the spilled oil was covered with absorbent material. To further limit the spread of the oil, the spill area and scrap container were covered with plastic sheeting, the perimeter of the spill area was lined with sand bags, and cleanup was initiated. Because the reporting thresholds for PCBs under both the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)[6] and the Toxic Substances Control Act (TSCA)[7] were exceeded, the Laboratory notified the regulatory agencies as required and initiated an Occurrence Report. (For additional details, see section 3.4.3.3.)

On November 4, during a routine inspection of trash dumpsters by Berkeley Lab staff, two reagent product containers (citric acid and sodium bisulfate, both California-regulated corrosive solids) were found in the dumpster between Buildings 70 and 70A. These materials are hazardous wastes under California regulations. The chemicals were immediately removed from the dumpster and placed into the appropriate hazardous waste storage area within Building 70.

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[8] is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into 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[9] 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). Both categories were reviewed in August 2004, when representatives from the United State Environmental Protection Agency (US/EPA) Region 9 visited Berkeley Lab to evaluate the Laboratory's compliance in general with the Clean Air Act and specifically with the rules that apply to radiological NESHAPs 40 CFR 61, Subpart H *[National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities])*,[10] nonradiological halogenated solvents, and ozone-depleting substances. Personnel from the California Department of Health Services (DHS) and the DOE Oakland Operations Office also attended as observers. The evaluators reviewed applicable operations and the sampling and monitoring systems used to quantify air emissions. No violations of the Clean Air Act have been issued as a result of this inspection.

3.4.1.1 Radiological

Radionuclides released to the atmosphere from Laboratory research activities must adhere to NESHAPs regulations as well as sections of DOE Order 5400.5.[11] The US/EPA administers the National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations.

To properly account for radiological air emissions, Berkeley Lab conducts a preliminary review of projects that could result in a dose to the public or environment. This review includes a determination of the maximum hypothetical dose to the nearest off-site member of the public (the maximally exposed individual); the determination follows NESHAPs regulations and DOE EH-0173T[12] guidance. It takes a conservative, or worst-case, approach by assuming that no portion of the radionuclides projected to be released is collected by emission controls, even if such controls exist. Berkeley Lab's method for determining the appropriate level of sampling, monitoring, and administrative control necessary to maintain compliance with NESHAPs has been approved by US/EPA and is summarized in Table 4-2 (see Section 4.2). (Results of the emissions sampling and monitoring program are also presented throughout Chapters 4 and 9. The Laboratory documents its NESHAPs 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 NESHAPs regulations.

At the end of 2004, Berkeley Lab held operating permits issued by BAAQMD for 35 activities.[13] 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, a collaboration involving Berkeley Lab, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory research groups. No new operating permits were issued during the year, although in December Berkeley Lab requested authority to construct an emergency generator to support the molecular foundry facility that is presently under construction. For a list of active operating permits, see Table 3-4.

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.[14] Activities covered by permits also are subject to periodic inspection. On May 25, BAAQMD conducted a partial inspection of Berkeley Laboratory's permitted air emission activities. The inspection looked at several of the Laboratory's emergency generators as well as the soil vapor extraction systems, the sandblasting booth, and the solvent vapor degreasing system. All activities were found to comply with permit requirements.

Table 3-4 Air Emission Sources Permitted by BAAQMD[a] at the End of 2004

BAAQMD category	Description	Building	Abatement type
Combustion equipment	Standby emergency generators	64,70	Catalytic converter
	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. The JGI is a joint venture between LBNL, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory.

Over the past decade, one of the main air quality issues in California has been 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*[15] 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 (ATCM), which are then implemented by local agencies such as BAAQMD in the case of stationary activities (i.e., nonmobile sources). In November 2004, an ATCM that significantly affects Berkeley Lab activities was approved. This ATCM targets stationary diesel-fueled compression ignition engines, which for Berkeley Lab means the emergency generators permitted by BAAQMD. In 2005, BAAQMD is expected to issue updated rules related to these generators.

In other fuel-related air quality activities, Berkeley Lab began operating its recently permitted E85-fuel dispensing facility at the Building 76 Motor Pool in June 2004. 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 unit. 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 is currently one of fewer than a half-dozen sites in all of California authorized to use this alternative fuel.

Regulations affecting the phaseout of ozone-depleting substances are largely administered at the federal level by US/EPA. The Laboratory has made extensive progress in eliminating emissions of the Class I ozone-depleting substances from equipment and activities such as centrifugal chillers, refrigeration and freezer appliances, solvent-cleaning systems, fire-suppression operations, and research apparatus. Much of the reduction occurred during the mid-1990s. The aggressive reduction program began in 1991, when annual emissions of Class I ozone-depleting substances were estimated at nearly 6,000 kilograms (kg) (13,200 pounds [lb]). Currently, Laboratory emissions are estimated at less than 10 kg (22 lb) each year, a reduction of more than 99% from levels a decade earlier. (For more information, see http://www.lbl.gov/ehs/wastemin/goals/haz_ozone.html.) US/EPA inspected the Laboratory's ozone-depleting substances compliance program in August. No violations were noted.

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

The CERCLA[6] authorizes the US/EPA to manage the cleanup of abandoned or uncontrolled hazardous waste sites. There were no releases in 2004 reportable under CERCLA, and Berkeley Lab conducted no remedial activities related to the Act. However, in 2004 Berkeley Lab continued to investigate and remediate areas of concern at the site under the requirements of the Corrective Action Program of the Resource Conservation and Recovery Act of 1976 (RCRA).[16] (Because these actions are primarily related to the protection of groundwater, they are described in Chapter 6.)

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); 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).[17] 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.[18] 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 (*Greening the Government through Leadership in Environmental Management*),[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 the US/EPA Form R.

Berkeley Lab determined that no chemical usage in CY 2004 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 3-5 shows the highest usage levels of the chemicals from the Laboratory's assessments over the past several years.

Table 3-5 Trends in Highest Quantities of EPCRA[a] Toxic Release Inventory Reporting

Substance	2000 (kg)	2001 (kg)	2002 (kg)	2003 (kg)	2004 (kg)
Chlorofluorocarbons	246	280	164	61	72
Methanol	468	593	322	228	206
Nitric acid	746	861	778	582	511
1,1,1-trichloroethane	21	2	<1	7	<1

[a] Emergency Planning and Community Right-to-Know Act

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 2004, 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)[19] to the City of Berkeley, although federal sovereign immunity from such regulations has not been waived.

The 2004 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 [200 cubic feet] for compressed gases) per building. The plan included annotated floor plans as well as summaries of emergency plans, procedures, and training. In addition, the HMBP included permit renewal for the underground storage tanks (USTs) and fixed treatment units (FTUs).

3.4.3.1.3 Risk Management and Prevention Plan

The City of Berkeley requires an RMPP[20] 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[21] 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[7] 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.

PCBs are one of the principal substances at Berkeley Lab currently affected by the TSCA regulations. On November 1, 2004, approximately 11.4 L (3 gal) of mineral oil leaked onto the surrounding asphalt from capacitors that were being prepared for disposal. The spill occurred outside of a loading dock on the north side of Building 71. The leakage was stopped and absorbents were spread on the spilled oil within 20 minutes. A sample was collected, and the oil was found to contain 60% PCB. Berkeley Lab reported the spill to a number of agencies, including the National Response Center, US/EPA Region 9, and the City of Berkeley.

The top layer of asphalt was removed at the spill area by mid-November. Sampling to ensure clean-up found that PCB remained in the spill area. In a second removal executed in December, asphalt and base rock material were removed to a depth of 30 centimeters (cm) (12 inches [in]). A second round of sampling confirmed that all the PCB had been cleaned up well below the target goal of 1 mg/kg. On January 6, 2005, the excavation was backfilled with low-strength concrete, and on January 14, the site was paved with asphalt.

3.4.4 Hazardous Waste (Resource Conservation and Recovery Act)

The primary goal of the RCRA[22] 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.[23] 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. The following list shows the tiers 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 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[24] 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.

Berkeley Lab's waste management program sends hazardous, 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 (see Section 3.4.4.2). Low-level radioactive waste is managed in accordance with DOE orders. Specific low-level aqueous wastes at Berkeley Lab (containing only radioisotopes with short half-lives) are stored until the radioactivity has decayed to undetectable levels; then the wastes are discharged in conformance with the EBMUD wastewater discharge permits.

In a July 13 report, DTSC identified seven violations from the March 2004 inspection of the HWHF and its operating records.[25] Three of the violations were related to inadvertent shipment of wastes from the Laboratory main site to the off-site warehouse at Building 903 and return of these items to the permitted HWHF on the main site. The other four violations were related to storage of waste at generator sites for more than 275 days, inconsistency in the HWHF operating record, absence of the time of inspection on the inspection logs, and a minor labeling issue on one container. The Laboratory contested the identified violation for receipt at the HWHF of wastes shipped from Building 903 (but originally generated at the Laboratory main site) and an identified violation of the HWHF permit for storage of waste at generator sites for more than 275 days.

On August 13, DTSC issued another report of violation to Berkeley Lab titled *Complaint Investigation Report* for two alleged violations at Building 903 based on the transfers of wastes from the Laboratory main site to Building 903 and the transfers of wastes to the HWHF at the Laboratory main site from Building 903, which formed the bases for the violations alleged in the July 2004 *Inspection Report*.[25] Berkeley Lab met with DTSC on October 21, 2004, to discuss the administrative process that was used to issue the second report. The response to the *Complaint Investigation Report* was submitted to DTSC on November 19, 2004, contesting one violation.

Berkeley Lab has an additional hazardous waste permit[26] to operate five FTUs. The type and location of each unit are listed in Table 3-6. 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 2004, the Laboratory submitted the 2004 FTU renewal package to the City of Berkeley.

Table 3-6 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	8,974
003	76	Oil/water separation	Conditional authorization	9,678
004	70A/70F	Acid neutralization	Conditional authorization	686,480
005	2	Acid neutralization	Conditional authorization	296,128
006	77	Metals precipitation and acid neutralization	Permit-by-rule	44,914

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

- The *Annual Hazardous Waste Report*,[27] 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*,[28] 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*,[29] 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 (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 research relevant to the diagnosis, treatment, or immunization of human beings or animals or in the production of biological products used in medicine. In California, the state's Medical Waste Management Act[30] contains requirements designed to ensure the proper storage, treatment, and disposal of medical waste. The state program is administered by the DHS.

The Laboratory generates medical waste at about 150 different locations distributed over 15 buildings, including 2 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 16,128 kg (35,482 lb) of medical waste in CY 2004. 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 annual inspections. DHS did not inspect the medical waste program at Berkeley Lab in 2004.

3.4.4.3 RCRA Corrective Actions Program (Site Environmental Restoration)

Berkeley Lab's Environmental Restoration Program (ERP) is conducted under the requirements of the RCRA Corrective Action Program (see Chapter 6). 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 Corrective Action Program, including the DTSC, the Regional Water Quality Control Board (RWQCB), the City of Berkeley, and interested community members. ERP holds regularly scheduled meetings with these agencies, at which planned and completed activities are discussed.

The *RCRA Facility Investigation Work Plan,*[31] 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*[32] and *Phase II Progress Report*,[33] and in the *Draft Final RCRA Facility Investigation Report*,[34] 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*[35] 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*[36] and *Ecological Risk Assessment*[37] 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 initial *Draft Corrective Measures Study (CMS) Report*[38] was submitted to the DTSC on July 19, 2004. The primary purpose of the CMS 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. The Draft CMS Report as well as the other documents listed are available for public review at the City of Berkeley main public library and on Berkeley Lab's Environmental Services Group page at http://www.lbl.gov/ehs/esg/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)*

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

In procuring these items, as of December 31, 2004, all federal agencies must buy 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 in order 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 impracticable
- 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 government

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 2004 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 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. 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 2004. (For more information regarding the results of the Laboratory's annual wastewater self-monitoring program, see Chapter 5.)

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 also inspects the Laboratory's sanitary sewer discharge activities without prior notice, which includes the collection and analysis of wastewater samples. The agency conducted inspections on nine 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] and the TOMP and ASPCP for Building 25 will also be combined to reduce duplication of information.

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 contains requirements for inspections of operations and report submittals, but no monitoring requirements.

3.4.6.2 Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide General Permit for Stormwater Discharges Associated with Industrial Activity.[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 *Stormwater Monitoring Program*.[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 5.) No inspections of this program took place in 2004.

The State of California has also issued a Stormwater General Permit for Construction Activity. Berkeley Lab holds such a permit for the construction of the Molecular Foundry, which exceeds 0.4 hectare (one acre) in size.[55] During 2004, the second year of this ongoing project, the Laboratory submitted an annual report, revised the SWPPP, and implemented Best Management Practices as appropriate in accordance with permitting requirements.

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. Table 3-7 summarizes information on ASTs.

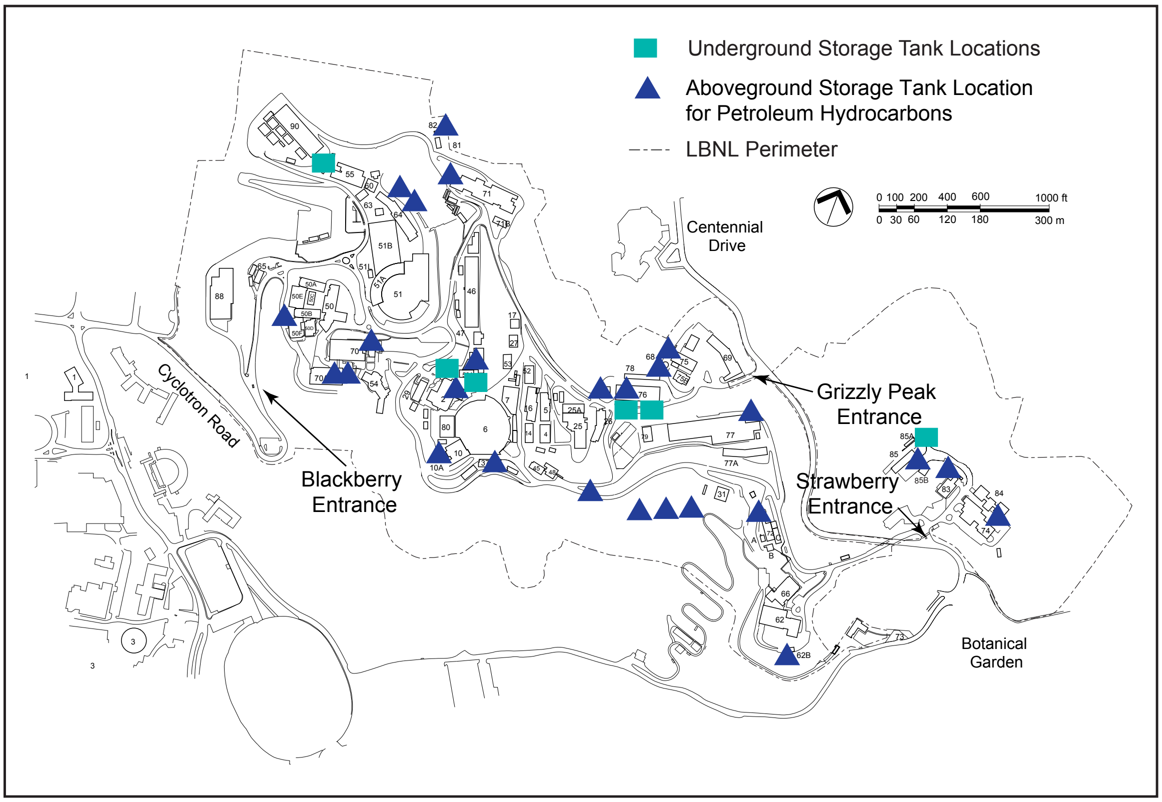


Figure 3-2 Aboveground and Underground Storage Tank Locations at the end of Calendar Year 2004

Table 3-7 Aboveground Storage Tanks

Building	Contents	Use	Containment
2	Diesel	Service to engine generator	Concrete berm with coating
10A	Diesel	Service to engine generator	Double-walled tank
Portable	Diesel	500 kW[a] generator	Spill kit provided
Portable	Diesel	100 kW generator	Spill kit provided
Portable	Diesel	150 kW generator	Metal berm
37	Diesel	Service to EG-73-6	Concrete berm inside building
48	Diesel	Service to engine generator	Double-walled tank with leak detection
50 Complex	Diesel	Service to engine generator	Double-walled tank with leak detection
58A	Transformer Oil	Service to tanks	Double-walled tank with leak detection
62B	Diesel	Service to engine generator	Double-walled tank
64	Diesel	Service to engine generator	Double-walled tank
64	Diesel	Service to 2 MW[b] engine generator	Double-walled tank
64	Motor Oil	Service to 2 MW engine generator	Single-walled tank
66	Diesel	Service to engine generator	Double-walled tank with leak detection and alarm
68	Diesel	Service to fire water pump	Metal containment bin inside building
70	Diesel	Service to engine generator	Double-walled tank
70A	Diesel	Service to engine generator	Double-walled tank with leak detection
70A	Diesel	Day tank filled fromTK-15-70A	Inside building, double-walled with leak detection
72	Diesel	Service to EG-098-72	Double-walled tank with leak detection
75	Diesel	Service to EG-89-75	Metal containment bin with cover
76	85% Ethanol/ 15% Gasoline	Fuel dispensing	Double-walled tank, with leak detection at tank connected to monitoring system
76	Motor oil	Storage, motor pool	Double-walled tank
77	Diesel	Service to EG-94-77	Double-walled tank
82	Diesel	Service to fire water pump	Metal containment bin inside building
83	Diesel	Service to engine generator EG-61-74	Double-walled tank with leak detection
84	Diesel	Service to engine generator	Double-walled tank with leak detection; in locked room
85	Diesel	Service to EG-85 (day tank)	Double-walled tank with leak detection

[a] kW=kilowatt

[b] MW=megawatt

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.

On June 16, 2004, a 15,100 L (4,000 gal) AST was put into service to support an ethanol/gasoline dispensing station. The ethanol/gasoline dispensing station operates under a research and development permit issued by the California Air Resources Board (CARB).[5] Testing of the tank system components is being performed under CARB oversight.

The 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. The National Ethanol Vehicle Coalition has commended the Laboratory for installing the 85%-ethanol 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.

At the end of 2004, six permitted USTs were in operation at the Laboratory (see Table 3-8 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 3-8 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 3 and September 17, 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 2004, all product piping (pressure and suction) was pressure-tested for all six 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.

In December 2004, two employees passed the State of California exam to become a UST Designated Operator, thereby meeting a January 1, 2005, regulatory deadline. These two employees now are responsible for conducting inspections of the UST systems monthly, supplementing the daily inspections conducted by other UST-trained employees. The UST Designated Operator is also responsible for providing annual training to those employees.

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 did not issue any major NEPA or CEQA documents during 2004.

3.4.9 Federal Endangered Species Act

Under the Federal Endangered Species Act (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 National Environmental Policy Act (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 United States Fish and Wildlife Service as appropriate and required under the FESA.

3.4.10 California Endangered Species Act

Under the California Endangered Species Act (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, a new water meter was installed at the Shasta supply line to identify any water leaks. In fiscal year (FY) 2004, the main site purchased 142 million L (37.5 million gal) of water compared to 149 million L (39.4 million gal) that were purchased in FY 2003. Water use in FY 2004 was reduced by 7.2 million L (1.9 million gal), or about 5% from the previous year.

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 high insulation values for buildings.

In FY 2004, 71,000 megawatt-hours (MW-hours) of electrical energy were used compared to 75,000 MW-hours in FY 2003. That is a decrease of 4,000 MW-hours or 5%. In FY 2004, 158 million therms were used compared to 163 million therms in FY 2003. That is a reduction of 5 million therms or about 3%.

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 the Molecular Foundry that is under construction and is planned to be completed in late 2005. 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." Table 3-9 summarizes the UCOP and DOE ratings for each of the environmental performance measures for FY 2004.[67]

Table 3-9 Environmental Performance Measure Ratings for Fiscal Year 2004

Performance measure	UCOP rating	DOE rating
Tracking of environmental incidents	Excellent	Excellent
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Completion of milestones for an Environmental Management System	Outstanding	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.

