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Radionuclide Air Emission Report for 2012

Prepared by
Environment / Health / Safety / Safety Division
Environmental Services Group

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U.S. Department of Energy
Radionuclide Air Emission Report for 2012
(in compliance with 40 CFR 61, Subpart H)

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Preface

As a U.S. Department of Energy (DOE) facility whose operations involve the use of radionuclides, Berkeley Lab is subject to U.S. Environmental Protection Agency (EPA) radioactive air emission regulations that are found in the Code of Federal Regulations (CFR) Title 40, Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA 1989a). Subpart H of this regulation (subsequently referred to as NESHAP) establishes standards for exposure of the public to radionuclides (other than radon) released from DOE facilities. This regulation limits the emission of radionuclides to the environment from DOE facilities. Such emissions may not exceed amounts that would cause any member of the public to receive an effective dose equivalent (subsequently referred to as dose) of 10 mrem/yr (0.1 mSv/yr).

Under the NESHAP regulation, DOE facilities are required to submit an annual report each year. The NESHAP regulation specifies the content of the report and DOE provides further guidance (DOE 1994). This document is Berkeley Lab's annual report of radionuclide air emissions for 2012 and meets the NESHAP requirements for reporting. This report can be found on the Laboratory's website at http://www.lbl.gov/ehs/esg/Reports/tableforreports.shtml.

Executive Summary

Berkeley Lab operates facilities where radionuclides are produced, handled, stored, and potentially emitted. These facilities are subject to the EPA radioactive air emission regulations in 40 CFR 61, Subpart H (EPA 1989a). Radionuclides may be emitted from stacks or vents on buildings where radionuclide production or use is authorized or they may be emitted as diffuse sources. In 2012, all Berkeley Lab sources were minor sources of radionuclides (sources resulting in a potential dose of less than 0.1 mrem/yr [0.001 mSv/yr]). These minor sources included about 140 stack sources and no diffuse sources. There were no unplanned airborne radionuclide emissions from Berkeley Lab operations. Emissions from minor sources were measured by sampling or monitoring or were calculated based on quantities used, received for use, or produced during the year. Using measured and calculated emissions, and building-specific and common parameters, Laboratory personnel applied the EPA-approved computer codes, CAP88-PC and COMPLY, to calculate doses to the maximally exposed individual (MEI) at any offsite point where there is a residence, school, business, or office. Because radionuclides are used at three noncontiguous locations (the main site, Berkeley West Biocenter, and Joint BioEnergy Institute), three different MEIs were identified.

The dose from all sources at the Berkeley Lab main site in 2012 was 5.6×10^{-3} mrem/yr (5.6×10^{-5} mSv/yr) to the MEI, well below the 10 mrem/yr (0.1 mSv/yr) dose standard. The location of this MEI is at the University of California (UC) Lawrence Hall of Science, a public science museum about 1500 ft (460 m) east of Berkeley Lab's Building 56. The estimated collective dose to persons living within 50 mi (80 km) of the Berkeley Lab main site was 8.7×10^{-2} person-rem (8.7×10^{-4} person-Sv) attributable to the Lab's airborne emissions in 2012.

The dose from all sources at Berkeley Lab operations at the Berkeley West Biocenter (Building 977 at 717 Potter Street, Berkeley) in 2012 was 8.7×10^{-3} mrem/yr (8.7×10^{-5} mSv/yr) to the MEI, well below the 10 mrem/yr (0.1 mSv/yr) dose standard. The location of this MEI is in the Potter Street building (that is, the MEI is in the same building as the source of radioactive air emissions), about 98 ft (30 m) from the point where emissions from Berkeley Lab operations are released. The estimated collective dose to persons living within 50 mi (80 km) was 4.5×10^{-4} person-rem (4.5×10^{-6} person-Sv) attributable to the Lab's airborne emissions from Building 977 in 2012.

The dose from all sources at Berkeley Lab operations at the Joint BioEnergy Institute (Building 978 at 5885 Hollis Street, Emeryville) in 2012 was 3.4×10^{-4} mrem/yr (3.4×10^{-6} mSv/yr) to the MEI, well below the 10 mrem/yr (0.1 mSv/yr) dose standard. The location of this MEI is in the Hollis Street building (that is, the MEI is in the same building as the source of radioactive air emissions), about 62 ft (19 m) from the point where emissions from Berkeley Lab operations are released. The estimated collective dose to persons living within 50 mi (80 km) was 5.0×10^{-6} person-rem (5.0×10^{-8} person-Sv) attributable to the Lab's airborne emissions from Building 978 in 2012.

Acronyms

ALS	Advanced Light Source
CAP88-PC	EPA-approved dose calculation software
CFR	Code of Federal Regulations
COMPLY	EPA-approved dose calculation software
DOE	U. S. Department of Energy
EPA	U. S. Environmental Protection Agency
HEPA	High-efficiency particulate air
JBEI	Joint BioEnergy Institute
LHS	Lawrence Hall of Science
LOASIS	Lasers and Optical Accelerator Systems Integrated Studies
MEI	Maximally exposed individual
NESHAP	National Emission Standards for Hazardous Air Pollutants
TEDA	Triethylene diamine
TEDA-DAC	Triethylene-diamine-doped activated carbon
UC	University of California

1.0
Facility Information

Lawrence Berkeley National Laboratory, also known as Berkeley Lab, was founded by Ernest O. Lawrence in 1931. Lawrence invented a unique particle accelerator, called a cyclotron, which ushered in a new era in the study of subatomic particles. In 1939, he was awarded the Nobel Prize in physics. Through his work, Lawrence launched the modern era of multidisciplinary, team science. Today, Berkeley Lab continues the tradition of multidisciplinary scientific teams working together to solve global problems in human health, technology, energy, and the environment.

The Laboratory supports work in such diverse fields as genomics, physical biosciences, alternative fuels, nanoscience, life sciences, fundamental physics, accelerator physics and engineering, energy conservation technology, and materials science. Through its fundamental research in these fields, Berkeley Lab has achieved international recognition for its leadership and has made numerous contributions to national programs. Berkeley Lab's research embraces the following concepts to align with the DOE mission:

- Explore the complexity of energy and matter
- Advance the science needed to attain abundant clean energy
- Understand energy impacts on our living planet
- Provide extraordinary tools for multidisciplinary research

1.1 Site Description

Berkeley Lab is located about 3 mi (5 km) east of San Francisco Bay (see Figure 1-1) on land owned by UC. The Laboratory's main site is situated on approximately 202 acres (82 hectares) of this land. University of California provides long-term land leases to the DOE for many of the buildings and facilities at the Laboratory.

The main site lies in the hills above the UC Berkeley campus, on the ridges and draws of Blackberry Canyon (which forms much of the western part of the site) and Strawberry Canyon (which forms much of the southern part of the site). Elevations across the site range from 450 to 1,150 ft (135 to 350 m) above sea level. The western portion of the site is in Berkeley, while the eastern portion is in Oakland; the entire site is located within Alameda County (see Figure 1-2). The residential population of Berkeley is estimated at 113,000 and that of Oakland at 391,000 (MTC/ABAG 2010).

Berkeley Lab also leases space at two nearby, off-site buildings where radionuclides are used in biological research. The Berkeley West Biocenter (Building 977) is located at 717 Potter St. in Berkeley, and the Joint BioEnergy Institute (JBEI, Building 978) is located at 5885 Hollis St. in Emeryville (see Figure 1-2). Elevations at these buildings range from 35 to 50 ft (11 to 15 m) above sea level. Emeryville is a small community between Berkeley and Oakland with a residential population of 10,100 (MTC/ABAG 2010).

