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LLNL NESHAPs 2009 Annual Report

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Radionuclide Air Emission Report for 2009
(in compliance with 40 CFR 61, Subpart H)

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Executive Summary

Lawrence Livermore National Security, LLC operates facilities at Lawrence Livermore National Laboratory (LLNL) where radionuclides are handled and stored. These facilities are subject to the U.S. Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants (NESHAPs) in Code of Federal Regulations (CFR) Title 40, Part 61, Subpart H, which regulates radionuclide emissions to air from Department of Energy (DOE) facilities. Specifically, NESHAPs limits the emission of radionuclides to the ambient air to levels resulting in an annual effective dose equivalent of 10 mrem (100 μSv) to any member of the public. Using measured and calculated emissions, and building-specific and common parameters, LLNL personnel applied the EPA-approved computer code, CAP88-PC, Version 1.0, to calculate the dose to the maximally exposed individual for the Livermore site and Site 300. The dose for the LLNL site-wide maximally exposed members of the public from operations in 2009 are summarized here:

- Livermore site: 0.0042 mrem (0.042 μSv) (36% from point source emissions, 64% from diffuse source emissions). The point source emissions include gaseous tritium modeled as tritiated water vapor as directed by EPA Region IX; the resulting dose is used for compliance purposes.

- Site 300: 2.7×10^{-7} mrem (2.7×10^{-6} μSv) (100% from point source emissions).

1
Background Information

LLNL is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within DOE. As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory serves as a scientific resource to the U.S. government and a partner to industry and academia.

Because LLNL is a DOE facility, it is subject to the requirements of 40 CFR 61, Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities. This regulation limits emissions of radionuclides to ambient air to levels resulting in an annual effective dose equivalent of 10 mrem (100 μSv) to any member of the public. The regulation also requires annual reporting of the emissions and resulting dose.

1.1 SITE DESCRIPTION

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site;" and a rural experimental test site, referred to as "Site 300," near Tracy, California (**Figure 1**).

Figure 1. Locations of LLNL's Livermore site and Site 300.

The Livermore site is just east of Livermore, a city of about 80,000 in Alameda County. The site occupies 1.3 square miles, including the land that serves as a buffer zone around most of the site. Within a 50-mile radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.2 million people within 50 miles of the Laboratory, only about 10% are within 20 miles.

Site 300, LLNL's Experimental Test Site, is located in the Altamont Hills of the Diablo Range and straddles the San Joaquin and Alameda county line. The site is 12 miles east of the Livermore site and occupies 10.9 square miles. The city of Tracy, with a population of over 80,000, is approximately 6 miles to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 6.7 million people who live within 50 miles of Site 300, 95% are more than 20 miles away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

The weather conditions at the Livermore site and Site 300 are very similar. The climate at both sites is best described as Mediterranean, characterized by mild, rainy winters and warm-to-hot, dry summers. However, the complex topography of Site 300 does influence local wind and temperature patterns. The stronger winds that occur at the higher elevations of Site 300 (see **Figure 2**) results in warmer nights and slightly cooler days than the Livermore site.

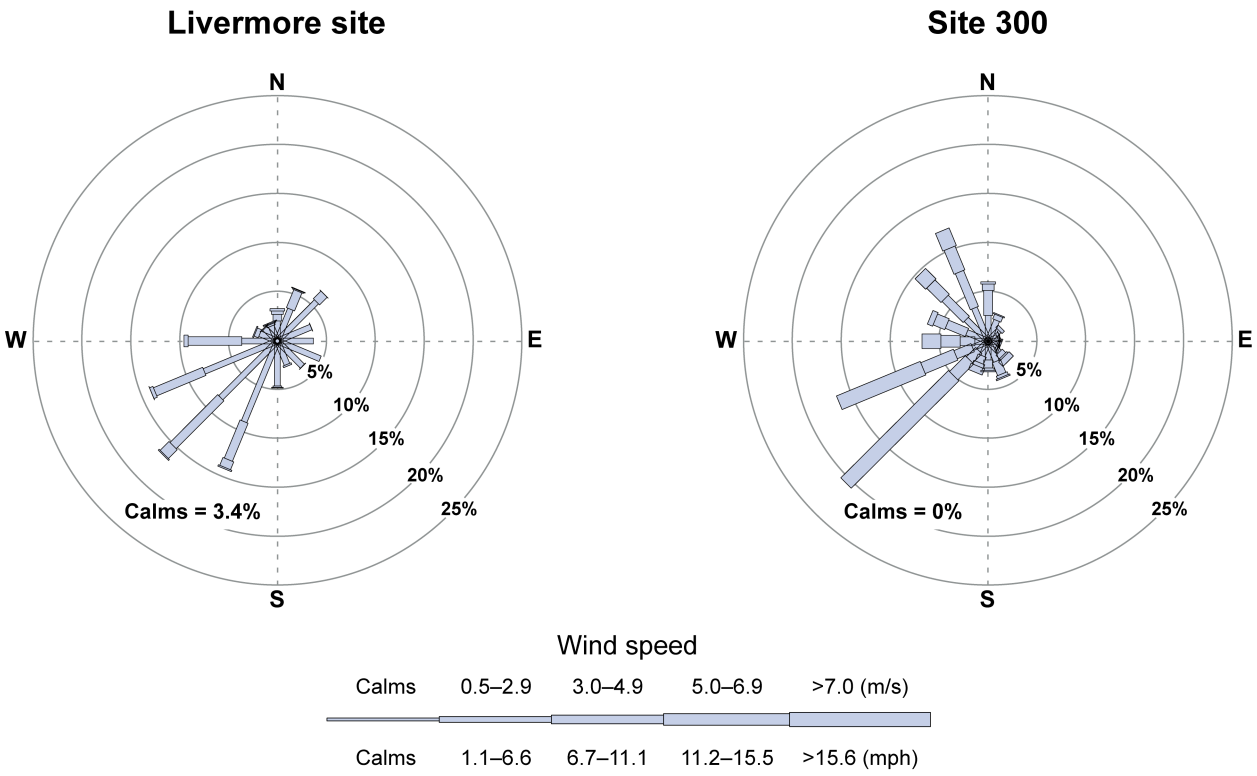

Figure 2. Wind roses for the Livermore site and Site 300 for 2009.

The 2009 annual wind data for both sites are displayed as wind roses in **Figure 2**. In the wind rose, the length of each spoke is proportional to the frequency at which the wind blows from the indicated direction; different line widths of each spoke represent wind speed classes. These data show that for the Livermore site, winds blew from the south-southwest through west-southwest about 45% of the time; for Site 300, the data show that the winds blew from the southwest to the west-southwest more than 35% of the time. The average wind speed in 2009 at the Livermore site was 2.3 m/s (5.2 mph), and the average wind speed at Site 300 was 5.8 m/s (13.0 mph). In 2009, the Livermore site received 31.1 cm of rain and Site 300 received 21.4 cm.

1.2 SOURCE DESCRIPTION

Many different radioisotopes were available for use at LLNL in 2009 for research purposes, including biomedical tracers, tritium, mixed fission products, transuranic isotopes, and others—see **Table 1**. Radioisotope handling procedures and work enclosures are determined for each project or activity, depending on the isotopes, the quantities being used, and the types of operations being performed. Work enclosures include gloveboxes, exhaust hoods, and laboratory bench tops. Exhaust paths to the atmosphere include High Efficiency Particulate Air (HEPA) filtered ventilation systems, roof vents and stacks lacking abatement devices, direct open-air dispersal of depleted uranium during explosives testing at Site 300, and releases to ambient air from a variety of diffuse area sources. **Table 2** identifies the buildings, by managing organization, at LLNL where there was a potential for release of radioactive materials to the air in 2009.

Table 1. Radionuclides used at LLNL during 2009.

Hydrogen-3	Rubidium-83	Iodine-129	Bismuth-207	Thorium-232	Plutonium-240
Beryllium-10	Krypton-83m	Iodine-131	Mercury-203	Uranium-232	Americium-241
Carbon-14	Krypton-85	Barium-133	Polonium-208	Uranium-233	Plutonium-241
Sodium-22	Strontium-85	Cesium-134	Polonium-209	Uranium-234	Plutonium-242
Aluminum-26	Yttrium-88	Cesium-137	Lead-210	Uranium-235	Americium-242m
Phosphorus-32	Strontium-90	Cerium-139	Polonoium-210	Plutonium-236	Americium-243
Chlorine-36	Technetium-99	Cerium-144	Radium-226	Uranium-236	Curium-244
Calcium-41	Technetium-99m	Gadolinium-148	Actinium-227	Neptunium-236	Plutonium-244
Manganese-54	Cadmium-109	Europium-152	Thorium-228	Neptunium-237	Curium-246
Iron-55	Silver-110m	Manganese-154	Thorium-229	Plutonium-238	Curium-248
Cobalt-57	Tin-113	Europium-154	Thorium-230	Uranium-238	Californium-249
Cobalt-60	Iodine-125	Europium-155	Protactinium-231	Plutonium-239	Californium-252
Nickel-63	Antimony-125				

Table 2. Buildings at LLNL, by managing organization, where there is a potential for the release of radioactive materials to the air.

