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Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

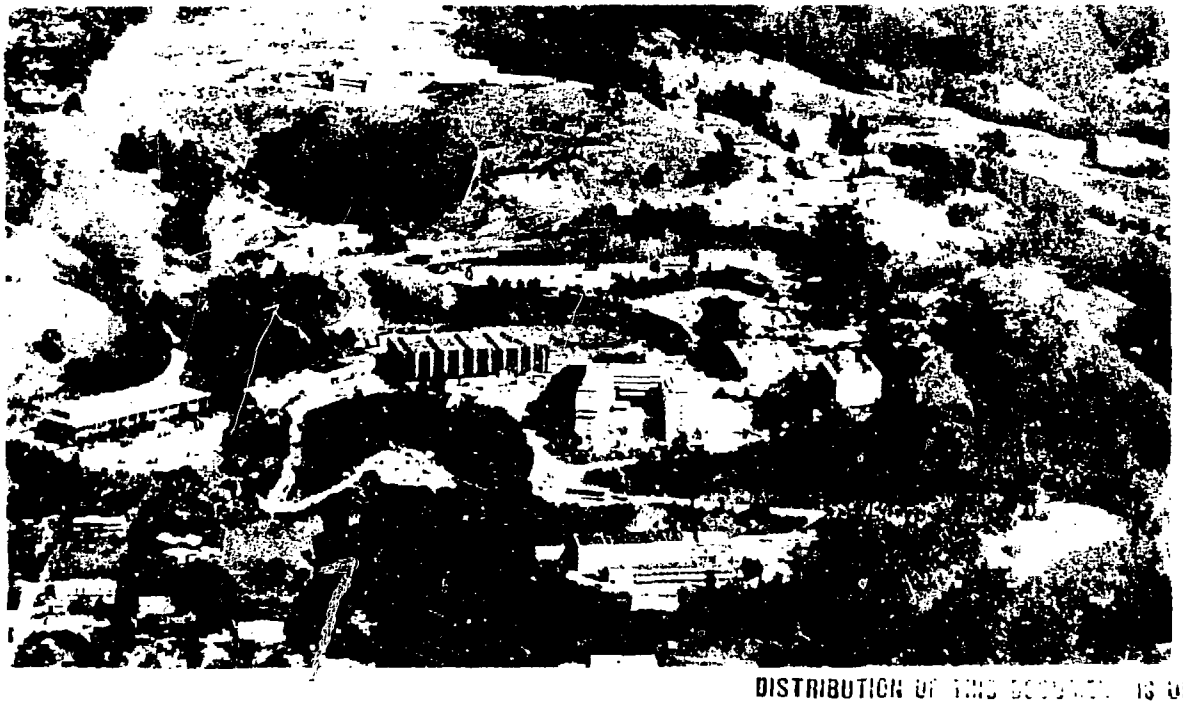
Facilities Management & Technical Services Division

ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY

1985

Prepared by the Staff of the
Facilities Management
&
Technical Services Division
Lawrence Berkeley Laboratory
University of California, Berkeley 94720

April 1986



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Prepared by the Staff of the
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Editors: Gary E. Schleimer
Ronald O. Pauer

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PREFACE

In 1976 R.H. Thomas published the LBL Annual Environmental Monitoring Report in two parts. Part I (LBL-4678) discussed in detail the modeling used to determine the population dose equivalent due to Laboratory radiological operations. That volume also described natural radiation background, geological features, climate and meteorology, and the environmental surveillance program of the Lawrence Berkeley Laboratory (LBL). Part II (LBL-4827) included only the results of the sampling and measuring programs and other data necessary to determine the environmental impact of Laboratory radiological operations for 1975. A format similar to LBL-4827 was used in the 1976, 1977, 1978, and 1979 Annual Monitoring Reports (LBLs 6405, 7530, 9080, and 11192, respectively).

While the 1980 Annual Report, LBL-12604, was kept brief, abstracted sections from LBL-4678 were included so that the document might stand alone. The same format has been used in this report, along with updates to LBL-4678 where appropriate, and a greatly expanded description of LBL's nonradiological environmental activities.

Readers wishing a more comprehensive discussion of LBL site characteristics and population dose modeling may obtain a copy of LBL-4678 from

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R.O. Pauer and G.E. Schleimer of the Environmental Health and Safety Department of the Facilities Management and Technical Services Division contributed to the preparation of this report.

The bulk of the sample preparation and lab work was done by V.J. Montoya. Sample assays and computer data entry were done by W.B. Corniea.

The editor wishes to gratefully acknowledge the assistance of the Technical Information Department's editorial and word processing groups.

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ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY, 1985

ABSTRACT

The Environmental Monitoring Program of the Lawrence Berkeley Laboratory is described. Data for 1985 are presented and general trends are discussed.

INTRODUCTION

Laboratory Operations

The Lawrence Berkeley Laboratory (LBL) is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy (DOE). LBL's major role is to conduct basic and applied science research that is appropriate for an energy research laboratory but not suited to the program goals or resources of a university or an industrial laboratory. LBL, birthplace of the cyclotron, was founded by the late Nobel Laureate Ernest Orlando Lawrence 54 years ago.

The Laboratory also supports nationwide university-based research by providing National facilities including the Bevalac/SuperHILAC Complex, the 88-Inch and 184-Inch Cyclotrons, the National Center for Electron Microscopy, the National Tritium Labeling Facility, and the Neutral Beam Engineering Test Facility.

The Site

LBL is situated upon a hillside above the main campus of the University of California, Berkeley. The 130-acre site is located on the west-facing slope of the Berkeley Hills, at elevations ranging from 500 to 1,500 feet above sea level. Most of the site is within the City of Berkeley, but about one-quarter of the eastern part is within the City of Oakland. It is located three miles east of San Francisco Bay and about fifteen miles east of San Francisco.

LBL is located in an urban environment on land owned by the University. The LBL site is bordered on the north by predominately single-family homes and on the west by multiunit dwellings, student residence halls, and commercial districts. The area to the south, which is part of the University lands, is maintained in a largely natural state and includes recreational facilities and the University Botanical Garden. The population within an 80-km (50-mi) radius of the Laboratory is ≈5.2 million (1980 census).[1]

The Laboratory's activities are located both on-site and off-site. There are 67 buildings on the LBL hillside site, plus additional facilities located on the University campus, notably the Donner Laboratory of Biology and Medicine and the Melvin Calvin Laboratory. The on-site

space consists of 1,350,000 gross square feet (GSF) in about 60 buildings: 1,307,000 in DOE buildings and trailers and 43,000 in University-owned buildings. Off-site space utilized by LBL consists of 260,000 GSF in various University buildings on the UCB campus and 130,000 GSF in leased facilities in Emeryville and Berkeley.

The Laboratory's population is approximately 3,850 including about 600 visiting scientists and engineers. About 3,100 are located on-site, 700 are located in campus buildings, and about 50 are in off-site leased space.

The Climate

The climate of the LBL site is greatly influenced by its nearness to the Pacific Ocean and its exposure to the maritime air that flows in from the San Francisco Bay. Seasonal temperature variations are small, with a mean temperature difference between the summer 63°F and winter 48°F of only 15 degrees. Relative humidity ranges from 85–90 percent in the early morning to 65–75 percent in the afternoon. The average annual rainfall is 25 inches. About 95 percent of the rainfall occurs from October through April, and intensities are seldom greater than 0.5 inch per hour. Thunderstorms, hail, and snow are extremely rare. Winds are usually light, but summer sea breezes range up to 20–30 mph. Winter storm winds from the south or southwest have somewhat lesser velocities.

Geology

Most of the LBL site is underlain by complex sedimentary and volcanic rock. In general, the bedrock is relatively weak and weathers deeply. Consequently, a colluvial cover a few feet thick has been produced. The major geologic unit consists of poorly consolidated sandstones, siltstones, claystones, and conglomerates of relatively low strength and hardness. These rocks are blanketed by clay soils having high shrink-swell characteristics. The western and southern portions of the site are underlain by moderately well consolidated shales, siltstones, sandstones, and conglomerates. Throughout most of the upper elevations a volcanic unit overlays and is interbedded with the upper layers of the major geologic unit.

The Hydrogeology

Highly complex ground-water conditions are present at LBL. Year-round springs, annual surface seeps and variable water levels in observation wells indicate discontinuous and localized aquifers. These conditions are due to a combination of factors: open fracture volcanic flow rock, impervious claystone interbeds, permeable sandstone lenses, and irregular fracture patterns associated with past folding and faulting. During the rainy season, ground-water levels increase and cause a decrease in slope stability. Consequently, the Laboratory has installed an elaborate ground-water detection and drainage system. Ground-water wells are not used as a source of Laboratory drinking water. Ground-water drainage feeds into Blackberry Creek on the north portion and into Strawberry Creek on the south portion of the Laboratory. Both creeks eventually flow through the Berkeley campus and then into the City of Berkeley storm drainage system, which empties into San Francisco Bay.

Water Supply

The Laboratory's primary water supply is the East Bay Municipal Utility District (EBMUD) Shasta Reservoir, which holds approximately two million gallons. The Laboratory's high pressure fire and domestic systems are supplied from this reservoir. A secondary source is the EBMUD's Berkeley View Tank, which holds approximately one million gallons. Water mains have automatic shutoff valves for protection in case of a main breakage. The LBL water distribution system operates entirely by gravity flow, requiring no pumps or energy consumption. The Laboratory has recently installed two 200,000-gallon water storage tanks at separate locations for fire protection. Diesel-powered pumps provide the necessary flow and pressure for maintaining a reliable fire protection system during emergencies.

Sanitary Sewer Systems

The west-side LBL sanitary system connects to the City of Berkeley sewer main at Hearst Avenue. On the south side of the Laboratory, a second connection is also made to the City of Berkeley system. The Berkeley system flows to the EBMUD Sewage Treatment Facility, where the wastewater undergoes primary and secondary treatment before its discharge to San Francisco Bay. To insure that its wastewater complies with the EBMUD discharge limits, the Laboratory monitors its wastewater for pH, toxic metals, and radioactivity. In addition, wastewater from both plating shops and a chemistry building is monitored and treated appropriately before discharge.

Storm Drainage System

Because of its hillside location and moderate annual rainfall, surface run-off is a prevalent feature at LBL. Consequently, an inclusive storm system designed and installed in the 1960's, discharges into the Blackberry Creek watershed on the north side of LBL and the Strawberry Creek watershed on the south side. This system provides for runoff intensities expected in a 25-year maximum designed storm.