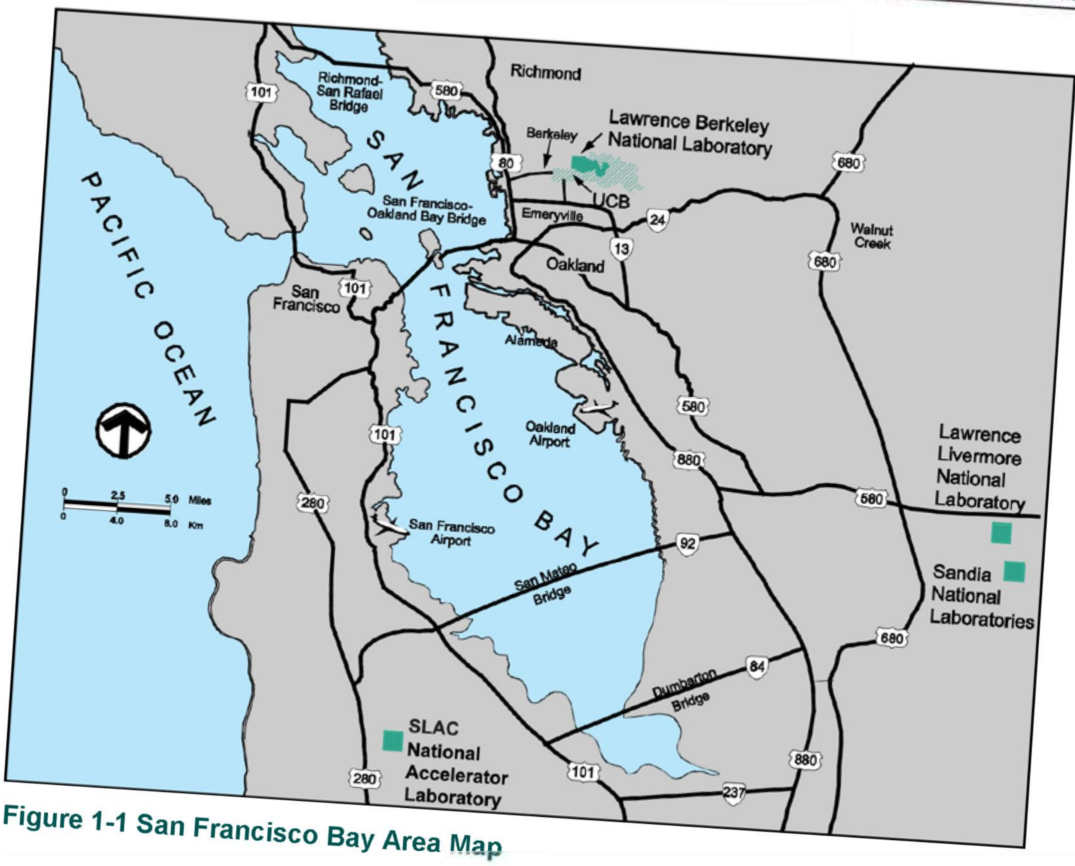

Figure 1-1 San Francisco Bay Area Map

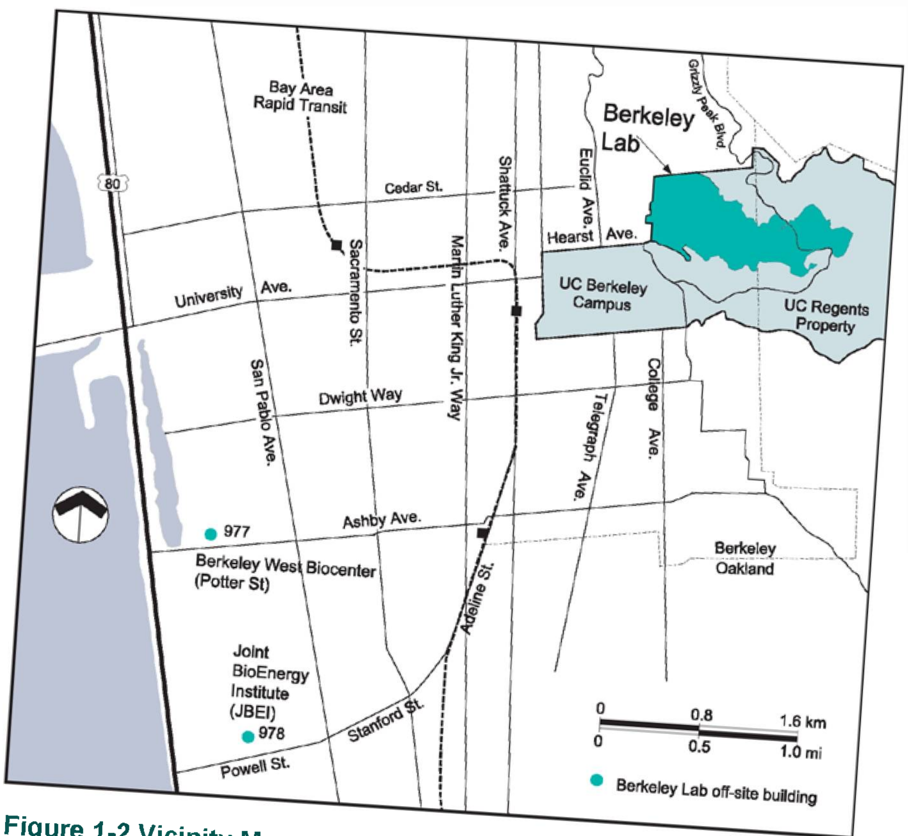

Figure 1-2 Vicinity Map

Adjacent land use consists of residential, institutional, and recreational areas. The area to the south and east of the Laboratory main site, which is UC land, is maintained largely in a natural or undeveloped state but includes UC Berkeley's Strawberry Canyon Recreational Area and Botanical Garden. To the northeast are the university's Lawrence Hall of Science, Space Sciences Laboratory, and Mathematical Sciences Research Institute. Berkeley Lab is bordered on the north by a residential neighborhood of low-density, single-family homes and on the west by the UC Berkeley campus, as well as by multiunit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.

The climate of the site is temperate, influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west, and on the east by the East Bay hills paralleling the eastern shore of this same bay. These physical barriers contribute significantly to the relatively warm, wet winters and cool, dry summers of the site. In 2012, precipitation totaled 38.9 in. (98.8 cm), absolute humidity averaged 7.8 g/m^3, and ambient temperature averaged 55.0 °F (12.8 °C).

On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the bay, followed by lighter nighttime southeasterly drainage winds of the East Bay hills. The other predominant wind pattern is associated with storm systems passing through the region, which usually occur during the winter months. South-to-southeast winds in advance of each storm are followed by a shift to west or northwest winds after passage of the system.

Vegetation on the Berkeley Lab main site is a mixture of native plants, naturalized exotics, and ornamental species. The site was intensively grazed and farmed for approximately 150 years before the development of Berkeley Lab on it in the 1930s. At the main site, the Laboratory manages vegetation in harmony with the local natural succession of native plant communities. Berkeley Lab also works to maintain a wooded and savanna character in the areas surrounding buildings and roads. Ornamental species are generally restricted to public spaces and courtyards and to areas adjacent to buildings. The site has no rare, threatened, or endangered species of plants.

Wildlife is abundant at the Berkeley Lab main site because the site is adjacent to open spaces managed by the East Bay Regional Park District and the university. Wildlife that frequents the site is typical of wildlife in disturbed (for example, previously grazed) areas that have a Mediterranean climate and are located in midlatitude California. More than 120 species of birds, mammals, reptiles, and amphibians are thought to exist on the site. The most abundant large mammal is the Colombian black-tailed deer. The Berkeley Lab main site includes protected habitats for riparians, a certain spider species, and a threatened snake species.

1.2 Source Description

Berkeley Lab operates facilities subject to the EPA's NESHAP regulations where radionuclides are produced, handled, stored, and potentially emitted (EPA 1989a). Figure 1-3 illustrates the Berkeley Lab general site configuration, including locations of buildings where radionuclides are used or produced, and

Figure 1-3 Berkeley Lab Buildings Where Radionuclides are Used or Produced

the Lawrence Hall of Science (LHS), the location of the MEI. Radionuclides are also used at two offsite locations, Building 977 and Building 978, shown on Figure 1-2.

Researchers at the Lab use a wide variety of radionuclides in gas, liquid, and solid phases in their research programs. Work with radioactive material may be conducted on laboratory bench tops, in fumehoods, in gloveboxes, and/or under ultra-high vacuum. In addition, short-lived radioactive gases are a by-product of charged-particle accelerator operations in Buildings 6, 56, 71, and 88.