Director's Office	Science & Technology		Weapons & Complex Integration	National Ignition Facility & Photon Science	Operations & Business
B253	B131	B321	B331[a]	B162	B419
B254	B132N/B132S[b]	B322	B332[a]	B298	B597
B255	B151	B327	B612	B381	
	B194	B341	B625	B491[a]	
	B231	B361	B695/696[a]		
	B235[a]	B362	B697		
	B241	B364	B801[a]		
	B243	B378	B804		
	B281	B810A[c]	B812[d]		
	B282	B810B[c]	B850[d]		
	B292		B851		
			B883		

[a] Continuous monitoring occurs at one or more exhaust points at the building.
[b] B132S is managed by Global Security.
[c] The managing organization for B810A and B810B changed during calendar year 2009 from Science & Technology to Weapons & Complex Integration.
[d] The managing organization for B812 and B850 changed during calendar year 2009 from Weapons & Complex Integration to Operations & Business.

2
Emissions Data

At LLNL, radionuclide emission sources are placed into one of two categories; major sources or minor sources. Major sources are defined as those that have the potential to emit radionuclides that could result in an annual potential dose of 0.1 mrem (1 μSv) or more to a member of the public at an off-site location; the radionuclide NESHAPs regulation requires continuous monitoring where the annual potential dose is in excess of 0.1 mrem (1 μSv). Minor sources are defined as sources that do not have the potential to cause an annual dose of 0.1 mrem (1 μSv/yr). At LLNL, all major sources of emissions are point sources, i.e., stack emission points; however, minor sources include both point sources and area sources.

2.1 MAJOR SOURCES: MEASURED EMISSIONS

LLNL measures emissions at six facilities. Some of these facilities have the potential to emit radionuclides that would cause an annual dose in excess of the 0.1 mrem (1 mSv/yr) standard; these sources are major sources following the definition given above. Others of these facilities have historically had emissions that would require monitoring, and the monitoring has been maintained to assure that the emissions are well characterized and that the potential effect on the public and the environment is well understood.

In 2009, there were five facilities at the Livermore site and one facility at Site 300 that had radionuclide air effluent monitoring systems. These facilities are listed in **Table 3**, along with the number of samplers, the types of samplers, and the analytes of interest.

Many of the monitored stacks at LLNL have effluent controls, such as HEPA filters, to collect materials before they are emitted to the atmosphere. Air samples for particulate emissions are extracted downstream of HEPA filters and prior to the discharge point to the atmosphere. Particles are collected on cellulose membrane filters. The sample filters are removed and analyzed for gross alpha and gross beta activity on a weekly or bi-weekly frequency depending on the facility. In all cases, continuous passive filter aerosol collection systems are used. At some facilities, continuous air monitors (CAMs) are also deployed for sampling. CAMs have an alarm capability for the facility in the event of an unplanned release of alpha activity. CAMs are used for facility personnel safety; they are not used for NESHAPs compliance demonstration.

Table 3. Air effluent sampling systems and locations.

Building	Facility	Analytes	Sample type	Number of samplers
235	Building in Physical and Life Sciences Directorate	Gross α, β on particles	Filter	1
331	Tritium Facility	Gaseous tritium/ tritiated water vapor	Ionization Chamber[a]	4
		Gaseous tritium/ tritiated water vapor	Glycol Bubblers	2
332	Plutonium Facility	Gross α, β on particles	Filters	15
		Gross α, β on particles	CAM[a]	12
491	Isotope Separation[b]	Gross α, β on particles	Filter	1
695/696	Decontamination and Waste Treatment Facility	Gross α, β on particles	Filter	1
		Gaseous tritium/ tritiated water vapor	Glycol Bubbler	1
801A	Contained Firing Facility	Gross α, β on particles	Filter	1

Note: "CAM" denotes continuous air monitors.
[a] Alarmed systems used for facility personnel safety, not for NESHAPs compliance demonstration.
[b] Isotope separation operations are discontinued; area now used for storage of contaminated parts.

Detection of gross alpha and gross beta activity resulting from particles collected on the air filters is accomplished using gas flow proportional counters. Analysis is delayed for at least four days from the end of sample collection to allow for the decay of naturally occurring short-lived radon daughters. For verification of the operation of the counting system, calibration sources, as well as background samples, are intermixed with the sample filters for analysis. The Radiological Measurements Laboratory (RML) in LLNL's Hazards Control Department (HCD) performs the analyses.

For particles collected on a filter with a result greater than the minimum detectable concentration (MDC) for gross alpha activity, the filter is recounted a second time. If the second result is also above the MDC, the filter is submitted for isotopic analysis to determine whether the activity on the filter is the result of naturally occurring radiation or is reportable as a radionuclide emission from facility activities. The Environmental Monitoring Radioanalytical Laboratory (EMRL) in the Physical and Life Sciences Directorate performs the isotopic analysis.

Glycol bubblers are used to monitor for tritium releases from the Decontamination Waste Treatment Facility (DWTF) stack and each stack of the Tritium Facility (Building 331). (In addition to this NESHAPs compliance monitoring, the Tritium Facility stacks are monitored using ion chambers. The ion chamber monitors are set to alarm at designated tritium concentrations for accidental or off-normal releases. Ion chambers are in place solely for facility personnel safety; they are not used for NESHAPs compliance demonstration.) All of the stack samplers monitor continuously.

Because the release of tritium can be either in the form of tritiated water vapor (HTO) or gaseous tritium (HT), the glycol bubblers in use at DWTF and the Tritium Facility employ a two-stage glycol impinging process to capture each physical form. Stack air to be sampled enters the instrument and flows through the first stage, which is two impingers in series, capturing the HTO present. Next, the sampled air is directed through a palladium catalyst where oxidation of any HT in the sample takes place, converting gaseous tritium to HTO, which is then collected in the second stage, the final two impingers (also in series). The impingers are analyzed by the RML using liquid scintillation analysis. This type of sampling quantifies the amount of tritium for both tritium species, HT and HTO.

In 2009, a total of 16.7 Ci (618 GBq) of measured tritium was released from the Tritium Facility. Of this, approximately 14.7 Ci (544 GBq) of tritium was released as vapor (HTO). The remaining tritium released, 2.0 Ci (74 GBq), was gaseous tritium (HT).

In 2009, 3.9×10^{-2} Ci (1.4 GBq) of measured tritium was released from DWTF as HTO. Tritium in the gaseous state (HT) was measured at 6.8×10^{-3} Ci (0.25 GBq) from the stack effluent in 2009. The total tritium released from DWTF for 2009 was 4.6×10^{-2} Ci (1.7 GBq)

The Contained Firing Facility at Site 300 had measured depleted uranium emissions in 2009. A total of 3.3×10^{-8} Ci (1.2×10^{-6} GBq) of uranium-234, 1.8×10^{-9} Ci (6.8×10^{-7} GBq) of uranium-235, and 5.4×10^{-8} Ci (2.0×10^{-6} GBq) of uranium-238 was released in particulate form.

None of the other facilities monitored for radionuclides had reportable emissions in 2009.

2.2 MINOR SOURCES: AMBIENT MEASUREMENT COMPARISON

With EPA's Region IX approval, LLNL demonstrates compliance for minor emissions sources (both non-monitored stack and area sources) through the use of ambient air monitoring data. The method entails comparing measured ambient air concentrations at the location of the site-wide maximally exposed individual (SW-MEI) to concentration limits set by EPA in its Table 2 of Appendix E to 40 CFR 61. The radionuclides for which the comparisons are made are tritium and plutonium-239+240 for the Livermore SW-MEI and uranium-238 for the Site 300 SW-MEI (see **Table 6** in section 3.3.2).

2.3 MINOR SOURCES: CORRELATION MODEL ESTIMATE

To estimate the source term for diffuse minor sources of tritium emissions so their dose contribution can be taken into account, LLNL conducts further evaluation of the ambient tritium measurements. The approach used involves correlating the annual average measured air tritium concentrations with the CAP88-PC modeled air concentrations. It is assumed that a combined distribution of varied diffuse emission sources, as

dispersed by site-specific LLNL meteorology modeled in CAP88-PC, yield the concentrations measured at the air samplers. The approach begins by using a unit area source model activity of 1 Ci parameterized by even grid spacing, a 1-meter height and a 10-meter diameter, and a fixed plume rise across stability classes A through F. The LLNL 2009 wind file is input into the CAP88-PC model. The execution of the model yields a set of modeled air concentrations that are then placed in a coordinate system centered at selected known diffuse source locations and corresponding distances and directions to the air tritium sampling locations (see **Figure 5** in section 3.3.2 for the location of air samplers). A Microsoft Excel™ spreadsheet is used to vary the unit source terms at each diffuse source location while accounting for the contributions of the two stack sources, Building 331 and Building 695, and summing their respective modeled concentrations. The result of this correlation effort yielded a source term of 2.4 Ci for Building 331 Waste Accumulation Area (WAA), 0.6 Ci for Building 612 Yard, and 0.05 Ci for Building 695/696 Yard. The results of the model estimate are displayed in **Figure 3**.

