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Environment, Health, and Safety Division
Environmental Services Group



United States Department of Energy

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Radionuclide Air Emission Report for 2002

(in compliance with 40 CFR 61, Subpart H)

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Site Name: **Ernest Orlando Lawrence Berkeley National Laboratory**

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FACILITY INFORMATION

- 1.1 SITE DESCRIPTION
- 1.2 COMPLIANCE STATUS OF BERKELEY LAB
- 1.3 SOURCE DESCRIPTION

1.1 SITE DESCRIPTION

1.1.1 Laboratory Operations

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multi-program national laboratory managed by the University of California (UC) for the U.S. Department of Energy (DOE). Berkeley Lab's major role is to conduct basic and applied research in biology, physics, chemistry, materials, and energy. Berkeley Lab, the birthplace of the cyclotron, was founded by the late Nobel laureate, Ernest Orlando Lawrence, in 1931.

Berkeley Lab operates facilities encompassing areas where radionuclides are handled and stored that are subject to the U.S. Environmental Protection Agency (EPA) radioactive air emission regulations in 40 CFR Part 61, Subpart H, "National Emission Standard for Hazardous Airborne Pollutants other than Radon from DOE Facilities" (NESHAP). Figure 1 illustrates the Berkeley Lab general site configuration and locations of buildings.

Radiochemical and radiobiological studies performed at Berkeley Lab typically use millicurie¹ quantities of a variety of radionuclides. All use of radioactive material at Berkeley Lab must be in accordance with an approved authorization or permit. A radiation work authorization is issued for long-term projects under routine radiological conditions; a radiation work permit is issued for nonresearch projects or tasks that require radiation protection measures. Each authorization or permit is reviewed at least every 18 months, depending on changes to the project. An authorization or permit establishes the location of radioactive material areas (work areas where unsealed radioactive material is handled) and radioactive material storage areas (controlled areas where radioactive material is stored only, with no direct manipulation of the material). Table 1 identifies buildings at Berkeley Lab where handling of unsealed radioactive material was authorized in 2002.

¹ One millicurie (mCi) is equal to 3.7×10^7 Becquerel (Bq).

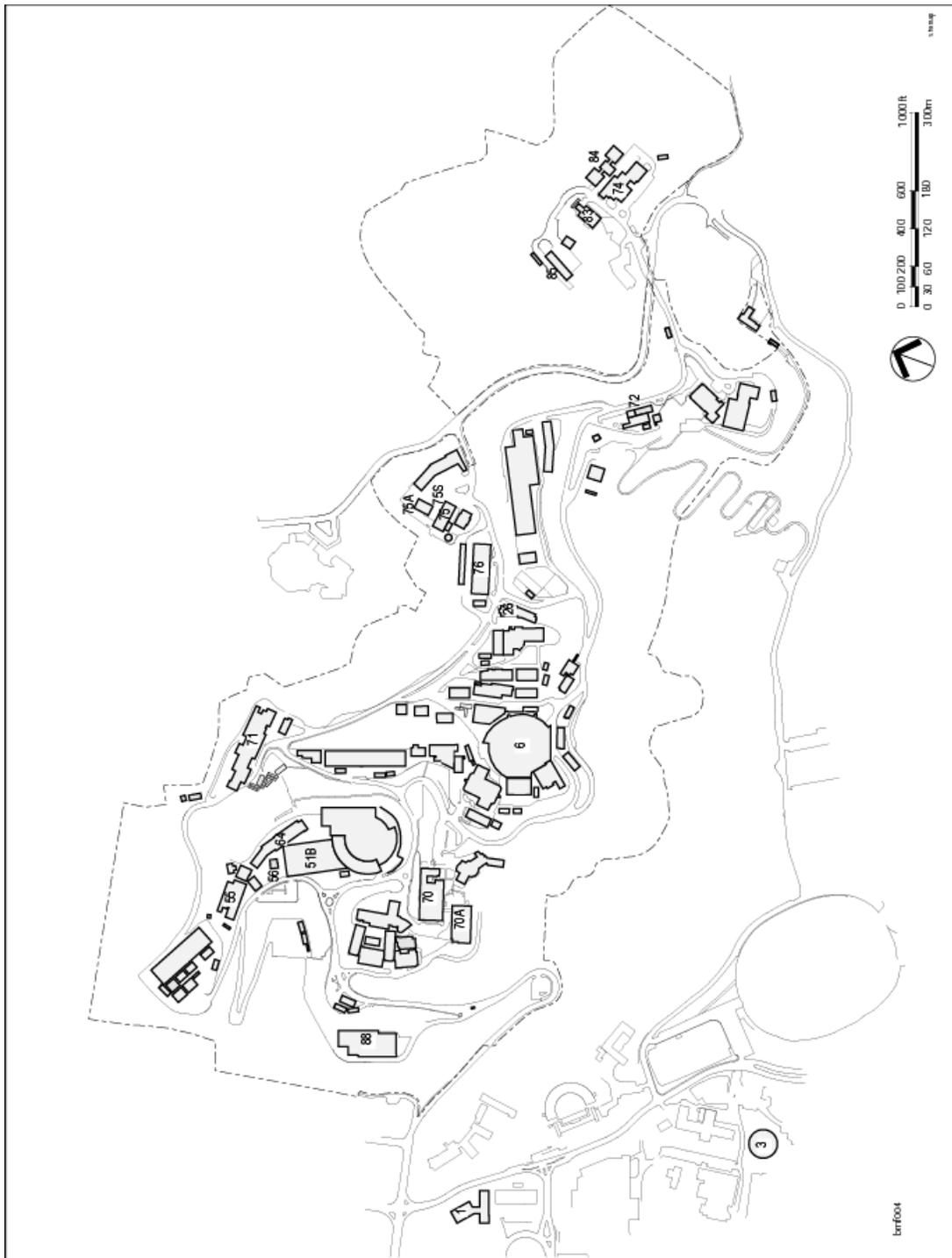


Figure 1. Berkeley Lab Buildings

Table 1. Berkeley Lab Buildings Where Use of Unsealed Radionuclides is Authorized

Building Number	Building Description or Function
1	Donner Laboratory
3	Calvin Laboratory
6	Advanced Light Source (ALS)
26	Radioanalytical Laboratory
51B	Bevatron
55	Center for Functional Imaging and Life Sciences Research
56	Biomedical Isotope Facility
64	Life Sciences Research
70	Environmental Energy Technology and Nuclear and Earth Sciences Research
70A	Nuclear, Chemical, and Life Sciences Research
71	Accelerator and Fusion Research
72	Low-Background Facility
74	Life Sciences Research
75	Former National Tritium Labeling Facility (NTLF)
75A	Old Hazardous Waste Facility
75S	Tritium Storage Locker
76	Radioanalytical Laboratory
83	Life Sciences Research
84	Human Genome Facility
85	Hazardous Waste Handling Facility
88	88-Inch Cyclotron

1.1.2 Berkeley Lab Site

Berkeley Lab is situated on a hillside above the main campus of UC Berkeley. The 200-acre (80-hectare) site is located on the west and southwest-facing slope of the Berkeley hills, at elevations ranging from 500 to 1,100 ft (150 to 330 m) above sea level within the cities of Berkeley and Oakland. It is located about 3 miles (5 km) east of San Francisco Bay and about 15 miles (25 km) east of the city of San Francisco (Figure 2).

Berkeley Lab is located in an urban/wildland interface zone on land owned by the university. Berkeley Lab is surrounded by university land on nearly all sides. In addition, Berkeley Lab maintains a landscape buffer zone between its facilities and the site boundary. Beyond the northern boundary of Berkeley Lab are university facilities and single-family homes, and beyond the western boundary are multiunit dwellings, student residence halls, and commercial buildings. The area to the east and south, which is part of the university's lands, is maintained in a largely natural state and includes recreational facilities and the UC Botanical Garden. The nearest farm is in Wildcat Canyon Regional Preserve, which is about 2 miles (3.2 km) north of Berkeley Lab, where cattle graze.

The western portion of Berkeley Lab is in Berkeley (population 102,743) and the eastern portion is in Oakland (population 399,484). The population within 50 miles (80 km) of Berkeley Lab increased by about 30% during the 1980s and 1990s from 5 to 6.6 million, as tabulated by the 2000 census.