Radiochemical and radiobiological studies performed at Berkeley Lab typically use microcurie to tens of millicurie quantities of a variety of radionuclides. All radioactive material is used in accordance with a Berkeley Lab authorization or permit, which includes the location of radiologically controlled areas (areas to which access is managed to protect individuals from exposure to radiation or radioactive materials), the required handling procedures, and appropriate work enclosures for each project.

Table 1-1 identifies buildings at Berkeley Lab where use or production of unsealed radioactive material was authorized in 2012 and the radionuclides that were produced or authorized for use. Note that not all authorized radionuclides were used during the year because of the variable nature of Berkeley Lab research projects.

Table 1-1 Buildings Where Unsealed Radionuclide Use or Production is Authorized by Berkeley Lab

Building	Building Name/Function	Radionuclides Authorized by Berkeley Lab
1	Donner Laboratory	C-14, H-3, P-32, U-238
5	Accelerator and Fusion Research	Activation products[a]
6	Advanced Light Source (ALS)	Activation products,[a] Am-241, Am-243, Cm-243, Cm-244, Cm-246, Cm-248, Eu-152, Eu-154, Kr-85, Np-237, Po-210, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Sr-90, Tc-99, Th-232, U-232, U-233, U-234, U-234, U-235, U-238
16	Accelerator and Fusion Research	Activation products[a]
50 complex	Physics Research	Ag-105, Ag-106m, Au-194, Be-7, Co-56, Co-57, Co-58, Co-60, Mn-52, Mn-54, Na-22, Ni-57, Re-184m, Sc-46, Sc-48, Se-75, Ta-182, V-48, Zn-65
55	Center for Functional Imaging	C-11, C-14, Ce-141, Co-55, Co-57, Cr-51, Cu-64, F-17, F-18, Ge-68, H-3, I-123, I-125, I-131, N-13, Nb-95, O-14, O-15, Pb-212, Ru-103, Sc-46, Sr-85, Sr-89, Sr-90, Tc-99, Tc-99m, Th-228, Th-230, Th-232, Tl-201, U-238, Zr-89
56	Biomedical Isotope Facility	C-11, Co-55, Co-57, Cr-51, F-17, F-18, N-13, O-14, O-15, Tc-99m, Zr-89
64	Earth Sciences	H-3, K-40, Pb-212, Sr-89, Sr-90, Tc-99, Th-228, Th-230, Th-232, Tl-208, U-234, U-235, U-238
67	Materials Sciences	U-238
70	Environmental Energy Technology, Nuclear Science, and Earth Sciences Research	Ac-227, Am-240, Am-241, Am-243, Au-198, Ba-133, Be-10, Be-7, Bi-207, Bk-249, C-11, C-14, Cd-109, Cf-249, Cf-250, Cf-251, Cf-252, Cl-36, Cm-242, Cm-243, Cm-244, Cm-248, Co-56, Co-57, Co-58, Co-60, Cr-51, Cs-134, Cs-137, Er-165, Er-169, Er-171, Es-253, Es-254, Eu-152, Eu-154, Eu-155, Fe-55, Fe-59, Fm-257, H-3, Ho-166m, Hf-172, Hf-175, Hf-181, Hg-203, Ho-166m, I-125, I-129, Kr-85, Mn-54, Na-22, Nb-95, Ni-57, Ni-63, Ni-65, Np-237, Np-239, P-32, Pa-231, Pa-233, Pb-210, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Ra-226, Ra-228, Re-189, Rh-101, Ru-106, Sb-124, Sb-125, Sc-46, Se-75, Sr-90, Ta-179, Ta-182, Tb-160, Tc-99, Th-228, Th-229, Th-230, Th-232, Tl-204, Tm-170, U-232, U-233, U-234, U-235, U-236, U-238, V-48, Y-90, Zn-65, Zr-88, Zr-95
70A	Nuclear, Chemical, and Life Sciences Research	Ac-227, Am-241, Am-243, Ba-133, Bi-207, Bk-249, C-14, Cf-249, Cf-250, Cf-251, Cf-252, Cl-36, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cm-248, Co-60, Cs-137, Es-253, Es-254, Eu-152, Eu-154, Eu-155, Fe-55, Fe-59, H-3, Ho-166m, I-125, I-129, Ni-63, Ni-65, Np-237, Np-239, Pa-231, Pa-233, Pb-205, Pb-210, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Ra-226, Ra-228, Ru-106, Sr-90, Tc-99, Th-228, Th-229, Th-230, Th-232, U-232, U-233, U-234, U-235, U-236, U-238
71	Lasers and Optical Accelerator Systems Integrated Studies (LOASIS)	Activation products[a]

Building	Building Name/Function	Radionuclides Authorized by Berkeley Lab
72	Low-Background Facility	Ac-227, Am-241, Au-198, Be-10, Be-7, C-11, Cf-249, Cf-252, Co-56, Co-57, Co-58, Co-60, Cr-51, Cs-134, Cs-137, Eu-152, Eu-154, Fe-55, Fe-59, Mn-54, Na-22, Np-237, Np-239, P-32, Pa-231, Pa-233, Pu-238, Pu-239, Sb-124, Sc-46, Se-75, U-238, Zn-65
75	Radioanalytical Laboratory	Ac-227, Am-241, Am-243, C-11, C-14, Cm-244, Cs-137, F-18, Fe-55, H-3, I-125, I-129, I-131, Np-237, P-32, Pb-210, Pu-238, Pu-239, Pu-242, S-35, Sr-90, Th-229, Th-230, Th-232, U-232, U-238
77	Physics Research	Co-58, Mn-54
77A	Physics Research	Ag-105, Ag-106m, Au-194, Be-7, Co-56, Co-57, Co-58, Co-60, Mn-52, Mn-54, Na-22, Ni-57, Re-184m, Sc-46, Sc-48, Se-75, Ta-182, V-48, Zn-65
83	Life Sciences Research	P-32
84	Life Sciences Research	P-32, S-35
85	Hazardous Waste Handling Facility	Alpha-emitting radionuclides, beta-gamma-emitting radionuclides, Bk-249, C-14, H-3, Np-237, Pu-238, Pu-239, Pu-242, U-233, U-235, U-238
86	Animal Handling Facility	Ce-141, Cr-51, F-18, I-123, I-125, I-131, Nb-95, Ru-103, Sc-46, Sr-85, Tc-99m, Tl-201, U-238
88	88-Inch Cyclotron	Activation products,[a] Ac-227, Am-241, Am-243, Au-198, Be-10, Be-7, Bi-207, C-11, Cf-249, Cf-252, Cm-242, Cm-244, Cm-245, Cm-246, Cm-247, Cm-248, Co-56, Co-57, Co-58, Co-60, Cr-51, Cs-134, Cs-137, Eu-152, Eu-154, Fe-55, Fe-59, Mn-54, Na-22, Np-237, Np-239, Os-185, P-32, Pa-231, Pa-233, Pa-233, Pb-212, Pu-238, Pu-239, Pu-242, Pu-244, Re-183, Re-184, Re-184m, Rh-101, Sb-124, Sc-46, Se-75, Th-228, Th-229, Th-232, U-234, U-235, U-236, U-238, Zn-65
977	Berkeley West Biocenter (Potter Street Facility)	C-14, H-3, P-32, S-35
978	Joint BioEnergy Institute (JBEI)	C-14, H-3, P-32, S-35

[a] Produced when materials such as air, water, and metals are activated by neutrons from accelerator or reactor operations; may include ^{41}Ar, ^{7}Be, ^{11}C, ^{13}N, ^{15}O, ^{18}F, ^{38}Cl, and ^{39}Cl

2.0
Air Emissions Data

At Berkeley Lab, radionuclides may be emitted from stacks or other exhaust points (such as vents) on the buildings where radionuclide use is authorized (see Table 1-1). Alternatively, radionuclides may be uniformly released from an area or emanate from a number of points randomly distributed over an area; this is a diffuse source. In 2012, there were no diffuse sources at Berkeley Lab.

If the radionuclides emitted from any type of source could result in a potential dose of 0.1 mrem/yr (0.001 mSv/yr) or more to a member of the public at an offsite point where there is a residence, school, business, or office, it is considered a major source, and the EPA requires the Lab to measure its emissions continuously. Berkeley Lab has no major sources.