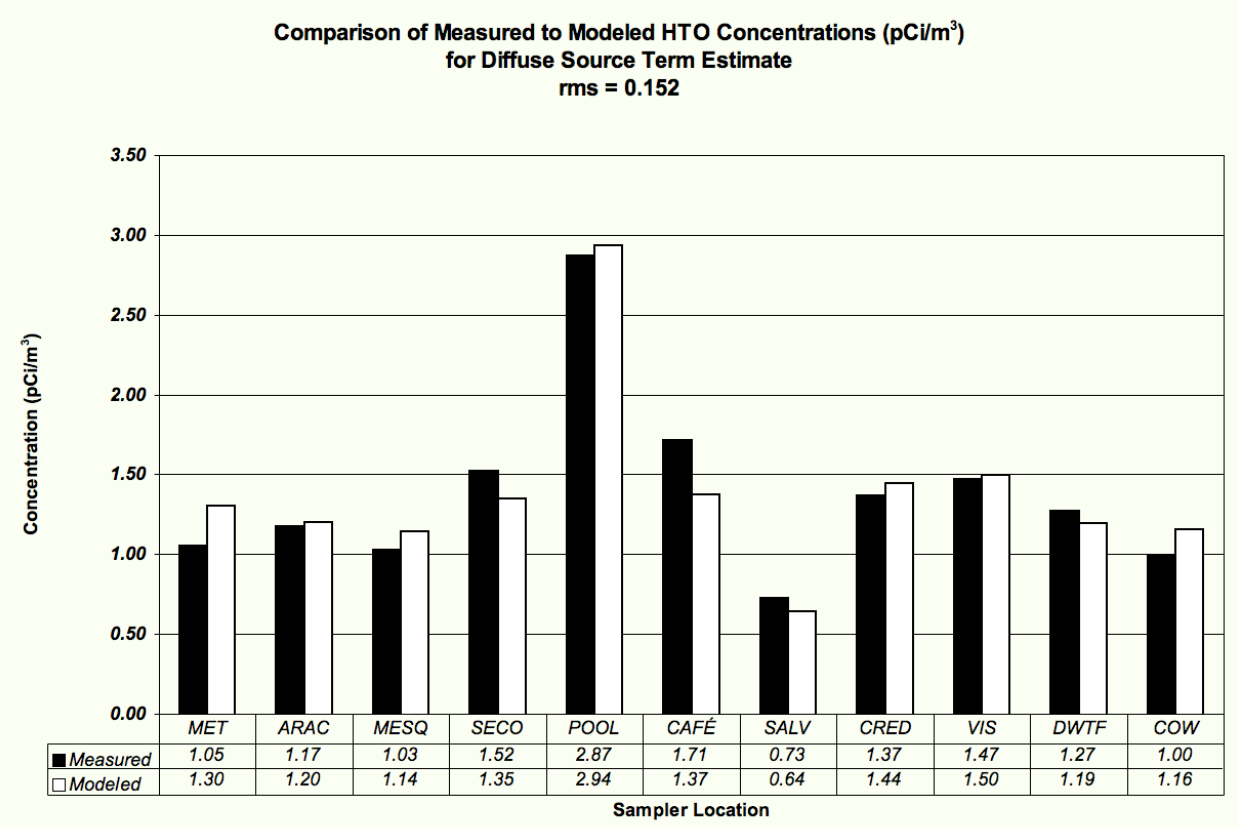

Figure 3. Comparison of measured and modeled annual mean concentrations of tritiated water vapor (HTO) in air at Livermore site locations, 2009.

2.4 MINOR SOURCES: OPEN-AIR TESTS

Another potential source of radioactive air emissions from LLNL operations at Site 300 is the emission of materials from open-air explosives tests. In 2009, there were no open-air explosives tests that contained radioactive materials.

3
Dose Assessment

3.1 GENERAL

To comply with NESHAPs regulations and DOE guidance, the EPA-approved atmospheric dispersion and radiation dose calculation computer code, CAP88-PC, Version 1.0, was used to calculate the dose at various distances and from various release points. For diffuse sources having a significant contribution to total dose, in addition to comparing the emissions to the concentration limits set by EPA in its Table 2 of Appendix E to 40 CFR 61, doses were calculated using either CAP88-PC or standard breathing rates and dose conversion factors.

For LLNL to comply with the NESHAPs regulations, the LLNL SW-MEI cannot receive an effective dose equivalent greater than 10 mrem/y (100 μSv/y). The SW-MEI is defined as the *hypothetical* member of the public at a single residence, school, business, church, or other such facility who receives the greatest LLNL induced dose from the combination of all evaluated radionuclide source emissions, as determined by modeling. At the Livermore site, the SW-MEI for 2009 was located at the UNCLE Credit Union, about 30 feet (10 m) outside the controlled eastern fence line of the site, but about 30 feet (10 m) within the perimeter of the site property. At Site 300, the 2009 SW-MEI was located at the boundary with the Carnegie State Vehicle Recreation Area, managed by the California Department of Parks and Recreation, approximately 1.9 miles (3.2 km) south-southeast of the firing table at Building 851. The locations of the SW-MEIs for both LLNL sites are shown in **Figure 4**.

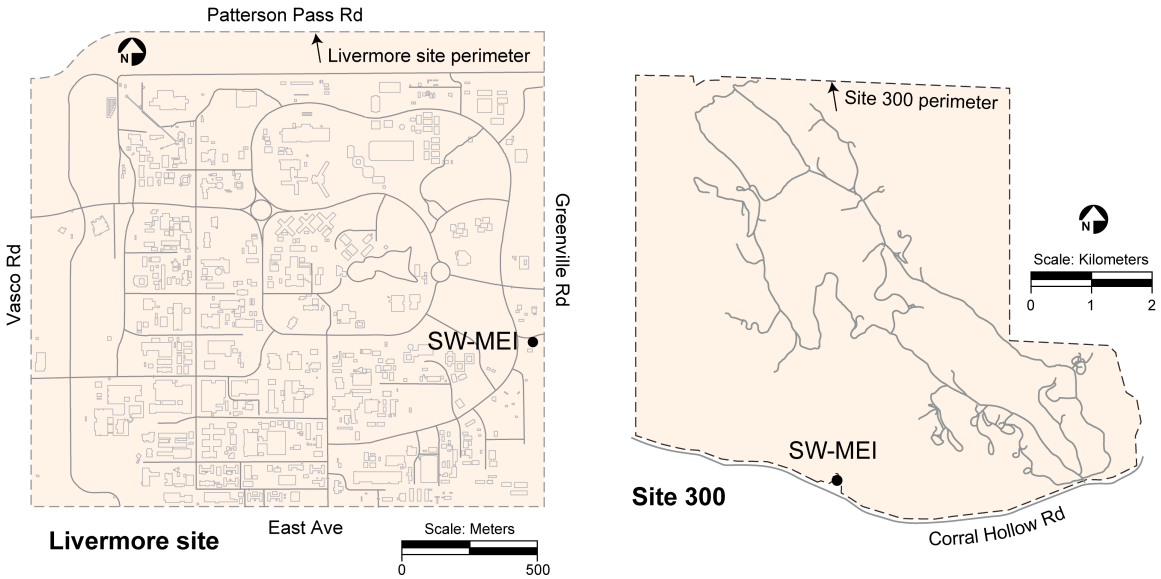

Figure 4. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at the Livermore site and Site 300, 2009.

3.2 CAP88-PC INPUT PARAMETERS

Input parameters to CAP88-PC include the emissions discussed in section 2, and building-specific and common parameters, discussed below. To estimate dose, CAP88-PC, Version 1, provides a library of 265 radionuclides. In addition, when calculating dose from particulate alpha- and beta-emitting radionuclides, LLNL assigns gross alpha and gross beta measurements to the radionuclides handled in the facility, when they can be specifically identified, or to plutonium-239+240 and strontium-90, respectively. The use of plutonium-239+240 and strontium-90 to represent alpha and beta emissions provides a health-conservative estimate of the dose.

3.2.1 Building-Specific Parameters

For dose assessment, LLNL uses building-specific information about radionuclide releases, as well as building-specific parameters for stack height, stack exhaust rate, stack diameter, and distances to the fence line. The building specific parameters are presented in Attachment 1.

3.2.2 Common Parameters

The input parameters that are common among LLNL sources are the agricultural parameters. Meteorological data from the LLNL Livermore site meteorological tower are used to model Livermore site sources, and meteorological data from the LLNL Site 300 meteorological tower are used to model Site 300 sources. Site-specific values for annual precipitation (12.2 in. [31.1 cm] for the Livermore site and 8.4 in. [21.4 cm] for Site 300) and annual ambient temperature (57.9°F [14.4°C] for the Livermore site and 61.7°F [16.5°C]) were used. The CAP88-PC, Version 1, default for absolute humidity, 8 g/m3, which is reasonably representative of conditions at LLNL, was used. The value for lid (mixing) height of 2,460 ft (750 m), was chosen for the Livermore site, whereas the lid height value for Site 300 was 3,280 ft (1,000 m). The 2009 wind data are provided in Attachment 2.