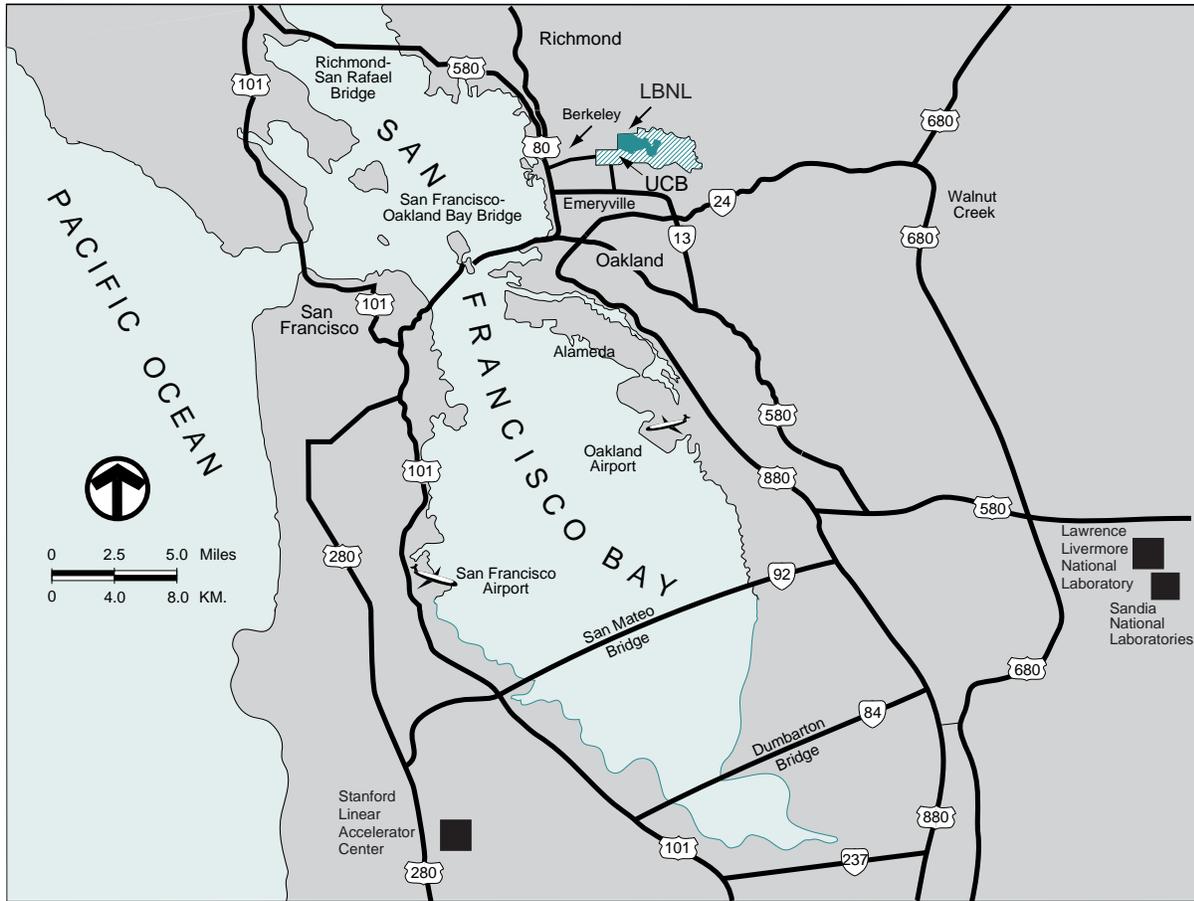


Figure 2. San Francisco Bay Area Map

1.1.3 The Climate at Berkeley Lab

The climate of the Berkeley Lab site is greatly influenced by its proximity to the Pacific Ocean and its exposure to the maritime air that flows in from San Francisco Bay. Seasonal temperature variations are small, with approximate mean temperatures of 63 °F (17 °C) during the summer and 48 °F (9 °C) during the winter. The site’s proximity to San Francisco Bay and the Pacific Ocean also keeps the humidity relatively high. The average annual rainfall is about 29 in. (74 cm). About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 0.5 in./h (1.3 cm/h). Thunderstorms, hail, and snow are extremely rare. Winds are usually light, but summer sea breezes can reach up to 20–30 mph (9–13 m/s). Winds from winter storms can reach speeds of 30–40 mph (13–18 m/s). The predominant wind directions are westerly and northwesterly during fair weather and southeasterly in advance of storms.

1.2 COMPLIANCE STATUS OF BERKELEY LAB

Berkeley Lab has been in full compliance with the requirements of 40 CFR, Part 61, Subpart H, since 1995, when EPA sent DOE written confirmation that Berkeley Lab had satisfactorily completed all

requirements of a federal facilities compliance agreement (FFCA) to achieve compliance. As part of the FFCA, Berkeley Lab formalized all phases of its NESHAP program and proposed a graded strategy for performing emissions measurements required by Section 61.93(b)(4)(i) of the NESHAP regulations. Measurement categories are determined by the potential dose from airborne radionuclide emissions (discussed below). Table 2 summarizes the EPA-approved NESHAP compliance strategy for emissions measurements that Berkeley Lab has followed since the beginning of 1995 and lists the number of potential release points in each measurement category in 2002.

1.3 SOURCE DESCRIPTION

Berkeley Lab uses a wide variety of radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are a by-product of charged-particle accelerator operations. Radioactive gases produced by accelerator operations in Buildings 6, 56, and 88 are mainly short-lived radionuclides such as ^{11}C , ^{13}N , ^{15}O , and ^{18}F .

All radionuclides that are authorized for use or storage at Berkeley Lab are considered when evaluating the potential for airborne radionuclide emissions. A list of these authorized radionuclides is maintained in the NESHAP files. As required by 40 CFR Part 61, no credit is taken for emission controls, such as filters and other devices that prevent radionuclides from being emitted into the air, and the appropriate EPA-specified physical state factor (provided in 40 CFR Part 61, Appendix D) is

Table 2. Summary of NESHAP Compliance Strategy for Measuring Emissions in 2002

Annual Effective Dose Equivalent (EDE) (mrem/y) ^a	Category	Requirements	Number of Potential Release Points
$\text{EDE} \geq 10.0$	Non-compliant	Reduction or relocation of source term and reevaluation prior to authorization.	0
$10.0 > \text{EDE} \geq 1.0 \times 10^{-1}$	I	<ul style="list-style-type: none"> • Continuous sampling or monitoring. • Telemetry for nuclides with half-lives < 100 h • EPA application to construct or modify. 	1 ^b
$1.0 \times 10^{-1} > \text{EDE} \geq 5.0 \times 10^{-2}$	II	Continuous sampling with weekly analysis.	11
$5.0 \times 10^{-2} > \text{EDE} \geq 1.0 \times 10^{-2}$	III	Continuous sampling with monthly analysis.	17
$1.0 \times 10^{-2} > \text{EDE} \geq 1.0 \times 10^{-3}$	IV	Sampling annually during project activity.	0
$\text{EDE} < 1.0 \times 10^{-3}$	V	Inventory controlled by radiation work authorization/permit and periodic evaluation. No monitoring required.	115

^a 1 mrem = 1.0×10^{-2} mSv

^b In December 2002, the only Category I release point at Berkeley Lab was changed to Category III based on source reduction at the former National Tritium Labeling Facility (NTLF)

applied. Based on the potential to emit airborne radionuclides, the number and location of monitored and sampled stacks subject to each compliance category changes throughout the year in response to changes in research projects. In 2002, as many as 29 stacks at nine facilities at Berkeley Lab had the potential to emit radionuclides into the atmosphere at a level that required sampling under the criteria in Table 2 (Category I through IV). The potential release points that these stacks exhaust are listed in Table 3, along with the measurement categories of these facilities in 2002.

Based on historical operations, maximum authorized quantities of radionuclides, and emissions measurements, one potential release point met Category I criteria for part of 2002: the former National Tritium Labeling Facility (NTLF) in Building 75. In the fall of 2001, the National Institutes of Health announced that it was canceling its funding of the NTLF, and the facility ceased labeling operations in December 2001. The first phase of closure activities was completed in April 2002, and the second phase was completed in October 2002. By the end of 2002, emissions from the former NTLF were due primarily to low-level contamination in the building exhaust components that have not yet been removed (Phase III of closure). At this point, the facility met Category III criteria.

All other Berkeley Lab areas that were operational in 2002 were minor sources; that is, the effective dose equivalent from each potential release point was less than 0.1 mrem/y (1.0×10^{-3} mSv/y), the

Table 3. Facilities with Potential to Emit Airborne Radionuclides in 2002

Facilities with Potential Release Points	NESHAP Compliance Strategy Category					Total
	Category I	Category II	Category III	Category IV ^a	Category V	
1	0	0	3	0	7	10
3	0	0	0	0	2	2
6	0	0	0	0	9	9
26	0	0	0	0	3	3
51B	0	0	0	0	1	1
55	0	0	1	0	10	11
56	0	2	0	0	0	2
64	0	0	0	0	1	1
70	0	2	4	0	9	15
70A	0	2	4	0	24	30
71	0	0	0	0	2	2
72	0	0	0	0	1	1
74	0	0	0	0	15	15
75	1 ^b	1	2	0	3	7
75A	0	0	0	0	1	1
75S	0	0	1	0	0	1
76	0	0	0	0	1	1
83	0	0	0	0	3	3
84	0	0	0	0	11	11
85	0	2	0	0	0	2
88	0	2	2	0	12	16
Total	1^b	11	17	0	115	144

^a No sources were measured under Category IV requirements; sources having a potential dose impact between 1.0×10^{-2} and 1.0×10^{-3} mrem/y (1.0×10^{-4} and 1.0×10^{-5} mSv/y) were measured using the more rigorous Category III requirements.

^b In December 2002, the only Category I release point at Berkeley Lab was downgraded to Category III based on source reduction at the former National Tritium Labeling Facility (NTLF)

threshold limit for Category I. Small sources (Category II through IV) were continuously sampled with weekly or monthly analysis of the samples. As shown in Table 3, all Category IV sources were measured using the more rigorous Category III requirements.

To determine the annual dose from airborne emissions, the full set of authorized radionuclides was reviewed, and a subset was developed that includes radionuclides that were potentially used (received or measured) in 2002 (Table 4).

Table 4. Radionuclides Potentially Used (Received or Measured) In 2002

Element	Atomic Number	Radionuclide	Principal Radiation Types	Energy (MeV)	Half-Life
Americium	95	²⁴¹ Am	alpha	5.41 5.44	432.7 years
Calcium	20	⁴⁵ Ca ⁴⁹ Ca	gamma beta beta	0.060 0.258 2.18	162.7 days 8.7 minutes
Carbon	6	¹¹ C ¹⁴ C	positron/gamma beta	0.511 0.156	20.5 minutes 5730 years
Cerium	58	¹⁴¹ Ce	beta	0.436 0.581	32.5 days
Chromium	24	⁵¹ Cr	gamma	0.145	
Cobalt	27	⁶⁰ Co	gamma beta	0.320 0.318	27.7 days 5.3 years
Europium	63	¹⁵² Eu	gamma beta gamma	1.33 0.699 0.122	13.5 years
Fluorine	9	¹⁸ F	gamma	0.344 1.408	
Gadolinium	64	¹⁵³ Gd	positron/gamma	0.511	109.7 minutes
Hydrogen (Tritium)	1	³ H	gamma	0.097	241.6 days
Iodine	53	¹²³ I ¹²⁵ I ¹³¹ I	beta	0.0186	12.3 years
Iron	26	⁵⁵ Fe ⁵⁹ Fe	gamma gamma x-rays beta gamma	0.159 0.035 0.606 0.364 0.108 0.466 1.099 1.292	13.2 hours 59.4 days 8.0 days
Neptunium	93	²³⁷ Np	gamma alpha gamma	4.78 0.030 0.087	2.1 × 10 ⁶ years
Niobium	41	⁹⁵ Nb	beta gamma	0.160 0.765	35.0 days
Nitrogen	7	¹³ N	positron/gamma	0.511	10.0 minutes
Oxygen	8	¹⁵ O	positron/gamma	0.511	122 seconds
Protactinium	91	²³³ Pa	beta gamma	0.256 0.312	27 days
Phosphorus	15	³² P ³³ P	beta beta	1.71 0.25	14.3 days 25.3 days