LBL research facilities include: four large accelerators, several small accelerators, a number of radiochemical laboratories, several large gamma irradiators, and a tritium (^{3}H) labeling laboratory. The Bevatron (Building 51 in Fig. 1) is the most massive of LBL's accelerators. Originally designed as a 6-GeV proton synchrotron, it is presently capable of accelerating ions up to ^{40}Ca from 8.5 MeV/nucleon to 2.1 GeV/nucleon, and ions up to uranium to 1 GeV/nucleon, when using the SuperHILAC as an injector. (This combination is called the Bevalac.) The SuperHILAC (Building 71), a heavy-ion accelerator, is a multiprogrammable research accelerator in its own right and produces ion beams up to 8.5 MeV/nucleon. The 88-Inch Variable Energy Sector-Focused Cyclotron (Building 88) routinely produces intense beams of protons to about 60 MeV, alpha particles to 140 MeV, and heavy ions to mass 40 to energies of 350 MeV. The 184-Inch Cyclotron (Building 6) provides alpha particle beams with energies up to approximately 1 GeV. Aside from shutdown periods, the first two of these accelerators provide beams around the clock. The 88-Inch Cyclotron provides beams ≈120 hr/wk; the

KEY TO LBL BUILDINGS SHOWN IN FIGURE 1

Bldg. No.	Description
	Hill-Site Buildings
4	Magnetic Fusion Energy (MFE)
5	Magnetic Fusion Energy (MFE)
6	184-Inch Cyclotron
7	Central Stores & Electronics Shops
9	Magnetic Fusion Energy—EBIS
10	Biomedical Research
12	MFE—EBIS/Central Stores Annex
14	Nuclear Instrumentation
16	Magnetic Fusion Energy Laboratory
17	Storage
25	Mechanical Technology
25A	Electronics Development
26	Medical Services
27	Cable Shop & High Voltage Test
29	Instrumentation Techniques & Biomedical Research
37	Utilities Service
40	Electronics Warehouse
42	Equipment Storage—Geothermal
41	WIN Training Center
43	Employee Buying Service
44	Indoor Air Pollution Studies
45	Fire Apparatus
46	Accelerator Development, Electronics Projects, & Real Time Systems Group (RTSG)
46A	Real Time Systems Group (RTSG)
47	Advanced Accelerator Study
50	Physics, Accelerator & Fusion Divisions
50A	Physics & Director's Office
50B	Physics & Computation Department
50D	MMRD & Nuclear Science
50E	Accelerator Development
51	Bevalac
51A	Bevalac Annex
51B	External Particle Beam (EPB) Hall
52	Magnetic Fusion Energy Laboratory
53	SuperHILAC Development
54	Cafeteria
55	Research Medicine
56	Cryogenic Facility
58	Accelerator Research & Development
58A	Accelerator Research & Development Addition
60	Cryogenic Laboratory
61	Standby Propane Plant
62	Materials & Molecular Research
63	Accelerator & Fusion Research
64	Accelerator & Fusion Research
65	Data Processing
68	Upper Pump House
69	Supply Services
69A	Supply Services
70	Nuclear Science, Applied Science, & Earth Sciences
70A	Nuclear Science, Materials & Molecular Research, & Earth Sciences
71	Heavy Ion Linear Accelerator (HILAC)
71A	HILAC Rectifier
72	MMRD, National Center for Electron Microscopy, Atomic Resolution Microscope (ARM), & High Voltage Electron Microscope (HVEM)
73	Atmospheric Aerosol Research
74	Biomedical Laboratory
74B	Biomedical Laboratory Annex
75	Radioisotope Service
76	Craft & Maintenance Shops
77	Mechanical Shops
78	Craft Stores
79	Metal Stores
80	General Research Laboratory
80A	Telephone Services
81	Liquid Gas Storage
82	Lower Pump House
83	Cell Culture Laboratory
88	88-Inch Cyclotron
90	Applied Science, Chief Financial Office, Earth Sciences, Engineering, Personnel, Protective Services, & Technical Information Department
	Small Buildings
B-13A	Environmental Monitoring West of 88
B-13B	Environmental Monitoring West of 90
B-13C	Environmental Monitoring South of UC Recreation Area
B-13D	Environmental Monitoring North of 71
B-13E	Sewer Monitoring Station, Hearst Avenue
B-13F	Sewer Monitoring Station, Strawberry Canyon
	Campus Buildings Assigned LBL Numbers
1	Donner Laboratory
3	Melvin Calvin Laboratory (MCL)
18	Gilman Hall
21	Low Temperature Laboratory—Giauque Hall
22	Latimer Hall
38	Lewis Hall
57	Cowell Hospital—Donner Pavilion

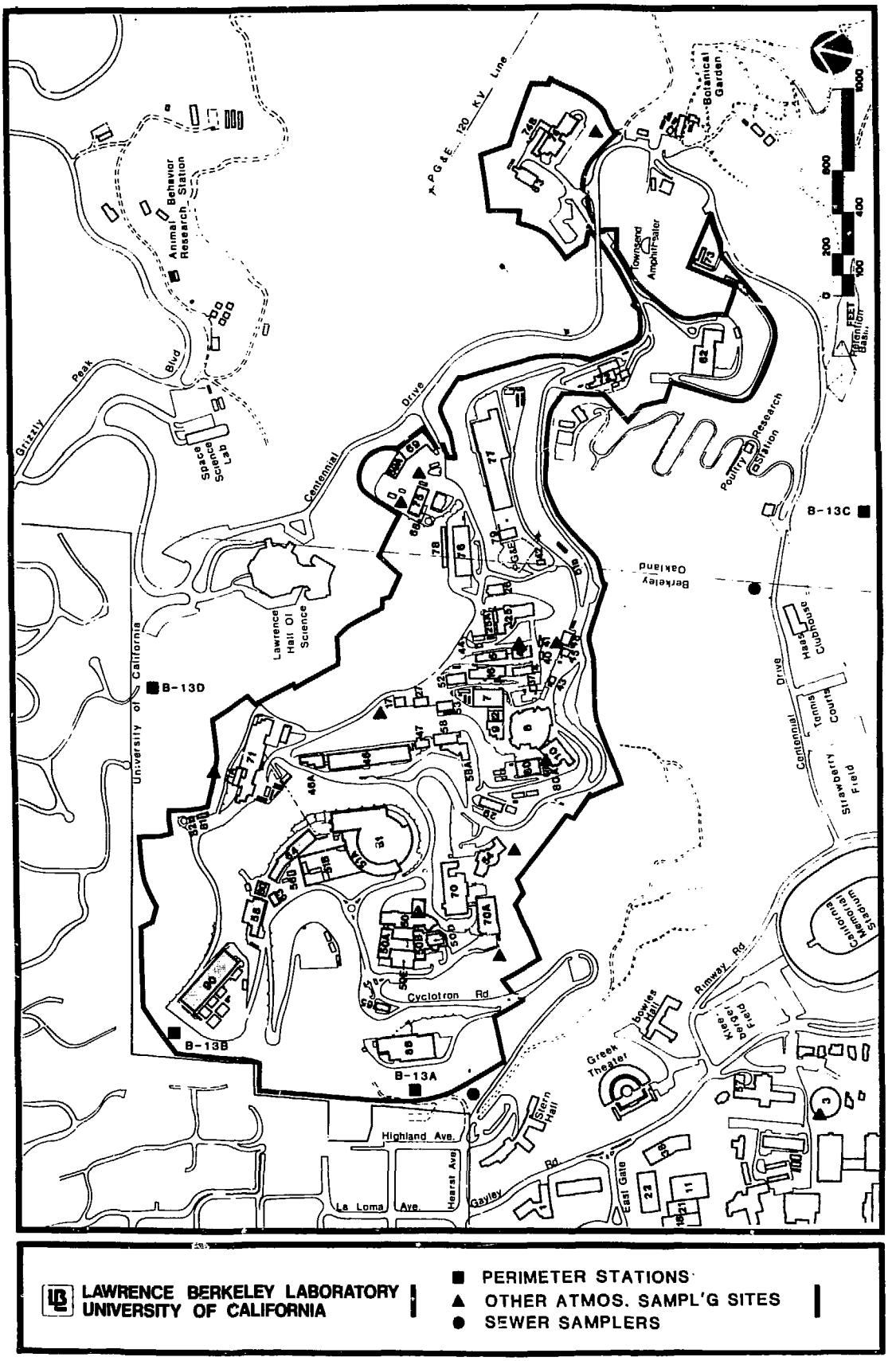

Figure 1. Lawrence Berkeley Laboratory buildings. XBL 844-1478

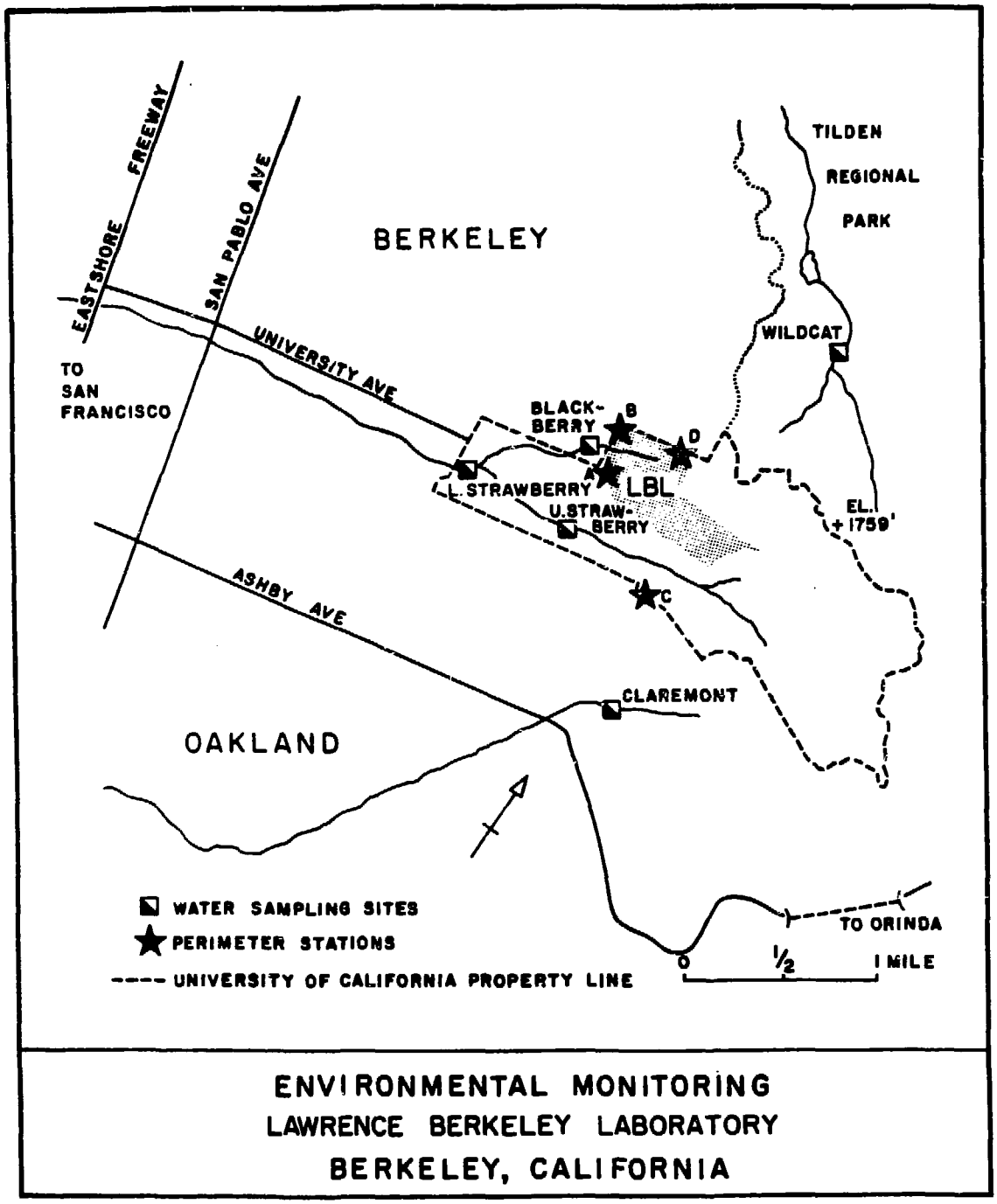

Figure 2. Environmental Monitoring, Lawrence Berkeley Laboratory.