For agricultural parameters in CAP88-PC, LLNL used mean values for California based on data from the U.S. Department of Agriculture (USDA 2007). The mean values are shown in **Table 4**.

Table 4. Agricultural parameter values representing LLNL used in CAP88-PC.

Parameter	Value
Beef cattle density (# cows/km^2)	4.8
Milk cattle density (# cows/km^2)	0.025
Land fraction cultivated for vegetable crops	0.065

For individual dose from ingestion, it was assumed that 25% of the vegetables and meat are home-grown, while the remaining 75% of vegetables and meat and 100% of the

milk is imported (i.e., free from LLNL-generated radioactivity). For collective dose, the urban default choice in CAP88-PC was used (in which 7.6% of vegetables, 0% of milk, and 0.8% of meat are home-grown, with the balances obtained from the assessment area exposed to the released radioactivity).

3.3 COMPLIANCE ASSESSMENT

3.3.1 Major Sources

Doses from LLNL's major sources, which are point sources for which monitoring is required, were evaluated using CAP88-PC and the input parameters discussed above. The sources evaluated were the monitored facilities, i.e., Buildings 235, 331, 332, 491, 695/696, and 801. The doses for the facilities where there were measurements greater than the minimum detectable concentration (MDC) are shown in **Table 5**. The specific results for all sources are provided in Attachment 1. The total dose from point sources was 1.5×10^{-3} mrem (1.5×10^{-2} μSv) for the Livermore site and 2.7×10^{-7} mrem (2.7×10^{-6} μSv) for Site 300.

Table 5. Point source doses for 2009.

Facility	Dose (mrem)
Tritium Facility	1.5×10^{-3}
DWTF	1.3×10^{-6}
CFF	2.7×10^{-7}

3.3.2 Minor Sources

LLNL has many minor sources; most of these sources are point sources and some of these sources are diffuse, or area sources. As stated previously, with EPA's Region IX approval, LLNL demonstrates compliance for minor emissions sources (both non-monitored stack and area sources) through the comparison of ambient air monitoring data to concentration limits set by EPA in its Table 2 of Appendix E to 40 CFR 61. The radionuclides for which the comparisons are made are tritium and plutonium-239+240 for the Livermore SW-MEI and uranium-238 for the Site 300 SW-MEI. The 2009 average monitoring results for tritium and plutonium from the sampling location in closest proximity to the SW-MEI (UNCLE Credit Union [CRED]) represent the SW-MEI for the purposes of this minor source comparison. (See **Figure 5** for a map of all sampling locations, including CRED.) For the 2009 comparison of the mean measured plutonium-239 concentration to the Table 2 standard, only those concentrations that were greater than zero from the CRED sampling location were averaged to represent the SW-MEI. At Site 300, wind-driven resuspension of soil contaminated with depleted uranium is of greatest interest in the minor source category. However, as in 2008, but in contrast to prior years, no ambient measurements for uranium showed a contribution

from depleted uranium—the uranium-238 value in **Table 6** represents a natural background value. The lack of measurements indicating the presence of depleted uranium may also be related to the fact that no outdoor explosives tests that included depleted uranium were conducted in 2009. Because there was no source term for depleted uranium resuspension at Site 300, there is no dose calculated for 2009.

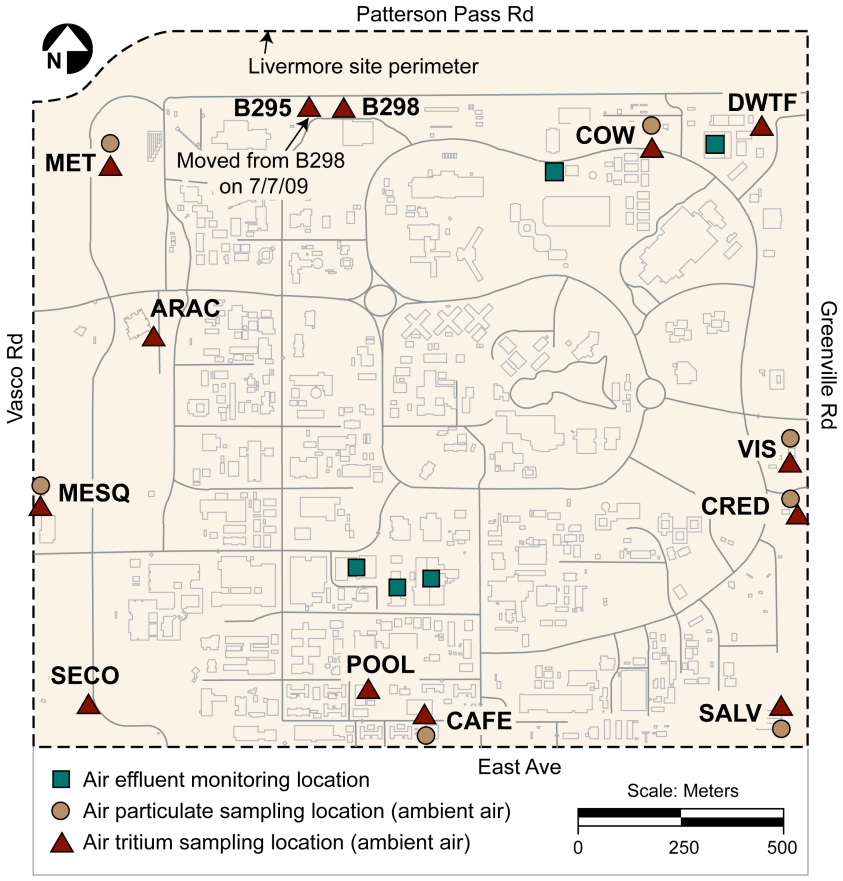

Figure 5. Radiological air monitoring locations at the Livermore site in 2009.

The measured concentrations at the SW-MEI are presented in **Table 6**. Also shown in **Table 6** are EPA's standards from Table 2 of Appendix E to 40 CFR 61. As demonstrated by the calculation of the fraction of the standard, LLNL's measured concentrations in air for tritium, plutonium-239+240, and uranium-238 are a fraction 0.002 or less of the standard for these radionuclides.

In order to obtain an estimate of the contribution of diffuse sources to the total dose impacts of LLNL operations, doses for uranium and plutonium can also be estimated from the concentrations listed in **Table 6**. The source term for diffuse sources of tritium was developed using a mathematical model as stated in section 2.3. The specific doses for 2009 are listed in Attachment 1. The total diffuse source dose for 2009 was 2.7×10^{-3} mrem (2.7×10^{-2} μSv) for the Livermore site; because there was no diffuse source term for Site 300, no dose was calculated.

Table 6. Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2009 compared to EPA's concentration standard.

Location	Nuclide	EPA's Table 2 concentration standard	Mean measured concentration	Measured concentration as a fraction of the standard	Detection limit
Livermore site SW-MEI	Tritium	1.5×10^{-9} Ci/m^3	1.6×10^{-12} Ci/m^3[a]	1.1×10^{-3}	1×10^{-12} Ci/m^3
Livermore site SW-MEI	Plutonium-239	2.0×10^{-15} Ci/m^3	3.9×10^{-19} Ci/m^3[b]	1.9×10^{-4}	5×10^{-19} Ci/m^3
Site 300 SW-MEI	Uranium-238	8.3×10^{-15} Ci/m^3	2.0×10^{-17} Ci/m^3[c]	2.4×10^{-3}	3×10^{-20} Ci/m^3

[a] The measured tritium value includes contributions from all minor sources (including the Building 612 Yard and the Building 331 Outside Yard), Tritium Facility, and DWTF; it is not possible to differentiate the contributions of the Tritium Facility and DWTF from those of the minor sources.

[b] Note that the mean measured concentration for plutonium is less than the detection limit; only 1 of the 7 values comprising the mean was a measured detection. Only values greater than zero are used in the calculation of the mean.

[c] The average ratio of uranium-238 and uranium-235 concentrations for 2009 is 0.0072, which is the ratio of these isotopes for naturally occurring uranium. This value for uranium-238 is from naturally occurring uranium resuspended in the soil.

3.3.3 MEI Dose

Doses from LLNL's airborne emissions are well below the 10 mrem (100 μSv) NESHAPs annual dose standard. As shown in Attachment 1, the annual doses to the hypothetical SW-MEI at the Livermore site and at Site 300 are:

- Livermore site: 4.2×10^{-3} mrem (4.2×10^{-2} μSv)
- Site 300: 2.7×10^{-7} mrem (2.7×10^{-6} μSv)

The EPA-approved software calculates the dose assuming a person resides there all year for 24 hours a day, eats meat and vegetables grown at the location (see agricultural parameters in section 3.2.2), and drinks contaminated water. Thus, the calculated dose to this hypothetical person, the SW-MEI, is greater than the dose to an actual resident.