If emitted radionuclides could result in a potential dose of less than 0.1 mrem/yr (0.001 mSv/yr), the source of the radionuclides is considered a minor source. The EPA requires the Lab to perform periodic confirmatory measurements on such sources. In 2012, all Berkeley Lab sources were minor sources of radionuclides. Emissions from minor sources were measured by real-time monitoring, continuous sampling with monthly analysis of the samples, or sampling for one month at a time four times a year; or were calculated based on quantities received, used, or produced during the year. The approach to measuring radionuclides from Berkeley Lab sources is summarized in Table 2-1, which EPA Region 9 approved in 2005 (Jordan 2005).

Table 2-1 EPA-Approved Radionuclide Emissions Measurement Approach

Potential Dose (mrem/yr)[a]	Category	Requirements
dose $\geq$ 10.0	Non-compliant	Reduction or relocation of source term and reevaluation prior to authorization.
10.0 > dose $\geq$ 1.0	1	• Continuous sampling with weekly collection and analysis AND • Real-time monitoring with alarming telemetry for short-lived ($t_{1/2}$< 100 h) radionuclides resulting in >10% of potential dose to the maximally exposed individual.
1.0 > dose $\geq$ 0.1	2	• Continuous sampling with monthly collection and analysis OR • Real-time monitoring for short-lived ($t_{1/2}$ < 100 h) radionuclides resulting in >10% of potential dose to the maximally exposed individual.
0.1 > dose $\geq$ 0.01	3	Periodic sampling 25% of the year.
dose < 0.01	4	Potential dose evaluation before project starts and when annual radionuclide use limits (as authorized by internal Lab documents) are revised; no sampling or monitoring required.

[a] 1 mrem = 0.01 mSv

Among the minor sources at Berkeley Lab are a few stacks, or point sources, where the emissions are measured. There are many more radiologically controlled areas, or group sources, where emissions are calculated.

A single building may have all three types of sources: point (measured stacks [typically Category 3]), group (calculated emissions [Category 4]), and diffuse (calculated wide-area emissions [Category 3 or 4]) sources (note that in 2012, there were no diffuse sources at Berkeley Lab). A tabulation of the different types of Berkeley Lab sources is provided in Table 2-2.

The point and group sources at Berkeley Lab comprise many different radionuclides that were authorized for use in 2012 (see Table 1-1); however, not all of those radionuclides were actually received, used, or produced (and thus potentially emitted into the air) during the year because of the variable nature of Berkeley Lab research projects.

Table 2-2 Measurement Category of Sources

Building	Major Sources		Minor Sources		Total
	Category 1	Category 2	Category 3	Category 4	
1	0	0	0	8	8
5	0	0	0	1	1
6	0	0	0	4	4
16	0	0	0	2	2
50 complex	0	0	0	5	5
55	0	0	0	17	17
56	0	0	2	0	2
64	0	0	0	2	2
67	0	0	0	2	2
70	0	0	0	17	17
70A	0	0	5	36	41
71	0	0	0	1	1
72	0	0	0	1	1
75	0	0	1	2	3
77	0	0	0	1	1
77A	0	0	0	2	2
83	0	0	0	3	3
84	0	0	0	8	8
85	0	0	2	0	2
86	0	0	0	1	1
88	0	0	3	4	7
977	0	0	0	6	6
978	0	0	0	4	4
Total	0	0	13	127	140

Radionuclides that could have been emitted during the year are listed in Table 2-3, along with the total activity of each radionuclide from stack air measurements and calculations.

2.1 Point Sources: Measured Emissions

In accordance with the EPA-approved approach (Table 2-1), Berkeley Lab measures emissions from stacks or other exhaust points if the potential dose from the sources could exceed 0.01 mrem/yr (0.0001 mSv/yr); these are Category 3 sources (recall that Berkeley Lab has no major [Category 1 or 2] sources). Additionally, Berkeley Lab may choose to measure emissions from stacks with less dose impact (Category 4) to ensure that those emissions are well understood. Thus stacks where emissions are measured include both Category 3 and Category 4 sources (Table 2-4).

At sampled stacks, a representative sample of the exhaust air passes through the appropriate collection medium (silica gel for ^{3}H, sodium hydroxide solution for ^{14}C, activated carbon for ^{125}I, and fiberglass filter for particulate alpha- and beta-emitting radionuclides). Each medium is changed out after a month, and the radionuclides collected on the media are analyzed at a commercial laboratory. At sites that are continuously monitored in real time, a sample of the exhaust air is passed through or over detectors that provide a nearly instantaneous measurement of positron-emitting radionuclides (at Buildings 56 and 88) or alpha-emitting radionuclides (at Building 70A). Real-time measurements are recorded and archived.

Many stacks and vents at Berkeley Lab have effluent controls; that is, a filter to collect airborne particulates or gases before they are released to the atmosphere. For example, the measured stacks (point sources) on Building 88 have high-efficiency particulate air (HEPA) filters to prevent

Table 2-3 Total Activity Emitted in 2012

Radio-nuclide	Activity (Ci/yr)[a]	Radio-nuclide	Activity (Ci/yr)	Radio-nuclide	Activity (Ci/yr)	Radio-nuclide	Activity (Ci/yr)
F-18	1.35E+00	Eu-152	5.01E-07	Eu-154	2.20E-09	Pu-239	1.69E-11
C-11	9.40E-03	Cd-109	5.00E-07	Pu-242	1.93E-09	Pa-231	9.01E-12
Kr-85	2.00E-03	Ar-41	5.00E-07	Co-57	1.11E-09	Ac-227	7.30E-12
Tc-99m	1.02E-03	Be-7	2.70E-07	Ra-226	1.09E-09	Na-24	7.20E-12
N-13	8.47E-04	Alpha (Th-232)	2.67E-07	Th-228	1.00E-09	Co-56	6.26E-12
Cu-64	1.83E-04	Cl-38	1.70E-07	Ba-133	8.07E-10	Tc-99	5.06E-12
H-3	8.68E-05	Ge-71	9.20E-08	Co-60	7.12E-10	Au-194	4.77E-12
I-123	4.00E-05	C-14	4.08E-08	Na-22	4.24E-10	Pu-241	4.00E-12
O-15	1.83E-05	Np-237	3.51E-08	Cm-248	4.00E-10	Bi-207	3.17E-12
Tl-201	1.80E-05	Zr-95	1.90E-08	Sb-122	8.33E-11	Hg-194	2.99E-12
Ge-68	1.50E-05	Th-229	1.50E-08	Mn-54	7.16E-11	Cr-51	2.32E-12
Cl-39	2.10E-06	Th-232	1.40E-08	Cs-137	3.18E-11	Y-88	4.53E-13
Beta (Sr-90)	1.96E-06	U-238	1.34E-08	Sb-124	3.00E-11	Th-230	3.00E-13
P-32	1.25E-06	Fe-55	8.00E-09	Au-195	2.40E-11	Zn-65	8.80E-14
I-125	1.00E-06	Am-241	3.22E-09	Sr-90	2.40E-11	Am-243	0.00E+00
Hg-203	1.00E-06	I-131	2.23E-09	Co-58	2.04E-11		
						Total	1.37 Ci/yr

[a] 1 Ci = 3.7 × 10^{10} Bq

small particles from entering the atmosphere. Where effluent controls are in place, samples are collected downstream from the filter. Table 2-4 details effluent controls on stacks.

2.2 Group Sources: Calculated Emissions

In accordance with the EPA-approved approach (Table 2-1), Berkeley Lab calculates emissions from stacks or other exhaust points if the potential dose from the sources is less than 0.01 mrem/yr (0.0001 mSv/yr). These Category 4 sources (typically radiologically controlled areas where small amounts of radionuclides are authorized for use) are grouped by building, as shown in Table 2-5, to simplify reporting (DOE 1994). The amount of each radionuclide emitted is calculated by multiplying the entire quantity of that radionuclide received, used, or produced during the year by the appropriate EPA-specified release factor based on the radionuclide's physical state (provided in 40 CFR Part 61, Appendix D). This method provides a conservative, upper-bound estimate of the annual emissions.