184-Inch Cyclotron is only run for brief periods each week, mostly for tumor therapy.

The tritium facility located in Building 75 was designed to handle kilocurie quantities of tritium used as a labeling agent for a variety of molecules subsequently employed in chemical and biomedical research. The facility was expanded during 1983 and is now funded by the National Institutes of Health. Radiochemical and radiobiological studies performed in many laboratories at LBL typically use millicurie quantities of a great variety of radionuclides. The workplace and effluent release points are continuously sampled at all installations where significant quantities of radionuclides are handled.

The proximity of populated areas to LBL significantly influenced the structure and implementation of the Laboratory's environmental monitoring program. Since there is essentially no buffer zone as is common for many remote DOE facilities, the program is heavily focused on measurements performed on site, close to the sources of potential environmental insults. Based on extensive studies of Laboratory operations and site characteristics, described in LBL-4678, an environmental program was developed that provides comprehensive and continuous surveillance of LBL activities.

1985 ENVIRONMENTAL MONITORING SUMMARY

In order to establish whether LBL research activities produced any impact on the population surrounding the Laboratory, a program of environmental air and water sampling and continuous radiation monitoring was carried on throughout the year.[2] For 1985, as in the previous several years, dose equivalents attributable to LBL radiological operations were a small fraction of both the relevant radiation protection guidelines (RPG)[3] and of the national radiation background. [The reader should note that throughout this report the phrase "population dose" should be taken to mean collective effective dose equivalent (CEDE) and "dose" or "dose equivalent" to mean effective dose equivalent.]

We define the maximum effective dose equivalent delivered to a hypothetical member of the community as the maximum perimeter dose equivalent. That value was $\leq$ 1.8 mrem [the 1985 dose equivalent measured at the Olympus Gate Environmental Monitoring Station (MS) B-13D, about 2% of the RPG]. The total population dose equivalent attributable to LBL operations during 1985 was $\leq$ 4 man-rem, about 0.0008% of the RPG of 100 mrem maximum effective dose equivalent to individual members of the surrounding population. [The collective effective dose equivalent (CEDE) is defined as the sum of the "doses" delivered to all individuals within a 80-km (50-mi) radius of the Laboratory.]

Small amounts of ^{14}C, ^{125}I, ^{131}I, and unidentified alpha and beta-gamma emitters were released from LBL laboratory stacks. The collective effective population dose equivalent attributable to the foregoing

releases is ~0.02 man-rem. The majority of the impact of LBL radionuclide operations is from the airborne release of a 190 Ci of tritium, which is responsible for a CEDE of approximately 1.5 man-rem.

To put the Laboratory's impact into perspective, an approximate value for absorbed dose from external natural sources (e.g., cosmic rays, radiation from continental rocks) to each person within 80 km (50 mi) of LBL is roughly 0.1 rem/yr, which produces a natural annual population dose of ~520,000 man-rem.

1985 ENVIRONMENTAL ACTIVITIES AND PERMITS ISSUED

Pursuant to LBL's long-term development plan, five environmental assessments (EAs) were prepared in 1985 by the Laboratory's Plant Engineering Department in consultation with Ira Fink and Associates of Berkeley, California. These assessments have the following titles:

1. East Canyon Site Utilities
2. Interim Corporation Yard
3. Ultra High Vacuum Facility/Building 77A
4. Building 69 Modifications
5. Advanced Materials Laboratory/Center for Advanced Materials

Copies of these assessments were presented to the San Francisco Operations Office of DOE and to the University of California. The assessments were prepared in compliance with the National Environmental Policy Act (NEPA).

For further information about these assessments contact

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In order to carry on its research, LBL designs and builds much of its required apparatus. These activities require substantial technical support, including the operation of fabrication, assembly, testing, and waste-handling facilities. The Laboratory operates these facilities under a series of environmental permits issued by state and local agencies. A list of these permits by type and issuing agency, with expiration date, is given below.

Environmental Permits

1) Source Operating Permits, Bay Area Air Quality Management District, Expire July 1, 1986.
   - Solvent Spray Hood, Building 25
   - Solvent Hood, Building 50
   - Ultrasonic Degreaser, Building 53
   - Machine Shop Tools, Building 53
   - Machine Shop Tools, Building 58
   - Machine Shop Tools, Building 70A
   - Sawdust Collector, Building 74
   - Machine Shop Tools, Building 76
   - Sawdust Collector, Building 76
   - Paint Spray Booth, Building 76
   - Gasoline Storage Tank, Building 76
   - Solder/Grinding Hood, Building 77
   - Vapor/Spray Degreaser, Building 77
   - Machine Shop Tools, Building 77
   - Paint Spray Booth, Building 77
   - Sandblast Exhaust, Building 77
   - Beryllium Machine Shop Tools, Building 77
   - Ceramic Machine Shop Tools, Building 77
   - Paint Drying Oven, Building 77
   - Machine Shop Tools, Building 88, Room 134
   - Machine Shop Tools, Building 88, Room 147
   - Solder Hood, Building 88

2) Wastewater Discharge Permit, East Bay Municipal Utility District, Expires June 10, 1986.
   - Plating Shop, Building 25
   - Plating Shop, Building 77

3) Hazardous Waste Facility Part B Permit, California Department of Health Services, Expires November 7, 1988.

4) Storage Tank Registration. California Department of Health Services. Eight underground storage tanks, seven for petroleum fuel, one for waste oil.

Environmental Activities

1) Metal Finishing Wastewater Control. A treatment unit is being installed at the Building 25 plating shop in order to achieve compliance with the Federal Pretreatment Categorical Standard for metal finishers (40 CFR 433). Discharge parameters to be controlled include pH, chromium, copper, iron, lead, and zinc.

2) A centralized storage facility for hazardous waste has been completed. The facility will be used for the storage of three categories of wastes: organic liquid/solvent wastes, radioactive mixed wastes, and other radioactive wastes. It has also been built to the standards required for the storage of PCB's; however, this material is currently stored at a separate location.

3) Sanitary Sewer Monitoring Station Upgrades. The installation of new sampling equipment for both the Strawberry and Hearst Monitoring Stations has been completed. The new equipment includes pH monitors, flow monitors, and wastewater samplers.

ENVIRONMENTAL MONITORING RESULTS

Radiological Results

Penetrating Radiation

To determine the radiological impact of LBL accelerator operations, we maintain permanent monitoring stations at four points about LBL's perimeter (see Fig. 1 and Table 1).

Table 1. Location of LBL monitoring stations (MS).

Building No. (see Fig. 1)	Name
B-13A	Building 88 Environmental MS
B-13B	Building 90 Environmental MS
B-13C	Panoramic Environmental MS
B-13D	Olympus Gate Environmental MS

Each station contains sensitive neutron and gamma pulse counters. The neutron detectors are ~500-cm^3 cylindrical BF_3 chambers housed in 2.5-inch-thick cylindrical paraffin moderators. The gamma detectors are energy-compensated Geiger-Muller chambers. The output pulses from each of the eight detectors (one of each type is installed at each monitoring station) are prescaled and telemetered to registers in Building 75.[4] Each LBL accelerator building contains at least one somewhat smaller moderated BF_3 neutron detector whose output pulses are also prescaled and telemetered to Building 75. By comparing the accelerator neutron monitor output with the output of the perimeter station neutron monitors, one may assign the perimeter dose equivalent to the accelerator responsible for it. Operational checks of the system are performed daily, and detectors are calibrated semiannually. A typical dose equivalent value for a perimeter monitoring station neutron detector corresponds to 0.43 μrem/pulse. A gamma register-pulse corresponds to about 1.3 μR.

The neutron background attributable to cosmic rays measured at LBL exhibits small fluctuations about a mean value of 3.3 mrem/year.[5] Table 2 lists the fence-post dose equivalents measured at each environmental monitoring station during 1985.

Table 2. Fence-post effective dose equivalent at the LBL boundary due to accelerator operation, 1985.

Station	1985 total above background		
	gamma (mrem)	n (mrem)	Total[a] (mrem)
Olympus Gate MS	0	1.8 ± 0.2	1.8 ± 0.2
Building 90 MS	0	< 0.4	< 0.4
Building 88 MS	0	1 ± 0.2	1 ± 0.2
Panoramic MS	0	0	0
Standard for comparison (Dose to individuals at maximum point of exposure)		100[b]	

[a]The errors shown are those associated with the actual counts. Dose conversion factors are not known to this accuracy.

[b]Source: Reference 3.

The fence-post neutron dose equivalent and gamma-ray dose equivalent attributable to LBL accelerator operations in 1985 are characterized as follows.

1. The 184-Inch Cyclotron produced no dose discernible above background as measured at the Panoramic Environmental Monitoring Station.

2. While the SuperHILAC and Bevatron both contributed to the fence-post dose equivalent measured at the Olympus Gate Environmental Monitoring Station, the dose equivalent is entirely assigned to the Bevatron (a conservative assumption). The 1.8 mrem was delivered fairly uniformly during the Bevatron's operating year.

3. The 88-Inch Cyclotron fence-post dose equivalent of 1.0 mrem is primarily attributable to a dozen light-ion (helium-3, p^+, D^+, helium-4) runs that occurred at roughly monthly intervals during 1985.