Table 7 presents 2009 doses with those of previous years. Diffuse source doses were not reported for the Livermore site for 1990 and 1991, and were not reported for Site 300 for 1990 through 1992. No diffuse source dose was calculated for Site 300 for 2009 because the ambient sampling results at the SW-MEI yielded data that indicated the presence of natural uranium only.

Table 7. Doses (in mrem) calculated for the Site-Wide Maximally Exposed Individual (SW-MEI) for the Livermore site and Site 300, 1990 to 2009.

Year	Total Dose	Point Source Dose	Diffuse Source Dose
Livermore site			
2009	0.0042[a]	0.0015[a]	0.0027
2008	0.0013[a]	0.00033[a]	0.00095
2007	0.0031[a]	0.0013[a]	0.0018
2006	0.0045[a]	0.0016[a]	0.0029
2005	0.0065[a]	0.0027[a]	0.0038
2004	0.0079[a]	0.0021[a]	0.0058
2003	0.044[a]	0.024[a]	0.020
2002	0.023[a]	0.010[a]	0.013
2001	0.017[a]	0.0057[a]	0.011
2000	0.038[a]	0.017[a]	0.021
1999	0.12[a]	0.094[a]	0.028
1998	0.055[a]	0.031[a]	0.024
1997	0.097	0.078	0.019
1996	0.093	0.048	0.045
1995	0.041	0.019	0.022
1994	0.065	0.042	0.023
1993	0.066	0.040	0.026
1992	0.079	0.069	0.010
1991	0.234	—[b]	—[b]
1990	0.240	—[b]	—[b]
Site 300			
2009	2.7×10^{-7}	2.7×10^{-7}	—[c]
2008	4.4×10^{-8}	4.4×10^{-8}	—[c]
2007	0.0035	0.0031	0.00035
2006	0.016	0.014	0.0020
2005	0.018	0.0088	0.0094
2004	0.026	0.025	0.00086
2003	0.017	0.017	0.00034
2002	0.021	0.018	0.0033
2001	0.054	0.050	0.0037
2000	0.019	0.015	0.0037
1999	0.035	0.034	0.0012
1998	0.024	0.019	0.005
1997	0.020	0.011	0.0088
1996	0.033	0.033	0.00045
1995	0.023	0.020	0.003
1994	0.081	0.049	0.032
1993	0.037	0.011	0.026
1992	0.021	0.021	—[d]
1991	0.044	0.044	—[d]
1990	0.057	0.057	—[d]

[a] The dose includes HT emissions modeled as HTO. Modeling HT emissions as such results in an overestimation of the dose. This methodology is used for purposes of compliance, as directed by EPA Region IX.

[b] Point and diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991.

[c] No diffuse emissions dose was calculated for 2008 or 2009 because ambient monitoring yielded no results indicating the presence of depleted uranium.

[d] No diffuse emissions were evaluated at Site 300 for years before 1993.

4
Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: Steven Wuthrich
Director
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Signature: Roy F. Gayll for Steven Wuthrich Date: 6/24/2010

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.

Name: Michael G. Brown
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Signature: Michael G. Brown Date: 6/29/2010

5
Additional Information

5.1 ADDITIONS OR MODIFICATIONS

5.1.1 National Ignition Facility

The National Ignition Facility (NIF) Project was certified complete for operation on March 31, 2009, and formally dedicated on May 29, 2009. One of the Grand Challenges in science and engineering is the demonstration of inertial confinement fusion (ICF), thermonuclear ignition and net energy gain, in the laboratory. LLNL, in collaboration with its partners in the National Ignition Campaign (NIC)—Los Alamos and Sandia National Laboratories, the Laboratory for Laser Energetics at the University of Rochester and General Atomics of San Diego—will tackle this challenge with a credible attempt at ignition on the National Ignition Facility by 2010. NIC is the “bridge” that will take NIF to routine operations as a highly flexible high energy density science facility by 2013.

NIF's ICF experiments will be designed to advance the NNSA's Stockpile Stewardship Program as well as basic high energy density science research in such fields as astrophysics, nuclear physics, radiation transport, materials dynamics and hydrodynamics. Other experiments will provide scientists with the necessary understanding of the physics underlying the use of ICF for safe, clean energy production.

Experiments with radionuclides that have the potential to be released to the air are planned to begin at NIF in calendar year 2010. The NIF will have stack monitoring that is in compliance with the radionuclide NESHAPs regulations.

5.2 UNPLANNED RELEASES

There were no unplanned releases from the Livermore site or Site 300 in 2009.

6
Supplemental Information

6.1 COLLECTIVE DOSE ASSESSMENT

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 in 2009 were assumed to be released from a central location. Based on the 2007 update of the LandScan Global Population Database (Dobson and Bright, 2002), the total population within 50 miles (80 km) of the Livermore site is approximately 7,200,000, and the total population within 50 miles (80 km) of Site 300 is approximately 6,700,000. The population file is provided in Attachment 3. The estimated collective dose attributable to LLNL airborne emissions in 2009 to persons living within 50 miles (80 km) of the Livermore site is 2.0×10^{-1} person-rem (2.0×10^{-3} person-Sv) and to persons living within 50 miles (80 km) of Site 300 is 5.1×10^{-5} person-rem (5.1×10^{-7} person-Sv).

Although collective doses from LLNL are high relative to other DOE facilities, it is because of the large populations lying within 80 km of the Livermore site and Site 300. Even though the collective doses may be the same, a large dose to a small number of people is not equivalent to a small dose to many people. A more detailed understanding of the population dose can be had by disaggregating the population dose by categories of individual dose. The disaggregated population doses for the Livermore site and Site 300 are shown in Table 8.

Table 8. Disaggregation of collective dose, 2009.

Individual dose (mrem/y)	Collective dose (person-rem/y)	Percent total collective dose
Livermore site		
1×10^{-4} to 1×10^{-3}	0.0190	9.4%
1×10^{-5} to 1×10^{-4}	0.177	87%
1×10^{-6} to 1×10^{-5}	0.00668	3.3%
Total	**0.203**	**100%**
Site 300		
1×10^{-7} to 1×10^{-6}	0.0000152	29.8%
1×10^{-8} to 1×10^{-7}	0.0000149	29.1%
1×10^{-9} to 1×10^{-8}	0.0000210	41.1%
Total	**0.0000511**	**100%**

The largest collective dose for the Livermore site is in the sector that is between 64 and 80 km west of the site. This sector has an estimated population of 1,053,040, which received an extremely low individual modeled dose of 0.000025 mrem/y. By multiplying the per capita dose in this sector by the number of people who received this dose, the collective dose for this sector is calculated to be 0.0263 person-rem/y.

The concept of population dose has a number of limitations. For example, the attempt to make a valid estimate of the dose that a member of the public could receive should address the time duration that individuals actually receive the dose. In addition, proximity weighting to the source of the contamination should be considered. Simple comparisons across facilities of a collection of individual doses expressed as a single value should be untaken carefully (NCRP, 1995).

6.2 40 CFR 61 SUBPARTS Q AND T

LLNL does not have storage and disposal facilities for radium containing materials that would be a significant source of radon. Emissions of radon from LLNL research experiments did not occur in 2009. LLNL does not have or store any uranium mill tailings.

6.3 PERIODIC CONFIRMATORY MEASUREMENT

Results of NESHAPs periodic confirmatory measurements (PCM) are intended to support or confirm two objectives: 1) that those operations not continuously monitored do not, in fact, need to be continuously monitored and 2) that radionuclide usage-inventory-based estimates of emissions and their corresponding doses are conservative.

For sources evaluated to have a potential to result in a dose less than the regulatory value of 0.1 mrem/y that requires continuous monitoring under Subpart H, LLNL achieves the PCM objectives by fulfilling the requirements stated in 40 CFR 61.93, paragraph (e) with its ambient air monitoring program. The ambient air monitoring effort includes thirty-two sampling locations with forty-six samplers placed in strategic areas (see the Air Monitoring Programs section in the LLNL Site Annual Environmental Report [https://saer.llnl.gov/] for a description of LLNL's ambient air radiological monitoring).

6.4 LLNL FUNCTIONAL AREA MANAGEMENT/LINE MANAGEMENT REVIEW

LLNL's NESHAPs program was reviewed for compliance with the Quality Assurance aspects of 40 CFR 61, Subpart H and Appendix B Method 114, QA Methods. In general, LLNL's program is based on the Environmental Protection Department (EPD) guidance documents, planning documents, and procedures. Procedures and processes were found to be documented, implemented and meet the requirements of the standards. However, the review resulted in the observation was that one relevant document, the Environmental Monitoring Plan, had not been updated since 2005. At

the time of the review, the revision of the Environmental Monitoring Plan was in progress. The Environmental Monitoring Plan revision has been completed, and the observation has been corrected. With the exception of this noted observation, which has been corrected, the NESHAPs program was found to be compliant.