The FY 2004 performance contract retired many of past performance periods' environmental measures because the results were consistently positive over the years. The remaining measures are related to environmental releases, regulatory violations, and costs and schedule variance for environmental restoration activities. These measures are part of the overall evaluation of "performing work" under the contract requirements for ISM. Berkeley Lab is also focused now on developing and implementing a comprehensive EMS that has many of the valuable attributes found in the internationally recognized ISO 14001 EMS Standard. For FY 2004, the Laboratory has completed all scheduled milestones and is on track to having a fully implemented and validated EMS by the end of 2005. For more information on environmental performance objectives, criteria, and measures, go to Berkeley Lab's Office of Assessment and Assurance home page at http://www.lbl.gov/ehs/oaa/.

4

Air Quality

Electric vehicle utilized by Berkeley Lab for onsite transportation

4.1 BACKGROUND

Lawrence Berkeley National Laboratory's air monitoring program is primarily designed to measure the impacts from radiological air emissions. The program is designed to meet the requirements established by the United States Environmental Protection Agency (US/EPA) and the United States Department of Energy (DOE) that are contained in the following references:

- 40 CFR Part 61, Subpart H (*National Emission Standards for Hazardous Air Pollutants,* or NESHAPs) [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.

- Radiological substances measured in stack emissions and ambient air are presented in this chapter.
- Estimates of nonradiological air emissions generally use alternative methodologies such as engineering calculations, record keeping, and dose or risk modeling to satisfy regulatory requirements.

Of the Laboratory's activities permitted by the Bay Area Air Quality Management District, only a few require periodic monitoring of emissions as a permit condition; those results are not presented here because those measurements are not part of the air monitoring program.

The air monitoring 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 EXHAUST-EMISSIONS MONITORING RESULTS

Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. In addition, the operations of charged-particle accelerators generate radioactive materials. Radionuclide releases through building exhaust systems usually occur in the form of vapor or gas. Releases of solid particulate are the least common form because high-efficiency particulate air filters are used to remove particles in the exhaust systems.

Table 4-1 lists the most significant radionuclides used at Berkeley Lab and their decay characteristics. Radioactive gases produced by accelerator operations are mainly short-lived radionuclides, such as carbon-11, and fluorine-18.

Table 4-1 Most Significant Radionuclides Used at Berkeley Lab[a]

Nuclide name (atomic number)	Symbol	Principal radiation types	Half-life
Carbon (6)	^{11}C ^{14}C	positron/gamma beta	20.5 minutes 5,730 years
Fluorine (9)	^{18}F	positron/gamma	109.7 minutes
Hydrogen/Tritium (1)	^{3}H	beta	12.3 years
Iodine (53)	^{125}I	beta	60.14 days

[a] For a complete list of radionuclides evaluated under NESHAPs regulations, see the *Radionuclide Air Emission Annual Report for 2004*, found at Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/esg/.

As mentioned in Section 3.4.1.1, Berkeley Lab uses a comprehensive strategy approved by the US/EPA to satisfy this agency's requirements. The strategy involves three distinct levels of assessment:

- Real-time monitoring: sophisticated monitoring systems that provide nearly instantaneous measurements
- Continuous sampling: collection of time-integrated air samples that undergo laboratory analysis adhering to US/EPA protocols
- Administrative controls: estimation of emissions, calculated based on limits on the Laboratory's radionuclide inventories

These assessment levels are each assigned to one of the six source compliance categories (see Table 4-2). The number and locations of sources subject to each compliance category change in response to the current research at Berkeley Lab. In 2004, all sources evaluated for NESHAPs compliance were considered "small sources" of emissions (Category II through V). Most sources fall into Category V, which requires no monitoring but which requires the sources to adhere to strict inventory limits specified in individual work authorizations. In 2004, Berkeley Lab had 103 sources in Category V. The Laboratory had 24 sources assessed as Category II or III, which require continuous sampling. Of these locations, 3 have more rigorous real-time monitoring systems to estimate emissions (Buildings 56, 70A, and 88).

Table 4-2 US/EPA-Approved NESHAPs Compliance Strategy

Compliance category	Annual effective dose equivalent[a] (mSv/yr)[b]	Sampling/monitoring strategy
Noncompliant	AEDE ≥ 0.1	Reduction or relocation of the source and reevaluation before authorization
I	0.1 > AEDE ≥ 0.001	Continuous sampling with telemetry to central computer for half-life less than 100 hours and weekly analysis for half-life greater than 100 hours. (US/EPA approval required to construct or modify emission source.)
II	0.001 > AEDE ≥ 0.0005	Continuous sampling with weekly analysis
III	0.0005 > AEDE ≥ 0.0001	Continuous sampling with monthly analysis
IV	0.0001 > AEDE ≥ 0.00001	Annual sampling during project activity
V	0.00001 > AEDE	Control of inventory by administrative methods (Radiation Work Authorization/Permit): No monitoring required

[a] Abbreviated as AEDE
[b] 1 mSv = 100 mrem

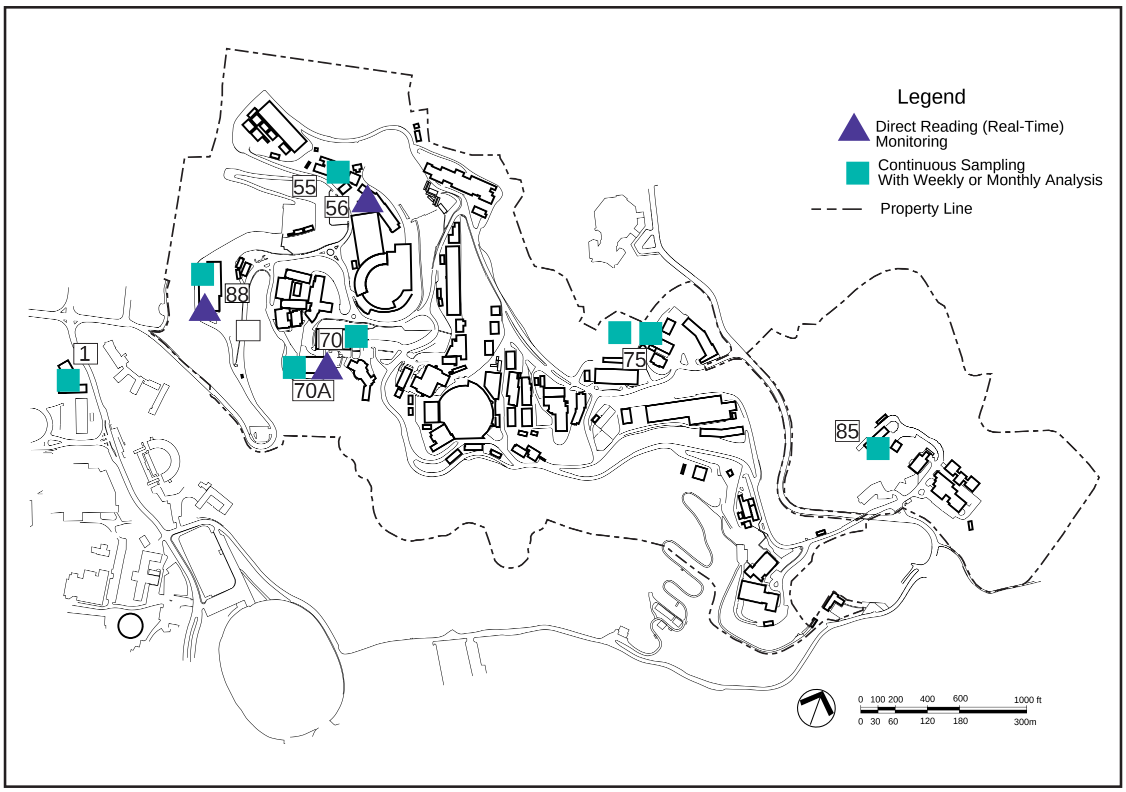


Figure 4-1 Locations of Building Exhaust Sampling and Monitoring in 2004

Figure 4-1 shows locations where sources are sampled and monitored. Table 4-3 lists the sampling and monitoring profile for the reporting year.

Table 4-3 Building Exhaust Sampling and Monitoring Profile in 2004

Monitoring type	Method	Location
Continuous real-time	Real-time monitoring of ^{11}C, ^{13}N, and ^{15}O	Building 88 accelerator stack
	Real-time monitoring of ^{11}C, ^{13}N, ^{15}O, and ^{18}F	Building 56 Biomedical Isotope Facility accelerator and glove box stacks
	Real-time monitoring of gross alpha	Building 70A Heavy Element Research Laboratory glove box stack
Continuous sampling	Sampling with weekly analysis	6 stacks at Buildings 70, 70A, 85, and 88
	Sampling with monthly analysis	14 stacks and 1 room at Buildings 1, 55, 70, 70A, 75, and 88
No monitoring	Inventory (administrative) control	103 rooms throughout LBNL

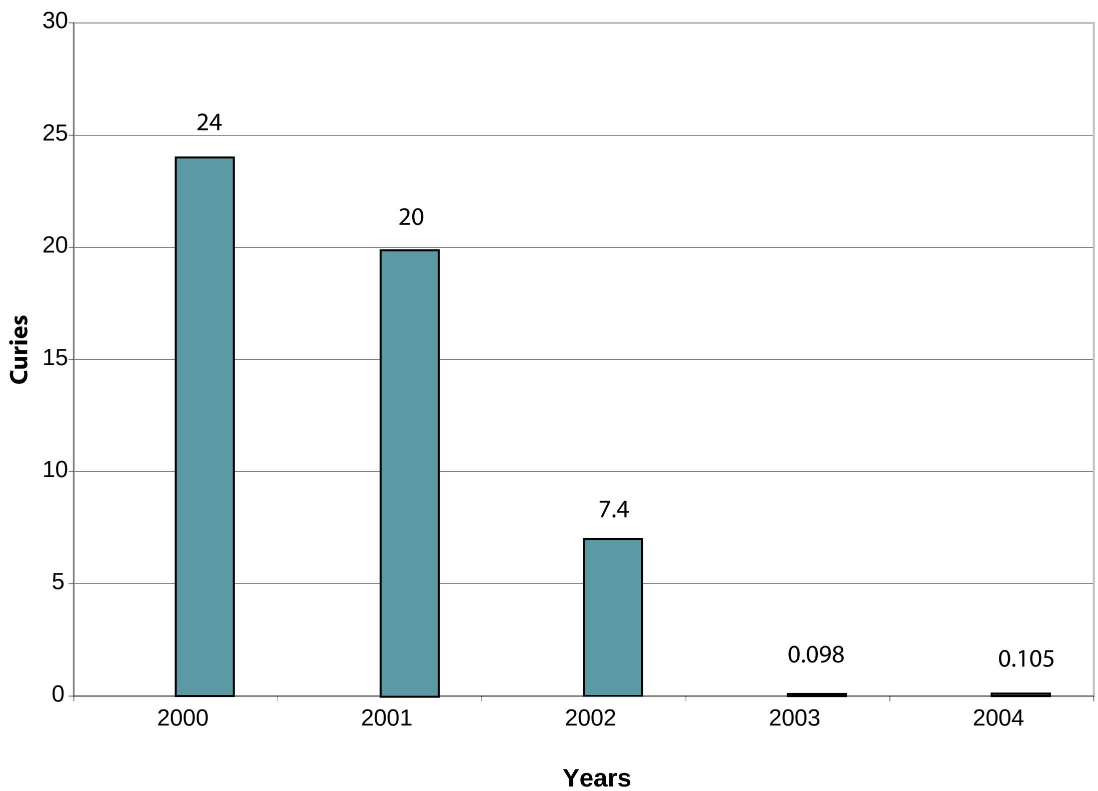
Table 4-4 Summary of Berkeley Lab Radiological Air Emissions[a]

Nuclide	Total (Bq/yr[b])	Percentage
^{18}F	1.2×10^{11}	85.5%
^{11}C	1.5×10^{10}	10.4%
^{3}H	5.7×10^{9}	4.0%
^{14}C	1.4×10^{8}	0.1%
^{125}I	1.5×10^{7}	< 0.1%
All others	2.6×10^{7}	< 0.1%
Total	1.4×10^{11}	100%

[a] For a complete list of radiological air emissions, see NESHAPs *Annual Radionuclide Air Emission Report for 2004*, found at Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/esg/.
[b] Bq/yr= becquerels per year

Stack exhaust samples collected during 2004 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 2004, positron emitters fluorine-18 and carbon-11 were the predominant radionuclides emitted. The Building 56 accelerator was the main source of fluorine-18 emissions; the Building 88 accelerator was the primary source of carbon-11. Table 4-4 provides a list of the most significant radionuclide air emissions from site activities for the year. (For information on the projected dose from all radionuclide emissions, see Chapter 9.)

(Bq) (0.105 curie [Ci])—was far below both the five- and ten-year averages for the facility. For information on trends in annual tritium releases from the former NTLF, see Figure 4-2.



* Figure 4-2 contained an error in the value for the annual tritium releases from the NTLF in 2004 (0.091 curie). The figure was modified on January 25, 2006 to reflect the correct value of 0.105 curie.

Figure 4-2 Trends in Annual Tritium Releases from former National Tritium Labeling Facility

In addition to air emissions from exhaust systems, Berkeley Lab also collects and analyzes (for tritium) rainwater that drains down the stacks associated with the former NTLF. The average concentration of tritium in drain water analyzed in 2004 was 4.07×10^4 becquerels per liter (Bq/L) (1.10×10^6 picocuries per liter [pCi/L]) and the maximum was 1.00×10^5 Bq/L (2.80×10^6 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 3.73 × 10^6 Bq (1.01 × 10^8 pCi), which is 0.002% of East Bay Municipal Utility District's annual limit of 1.9 × 10^{11} Bq (5 × 10^{12} pCi) for tritium disposal in the sewer.

4.3 AMBIENT-AIR MONITORING RESULTS

The following sections discuss the results for ambient-air tritium and particulate gross alpha/beta monitoring.

4.3.1 Tritium

Since the closure of the former NTLF at the end of 2002, both tritium stack emissions and ambient concentrations have decreased markedly. The number of sampling locations in the ambient-air tritium monitoring network totaled five throughout 2004. The sampling locations cover the extent of the site, especially downwind of historically key sources of tritium emissions. Locations are shown in Figure 4-3. Instrumentation at each site operates on the principle of continuously drawing outdoor air through sampling media (i.e., silica gel) at a constant rate.

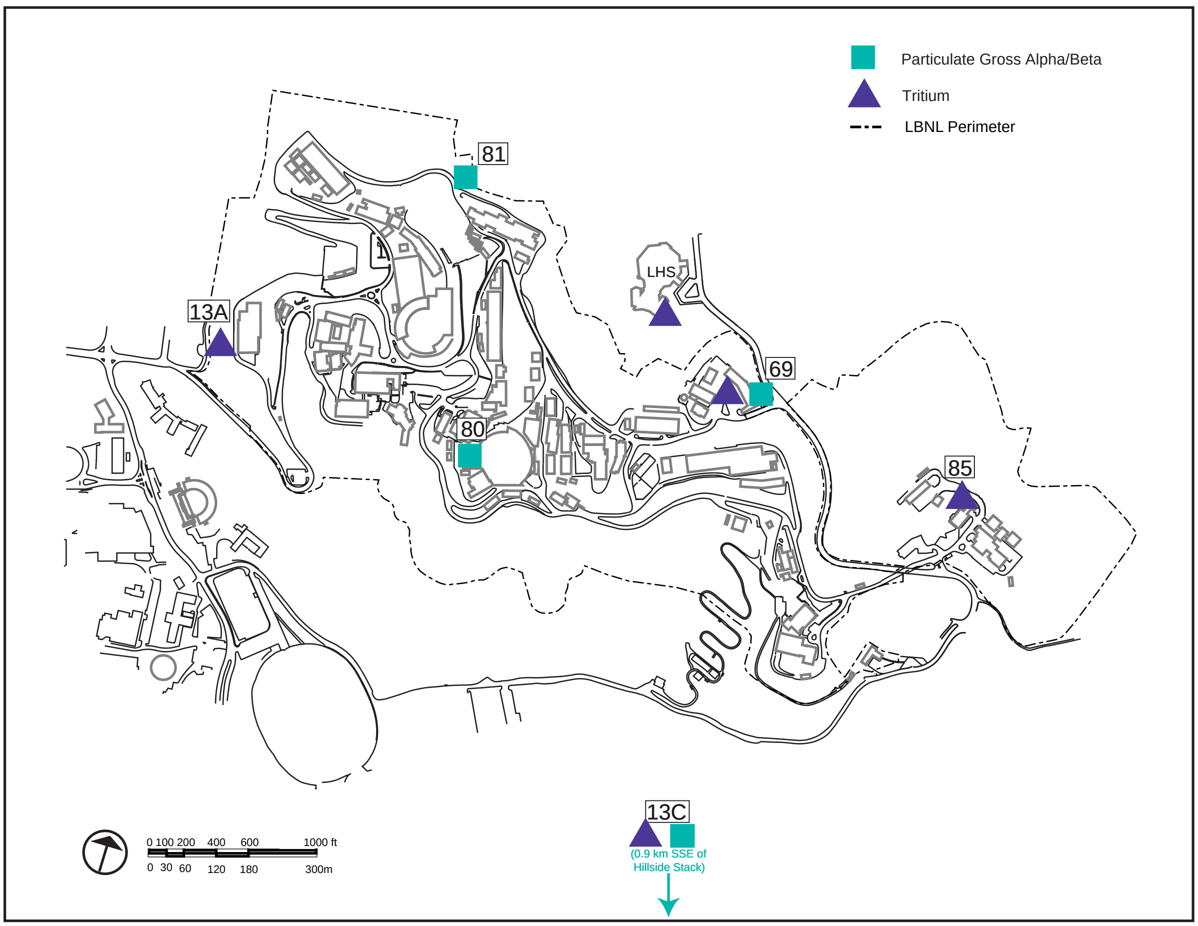


Figure 4-3 Ambient-Air Monitoring Network Sampling Locations

Berkeley Lab replaces the sampling media monthly and submits the samples to a certified laboratory for analysis. The Laboratory collected and submitted 60 samples and 12 quality-assured split samples during the year. All results fell below the analytical detection limit, which averages about 0.09 becquerel per cubic meter (Bq/m^3) (2.4 picocuries per cubic meter [pCi/m^3]). By comparison, the DOE annual exposure standard for airborne tritium from all exposure modes and radiation sources[2] is 3.7×10^3 Bq/m^3 (1.0×10^5 pCi/m^3), while the reference concentration for the US/EPA NESHAPs dose standard for inhalation alone[1] is 3.7×10^2 Bq/m^3 (1.0×10^4 pCi/m^3).

4.3.2 Particulate Gross Alpha/Beta

The ambient-air sampling network includes stations with instrumentation designed to collect air particulate samples for measurement of gross alpha and gross beta levels. These sites are presented in Figure 4-2. This network complements the exhaust-system sampling program discussed earlier in this chapter. The air-particulate sampling network remained unchanged from the previous year, with three sites on the main grounds of the Laboratory and a fourth at Berkeley Lab's main off-site location, ENV-B13C. 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 purchased collection 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 4-5 summarizes gross alpha and beta sample results from routine monitoring activities.

Table 4-5 Summary of Gross Alpha and Gross Beta Ambient-Air Particulate Sampling Network 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 air particulate.

Although DOE Order 5400.5 does not provide a standard for particulate gross alpha and beta radiation, several observations about these results are apparent:

- They are at or below the analytical detection limits.
- Results reveal little variability from station to station, including station ENV-B13C, located about 1.0 kilometer (0.6 mile) southeast of the site. There is some indication that gross beta levels vary from season to season, with wintertime levels slightly higher than other times of the year.
- Results for each parameter change little from one year to the next.