The U.S. Department of Energy orders, which provide detailed requirements for radiation protection, under which DOE contractors (LBL, for example) operate include a table (see Ref. 2) that assigns dose equivalent rate vs. neutron flux density values for neutrons of various energies. In the interest of more accurately reporting the impact of the 88-Inch Cyclotron on LBL's neighbors, measurements of the average energies of the stray neutrons that were produced during the 88-Inch Cyclotron light-ion runs were made at the 88-Inch Environmental Monitoring Station (EMS) in 1985. The measurements[6] indicated that historically reported values of fence-post dose equivalent attributable to neutron fluence detected at the 88-Inch EMS were conservatively reported by

a factor of more than five. The value of 1.0 ± 0.2 mrem reported for 1985 reflects less conservative but more realistic neutron energy vs. dose equivalent values.

4. The continuous gamma measurements telemetered from the four monitoring stations showed no significant correlation with LBL accelerator operation and were thus interpreted as constituting the natural background for 1985. The mean value of gamma background inside the monitoring stations was 81 ± 7 mrem for 1985.

LBL's Environmental Health and Safety Department (EH&S) operates a radiological and chemical waste storage yard and an instrument calibration facility south of Building 75. (The small trailer "complex" on Fig. 1 south of Building 75 is Building 75B, which houses EH&S administrative and operational personnel.)

A recording Geiger-Muller instrument in the southeast corner of Building 75B continuously monitors impact from waste handling and calibration activities. The instrument recorded a total exposure of 200 ± 15 mrem during 1985 for a net annual effective dose equivalent of 119 ± 15 mrem.

The instrument is located roughly 10 m from sources of radiation, 70 m from the perimeter fence, 270 m from the nearest commercial (40 hour/wk) occupancy [the Lawrence Hall of Science (LHS)], and 500 m from the nearest home.

The ≈120 mrem net exposure at 75B predicts an impact of ~2.4 mrem/yr at the perimeter; < 0.04 mrem/yr (40 hours/wk occupancy) at LHS; and < 0.05 mrem/yr at the nearest home.

Although the 2.4-mrem/yr effective dose equivalent (EDE) attributable to this source exceeds the 1.8 mrem/yr measured at Olympus Gate, it is not used as the maximum fence-post dose for three reasons: (1) unlike the Olympus Gate station, where there are homes 20 meters from where perimeter measurements are taken, there is no occupancy of this area anywhere near the Building 75B perimeter fence (the entire environs are University of California land); (2) the 2.4-mrem annual EDE is from gamma rays, which are attenuated by the atmosphere more than twice as rapidly as are Bevatron neutrons (the putative agent in the Olympus Gate EDE); (3) the populated area nearest the source of the gamma rays is shielded from them by a hill.

LBL has several multicurie gamma irradiators used in radiobiological and radiochemical research. The largest of these units is a ^{60}Co unit housed in an interlocked, massive, reinforced concrete-covered labyrinth built as part of LBL's Building 74. (This unit is also the irradiator closest to the LBL perimeter.) Surveys taken when the irradiator was upgraded and loaded found no area where the stray radiation field exceeded 1 mrem/hr 1 meter from the outside walls or ceiling. This irradiator is ~80 meters from the LBL perimeter fence, 150 meters from the nearest "commercial" occupancy (a UCB Botanical Garden building), and more than 700 meters from the nearest house. The projected annual dose equivalents to members of the public would be: at the perimeter fence <1.4 mrem/yr; at the Botanical Garden house (40-hr/wk occupancy) <0.1 mrem/yr; and at the nearest house <0.02 mrem/yr (168-hr/wk occupancy).

Airborne Radionuclides

Gross atmospheric beta and alpha activities are measured by air sampling at 14 points: Four perimeter environmental monitoring stations and 10 of the 12 "other atmospheric sampling sites" identified in Fig. 1. The sites on the north side of Building 75 and the roof of Building 4 are rain collectors. The Building 3 site contains samplers for HTO (tritiated water) and $^{14}CO_2$.

The gross beta and alpha sampling media are 10 cm × 23 cm (4 × 9 inch) fiberglass-polyester filters through which air is pumped at 113 l/min (4 ft^3/min). Samples are removed weekly. Before they are counted, they are set aside for five days to enable short-lived radon and thorium daughters (naturally occurring airborne radionuclides) to decay. The filters are loaded into an automatic counter that determines their gross alpha activity by means of a large-area 0.25-mil Mylar window gas proportional counter. Gross beta activity is counted with Geiger-Muller detectors with 30 mg/cm^2 windows. The detection limit for alpha emitters is 2×10^{-15} μCi/ml. The detection limit for beta emitters is 80×10^{-15} μCi/ml.

To ensure accuracy of all counting results, each group of samples counted includes at least one radiation standard sample and a number of background samples.

Tritium, as HTO, is sampled by passing atmospheric air through a column containing silica gel. Adsorbed water is "exchanged" into distilled water, and an aliquot (5 ml) is placed in a vial and counted in a scintillation counter. The detection limit for HTO in air is 700×10^{-12} μCi/ml.

As with gross alpha and beta samples, silica gel HTO samples are changed weekly. Each of the four perimeter environmental monitoring stations contains a tritium sampler, as does the Building 3 site. The stack from the tritium labeling facility is also monitored for tritium as described above. An additional site is sampled for airborne HTO, which is not shown on Fig. 1. The sample is designated ENV 69A and is located at the northeast corner of Building 69A.

The concentration of $^{14}CO_2$ in air is determined by air sampling with NaOH. Samples are changed weekly. Air is bubbled through a jar containing 30 ml of 0.2 M NaOH and thymol blue as a pH indicator. If acid fumes in the sampled air drop the pH of the sample to about 6, a color change results, and the sample is assumed to be invalid (an infrequent occurrence). An aliquot (5 ml) of the NaOH is added to a scintillation cocktail and counted in a liquid scintillation counter. The detection limit for $^{14}CO_2$ is 200×10^{-12} μCi/ml.

Table 3. Total quantities of radionuclides discharged into the atmosphere, 1985.

Nuclide	Quantity discharged (Ci)
Unidentified alpha emitters[a]	5×10^{-8}
Unidentified beta-gamma emitters[b]	3×10^{-5}
Carbon-14	3×10^{-3}
Tritium	190
Iodine-125	2×10^{-3}
Iodine-131	3×10^{-6}

[a] Conservatively assumed to be ^{232}Th
[b] Conservatively assumed to be ^{90}Sr

The total quantities of radionuclides discharged into the atmosphere are summarized in Table 3. The figures are similar to those of last year, and the releases resulted in a small collective effective dose equivalent (see Table 11, page 27). One may note that a number of the average values listed in several of the tables in this report (notably Tables 4, 6, 7, and 8) are less than the minimum values listed for individual samples. The foregoing occurs whenever the actual average value of a substance measured is less than the detection limit for that substance in an individual sample, and the average represents the arithmetic sum of all measurements divided by the number of measurements taken (as in this report). The uncertainties listed with tabular quantities represent 95% confidence limits of the assay values (or sum of assay values).

While small quantities of radionuclides (Table 3) were discharged into the atmosphere during 1985, all data from the general environmental air sampling program were within the range of normal background (Table 4). All measurements of atmospheric deposition at outlying perimeter stations lie within the range of normal background; however, tritium was detected in rainfall collected within the Laboratory boundary near the stack from the Building 75 tritium facility (Table 5).

The environmental air sampling program for ^{14}C and ^{3}H found detectable concentrations of these nuclides (Table 6). Essentially, 100% of the tritium released from LBL was discharged from the Building 75 stack.

Waterborne Radionuclides

Rainwater, creek water, and sewage from LBL's two sewer outfalls are analyzed for gross beta and alpha emitters (see Fig. 1; the Strawberry Sanitary Sewer is the southern site, Hearst is the western sewer). Additionally, sewer effluent is analyzed for gross halogen

Table 4. Summary of air samples, 1985.

		Concentration (10^{-15} µCi/ml)					
		Alpha			Beta		
	No. of samples	Avg.	Min.	Max.	Avg.	Min.	Max.
On-site average of 10 locations	500	0.39 ± 0.12	< 2	4 ± 3	5.3 ± 3.8	< 80	140 ± 90
Perimeter Stations							
Bldg. 88	50	0.55 ± 0.32	< 2	< 3	12 ± 12	< 80	120 ± 80
Bldg. 90	47	0.38 ± 0.32	< 2	4 ± 3	12 ± 12	< 80	80 ± 80
Panoramic Way	50	0.68 ± 0.33	< 2	4 ± 3	14 ± 12	< 80	90 ± 80
Olympus Gate	51	0.56 ± 0.31	< 2	3 ± 3	9 ± 12	< 80	100 ± 80

Note: This additional information is provided as part of old DOE Order 5484.1

Table 5. Summary of atmospheric deposition, 1985.

	Total deposition (10^{-3} µCi/m^2)						Tritium in rainfall as HTO[a] (µCi/m^2)		
		Alpha		Beta					
	No. of samples	Avg.	Max.[b]	Avg.	Min.	Max.[b]	No. of samples	Avg.	Max.[b]
On-Site (9 locations)	106	0.02	0.04	0.8	0.2	2	116	11	64
Perimeter (4 locations)	48	0.02	0.4	0.7	0.3	2	27	< 0.2	0.2

No standards for comparison have been established.

[a]The on-site tritium-in-rainfall data are computed from samples taken at 11 locations.

[b]Highest total for any one site.

Table 6. Summary of airborne environmental HTO and $^{14}CO_2$ sampling, 1985.

	No. of samples	Concentration (10^{-9} µCi/ml) Avg.	Min.	Max.	Average as % of standard[a]
Samples for Tritium as HTO					
On-Site					
Bldg. 69A	42	3 ± 0.5	< 0.7	42 ± 8	0.03
Bldg. 3 roof	51	0.8 ± 0.1	< 0.7	11 ± 1	0.4
Standard for Comparison[a]		10,000			
Perimeter					
LHS	51	≤ 0.3	< 0.7	4.6 ± 0.9	< 0.2
B-13D (Olympus)	51	≤ 0.3	< 0.7	< 0.7	< 0.2
Standard for Comparison[a]		200			
Samples for Carbon-14 (as $^{14}CO_2$)					
On-Site					
Bldg. 3 roof	50	≤ 0.1	< 0.2	1.1 ± 0.4	< 0.02
Standard for Comparison		500			

[a]Reference 3.

(radioiodine) content and for tritium. Rainwater is also analyzed for tritium (the Building 75 tritium labeling facility does not release liquid effluent into surface streams).

Sewer outfalls are sampled continuously, sample-to-flow ratios are designed to be between 10 and 20 ppm, and composite samples are taken weekly. The five creek sample points indicated in Fig. 2 are sampled weekly. A one-quart grab sample is taken from each site and analyzed for gross alpha and beta emitters only.