6.5 FACILITY COMPLIANCE

In 2009, LLNL maintained its compliance with 40 CFR 61 Subpart H. All emissions resulted in calculated doses well below the 10 mrem (100 μSv) standard. The total estimated dose from airborne emissions from the Livermore site was 0.0042 mrem (0.042 μSv) and the total estimated dose from airborne emissions from Site 300 was 2.7×10^{-7} mrem (2.7×10^{-6} μSv). Attachment 1 provides the dose estimates for each individual source.

References

Dobson and Bright 2002: Dobson, J. E., and E. A. Bright, Landscan Global Population 1998 Database, www.ornl.gov/gist/projects/LandScan/landscan_doc.htm (August 2002).

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

National Council on Radiation Protection and Measurements (NCRP), Principles and Application of Collective Dose in Radiation Protection, NCRP Report No. 121 (1995).

USDA 2007. United States Department of Agriculture. The Census of Agriculture. 2007 Census Publications. Volume 1, Chapter 2, County Level Data. Table 1 and Table 11. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/California/index.asp (accessed May 19, 2009).

Errata

In the 2008 NESHAPs report, the sentence “The open source statistical code language, R, is used to vary the unit source terms at each diffuse source location while holding the known contributions of the two stack sources, Building 311 and Building 695, constant and summing their respective modeled concentrations.” was incorrect in identifying Building “311” as a source of emissions. The building should have been identified as Building “331”.

Attachments

Attachment 1 - 2009 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement: Distance to SW-MEI (m)	Direction to SW-MEI	EDE (mrem)	0.1 mrem/y Monitoring Requirement: Distance to MEI (m)	Direction to MEI	EDE (mrem)
LIVERMORE SITE POINT SOURCES																		
Building 235 is part of the Physical and Life Sciences Directorate. Operations in the facility include examination of material structure, surface, and subsurface; precision cutting, ion implanting, and metallurgical studies.																		
235	1130	FHE-1A/1B, FHE2A/2B and	Preparation of plutonium	Gross alpha	[a]	NA	10.7	0.30	6.9	Double HEPA	0.0001	0.0E+00	1065	ENE	0.0E+00	[b]	[b]	[b]
		FGBE-1A/1B through	samples for diamond anvil studies	Gross beta	[a]	NA						0.0E+00						
		FHE-1000/2002																
Building 331 is operated by the Defense and Nuclear Technologies Directorate. The building houses the tritium research facility and associated laboratories.																		
331	All	Stack 1	Tritium research and development	H-3	[d]	1.0E+00	30.0	1.22	6.6	None	1	1.64E+01	957	ENE	1.5E-03	957	ENE	1.5E-03
		Stack 2	Decontamination of parts	H-3	[d]	1.0E+00	30.0	1.22	9.8	None	1	2.7E-01						
Building 332 is operated by the Defense Sciences Program for plutonium research. Exhausts from glove box operations and the workplace are double or triple filtered by high efficiency particulate air (HEPA) filters. Exhausts are monitored with both continuous filter sampling and plutonium-specific, continuous real-time monitors (CAMs).																		
332	Increment 1 Rooms	FHE-1000/2000	Plutonium research	Transuranics	[a,c]	NA	8.8	0.8x1.1	15.7	Double HEPA	0.0001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Increment 1 Glove boxes	FGBE-1000/2000	Plutonium research	Transuranics	[a,c]	NA	11	0.3	5.7	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Loft	FE-4,5W	Loft exhaust	Transuranics	[a,c]	NA	11	0.6x0.9	4.5	HEPA	0.01	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
		FE-4,5E	Loft exhaust	Transuranics	[a,c]	NA	11	0.6x0.9	4.0	HEPA	0.01	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Increment 1 Glove boxes	FGBE-3000/4000	Plutonium research	Transuranics	[a,c]	NA	11	0.3	4.9	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Increment 3	FFE-1000/2000	Plutonium research	Transuranics	[a,c]	NA	10.1	0.9	10.7	Room—Double HEPA	0.0001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
	Room and Glove boxes	FGBE-7000/8000	Plutonium research	Transuranics	[a,c]	NA	10.1	0.27	2.5	Glove Box—Triple HEPA	0.000001	0.0E+00			0.0E+00	[b]	[b]	[b]
Building 491 is operated by the Space Action Team as an area for the storage of contaminated parts. Isotope separation activities that previously occurred in this building have been discontinued. Continuous stack sampling is planned until decontamination of the facility and associated equipment is complete. The facility operates with two in-series high efficiency particulate (HEPA) filter banks to control emissions.																		
491	All	FFE-1	Storage	Gross alpha	[a,f]	NA	9.1	0.9	4.5	Double HEPA	0.0001	0.0E+00	1000	SSE	0.0E+00	[b]	[b]	[b]
				Gross beta	[a,f]							0.0E+00			0.0E+00			
Building 695/696 is the Decontamination Waste Treatment Facility operated by Radiological and Hazardous Waste Management Division. All operations are HEPA filtered and have pre-filters in place; some operations have additional HEPA filtration.																		
695/696	DWTF	FHE 1000/2000/3000	Waste treatment	Gross alpha	[a]	NA	20.0	1.98	9.8	HEPA	0.01	0.0E+00	953	S	0.0E+00	198	ENE	[b,g]
				Gross beta	[a]	NA				Pre-filter	0.1	0.0E+00			0.0E+00			[b,g]
				Tritium	[d]	NA						4.6E-02			1.3E-06			1.5E-05
SITE 300 POINT SOURCES																		
Building 801 is the Contained Firing Facility, where explosives tests are conducted. This facilityand the 851 Firing Table are operated by the Defense and Nuclear Technologies Directorate.																		
801	Contained Firing Facility	FEFH-1, FE-2	Explosive tests	U-238	[a]	NA	16.8	1.60	4.7	HEPA	0.01	5.4E-08	3770	S	2.7E-07	[b]	[b]	[b]
				U-235	[a]	NA				Pre-filter	0.1	1.8E-09						
				U-234	[a]	NA						3.3E-08						
Explosives tests in which radionuclides may be present are conducted on open-air firing tables located at Bunker 851. These tests have depleted uranium material as part of the material inventory. There were no atmospheric tests using depleted uranium or any other radioactive material in 2009.																		
851	Firing Table	None	Explosive tests	U-238	N/A	1	NA	NA	NA	None	1	0.0E+00	3170	SSE	0.0E+00	N/A	N/A	N/A
				U-235	N/A	1						0.0E+00						
				U-234	N/A	1						0.0E+00						
LIVERMORE SITE DIFFUSE SOURCES																		
Building 331 - Contaminated equipment outside the facility awaiting decontamination or transport and storage by Radioactive and Hazardous Waste Management.																		
331	Outside	None	Storage of contaminated parts	Tritium	NA	1	NA	NA	NA	None	1	2.4E+00	957	ENE	7.1E-04	533	SW	2.3E-03
The Building 612 Yard is operated by the Radioactive and Hazardous Waste Management Division. The Yard consists of several areas where containers having radioactive wastes are stacked outdoors. The containers can outgas tritium.																		
612	Yard	Area Source	Storage of low level waste	Tritium	NA	NA	NA	NA	NA	None	1	6.0E-01	444	NE	9.6E-04	276	SW	1.9E-03
Building 695/696 is the Decontamination Waste Treatment Facility operated by Radiological and Hazardous Waste Management Division. The facility includes outside areas where waste containers are stacked. The containers can outgas tritium.																		
695/696	Yard	Area Source	Storage of low level waste	Tritium	NA	NA	NA	NA	NA	None	1	5.0E-02	933	SSE	5.7E-06	158	ENE	3.7E-04
The Southeast Quadrant of the Livermore Site has slightly elevated levels of Pu-239 in the surface soil and air. The source of the Pu-239 was past waste management operations.																		
Southeast Quadrant		Area Source	Resuspension	Pu-239	NA	NA	NA	NA	NA	None	1	NA	NA	NA	1.0E-03	NA	NA	NA
SITE 300 DIFFUSE SOURCES																		
Diffuse sources consist of resuspension of depleted uranium from historical explosive tests. The SW-MEI isotpoic ratio for S300 in CY09 was 0.0072 and is the ratio for naturally occuring uranium. There were no atmospheric depleted uranium shots in CY09.																		
Site 300	All	Area Source	Soil resuspension	U-238	NA	NA	NA	NA	NA	None	1	NA	NA	NA	0.0E+00	NA	NA	NA
				U-235	NA	NA						NA						
				U-234	NA	NA						NA						

NOTE: To convert curies to becquerels use 1 Ci=3.7E+10 Bq and to convert millirem to sieverts use 1 Sv=1.0E+05 mrem.

[a] Gross alpha and Gross beta emissions are continuously monitored at the stack.

[b] Because monitoring takes place after HEPA filtration, an unabated EDE cannot be determined from the monitoring data (see discussion in Section 2, Emissions Data).

[c] Stack emissions have been combined as permitted by the EPA/DOE Memorandum of Understanding.

[d] Tritium HT and HTO emissions from the stack are continuously monitored.

[e] The air monitoring data for all emission points show no detectable released alpha activity, i.e., the measurements are at or below the limit of sensitivity of the analytical method.