These observations show that environmental impacts from the Laboratory's radioactive releases of alpha- and beta-emitting isotopes to the atmosphere are negligible.

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5

Surface Water and Wastewater

Automatic water-sampling and flow-measurement
instruments at the Hearst Sewer Monitoring Station

5.1 INTRODUCTION

This chapter discusses the surface water and wastewater monitoring programs conducted at Lawrence Berkeley National Laboratory. The following sections describe the monitoring requirements, sampling networks, and results. (The individual sample data are reported in Volume II.)

5.2 SURFACE WATER PROGRAM

Lawrence Berkeley National Laboratory's surface water monitoring in calendar year (CY) 2004 included rainwater, creeks, and stormwater. Rainwater and creeks are monitored primarily for gross alpha radiation, gross beta radiation, and tritium, based on United States Department of Energy (DOE) orders[1] that prescribe monitoring requirements for radioisotopes. Surface water is also monitored for nonradiological analytes as part of the Laboratory's ongoing efforts to characterize and manage its overall impact on the environment. Stormwater monitoring is performed under the California General Permit for Stormwater Discharges Associated with Industrial Activities[2] and includes monitoring for metals and other constituents.

To place the Laboratory's surface water results in a familiar context, this chapter uses drinking-water standards as conservative reference points. However, drinking-water standards are not directly applicable because the surface water being monitored is not a source of public drinking water. No standards exist for surface water other than sources of drinking water.

The federal and state maximum contaminant levels (MCLs) for alpha and beta radioactivity in drinking water are 0.6 becquerel per liter (Bq/L) (15 picocuries per liter [pCi/L]) and 1.9 Bq/L (50 pCi/L), respectively.[3] The United States Environmental Protection Agency (US/EPA) limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).[4]

Surface water samples were analyzed by state-certified laboratories.

5.2.1 Rainwater

In 2004, measurable rainfall occurred during January through May and October through December. During each month during those periods, a composite rainfall sample was collected near Building 75 (see Figure 5-1) and analyzed for tritium and gross alpha and beta radiation. All sample results were near detection limits or within the range of natural background levels.

5.2.2 Creeks

Given Berkeley Lab's location in the hills of the Strawberry Creek watershed, many streams and drainages, at and near the site, flow at varying intensities throughout the year. A grab sample is collected and analyzed quarterly for alpha and beta activity and tritium, if water is flowing in the creek. Creeks routinely sampled during CY 2004 were Chicken Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), Botanical Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek. For creek sampling locations, see Figure 5-1. No alpha or beta activity was detected at any sampling site. Tritium was measured near detection limits twice in Chicken Creek (see Figure 5-2) and three times in the North Fork of Strawberry Creek.

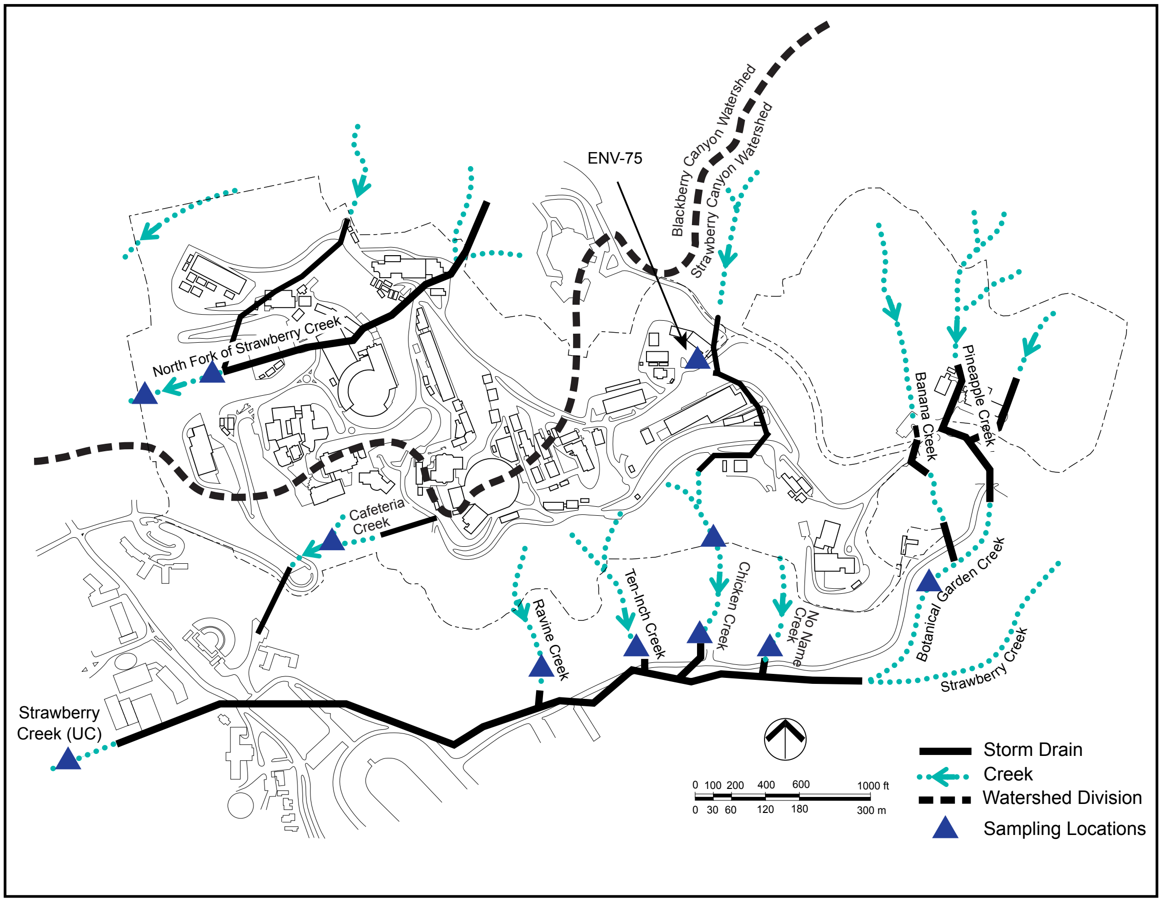


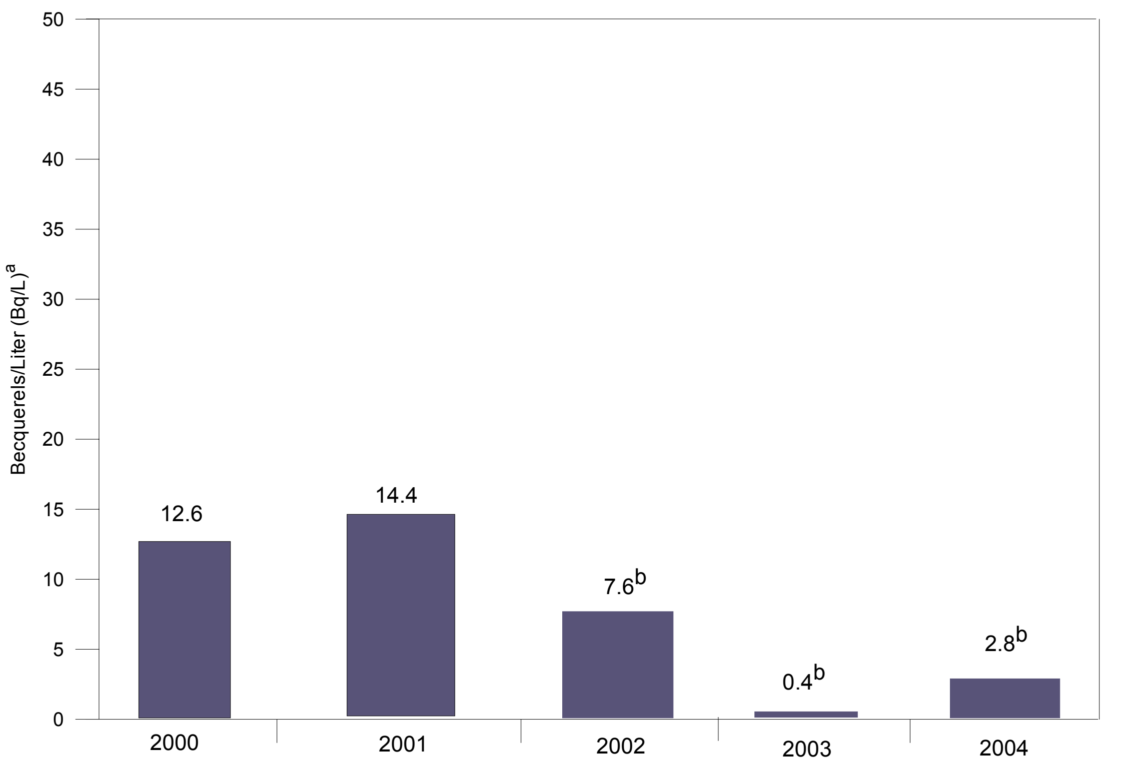
Figure 5-1 Creek and Rainwater Sampling Locations

Creeks were also sampled and analyzed for dissolved metals and volatile organic compounds (VOCs). No VOCs were detected at any location. Background levels of arsenic, barium, copper, molybdenum, nickel, selenium, vanadium, and zinc were measured. The only metal that exceeded the level set by the San Francisco Bay Region Basin Plan (Basin Plan)[5] was zinc, from a sample located off Berkeley Lab property at Botanical Garden Creek. The Basin Plan limits are not intended to be applied to creek water, but are referred to here for comparison purposes. (See Section 5.2.3 for more information on these limits.)

5.2.3 Stormwater

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon subwatersheds, which are part of the main 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), plus several small tributaries that generally flow only part of the year.



[a] 1 Bq = 27 picocuries
[b] The annual average tritium concentration is less than the normal detection limit. At these low levels, data trending is not meaningful due to large inherent analytical uncertainties.

Figure 5-2 Annual Averages for Tritium in Chicken Creek (2000–2004)

Surface runoff from Berkeley Lab is substantial because of the site's hillside location, the amount of paved or covered surface, and the moderate annual rainfall. All stormwater runoff from the site drains through its stormwater drainage system to either the south fork or the north fork of Strawberry Creek, which join below the Laboratory on the University of California (UC) Berkeley campus.

Under the State of California's National Pollutant Discharge Elimination System program, Berkeley Lab has obtained a General Permit for Stormwater Discharges Associated with Industrial Activities.[2] Permit holders must develop and maintain a *Storm Water Monitoring Program* (SWMP)[6] and a *Storm Water Pollution Prevention Plan* (SWPPP).[7] These are the guiding documents for the Laboratory's compliance with stormwater regulations. (For further discussion of this compliance program, see Section 3.4.6.2.) Sampling points are shown in Figure 5-3.

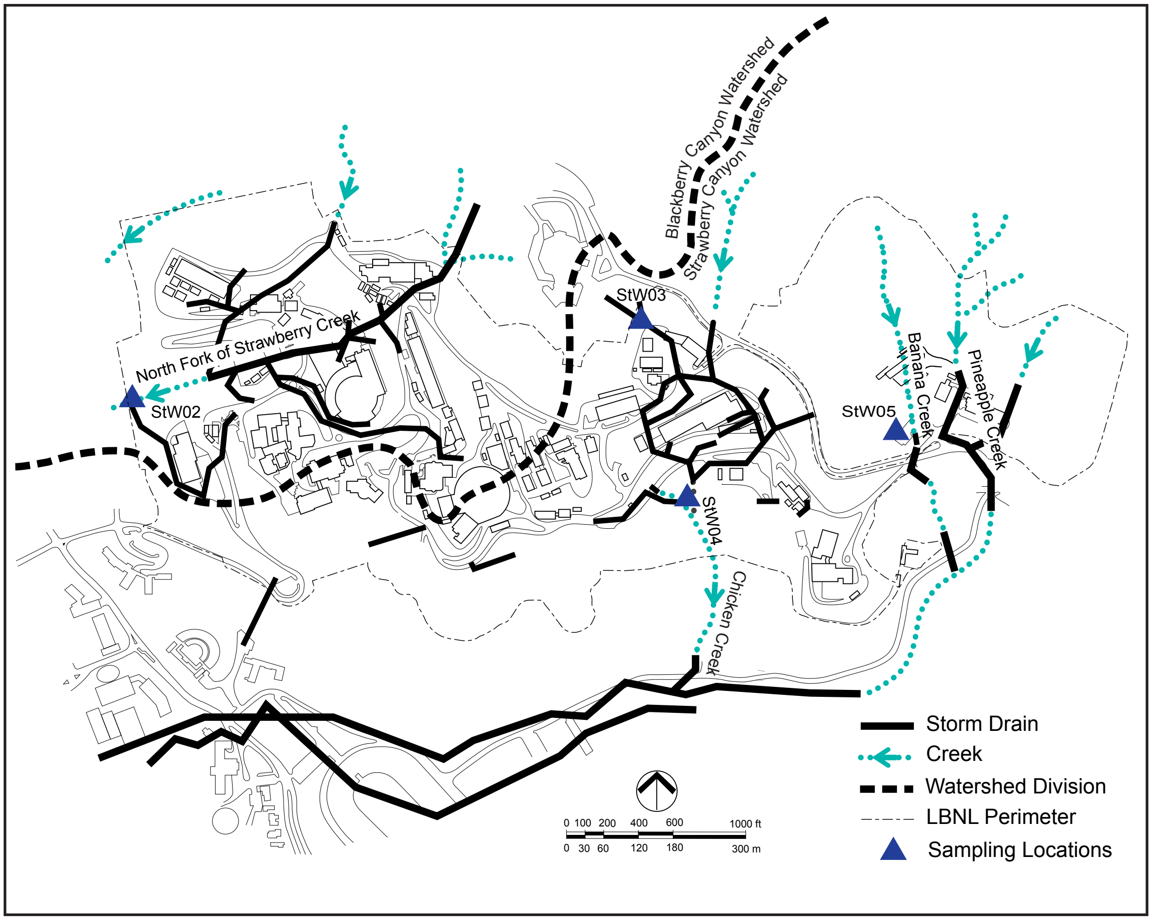


Figure 5-3 Stormwater Sampling Locations

Berkeley Lab's SWMP describes the rationale for sampling, sampling locations, and analytical parameters (radiological and nonradiological). In June 2002, the SWPPP was revised and updated; no substantive changes were required to be made to the previous best management practices identified in the SWPPP.

Under the terms of the General Permit, sampling must take place at least twice each stormwater year under specific conditions. Monitoring also includes visual observation of one storm per month and quarterly observation of authorized and unauthorized nonstormwater discharges. All sampling points must be monitored for the following:

- Total suspended solids (TSS), pH, specific conductance, and total organic carbon (TOC). Oil and grease may be substituted for TOC.
- Certain substances as prescribed by the permit if specific operations are present
- Substances that could be expected to be present, based on knowledge of operations

In CY 2004, the measure for TSS was usually very low, indicating clear water; an exception was one sample from Chicken Creek, which measured 420 milligrams per liter (mg/L) in a heavy storm. The measured pH was always near neutral. Specific conductance, usually a measure of the mineralization of water, generally was low and far below the MCL for domestic drinking water (1,600 micromhos per centimeter). Oil and grease were not detected. Total petroleum hydrocarbons (diesel) were measured in small quantities at all sampling points. Chemical oxygen demand (COD) is a measure that can be correlated to the amount of organic matter in the water; the COD levels in stormwater discharge for the Laboratory generally were low, again with the highest being in a sample from Chicken Creek (98 mg/L) collected on October 19. Nutrients such as ammonia nitrogen and nitrate plus nitrite also were measured at low levels at all stations.

For the four metals for which Berkeley Lab now analyzes, many results were below detection limits. Maximums were as follows: aluminum, 12 mg/L at Chicken Creek; iron, 13 mg/L at Chicken Creek; and magnesium, 13 mg/L at the North Fork of Strawberry Creek. Zinc was not measured above the detection limit. The General Permit does not contain specific discharge limits for metals. For comparison purposes, the Basin Plan[5] gives effluent limitations for selected toxic pollutants discharged to shallow surface waters applicable to point source discharges from Publicly Owned Treatment Works (such as the East Bay Municipal Utility District [EBMUD]) and industrial effluent; however, no levels are given for aluminum, iron, or magnesium.

Routine stormwater samples are also analyzed for alpha and beta emitters and tritium. No tritium or alpha emitters were detected; and beta emitters were measured once at the influent site, slightly above the detection limit.

5.3 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 5-4).

- 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 Laboratory's sanitary sewer system's connection to 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; those facilities are Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden.

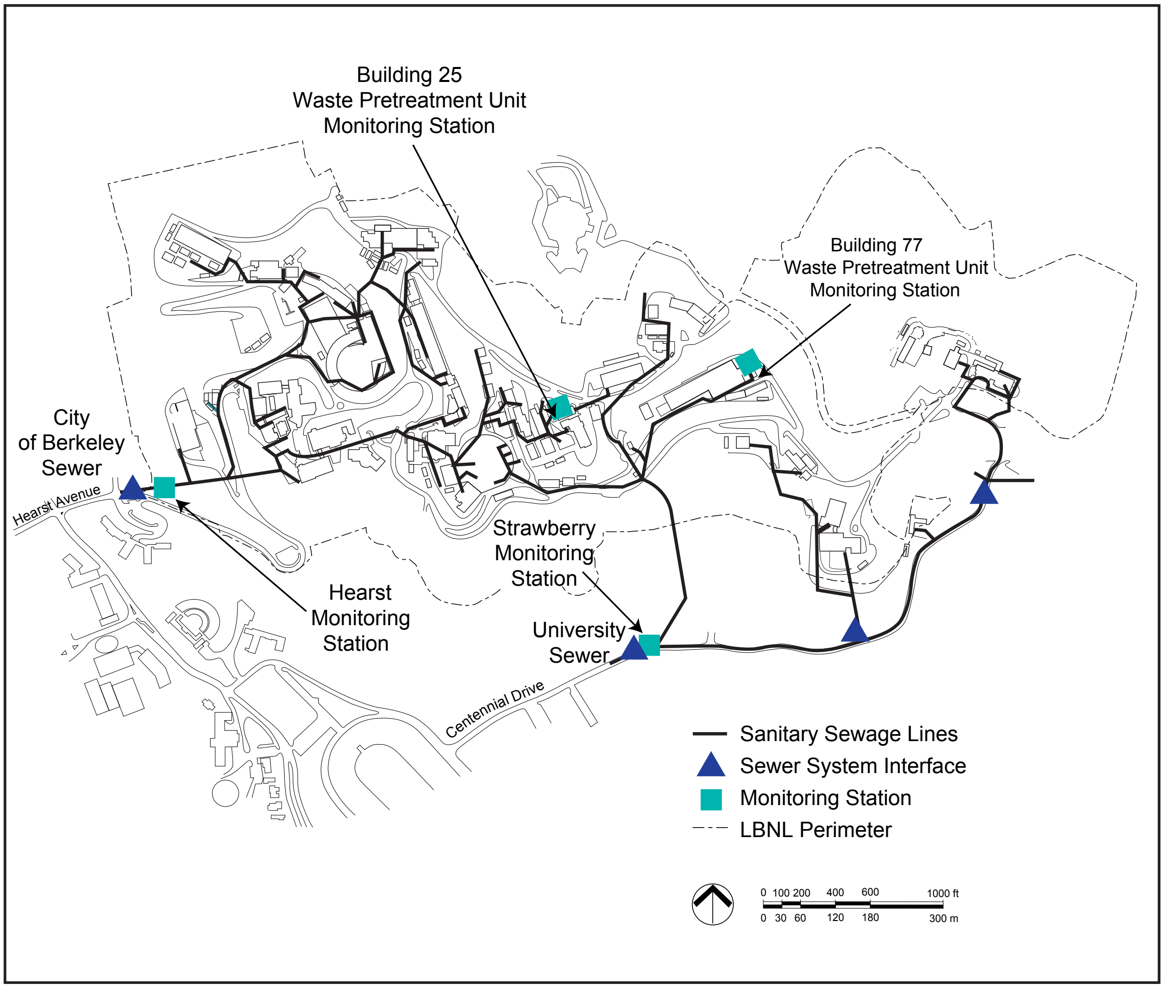


Figure 5-4 Sanitary Sewer System

Self-monitoring of wastewater discharges within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units (see Table 6-5), according to the terms of their respective EBMUD permits.[8] 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 2006, while the first two permits are valid until 2007. The Laboratory's sitewide permit requires periodic monitoring of wastewater discharges for various parameters and metals analysis once per year at times specified by EBMUD. In addition, EBMUD continues to perform unannounced monitoring of wastewater discharges four times per year. No changes in permit requirements have occurred, and all sampling results were below discharge limits.

