LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

UCRL-TR-113867-11

LLNL NESHAPs 2010 Annual Report

Wilson, K.
Bertoldo, N.
Gallegos, G.
MacQueen, D.
Wegrecki, A.

June 2011

This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

U.S. Department of Energy
Radionuclide Air Emission Report for 2010
(in compliance with 40 CFR 61, Subpart H)

Site Name: Lawrence Livermore National Laboratory

Operations Office Information

Office: U.S. Department of Energy
Livermore Site Office

Address: 7000 East Avenue, L-293
Livermore, CA 94551

Contact: Vijay Mishra **Phone**: (925) 423-8163

Site Information

Operator: Lawrence Livermore National Security, LLC

Address: 7000 East Avenue, L-626
Livermore, CA 94551

Contact: H. Bruce Schultz **Phone**: (925) 423-3978

Table of Contents

Executive Summary iii

1 **Background Information** 1-1
1.1 Site Description 1-1
1.2 Source Description 1-3

2 **Emissions Data** 2-1
2.1 Major Sources: Measured Emissions 2-1
2.2 Minor Sources: Ambient Measurement Comparison 2-4
2.3 Minor Sources: Correlation Model Estimate 2-4
2.4 Minor Sources: Open Air Tests 2-5

3 **Dose Assessment** 3-1
3.1 General 3-1
3.2 CAP88-PC Input Parameters 3-2
3.2.1 Building-Specific Parameters 3-2
3.2.2 Common Parameters 3-2
3.3 Compliance Assessment 3-3
3.3.1 Major Sources 3-3
3.3.2 Minor Sources 3-3
3.3.3 MEI Dose 3-5

4 **Certification** 4-1

5 **Additional Information** 5-1
5.1 Additions or Modifications 5-1
5.1.1 National Ignition Facility 5-1
5.2 Unplanned Releases 5-1

6 **Supplemental Information** 6-1
6.1 Collective Dose Assessment 6-1
6.2 40 CFR 61 Subparts Q and T 6-1
6.3 Periodic Confirmatory Measurement 6-1
6.4 Facility Compliance 6-2

References R-1

Errata E-1

Attachments A-1
Attachment 1: 2010 LLNL NESHAPs Annual Report Spreadsheet A-2
Attachment 2: Meteorological Data A-3
Attachment 3: Population Data A-5

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 2010 are summarized here:

- Livermore site: 0.011 mrem (0.11 μSv) (31% from point source emissions, 69% 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: 5.7×10^{-7} mrem (5.7×10^{-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.

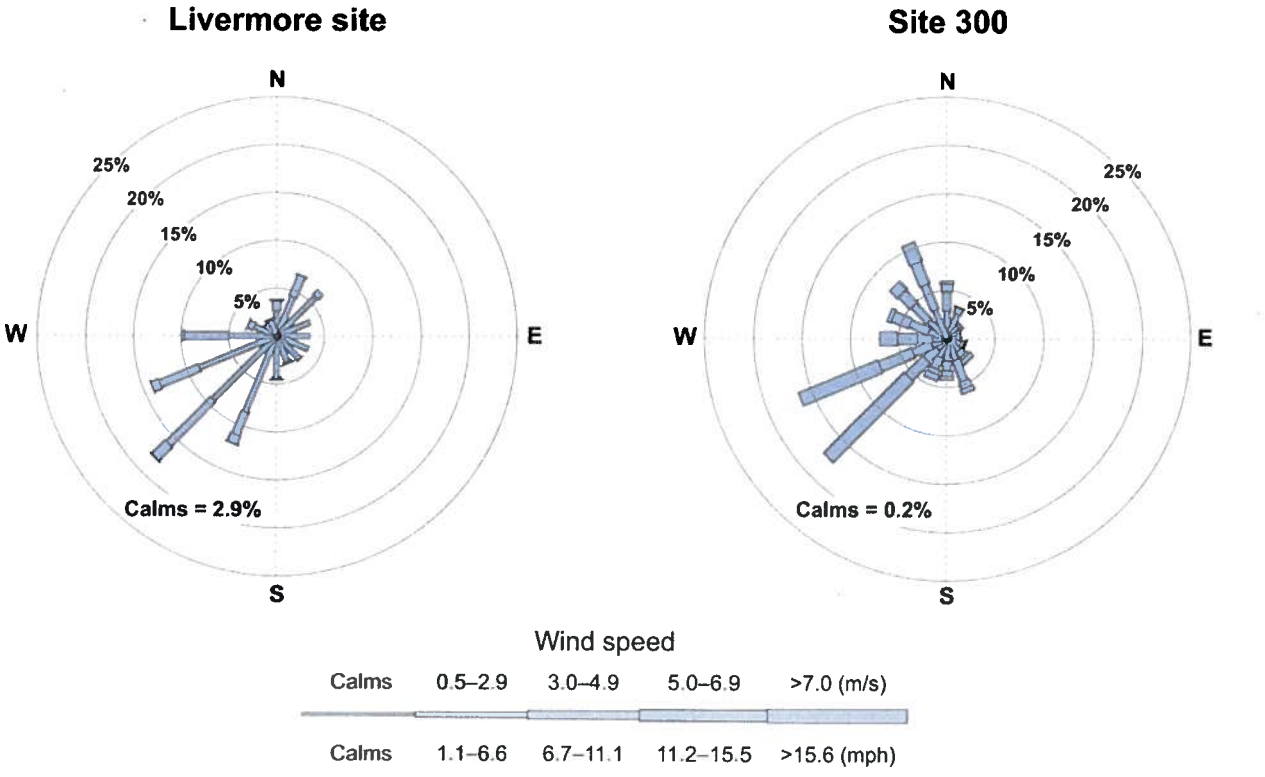

Figure 2. Wind roses for the Livermore site and Site 300 for 2010.