[f] Air emissions are continuously sampled at the post-HEPA-filter atmospheric discharge points, although potential emissions are low enough that stack monitoring is not required per the NESHAPs 40 CFR 61 regulations.

[g] The unabated EDE shown is only for the tritium source term.

ATTACHMENT 2: METEOROLOGICAL DATA

CAP88-PC requires meteorological data in the form of joint-frequency distributions of wind direction and wind speed organized by stability category. The first line of the file contains three hexadecimal file marks that are ignored by CAP88-PC. The second line is the average wind speed and is not used by CAP88-PC. The third line contains the wind frequency totals (in format 6.4, i.e., 6 places per value, 4 after the decimal place) beginning at the direction, N, and cycling counterclockwise through the wind directions. The following 8 lines contain the reciprocal average (or harmonic average) wind speed (in format 5.3) for each class of wind direction and stability. Each row is a stability class, A through G, and each "column" is the wind direction, again beginning at N and cycling counterclockwise. The next 8 lines are the arithmetic average wind speeds, in the same format as the reciprocal average. The final 16 lines are the frequencies of stability class, with the columns being the stability class and the rows the wind direction, beginning with N and cycling counterclockwise. The wind file for the Livermore site was created from 2009 data collected from the Livermore site meteorological tower at the 10-m level; the wind file for Site 300 was created from 2009 data collected from the Site 300 meteorological tower at the 10-m level.

A.2.1 LIVERMORE SITE TOWER

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2.31923

0.04720.02820.04070.05360.04240.03830.06740.05520.03180.01850.01760.02330.09410.13830.16
330.1401
1.3501.2811.0001.0001.0001.0002.1572.1621.9711.7851.7231.7872.0482.1092.0821.790
1.6921.2161.6550.9151.6071.6682.3222.5572.3521.5141.6621.7333.0852.7072.8392.270
1.4161.4451.0721.6630.8621.5502.4832.7682.4221.4301.2591.7903.3432.8703.2443.073
1.8921.6311.0650.9490.7391.2241.8361.7992.0581.7590.9821.7442.8782.6233.2353.216
1.2441.0590.8960.8240.8511.0501.2651.1330.9100.9670.8401.0021.4331.9381.9091.848
0.9570.7310.6450.6540.6170.6800.7420.7720.7370.8180.7500.9210.9971.1651.1551.168
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1.3521.3991.0001.0001.0001.0002.2872.3302.0701.8111.8201.8252.1822.2172.1701.837
1.8241.2161.7100.9151.6241.8872.5392.8632.8951.8171.8772.2003.4553.0473.1902.992
2.0021.4611.3871.6630.9101.7912.7293.2073.2702.0261.5442.6023.7933.4113.7003.686
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1.5391.4231.2450.9311.0021.2201.5601.5061.3941.1961.0161.1861.7571.1002.1132.073
1.1200.8350.7140.7300.6790.7680.8660.8610.7870.9230.8271.1221.1621.3651.3211.321
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
    0.0048    0.0242    0.0339    0.1283    0.2228    0.5860    0.0000
    0.0081    0.0040    0.0081    0.1053    0.1781    0.6964    0.0000
    0.0000    0.0056    0.0169    0.0506    0.1208    0.8062    0.0000
    0.0000    0.0021    0.0021    0.0405    0.0981    0.8571    0.0000
    0.0000    0.0108    0.0162    0.0243    0.1159    0.8329    0.0000
    0.0000    0.0448    0.0806    0.1224    0.2299    0.5224    0.0000
    0.0186    0.1305    0.2915    0.2000    0.1492    0.2102    0.0000
    0.0331    0.1698    0.3602    0.1884    0.0994    0.1491    0.0000
    0.0396    0.1367    0.2446    0.3165    0.1007    0.1619    0.0000
    0.0370    0.1975    0.1605    0.2840    0.1667    0.1543    0.0000
    0.0909    0.2987    0.2078    0.1558    0.1169    0.1299    0.0000
    0.1127    0.2304    0.2892    0.1863    0.0686    0.1127    0.0000
    0.0644    0.3026    0.3269    0.1908    0.0559    0.0595    0.0000
    0.0620    0.2463    0.2149    0.2504    0.1190    0.1074    0.0000
    0.0217    0.1043    0.1805    0.4332    0.1407    0.1197    0.0000
    0.0024    0.0204    0.0661    0.4315    0.2300    0.2496    0.0000
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A.2.2 SITE 300 TOWER

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   5.82248

0.03110.04050.02890.01320.01180.01270.01890.02920.06040.12200.09760.06390.06720.16380.20
440.0342
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1.7532.3062.5952.2902.1192.0332.1982.2602.9592.8623.2762.6773.1113.9175.4362.607
3.0842.5912.5822.1262.0832.0762.0772.1853.0543.5863.6333.6544.7715.9805.9462.916
3.3853.3013.7212.8802.3251.9531.6612.0973.0794.6214.4134.2165.7097.2278.8814.504
2.2102.2811.9071.5091.7851.2481.4511.4111.4291.7271.9662.0772.3202.2072.4632.032
1.2911.3661.2461.1840.9970.9531.0500.9841.1371.1971.3291.2641.3071.2401.2041.247
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
1.0001.0001.0001.0001.0001.0002.4382.7782.5223.1251.0003.3193.6742.8971.0001.000
1.8722.4552.7402.2902.6222.4132.4692.5033.3033.4203.8293.4243.8074.4045.5352.781
3.7532.9492.8612.5592.6352.5592.3562.5313.6034.1364.3484.3355.6127.1317.1713.963
4.1714.0016.1054.8803.9702.5021.9183.0485.2616.5435.4545.0596.6768.27510.586.365
2.4322.4432.0901.7921.9771.3421.5981.5001.7602.0352.1732.2962.6262.6892.7562.306
1.4471.5111.3501.3121.0691.0341.1531.0461.2311.3131.4491.3861.4251.4171.3441.362
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
    0.0000    0.0074    0.0480    0.4280    0.3653    0.1513    0.0000
    0.0000    0.0085    0.0765    0.5354    0.2720    0.1076    0.0000
    0.0000    0.0278    0.1032    0.5556    0.2262    0.0873    0.0000
    0.0000    0.0087    0.1304    0.3652    0.1826    0.3130    0.0000
    0.0000    0.0485    0.3010    0.3592    0.0874    0.2039    0.0000
    0.0000    0.1982    0.2793    0.2072    0.1171    0.1982    0.0000
    0.0182    0.3455    0.2970    0.1576    0.0364    0.1455    0.0000
    0.0392    0.4118    0.2902    0.1059    0.0667    0.0863    0.0000
    0.0076    0.3586    0.3795    0.1537    0.0474    0.0531    0.0000
    0.0009    0.1316    0.3271    0.4305    0.0639    0.0461    0.0000
    0.0000    0.0517    0.1786    0.5711    0.1293    0.0693    0.0000
    0.0018    0.0395    0.1329    0.5314    0.1813    0.1131    0.0000
    0.0034    0.0085    0.1451    0.6468    0.1382    0.0580    0.0000
    0.0007    0.0126    0.0931    0.7878    0.0665    0.0392    0.0000
    0.0000    0.0034    0.0483    0.8838    0.0404    0.0241    0.0000
    0.0000    0.0101    0.0436    0.5570    0.2550    0.1342    0.0000
```

ATTACHMENT 3: POPULATION DATA

The source of the geographic population distribution data used for this report is Oak Ridge National Laboratory (ORNL) LandScan 2007 data (see Dobson and Bright, 2002). The data are placed into an annular grid that is created from sixteen 22.5-degree sectors centered on the cardinal wind directions and five distances spaced at 16 km to a total 80-km radius. In deriving the population for each site, the ORNL data set is input into ESRI ARCMAP with the 80-km grid for the Livermore site centered at -121.7045 W longitude, 37.686 N latitude (near the center of the site) and Site 300 centered at the 52-m meteorological tower located -121.541 W longitude, 37.675 N latitude. The first line of the input file is informational. Distances are shown in the second row. Population data begin in the third row starting with direction, N. There are 20 spaces reserved for each direction no matter how many are used; i.e., the next direction, NNW, starts approximately half-way through the fifth row, 21 values after the first value.

A.3.1 LIVERMORE SITE