5.3.1 Hearst and Strawberry Sewer Outfalls

Sanitary sewer discharge monitoring is divided into two types, nonradiological and radiological: Nonradiological monitoring is generally termed "self-monitoring" and is mandated in the wastewater discharge permits granted by EBMUD. Sitewide samples are always analyzed for pH, total identifiable chlorinated hydrocarbons, TSS, and COD, with additional analyses for metals required once during the permit year. Additionally, total flow is measured and recorded. In 2004, Berkeley Lab discharged approximately 21 million gallons through Hearst Sewer and 31 million gallons through Strawberry Sewer. In comparison, the discharge volumes in 2003 for Hearst and Strawberry Sewers were 18 million gallons and 25 million gallons, respectively.

Radiological monitoring is required by DOE orders[1] and guidance,[9] but the monitoring also ensures compliance with radiological limits under the California Code of Regulations,[10] cited in the EBMUD wastewater discharge permit. California regulations now incorporate by reference the applicable federal regulations[11] 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.

5.3.1.1 Nonradiological Monitoring

Two self-monitoring samples were taken from the Hearst and Strawberry outfalls during CY 2004. All results were well within discharge limits, as were all measurements made by EBMUD in its four independent samplings. 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. Figure 5-5 shows the metal results as a percentage of discharge limits.

No chlorinated hydrocarbons were detected, except for chloroform (which is present in EBMUD supply water) and a very small amount of 1,4-dichlorobenzene (in Strawberry). 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 are measured to determine wastewater strength, which forms the basis for the costs charged by EBMUD to the Laboratory for wastewater treatment. Berkeley Lab projects the average and maximum wastewater strength for the coming period in its permit application on the basis of past years' monitoring results; these projections then become the permit guidelines. TSS and COD in CY 2004 were within normal levels at both outfalls, with a maximum of 500 mg/L in one Strawberry sample.

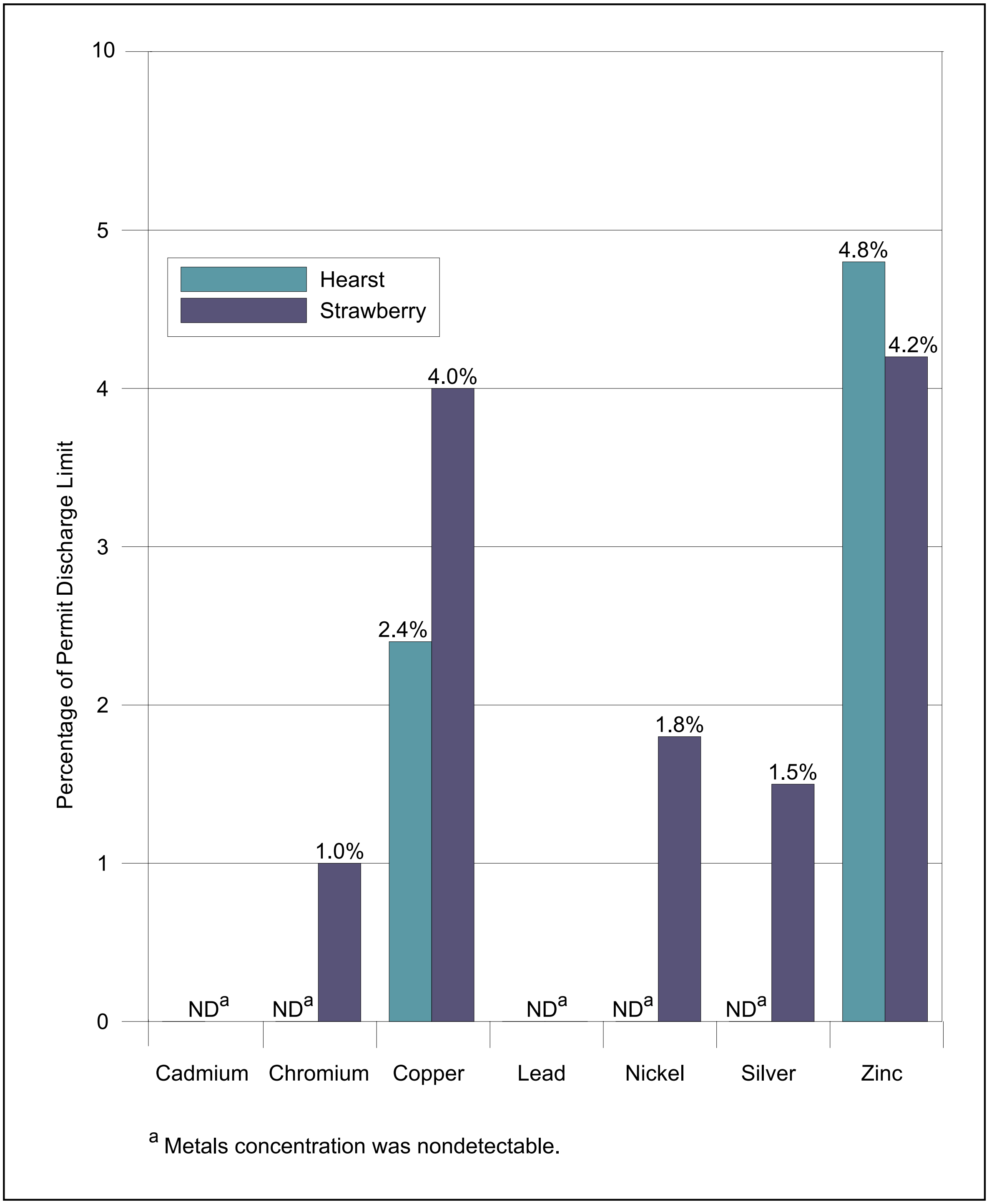


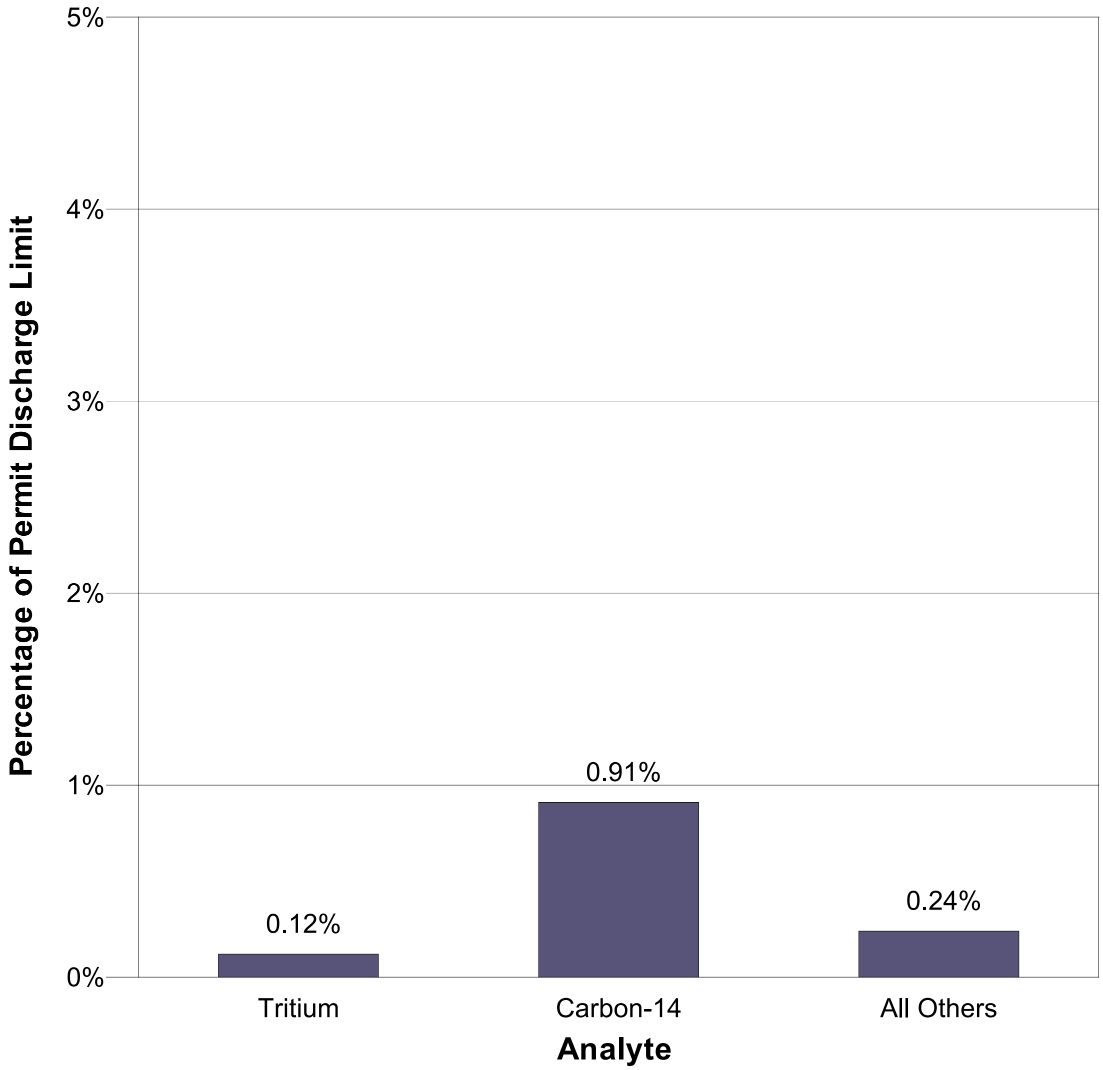
Figure 5-5 Concentration of Metals in Sewer Water Samples as a Percentage of Permit Discharge Limit

5.3.1.2 Radiological Monitoring

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 purposes.

The federal[11] and state[10] 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 it 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. Radioisotopes discharged into Berkeley Lab's sewer wastewater, expressed as a percentage of their permit discharge limit, are summarized in Figure 5-6.

Tritium levels were below the minimum detectable amount at Hearst Monitoring Station, with one exception of a sample just at the detection limit. At Strawberry Monitoring Station, tritium was not detected above the minimum detectable amount. The total annual discharge of tritium in wastewater was 2.2×10^{8} Bq (0.0061 Ci); discharge of carbon-14 was 3.4×10^{8} Bq (0.0091 Ci); and the total discharge of other radioisotopes was 8.7×10^{7} Bq (0.0024 Ci). The amount of tritium decreased from last year's level by 40%, while the total discharge of other radioisotopes remained relatively stable. All values, however, were well below allowable limits. For example, tritium was only 0.12% of the allowable federal and state limit, carbon-14 was 0.91% of its limit, and all other isotopes together were approximately 0.24% of their limit.



Note: "All Others" consists of gross alpha and beta, iodine-125, phosphorus-32, and sulfur-35.

Figure 5-6 Radioisotopes Discharged to Sewers in 2004 as a Percentage of Permit Discharge Limit

Figure 5-7 trends the total amount of tritium released to Berkeley Lab's sewers over the past five years. Results were consistently under 10% of the permitted level, and in the past four years have trended downward.

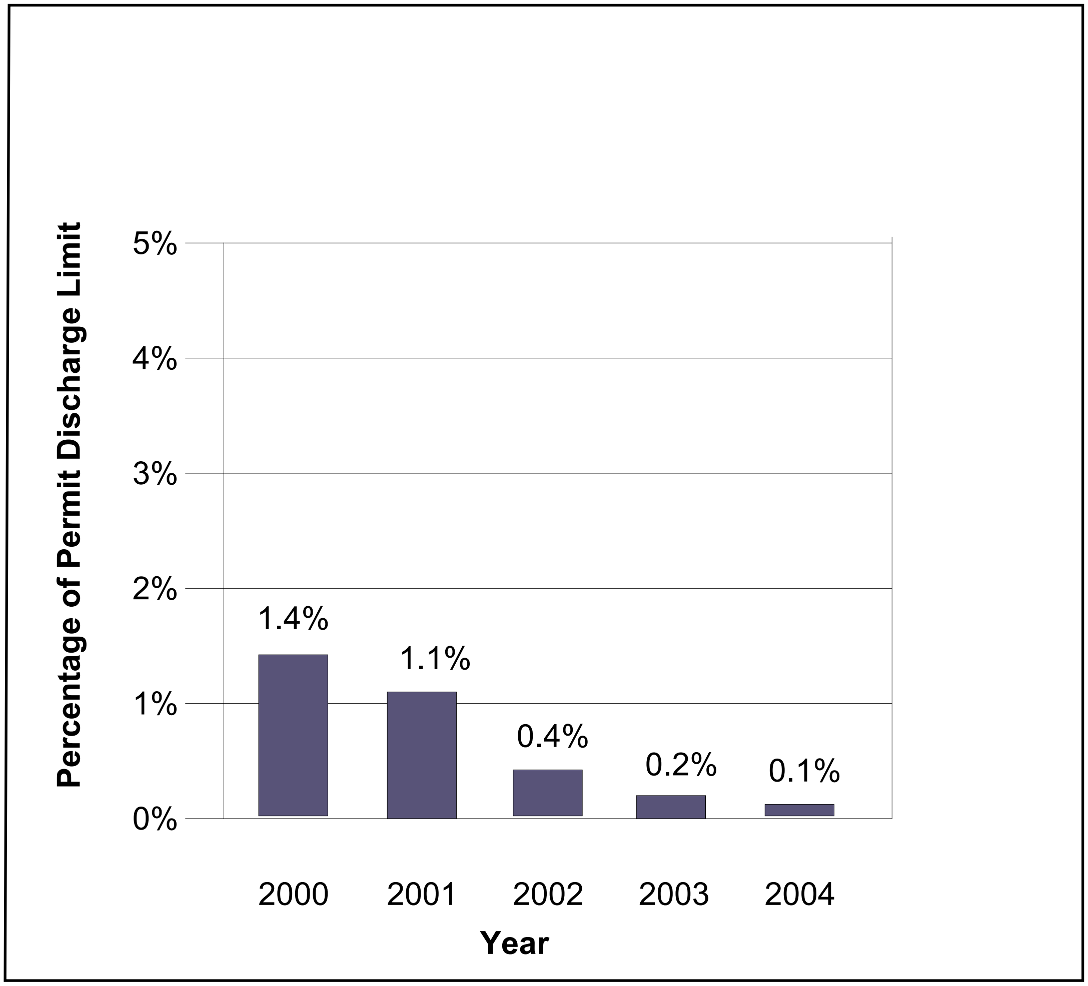


Figure 5-7 Annual Releases of Tritium to Sewers (2000–2004) as a Percentage of Permit Discharge Limit

5.3.2 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 a fixed treatment unit (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 two efforts by EBMUD—yielded daily maximum and monthly average results well within EBMUD discharge limits.[8]

5.3.3 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 three self-monitoring samples and the two EBMUD inspection samples were 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* twice per year, certifying that Buildings 25 and 77 are implementing the applicable solvent management plan and that dumping of concentrated toxic organics into wastewaters has not occurred.

5.3.4 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 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. (For further discussion of groundwater monitoring and treatment, see Chapter 6.)

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6

Groundwater

Collection of a groundwater sample from a well on the slope of Building 53/58

6.1 BACKGROUND

This chapter reviews the groundwater monitoring program at Lawrence Berkeley National Laboratory, emphasizing the calendar year (CY) 2004 results. Additional details on the program can be obtained from Environmental Restoration Program quarterly progress 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.

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 near existing and removed hazardous materials or hazardous waste storage units, including underground storage tanks (USTs)

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 monitored for additional potential contaminants. Wells are also sampled for other water quality parameters, including total dissolved solids (TDS), cations, and anions.

Maximum contaminant levels (MCLs) for drinking water are included in this chapter for contaminants with established limits. Groundwater at Berkeley Lab is not used for human consumption, and the use of MCLs is included only for comparison purposes.

Under the Resource Conservation and Recovery Act of 1976 (RCRA) Corrective Action Program,[1] 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.

Activities are closely coordinated with the regulatory oversight agencies, including the lead agency, the California Environmental Protection Agency Department of Toxic Substances Control (DTSC); the San Francisco Bay Regional Water Quality Control Board (Regional Water Board); the City of Berkeley; and the United States Department of Energy (DOE). Berkeley Lab meets with these agencies at least monthly to discuss current and planned activities.

6.2 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 2.3.4.)

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 6-1 shows groundwater elevations at Berkeley Lab. This map shows that the groundwater surface generally mirrors the surface topography.

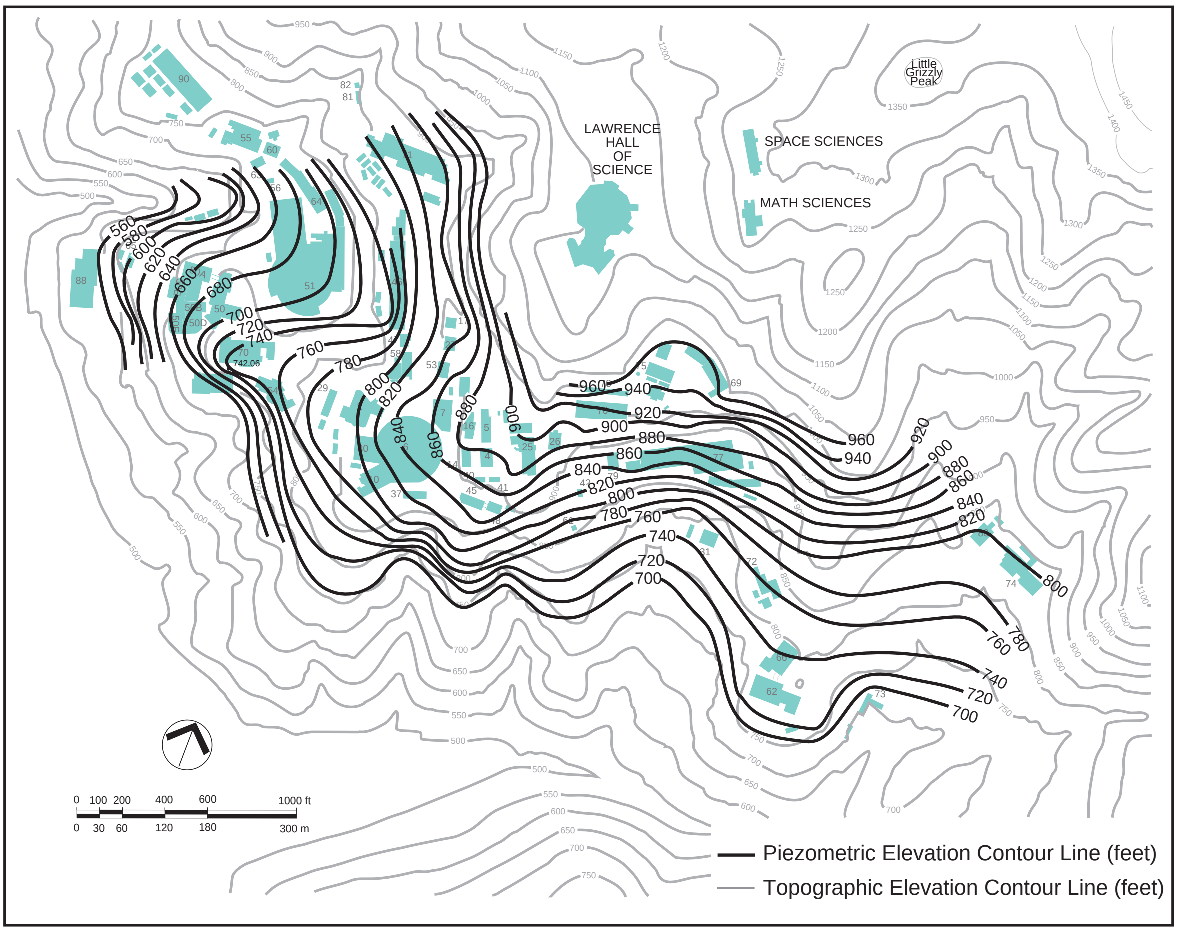

Figure 6-1 Groundwater Piezometric Map

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 show local deviations 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).