The four perimeter environmental monitoring stations have 46-cm-diameter (18-in.) cylindrical rainfall collectors on their roofs. During rainy months (generally October through May) rainwater is picked up monthly and analyzed for gross alpha and beta activities and for tritium. During the dry California summer, each collector is rinsed with a quart of tap water, and the rinse is analyzed for "dry deposition." The 10 other atmospheric sampling sites alluded to in the air sampling section of this report also contain 46-cm-diameter (18-in.) combination rain/dry deposition collectors, which are sampled on a monthly basis in the same manner as the four perimeter environmental monitoring stations.

Rain that falls into the collector on the north side of Building 75 is analyzed on a storm-by-storm basis for tritium and gross alpha and beta activities. Tritium analysis of water samples is accomplished by liquid scintillation counting. Water samples are prepared for gross alpha and beta analysis by acidification (HNO_3) and evaporation into 2-inch stainless steel planchettes. Organic residues not wet-ashed by the nitric acid treatment are oxidized by flaming the planchettes.

Since radioiodine is driven out of the water samples when they are acidified, aliquots of the sewer effluent samples are preserved for radioiodine analysis. The iodine contained in the samples is precipitated with silver using stable KI as a carrier. The iodine aliquots are filtered, and the filtrate is processed in the same manner as the acid (HNO_3) samples described earlier. After flaming the filtrate planchette, the filter containing any precipitated radioiodine is placed in the planchette and counted.

The prepared planchettes are weighed (the tare weight of each planchette is first determined) and counted in a thin-window, low-background gas proportional counter for both gross alpha and beta activities. Since the samples are thick, self-absorption is computed based on areal sample density, which is the sample weight divided by the area of the planchette (20.26 cm^2), assuming an alpha energy of 5.2 MeV and a beta energy of 1 MeV.

Table 7 summarizes the 1985 data from the surface water and tap water sampling programs. These results are similar to those obtained in past years and all lie within the normal range of background activity. There is no reason to suspect that any of the observed radioactivity originated from LBL.

Table 8 summarizes the sewage sampling data for 1985. The average and maximum values listed for sewer beta concentrations reflect the weekly activity found in the hotter of the acid or radioiodine planchettes.

Table 7. Summary of surface water and tap water samples, 1985.

	No. of samples	Concentration (10^{-9} µCi/ml)						Average as % of standard	
		Alpha			Beta				
		Avg.	Min.	Max.	Avg.	Min.	Max.	Alpha	Beta
On-site streams									
Blackberry	51	< 0.2	< 0.5	≤ 2	2.0 ± 0.1	0.9 ± 0.7	3 ± 1	< 0.4	0.2
Lower Strawberry	51	< 0.1	< 0.4	≤ 1	1.7 ± 0.1	≤ 0.8	6 ± 1	< 0.2	0.2
Upper Strawberry	51	< 0.2	< 0.8	< 2	2.2 ± 0.1	< 0.7	25 ± 2	< 0.4	0.2
Average		< 0.2			2.0 ± 0.05			< 0.4	0.2
Off-site streams									
Claremont	50	0.34 ± 0.3	< 0.9	3 ± 3	1.7 ± 0.1	≤ 0.8	5 ± 1	0.6	0.2
Wildcat	51	≤ 0.2	< 0.5	2 ± 2	1.1 ± 0.1	≤ 0.8	3 ± 1	0.4	0.1
Tap Water	51	0.06 ± 0.05	≤ 0.2	2 ± 2	0.86 ± 0.09	≤ 0.5	2 ± 1	0.1	0.1
Standard of Comparison[a]		50[b]			1000[c]				

[a]Source: Reference 3.
[b]Conservatively assumed to be ^{232}Th.
[c]Conservatively assumed to be ^{90}Sr.

Table 8a. Summary of sewage sampling data, 1985.

Total quantities discharged	Total volume (10^6 liters)	Alpha (μCi)	Beta (mCi)	Tritium (Ci)
Hearst Sewer	160	10 ± 16	3	< 0.2
Strawberry Sewer	116	< 20	17	5.5

Table 8b. Summary of sewage sampling data, 1984 (continued).

Net concentrations	No. of samples	Concentration (10^{-9} μCi/ml) Alpha Avg.	Alpha Min.	Alpha Max.	Beta Avg.	Beta Min.	Beta Max.	Concentration (10^{-6} μCi/ml) Tritium Avg.	Tritium Min.	Tritium Max.	Average as % of standard Alpha %	Beta %	Tritium %
Hearst	50	< 0.16	< 0.5	< 3	15	< 3	90 ± 10	< 0.5	< 0.5	30	< 0.3	2	< 0.02
Strawberry	49	< 0.16	< 0.4	< 2	140	6 ± 4	1600 ± 30	40 ± 8	0.9	700 ± 50	< 0.3	14	2
Overall		< 0.1			70			20			< 0.2	7	1
Standard for comparison[a]		50[b]			1000[c]			2000					

[a]Source: Reference 3.
[b]Conservatively assumed to be ^{232}Th
[c]Conservatively assumed to be ^{90}Sr.
Note: The standards cited here are for specific radionuclides in drinking water, not sewage, and are provided for comparison purposes only.

Nonradioactive Pollutants

Airborne Pollutants

Beryllium Shop airborne emissions. Work in the Beryllium Shop has declined substantially in the last few years. As a result, it was decided to discontinue its operation. From 8-02-85 to 9-19-85, all of the machines and tools were removed, and the room was decontaminated.

The Beryllium Shop consisted of eight beryllium work areas: layout box, glove box, drill press, small mill, saw, Thompson grinder, lathe, and large mill. The machining operations carried out in these work areas may have generated beryllium aerosols. All beryllium work areas were partially or entirely enclosed, and these enclosures were maintained at negative pressures to the work room. HEPA filters were installed on the exhaust vent of all machine enclosures to remove beryllium particles before the air was discharged to the environment. The stack exhaust air was monitored whenever the room was occupied.

Beryllium emissions are regulated by the Clean Air Act, Section 112, National Emission Standards for Hazardous Air Pollutants and the Bay Area Quality Management District Regulation No. 11, Rule 3. Monthly reports were mandated by the Bay Area Air Quality Management District.

Table 9 summarizes the beryllium stack sampling results. The sampling results show full compliance with discharge limits.

Waterborne Pollutants

Plating Shop wastewater discharges. There are two plating shops at LBL: Building 25 and Building 77. Both shops are subject to the EPA Electroplating Pretreatment Standard (40 CFR 413), effective April 27, 1984. In general, this standard regulates metal and cyanide discharges based on discharge volume. Effective February 15, 1986, both plating shops will be required to comply with the Metal Finishing Pretreatment Standard (40 CFR 433). This Standard will lower the discharge limits for cyanide and most regulated metals. The Federal Categorical Pretreatment Standards have been adopted by the East Bay Municipal Utility District (EBMUD) in Ordinance No. 296.

Building 77 Plating Shop

EBMUD has mandated a quarterly sampling schedule for the Building 77 plating shop. The samples represent a 24-hour average discharge and are taken before its wastewater combines with significant amounts of process wastewater from nonelectroplating operations.

Periodically, EBMUD also obtains samples and reports the results to LBL. Table 10a following table shows the wastewater sample results.

Table 9. Beryllium stack sampling results.

Date of Operation	Amount of Beryllium (grams per 24 hours)
1-22-85	<0.01
2-01-85	<0.01
3-26-85	<0.01
3-28-85	<0.01
5-10-85	<0.01
7-18-85	<0.01
7-19-85	<0.01
8-02-85	<0.01
8-06-85	<0.01
8-08-85	<0.01
8-15-85	<0.01
8-16-85	<0.01
8-22-85	<0.01
8-23-85	<0.01
8-26-85	<0.01
8-27-85	<0.01
8-28-85	<0.01
8-29-85	<0.01
8-30-85	<0.01
9-03-85	<0.01
9-04-85	<0.01
9-05-85	<0.01
9-06-85	<0.01
9-09-85	<0.01
9-13-85	<0.01
9-17-85	<0.01
9-18-85	<0.01
9-19-85	<0.01
Sampling Permanently Terminated	
Discharge limit:	10

Table 10a. Building 77 wastewater sample results.

Sample Date	Cn mg/l	Cu mg/l	Ni mg/l	Cr mg/l	Zn mg/l	Pb mg/l	Cd mg/l
01-15-85	3.7	27.0	1.4	1.5	0.13	0.2	0.03
03-21-85[a]	<0.02	0.12	0.10	0.09	0.09	0.3	<0.01
04-23-85	0.13	1.3	0.04	0.13	0.1	0.10	0.01
08-13-85	0.01	0.21	0.1	0.6	0.06	0.04	0.02
11-22-85	<0.01	8.60	0.18	1.0	0.39	0.12	0.01
12-18-85	<0.01	0.11	0.05	0.36	0.08	0.01	0.01
12-19-85[a]	0.02	1.1	1.2	0.48	0.44	0.20	0.03
Limits (1984):	1.9	4.5	4.1	7.0	4.2	0.6	1.2
Limits (1986):	1.2	3.38	3.98	2.0	2.61	0.69	0.69

[a]Samples collected and analyzed by EBMUD.

The samples taken on 1-15-85 showed that the shop exceeded the discharge limits for copper and cyanide. To achieve compliance, a counter-current rinse system was established for the cyanide-copper plating tank. An additional rinse tank was installed between the plating tank and its original rinse tank. Water from the added rinse tank is used as make-up for the cyanide-copper plating tank.

The sample taken on 11-22-85 showed that the limit for copper was exceeded. The cause for the high copper discharge is undetermined; there was very little copper work performed in the shop on the day of the sample. Another sample was taken on 12-19-85 to recheck the copper discharge level. The result from this sample was well within the copper discharge limit.

Building 25 Plating Shop

Since the Building 25 plating shop discharges less than 10,000 gallons per day, it is currently regulated for the discharges of cyanide, lead, and cadmium only. EBMUD did not mandate that samples be taken for these materials because their use was judged to be insignificant.

Site Wastewater Discharges

The two sanitary sewers that drain wastewater from LBL are sampled for a number of heavy metals as mandated by EBMUD Ordinance No. 270, but EBMUD does not require a compliance report for these results. The pH of the sewage is continuously monitored as well.

Aliquots of the weekly flow-proportional grab samples (described previously in this report) are composited for a four-week period and analyzed for heavy metals. The analysis is performed by the Lawrence Livermore National Laboratory.

Tables 10b and 10c summarize the heavy metal released from the Strawberry and Hearst Sanitary Sewers. The LBL sewers drain to the

Table 10b. Hearst monitoring station 1985 sampling data.