Emissions are typically calculated assuming that all radionuclides received during the year are used in areas where stacks are not sampled or monitored. In fact, for some received radionuclides

Table 2-4 Stacks Where Radionuclide Emissions are Measured

Building	Number of Stacks	Stack Identification	Measurement Category	Effluent Control	Efficiency (%)
55	1	55-128H	4	HEPA [a] TEDA-DAC [b]	> 99 > 75
56	2	56-Accelerator 56-Glovebox	3 3	None [c] None	NA NA
70	1	70-147A	4	HEPA	> 99
70A	9	70A-1121A 70A-1121B 70A-1129P/RT 70A-1129H 70A-2211 70A-2217 70A-2223 70A-2229A 70A-2229B	3 3 3 3 4 4 3 4 4	None None HEPA HEPA None None None None None	NA NA > 99 > 99 NA NA NA NA NA
75	1	75-127H	3	HEPA	> 99
85	2	85-Fumehood 85-Glovebox	3 3	HEPA HEPA	> 99 > 99
88	3	88-135H 88-Cave0 88-RT	3 3 3	HEPA HEPA HEPA	> 99 > 99 > 99

[a] High-efficiency particulate air filter

[b] Triethylene-diamine-doped activated carbon trap

[c] Radionuclides emitted from Building 56 accelerators are short-lived, gaseous activation products, for which emission control is impractical

Table 2-5 Sources for Which Radionuclide Emissions are Calculated

Building	Number of Radiologically Controlled Areas	Emissions Control	Efficiency (%)
1	8	None	NA[a]
5	1	None	NA
6	4	None	NA
16	2	None	NA
50 complex	5	None	NA
55	17	HEPA[b] None	> 99 NA
64	2	None	NA
67	2	None	NA
70	17	HEPA None	> 99 NA
70A	36	HEPA None	> 99 NA
71	1	None	NA
72	1	None	NA
75	2	HEPA None	> 99 NA
77	1	None	NA
77A	2	None	NA
83	3	None	NA
84	8	None	NA
86	1	None	NA
88	4	HEPA	> 99
977	6	None	NA
978	4	None	NA

[a] Not applicable
[b] High-efficiency particulate air filter

that may be emitted through sampled or monitored stacks, reported emissions may be higher than actual emissions because they are accounted for as both calculated and measured emissions. For group sources there typically are no effluent controls because the emissions from these sources are very small.

2.3 Nonpoint Sources: Diffuse Emissions

Berkeley Lab had no diffuse emissions in 2012.

3.0
Dose Assessment

3.1 Dose Model

To comply with NESHAP regulations and DOE guidance, the EPA-approved atmospheric dispersion and radiation dose calculation computer code, CAP88-PC, Versions 2.1 and 3.0, was used to calculate the doses at various distances and from various release points (EPA 2006). For buildings 1, 977, and 978, where the nearest member of the public was much less than 328 ft (100 m) from the source, the EPA-approved dose model COMPLY was used to calculate MEI dose (the highest dose to any member of the public at any offsite point where there is a residence, school, business, or office); CAP88-PC was used for doses at all other distances from the building. Doses to members of the public nearest each building were compared, and the location where the dose was greatest was determined to be the MEI.

Doses to the MEI from emissions from individual Laboratory buildings were calculated. For all buildings on the main site, including Building 1, these individual doses were then summed. (Although Building 1 is located outside of Berkeley Lab`s main perimeter and could be considered a separate facility since it is not on the same contiguous site as other main site buildings [see Figure 1-3], Building 1 is located on the adjacent UC Berkeley campus and is within walking distance of the main Berkeley Lab site.)

For Buildings 977 and 978, doses were evaluated separately from other Laboratory main site buildings and from each other. Buildings 977 and 978 are located about 3 mi (5 km) west and southwest, respectively, of the main Laboratory site (see Figure 1-2). Separate MEIs were determined for each of these buildings.

3.2 Input Parameters

Input parameters to CAP88-PC and COMPLY include the emissions discussed in Section 2, and building-specific and common parameters discussed below. To estimate doses, CAP88-PC, Version 3, provides a library of 825 radionuclides, which includes data for all of the radionuclides listed in Table 2-3 except ^{248}Cm. For this radionuclide, Version 2.1 of CAP88-PC was used. (Note that the dose from ^{248}Cm to the main site MEI is very low—only about 0.02% of the total dose from all radionuclides.)

For very small quantities of radionuclides (less than 1×10^{-10} Ci [3.7 Bq]), CAP88-PC, Version 3, estimates a dose of zero. In 2012, 21 radionuclides were used in quantities less than 1×10^{-10} Ci (3.7 Bq) and were assumed not to contribute to the total dose to the public. To verify this assumption, all 21 radionuclides were modeled as hypothetical worst-case emissions from Building 75, near the location of the main site MEI, and were shown to estimate a dose of 0 mrem/yr.

When calculating doses from particulate alpha- and beta-emitting radionuclides, Berkeley Lab assigns gross alpha and gross beta measurements to the high-hazard alpha-emitting radionuclide, ^{232}Th, and the high-hazard beta-emitting radionuclide, ^{90}Sr, respectively. The use of the high-hazard radionuclides ^{232}Th and ^{90}Sr to represent alpha and beta emissions provides an upper-bound estimate of the dose.

In February 2013, DOE staff identified a potential error in CAP88-PC, Version 3, that could underestimate doses from multiple stacks (Appendix A). Berkeley Lab personnel tested Version 3 for the multiple stacks at Buildings 55 and 56; no error was identified in the software version currently in use at Berkeley Lab. The EPA subsequently posted a correction to Version 3 at http://www.epa.gov/rpdweb00/assessment/CAP88/index.html; Berkeley Lab personnel noted no significant difference between the corrected Version 3 and the old Version 3 currently in use at Berkeley Lab (and used for this report); however, the corrected Version 3 will be used for future dose estimates.

3.2.1 Building-Specific Parameters

For dose assessment, some Berkeley Lab buildings can be combined because they are near each other and similar operations are performed in these buildings (DOE 1994). For combined buildings and buildings with many unsampled stacks, average stack height along with assumed stack diameter (0.3 ft [0.1 m]), exit velocity (0 ft/s [0 m/s]), and receptor distance (from nearest edge of building) values are typically used (Table 3-1). These input values provide an upper-bound estimate of dose and ensure that stack emissions are not underestimated.

Table 3-1 Building-Specific Input Parameters

Building Number	Stack Height (m)[a]	Stack Diameter (m)	Exit Velocity (m/s)	Nearest Member of Public	MEI Location [b]	Farm Location [c]
1	18	0.1	0	10 m ESE	990 m ENE	4200 m N
5/6/16	9	0.1	0	350 m NNE	370 m NNE	3200 m N
55/56/64						
Accelerator stack	16	0.3	3.51	250 m NNW	460 m E	3200 m N
Glovebox stack	16	0.46	2.39	250 m NNW	460 m E	3200 m N
General stacks	12	0.1	0	250 m NNW	460 m E	3200 m N
70/70A	16	0.1	0	270 m WSW	530 m ENE	3200 m N
71	13	0.1	0	190 m NNW	310 m ESE	3200 m N
72/67	3	0.1	0	230 m SSW	500 m NW	3200 m N
75	7.4	0.35	8.33	110 m NW	110 m NW	3200 m N
83/84/86	7	0.1	0	160 m SSE	690 m WNW	3200 m N
85						
Glovebox stack	16	0.23	6.58	210 m SSE	570 m WNW	3200 m N
Fumehood stack	16	0.46	4.25	210 m SSE	570 m WNW	3200 m N
General stacks	16	0.1	0	210 m SSE	570 m WNW	3200 m N
88	13	0.1	0	110 m W	690 m ENE	3200 m N
977	16	0.1	0	30 m N	30 m N	8200 m N
978	28	0.26	0	19 m E	19 m E	8200 m N

[a] 1 m = 3.281 ft

[b] For main site buildings, the MEI is at the Lawrence Hall of Science; for offsite buildings, the MEI is in each offsite building

[c] Approximate distance to Wildcat Canyon Regional Preserve where cattle graze

For Buildings 56, 75, and 85, where some radionuclide emissions can be correlated to specific stacks (such as glovebox or fumehood stacks), the actual stack diameter and exit velocity are used and modeled separately. The input parameters that vary with building are shown in Table 3-1.