6.3 GROUNDWATER MONITORING RESULTS

The groundwater program monitors a total of 185 groundwater monitoring wells. These included 20 wells near the site boundary, and 1 offsite well (see Figure 6-2).

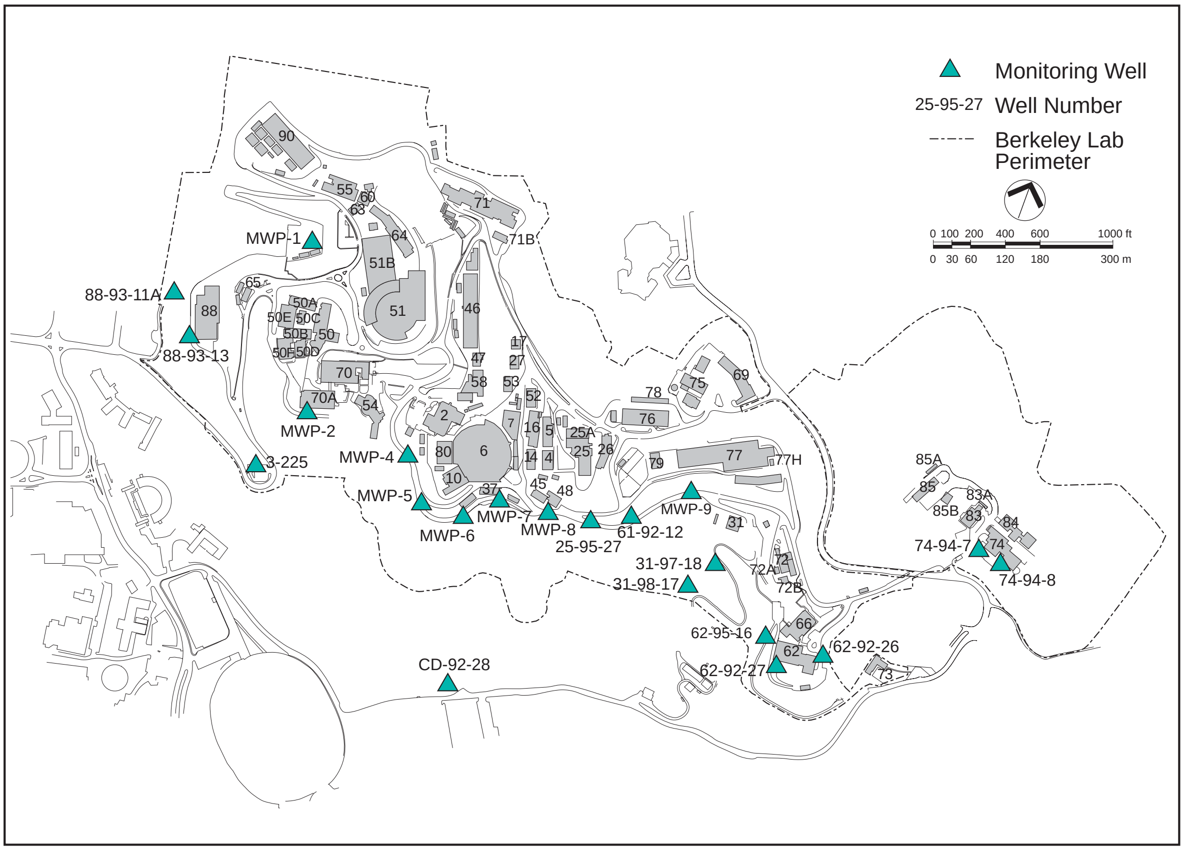

Figure 6-2 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

Tables 6-1, 6-2, and 6-3 summarize groundwater monitoring results for CY 2004 for metals, VOCs, and tritium, respectively. The metals and VOCs tables show the number of monitoring wells in which the analyte was detected, the ranges in concentrations detected during the year (in micrograms per liter [µg/L]), and the drinking-water standard (MCL) for each analyte detected.[2,3] The tritium table provides all the results from monitoring wells in CY 2004 in units of becquerels per liter (Bq/L). The TDS concentration measured in groundwater monitoring wells at Berkeley Lab has ranged from 406 to 2,180 milligrams per liter.

Table 6-1 Metals Detected in Groundwater Samples from Monitoring Wells[a] in 2004

Metal	Number of wells sampled	Number of samples	Number of wells in which analyte was detected	Range of concentrations (µg/L)[b]	Drinking water standard (MCL) (µg/L)
Antimony	27	32	1	4	6
Arsenic	41	46	34	2–110	50
Barium	29	34	28	13–1,200	1,000
Beryllium	26	31	0	ND[c]	4
Cadmium	26	31	0	ND	5
Chromium	29	34	3	5.6–32	50[d]
Hexavalent Chromium	1	1	0	ND	50[d]
Cobalt	26	31	1	76–200	—[e]
Copper	26	31	0	ND	1300[f]
Lead	26	31	2	1.4–1.6	15[f]
Mercury	28	33	1	0.77	2
Molybdenum	37	42	18	52–800	—
Nickel	27	32	1	9.2	100
Selenium	29	34	18	1.2–82	50
Silver	26	31	0	ND	100[g]
Thallium	26	31	0	ND	2
Vanadium	26	31	12	13–66	—
Zinc	26	31	22	10–69	5000[g]

[a] Wells sampled for the Hydrogen Release Compounds Pilot Test are not included.
[b] Micrograms per liter
[c] Not detected
[d] Drinking water standard is for total chromium
[e] No MCL specified
[f] Action Level: If system exceeds the action level, it must take certain actions, such as additional monitoring, corrosion control studies and treatment, and for lead, a public education program.
[g] Secondary MCL (guidelines for cosmetic or aesthetic effects)

Table 6-2 Volatile Organic Compounds Detected in Groundwater Samples from Monitoring Wells[a] in 2004

Analytes detected	Number of wells in which analyte was detected	Range of concentrations (µg/L)[b]	Drinking-water standard (MCL) (µg/L)
Aromatic or nonhalogenated hydrocarbons			
Benzene	5	0.75–59.6	1
1,4-dichlorobenzene	1	1.1	5
p-isopropyltoluene	1	1.3	—[c]
Methyl tert-butyl ether	1	2.5	13
Toluene	9	1–105	150
Xylenes (total)	1	1.3	1750
Halogenated hydrocarbons			
Bromodichloromethane	2	1.1–1.5	80[d]
Bromoform	1	6.1	80[d]
Carbon tetrachloride	21	1–1690	0.5
Chloroform	22	1.5–40.9	80[d]
1,1-dichloroethane	25	1.1–194	5
1,2-dichloroethane	3	2.1–3.5	0.5
1,1-dichloroethene	29	1.4–80	6
cis-1,2-dichloroethene	56	1.1–620	6
Trans-1,2-dichloroethene	12	0.92–42.4	10
Methylene chloride	3	4.4–990	5
1,1,1,2-tetrachloroethane	1	64	—
Tetrachloroethene	57	0.63–48,000	5
1,1,1-trichloroethane	3	1.5–15	200
1,1,2-trichloroethane	1	5.3	5
Trichloroethene	74	1–24,700	5
1,1,2-trichlorotrifluoroethane (Freon 113)	2	3–4.4	1,200
Vinyl chloride	16	1.1–77.3	0.5

[a] 412 samples taken from 169 wells during the year
[b] Micrograms per liter
[c] No MCL specified
[d] Standard is for total trihalomethanes.

Table 6-3 Tritium Detected in Groundwater Samples from Monitoring Wells[a] (in Bq/L[b]) in 2004

Well Number	January–March	April–June	July–September	October–December
31-97-17	28	NS[c]	74	NS
71-95-9	<11	<11	21	21
71B-98-13	<11	<11	<11	23
71B-99-3R	<11	<11	<11	16
75-92-23	58	NS	54	NS
75-97-5	856; 810[d]	807; 699[d]	785; 755[d]	763; 707[d]
75-97-7	15	NS	14	NS
75-98-14	188	346; 287[d]	282; 269[d]	239; 225[d]
75-99-6	90	87	107	107
75-99-7	250	260; 226[d]	239	246; 236[d]
75B-92-24	39	NS	82	NS
76-93-6	166	NS	140	NS
77-94-6	338; 333[d]	NS	330; 302[d]	NS
77-97-9	383; 347[d]	NS	398; 354[d]	NS
77-97-11	200	NS	206	NS
78-97-20	68	NS	60	NS
MW91-2	22	NS	30	NS
MW91-4	<11	NS	18	NS
MW91-5	44	NS	60	NS
MW91-6	78	NS	94	NS

[a] For comparison, the drinking water standard determined by California Department of Health Services is 740 becquerels per liter (Bq/L) (20,000 picocuries per liter [pCi/L]).
[b] Becquerels per liter
[c] NS=Not sampled
[d] Duplicate sample

6.4 GROUNDWATER CONTAMINATION PLUMES

Based on groundwater monitoring results, nine principal groundwater contamination plumes have been identified on-site. The plumes are listed below, and the locations are shown in Figure 6-3:

- *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

The Old Town plume has been subdivided into multiple lobes to reflect the commingling of contaminated groundwater derived from different sources. Groundwater contaminated with VOCs also was detected in three other areas of the site (Buildings 75/75A, 75B, and 77) in CY 2004; the extent of contamination in each of these areas is limited.

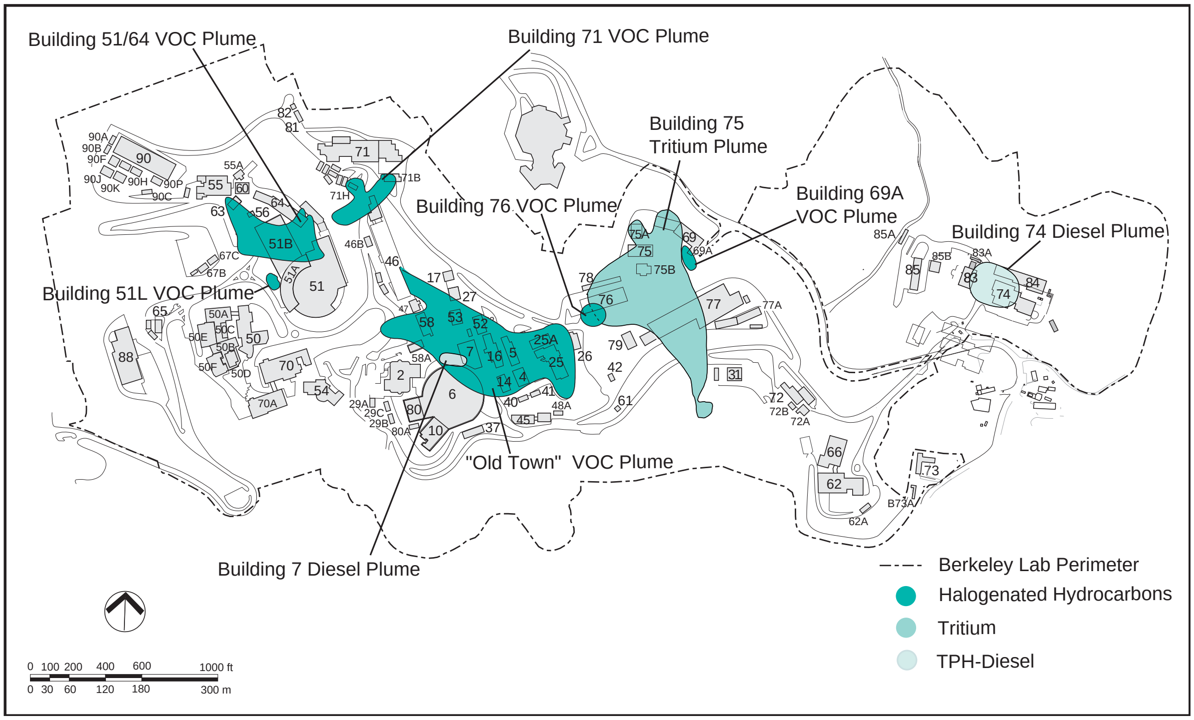

Figure 6-3 Groundwater Contamination Plumes (September 2004)

6.4.1 Volatile Organic Compound Plumes

Covering the area of Buildings 4, 5, 7, 14, 16, 25, 27, 52, 53, and 58, and 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), trichloroethene (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 maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume monitoring wells in CY 2004 was 73,750 µg/L, which primarily consisted of PCE (48,000 µg/L) and TCE (24,300 µg/L). Figure 6-4 shows the areal extent of VOCs in groundwater in the Old Town area.

The presence of the maximum VOC concentrations north of Building 7 suggested that the primary source of the Old Town VOC plume was an abandoned sump located between Buildings 7 and 7B. Relatively high 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

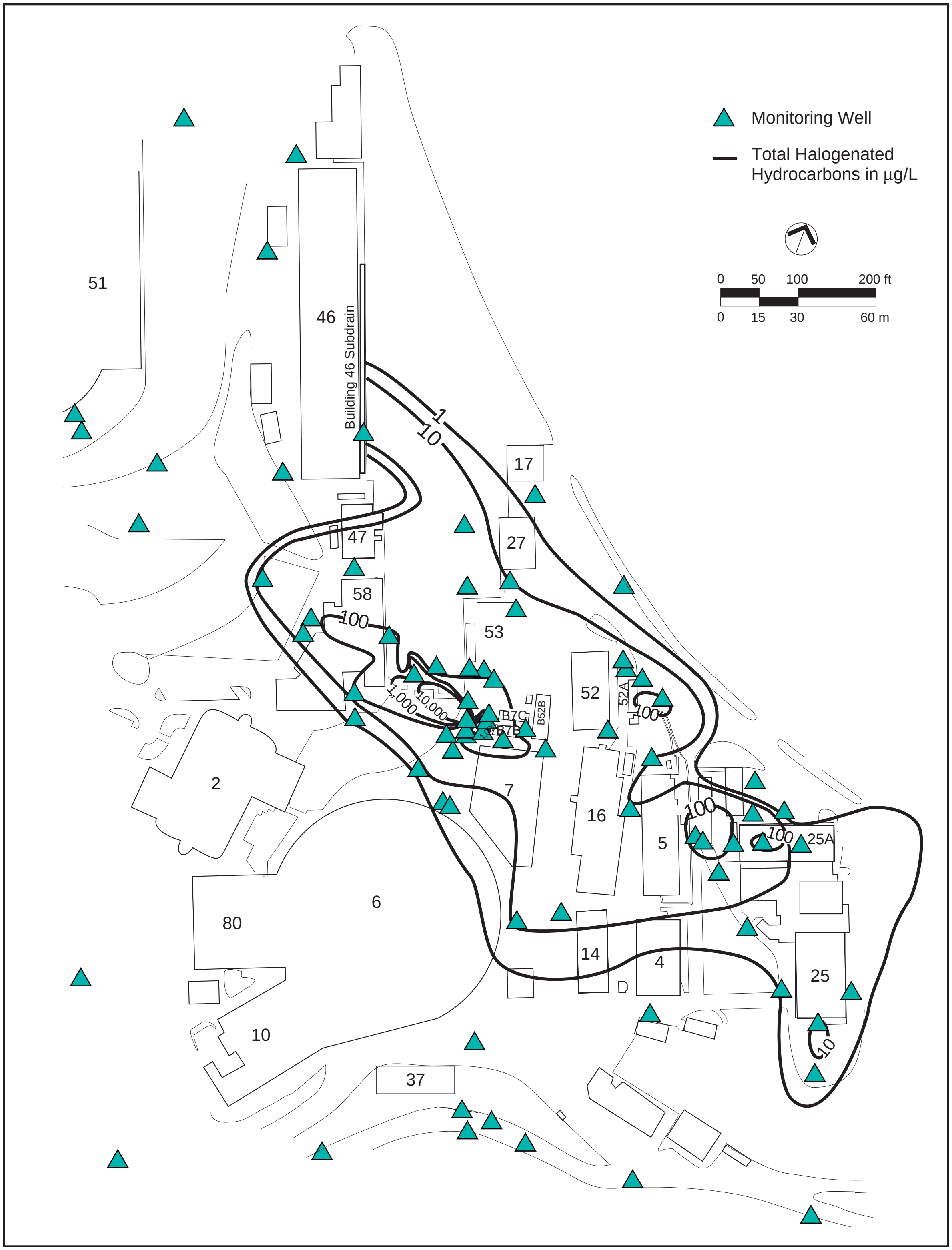

Figure 6-4 Groundwater Contamination (Total Halogenated Hydrocarbons in Micrograms per Liter [µg/L]) in Old Town Area (September 2004)

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 52A lobe was removed.

A second plume of VOC-contaminated groundwater, the Building 51/64 VOC plume (see Figures 6-3 and 6-5), extends from the southeast corner of Building 64, under Buildings 64 and 51B. In 2000, highly contaminated soil was excavated from the source area of the plume as an interim corrective measure (see Section 6.5.1). 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 in CY 2004 at a maximum total concentration of 17,593 µg/L in a groundwater sample from a temporary sampling point close to the previously removed source area of the plume. The primary contaminant was 1,1-DCA. The maximum concentration of total halogenated hydrocarbons in CY 2004 in samples collected from groundwater monitoring wells in the Building 51/64 area was 696 µg/L. The contaminants consisted primarily of PCE (406 µg/L); 1,1-DCA (141 µg/L); TCE (99 µg/L); and 1,1-DCE (29 µg/L).

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 71 (Building 71 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) (see Figure 6-3).