Table 4. Radionuclides Potentially Used (Received or Measured) In 2002 (continued)

Element	Atomic Number	Radionuclide	Principal Radiation Types	Energy (MeV)	Half-Life
Plutonium	94	²³⁸ Pu	alpha	5.50	87.7 years
Rhenium	45	^{103m} Rh	x-rays	0.040	56.1 minutes
Rubidium	37	⁸⁶ Rb	beta	1.77	18.7 days
Ruthenium	44	¹⁰³ Ru	gamma	1.08	
			beta	0.223	39.3 days
Scandium	21	⁴⁶ Sc	gamma	0.497	
			beta	0.357	83.8 days
			gamma	1.121	
				0.889	
		⁴⁹ Sc	beta	2.01	57.3 minutes
Sulfur	16	³⁵ S	beta	0.167	87.2 days
Strontium	38	⁹⁰ Sr	beta	0.546	28.8 years
Technetium	43	⁹⁹ Tc	beta	0.294	2.1 × 10 ⁵ years
		^{99m} Tc	gamma	0.141	6.0 hours
Thallium	81	²⁰¹ Tl	gamma	0.167	3.0 days
Thorium	90	²³² Th	alpha	4.01	1.4 × 10 ¹⁰ years
Uranium	92	²³³ U	alpha	4.82	1.59 × 10 ⁵ years
		²³⁴ U	alpha	4.77	2.46 × 10 ⁵ years
				4.72	
		²³⁵ U ^a	alpha	4.40	7.04 × 10 ⁸ years
				4.37	
			gamma	0.143	
				0.185	
		²³⁸ U ^a	alpha	4.20	4.47 × 10 ⁹ years
Yttrium	39	⁸⁸ Y	positron	0.76	106.7 days
			gamma	0.898	
				1.836	
		⁹⁰ Y	beta	2.281	2.67 days
Zirconium	40	⁹⁵ Zr	beta	0.368	64.0 days
				0.400	
			gamma	0.724	
				0.757	
		⁹⁷ Zr	beta	1.92	16.8 hours
			gamma	0.743	

^aIncludes progeny

As discussed above, potential release points in categories I through IV were sampled or monitored, in accordance with Berkeley Lab's *Quality Assurance Project Plan for Radionuclide NESHAP*. At continuously sampled sites, a representative sample of the exhaust air passes through the appropriate collection medium (silica gel for tritium, sodium hydroxide for ¹⁴C, charcoal for ¹²⁵I, and fiberglass filter for particulate alpha- and beta-emitting radionuclides). Each medium is replaced either weekly or monthly, depending on the measurement category. The radionuclides collected on the media are analyzed either at a commercial laboratory (for tritium) or an on-site laboratory (for all other radionuclides). At sites continuously monitored in real time, a sample of the exhaust air is passed through detectors that provide a nearly instantaneous measurement of positron-emitting radionuclides (at Buildings 56 and 88), alpha-emitting radionuclides (at Building 70A), or tritium (at Building 75 NTLF).

Potential release points in Category V were, in general, not sampled or monitored. Instead, Berkeley Lab evaluated the effective dose equivalent from Category V potential release points by assuming that all radionuclides received during the year were emitted, whether they were actually used or not. The amount of each radionuclide emitted was determined by multiplying the entire quantity of that radionuclide received during the year by the appropriate EPA-specified physical state factor (provided in 40 CFR Part 61, Appendix D). This provides a conservative, upper-bound estimate of the annual emissions. The total number of Category V potential release points in 2002 is based on the number of areas where radionuclide use was authorized. All radioactive material areas were included, regardless of whether radionuclides were actually used there in 2002. This also provides a conservative, upper-bound estimate of the impact of radioactive airborne emissions. One area source of potential fugitive emissions identified in 2002 at Building 51B was also determined to be Category V.

To estimate effective dose equivalent, CAP88-PC, Version 2, provides a library of 265 radionuclides; however, this library does not include all of the radionuclides used at Berkeley Lab. For radionuclides not included in the library, Berkeley Lab selects a surrogate radionuclide that is similar to the actual radionuclide in its metabolic behavior, mode of decay, and decay energy.

In addition, Berkeley Lab conservatively assigns the high-risk alpha-emitting radionuclide, ^{232}Th , and the high-risk beta-emitting radionuclide, ^{90}Sr , as surrogates for gross alpha and gross beta measurements, respectively. To evaluate this assumption, in 2002 the Berkeley Lab Low Background Facility analyzed samples from Buildings 70 and 70A by gamma spectroscopy to identify the radionuclides responsible for gross alpha and gross beta measurements. The results of gamma spectroscopy indicate that the radionuclides represented by gross alpha and gross beta measurements are actually lower-risk radionuclides such as daughters of ^{238}U (^{210}Pb) and ^{235}U (^{231}Pa), ^{241}Am , ^7Be , and ^{40}K . Thus, the use of the higher-risk radionuclides ^{232}Th and ^{90}Sr provides an upper-bound estimate of the effective dose equivalent.

Furthermore, all tritium releases are assumed to be in the form of tritiated water because CAP88-PC cannot calculate doses from releases of tritiated hydrogen gas. CAP88-PC treats all tritium gas releases as tritiated water, which overestimates the dose from inhalation by a factor of 10,000.¹

In estimating effective dose equivalent from Category I—IV potential release points, the actual measured activities were used, in accordance with DOE guidance,² even when the measured amount was less than the analytical laboratory's minimum detectable activity. Of the radionuclides listed in

¹ International Commission on Radiological Protection. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 4, Inhalation Dose Coefficients*, ICRP 71, Elsevier Science, Inc., Tarrytown, NY (1996).

² Department of Energy. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T, Washington, D.C. (January 1991).

Table 4, five radionuclides account for nearly all (more than 99.9%) of the activity emitted: hydrogen-3 (tritium or ^3H), fluorine-18 (^{18}F), carbon-11 (^{11}C), carbon-14 (^{14}C), and sulfur-35 (^{35}S).

Following DOE guidance,¹ many Berkeley Lab potential release points were grouped using the following criteria:

- The sum of the effective dose equivalent attributable to all stacks in the group must be less than 0.1 mrem (1×10^{-3} mSv).
- Release points must be in close proximity (in the same or a nearby building), with similar operations and similar nuclides used in the facilities.
- Critical receptors must be the same.

Using this grouping scheme, Berkeley Lab identified 14 NESHAP sources (Table 5). For each source, Berkeley Lab used the EPA-approved atmospheric dispersion dose calculation computer code CAP88-PC, Version 2, to estimate the effective dose equivalent to an off-site maximally exposed individual. The 14 CAP88-PC computer model assessments were performed separately to simulate eight point sources, five grouped sources, and one area source.

As identified in Figure 1, Buildings 1 and 3 are located outside of Berkeley Lab’s main perimeter and could be considered separate facilities since they are not on one contiguous site. However, Buildings 1 and 3 are located on the adjacent UC Berkeley campus and are within walking distance of the main Berkeley Lab site. Annual radioactive air emissions from these off-site buildings and the associated effective dose equivalent at each local receptor are much less than the highest building emissions and doses at the main Berkeley Lab site. Thus, it would be inappropriate and misleading to model and report these much lower doses separately. Therefore, for reporting and dose-modeling purposes, all of these off-site buildings are considered as being on one contiguous Berkeley Lab site.

Table 5. NESHAP Point, Group, and Area Sources In 2002

NESHAP Sources	Type of Source	Location
Building 1	Point	UC Berkeley Campus
Building 3	Point	UC Berkeley Campus
Building 6	Point	Main Site
Buildings 26 and 76	Group	Main Site
Building 51B	Area	Main site
Buildings 55, 56, and 64	Group	Main Site
Buildings 70 and 70A	Group	Main Site
Building 71	Point	Main Site
Building 72	Point	Main Site
Buildings 74, 83, and 84	Group	Main Site
Building 75 (NTLF)	Point	Main Site
Buildings 75 (Other), 75A, and 75S	Group	Main Site
Building 85	Point	Main Site
Building 88	Point	Main Site

¹ Department of Energy. “Guidance for the Preparation of the 1992 Radionuclide Air Emissions Annual Report under Subpart H of 40 CFR Part 61,” DOE memorandum (1993).

1.3.1 Building 1 (Donner Laboratory)

Scientists at Donner Laboratory conduct research in nuclear medicine through the use of new chemical probes and new instrumentation for applications to aging, atherosclerosis, and cancer. The building is located at the eastern edge of the UC Berkeley campus. The predominant radionuclides used are ^{14}C , ^3H , ^{125}I , ^{32}P , and ^{35}S as labeled amino acids and DNA precursors. Many UC Berkeley campus employees share this building for various other research activities. Work is mostly done on bench tops and in hoods. Emissions are from building vents and hoods.

In 2002, most potential release points at Building 1 were classified as Category V, for which the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. Three stacks in Building 1 were sampled and analyzed monthly for ^{125}I , ^{14}C , gross alpha, gross beta, and tritium. For conservatism in estimating the dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 6.