For Buildings 50 complex, 77, and 77A, authorized radionuclides are in the form of activated components, which are fixed and not readily dispersed into the air. Because airborne radionuclides are unlikely to be released from these buildings, no releases were modeled.

For Buildings 977 and 978, which are off the main site and are shared by Berkeley Lab employees and members of the public, the distance to the MEI is the shortest distance from the release point on the building roof to the location of the nearest member of the public in the building (measured along the building surfaces). This is the distance calculation required by the COMPLY software (EPA 1989b).

3.2.2 Common Parameters

The input parameters that are common among Berkeley Lab sources include meteorological data and agricultural data. Meteorological data were compiled from onsite data for 2012. Berkeley Lab collects this data from an 86-ft (26-m) tower centrally located at the Laboratory (see Figure 1-3). Site-specific values for annual precipitation (38.9 in. [98.8 cm]), average ambient temperature (55.0 °F [12.8 °C]), and average absolute humidity (7.8 g/m^3) were used. The default value for lid (mixing) height, 3300 ft (1000 m), was chosen. The 2012 wind data are provided in Appendix B.

Agricultural data were obtained from the California Department of Food and Agriculture and the urban scenario was chosen (Wahl 2004). The values include the following.

- Vegetables, fraction home-produced: 0.076
- Vegetables, fraction from assessment area: 0.924
- Milk, fraction from assessment area: 1
- Meat, fraction home-produced: 0.008
- Meat, fraction from assessment area: 0.992
- Beef cattle density: 1.9 per km^2
- Milk cattle density: 4.0 per km^2
- Land fraction cultivated for vegetable crops: 4.6%

3.3 Compliance Assessment

3.3.1 MEI Dose and Location

Doses from Berkeley Lab's airborne emissions are well below the 10 mrem/yr (0.1 mSv/yr) NESHAP dose standard. As shown in Table 3-2, the sum of calculated doses from all sources at Berkeley Lab main site in 2012 was 5.6 × 10^{-3} mrem/yr (5.6 × 10^{-5} mSv/yr) to the MEI (the member of the public who potentially received the highest dose at any offsite point where there is a residence, school, business, or office). The location of this hypothetical person is the UC Lawrence Hall of Science, about 1500 ft (460 m) east of Buildings 55 and 56. The calculated doses from sources at the offsite Buildings 977 and 978 to

Table 3-2 Dose Assessment Results

Building	Primary Radionuclides Contributing to MEI Dose[a]	Dose to MEI (mrem/yr)[b]	Percent of Total Dose (%)
1	None	5.4E-7	< 0.1
5/6/16	None	9.7E-6	0.2
55/56/64	F-18, Ge-68	5.5E-3	97.2
70/70A	None	1.3E-4	2.2
71	None	1.1E-7	< 0.1
72/67	None	0	< 0.1
75	None	4.3E-6	< 0.1
83/84/86	None	4.1E-7	< 0.1
85	None	1.2E-6	< 0.1
88	None	1.3E-5	0.2
Total (Main Site)		5.6E-3	100
977	P-32	8.7E-3	100
978	P-32	3.4E-4	100

[a] Radionuclides that contribute more than 1% of the potential dose to the MEI from this source
[b] Dose from all radionuclides emitted; 1 mrem = 0.01 mSv

the nearest member of the public working in the same building (the building-specific MEI) were 8.7×10^{-3} mrem/yr (8.7×10^{-5} mSv/yr) and 3.4×10^{-4} mrem/yr (3.4×10^{-6} mSv/yr), respectively.

Although no one actually lives at the MEI locations, the EPA-approved software calculates the dose assuming a person resides there 24 hours a day for the entire year, eats meat and vegetables grown nearby (see the agricultural parameters in Section 3.2.2), and drinks water from local wells contaminated with deposited airborne radionuclides. Thus the calculated dose to this hypothetical person, the MEI, is greater than the dose to an actual member of the public visiting the Hall of Science or working in Buildings 977 or 978.

Fluorine-18 emitted from Building 56 stacks accounts for about 94% of the dose to the Berkeley Lab main site MEI. Reported annual ^{18}F emissions from Building 56 stacks are likely to be higher than actual emissions because false-positive results occur when ^{18}F adsorbs onto the real-time detectors and continues to decay there. These false positive measurements are included in the calculation of annual ^{18}F emissions. As a result, the calculated dose represents an upper-bound estimate of dose from ^{18}F. Even with this upper-bound estimate, the dose to the MEI from ^{18}F is very low, only about 0.05% of the EPA limit of 10 mrem/yr (0.1 mSv/yr).

The CAP88-PC and COMPLY codes were validated by performing sample assessments. The output of each sample assessment was compared to output provided in the users' guides (EPA 2007, EPA 1989b). The two outputs are identical, indicating that the code performed as intended.

3.3.2 Certification

As required by 40 CFR 61.94(b)(9), the following declaration must be signed and dated by officials in charge of Berkeley Lab: "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)."

Certified By: Joe Dionne Date: 4/30/2013

Joe Dionne, Interim Division Director
Environment / Health / Safety / Security Division
Lawrence Berkeley National Laboratory

Aundra Richards Date: 5/13/2013

Aundra Richards, Site Manager
Department of Energy
Lawrence Berkeley Site Office

4.0

Additional Information

4.1 Additions or Modifications

There was no facility construction or modification (fabrication, erection, or installation) in 2012 relevant to the NESHAP regulation. Other changes in work authorized noted in this report include

- authorization of work with radionuclides in Buildings 67 and 77; and
- cessation of demolition work at Building 51 that could potentially result in diffuse airborne emissions.

4.2 Unplanned Releases

There were no unplanned releases in 2012 from Berkeley Lab operations.

4.3 Diffuse Emissions

There were no diffuse emissions in 2012 from Berkeley Lab operations.

5.0
Supplemental Information

5.1 Collective Dose Estimate

Collective population dose is calculated as the average radiation dose to a person in a specified area, multiplied by the number of people in that area. In accordance with DOE and EPA guidance documents, all radionuclides potentially emitted from the main Laboratory site in 2012 (shown in Table 2-3) were assumed to be released from a hypothetical, centrally located stack that is 52 ft (16 m) high, is 1 ft (0.3 m) in diameter, and has an exit velocity of 13.5 ft/s (4.1 m/s) (Wahl 2003). Radionuclides potentially emitted from Building 977 were assumed to be released from the building stack, which is 52 ft (16 m) high, is assumed to be 0.3 ft (0.1 m) in diameter, and has an assumed exit velocity of 0 ft/s (0 m/s). Radionuclides potentially emitted from Building 978 were assumed to be released from the building stack, which is 92 ft (28 m) high, is 0.85 ft (0.26 m) in diameter, and has an assumed exit velocity of 0 ft/s (0 m/s).

The total daytime population within 50 mi (80 km) of the main Laboratory site is approximately 7,253,038 based on the LandScan USA 2010 data product (Bright 2011). The same population was assumed to be appropriate for Buildings 977 and 978, since they are relatively close to (within 3 mi [5 km] of) the main Laboratory site. The population file is provided in Appendix C, which was updated in 2012 to incorporate 2010 U.S. census data (Rose 2012; Appendix D). Daytime population is greater than nighttime population in the area surrounding Berkeley Lab, and when doses to both daytime and nighttime populations were compared, daytime population files yielded higher doses, so daytime population was the basis for 2012 collective dose estimates. The estimated collective dose to persons living within 50 mi (80 km) of the main Berkeley Lab site is 8.7×10^{-2} person-rem (8.7×10^{-4} person-Sv) attributable to Berkeley Lab airborne emissions in 2012. The collective doses from Building 977 and 978 are 4.5×10^{-4} person-rem (4.5×10^{-6} person-Sv) and 5.0×10^{-6} person-rem (5.0×10^{-8} person-Sv), respectively.