The 2010 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 44% of the time; for Site 300, the data show that the winds blew from the southwest to the west-southwest about 34% of the time. The average wind speed in 2010 at the Livermore site was 2.3 m/s (5.1 mph), and the average wind speed at Site 300 was 5.5 m/s (12.3 mph). In 2010, the Livermore site received 40.2 cm of rain and Site 300 received 38.5 cm.

1.2 SOURCE DESCRIPTION

Many different radioisotopes were available for use at LLNL in 2010 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 glove boxes, 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 2010.

Table 1. Radionuclides used at LLNL during 2010.

Ag-110m	Cl-36	H-3	Np-236	Ra-226	Th-228
Al-26	Cm-242	Hg-203	Np-237	Ra-228	Th-229
Am-241	Cm-244	I-125	Np-239	Rb-83	Th-230
Am-242m	Cm-246	I-129	P-32	Rb-85	Th-232
Am-243	Cm-248	I-131	Pa-231	Rh-105	Th-234
Ba-133	Co-56	I-133	Pa-233	Ru-103	U-232
Ba-140	Co-57	Ir-192	Pa-234	Ru-105	U-233
Be-7	Co-58	K-40	Pa-234m	Ru-106	U-234
Be-10	Co-60	Kr-83m	Pm-149	S-35	U-235
Bi-207	Cs-134	Kr-85	Pb-210	Sb-125	U-236
Bi-210	Cs-135	La-140	Po-208	Sn-113	U-238
C-14	Cs-137	Mn-54	Po-209	Sr-85	Y-88
Ca-41	Eu-152	Mo-99	Po-210	Sr-90	Y-90
Cd-109	Eu-154	Na-22	Pr-143	Ta-177	Zr-89
Cd-114	Eu-155	Nb-95	Pu-236	Ta-182	Zr-95
Ce-139	Fe-55	Nd-147	Pu-238	Tc-99	Zr-97
Ce-143	Fe-59	Ni-56	Pu-239	Tc-99m	
Ce-144	Fe-60	Ni-57	Pu-240	Te-132	
Cf-249	Gd-148	Ni-59	Pu-241		
Cf-250		Ni-63	Pu-242		
Cf-252		Ni-66	Pu-244		

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	Physical & Life Sciences	Engineering	Weapons & Complex Integration	National Ignition Facility & Photon Science	Operations & Business
B253	B132[a]	B131	B331[b]	B162	B419
B254	B151	B231	B332[b]	B298	B597
B255	B194	B321	B612	B381	B812[c]
	B235[b]	B322	B625	B391	B850[c]
	B282	B327	B695/696[b]	B581[b]	
	B292		B697	B582	
	B341		B801[b]	B491[b]	
	B361		B804		
	B364		B810A		
	B378		B810B		
			B851		
			B883		

[a] B132 is managed by Global Security.

[b] Continuous monitoring occurs at one or more exhaust points at the building.

[c] Firing table operations at B812 and B850 have been discontinued. B850 was removed from a radioactive materials area status on 7/22/10 after the completion of the soil removal and stabilization project.

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 seven 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 μSv) 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 2010, there were six 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 radioactive particulate 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
581	National Ignition Facility	Gross α, β, Gamma suite on particles	Filter	1
		Radioiodine (volatile)	TEDA cartridge	1
		Gaseous tritium/ tritiated water vapor	Glycol Bubbler	1
		Gaseous tritium/ tritiated water vapor	Ionization Chamber[a]	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 notification only so that any unplanned release may be detected and mitigated; they are not used for NESHAPs compliance demonstration.
[b] Isotope separation operations are discontinued; area now used for storage of contaminated parts.

Detection of radioactive particulate activity resulting from particles collected on the air filters is accomplished using gas flow proportional counters and gamma spectroscopy. 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 Radiation Protection Functional Area and the Environmental Monitoring Radiological Laboratory (EMRL) in the Physical and Life Sciences Directorate performs the analysis.

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 EMRL performs the isotopic analysis.

Glycol bubblers are used to monitor for tritium releases from the Decontamination Waste Treatment Facility (DWTF) stack, the two Tritium Facility (Building 331) stacks, and the National Ignition Facility (NIF) stack. In addition to this NESHAPs compliance monitoring, the two Tritium Facility stacks, and the NIF stack 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 for notification only so that any unplanned release may be detected and mitigated; 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), glycol bubblers 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 impingers, capturing the HTO present. Next, the sampled air is directed through a heated 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 impingers. The impingers are analyzed by the RML using liquid scintillation analysis. This type of sampling quantifies the amount of tritium for both species, HT and HTO.

Triethylenediamine (TEDA) cartridges are used for the capture of radioactive iodines in gaseous or vapor state. The TEDA is impregnated into carbon (activated carbon) by the manufacturer and is housed in a plastic cartridge of standard industry size 2 ¼" diameter by 1" thick (30 x 50 Mesh). Stack air is directed through the TEDA cartridge that is located post a particulate filter (two-stage filter housing). Both the particulate filter and the TEDA cartridge are counted on gamma spectroscopy by the EMRL.

In 2010, a total of 36.2 Ci (1339 GBq) of measured tritium was released from the Tritium Facility. Of this, approximately 99% of tritium was released as vapor (HTO). The remaining 1% released was gaseous tritium (HT).