Sample Date	Flow (Ml)	pH	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)	Ni (mg/l)	Ag (mg/l)	Zn (mg/l)
1-03	2.0	6.8								
1-08	1.1	6.8								
1-15	1.7	6.6								
1-23	2.0	6.8								
Composite			< 0.04	0.08	0.31	0.84	< 0.39	< 0.11	0.08	0.35
1-30	1.5	7.4								
2-06	2.4	6.6								
2-13	2.1	6.5								
2-20	0.4	6.6								
Composite			< 0.03	0.09	0.96	2.01	< 0.40	< 0.10	0.04	0.40
2-27	1.0	6.7								
3-06	1.5	7.3								
3-13	1.4	7.1								
3-20	1.4	7.2								
Composite			< 0.03	0.18	0.92	4.9	< 0.38	< 0.10	< 0.04	0.70
3-27	1.6	6.7								
4-03	1.6	6.8								
4-10	1.5	6.8								
4-17	1.5	6.7								
Composite			< 0.04	0.48	2.98	8.0	1.02	< 0.23	0.34	3.12
1-24	1.4	6.5								
5-01	1.8	6.5								
5-08	1.6	6.4								
5-15	1.6	6.5								
Composite			< 0.03	0.09	1.16	3.25	< 0.39	< 0.12	< 0.04	1.1
5-22	1.7	6.5								
5-29	1.6	6.8								
6-05	1.7	6.3								
6-12		5.5								
Composite			0.04	0.12	1.78	2.08	< 0.37	< 0.10	0.11	1.45
6-19	3.4	6.1								
6-26	5.5	6.0								
7-03										
7-10		6.6								
Composite			0.04	0.37	0.68	4.70	0.22	< 0.10	0.07	2.45
7-17		6.3								
7-24		6.3								
7-31		6.2								
8-07		6.7								
Composite			0.04	0.12	7.2	3.15	< 0.65	< 0.2	0.37	1.25
8-14		6.4								
8-21		6.3								
8-28	2.6	6.5								
9-04	2.2	6.5								
Composite			0.04	0.10	0.32	2.8	< 0.35	< 0.10	0.06	0.9
9-11	3.3	6.5								
9-18	2.4	6.3								
9-25	4.7	6.1								
10-02	6.3	6.2								
Composite			0.02	0.33	1.42	5.70	< 0.33	0.08	0.06	1.70
10-09	6.3	6.4								
10-16	3.0	6.3								
10-23	1.9	6.2								
10-30		6.0								
Composite			0.04	0.08	1.5	2.8	0.30	< 0.11	< 0.04	1.15
11-06		6.4								
11-13	1.6	6.7								
11-20	1.7	6.7								
11-27	1.5	5.5								
Composite			< 0.05	0.33	1.78	17.13	< 0.63	< 0.21	< 0.07	6.88
12-04	1.6	6.4								
12-11	1.6	6.6								
12-18	1.5	6.3								
Composite			0.04	0.18	1.45	3.80	< 0.69	< 0.21	0.13	1.05
Limits:		5.5	1	2	5	100	2	5	1	5

Ml = megaliters
mg/l = milligrams per liter

Table 10c. Strawberry monitoring station 1985 sampling data.

Sample Date	Flow (Ml)	pH	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)	Ni (mg/l)	Ag (mg/l)	Zn (mg/l)
1-03	1.8	6.5								
1-08	0.6	6.7								
1-15	1.1	6.9								
1-23	1.0	7.1								
Composite			< 0.04	0.09	0.64	3.4	< 0.39	< 0.11	0.10	0.30
1-30	0.9	6.8								
2-06	1.4	6.7								
2-13	1.4	7.0								
2-20	2.0	7.0								
Composite			< 0.03	< 0.16	0.26	3.7	< 0.40	< 0.10	< 0.04	0.27
2-27	3.0	7.0								
3-06	2.5	7.4								
3-13		6.9								
3-20		7.3								
Composite			< 0.03	< 0.04	0.32	2.8	< 0.38	< 0.38	< 0.04	0.65
3-27		7.0								
4-03		6.7								
4-10		6.6								
4-17	2.3	6.6								
Composite			< 0.20	0.60	2.86	6.96	1.92	1.92	< 0.08	1.94
4-24	2.0	6.7								
5-01		6.1								
5-08	0.9	6.5								
5-15	1.9	6.7								
Composite			< 0.03	< 0.04	0.62	1.85	< 0.39	< 0.01	< 0.04	0.42
5-22		6.3								
5-29		6.6								
6-05		6.3								
6-12		6.4								
Composite			0.04	0.13	0.55	1.46	< 0.37	< 0.10	< 0.08	0.60
6-19	2.8	6.5								
6-26	2.6	6.4								
7-03	2.5	6.3								
7-10	3.7	6.5								
Composite			0.04	0.13	0.26	3.80	0.04	< 0.10	< 0.04	0.34
7-17	2.5	6.4								
7-24	2.5	6.8								
7-31	2.7	6.5								
8-07	3.1	6.5								
Composite			0.04	0.09	0.32	6.75	< 0.65	0.11	0.03	0.45
8-14	2.6	6.7								
8-21	2.3	6.5								
8-28										
9-04	2.5	6.7								
Composite			0.04	0.09	0.26	2.45	0.40	0.10	< 0.04	0.38
9-11	2.9	6.5								
9-18		6.4								
9-25	2.5	6.3								
10-02	2.0	6.4								
Composite			0.04	0.04	5.15	2.65	< 0.33	0.12	< 0.04	0.90
10-09	2.0	6.3								
10-16		6.2								
10-23	3.6	6.6								
10-30		6.3								
Composite			0.02	0.12	0.74	4.75	0.27	< 0.11	< 0.04	0.95
11-06	2.0	6.1								
11-13	2.0	6.4								
11-20										
11-27	3.3	5.7								
Composite			< 0.05	0.10	0.68	28.63	< 0.63	0.16	< 0.07	4.13
12-04		6.4								
12-11	1.4	6.6								
12-18	1.2	6.4								
Composite		0.04	0.07	0.78	7.28	< 0.69	0.11	< 0.08	0.95	
Limits:		5.5	1	2	5	100	2	5	1	5

Ml = megaliters

mg/l = milligrams per liter

regional EBMUD's treatment facility before discharge into the San Francisco Bay.

POPULATION DOSE RESULTING FROM LBL OPERATIONS

The development of LBL's two models used to assess the population dose equivalent attributable to penetrating radiation and airborne radionuclides, respectively, was detailed in Ref. 5. Both of the models used population figures from the 1970 U.S. census.

While the population within 80 km (50 mi) of LBL increased by 13% during the 1970s[1,7,8] from 4.6 to 5.2 million people, the populations of Berkeley and Oakland, the two cities immediately adjacent to LBL, declined. Recomputing the population dose models with population statistics from the 1980 census produced no significant difference in the impact/insult values for either the penetrating radiation or radionuclide release models.

Accelerator-Produced Radiation

The LBL model developed by Thomas[5] for determining population dose equivalent from the maximum measured value of perimeter (fence-post) dose assumes that the fence-post rate changes are uncorrelated with fluctuations in population. During 1985 the maximum fence-post dose was measured at the Olympus Gate Monitoring Station and was 1.8 man-mrem for the year (Table 2). An examination of the time sequence of the telemetered neutron fluence from the Olympus detector indicated that the neutron fluence peaks correlated well with the fluence peaks from the neutron detector located in the Bevatron building. The Bevatron operated continuously seven days a week during 1985 except for maintenance, a "summer" shutdown from July 1 through October 1, and a year-end shutdown December 22–31.

Aside from shutdown periods the modest fence-post dose equivalent was produced with reasonable uniformity throughout the year and does not seriously compromise the Thomas model's assumptions. The model's expression relating population dose equivalent M (in man-rem) to maximum measured fence-post dose H_o (in rem) is

$$M < 10^3 \times H_o \, (1.0 - 0.56f) \, , \qquad (1)$$

where f = the fraction of the fence-post dose contributed by the 88-Inch Cyclotron and/or the SuperHILAC. Since the fence-post dose has been assigned to the Bevatron, f = 0 [in Eq. (1)].

Thus the expression becomes

$$M < 10^3 \, H_o \, . \qquad (2)$$

Since H_o was 1.8 mrem (or 0.0018 rem), the population dose equivalent attributable to LBL accelerator operation during 1985 was

$$M < 10^3 \times 0.0018$$
$$< 1.8 \text{ man-rem.}$$

Airborne Radionuclides

The population dose equivalent resulting from airborne releases of radioactive nuclides can be determined from the model developed by Cantelow.[5] To provide more consistent reporting of these data, new values have been calculated for the constant R (man-rem per curie released). These values, shown in Table 11, are based on the derived concentration guides (DCGS) from Table 1 Reference 3. These values replace those listed in Table 16 of Reference 5. The reader should note that Reference 3 admonishes DOE facilities not to use the DCGs in the foregoing way as "... The values given in Table 1 only account for drinking water or inhaled air and do not include other potentially significant environmental pathways."

Table 11. Population effective dose equivalent resulting from the release of 1 Ci of various radionuclides.

Nuclide	DCG[a] (μCi/ml)	R[a] (rem $m^3 Ci^{-1} s^{-1}$)	α_R[a] (man-rem/Ci)
Unidentified α emitters[b]	7×10^{-15}	5×10^5	2×10^5
Unidentified β emitters[c]	9×10^{-12}	4×10^2	2×10^2
^3H	2×10^{-7}	2×10^{-2}	8×10^{-3}
^{14}C	5×10^{-7}	6×10^{-3}	3×10^{-3}
^{125}I	5×10^{-10}	6	3
^{131}I	4×10^{-10}	8	3

[a]Source: Reference 3.
[b]Conservatively assumed to be ^{232}Th.
[c]Conservatively assumed to be ^{90}Sr.

We believe that it is appropriate to use the DCGs as we have, since, for airborne radionuclides released by LBL, the small internal doses to the public are produced primarily by inhalation and skin absorption. Furthermore, since the new radiation protection guides do not provide default values for unidentified isotopes, such activities must either be ignored or assigned some identity--we choose the latter. For the purposes of estimating collective effective population dose, all unidentified alpha-emitting activity is conservatively assumed to be

^{232}Th, and unknown beta emitting activity is conservatively assumed to be ^{90}Sr. (The assertion of conservatism is made because, while ^{90}Sr and ^{232}Th are found at LBL, they are only in a few LBL laboratories and, for isotopes used at LBL, represent the most restrictive beta and alpha emitters, respectively, listed in Reference 3; ^{227}Ac, which is 4500 times more restrictive a beta emitter than ^{90}Sr, is also found at LBL, but its most likely state is in equilibrium with its alpha emitting daughters, 18-day ^{227}Th and 14-day ^{223}Ra.) Table 12 of this report summarizes the total population dose equivalent due to LBL operations.