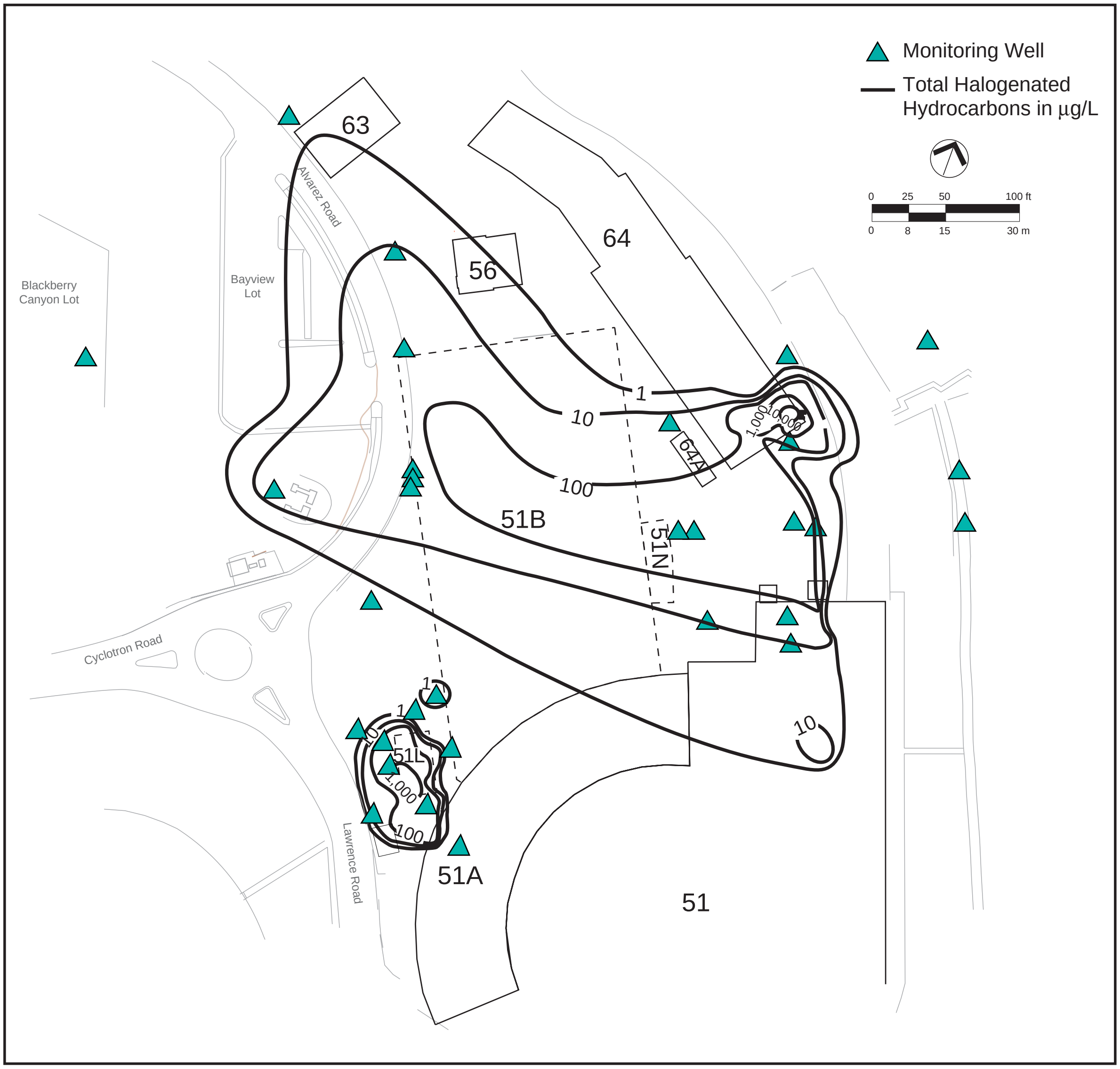

Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in Micrograms per Liter [µg/L]) at Building 51/64 VOC Plume (September 2004)

The Building 71 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 CY 2004 at a maximum total concentration of 6,761 µg/L (almost exclusively PCE) in a groundwater sample from a temporary sampling point close to the source area of the plume. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in 2004 was 1,805 µg/L, in a monitoring well south of Building 71B. The contaminants consisted of TCE (862 µg/L); PCE (689 µg/L); cis-1,2-DCE (204 µg/L); and vinyl chloride (50 µg/L). Contaminated groundwater from the plume is discharged continuously through five subhorizontal drains (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 CY 2000, CY 2003, and CY 2004 as interim corrective measures (see Section 6.5.1).

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 CY 2004 at a maximum total concentration of 3,205 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 (1,960 µg/L); trans-1,2-DCE (533 µg/L); TCE (324 µg/L); and vinyl chloride (287µg/L).

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 in CY 2004 was 53 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 wells monitoring the plume in CY 2004 was 22 µg/L.

6.4.2 Tritium Plume

The tritium plume covers the areas of Buildings 31, 75, 76, 77, and 78. Figure 6-6 shows groundwater tritium concentration contours in this area. The area of tritium-contaminated groundwater extends southward from Building 75 toward Chicken Creek, in the direction of groundwater flow. In addition, low concentrations of tritium, 23 Bq/L (621 picocuries per liter [pCi/L]) maximum in CY 2004, have been detected in monitoring wells in the Building 71B area. The source of the tritium was the former National Tritium Labeling Facility (NTLF) at Building 75. The maximum concentration of tritium detected in groundwater in CY 2004 was 856 Bq/L (23,100 pCi/L), at monitoring well 75-97-5, which is above the drinking-water standard of 740 Bq/L (20,000 pCi/L).[2] 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; if this trend continues, tritium concentrations should fall below the MCL within approximately a year. In addition to the wells listed in Table 6-3, samples from 50 other monitoring wells, including quarterly samples from 20 wells close to the Berkeley Lab property line, were analyzed for tritium in CY 2004. No tritium above the reporting limit of 11 Bq/L (300 pCi/L) was detected in any of these samples.

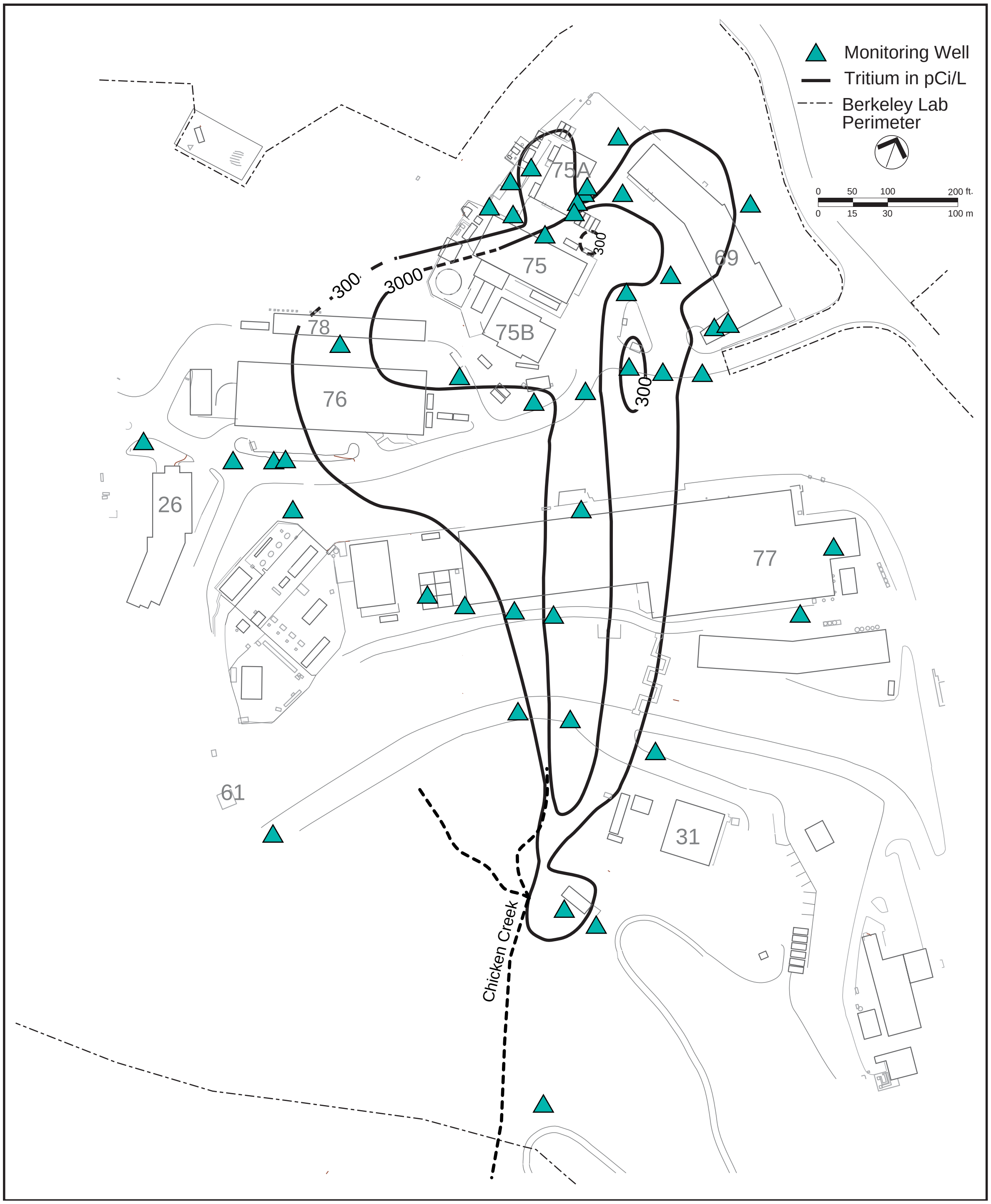

Figure 6-6 Groundwater Contamination (Tritium in Picocuries per Liter [pCi/L]) (September 2004)

6.4.3 Petroleum Hydrocarbon Plumes

Monitoring wells have been installed at, or downgradient from, two abandoned and five removed USTs. Figure 6-7 shows the approximate locations of these wells. The maximum concentrations of total petroleum hydrocarbons (TPH) detected at these sites in CY 2004 are listed in Table 6-4.

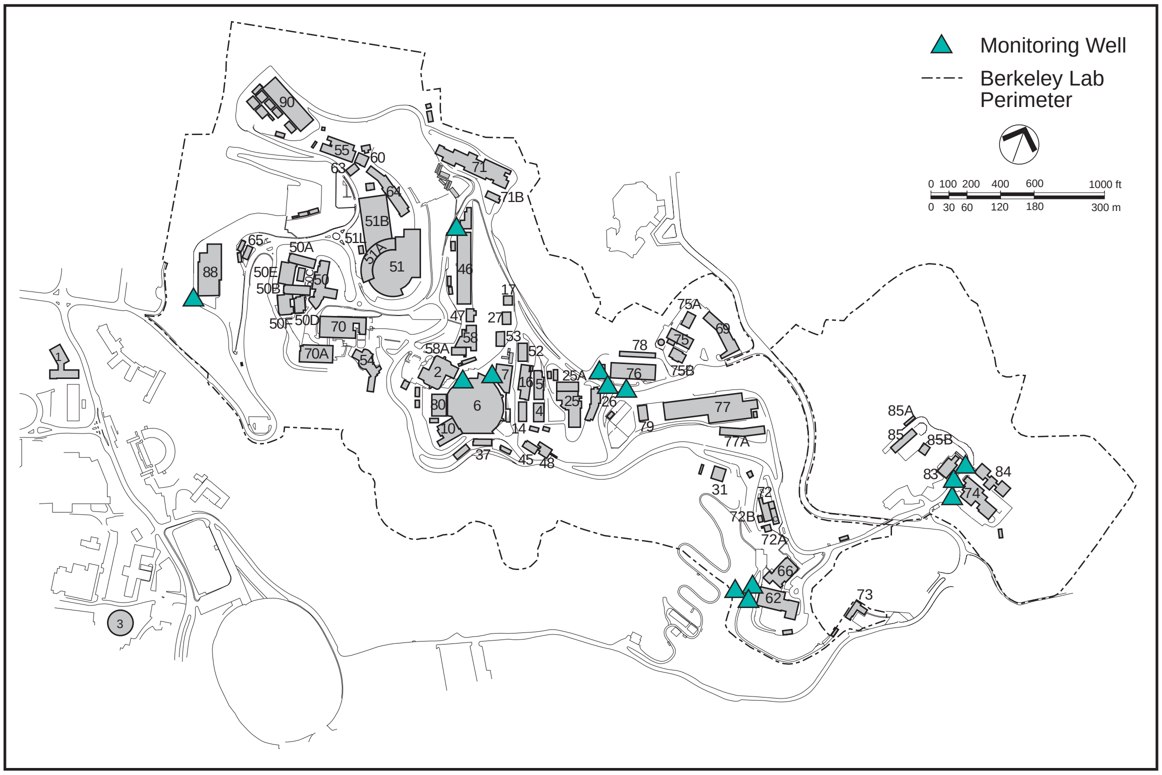

Figure 6-7 Approximate Locations of Monitoring Wells Associated with Former Underground Storage Tanks

Table 6-4 Total Petroleum Hydrocarbons (TPH) Detected in Groundwater Samples from Monitoring Wells at Former Underground Storage Tank (UST) Sites in 2004

UST Location	Status	Present or previous contents	Maximum concentration (µg/L)
Building 7E	Removed	Kerosene or Diesel	TPH-K[a] = 7,800 TPH-D[b] = 590 Hydraulic/Motor Oil = 170
Building 62[c]	Removed	Diesel	TPH-D = 53
Building 74[c]	Removed	Diesel	TPH-D = 1400
Building 76 (Tank No. 1)[c]	Removed	Diesel	TPH-D = 290
Building 76 (Tank No. 2)[c]	Removed	Gasoline	TPH-G[d] = 99
Building 88[c]	Abandoned	Diesel	TPH-D = 410

[a] TPH-K = TPH quantified as kerosene-range hydrocarbons
[b] TPH-D = TPH quantified as diesel-range hydrocarbons
[c] Approved No Further Action (NFA) Status by the City of Berkeley
[d] TPH-G = TPH quantified as gasoline-range hydrocarbons

Petroleum hydrocarbon plumes are located in three areas: north of Building 6, near Building 74, and south of Building 76. No aromatic hydrocarbons including BTEX components (i.e., benzene, toluene, ethyl benzene, xylenes) were detected at UST sites in CY 2004. A dual-phase (groundwater and soil vapor) extraction and treatment system has been installed at the location of the Building 7E former UST as an interim corrective measure.

Methyl tertiary butyl ether (MTBE) was detected in one monitoring well in CY 2004 at a concentration of 2.5 µg/L. The California MCL for MTBE is 13 µg/L.

6.5 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 Corrective Action Process, 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

6.5.1 Source Removal or Control

The need for interim corrective measures is evaluated if the contaminant poses a potential threat to human health or the environment. Several sources of contamination have been removed. The following is a list of such actions:

- Removed approximately 35 cubic meters (m^3) (46 cubic yards [yd^3]) of VOC-contaminated soil from the source area of the Building 52A 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 Building 51/64 plume
- Removed more than 100 m^3 (131 yd^3) of soil contaminated with polychlorinated biphenyls (PCBs) and tritium from the Building 75A area
- Removed more than 22 m^3 (29 yd^3) of PCB-contaminated soil at Building 88

6.5.2 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) discharging to the creeks, Berkeley Lab installed a system to collect and treat hydrauger effluent that is contaminated with VOCs. See Sections 5.3.4 and 6.5.5 for more information on discharge from this system. Additionally, effluent from a subdrain east of Building 46 (see Figure 6-4) that collects VOC-contaminated groundwater is treated.

6.5.3 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.

6.5.4 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 CY 2004:

- 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 and treatment system was installed west of Building 25A to control migration of contaminated groundwater from the Old Town plume Building 25A lobe source area.

6.5.5 Treatment Systems

As described above, Berkeley Lab is using collection trenches and subdrains to control groundwater plumes that could migrate off-site or contaminate surface water. Eleven granular-activated carbon treatment systems were operated in CY 2004. The treated water is recycled for industrial use on-site, released to the sanitary sewer in accordance with Berkeley Lab's treated groundwater discharge permit from the East Bay Municipal Utility District,[4] or recirculated to flush contaminants from the subsurface.

Table 6-5 lists both the volume of contaminated groundwater treated by each system in CY 2004 and the total volume treated since the treatment systems were first placed in operation.

Table 6-5 Treatment of Contaminated Groundwater in 2004

Source of contamination	Treatment system	Volume of water treated in 2004 (liters)[a]	Total volume treated through December 2004 (liters)[b]
Building 6 former underground storage tank	Building 6 Bioventing	2,083,650	7,724,114
Old Town VOC plume (Building 7 lobe)	Building 7 Trench	7,811,714	23,934,289
Old Town VOC plume (Building 25A lobe)	Building 25A	594,957	1,830,048
Building 37 hydrauger 37-01-01, and utility manhole MH-133[c]	Building 37	946,568	5,826,451
Old Town VOC plume (Building 52 lobe)	Building 46	6,934,578	51,322,276
Old Town VOC plume, Building 51 hydraugers, and water collected from purging monitoring wells	Building 51 Firetrail	5,211,896	59,140,557
Building 51 subdrain system and Building 64 source area	Building 51 Basement	1,430,495	10,857,685
Building 51L VOC plume	Building 51L	949,093	2,466,060
Old Town VOC plume (Building 52 lobe)	Building 53	396,831	396,831
Building 51/64 VOC plume	Building 64	934,301	952,643
Building 71B VOC plume	Building 71B	260,945	260,945
Total volume treated		27,555,028	164,711,899

[a] 1 liter = 0.264 gallons
[b] Total volume treated since system was placed in operation
[c] Treatment of Building 37 VOC plume groundwater was discontinued in June 2001 after concentrations of VOCs remained below MCLs for more than one year.

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7

Soil and Sediment

Laboratory analysis of a soil sample

7.1 BACKGROUND

The analysis of soil and sediment as part of a routine environmental monitoring program can provide information regarding past releases to air or water. Berkeley Lab performs annual soil and sediment sampling to determine long-term accumulation trends and baseline profiles.[1] No specific regulatory requirements exist for routinely assessing these media, although contamination discovered by sampling must be handled according to federal and state hazardous waste regulations.

Berkeley Lab's *Environmental Monitoring Plan*[2] sets out the details of the soil and sediment program. In calendar year (CY) 2004, routine sampling was performed in October, before the rainy season. Nonroutine soil and sediment sampling was performed in January and April of 2004. All individual sampling results are reported in Volume II.

7.2 SOIL AND SEDIMENT SAMPLING

Soil samples 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 7-1). When possible, locations were chosen to coincide with the locations of ambient-air sampling stations. Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, moisture content, and pH.

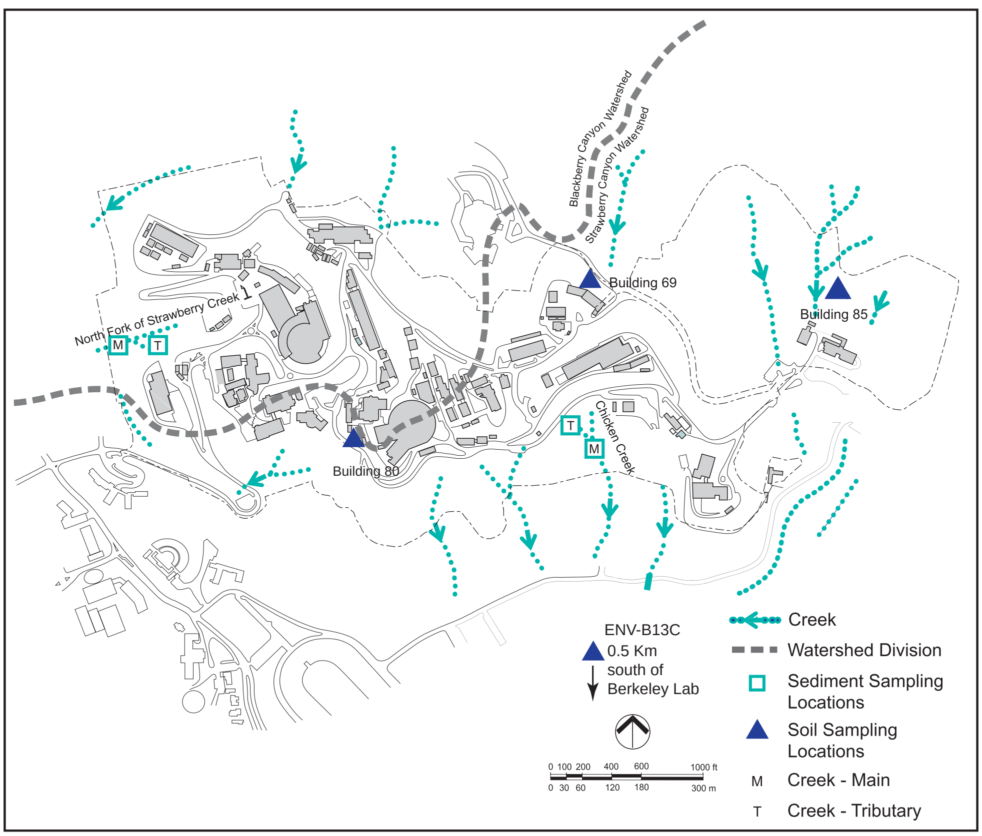

Figure 7-1 Soil and Sediment Sampling Sites

Sediment samples were collected from main and tributary creek beds of the North Fork of Strawberry Creek and Chicken Creek (see Figure 7-1). The samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, polychlorinated biphenyls (PCBs), petroleum hydrocarbons (diesel fuel and oil/grease), moisture content, and pH.