In 2010, 1.2 Ci (44.4 GBq) of measured tritium was released from the DWTF stack exhaust. The tritium released was approximately 76% vapor (HTO) and 24% gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 0.403 Ci (14.9 GBq) of measured tritium from the stack exhaust in 2010. A total of 0.104 Ci (3.8 GBq) was released as vapor (HTO), 0.299 Ci (11.1 GBq) as gaseous (HT), and 6.9×10^{-8} Ci (2.6×10^{-6} GBq) of tritiated particulate.

The Contained Firing Facility at Site 300 had measured depleted uranium emissions in 2010. A total of 1.3×10^{-8} Ci (4.8×10^{-7} GBq) of uranium-234, 9.2×10^{-10} Ci (3.4×10^{-8} GBq) of uranium-235, and 8.7×10^{-8} Ci (3.2×10^{-6} GBq) of uranium-238 was released in particulate form.

None of the other facilities monitored for radionuclides had reportable emissions in 2010.

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 2010 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). The open source statistical code language, R, is used to vary the unit source terms at each diffuse source location while accounting for the contributions of the stack sources, and summing their respective modeled concentrations. The result of this correlation effort yielded a source term of 0.21 Ci from B298 NIF support activities, 3.0 Ci for Building 331 Waste Accumulation Area (WAA), 2.8 Ci for Building 612 Yard, 0.14 Ci for Building 695/696 Yard. The results of the model estimate are displayed in **Figure 3**.

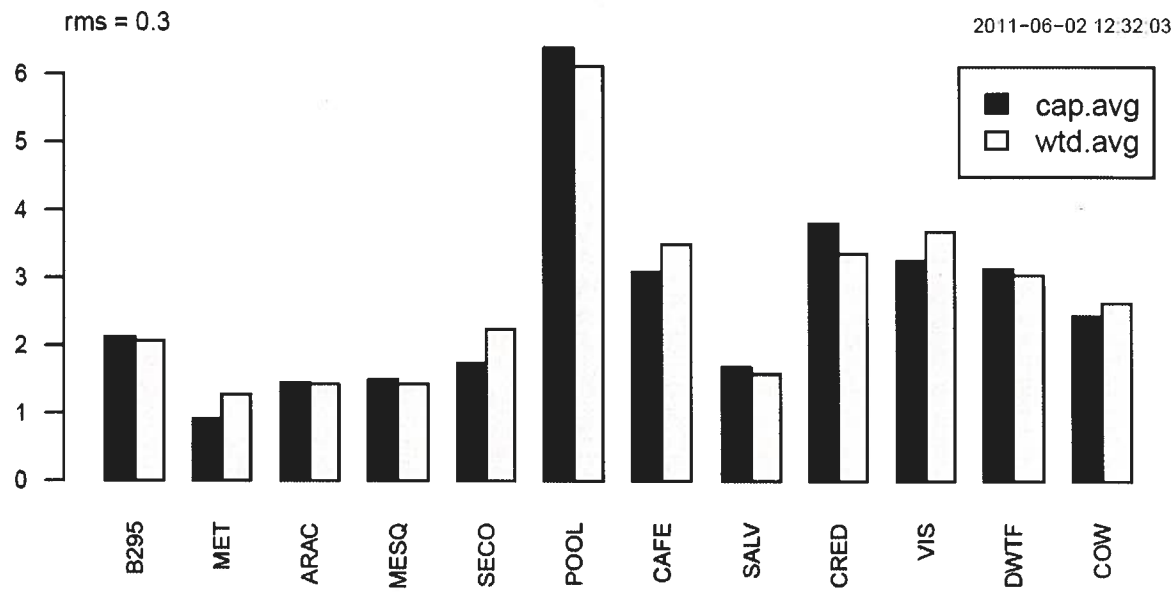

Figure 3. Comparison of measured (wtd.avg) and modeled (cap.avg) annual mean concentrations of tritiated water vapor (HTO) in units of pCi/m^3 in air at Livermore site locations, 2010.

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 2010, 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 2010 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 2010 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**.

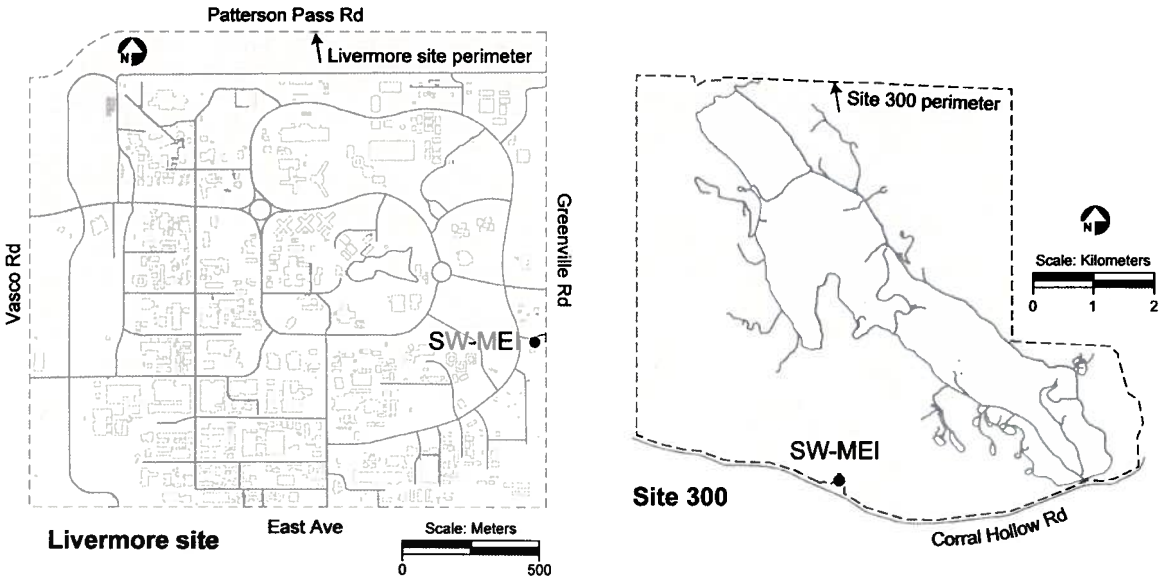

Figure 4. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at the Livermore site and Site 300, 2010.