Table 6. Building 1 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
18	10	ESE	UC Berkeley	^{14}C	9.01×10^{-4}	2.3×10^{-5}	1.2
				^3H	6.25×10^{-5}	5.7×10^{-8}	< 0.1
				^{125}I	4.12×10^{-4}	1.6×10^{-3}	83.8
				^{32}P	1.90×10^{-5}	1.6×10^{-6}	< 0.1
				^{35}S	4.43×10^{-5}	1.0×10^{-6}	< 0.1
				Gross alpha (^{232}Th)	1.98×10^{-7}	2.7×10^{-4}	14.3
				Gross beta (^{90}Sr)	1.47×10^{-6}	8.8×10^{-6}	0.5
				Total		1.9×10^{-3}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

1.3.2 Building 3 (Calvin Laboratory)

The Calvin Laboratory conducts basic research on the dynamics of living cells and on the interaction of radiant energy with organic matter. The laboratory has made significant contributions to our understanding of the molecular mechanisms of photosynthesis and of the effects of environmental pollutants on plant and animal cells. As with Building 1, this building is located in the eastern portion of the UC Berkeley campus. The predominant radionuclides used are ^{32}P , ^{33}P , and ^{35}S as labeled amino acids and DNA precursors. Building 3 is occupied by Berkeley Lab and UC Berkeley personnel. Work is done on bench tops and in hoods. Emissions are from building vents and hoods.

In 2002, all potential release points in Building 3 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections.

No sampling or monitoring was required. For dose calculations, ^{32}P was used as a surrogate for ^{33}P , which is not included in the CAP88-PC library, because they have similar metabolic and radiological properties. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 7.

Table 7. Building 3 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
15	30	S	UC	^{32}P	1.5×10^{-6}	1.4×10^{-7}	75.2
			Berkeley	^{33}P (^{32}P)	2.5×10^{-7}	2.3×10^{-8}	12.5
				^{35}S	1.0×10^{-6}	2.2×10^{-8}	12.2
				Total		1.8×10^{-7}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

1.3.3 Building 6 (Advanced Light Source)

The Advanced Light Source (ALS) in Building 6 is one of the world's brightest synchrotron radiation sources, producing light in the extreme ultraviolet and soft x-ray regions of the spectrum. The ALS is a national user facility open to qualified scientists and engineers, in a broad range of disciplines, from national laboratories, private industry, and universities.

The ALS synchrotron accelerates electrons to 1.5 GeV, and the storage ring maintains a normal operating beam current of 400 mA at an energy between 1 and 2 GeV. The ALS produces neutrons during its operation, which activate the components of air in the injector vault. Because the ALS is a low-power accelerator, compared to Berkeley Lab's other accelerators such as the 88-Inch Cyclotron, its generation of air activation products is substantially lower. The maximum potential annual emissions of ^{13}N and ^{15}O (the most significant air activation products) are calculated to be 1.8×10^{-5} Ci (6.5×10^5 Bq) and 9.4×10^{-8} Ci (3.5×10^3 Bq), respectively.¹

At the ALS, the beam is under ultra-high vacuum within the beam enclosure. The beam enclosure is ventilated by a fan system to a roof stack. These stacks are not sampled or monitored because Building 6 potential release points are classified as Category V, and no special effluent holding or recovery systems are required for the ALS emissions.

The radionuclide inventory at Building 6 was controlled by radiation work authorizations and permits and by periodic inspections. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 8.

¹ Donahue, R. "Air Activation in the ALS Storage Ring," Health Physics Note #191, Lawrence Berkeley National Laboratory, Berkeley, CA (April 8, 1991).

Table 8. Building 6 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
9	370	NNE	UC	¹³ N	1.8×10^{-5}	1.3×10^{-8}	99.7
			Lawrence Hall of Science	¹⁵ O	9.4×10^{-8}	5.5×10^{-11}	0.4
				Total		1.3×10^{-8}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

^d Includes progeny

1.3.4 Buildings 26 and 76 (Radioanalytical Laboratories)

In these buildings, low-activity radiochemical analyses of bioassay samples, work-place and environmental samples, and hazardous waste are performed by Berkeley Lab. In addition, Building 76 has some detector calibration sources. Trace quantities of radionuclides are used in sample spiking and standards preparation. Emissions are from building vents and hoods.

In 2002, potential release points within Buildings 26 and 76 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. No sampling or monitoring was required. Because all radioactive samples analyzed during the year were sent to the Hazardous Waste Handling Facility after analysis, the annual emissions were conservatively estimated as the amount sent as waste multiplied by the appropriate EPA-specified physical state factor (provided in 40 CFR Part 61, Appendix D). A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 9.

Table 9. Building 26/76 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
8	250	N	UC	¹⁴ C	3.5×10^{-10}	5.2×10^{-12}	< 0.1
			Lawrence Hall of Science	³ H	3.7×10^{-7}	2.7×10^{-10}	< 0.1
				²³⁸ Pu	1.0×10^{-11}	1.1×10^{-8}	< 0.1
				²³³ U	1.0×10^{-8}	4.6×10^{-6}	19.8
				⁹⁰ Sr ^d	4.0×10^{-12}	1.1×10^{-11}	< 0.1
				²⁴¹ Am	1.0×10^{-8}	1.8×10^{-5}	80.2
				Total		2.3×10^{-5}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

^d Includes progeny

1.3.5 Building 51B (Bevatron)

Building 51B is an open-sided storage and work area adjacent to the former Bevatron, an accelerator that ceased operating in 1993. In 2002, Building 51B was the site of various operations in preparation for the removal of excess material from the Bevatron complex. One such operation was the cutting of large steel slabs from the Heavy Ion Spectrometer System (HISS) magnet, some of which were expected to contain radionuclides as a result of activation during the Bevatron's operation. Although dust was controlled in part by a point-of-use filtered particulate collection system, the cutting operation released some airborne particulates. The emissions were quantified using measurements of the radionuclide concentration in the slag produced by cutting (0.14 pCi/g [5.2×10^{-3} Bq/g] of ^{60}Co) and conservative estimates of the volume of steel cut ($4.0 \times 10^4 \text{ in.}^3$ [$6.6 \times 10^5 \text{ cm}^3$]) and the amount of dust produced and released from Building 51B (1100 lb [500 kg]). A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 10.

Table 10. Building 51B Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
0	310	NNW	Residence	^{60}Co	7.0×10^{-8}	6.9×10^{-6}	100
					Total	6.9×10^{-6}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

1.3.6 Buildings 55, 56, and 64 (Center for Functional Imaging, Biomedical Isotope Facility, and Life Sciences Research)

In Building 56, researchers at the Biomedical Isotope Facility develop radiopharmaceuticals and advanced medical imaging technologies, including positron emission tomography (PET), single photon emission computed tomography (SPECT), and nuclear magnetic resonance imaging (MRI). Researchers apply these technologies to the study of heart disease, aging, neurological and psychiatric diseases, and cancer. Building 56 houses a small cyclotron to support such studies.

The Building 56 cyclotron accelerates protons to 11 MeV, with a normal operating beam current of 50 μA . The cyclotron produces ^{18}F , ^{11}C , ^{13}N , and ^{15}O for positron emission tomography and other experimental studies. In addition, in collaboration with the 88-Inch Cyclotron, the Building 56 cyclotron produces ^{11}C , ^{14}O , ^{15}O , ^{13}N , ^{17}F , and ^{18}F for the Berkeley Experiments with Accelerated Radioactive Species (BEARS) Project. All the potentially airborne radionuclides produced at Building 56 are positron emitters.

At the Building 56 cyclotron, the entire beam path is enclosed within shielding, and the enclosure is ventilated by a fan system to a roof stack. All emissions from the cyclotron enclosure are through the roof stack, which is monitored by a real-time positron detector. No special effluent holding or recovery systems are required for the cyclotron emissions.

A second stack at Building 56 is also continuously monitored for positron emitters using real-time radiation detectors. This stack exhausts lead-shielded glove boxes in Room 56-100, adjacent to the cyclotron enclosure, where positron-emitters produced in the cyclotron are handled.

The Building 56 cyclotron's safety systems (monitoring, filtration, isolation, safety interlocks, and ventilation) were designed to ensure that the facility has a negligible impact on the surrounding environment. In 1995, a safety analysis determined that the facility is designed and operated to maintain exposures to the public and the environment as low as reasonably achievable.

For dose calculations, all positron emissions measured in the Building 56 stack effluent are assumed to be ^{18}F . Fluorine-18 is an appropriate surrogate for radioisotopes of carbon, nitrogen, and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides. Annual ^{18}F emissions are overestimated because false-positive results occur when radionuclides absorb onto the real-time detectors, causing positive responses and dose estimates that are not correlated with laboratory activities. These false positives are included in the calculation of annual ^{18}F emissions. In 2003, changes to monitoring equipment are planned to reduce false positives.

At Building 55, the primary radiological activities carried out by life sciences researchers are positron emission tomography using ^{18}F (produced at the Building 56 cyclotron) and metabolic studies using ^{125}I . Other projects include a gene therapy study, work with ^{32}P to determine the metabolic fate of DNA-based imaging agents, and evaluation of cardiac kinetics using various radioactive tracers (such as ^{153}Gd , ^{103}Ru , $^{99\text{m}}\text{Tc}$, and ^{201}Tl). Work with radioactive iodine is done in a fume hood that is fitted with a high-efficiency particulate air (HEPA) filter and a tetraethylene diamine (TEDA)-doped carbon filter.

In 2002, ^{153}Gd and ^{201}Tl were among the radionuclides received for use at Building 55, but they are not included in the CAP88-PC library. To model the dose from these radionuclides, the surrogates ^{113}Sn and ^{67}Ga , respectively, were used. The surrogates are appropriate because they have similar metabolic and radiological properties to the received radionuclides. In 2002, one stack on Building 55 was sampled and analyzed monthly for ^{125}I , gross alpha, and gross beta. For conservatism in estimating the dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively.

In Building 64, life sciences researchers use ^{32}P to label probes for DNA analysis. In 2002, the potential release point in Building 64 was classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 11.