7.3 SOIL AND SEDIMENT RESULTS FROM NONROUTINE SAMPLING IN JANUARY AND APRIL

In addition to the routine soil and sediment sampling that was performed in October 2004, soil and sediment sampling was performed in January and April 2004 to investigate the following results obtained from two locations in CY 2003: mercury in soil at the Building 80 location (0.98 milligram per kilogram [mg/kg]) and oil/grease and diesel fuel in sediment from the Chicken Creek tributary location (10,000 mg/kg of oil/grease and 340 mg/kg of diesel fuel).

As was reported in the *Site Environmental Report for 2003*, in January 2004 a soil sample was obtained at the Building 80 location; the sample was analyzed for metals and was determined to contain 0.56 mg/kg mercury. Also, a sediment sample was collected from the Chicken Creek tributary location and was determined to contain 3,100 mg/kg oil/grease and 170 mg/kg diesel fuel.

To assess the areal extent of the measured mercury levels, five additional soil samples (plus one duplicate sample) were collected in April 2004 at the Building 80 location and measured for mercury. The mercury results from the April samples were comparable to those measured previously: The maximum mercury concentration was determined to be 1.3 mg/kg. Although the maximum mercury level is slightly above the upper level site background concentration for mercury in soil (0.60 mg/Kg),[3] this level is 0.4% of the United States Environmental Protection Agency Preliminary Remediation Goals for mercury in soil (310 mg/kg).[4]

Tables 7-1 and 7-2 show results from the samples analysis for metals, oil/grease, and diesel fuel for any sample that had at least one result above the practical quantification limit.

7.4 SOIL AND SEDIMENT RESULTS FROM ROUTINE SAMPLING IN OCTOBER

The gross alpha and beta radiation and gamma emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soil and sediment.

Sediment samples were analyzed for PCB aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, and total PCBs. All PCB results were below practical quantification limits (0.02 mg/kg). Measurements of pH for all samples were within the normal range for soils and sediments.

Table 7-1 Metals Results[a] from Soil Samples in milligrams per kilograms (mg/kg)

Analyte	Locations				PRG[b]
	B69	B80	B85	ENV-B13C	
Aluminum	31,000	20,000	37,000	13,000	100,000
Arsenic	3	7.0 (6.2)[c]	3	8	16
Barium	160	260 (190)[c]	140	150	67,000
Chromium	100	54 (44)[c]	110	30	450
Cobalt	<25[d]	<25[d] (13)[c]	<25[d]	<25[d]	1,900
Copper	26	43 (37)[c]	39	26	41,000
Iron	49,000	33,000	38,000	21,000	100,000
Lead	<50[d]	200 (160)[c]	<50[d]	93	800
Magnesium	14,000	8,300	9,100	3,800	N/A
Manganese	1,000	990	1,100	470	19,000
Mercury	<0.1[d]	0.87 (1.3)[c]	<0.1[d]	0.17	310
Nickel	67	64 (49)[c]	63	31	20,000
Vanadium	96	50 (43)[c]	130	40	1,000
Zinc	71	120 (87)[c]	74	100	100,000

[a] Results for antimony, beryllium, boron, cadmium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in this table; these results are included in Volume II.
[b] Preliminary Remediation Goals, United States Environmental Protection Agency Region 9 Table, October 2004
[c] Maximum results from January and April samplings are shown in parentheses.
[d] Result is below detection limit.

Other than one of the metal concentrations measured in the soil and sediment samples, all were at or near the established background values for the Berkeley Lab site. The soil sample collected at the Building 80 location contained a mercury concentration of 0.87 mg/kg, which is slightly above the upper-level background value for mercury (0.60 mg/kg) in soil at Berkeley Lab.[3] This location will be sampled in future years to monitor any changes in mercury concentrations.

The maximum concentration of oil/grease in sediment was 890 mg/kg measured in the sample collected at the North Fork Strawberry tributary location. This concentration of oil/grease is well below the maximum levels measured in CY 2003 (10,000 mg/kg). The maximum concentration of diesel fuel sediment was 21 mg/kg measured in the Chicken Creek tributary location. This level of diesel fuel also is well below the maximum level measured in CY 2003 (340 mg/kg). These forms of contamination are commonly associated with local motorized vehicle use on roads and parking lots that drain to creeks. This location will be sampled in future years to monitor any changes in oil/grease and diesel fuel concentrations.

Table 7-2 Metals, Oil/Grease, and Diesel Fuel Results[a] for Sediment Samples in milligrams per kilograms (mg/kg)

Analyte	Locations				PRG[b]
	Chicken Creek – Main	Chicken Creek – Tributary	N. Fork Strawberry Creek – Main	N. Fork Strawberry Creek – Tributary	
Aluminum	13,000	9,000	12,000	6,100	100,000
Arsenic	2.6	3.2	7.6	5.5	16
Barium	120	80	85	50	67,000
Boron	6.5	<5[d]	<5[d]	<5[d]	100,000
Chromium	49	37	37	23	450
Cobalt	10	6.3	14	5.2	1,900
Copper	29	29	16	26	41,000
Iron	19,000	15,000	17,000	17,000	100,000
Lead	34	21	<10[d]	22	800
Magnesium	7,400	4,500	6,200	3,600	N/A
Manganese	360	270	410	230	19,000
Mercury	<0.1[d]	<0.1[d]	0.24	0.11	310
Nickel	56	40	26	22	20,000
Vanadium	34	28	49	26	1,000
Zinc	170	150	140	170	100,000
Diesel Fuel	<20[d]	21 (170)[c]	<10[d]	<10[d]	N/A
Oil & Grease	270	400 (3100)[c]	620	890	N/A

[a] Results for antimony, beryllium, cadmium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in this table; these results are included in Volume II.
[b] Preliminary Remediation Goals, United States Environmental Protection Agency Region 9 Table, October 2004
[c] Maximum results from January and April samplings are shown in parentheses.
[d] Result is below detection limit.

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8

Vegetation and Foodstuffs

Goats grazing behind Building 46 for vegetation management

8.1 BACKGROUND

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 Lawrence Berkeley National Laboratory activities and to calculate potential human doses that would occur from consuming vegetation and foodstuffs. Possible pathways or routes for ingesting radionuclides include the following:

- Liquid effluent → aquatic species → human
- Airborne emissions → vegetable crop → human
- Airborne emissions → forage crop → meat (milk) animal → human
- Airborne emissions → surface water body → aquatic species → human
- Airborne emissions → surface water or groundwater → vegetable crop → human

Due to historical air emissions from the former National Tritium Labeling Facility (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 2004, no routine vegetation samples were collected for those purposes.

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 (see Section 8.2). In 2004, there were ten trees sampled for landscape management.

Measurements of tritium in local vegetation are used to better understand the integrated impact of Berkeley Lab's operations on all media in the surrounding environment and to verify its overall dose-assessment program. This assessment program, presented in Chapter 9, includes vegetation and foodstuffs as one of the contributing pathways in determining the overall impact from Berkeley Lab's airborne radionuclides. The dose assessments, which have been performed using conservative assumptions, indicate extremely low potential impacts.

8.2 TREE SAMPLING FOR LANDSCAPE MANAGEMENT

Berkeley Lab manages on-site trees and vegetation (and some immediately adjacent to the University of California) as part of a multiyear wildland-fire risk-management program and a maintenance program for a fire-safe landscape.

Environmental tritium levels have been determined to be above regional background levels near the former NTLF in Building 75; they decrease with distance from the Building 75 Hillside Stack. At a few hundred meters from the Hillside Stack, TFWT and OBT levels in tree wood are at or below detection limits: less than 0.019 becquerel per gram (Bq/g) (0.5 picocurie per gram [pCi/g]) for TFWT and 0.19 Bq/g (5 pCi/g) for OBT.[1]

Before Berkeley Lab considers the removal and release of trees to the public, a representative subgroup of the trees is sampled and analyzed for tritium, using commercially available analytical methods. The tritium results are evaluated using a method, approved by the United States Department of Energy, that is based on the fact that tritium in uncontaminated trees is so low that the analytical laboratory cannot detect it (i.e., tritium is less than the minimum detectable activity [MDA]).[2,3] Thus the MDA is used as the background tritium level, and if the representative subgroup of trees has an average tritium level less than the average MDA, the whole group of trees is considered indistinguishable from background. If the average tritium level of the subgroup of trees is greater than the average MDA, a statistical test (the paired t-test) is performed to determine whether the difference between the results and the MDAs is likely to have occurred by chance. A chance occurrence indicates that the tritium level of the trees does not significantly differ from the MDA (within a certainty of 95%), and so is determined to be indistinguishable from background. Only trees with tritium levels that are indistinguishable from background are released to the public.

In 2004, Berkeley Lab marked and sampled several trees that were to be removed to make room for the new Molecular Foundry Building, near Building 72 (see Figure 8-1). In trees at this distance from the former NTLF, greater than 350 meters (m) (1,150 feet [ft]), tritium was expected to be low and indistinguishable from regional background levels.

Five trees at the Molecular Foundry building site near Building 72 were sampled using a documented procedure.[4] (See data in Volume II.) The procedure was designed to provide representative samples for characterizing tritium levels within the tree stands and to prevent sample cross-contamination. A commercial laboratory analyzed the samples for TFWT and OBT. All samples were found to be less than the MDA. Thus, as expected, tritium levels in trees near Building 72 were indistinguishable from background. Based on this determination, several trees in the area were cut down and removed from Berkeley Lab property.

At other on-site locations within 150 m (490 ft) of the Hillside Stack, five trees were sampled, using the same documented procedure, to determine whether they could be cut down and removed from the site. A commercial laboratory analyzed the samples for TFWT and OBT.

All five trees were found to have detectable TFWT levels but nondetectable OBT levels, as shown in Table 8-1. Because these five trees are not within a single group of trees, and thus not representative of a single population of trees, performing statistical analysis would have been inappropriate. Based on the individual results, it was determined that all these trees have tritium concentrations greater than background levels and they were not removed from the Berkeley Lab site.

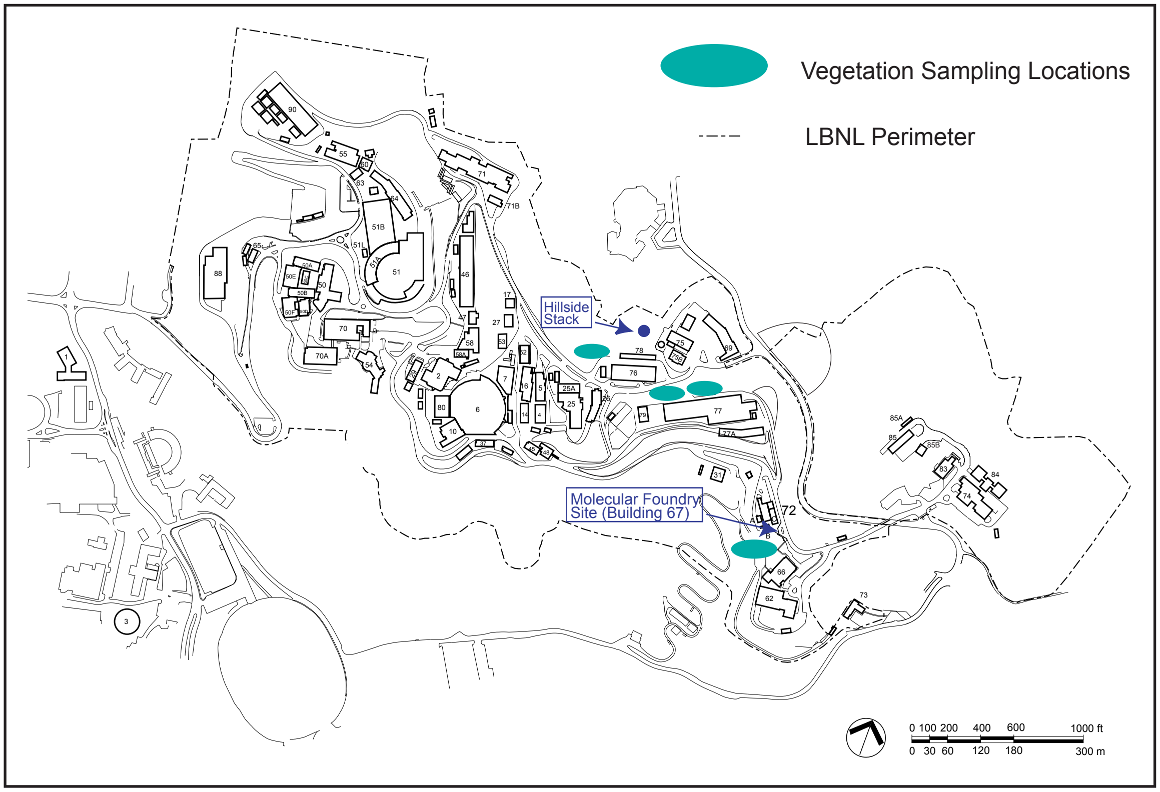

Figure 8-1 2004 Vegetation Sampling Locations

Table 8-1 Results of Landscape Management Sampling of Trees within 150 meters (492 feet) of Hillside Stack

Sample Description	Result (Bq/g)[a]	MDA[b] (Bq/g)	Result (pCi/g)[c]	MDA[b] (pCi/g)
Tissue-Free Water Tritium (TFWT)				
B75 Tree #9-Chip	0.019	0.0036	0.51	0.097
B75 Tree A-Chip	0.019	0.0037	0.51	0.1
B76K Tree A-Chip	0.0046	0.003	0.12	0.08
B78 Tree A-Chip	0.0052	0.0033	0.14	0.089
B79 Tree A-Chip	0.0045	0.0026	0.12	0.07
Organically Bound Tritium (OBT)				
B75 Tree #9-Chip	<0.14	0.14	<3.7	3.7
B75 Tree A-Chip	<0.14	0.14	<3.7	3.7
B76K Tree A-Chip	<0.12	0.12	<3.3	3.3
B78 Tree A-Chip	<0.11	0.11	<3.0	3.0
B79 Tree A-Chip	<0.12	0.12	<3.3	3.3

[a] Becquerels per gram
[b] MDAs vary between sample results due to analytical variables.
[c] Picocuries per gram

The results from the sampling and analyses conducted in 2004 confirm what has been measured and reported previously: Trees more than a few hundred meters from the NTLF's Hillside Stack have tritium concentrations indistinguishable from background levels, and tritium concentration in vegetation decreases with distance from the stack. [1]

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9

Radiological Dose Assessment

Loading environmental samples on a gamma spectrometer in Building 76

9.1 BACKGROUND

This chapter presents the estimated dose results from Lawrence Berkeley National Laboratory's penetrating radiation and airborne radionuclide monitoring programs. 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 plants and animals is discussed.

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." An important measure for evaluating the impact of any radiological program, dose can be estimated for individuals as well as for populations. The following factors affect both individual dose and population dose: the type of radiation, emission levels, complexity of terrain, meteorological conditions, distance of the receiver from the source, food production and consumption patterns, and length of exposure. The International System of Units (SI) uses sieverts (Sv) or millisieverts (mSv) to express doses to humans; the common units are rem or millirem (mrem). Doses to animals and other nonhuman biota are expressed in the SI units of grays (Gy) and the common units of rad.

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 Berkeley Lab 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 National Emission Standards for Hazardous Air Pollutants (NESHAPs)[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 (10 person-rem) to a population, an in-depth quantitative review is performed.

9.2 PENETRATING RADIATION MONITORING RESULTS

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 operational, accelerators produce both gamma and neutron forms of radiation. Irradiators are primarily limited to gamma radiation production.

Historically, United States Department of Energy (DOE) facilities have reported "fence-post doses": measured or computed values that reflect the exposures to an individual assumed to be living 100% of the time at the perimeter or fence line of the facility. This chapter provides both maximum fence-post dose estimates and the more realistic estimates of exposures to workplaces or residences of Berkeley Lab's nearest neighbors.

9.2.1 Accelerator-Produced Penetrating Radiation

Berkeley Lab operates 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:

One method consists of a network of three real-time environmental monitoring stations; two located around the perimeter of the site (ENV-B13A and ENV-B13H) and one at a remote location (ENV-B13C). These stations track instantaneous gamma and neutron radiation dose impacts. Figure 9-1 shows the location of these stations. Each real-time station contains sensitive gamma and neutron pulse counters, which continuously detect and record direct radiation doses. The annual doses to an individual member of the public from each form of penetrating radiation are derived from measurements at these stations.

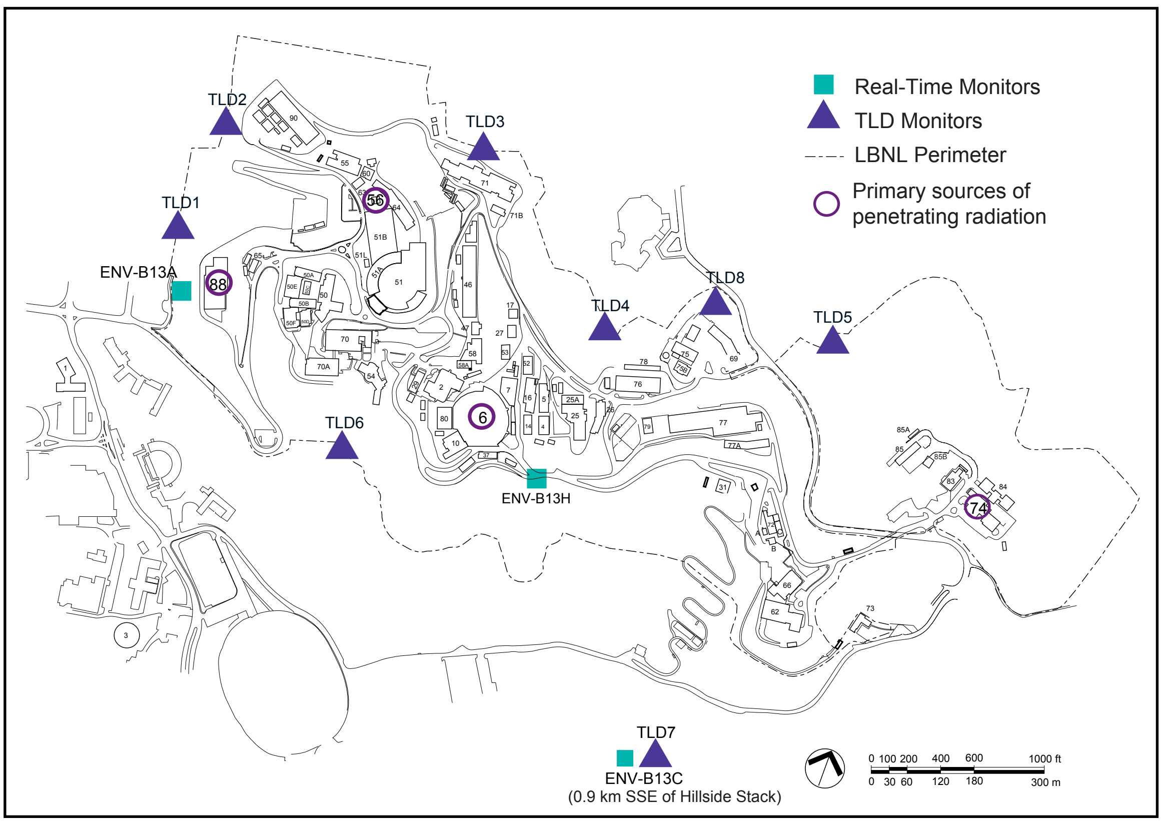

Figure 9-1 Environmental Penetrating Radiation Monitoring Stations

The results for 2004 indicate that the maximum dose to a member of the public (person residing near the 88-inch Cyclotron) from direct radiation was indistinguishable from natural background levels.

The second method uses passive detectors known as thermoluminescent dosimeters (TLDs). Figure 9-1 also shows the locations of Berkeley Lab's TLD sites. Currently, seven TLDs (TLDs 1 through 6 and 8) are near the site boundary, and one (TLD 7) is positioned at the remote location ENV-B13C. TLDs are used to measure gross gamma radiation, and they do not exclude background radiation. In addition, results from TLDs provide an average dose over time that must be determined by laboratory analysis rather than real-time instrumentation.