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 (15.8 in. [40.2 cm] for the Livermore site and 15.2 in. [38.5 cm] for Site 300) and annual ambient temperature (57.4°F [14.1°C] for the Livermore site and 60.1°F [15.6°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 2010 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, 581, 695/696, and 801. The modeled 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 to SW-MEI from point sources was 3.3×10^{-3} mrem (3.3×10^{-2} µSv) for the Livermore site and 5.7×10^{-7} mrem (5.7×10^{-6} µSv) for Site 300.

Table 5. Point source doses for 2010.

Facility	Dose (mrem)
Tritium Facility	3.3×10^{-3}
NIF	7.5×10^{-6}
DWTF	3.8×10^{-5}
CFF	5.7×10^{-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 2010 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 2010 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 and 2009, 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 2010. Because there was no source term for depleted uranium resuspension at Site 300, there is no dose calculated for 2010.

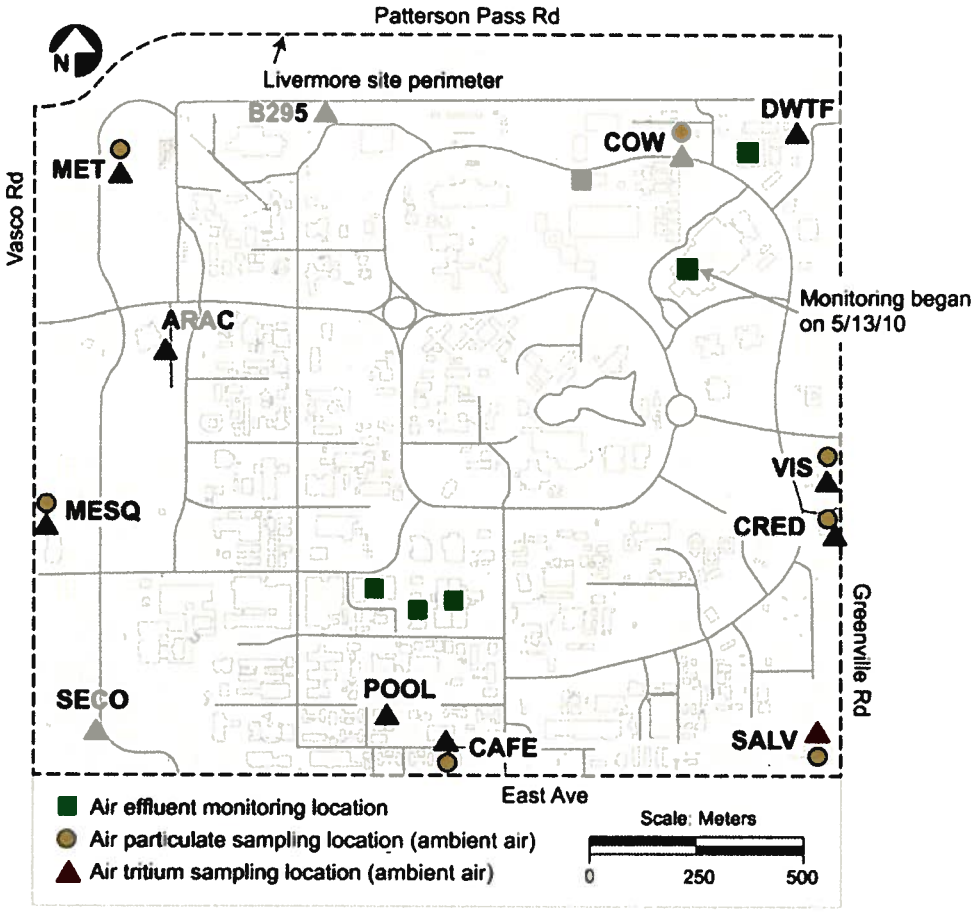

Figure 5. Radiological air monitoring locations at the Livermore site in 2010.

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 0.004 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 2010 are listed in Attachment 1. The total diffuse source dose for 2010 was 7.4×10^{-3} mrem (7.4×10^{-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 2010 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	4.3×10^{-12} Ci/m^3[a]	2.9×10^{-3}	1×10^{-12} Ci/m^3
Livermore site SW-MEI	Plutonium-239	2.0×10^{-15} Ci/m^3	2.9×10^{-19} Ci/m^3[b]	1.5×10^{-4}	5×10^{-19} Ci/m^3
Site 300 SW-MEI	Uranium-238	8.3×10^{-15} Ci/m^3	3.0×10^{-17} Ci/m^3[c]	3.6×10^{-3}	3×10^{-20} Ci/m^3

[a] The measured tritium value includes contributions from all major and minor sources including stack and diffuse releases at the location of the SW-MEI.

[b] Note that the mean measured concentration for plutonium is less than the detection limit; only 3 of the 8 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 2010 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: 0.011 mrem (0.11 μSv)
- Site 300: 5.7×10^{-7} mrem (5.7×10^{-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 2010 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 2010 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 2010.