```
$ LLNL, 2008 LIVERMORE     LAT=  37.686 LON=121.7045 NSEC=16 NRADS= 5
        16         32         48         64         80
     3045.     44963.     38552.      7142.      1630.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.      5604.      7802.    137767.       282.
   195714.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
     5025.     10981.    268712.     92898.    156846.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.      9317.    103970.    105871.    495265.
   210134.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
    46805.     84529.    373547.    115462.   1053040.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.     22516.     66071.    175926.    415385.
    30412.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
      633.     70592.    295044.    302803.      6539.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.       876.      4346.    609985.    325942.
    43001.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
      194.       49.     40894.     65550.     63776.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.      1709.         8.        29.        27.
     4498.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
      288.       70.        49.         6.       289.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.       293.       140.       498.     17295.
    14640.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
      440.     28770.      9827.     36581.    346382.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.      1375.     48605.     50351.    102658.
     6822.         0.         0.         0.         0.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
      331.      1140.     23879.    307317.     58823.         0.         0.         0.
        0.         0.         0.         0.         0.         0.         0.         0.
```

A.3.1 LIVERMORE SITE (continued)

0.	0.	0.	0.	1464.	12442.	2548.	2901.
26644.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.

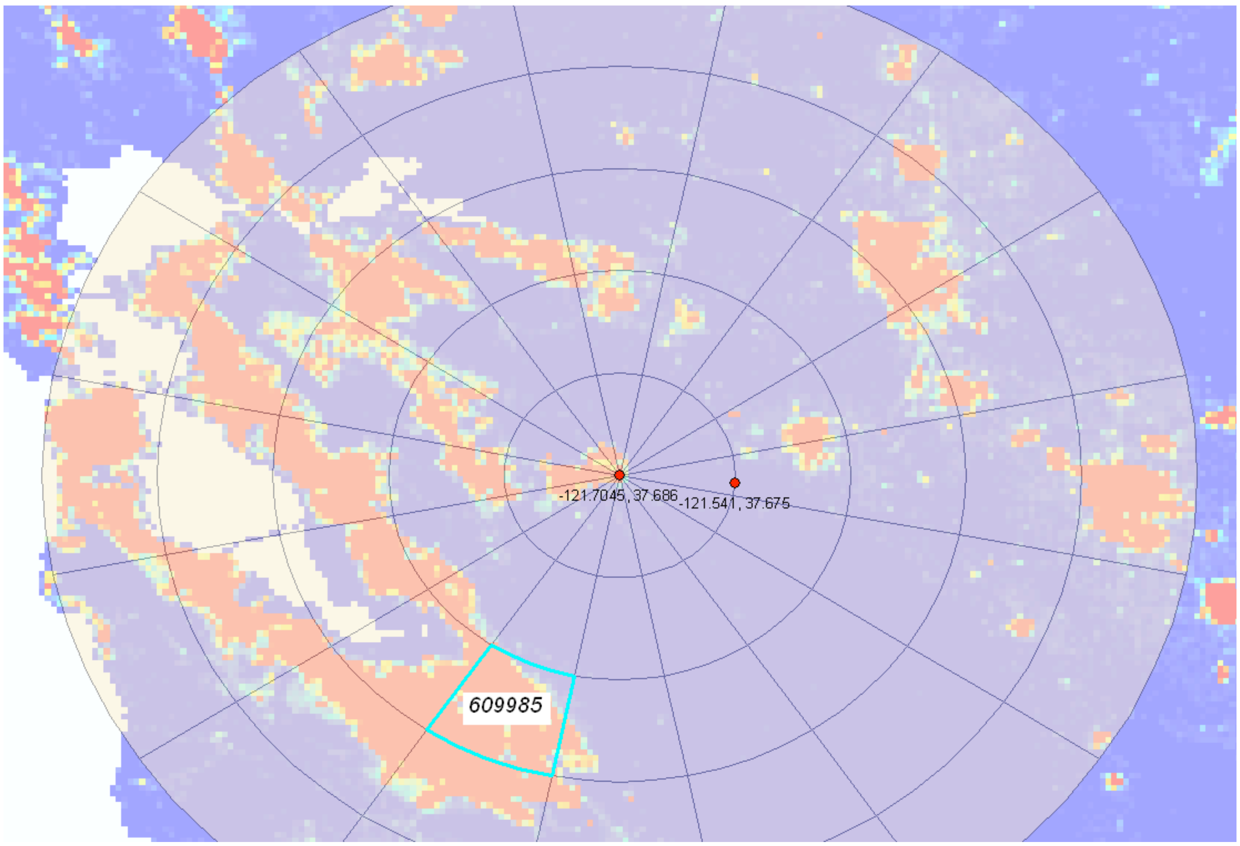

Figure A-1. Livermore Site 80-km population grid illustrating the population in the south-southwest sector at 32 to 48 km.

A.3.2 SITE 300

```
$ LLNL, 2008 S-300          LAT=37.67502 LON= 121.541 NSEC=16 NRADS= 5
        16        32        48        64        80
     2419.     5491.     2612.     5558.     7391.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.      325.    24935.   117067.     5845.
    82972.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
       54.      191.    68806.   274634.   159201.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.     5001.     9879.   124491.   334380.
   561745.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
     9230.   129854.   209233.   340417.   788802.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.      368.     1464.   252586.   312999.
   184528.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
       72.       29.   393199.   775283.    15321.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.       30.        0.    91866.   198461.
    14540.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
       17.       50.       30.    28921.    59084.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.       11.        6.       33.        6.
      187.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
       79.        5.     1961.     9329.     9182.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.      214.     1021.    17895.    19322.
      217.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
     1240.     2696.   143623.   209271.    15503.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.    29067.    45912.    33414.    12145.
        3.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
    41388.    12316.   173133.     8968.     4074.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.     3009.      947.   199760.    83431.
    28823.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.        0.        0.        0.        0.        0.        0.
```

A.3.2 SITE 300 (continued)

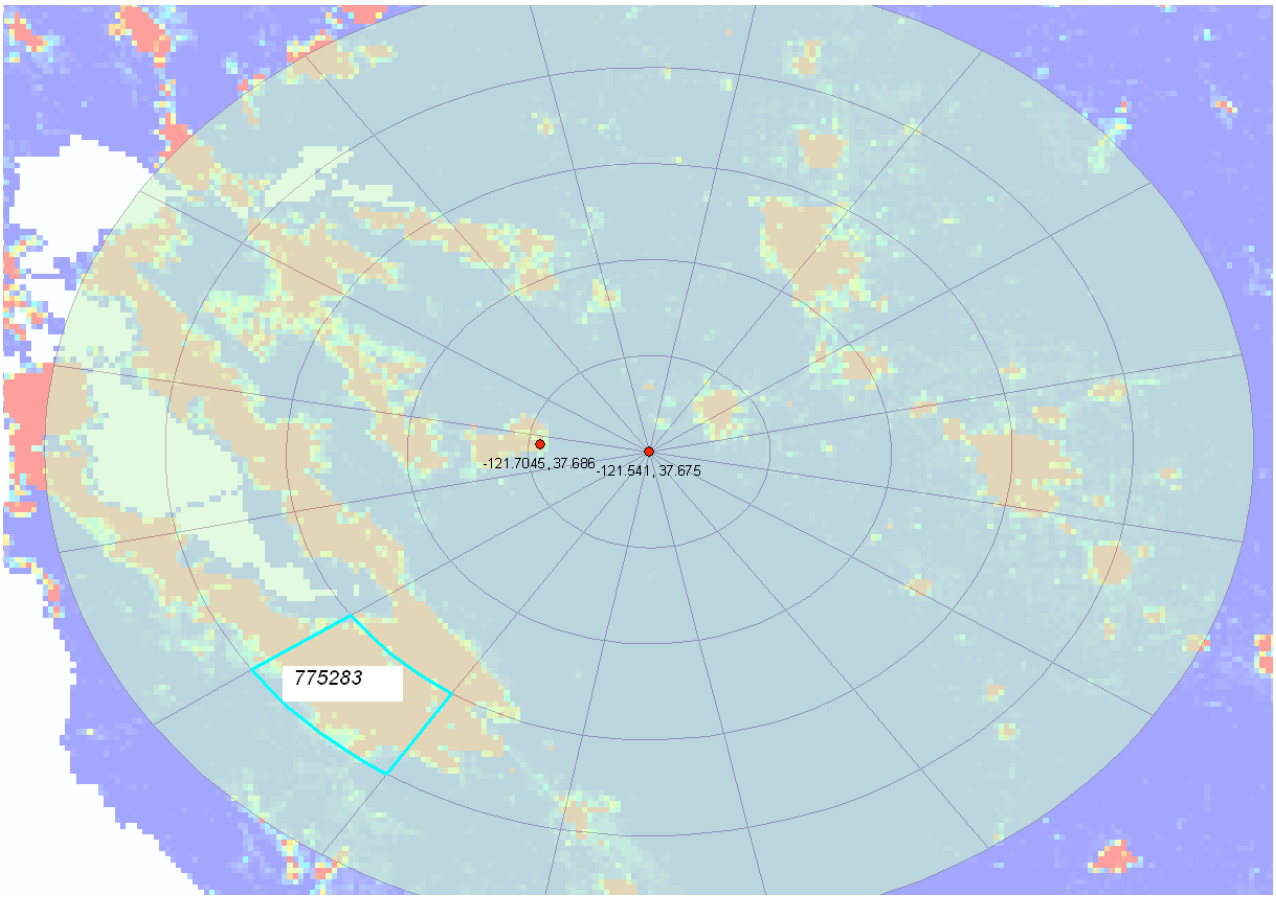

Figure A-2. Site 300 80-km population grid illustrating the population in the southwest sector at 48 to 64 km.