The objectives of the TLD program are to record and compare the gross penetrating radiation exposures (from Berkeley Lab operations and background) to ensure that public radiation exposure is kept well below allowable regulatory limits. The mean fence-line gamma radiation dose recorded by these TLDs for calendar year 2004 was indistinguishable from the remote background dose measured at ENV-B13C. The TLD results are consistent with the low-dose values measured by the real-time monitoring stations.

9.2.2 Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiophysics research, a gamma irradiator with a 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 meter (3.3 feet) from the outside walls or ceiling of the labyrinth were indistinguishable from background levels (0.001 mSv per hour [0.1 mrem per hour]).

Berkeley Lab also uses other, smaller, well-shielded gamma irradiators, which pose considerably less potential for environmental impact than the Building 74 irradiator. This class of smaller irradiators does not measurably increase the dose to the public.

9.3 DISPERSIBLE AIRBORNE RADIONUCLIDE RESULTS

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 that affect the environmental surroundings of Berkeley Lab—and consequently the projected dose from Laboratory activities—originate as emissions from building exhaust points generally located on rooftops. 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.

Determining the dose to an individual and the population is accomplished using multipathway dispersion models. The primary radionuclides used for this modeling are the airborne emissions presented in Chapter 4. The NESHAPs regulation requires that any facility that releases airborne radionuclides assess the impact of such releases using a computer program approved by the United

States Environmental Protection Agency (US/EPA).[1] Berkeley Lab satisfies this requirement with the use of CAP88-PC.[2]

CAP88-PC is both a dispersion and dose-assessment predictive model. It computes the cumulative dose from all significant exposure pathways, such as inhalation, ingestion, and skin absorption. The methods and parameters used to calculate the dose are very conservative, taking an approach that reports dose calculations as "worst case" doses to the population exposed. For example, the model assumes that some portion of the food consumed by the individual was grown within the assessed area, that the individual resided at this location (i.e., a single, specific point) continuously throughout the year, and that all the radioactivity released was of the most hazardous form. Consequently, this worst-case dose is an upper-bound estimate, and one not likely to be received by anyone.

In addition to the emissions information, dose-assessment modeling requires the meteorological parameters of wind speed, wind direction, and atmospheric stability. Berkeley Lab uses on-site data from its local meteorological station for the dispersion-modeling module of CAP88-PC.

Berkeley Lab performed individual CAP88-PC modeling runs to predict the impact from groupings of the Laboratory's release points. Table 9-1 lists the attributes of these groupings.

Details of these groupings and modeling runs are included in the Laboratory's annual NESHAPs report. After the modeling runs were completed, the location of the maximally exposed individual (MEI) to airborne emissions was determined to be at the Lawrence Hall of Science (LHS). The source groupings listed in Table 9-1 give the orientation of the air emissions release points relative—in distance and direction—to the location of the MEI. The combined dose to the MEI (a person residing at the LHS) to airborne radionuclides for 2004 was about 0.0001 mSv (0.01 mrem).

The dose from airborne radionuclides to the surrounding population is estimated for a region that extends from the site for 80 kilometers (km) (50 miles [mi]). This region is divided into 208 sectors (i.e., 13 increasingly smaller circles, each divided into 16 equally spaced sectors). CAP88-PC is used to estimate the average dose to each sector for each radionuclide used at the Laboratory. Combining this dose with the most recent (2001) population data[3] for each sector gives a population dose to that sector. The total population dose represents the summation of the population doses from all sectors. This approach estimated an annual population dose from all airborne radionuclides of 0.0012 person-Sv (0.12 person-rem).

Table 9-1 Summary of Dose Assessment at Location of Maximally Exposed Individual (MEI) from Airborne Emissions

Building	Building description	Distance to MEI[a] (m)	Direction to MEI[a]	Dose to MEI (mSv/yr)[b]	Percent of MEI total dose
55/56/64	Department of Nuclear Medicine and Functional Imaging	460	E	7.8×10^{-5}	85.2%
75	Former National Tritium Labeling Facility	110	NW	4.5×10^{-6}	4.9%
85	Hazardous Waste Handling Facility	570	WNW	3.1×10^{-6}	3.4%
70/70A	Nuclear/Life Sciences	530	ENE	2.9×10^{-6}	3.2%
88	88-Inch Cyclotron	690	ENE	2.3×10^{-6}	2.5%
1	Donner Laboratory (UC Berkeley)	990	ENE	2.5×10^{-7}	0.3%
72	Low-Background Counting Facility	500	NW	2.3×10^{-7}	0.3%
74/83/84	Human Genome Facility/Life Sciences	690	WNW	1.9×10^{-7}	0.2%
26/76	Radioanalytical Laboratory	250	N	1.3×10^{-7}	0.1%
3	Calvin Lab (UC Berkeley)	1,060	NE	1.2×10^{-8}	<0.1%
6/16/52	Advanced Light Source/Accelerator and Fusion Research	350	NNE	1.5×10^{-10}	<0.1%
			Total	**9.2×10^{-5}**	**100%**

[a] Distances and directions reflect airborne emissions from the source to the maximally exposed individual.
[b] 1 mSv = 100 mrem

9.4 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 direct radiation was indistinguishable from background radiation levels, the 2004 total dose to the MEI from Berkeley Lab activities is due solely to exposure to airborne radiation. As presented in Table 9-2 and Figure 9-2, the maximum effective dose equivalent from Berkeley Lab operations to an individual residing at the LHS in 2004 is about 0.0001 mSv (0.01 mrem) per year. This value is approximately 0.004% of the nominal background radiation[4] in the Bay Area (2.6 mSv/yr [260 mrem/yr]) and about 0.1% of the US/EPA annual limits (0.10 mSv/yr [10 mrem/yr]).[1]

Table 9-2 Comparison of Radiological Dose Impacts

	Dose from direct radiation	Dose from airborne radionuclides
Annual effective dose equivalent to the MEI[a]	Indistinguishable from background	0.0001 mSv/yr
Regulatory standard	1 mSv[b]/yr (DOE[c])	0.10 mSv/yr (US/EPA[d])
Dose to MEI as percentage of standard	Not applicable	0.1%
Annual background	1 mSv/yr	1.6 mSv/yr
Dose to MEI as percentage of background	Indistinguishable from background	0.006 %

[a] MEI = maximally exposed individual
[b] 1 mSv = 100 mrem
[c] DOE = United States Department of Energy
[d] US/EPA = United States Environmental Protection Agency

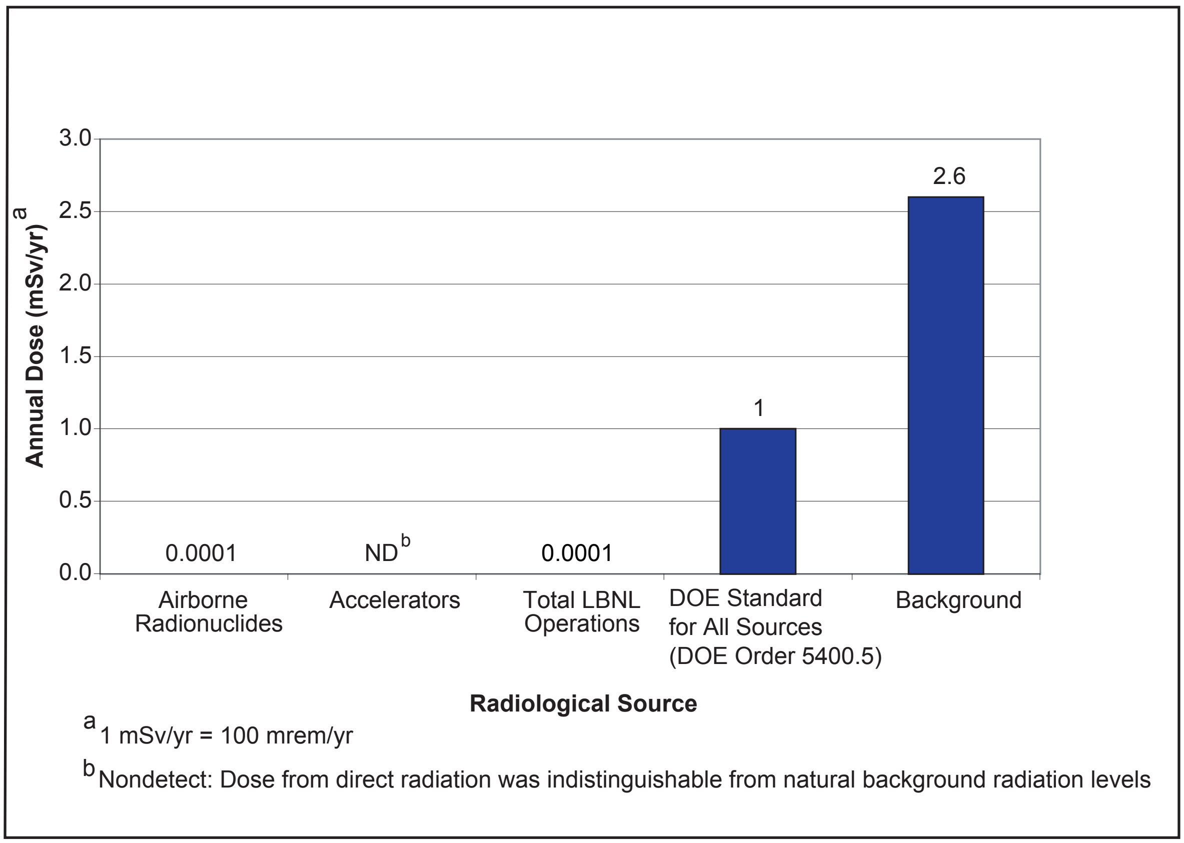

Figure 9-2 Comparison of Radiological Dose Impacts for 2004

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 0.0012 person-Sv (0.12 person-rem) for the same period. From natural background airborne radionuclides alone, this same population receives an estimated dose of 11,000 person-Sv (1,100,000 person-rem). The dose to the population from Berkeley Lab is less than 0.00001% of the background level.

9.5 DOSE TO ANIMALS AND PLANTS

Liquid and airborne emissions may have pathways to animals and plants in addition to their pathways to humans (see discussion in Section 8.1). DOE requires aquatic organisms be protected by limiting their radiation doses to 1 rad/day (0.01 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 not exceed 1 rad/day (0.01 Gy/day).[6]

To assist sites in demonstrating compliance with these limits, DOE approved a technical standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, in August 2002.[6] Berkeley Lab applied the standard to evaluate aquatic and terrestrial plants and animals across the Laboratory's site.

Several sources of exposure were considered, including animal ingestion of vegetation, water, and soil; animal inhalation of soil; plant uptake of water; and external exposure of animals and plants to radionuclides in water, soil, and sediment. Creek water, soil, and sediment samples were collected in 2004 and analyzed for several radionuclides, including tritium and alpha-, beta-, and gamma-emitting radionuclides.

These radionuclides, with the exception of tritium, were measured at levels similar to natural background levels. In creek water, tritium slightly exceeded the minimum detectable activity (MDA) in five out of 53 samples. In soil and sediment, radionuclide levels were similar to, and within the error range of, background levels. Sample results are provided in Volume II. All measured radionuclides 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 the 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.

10

Quality Assurance

Stack air sampler calibration with oversight by staff of DOE's Berkeley Site Office

10.1 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 United States Department of Energy (DOE)[3] and United States Environmental Protection Agency (US/EPA)[4] guidance. When special quality assurance and quality control (QC) requirements are necessary for environmental monitoring (such as the National Emission Standards for Hazardous Air Pollutants [NESHAPs] 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 calendar year 2004, 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 in 2004. Any minor deficiencies identified in the audits are followed by corrective action plans and tracked to closure.

To verify that environmental monitoring activities are adequate and effective, internal and external oversight is performed as required:

Internal oversight activities consist of assessments performed by the Environmental Services Group (ESG) and the Berkeley Lab Office of Assessment and Assurance (OAA). In 2004, both an ESG subject-matter expert and the OAA performed assessments on the NESHAPs Monitoring Program. Both assessments found the NESHAPs Monitoring Program to be in compliance with US/EPA and Berkeley Lab requirements.

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.

10.2 PROFILE OF ENVIRONMENTAL MONITORING SAMPLES AND RESULTS

Berkeley Lab's environmental monitoring programs remain comprehensive, although compared to 2003, the number of samples collected decreased by more than 10% and results generated decreased by more than 20% from the previous year. In 2004, 1,733 individual air, sediment, soil, vegetation, and water samples were collected, from which 3,337 results were generated. The stack exhaust air monitoring program accounted for nearly three of every four samples collected, as reflected by Figure 10-1. As in previous years, the combination of the stack and ambient-air monitoring programs totaled more than 80% of all samples collected.

The number of analytical results for each program is shown in Figure 10-2. The stack exhaust air monitoring program generated more than 50% of the total program results. The various water monitoring programs, which require a larger number of analytical tests per sample than other programs, tallied a relatively higher percentage of total program results compared to samples collected. For example, the wastewater monitoring programs account for more than 7% of the total samples collected, but they generate nearly 19% of the total monitoring program results.

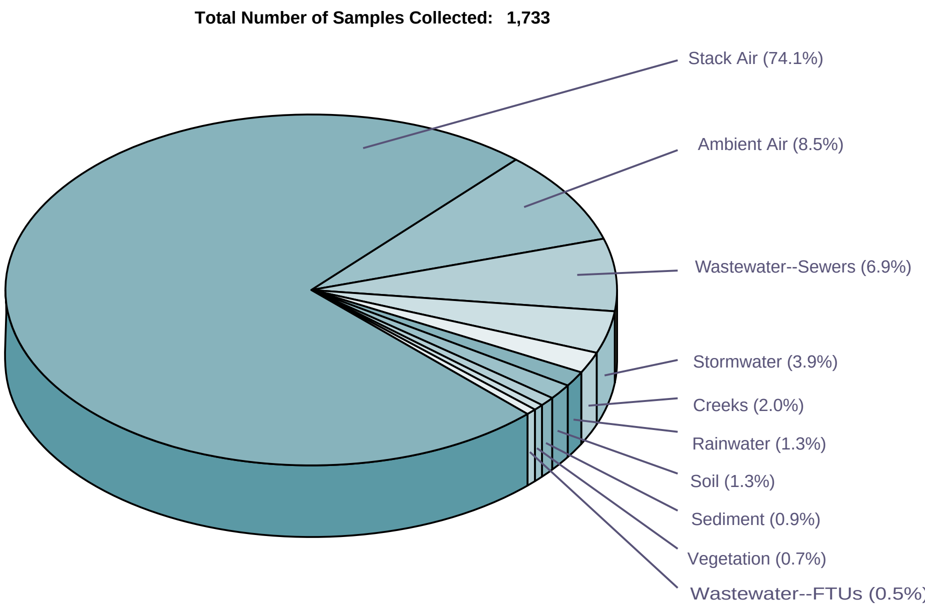

Figure 10-1 Quantity of Samples Collected per Program

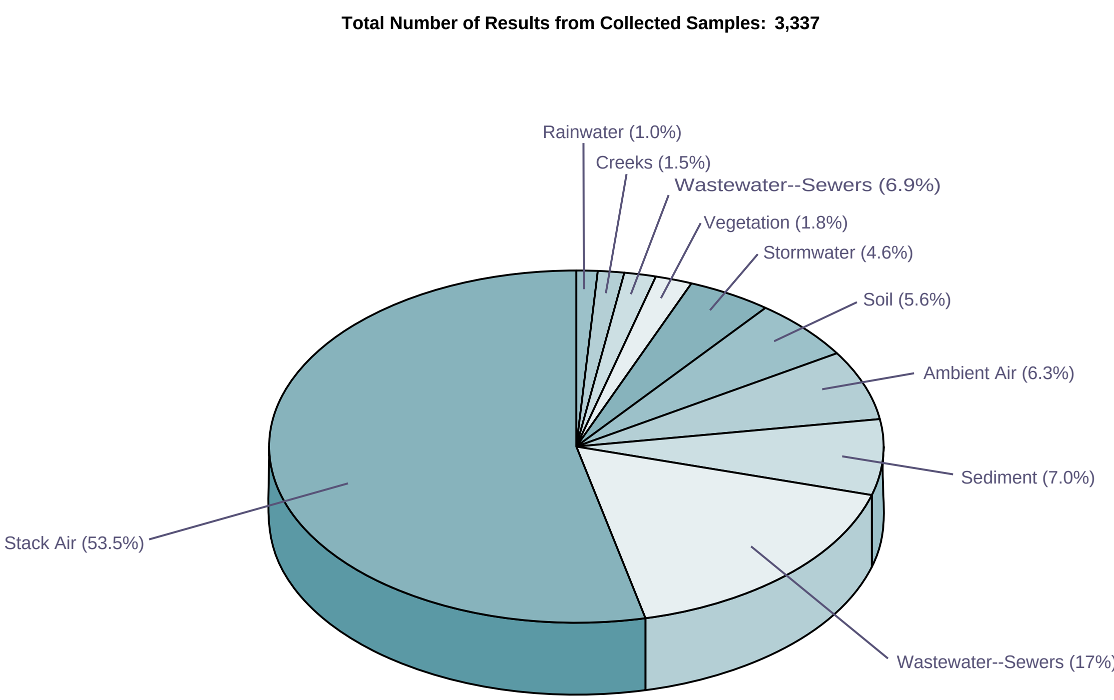

Figure 10-2 Quantity of Analytical Results per Program

10.3 SPLIT AND DUPLICATE RESULTS FROM ENVIRONMENTAL MONITORING

Berkeley Lab routinely collects split and duplicate samples for QA purposes. In 2004, 132 split and 83 duplicate samples of ambient air, rainwater, sediment, soil, surface water, stack exhaust air, wastewater, and vegetation were collected for both radiological and nonradiological analyses. Berkeley Lab uses the metrics of relative percent difference and relative error ratio to determine whether the paired results are within control limits. Relative percent difference is determined in all cases; relative error ratio is applicable only to radiological analyses. When QA pair results are outside of control limits, an investigation is performed to determine the cause of the discrepancy.

In 2004, 55% of the result pairs for splits and duplicates were below analytical detection limits. The remaining 45% of the result pairs were within the control limits. Individual data results for all monitoring programs are presented in Volume II.

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Acronyms and Abbreviations

AEDE	annual effective dose equivalent
ALARA	as low as reasonably achievable
ASPCP	Accidental Spill Prevention and Containment Plan
AST	aboveground storage tank
ATCM	airborne toxic control measures
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
CARB	California Air Resources Board
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
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
EMS	environmental management system
EPCRA	Emergency Planning and Community Right-to-Know Act
ERP	Environmental Restoration Program
ESG	Environmental Services Group
FESA	Federal Endangered Species Act
FTU	fixed treatment unit
FY	fiscal year
gsf	gross square feet
gsm	gross square meters
Gy	gray (measure of radiation in SI)
HMBP	Hazardous Materials Business Plan
HWHF	Hazardous Waste Handling Facility
ISM	Integrated Safety Management
ISO	International Organization for Standardization
kg	kilogram
km	kilometer
kW	kilowatt
L	liter
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
MTBE	methyl tertiary butyl ether
ND	not detected
NEPA	National Environmental Policy Act of 1969
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOI	Notice of Intent
NOV	Notice of Violation
NQA	Nuclear Quality Assurance
NTLF	National Tritium Labeling Facility
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
RCRA	Resource Conservation and Recovery Act
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

TBq	terabecquerel (one-trillion becquerels)
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
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

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.

Collective effective dose equivalent
The sum of the effective dose equivalents of all individuals in an exposed population within a certain radius, usually 80 kilometers, for NESHAPs compliance. This value is expressed in units of person-sievert (SI unit) or person-rem (conventional unit).

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 × 1/2); after three half-lives, one-eighth of the original activity remains (1/2 × 1/2 × 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.

Millirem

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

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 definition of Collective effective dose equivalent.

Person-sievert
See definition of Collective effective dose equivalent.

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.

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.

[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).

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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