Year	Total Dose	Point Source Dose	Diffuse Source Dose
Livermore site			
2010	0.011	0.0033[a]	0.0074
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			
2010	5.7×10^{-7}	5.7×10^{-7}	—[c]
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, 2009, and 2010 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: Reginald F. Gaylord
Acting Director
Environment, Safety & Health
Lawrence Livermore National Laboratory
7000 East Avenue, L-510
Livermore, CA 94551

Signature: Regl F. Gaylord Date: June 28, 2011
Reginald F. Gaylord

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: Kirk Keilholtz
Assistant Manager for Environment, Safety & Health
U.S. Department of Energy
National Nuclear Security Administration
Livermore Site Office
7000 East Avenue, L-293
Livermore, CA 94551

Signature: Date: 6/30/11
Kirk Keilholtz

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.

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.

Continuous stack monitoring for radionuclides from the NIF stack began on May 13, 2010 after extensive commissioning testing of the stack monitoring system. Continuous baseline stack monitoring data continued for several months prior to radioactive material being introduced into the NIF in September of 2010. The NIF stack monitoring system 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 2010.

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 2010 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 2010 to persons living within 50 miles (80 km) of the Livermore site is 0.57 person-rem (0.0057 person-Sv) and to persons living within 50 miles (80 km) of Site 300 is 1.9×10^{-4} person-rem (1.9×10^{-6} person-Sv).

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 2010. 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 FACILITY COMPLIANCE

In 2010, 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 0.011 mrem (0.11 μSv) and the total estimated dose from airborne emissions from Site 300 was 5.7×10^{-7} mrem (5.7×10^{-6} μSv). Attachment 1 provides the dose estimates for each individual source.

References

LandScan™ Global Population Database, 2007, http://www.ornl.gov/sci/landscan/landscan_documentation.shtml

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 2009 NESHAPs report, page 2-1 second paragraph stated "0.1 mrem (1mSv/yr) "; it should have read "0.1 mrem (1 μSv/yr)".

Attachments

Building	Room/Area	Stack ID	Operation	Radionuclides	Monitoring for Potental of Release	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]	10.7	0.30	6.0	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]						0.0E+00						
		FHE-1000/2002															
Building 331 is operated by the Weapons and Complex Integration (WCI) Directorate. The building houses the tritium research facility and associated laboratories.																	
331	All[c]	Stack 1	Tritium research and development	H-3	[d]	30.0	1.22	6.3	None	1	3.59E+01	957	ENE	3.3E-03	957	ENE	3.3E-03
		Stack 2	Decontamination of parts	H-3	[d]	30.0	1.22	10.2	None	1	2.92E-01				441	SSW	
Building 332 is operated by the WCI Directorate 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]	8.8	0.8x1.1	16.2	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]	11	0.3	6.8	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Loft	FE-4,5W	Loft exhaust	Transuranics	[a]	11	0.6x0.9	4.6	HEPA	0.01	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
		FE-4,5E	Loft exhaust	Transuranics	[a]	11	0.6x0.9	4.2	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]	11	0.3	4.9	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	[b]	[b]	[b]
332	Increment 3 Room and Glove boxes	FFE-1000/2000 FGBE-7000/8000	Plutonium research Plutonium research	Transuranics Transuranics	[a] [a]	10.1 10.1	0.9 0.27	10.9 2.4	Room—Double HEPA Glove Box—Triple HEPA	0.0001 0.000001	0.0E+00 0.0E+00	912	ENE	0.0E+00 0.0E+00	[b] [b]	[b] [b]	[b] [b]
Building 491 is operated by the National Ignition Facility and Photon Science as an area for the storage of contaminated parts and classified laser research. Isotope separation activities that previously occurred in this building have been discontinued. The facility operates with two in-series high efficiency particulate (HEPA) filter banks to control emissions.																	
491	All	FFE-1	Storage	Gross alpha	[a,e]	9.1	0.9	4.5	Double HEPA	0.0001	0.0E+00	1000	SSE	0.0E+00	[b]	[b]	[b]
				Gross beta	[a,e]						0.0E+00			0.0E+00			
Building 581 is operated by the National Ignition Facility and Photon Science Directorate. Operations of the facility include inertial confinement fusion experiments and laser related research. Stack exhaust is abated with HEPA filters, activated carbon filters, and molecular sieves. The stack exhaust is continuously monitored for radionuclides.																	
581	NIF	FE-1	ICF Research	Gross alpha	[a]	35	1.1	7.6	Double HEPA	0.0001	0.0E+00	705	SSE	0.0E+00	336	ENE	[bh]
				Gross beta	[a]						0.0E+00			0.0E+00			[bh]
				Gamma	[f]						0.0E+00			0.0E+00			[bh]
				Tritium	[d]				Double Molecular Sieves	0.01	4.03E-01			7.5E-06			5.8E-05
				Radioiodines	[g]				Double Activated Carbon Filters	0.01	0.0E+00			0.0E+00			[bh]
Building 695/696 is the Decontamination Waste Treatment Facility operated by Radiological and Hazardous Waste Management in WCI. 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]	20.0	1.98	9.6	HEPA	0.01	0.0E+00	953	S	0.0E+00	198	ENE	[b,h]
				Gross beta	[a]				Pre-filter	0.1	0.0E+00			0.0E+00			[b,h]
				Tritium	[d]						1.2E+00			3.8E-05			3.4E-04
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 Weapons and Complex Integration Directorate.																	
801	Contained Firing Facility	FEFH-1, FE-2	Explosive tests	U-238	[a]	16.8	1.60	4.6	HEPA	0.01	8.7E-08	3770	S	5.7E-07	1423	NNE	5.7E-06
				U-235	[a]				Pre-filter	0.1	9.2E-10						
				U-234	[a]						1.3E-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 2010.																	
851	Firing Table	None	Explosive tests	U-238	[i]	NA	NA	NA	None	1	0.0E+00	3170	SSE	0.0E+00	N/A	N/A	N/A
				U-235	[i]						0.0E+00						
				U-234	[i]						0.0E+00						
LIVERMORE SITE DIFFUSE SOURCES																	
Building 298 - NIF support activities																	
298	Facility	None	NIF support activities	Tritium	[j]	NA	NA	NA	None	1	2.1E-01	1412	SE	8.0E-06	294	NE	2.8E-04
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	[j]	NA	NA	NA	None	1	3.0E+00	953	E	5.9E-04	400	SSW	4.1E-03
The Building 612 Yard is operated by Radioactive and Hazardous Waste Management in WCI. 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	[j]	NA	NA	NA	None	1	2.8E+00	444	NNE	6.0E-03	275	SW	9.4E-03
Building 695/696 is the Decontamination Waste Treatment Facility operated by Radiological and Hazardous Waste Management in WCI. 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	[j]	NA	NA	NA	None	1	1.4E-01	933	S	2.7E-05	158	ENE	1.1E-03
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	[i]	NA	NA	NA	None	1	NA	NA	NA	7.4E-04	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 CY10 was 0.0072 and is the ratio for naturally occuring uranium. There were no atmospheric depleted uranium shots in CY10.																	
Site 300	All	Area Source	Soil resuspension	U-238	[i]	NA	NA	NA	None	1	NA	NA	NA	0.0E+00	NA	NA	NA
				U-235	[i]						NA						
				U-234	[i]						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] 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.