Table 11. Building 55/56/64 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
16	250	NNW	Residence	¹⁵³ Gd (¹¹³ Sn)	2.0×10^{-7}	1.6×10^{-8}	< 0.1
				³ H	1.5×10^{-6}	8.1×10^{-10}	< 0.1
				¹²³ I	6.5×10^{-5}	4.4×10^{-7}	< 0.1
				¹²⁵ I	5.6×10^{-4}	1.3×10^{-3}	14.3
				¹³¹ I	1.2×10^{-5}	9.1×10^{-6}	0.1
				³² P	7.5×10^{-7}	2.7×10^{-8}	< 0.1
				¹⁰³ Ru ^e	5.0×10^{-7}	5.7×10^{-8}	< 0.1
				^{99m} Tc	3.9×10^{-5}	1.6×10^{-8}	< 0.1
				²⁰¹ Tl (⁶⁷ Ga)	5.3×10^{-6}	2.0×10^{-8}	< 0.1
				Positrons (¹⁸ F)	4.1×10^0	7.6×10^{-3}	85.4
				Gross alpha (²³² Th)	2.5×10^{-8}	2.0×10^{-5}	0.2
				Gross beta (⁹⁰ Sr)	4.4×10^{-7}	1.1×10^{-6}	< 0.1
				Total		8.9×10^{-3}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

^e Includes progeny

1.3.7 Buildings 70 and 70A (Nuclear, Chemical, Life, and Earth Sciences and Environmental Energy Technology)

Nuclear Sciences Division programs include research in nuclear structure and reactions, relativistic nuclear collisions, nuclear and particle astrophysics, nuclear data evaluation, and nuclear theory. Chemical Sciences Division conducts research in the areas of chemical physics and the dynamics of chemical reactions, the structure and reactivity of transient species, electron spectroscopy, surface chemistry and catalysis, electrochemistry, chemistry of the actinide elements and their relationship to environmental and physiological issues, and atomic physics. Life Sciences Division programs include studies of tumor cells, DNA damage from radiation, and impacts of cosmic radiation exposure to astronauts. Earth Sciences Division and Environmental Energy Technology programs perform fundamental and applied research related to energy and environmental resources.

Programs carried out in these facilities include super-heavy nuclear studies, waste migration research using tracer amounts of radionuclides, nuclear chemistry experiments, analysis of activated geological samples, and radiation biology research. Research activities using radioactive material are carried out by various research groups in the many small laboratories within Buildings 70 and 70A.

In 2002, 33 potential release points in Buildings 70 and 70A were classified as Category V and the remaining 10 potential release points were sampled continuously and analyzed weekly or monthly. In addition to being continuously sampled, one stack on Building 70A was monitored for alpha-emitting radionuclides with a real-time, continuous air monitor. The greatest measured results, which were

from the continuous sampling system, were used to determine emissions from this stack. Sampled radionuclides include ^{125}I , ^{14}C , gross alpha, gross beta, and tritium.

In 2002, ^{49}Ca , ^{49}Sc , and ^{45}Ca were among the radionuclides received for use at Building 70, but they are not included in the CAP88-PC library. To model the dose from these radionuclides, the surrogates ^{92}Sr , ^{46}Sc , and ^{90}Sr , respectively, were used. The surrogates are appropriate because they have similar metabolic and radiological properties to the received radionuclides.

For conservatism in estimating dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. To evaluate this assumption, in 2002 the Berkeley Lab Low Background Facility analyzed samples from Buildings 70 and 70A by gamma spectroscopy to identify the radionuclides responsible for gross alpha and gross beta measurements. The results of gamma spectroscopy indicate that the radionuclides represented by gross alpha and gross beta measurements are actually lower-risk radionuclides such as daughters of ^{238}U (^{210}Pb) and ^{235}U (^{231}Pa), ^{241}Am , ^7Be , and ^{40}K . Thus, the use of the higher-risk radionuclides ^{232}Th and ^{90}Sr provides an upper-bound estimate of the effective dose equivalent.

A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 12.

Table 12. Building 70/70A Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
16	270	WSW	UC	¹⁴ C	2.1×10^{-4}	4.8×10^{-7}	0.3
			Berkeley dormitory	⁵⁹ Fe	1.0×10^{-6}	4.0×10^{-8}	< 0.1
				³ H	7.8×10^{-5}	6.4×10^{-9}	< 0.1
				²³⁷ Np	3.0×10^{-11}	5.0×10^{-9}	< 0.1
				³² P	3.0×10^{-6}	1.6×10^{-8}	< 0.1
				⁹⁹ Tc	8.2×10^{-7}	4.9×10^{-8}	< 0.1
				²³⁸ U ^e	7.1×10^{-8}	2.9×10^{-6}	1.5
				²³⁴ U	7.1×10^{-8}	3.2×10^{-6}	1.7
				²³⁵ U	7.1×10^{-8}	3.1×10^{-6}	1.6
				⁴⁹ Ca (⁹² Sr)	1.6×10^{-11}	9.3×10^{-15}	< 0.1
				⁴⁶ Sc	7.3×10^{-10}	8.8×10^{-11}	< 0.1
				⁴⁹ Sc (⁴⁶ Sc)	7.8×10^{-12}	9.4×10^{-13}	< 0.1
				⁴⁵ Ca (⁹⁰ Sr)	6.5×10^{-10}	2.5×10^{-10}	< 0.1
				⁶⁰ Co	4.7×10^{-11}	1.2×10^{-10}	< 0.1
				⁸⁶ Rb	1.0×10^{-10}	8.1×10^{-13}	< 0.1
				¹⁵² Eu	2.0×10^{-10}	5.2×10^{-10}	< 0.1
				¹⁴¹ Ce	3.5×10^{-11}	2.1×10^{-13}	< 0.1
				²³³ Pa	5.1×10^{-11}	4.4×10^{-13}	< 0.1
				¹²⁵ I	5.8×10^{-8}	2.1×10^{-8}	< 0.1
				Gross alpha (²³² Th)	1.4×10^{-6}	1.7×10^{-4}	93.2
				Gross beta (⁹⁰ Sr)	8.0×10^{-6}	3.1×10^{-6}	1.7
				Total		1.9×10^{-4}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

^e Includes progeny

1.3.8 Building 71 (Accelerator and Fusion Research)

Building 71 formerly housed the Heavy Ion Linear Accelerator (HILAC), which is no longer in operation. In 2002, the Laser Optics and Accelerator Systems Integrated Studies (L'OASIS) Group used the building for a low-voltage, laser-driven accelerator. This small accelerator operates at voltages too low to produce air activation products; however, in 2002 the accelerator was authorized to produce solid ¹⁸F on targets for use at other facilities. The potential release points in Building 71 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 13.

Table 13. Building 71 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
13	190	NNW	Residence	¹⁸ F	6.00×10^{-13}	1.3×10^{-15}	100
Total						1.3×10^{-15}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

1.3.9 Building 72 (Low-Background Facility)

The Low-Background Facility in Building 72 is used to perform gamma spectroscopy to characterize low-level radioactive material in support of low-activity materials certification, studies in cosmic ray and neutron activation, nuclear science experiments, and environmental health and safety activities. In 2002, ⁹⁷Zr was among the radionuclides received for use at Building 72, but it is not included in the CAP88-PC library. To model the dose from this radionuclide, the surrogate ⁹⁷Nb was used. The surrogate is appropriate because it has similar metabolic and radiological properties to the received radionuclide.

In 2002, potential release points in Building 72 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 14.

Table 14. Building 72 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
3	230	SSW	UC Berkeley	⁵¹ Cr	3.1×10^{-11}	4.7×10^{-13}	0.7
				⁵⁹ Fe	3.2×10^{-11}	2.4×10^{-11}	34.9
				⁹⁵ Zr ^e	2.4×10^{-11}	4.5×10^{-11}	63.9
				⁹⁷ Zr (⁹⁷ Nb)	3.7×10^{-11}	1.9×10^{-13}	0.3
Total						7.0×10^{-11}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

^e Includes progeny

1.3.10 Buildings 74, 83, and 84 (Human Genome Facility and Life Sciences)

Research in these buildings includes a wide variety of cell biology, virology, research medicine, and genomics projects. The Human Genome Center of Berkeley Lab is oriented almost exclusively toward developing and implementing methods for cost-effective and accurate high-throughput human DNA sequencing. Emissions from Building 74 come from hoods and stacks that vent individual workplaces. Buildings 83 and 84 vent through HEPA-filtered biological cabinets. When research

activities involve ¹²⁵I, they are normally carried out in TEDA-doped activated-carbon-filtered enclosures; however, no radioactive iodine was received in 2002.

In 2002, potential release points in Buildings 74, 83, and 84 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic inspections. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 15.

Table 15. Buildings 74/83/84 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
7	160	SSE	UC Berkeley	¹⁴ C	1.0×10^{-4}	1.4×10^{-5}	1.9
				³ H	1.0×10^{-2}	6.6×10^{-5}	9.0
				³² P	2.0×10^{-4}	8.4×10^{-5}	11.3
				³⁵ S	9.3×10^{-3}	5.8×10^{-4}	77.9
				Total		7.4×10^{-4}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

1.3.11 Building 75 (National Tritium Labeling Facility)

The National Tritium Labeling Facility (NTLF) was a national resource center funded by the National Institutes of Health and engaged in tritium-labeling research and development. The facility was mainly used for activities in which a wide variety of molecules were labeled with tritium and purified for further use in chemical, biochemical, and radiopharmaceutical studies. In fall 2001, the National Institutes of Health cancelled its funding of the NTLF. The facility ceased labeling operations in December 2001 and reduced its tritium inventory by 90%. By the end of 2002, closure activities that included removal of radioactive material, dismantling and disposition of equipment, and decontamination and decommissioning of the laboratories, outdoor facilities, and ancillary spaces were complete.

There are two stacks associated with NTLF activities: one on the northern hillside near Building 75 and one on the roof of Building 75. In 2002, continuous sampling with subsequent laboratory analysis was performed on both stacks. Emissions were in the form of gaseous tritium (about 10% of the total) and tritiated water (about 90% of the total). Gaseous tritium emissions were assessed as tritiated water even though their impacts through inhalation are about 0.01% of those of comparable emissions of tritiated water, resulting in a conservative overestimate of dose. In addition to continuous sampling, real-time monitoring was performed continuously on the hillside stack as a back-up to sampling and to determine more precisely when peak emissions occurred.

Approximately 80% of tritium emissions at Berkeley Lab come from the hillside stack. This stack is the closest discharge point to the off-site maximally exposed individual located at the UC Lawrence

Hall of Science, 110 m northwest of Building 75. The other discharge point on the roof of Building 75 is farther from the UC Lawrence Hall of Science.