Table 12. Population effective dose equivalent, 1985.[a]

Contributing factor	Population effective dose equivalent (man-rem)
Penetrating radiation from accelerator operations	1.8
Radionuclide release:	
^{3}H	1.5
^{14}C	0.000006
^{125}I	0.006
^{131}I	0.000007
Unidentified alpha emitters (as ^{232}Th)	0.01
Unidentified beta emitters (as ^{90}Sr)	0.006
LBL-produced effective population dose equivalent	< 4

[a]For 1985, the population dose attributable to natural background sources for the population within 80 km (50 mi) of LBL was approximately 5.2×10^6 persons $\times$ 0.1 rem/person-yr = 5.2×10^5 man-rem.

TRENDS--LBL ENVIRONMENTAL IMPACT

Accelerator-Produced Penetrating Radiation

Figures 3-6 show the annual accelerator-produced dose equivalent reported by the four perimeter environmental monitoring stations from the year they were established to date. During the past several years, the LBL accelerators have run heavy ions during a significant fraction of their operating schedules. Successful work in beam development had served to increase beam currents in recent years and had increased the dose equivalent at the Building 88 Environmental Monitoring Station somewhat. That upward trend was reversed in 1983. The maximum perimeter dose equivalent (Fig. 5) remains a diminishing fraction of the radiation protection guidelines[3] reflecting improvements in accelerator beam optics, local shielding, and cave selection.

Airborne and Waterborne Radionuclides

Figure 7 shows the annual releases of tritium (as HTO) from the Building 75 Tritium Facility from 1973 to 1985.

The 190 curies released during routine operations is somewhat less than the 1984 "routine" releases and is responsible for approximately 40% of the LBL-produced population-dose equivalent from all sources for 1985. The operational personnel of the tritium facility is investigating all sources of release so that future releases may be minimized. The releases occur during molecular tagging and tritium waste processing.

With the exception of occasional known releases, the atmospheric sampling program has yielded data over the past few years that are within the range of normal background.

The surface water program always yields results within the range of normal background. Because no substantial changes in the quantities of radionuclides used are anticipated, no changes are expected in these observations.

Under the terms of its license, the University of California Berkeley campus has discharged radionuclides into the Strawberry sewer, complicating the analysis of LBL sewer sampling data. After 1979 the University discharges were sharply curtailed and are expected to remain so in the future.

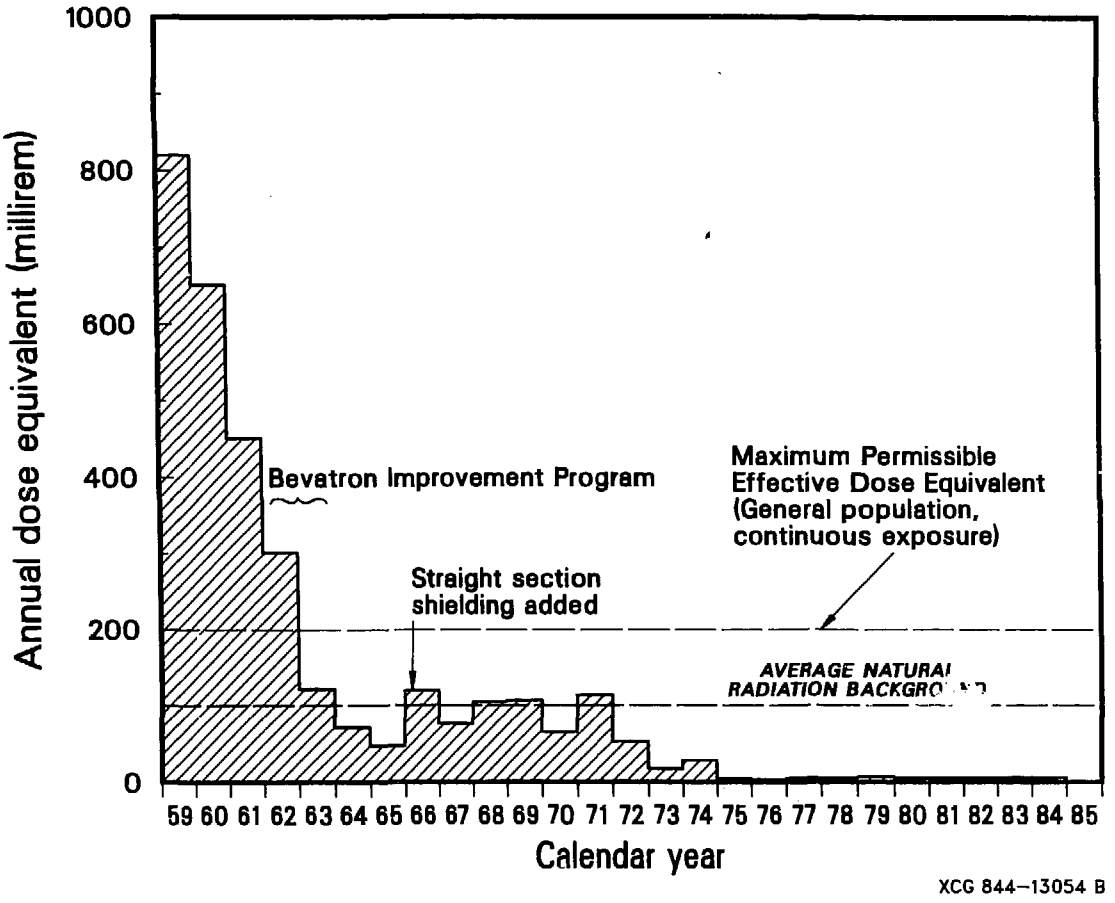

Figure 3. Annual accelerator-produced dose equivalent reported by the Olympus Gate Environmental Monitoring Station, 1959–1985. Maximum Permissible Dose (General Population) is the maximum permissible dose equivalent to any single individual in the general non-Laboratory population. The maximum permissible continuous average effective dose equivalent to the general population is 100 mrem/year.

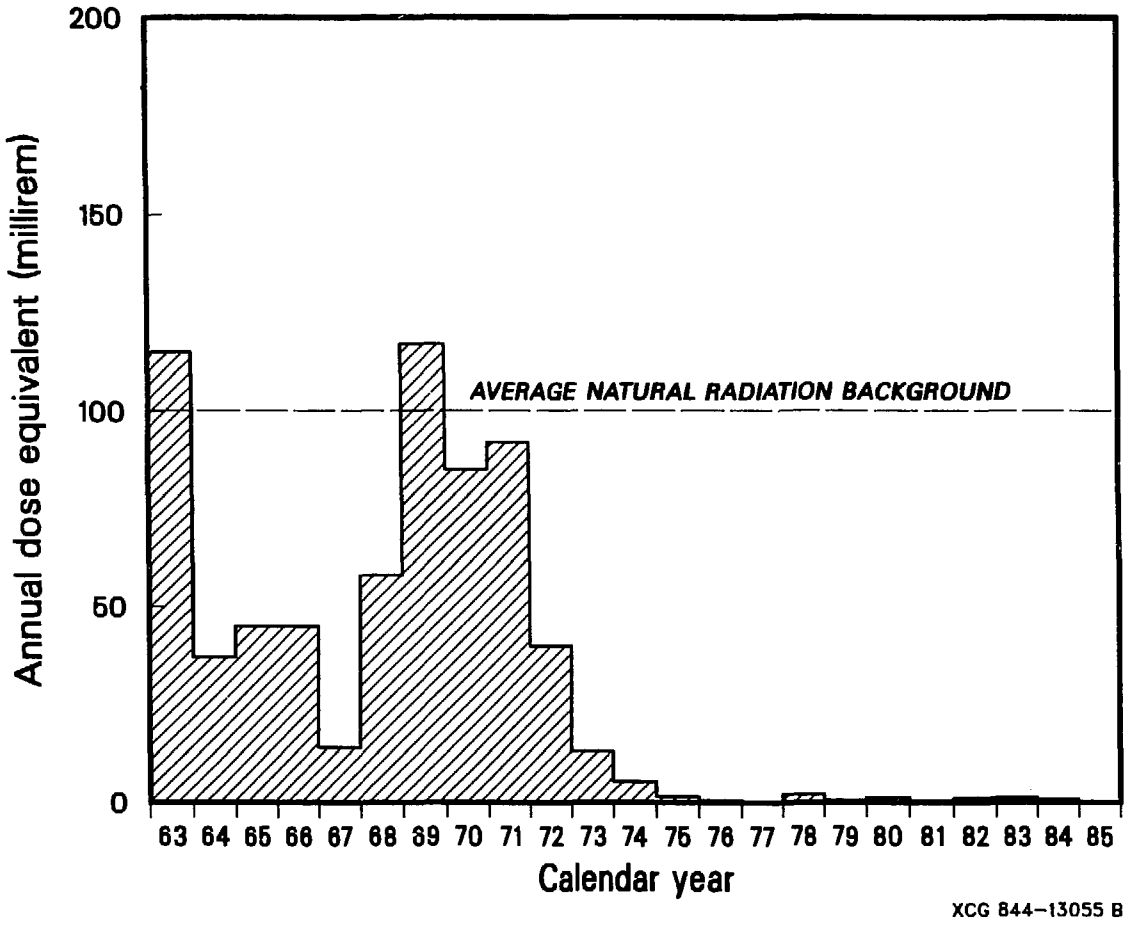

Figure 4. Annual accelerator-produced dose equivalent reported by the Building 90 Environmental Monitoring Station, 1962-1985.