[f] Gamma Emissions are continuously monitored at the stack

[g] Radioiodines are continuously monitored at the stack

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

[i] Continuous monitoring for radioactive particulate is in place at surveillance locations

[j] Continuous monitoring for tritium is in place at surveillance locations

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 2010 data collected from the Livermore site meteorological tower at the 10-m level; the wind file for Site 300 was created from 2010 data collected from the Site 300 meteorological tower at the 10-m level.

A.2.1 LIVERMORE SITE TOWER

2.26876

0.04480.03060.03520.04130.03920.04040.06350.06780.03720.01770.01560.03080.09800.13920.17850.1200
1.0001.7381.0001.8981.0001.9711.8012.2562.1262.0721.8701.7942.1432.2512.1711.943
1.6511.1800.9501.0001.3531.4372.2082.7682.3291.6371.4711.7872.9002.7562.7432.363
2.3712.0251.1010.8841.0741.2982.1612.6922.4331.3481.1992.3463.1563.0162.9892.785
2.0211.8461.3370.7991.1201.1411.6451.9251.3541.2131.0401.8592.3952.9423.2242.988
1.4231.0250.9280.8090.7640.9001.1961.0630.9060.9270.8701.1691.6911.7691.8191.712
0.9840.7970.6780.6370.6260.6530.7080.7330.7200.7330.7620.8751.0291.1581.2021.210
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
1.0001.7381.0001.8981.0002.0151.9442.3802.3842.4742.0401.8902.2972.3572.3151.943
1.7221.2890.9501.0001.3551.6452.4493.1283.0021.9601.6942.2223.2423.0153.1992.923
3.0522.5181.5571.1301.2781.4542.4743.1933.4021.9381.3922.9633.5593.4503.5463.644
2.8002.9271.7390.8971.2191.3091.9982.6292.6051.7921.2872.6722.9893.4703.7563.709
1.6871.3701.1781.9721.8751.0841.4601.4541.1181.1111.0991.4321.9551.9891.0171.958
1.1411.8991.7521.7121.6851.7201.7941.8341.8071.8221.8451.9951.1721.3571.3681.357
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000

0.0000	0.0102	0.0332	0.1735	0.2781	0.5051	0.0000
0.0037	0.0112	0.0187	0.1567	0.1604	0.6493	0.0000
0.0000	0.0032	0.0227	0.0422	0.1331	0.7987	0.0000
0.0028	0.0000	0.0083	0.0304	0.0994	0.8591	0.0000
0.0000	0.0117	0.0146	0.0437	0.1108	0.8192	0.0000
0.0056	0.0395	0.0650	0.0847	0.2627	0.5424	0.0000
0.0216	0.1619	0.2140	0.1888	0.1853	0.2284	0.0000
0.0236	0.1717	0.3519	0.1818	0.0960	0.1751	0.0000
0.0491	0.1840	0.2423	0.1902	0.1442	0.1902	0.0000
0.0516	0.2000	0.1935	0.1548	0.2258	0.1742	0.0000
0.0876	0.2190	0.1752	0.1679	0.1314	0.2190	0.0000
0.0963	0.2481	0.2000	0.1630	0.1222	0.1704	0.0000
0.0734	0.2284	0.3217	0.1993	0.0921	0.0851	0.0000
0.0648	0.2018	0.2018	0.2822	0.1485	0.1009	0.0000
0.0115	0.0979	0.1689	0.4472	0.1491	0.1254	0.0000
0.0010	0.0200	0.0685	0.3597	0.2483	0.3026	0.0000