For many years, Berkeley Lab overestimated the dose to the maximally exposed individual by not taking into account the momentum effect of effluent velocity (that is, stack effluent exit velocity was set to zero) in the CAP88-PC computer model. As recommended by EPA,¹ starting in 1998 Berkeley Lab began including the momentum effect (that is, the actual stack effluent exit velocity was applied) in the CAP88-PC computer model to more closely reflect the physical conditions of the hillside stack exhaust. Since 2001, the effluent exit velocity and stack diameter of each of the two NTLF stacks have also been taken into account, although CAP88-PC assumes conservatively that both are at the location of the hillside stack, which is closest to the UC Lawrence Hall of Science.

Building 75 is the only source at Berkeley Lab that historically resulted in more than 1% of the NESHAP effective dose equivalent standard of 10 mrem/y. There was no unplanned release from the NTLF in 2002. The maximally exposed individual for this source was also the maximally exposed individual for the entire Berkeley Lab site in 2002. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 16.

Table 16. Building 75 (NTLF) Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
8.5	110	NW	UC	³ H	6.1×10^0	1.3×10^{-2}	100
6.7	110	NW	Lawrence Hall of Science	³ H	1.4×10^0		
					Total	1.3×10^{-2}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

1.3.12 Building 75 (Other Than NTLF), 75S, and 75A

In 1997, Berkeley Lab's Hazardous Waste Handling Facility in Buildings 75A and part of Building 75 (Room 127) was moved to its present location at Building 85. In 2002, Building 75A was used for radiological characterization of large items in preparation for recycling, reuse, and repackaging. Building 75, Room 127, is used only for gamma spectroscopy of sealed material, but the ductwork in this room continues to be contaminated with low levels of tritium, probably from past handling of hazardous waste. Other rooms in Building 75 are used for tritium calorimetry and storage of tritium-contaminated items. In 2002, Building 75S was a storage locker used to hold tritium-contaminated waste until it was shipped for disposal. The exhaust from this locker was sampled for tritium until the locker was decontaminated and removed in August 2002. A summary of the CAP88-PC source term

¹ Rosenblum, S., and R. Lessler (EPA). Telephone conversation with S. Black (DOE), and R. Pauer, L. Wahl, M. Ruggieri (LBNL) (May 15, 2002).

input parameters and effective dose equivalent from Building 75 (other than NTLF), 75A, and 75S is presented in Table 17.

Table 17. Buildings 75 (Other), 75A, and 75S Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y) ^b	Local MEI dose (mrem/y) ^c	Percent of Total Dose (%)
7	150	NW	UC Lawrence Hall of Science	³ H	6.6×10^{-2}	2.7×10^{-4}	100
					Total	2.7×10^{-4}	100%

^a MEI = maximally exposed individual

^b 1 Ci = 3.7×10^{10} Bq

^c 1 mrem = 1.0×10^{-2} mSv

1.3.13 Building 85 (Hazardous Waste Handling Facility)

Berkeley Lab waste operations moved to the newly constructed Hazardous Waste Handling Facility at Building 85 in mid-1997. Radioactive and hazardous waste generated by Berkeley Lab research and support operations is sent to Building 85, where it is processed for shipping to off-site disposal facilities.

In 2002, this building had two stacks equipped with continuous air sampling systems to collect alpha- and beta-emitting radionuclides, ¹⁴C, ¹²⁵I, and tritium. For conservatism in estimating the dose, ²³²Th and ⁹⁰Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 85 is presented in Table 18.

Table 18. Building 85 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
16	210	SSE	UC Berkeley	¹⁴ C	7.0×10^{-2}	2.5×10^{-3}	70.1
				³ H	3.7×10^{-1}	4.7×10^{-4}	13.3
				¹²⁵ I	2.6×10^{-6}	1.4×10^{-5}	0.4
				Gross alpha (²³² Th)	2.9×10^{-7}	5.6×10^{-4}	16.0
				Gross beta (⁹⁰ Sr)	8.5×10^{-7}	5.0×10^{-6}	0.1
					Total	3.5×10^{-3}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

1.3.14 Building 88 (88-Inch Cyclotron)

The 88-Inch Cyclotron at Building 88 accelerates beams from hydrogen to uranium in support of national programs in nuclear science, biology, medicine, and industrial applications. The energy of the cyclotron's beam depends on the ion being accelerated. For example, protons, which are light ions, are accelerated to 65 MeV; ^{209}Bi , a heavy ion, is accelerated to 1.6 GeV. The normal operating current of the beam is 100 μA .

The ions accelerated in the cyclotron may be radioactive, and the targets that the ion beam strikes may also be radioactive. Use of these radionuclides is authorized by radiation work authorizations. In addition, the cyclotron produces neutrons during its operation, which can activate air. The major air activation products produced by the cyclotron are ^{11}C , ^{13}N , and ^{15}O , all positron-emitting radionuclides.

The cyclotron is enclosed within a vault, and the vault is ventilated by a fan system to a roof stack. Emissions from the roof stack are monitored by a real-time positron detector. For projects that accelerate radioactive gases, an effluent-holding system in the cyclotron pit collects and stores vacuum pump exhaust in holding bags until the short-lived radionuclides have decayed.

Emissions in 2002 were estimated based on radionuclide receipts, emissions measurements from three stacks that were sampled for alpha- and beta-emitting radionuclides, and positron emissions measurements from the stack that exhausts the cyclotron vault. In 2002, ^{97}Zr and ^{88}Y were among the radionuclides received for use at Building 88, but they are not included in the CAP88-PC library. To model the dose from these radionuclides, the surrogates ^{97}Nb and ^{90}Y , respectively, were used. These surrogates are appropriate because they have similar metabolic and radiological properties to the received radionuclides.

For conservatism in estimating the dose, all positron emitters from this facility were assumed to be ^{11}C , and alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr , respectively. Carbon-11 is an appropriate surrogate for radioisotopes of nitrogen and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 19.

Table 19. Building 88 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI ^a Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide (Surrogate) ^b	Annual Emission (Ci/y) ^c	Local MEI dose (mrem/y) ^d	Percent of Total Dose (%)
13	110	W	Residence	Positron emitters (¹¹ C)	1.7×10^{-1}	1.6×10^{-4}	50.7
				⁵⁵ Fe	1.1×10^{-12}	5.9×10^{-15}	< 0.1
				⁵¹ Cr	2.5×10^{-12}	7.9×10^{-15}	< 0.1
				⁵⁹ Fe	2.6×10^{-12}	4.2×10^{-13}	< 0.1
				⁹⁵ Zr ^e	2.0×10^{-12}	3.1×10^{-13}	< 0.1
				⁹⁷ Zr (⁹⁷ Nb)	3.0×10^{-12}	2.7×10^{-15}	< 0.1
				⁸⁸ Y (⁹⁰ Y)	4.0×10^{-12}	5.6×10^{-14}	< 0.1
				Gross alpha (²³² Th)	2.9×10^{-7}	1.6×10^{-4}	48.9
				Gross beta (⁹⁰ Sr)	1.0×10^{-6}	1.6×10^{-6}	0.5
				Total		3.2×10^{-4}	100%

^a MEI = maximally exposed individual

^b For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^c 1 Ci = 3.7×10^{10} Bq

^d 1 mrem = 1.0×10^{-2} mSv

^e Includes progeny

AIR EMISSIONS DATA

Source and emission control information are summarized in Table 20.

Table 20. Sources and Emission Controls In 2002

Source	Number of Potential Release Points	Type of Control	Efficiency (%)	Distance to Nearest Receptor ^a
Point Sources				
Building 1	10	None ^b	NA ^c	10 m (classrooms in same building)
Building 3	2	None ^b	NA	30 m (UC Berkeley)
Building 6	9	None ^d	NA	370 m (UC Lawrence Hall of Science)
Building 71	1	None	NA	190 m (Residence)
Building 72	1	None	NA	230 m (UC Berkeley)
Building 75 (NTLF)	2	Silica Gel ^e	>99	110 m (UC Lawrence Hall of Science)
		Molecular Sieve ^e	>99	
		Bubbler	>99	
Building 85	2	HEPA ^f	>99	210 m (UC Berkeley)
		TEDA-DAC ^g	>75	
Building 88	17	HEPA	>99	110 m (Residence)
		TEDA-DAC	>75	
Grouped Sources				
Buildings 26/76	4	HEPA	>99	250 m (UC Lawrence Hall of Science)
Buildings 55/56/64	14	HEPA	>99	250 m (Residence)
		TEDA-DAC ^h	>75	
Buildings 70/70A	43	HEPA	>99	270 m (UC Berkeley Dormitory)
		None ⁱ	NA	
Buildings 74/83/84	29	HEPA	>99	160 m (UC Berkeley)
		TEDA-DAC	>75	
Buildings 75 (Other)/75A/75S	7	HEPA	> 75	150 m (UC Lawrence Hall of Science)
		None	NA	
Area Sources				
Building 51B	1	HEPA ^j	≈ 50	310 m (Residence)

^a 1 m = 3.281 ft

^b Emissions are from Berkeley Lab fume hoods, which do not require filtration for the small radionuclide amounts used.

^c Not applicable

^d Radionuclides emitted from accelerators are short-lived air activation products, for which emission control is impractical.

^e In place during Phase I of NTLF clean-up. Silica gel and molecular sieve traps are more than 99% efficient for trapping tritiated water vapor when they are changed before breakthrough. Research personnel regularly change traps when working in the facility.

^f High-efficiency particulate air (HEPA)

^g Tetraethylene diamine (TEDA)-doped activated carbon traps

^h TEDA-DAC filters at Building 55 only

ⁱ Stacks included in this group vent a number of laboratories whose research employs microcurie and millicurie quantities (between 3.7×10^4 and 3.7×10^7 Bq) of a number of actinides. The most conservative dose-equivalent representative of the actinides was used.

^j HEPA-filtered particulate collection system efficiency is approximate

Quantities of radionuclides potentially emitted from Berkeley Lab sources in 2002 are presented in Table 21.