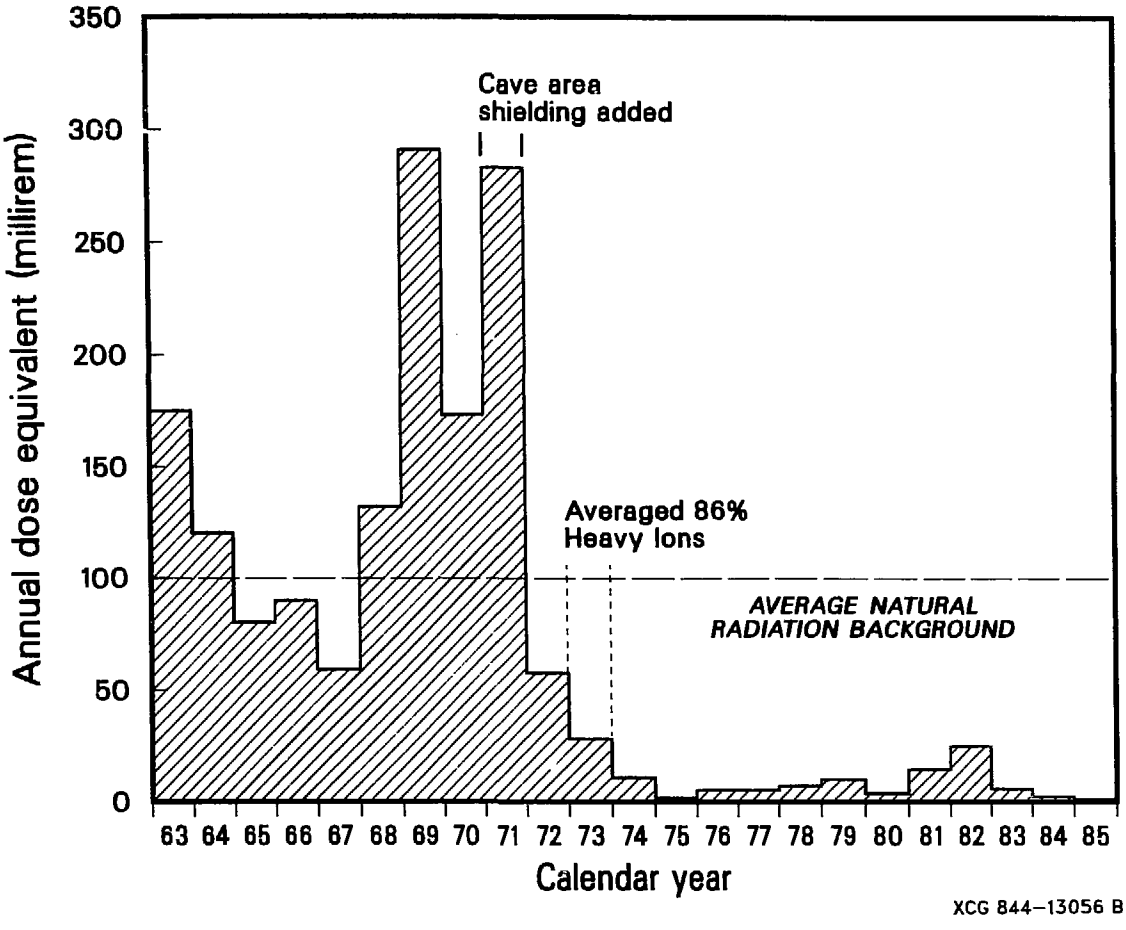

Figure 5. Annual accelerator-produced dose equivalent reported by the 88-Inch Cyclotron Environmental Monitoring Station, 1963-1985.

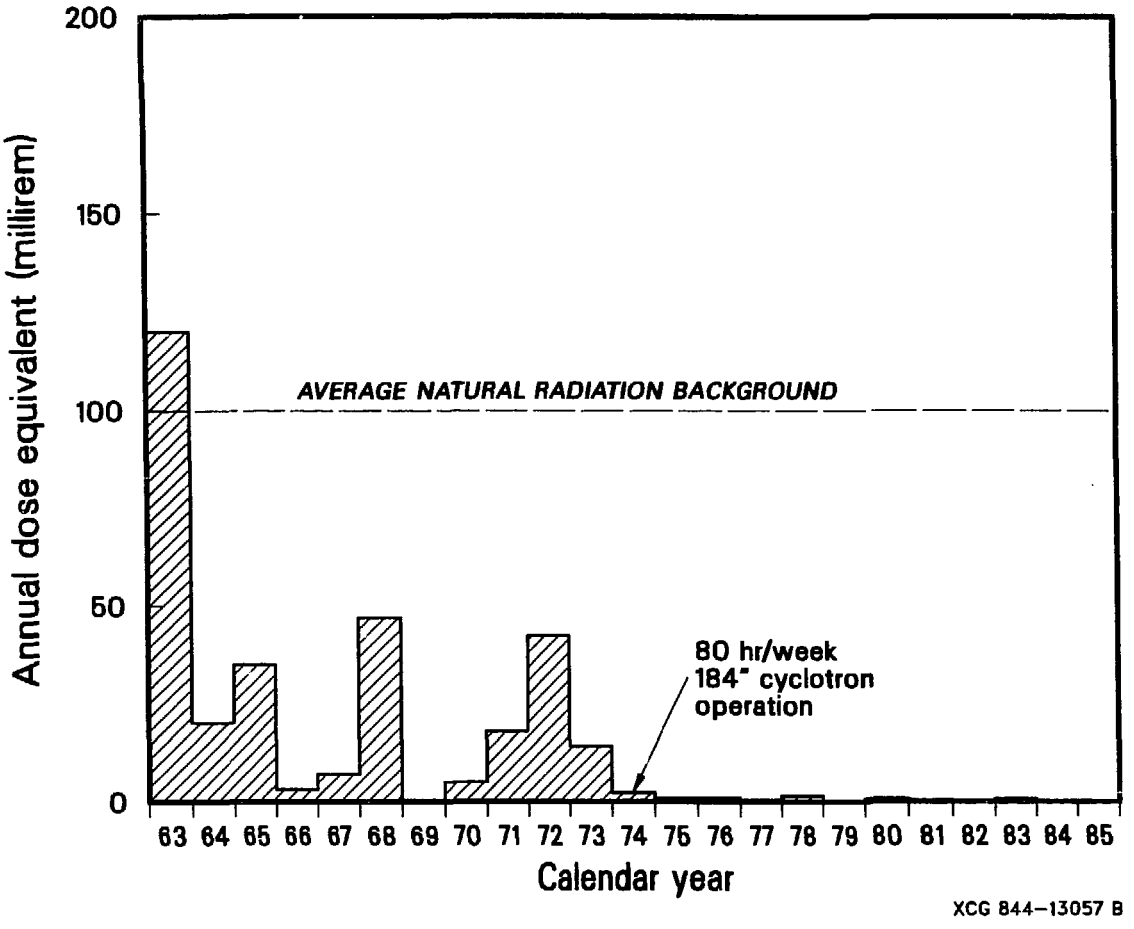

Figure 6. Annual accelerator-produced dose equivalent reported by the Panoramic Way Environmental Monitoring Station, 1963-1985.

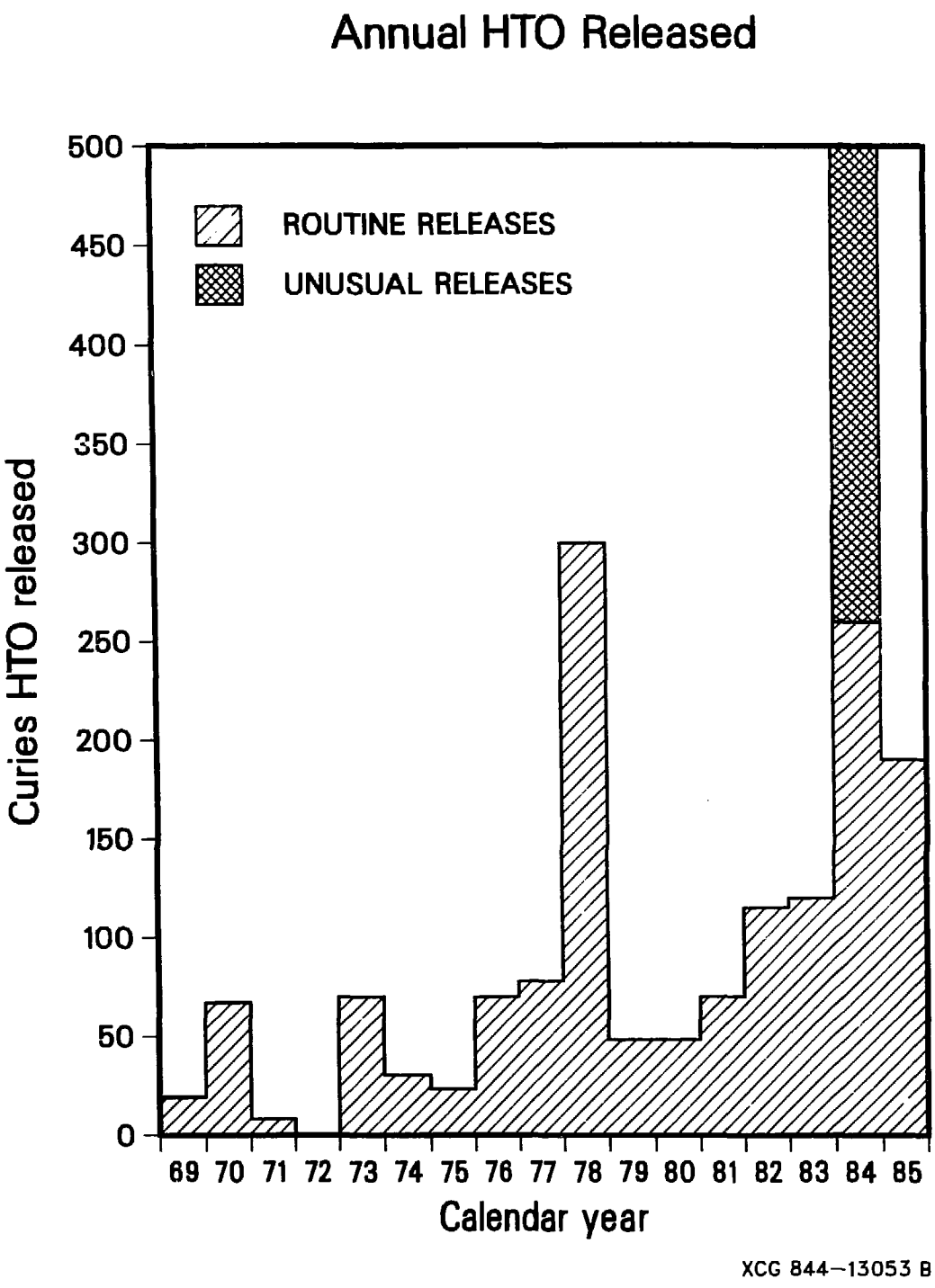

Figure 7. Annual releases of tritium (HTO) from the Building 75 Tritium Facility, 1969-1985.

QUALITY ASSURANCE

The Facilities Management and Technical Services Division of LBL is in the process of preparing a comprehensive division-wide quality assurance program. During 1985, in addition to the quality control procedures described in the body of this report, samples that were blind-spiked with tritium were worked up along with each group of environmental samples assayed for HTO.

The LBL Environmental Surveillance Group analyzed DOE's Environmental Measurements Laboratory QAPXXIV Water Sample (reported in Ref. 9) for tritium, with the following results:

LBL Value (pCi/mL HTO)	EML Value (pCi/mL HTO)	Ratio LBL/EML
22 ± 4	19.5 ± 1.1	1.13 ± 0.22

GROUND WATER MONITORING

LBL has no formal program to assay ground water at this time. As mentioned previously, the Laboratory does analyze the grab samples taken weekly from all permanent creeks that drain the LBL watershed (see Fig. 2 and Table 7).

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