A.2.2 SITE 300 TOWER

5.48139
0.04240.05950.03240.02020.01420.01440.02090.03510.05990.10600.07780.06460.06960.16420.17400.0447
1.0001.0001.0002.4031.0003.0872.6232.3232.3812.3033.0282.4821.7791.3042.4440.445
2.3322.1941.7501.7862.4232.3742.1942.1882.7672.9883.2623.7623.8754.4552.9583.203
3.2582.6362.5262.9292.3691.8291.9302.1442.8953.6063.5284.5374.4375.1176.1853.837
3.9404.0264.2122.4731.9212.0591.7541.6743.2774.6634.5394.3465.4157.1138.2844.298
2.1941.9001.7131.4741.5061.4621.2171.2471.7251.8271.8742.0992.0132.3672.3722.138
1.3651.4071.1881.0961.0111.1310.9901.1161.0391.2081.2781.3441.2761.3891.2631.307
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
1.0001.0001.0002.4031.0003.1162.7032.4762.5222.4483.1612.4821.7792.1592.4440.445
2.3612.4441.8521.9142.9232.7832.6132.5693.2023.5163.7184.1404.4204.6343.6993.583
3.8053.1842.9313.2262.9322.2162.3732.5843.6354.4734.0494.9615.2336.1878.2664.735
5.0044.9205.9893.4693.0602.5862.1271.8564.8396.1125.5885.0816.5578.2669.8915.508
2.3732.2752.1021.6331.6551.6291.4661.4541.9072.0402.2062.3542.4443.0092.8422.359
1.4891.4881.3651.1981.0581.1971.0811.2111.2181.3291.4921.4261.3621.4931.3611.426
0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000

0.0000	0.0081	0.0514	0.5108	0.2973	0.1324	0.0000
0.0000	0.0096	0.0886	0.6281	0.1888	0.0848	0.0000
0.0000	0.0212	0.0671	0.5336	0.2191	0.1590	0.0000
0.0057	0.0284	0.1307	0.4261	0.1932	0.2159	0.0000
0.0000	0.0887	0.2903	0.3548	0.1290	0.1371	0.0000
0.0317	0.2222	0.2540	0.2143	0.1270	0.1508	0.0000
0.0330	0.3571	0.2857	0.0934	0.0879	0.1429	0.0000
0.0359	0.4248	0.3301	0.0686	0.0588	0.0817	0.0000
0.0249	0.3174	0.3327	0.2256	0.0497	0.0497	0.0000
0.0097	0.1157	0.2962	0.4616	0.0616	0.0551	0.0000
0.0074	0.0471	0.1723	0.5508	0.1370	0.0854	0.0000
0.0018	0.0514	0.1294	0.5851	0.1418	0.0904	0.0000
0.0016	0.0247	0.1153	0.6639	0.1236	0.0708	0.0000
0.0014	0.0105	0.0747	0.8039	0.0733	0.0363	0.0000
0.0007	0.0079	0.0468	0.8603	0.0560	0.0283	0.0000
0.0026	0.0205	0.0436	0.5462	0.2564	0.1308	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 37.686 N latitude, -121.7045 W longitude (near the center of the site) and Site 300 centered at the 52-m meteorological tower located at 37.675 N latitude, -121.541 W longitude. 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.
```

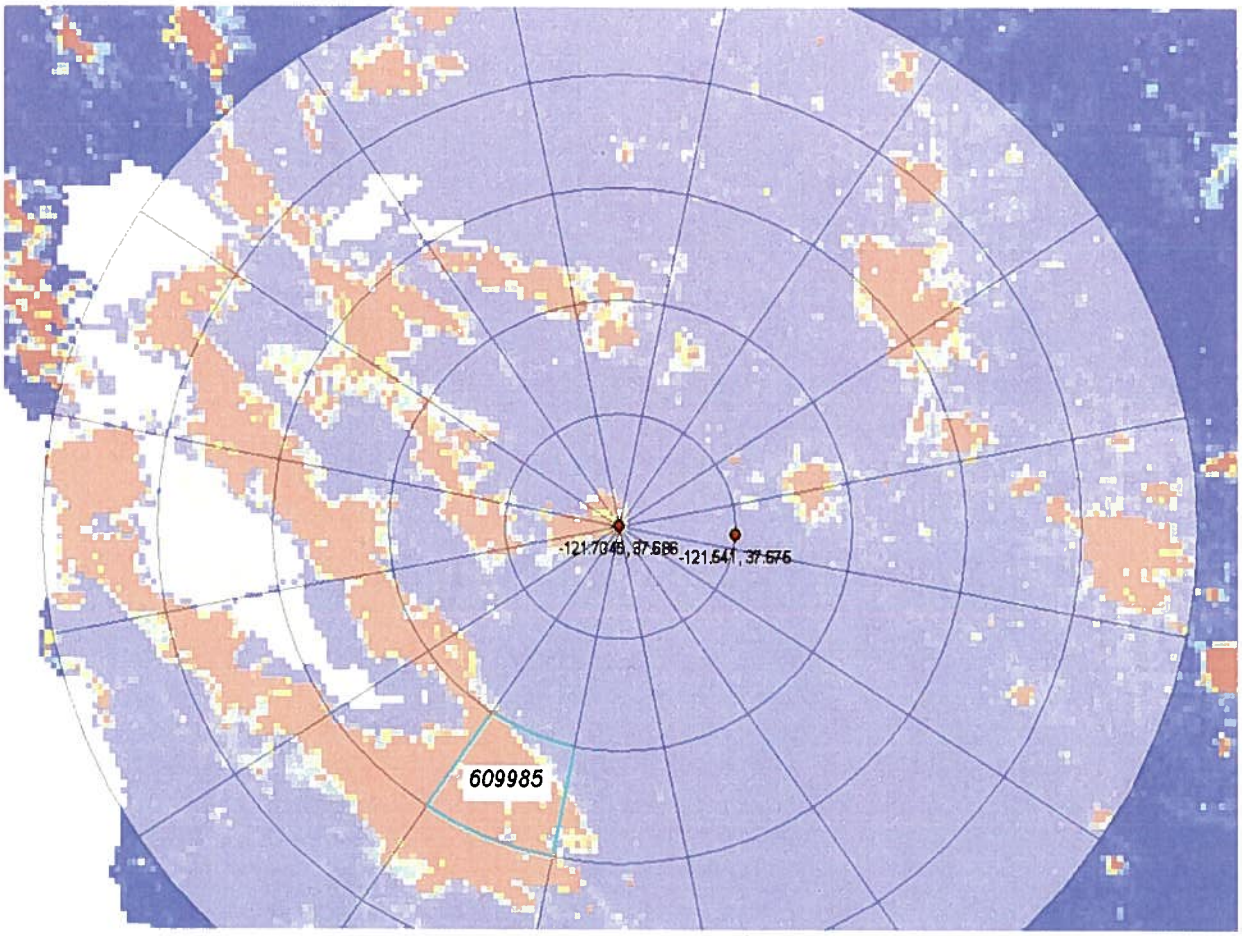

Figure A-1. Livermore Site 80-km population grid illustrating the population in the south-southwest sector at 32 to 48 km.

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.
```