Table 21. Airborne Radioactivity Potentially Emitted In 2002

Radionuclide (Surrogate) ^a	Activity Potentially Emitted		Total (%)
	(Ci/y)	(Bq/y)	
³ H	7.9×10^0	2.9×10^{11}	64.3
¹⁸ F	4.1×10^0	1.5×10^{11}	33.6
¹¹ C	1.7×10^{-1}	6.3×10^9	1.4
¹⁴ C	7.1×10^{-2}	2.6×10^9	0.6
³⁵ S	9.3×10^{-3}	3.5×10^8	0.1
¹²⁵ I	9.7×10^{-4}	3.6×10^7	< 0.1
³² P	2.6×10^{-4}	9.6×10^6	< 0.1
¹²³ I	6.5×10^{-5}	2.4×10^6	< 0.1
^{99m} Tc	3.9×10^{-5}	1.4×10^6	< 0.1
¹³ N	1.8×10^{-5}	6.7×10^5	< 0.1
¹³¹ I	1.2×10^{-5}	4.4×10^5	< 0.1
Beta (⁹⁰ Sr)	1.2×10^{-5}	4.4×10^5	< 0.1
²⁰¹ Tl (⁶⁷ Ga)	5.3×10^{-6}	2.0×10^5	< 0.1
Alpha (²³² Th)	2.2×10^{-6}	8.2×10^4	< 0.1
⁵⁹ Fe	1.0×10^{-6}	3.7×10^4	< 0.1
⁹⁹ Tc	8.2×10^{-7}	3.0×10^4	< 0.1
¹⁰³ Ru ^b	5.0×10^{-7}	1.9×10^4	< 0.1
³³ P (³² P)	2.5×10^{-7}	9.3×10^3	< 0.1
¹⁵³ Gd (¹¹³ Sn)	2.0×10^{-7}	7.4×10^3	< 0.1
¹⁵ O	9.4×10^{-8}	3.5×10^3	< 0.1
²³⁸ U ^b	7.1×10^{-8}	2.6×10^3	< 0.1
²³⁴ U	7.1×10^{-8}	2.6×10^3	< 0.1
²³⁵ U	7.1×10^{-8}	2.6×10^3	< 0.1
⁶⁰ Co	7.0×10^{-8}	2.6×10^3	< 0.1
²⁴¹ Am	1.0×10^{-8}	3.7×10^2	< 0.1
²³³ U	1.0×10^{-8}	3.7×10^2	< 0.1
⁴⁶ Sc	7.3×10^{-10}	2.7×10^1	< 0.1
⁴⁵ Ca (⁹⁰ Sr)	6.5×10^{-10}	2.4×10^1	< 0.1
¹⁵² Eu	2.0×10^{-10}	7.4×10^0	< 0.1
⁸⁶ Rb	1.0×10^{-10}	3.7×10^0	< 0.1
²³³ Pa	5.1×10^{-11}	1.9×10^0	< 0.1
⁹⁷ Zr (⁹⁷ Nb)	4.0×10^{-11}	1.5×10^0	< 0.1
¹⁴¹ Ce	3.5×10^{-11}	1.3×10^0	< 0.1
⁵¹ Cr	3.3×10^{-11}	1.2×10^0	< 0.1
²³⁷ Np	3.0×10^{-11}	1.1×10^0	< 0.1
⁹⁵ Zr ^b	2.6×10^{-11}	9.6×10^{-1}	< 0.1
⁴⁹ Ca (⁹² Sr)	1.6×10^{-11}	5.9×10^{-1}	< 0.1
²³⁸ Pu	1.0×10^{-11}	3.7×10^{-1}	< 0.1
⁴⁹ Sc (⁴⁶ Sc)	7.8×10^{-12}	2.9×10^{-1}	< 0.1
⁹⁰ Sr ^b	4.0×10^{-12}	1.5×10^{-1}	< 0.1
⁸⁸ Y (⁹⁰ Y)	4.0×10^{-12}	1.5×10^{-1}	< 0.1
⁵⁵ Fe	1.1×10^{-12}	4.1×10^{-2}	< 0.1
Total	1.2×10^1	4.5×10^{11}	100%

^a For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^b Includes progeny

DOSE ASSESSMENTS

- 3.1 DESCRIPTION OF DOSE MODEL
- 3.2 SUMMARY OF INPUT PARAMETERS
- 3.3 COMPLIANCE ASSESSMENT
- 3.4 CERTIFICATION

3.1 DESCRIPTION OF DOSE MODEL

To meet DOE guidance, the EPA atmospheric dispersion and radiation dose calculation computer code, CAP88-PC, Version 2.0, was used to calculate the effective dose equivalent to an individual within each population segment at various distances and from various release points. A total of 14 CAP88-PC individual runs were executed to model the 14 point, group, and area sources described in Section I. As discussed previously, the NTLF in Building 75 was identified as the major release point at Berkeley Lab. Therefore, the maximally exposed individual associated with this facility was also specified (with appropriate distances and directions) in each of the 14 individual CAP88-PC runs. The reported effective dose equivalent to the maximally exposed individual at Berkeley Lab includes contributions from all 14 CAP88-PC models (Table 22).

Collective population dose is calculated as the average radiation dose to an individual in a specified area, multiplied by the number of individuals in that area. All radionuclides potentially emitted in 2002 (Table 21) were assumed to be released from the major release point, the NTLF's hillside stack. Because CAP88-PC can only model 36 radionuclides at a time, the population dose assessment was performed with two population runs, and the results of the two runs were summed. A summary of the collective dose assessment attributed to each potentially emitted radionuclide is given in Table 23.

Input to the CAP88-PC calculations of individual and population dose were reviewed and verified by a consultant to Berkeley Lab. The consultant independently ran the CAP88-PC code using Berkeley Lab's source terms and meteorological data to validate the dose calculations. The consultant determined that the dose calculations are in compliance with 40 CFR 61, Subpart H.

Table 22. Summary of Dose Assessment from All Berkeley Lab Sources

			Relative to the Specified Building				Relative to the MEI ^a of Building 75 (NTLF)			
Building Number	Building Name/Function	Release Height (m)	Local MEI		Local MEI Dose (mrem/y) ^b	Bldg 75 (NTLF) MEI		Bldg 75 (NTLF) MEI Dose (mrem/y)	% Total Dose ^c	
			Distance (m)	Dir.		Distance (m)	MEI Dir.			
1	Donner Lab at UC Berkeley	18	10	ESE	UC Berkeley	1.9 × 10 ⁻³	990	ENE	1.9 × 10 ⁻³	6.3
3	Calvin Lab at UC Berkeley	15	30	S	UC Berkeley	1.8 × 10 ⁻⁷	1060	NE	1.7 × 10 ⁻⁷	< 0.1
6	Advanced Light Source (ALS)	9	370	NNE	UC Lawrence Hall of Science	1.3 × 10 ⁻⁸	370	NNE	1.3 × 10 ⁻⁸	< 0.1
26/76	Radioanalytical Lab	8	250	N	UC Lawrence Hall of Science	2.3 × 10 ⁻⁵	250	N	2.3 × 10 ⁻⁵	0.1
51B	Bevatron	0	310	NNW	Residence	6.9 × 10 ⁻⁶	440	E	3.6 × 10 ⁻⁶	< 0.1
55/56/64	Center for Functional Imaging/Biomedical Isotope Facility/Life Sciences	16	250	NNW	Residence	8.9 × 10 ⁻³	460	E	1.0 × 10 ⁻²	33.0
70/70A	Nuclear/Chemical/Life/Earth/Environmental Sciences	16	270	WSW	UC Berkeley Dormitory	1.8 × 10 ⁻⁴	530	ENE	4.9 × 10 ⁻⁴	1.6
71	Accelerator & Fusion Research	13	190	NNW	Residence	1.3 × 10 ⁻¹⁵	310	ESE	2.5 × 10 ⁻¹⁵	< 0.1
72	Low-Background Facility	3	230	SSW	UC Berkeley	7.0 × 10 ⁻¹¹	500	NW	8.7 × 10 ⁻¹¹	< 0.1
74/83/84	Human Genome Facility/Life Sciences	7	160	SSE	UC Berkeley	7.3 × 10 ⁻⁴	690	WNW	7.1 × 10 ⁻⁴	2.3
75 (NTLF)	National Tritium Labeling Facility (NTLF)	8.5 ^d 6.7 ^e	110	NW	UC Lawrence Hall of Science	1.3 × 10 ⁻²	110	NW	1.3 × 10 ⁻²	42.9
75 (Other)/75A/75S	Old Hazardous Waste Facility/Storage Locker	7	150	NW	UC Lawrence Hall of Science	2.7 × 10 ⁻⁴	150	NW	2.7 × 10 ⁻⁴	0.9
85	New Hazardous Waste Handling Facility	16	210	SSE	UC Berkeley	3.5 × 10 ⁻³	570	WNW	3.7 × 10 ⁻³	12.2
88	88-Inch Cyclotron	13	110	W	Residence	3.2 × 10 ⁻⁴	690	ENE	1.8 × 10 ⁻⁴	0.6
							Total		3.0 × 10⁻²	100%

^a MEI = maximally exposed individual

^b 1 mrem = 1.0 × 10⁻² mSv

^c Effective dose equivalent

^d NTLF hillside stack

^e NTLF rooftop stack

Table 23. Summary of Collective Dose to the Population within 80 km of Berkeley Lab