5.2 40 CFR 61 Subparts Q and T

Subparts Q and T of 40 CFR 61 are not applicable to Berkeley Lab, as the Laboratory does not operate a storage and disposal facility for radium-containing material or uranium mill tailings.

5.3 Radon Emissions

The Laboratory does not process, manage, or possess ^{232}U or ^{232}Th in quantities that could produce ^{220}Rn emissions having an impact $\geq$ 0.1 mrem/yr (0.001 mSv/yr) or $\geq$ 10% of the nonradon dose to the public. The Laboratory does not maintain nondisposal or nonstorage sources of ^{222}Rn emissions in quantities having an impact $\geq$ 0.1 mrem/yr (0.001 mSv/yr) or $\geq$ 10% of the nonradon dose to the public.

5.4 Facility Compliance

In 2012, no release points produced emissions having an impact $\geq$ 0.1 mrem/yr (0.001 mSv/yr) and no sources were subject to continuous monitoring requirements. Periodic confirmatory measurements were conducted in accordance with the EPA-approved measurement approach (Table 2-1).

6.0
References

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DOE 1994: U.S. Department of Energy, "Calendar Year 1993 Radionuclide Air Emissions Annual Reports for DOE Sites," memo to DOE site offices providing guidance for report preparation (March 22, 1994).

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

EPA 1989b: U.S. Environmental Protection Agency, *Users Guide for the COMPLY Code*. EPA 520/1-89/2003 (October 1989).

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

EPA 2007: U.S. Environmental Protection Agency, *CAP88-PC Version 3.0 User Guide*, Trinity Engineering Associates, Inc. (December 2007).

Jordan 2005: Jordan, D., "Request for Approval for LBNL to Revise Its Radionuclide NESHAP Monitoring Approach," memo from EPA Region 9 to R. Pauer, LBNL, documenting approval of monitoring approach (April 5, 2005).

MTC/ABAG 2010: Metropolitan Transportation Commission/Association of Bay Area Governments, *Bay Area Census*. 2010 census data website, http://www.bayareacensus.ca.gov/cities/cities.htm (accessed March 25, 2013).

Rose 2012: Rose, A. N., Oak Ridge National Laboratory, letter to L. Wahl, Lawrence Berkeley National Laboratory, describing population files prepared for use with CAP88-PC.

Wahl 2003: Wahl, L., "Annual Calculation of Collective Dose from Airborne Radionuclides," memo ES-03-037 to file documenting stack parameters for collective dose calculations (October 9, 2003).

Wahl 2004: Wahl, L., "Agricultural Data Used in CAP88-PC," memo ES-05-003 to file documenting source of agricultural values used for collective dose calculations (October 26, 2004).

Appendix A

Error in CAP88-PC, Version 3

3/5/13 Co-Located CAP88 Emission Point Runs - DOE Rad NESHAPs Blog

DOE Rad NESHAPs Blog

This Site: DOE Rad NESHAPs B

DOE RAD NESHAPS Community > DOE Rad NESHAPs Blog > Posts > Co-Located CAP88 Emission Point Runs

2/26/2013

Edit

Co-Located CAP88 Emission Point Runs

Current CAP88-PC Version 3 contains a typo in a variable name that makes it yield different results for co-located emission points when run together, versus when run separately and added (because of the typo the code is not storing the input for the second stack, without identifying a problem). EPA and its contractor, Trinity, have fixed the co-located software routine problem in CAP88-PC Version 3. EPA is working diligently to make the corrected software available ASAP on its website for DOE to download.

Posted at 10:32 AM by Barnett, J Matthew | Category: CAP88-PC Version 3 | Permalink | Email this Post | Comments (0)

Comments

There are no comments yet for this post.

Title

Body *

https://share.ornl.gov/sites/neshaps/blog/Lists/Posts/Post.aspx?List=34f82040-2139-41d1-9232-7f0037secc61&ID=31 1/1

Appendix B

Meteorological Data

Wind Direction	Stability Category	2012 Average Wind Frequency at Given Speed					
		1-3 knots	4-6 knots	7-10 knots	11-16 knots	17- 21 knots	> 21 knots
N	A	0.00080	0.00011	0.00000	0.00000	0.00000	0.00000
NNE	A	0.00046	0.00023	0.00000	0.00000	0.00000	0.00000
NE	A	0.00057	0.00080	0.00000	0.00000	0.00000	0.00000
ENE	A	0.00137	0.00068	0.00000	0.00000	0.00000	0.00000
E	A	0.00148	0.00068	0.00000	0.00000	0.00000	0.00000
ESE	A	0.00080	0.00046	0.00000	0.00000	0.00000	0.00000
SE	A	0.00034	0.00034	0.00000	0.00000	0.00000	0.00000
SSE	A	0.00023	0.00000	0.00000	0.00000	0.00000	0.00000
S	A	0.00046	0.00011	0.00000	0.00000	0.00000	0.00000
SSW	A	0.00046	0.00000	0.00000	0.00000	0.00000	0.00000
SW	A	0.00068	0.00034	0.00000	0.00000	0.00000	0.00000
WSW	A	0.00103	0.00011	0.00000	0.00000	0.00000	0.00000
W	A	0.00080	0.00000	0.00000	0.00000	0.00000	0.00000
WNW	A	0.00080	0.00000	0.00000	0.00000	0.00000	0.00000
NW	A	0.00046	0.00034	0.00000	0.00000	0.00000	0.00000
NNW	A	0.00034	0.00034	0.00000	0.00000	0.00000	0.00000
N	B	0.00046	0.00034	0.00000	0.00000	0.00000	0.00000
NNE	B	0.00080	0.00034	0.00000	0.00000	0.00000	0.00000
NE	B	0.00034	0.00046	0.00000	0.00000	0.00000	0.00000
ENE	B	0.00091	0.00103	0.00000	0.00000	0.00000	0.00000
E	B	0.00046	0.00034	0.00011	0.00000	0.00000	0.00000

Wind Direction	Stability Category	2012 Average Wind Frequency at Given Speed					
		1-3 knots	4-6 knots	7-10 knots	11-16 knots	17- 21 knots	> 21 knots
ESE	B	0.00034	0.00034	0.00000	0.00000	0.00000	0.00000
SE	B	0.00023	0.00011	0.00000	0.00000	0.00000	0.00000
SSE	B	0.00011	0.00023	0.00000	0.00000	0.00000	0.00000
S	B	0.00148	0.00239	0.00034	0.00000	0.00000	0.00000
SSW	B	0.00251	0.00353	0.00046	0.00000	0.00000	0.00000
SW	B	0.00103	0.00239	0.00125	0.00000	0.00000	0.00000
WSW	B	0.00068	0.00114	0.00091	0.00000	0.00000	0.00000
W	B	0.00160	0.00023	0.00000	0.00000	0.00000	0.00000
WNW	B	0.00034	0.00034	0.00000	0.00000	0.00000	0.00000
NW	B	0.00080	0.00068	0.00046	0.00000	0.00000	0.00000
NNW	B	0.00068	0.00125	0.00011	0.00000	0.00000	0.00000
N	C	0.00046	0.00011	0.00000	0.00000	0.00000	0.00000
NNE	C	0.00057	0.00000	0.00011	0.00000	0.00000	0.00000
NE	C	0.00046	0.00011	0.00034	0.00011	0.00000	0.00000
ENE	C	0.00046	0.00046	0.00057	0.00011	0.00000	0.00000
E	C	0.00034	0.00023	0.00023	0.00023	0.00000	0.00000
ESE	C	0.00057	0.00068	0.00000	0.00000	0.00000	0.00000
SE	C	0.00137	0.00182	0.00148	0.00125	0.00000	0.00000
SSE	C	0.00525	0.00718	0.00262	0.00103	0.00000	0.00000
S	C	0.00753	0.00490	0.00023	0.00000	0.00000	0.00000
SSW	C	0.00684	0.00433	0.00023	0.00000	0.00000	0.00000
SW	C	0.01209	0.00810	0.00091	0.00000	0.00000	0.00000
WSW	C	0.01197	0.01699	0.00604	0.00000	0.00000	0.00000
W	C	0.01574	0.02326	0.01197	0.00046	0.00000	0.00000
WNW	C	0.00262	0.00296	0.00251	0.00046	0.00000	0.00000