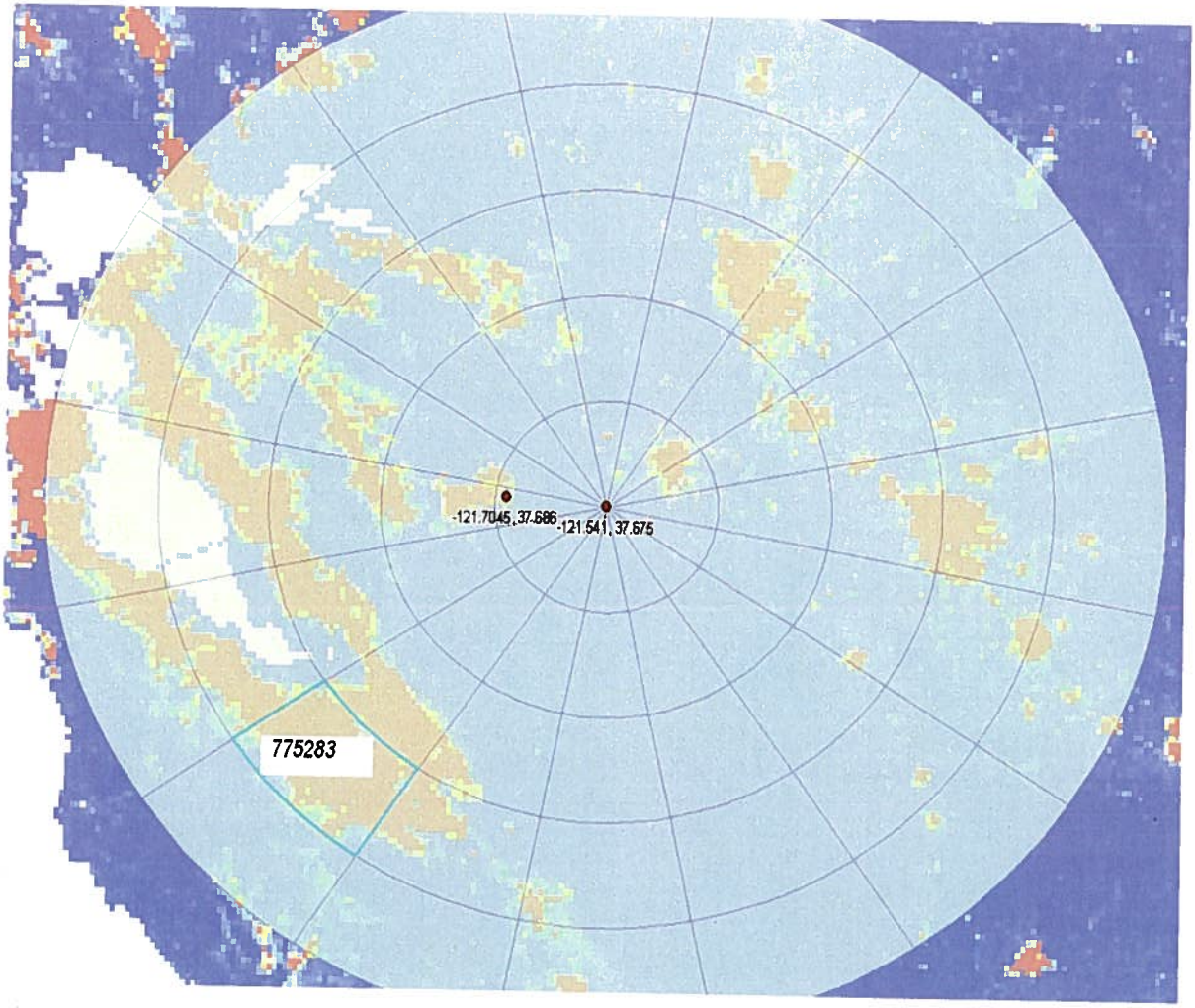

Figure A-2. Site 300 80-km population grid illustrating the population in the southwest sector at 48 to 64 km.