Radionuclide ^a (Surrogate)	Collective Dose (person-rem/y) ^b	% of Total
³ H	1.5×10^{-1}	46.1
¹⁸ F	9.6×10^{-2}	30.4
Alpha (²³² Th)	4.2×10^{-2}	13.2
¹⁴ C	2.5×10^{-2}	7.9
¹²⁵ I	3.3×10^{-3}	1.0
¹¹ C	1.2×10^{-3}	0.4
³⁵ S	9.2×10^{-4}	0.3
²³⁴ U	5.0×10^{-4}	0.2
²³⁵ U	4.7×10^{-4}	0.1
²³⁸ U ^c	4.4×10^{-4}	0.1
Beta (⁹⁰ Sr)	4.1×10^{-4}	0.1
²⁴¹ Am	2.9×10^{-4}	0.1
³² P	1.5×10^{-4}	< 0.1
²³³ U	7.1×10^{-5}	< 0.1
⁶⁰ Co	3.0×10^{-5}	< 0.1
¹³¹ I	2.3×10^{-5}	< 0.1
⁵⁹ Fe	6.3×10^{-6}	< 0.1
⁹⁹ Tc	4.9×10^{-6}	< 0.1
¹²³ I	2.0×10^{-6}	< 0.1
¹⁰³ Ru ^c	1.4×10^{-6}	< 0.1
²³⁷ Np	7.8×10^{-7}	< 0.1
²⁰¹ Tl (⁶⁷ Ga)	4.9×10^{-7}	< 0.1
^{99m} Tc	3.0×10^{-7}	< 0.1
¹⁵³ Gd (¹¹³ Sn)	2.3×10^{-7}	< 0.1
²³⁸ Pu	1.7×10^{-7}	< 0.1
³³ P	1.5×10^{-7}	< 0.1
¹⁵² Eu	9.0×10^{-8}	< 0.1
¹³ N	6.5×10^{-8}	< 0.1
⁴⁵ Ca (⁹⁰ Sr)	2.2×10^{-8}	< 0.1
⁴⁶ Sc	1.4×10^{-8}	< 0.1
⁹⁵ Zr ^c	1.6×10^{-10}	< 0.1
⁴⁹ Sc (⁴⁶ Sc)	1.5×10^{-10}	< 0.1
⁹⁰ Sr ^c	1.4×10^{-10}	< 0.1
⁸⁶ Rb	9.3×10^{-11}	< 0.1
²³³ Pa	6.5×10^{-11}	< 0.1
¹⁵ O	5.5×10^{-11}	< 0.1
¹⁴¹ Ce	3.0×10^{-11}	< 0.1
⁵¹ Cr	4.1×10^{-12}	< 0.1
⁸⁸ Y (⁹⁰ Y)	1.9×10^{-12}	< 0.1
⁴⁹ Ca (⁹² Sr)	9.2×10^{-13}	< 0.1
⁹⁷ Zr (⁹⁷ Nb)	5.7×10^{-13}	< 0.1
⁵⁵ Fe	1.5×10^{-13}	< 0.1
Total	3.2×10^{-1}	100%

^a For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

^b 1 person-rem = 1×10^{-2} person-Sv

^c Includes progeny

3.2 SUMMARY OF INPUT PARAMETERS

Run options for CAP88-PC individual dose assessments include distances to receptors. Twenty such distances were specified, including distance to the nearest local receptor, the residence nearest the 88-Inch Cyclotron, the residence nearest the Building 56 accelerator, and the Lawrence Hall of Science (the MEI). To estimate population dose, a new population file was prepared in 2002. The new population file is based on the LandScan Global Population Database for 2001, which is more comprehensive than 2000 census data because it considers not only residents but also workers and commuters and it has finer resolution. The population within 50 miles (80 km) of Berkeley Lab increased from 5,038,800 (based on the 1980 census) to 6,614,934 (based on 2001 LandScan data). Use of the LandScan database was documented in *Health Physics*, Volume 83, Number 2, pages 283—286 (August 2002).

Meteorological data were compiled from on-site data for 2002. Berkeley Lab began collecting this data in early 1994 at a 6-ft (20-m) tower located in the central portion of the Laboratory. The 2002 meteorological data is maintained in the NESHAP files.

Source data include source height, diameter, and exit velocity. Momentum plume rise was chosen for all sources. Release heights are shown in Table 22. For all point and group sources, except the former NTLF, other stack input parameters were 4 in. (0.1 m) diameter and 0 m/s exit velocity. At the former NTLF, input parameters for the hillside stack were 3 ft (0.91 m) diameter and 25.1 ft/s (7.66 m/s) exit velocity and for the roof stack were 1.7 ft (0.53 m) diameter and 18.7 ft/s (5.69 m/s) exit velocity. For the area source Building 51B, input parameters were 1076 ft² (100 m²) area and 0 m/s momentum.

Agricultural data were the CAP88-PC default values for an urban scenario, which is appropriate for the Berkeley Lab site.

Nuclide data for the 2002 radioactive air emissions were either measured or conservatively derived based on the inventory received during the year and are shown in Table 21 in Section II. Surrogates were chosen as described in Section 1.3. To estimate population dose, two CAP88-PC runs were performed based on the input parameters from the NTLF individual dose assessment, with the source term replaced by all the radionuclides listed in Table 21. One run included all radionuclides in Table 21 through ²³⁸U; the second run included ⁶⁰Co and all subsequent radionuclides. The results of the two runs were summed.

3.3 COMPLIANCE ASSESSMENT

This compliance assessment used the computer code CAP88-PC, Version 2.0, to calculate the effective dose equivalent to an off-site, maximally exposed individual. This exposure represents the sum of impacts from all 14 sources modeled to that location (the maximally exposed individual for the former NTLF). A summary of the dose assessment for each source is presented in Table 22.

Effective dose equivalent: 0.03 mrem/year (3.0×10^{-4} mSv/year)

Location of maximally exposed individual: UC Lawrence Hall of Science at 110 m northwest of Building 75

3.4 CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (See, 18 U. S. C. 1001).

Signature: Robin Wendt, for Date: 6/9/2003
David C. McGraw
Division Director, Environment, Health, and Safety

Signature: Hattie Carwell Date: 6/13/03
for Richard H. Nolan
Director, DOE Berkeley Site Office

ADDITIONAL INFORMATION

4.1 ADDITIONS OR MODIFICATIONS

4.2 UNPLANNED RELEASES

4.3 DIFFUSE EMISSIONS

4.1 ADDITIONS OR MODIFICATIONS

There were no facility additions or modifications in 2002. There were, however, changes in source measurement and reporting in 2002, based primarily on changes in work authorized. Changes from last year's report include addition and deletion of stack sampling locations.

4.1.1 New Sampling Locations

Four new sampling locations were added in 2002. Results of sampling at these locations are included in the source descriptions (Section 1.3).

- At Building 70, sampling began on a stack that exhausts glove boxes in Room 203. The glove boxes, which are old and currently used either for storage or not at all, are slated for decontamination and decommissioning. Sampling also began on the stack that exhausts fume hoods in Room 209, which are authorized for use along with fume hoods in Room 203.
- At Building 75, sampling and analysis began in Room 112B, where tritium calorimetry is performed.
- At Building 88, sampling began on a stack that exhausts a fume hood in the East Alley Mezzanine. Operations in the fume hood include authorized work with actinides.

4.1.2 Deleted Sampling Locations

In 2002, three sampling locations were deleted.

- At Building 1, work with radionuclides was no longer performed in Room 216.
- At Building 70, a fume hood in Room 157 was decontaminated, decommissioned, and removed.
- Building 75S, a storage locker used to hold tritium-contaminated waste until it was shipped for disposal, was decontaminated and removed in August 2002

4.2 UNPLANNED RELEASES

There were no unplanned releases in 2002.

4.3 DIFFUSE EMISSIONS

In 2002, one area source was identified that potentially presented a source of fugitive emissions to the maximally exposed individual. The source was a steel-cutting operation at Building 51B, a one-time activity that will not present diffuse emissions in the future. The source is discussed further in “Source Description.”

SUPPLEMENTAL INFORMATION

- 5.1 DOSE ESTIMATE
- 5.2 RADON EMISSIONS
- 5.3 EMISSION POINTS

5.1 DOSE ESTIMATE

Provide an estimate of collective effective dose equivalent (person-rem/y) for 2002 releases.

The estimated collective effective dose equivalent to persons living within 80 km of Berkeley Lab is 0.3 person-rem (0.003 person-Sv) attributable to 2002 Berkeley Lab airborne emissions (see Table 23).

5.2 RADON EMISSIONS

Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61, if applicable. Although exempt from Subpart H, provide information on ^{220}Rn emission from sources containing ^{232}U and ^{232}Th where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public. Provide information on nondisposal/nonstorage sources of ^{222}Rn emissions where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public.

Subparts Q and T of 40 CFR 61 are not applicable to Berkeley Lab, as the Laboratory does not process, manage, or possess uranium mill tailings, ^{226}Ra , ^{232}U , or ^{232}Th , in quantities that could produce an impact of 0.1 mrem/y (1×10^{-6} Sv/y) to a member of the public.

5.3 EMISSION POINTS

For the purpose of assessing facility compliance with the NESHAP effluent monitoring requirements of Subpart H under Section 61.93(b), give the number of emission points subject to the continuous monitoring requirements, the number of these emission points that do not comply with the Section 61.93(b) requirements, and if possible, the cost for upgrades. Describe site periodic confirmatory measurement plans. Indicate the status of the QA program described by Appendix B, Method 114.

In 2002, no potential release points produced emissions exceeding 0.1 mrem/y (1.0×10^{-3} mSv/y). For the first part of 2002, Berkeley Lab identified one source subject to the continuous monitoring requirements of 40 CFR, Subpart H, Section 61.93(b). By the end of 2002, however, that source had been greatly reduced and was no longer subject to continuous monitoring requirements. The Category

I source at Berkeley Lab was the Building 75 (NTLF) hillside stack and the effective dose equivalent to the maximally exposed individual was modeled at 1.3×10^{-2} mrem/y (1.3×10^{-4} mSv/y) for 2002.

Berkeley Lab's sampling, monitoring, and analytical methods fully conform to Section 61.93(b) requirements. Berkeley Lab has a) identified all potential release points and evaluated emissions, b) categorized potential release points by effective dose equivalent, and c) suggested suitable measurement methodology for each point.

The program meets or exceeds all provisions contained in Appendix B, Method 114. The current Berkeley Lab *Environmental Monitoring Plan* and Environmental Services Group procedures contain quality assurance elements consistent with Method 114. Berkeley Lab's *Quality Assurance Project Plan for Radionuclide NESHAP* was originally developed and approved in August 1994 and was most recently revised in November 2001.