Wind Direction	Stability Category	2012 Average Wind Frequency at Given Speed					
		1-3 knots	4-6 knots	7-10 knots	11-16 knots	17- 21 knots	> 21 knots
NW	C	0.00046	0.00205	0.00023	0.00000	0.00000	0.00000
NNW	C	0.00046	0.00057	0.00011	0.00000	0.00000	0.00000
N	D	0.00399	0.00616	0.00342	0.00000	0.00000	0.00000
NNE	D	0.00171	0.00171	0.00228	0.00023	0.00000	0.00000
NE	D	0.00125	0.00080	0.00137	0.00011	0.00000	0.00000
ENE	D	0.00091	0.00046	0.00228	0.00080	0.00000	0.00000
E	D	0.00251	0.00068	0.00228	0.00034	0.00000	0.00000
ESE	D	0.01471	0.01528	0.00981	0.00114	0.00000	0.00000
SE	D	0.03261	0.02440	0.01288	0.01482	0.00160	0.00000
SSE	D	0.01608	0.00433	0.00650	0.00399	0.00000	0.00000
S	D	0.00547	0.00023	0.00091	0.00034	0.00000	0.00000
SSW	D	0.00376	0.00000	0.00023	0.00023	0.00000	0.00000
SW	D	0.01277	0.00160	0.00057	0.00000	0.00000	0.00000
WSW	D	0.01311	0.00239	0.00080	0.00000	0.00000	0.00000
W	D	0.05599	0.02201	0.01117	0.00399	0.00023	0.00000
WNW	D	0.04527	0.02509	0.01608	0.00479	0.00023	0.00000
NW	D	0.01026	0.00422	0.00103	0.00000	0.00000	0.00000
NNW	D	0.00946	0.00410	0.00068	0.00000	0.00000	0.00000
N	E	0.00433	0.00376	0.00046	0.00000	0.00000	0.00000
NNE	E	0.00296	0.00148	0.00205	0.00011	0.00000	0.00000
NE	E	0.00205	0.00057	0.00057	0.00000	0.00000	0.00000
ENE	E	0.00182	0.00068	0.00068	0.00000	0.00000	0.00000
E	E	0.00353	0.00103	0.00023	0.00000	0.00000	0.00000
ESE	E	0.02052	0.00684	0.00125	0.00000	0.00000	0.00000
SE	E	0.02269	0.00889	0.00000	0.00000	0.00000	0.00000

Wind Direction	Stability Category	2012 Average Wind Frequency at Given Speed					
		1-3 knots	4-6 knots	7-10 knots	11-16 knots	17- 21 knots	> 21 knots
SSE	E	0.01231	0.00365	0.00080	0.00000	0.00000	0.00000
S	E	0.00490	0.00080	0.00011	0.00000	0.00000	0.00000
SSW	E	0.00308	0.00034	0.00023	0.00000	0.00000	0.00000
SW	E	0.00787	0.00160	0.00011	0.00000	0.00000	0.00000
WSW	E	0.00639	0.00490	0.00034	0.00000	0.00000	0.00000
W	E	0.00878	0.00422	0.00000	0.00000	0.00000	0.00000
WNW	E	0.01448	0.00171	0.00103	0.00000	0.00000	0.00000
NW	E	0.01060	0.00239	0.00011	0.00000	0.00000	0.00000
NNW	E	0.00821	0.00388	0.00011	0.00000	0.00000	0.00000
N	F	0.00308	0.00137	0.00000	0.00000	0.00000	0.00000
NNE	F	0.00319	0.00148	0.00000	0.00000	0.00000	0.00000
NE	F	0.00262	0.00148	0.00000	0.00000	0.00000	0.00000
ENE	F	0.00239	0.00239	0.00000	0.00000	0.00000	0.00000
E	F	0.00718	0.00080	0.00000	0.00000	0.00000	0.00000
ESE	F	0.01277	0.00023	0.00000	0.00000	0.00000	0.00000
SE	F	0.01072	0.00068	0.00000	0.00000	0.00000	0.00000
SSE	F	0.00855	0.00468	0.00000	0.00000	0.00000	0.00000
S	F	0.00787	0.00502	0.00000	0.00000	0.00000	0.00000
SSW	F	0.00604	0.00376	0.00000	0.00000	0.00000	0.00000
SW	F	0.00684	0.00433	0.00000	0.00000	0.00000	0.00000
WSW	F	0.00627	0.00331	0.00000	0.00000	0.00000	0.00000
W	F	0.00559	0.00103	0.00000	0.00000	0.00000	0.00000
WNW	F	0.00992	0.00023	0.00000	0.00000	0.00000	0.00000
NW	F	0.00912	0.00171	0.00000	0.00000	0.00000	0.00000
NNW	F	0.00547	0.00251	0.00000	0.00000	0.00000	0.00000

Appendix C

Population Data

Direction	Daytime Population at Given Distance from Center of Berkeley Lab												
	0.5 km	1 km	2 km	3 km	4 km	5 km	10 km	20 km	30 km	40 km	50 km	60 km	80 km
N	567	81	130	6	0	0	635	23847	82827	25150	69500	25407	2057
NNW	288	177	646	706	421	360	2221	44047	0	1505	15306	16894	146651
NW	2117	470	509	1724	2628	2432	27072	53782	759	47974	12010	63143	133736
WNW	1035	1272	2374	3707	5548	9824	11906	14989	104906	27867	1109	2206	213
W	588	5841	10215	3236	5045	8929	2212	5050	41590	1468	208	0	0
WSW	26	6068	30481	14780	3896	12215	16	186522	157613	0	0	0	0
SW	3	10876	9187	4977	5040	6451	27269	415153	336243	49559	7	0	0
SSW	0	2015	3578	8427	4124	9726	100986	14541	53596	135496	20513	2502	135
S	0	255	1477	3381	4895	8535	67419	65855	0	163234	234910	69451	3269
SSE	13	72	1687	818	1118	2344	35125	158180	165619	137362	154068	450963	1208150
SE	4	0	67	485	420	930	4715	10557	63937	59845	76387	11716	54799
ESE	10	81	0	10	12	0	3805	12731	81261	102471	75005	33070	55123
E	73	429	0	4	3	19	9152	72495	14988	564	41842	12620	52114
ENE	253	334	0	1	171	638	3588	92833	108690	68712	87238	10380	14795
NE	507	15	8	0	1	693	806	45538	34441	4250	112	1666	2487
NNE	525	425	0	0	0	0	15	5489	31120	17416	94187	78096	46520

Appendix D

2012 Population File Update

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

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Ms. Linnea Wahl
Environmental Services Group
Environment/Health/Safety/Security Division
Lawrence Berkeley National Laboratory

Sept. 21, 2012

Ms. Wahl:

We are pleased to provide the following population files for the Lawrence Berkeley National Laboratory (LBNL) site for use with CAP88-PC:

- CAP88 formatted daytime population table (0.5,1,2,3,4,5,10, 20, 30, 40, 50, 60, and 80 km radii)
- CAP88 formatted nighttime population table (0.5,1,2,3,4,5,10, 20, 30, 40, 50, 60 and 80 km radii)

The methodology used to create these files was as follows:

- The population data used for this assessment were taken from ORNL's LandScan USA data product. The version used for this work was LandScan USA 2010.
    - LandScan USA 2010 is based on 2010 U.S. Census Data (released in March 2011).
    - LandScan USA is a dasymetric population distribution model produced from the latest 2010 Census counts at the Block level.
    - Output is a 3 arc-second gridded population database.
    - A separate output is produced for nighttime and daytime populations.
- A sector-annuli rose was created using the site center point coordinates (37.8753N 122.2478W) and the distances (see above) provided by LBNL.
- The LandScan USA daytime and nighttime grids were each intersected with the sector-annuli rose to tabulate the final population counts for each distance and direction combination.
- The resulting population data were then converted into a daytime population data file and a nighttime population data file using CAP88PC version 3.

Please feel free to contact me if you have any questions or comments about this deliverable.

Sincerely,

Amy N. Rose

DE-AC02-05CH11231