U.S. Department of Energy

Office of Legacy Management

RADIONUCLIDE AIR EMISSION ANNUAL REPORT CALENDAR YEAR 2009

for the

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
UNIVERSITY OF CALIFORNIA, DAVIS

prepared for:

SM Stoller Corporation
2597 B ¾ Road
Grand Junction, Colorado 81503

prepared by:

Weiss Associates
5801 Christie Avenue, Suite 600
Emeryville, California 94608-1827

June 21, 2010
Rev. 0

Weiss Associates
Environmental and Geologic Services

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Appendix A. CAP88-PC Output Results

ACRONYMS AND ABBREVIATIONS

°C	degree(s) Celsius
CAP88-PC	atmospheric dispersion/radiation dose calculation computer code (US EPA)
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
Ci/yr	curies per year
cm	centimeter(s)
cm/s	centimeter(s) per second
DOE	United States Department of Energy
EDE	effective dose equivalent
EDPs	Eastern Dog Pens
Eq.	equation
g/m^2-hr	gram(s) per square meter-hour(s)
km	kilometer(s)
LEHR	Laboratory for Energy-related Health Research
m/s	meter(s) per second
m^2	square meter(s)
MEI	maximally exposed individual
mrem/yr	millirem(s) per year
mSv/yr	millisievert(s) per year
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
No(s).	number(s)
pCi/g	picocurie(s) per gram
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 micrometers
Ra-226	radium-226
ROD	Record of Decision
Sr-90	strontium-90
UC Davis	University of California, Davis
US EPA	United States Environmental Protection Agency

US Department of Energy
Radionuclide Air Emission Annual Report
(Subpart H of 40 CFR 61)
Calendar Year 2009

Site Name: Laboratory for Energy-related Health Research (LEHR)

Field Office Information

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1. FACILITY INFORMATION

This Radionuclide Air Emission Annual Report documents that, in 2009, the United States Department of Energy (DOE) areas at the Laboratory for Energy-related Health Research (LEHR) complied with the requirements of Title 40 Code of Federal Regulations (CFR) Part 61 Subpart H - National Emissions Standards for Hazardous Air Pollutants (NESHAPs) for Emissions of Radionuclides. This is the final NESHAPs annual report for the DOE areas at LEHR, per the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Record of Decision (ROD) (DOE, 2009).

LEHR is a former research facility that was located on the campus of the University of California, Davis (UC Davis). DOE activities at LEHR are currently limited to environmental restoration under CERCLA. Environmental restoration responsibilities at LEHR are shared by DOE and UC Davis, but this report applies to only the DOE areas at LEHR. The DOE areas will be referred to as "the Site," whereas the 15-acre property where both DOE and UC Davis conducted activities will be referred to as "LEHR." There are currently no point sources of radionuclide emissions at the Site, but there was one potential diffuse source (i.e., surface soil) of radionuclide emissions during 2009.

The NESHAPs regulations require that radionuclide emissions not exceed levels that would result in an effective dose equivalent (EDE) to a member of the public of 10 millirems per year (mrem/yr). The EDE's were modeled using the United States Environmental Protection Agency (US EPA) atmospheric dispersion/radiation dose calculation computer code, CAP88-PC, Version 1.0. Based on the results from this model, the total contribution to the maximum EDE to a member of the public from diffuse-source emissions for reporting year 2009 is estimated to be 2.8E-4 mrem/yr (about 0.003% of the 10 mrem/yr standard). This result is the lowest EDE modeled over the previous ten years (Table 1).

The remainder of Section 1 of this report documents relevant characteristics of the Site and the source of the radionuclide emissions, particularly focusing on the input parameters for the CAP88-PC dose-assessment model. Section 2 of this report discusses the emission of radionuclides from the Site to the atmosphere, which is a key input parameter for CAP88-PC. Section 3 presents the results of the dose-assessment modeling. Section 4 is a compliance assessment, and Sections 5 and 6 include additional information regarding radionuclide releases and regulatory compliance. Section 7 provides justification for the termination of future reporting under the NESHAPs regulations.

1.1 Site Description

LEHR is located in Solano County, California, in the southeast quadrant of Section 21, Township 8 North, Range 2 East, Mount Diablo Base and Meridian. It is approximately 1.5 miles south of the town of Davis (Figure 1) and occupies about 15 acres on the southeast portion of the UC Davis campus. LEHR is bounded by UC Davis research facilities, private farmland, and the South Fork of Putah Creek. The southern boundary is the northern levee of the South Fork of Putah Creek (Figure 2).

In the early 1950s, the Atomic Energy Commission (now DOE) began conducting radiological studies at UC Davis on laboratory animals, particularly beagles. Initial studies were carried out on the main campus, which is north of LEHR, and involved irradiation of beagles. DOE began operating at LEHR in 1958 when full-scale experimental use of radioactive materials began. Research at LEHR through the mid-1980s focused on the health effects from chronic exposure to radionuclides, primarily strontium-90 (Sr-90) and radium-226 (Ra-226). In the early 1970s, a cobalt-60 irradiator facility was constructed at LEHR to study the effects of chronic exposure to gamma rays on bone-marrow cells of beagles. In 1975, DOE initiated a program at LEHR to study the potential health effects of combustion products from fossil-fuel power plants. In 1983, the Toxic Pollutant Health Research Laboratory was established at the facility. In 1989, DOE-funded research ended at LEHR. The LEHR Site was listed on the US EPA National Priority list in May 1994. The area is presently occupied by the UC Davis Center for Health and the Environment.

The local climate is Mediterranean, with mild winters and dry summers. Precipitation and temperature data specific to 2009 were obtained from the Davis WSW weather station located approximately one mile northwest of LEHR (Western Regional Climate Center, 2010). The average temperature for 2009 was approximately 16.2 degrees Celsius (°C) (61.1 degrees Fahrenheit), and the total precipitation for 2009 was approximately 40.1 centimeters (cm) (15.8 inches). The sun shines approximately 95% of the time during daylight hours in the summer and about 45% of the time during daylight hours in the winter.

The prevailing wind direction is from the south, due to frequent incursions of marine air through the Carquinez Strait into the Sacramento Valley. However, changes in wind direction are common, with winds from the northwest occurring diurnally. Several times a year, strong winds blow from the north, generally following the passage of Pacific storm systems (DOE, 1994a). The Davis WSW weather station does not report wind speed; instead, wind data from the Sacramento Executive Airport, which is located approximately 15 miles east of LEHR, is used to represent wind conditions at LEHR. The average wind speed for the Sacramento Executive Airport in 2009 was 2.4 meters per second (5.4 miles per hour) (NCDC, 2010). The meteorological parameters required for input for CAP88-PC are listed in Table 2.

LEHR contains laboratory buildings and former animal-handling facilities (Figure 2). Approximately 45% of the Site is paved or covered by structures. Approximately 45% is unpaved and relatively free of vegetation, and 5% is covered by large, deep-rooted vegetation. Surface remnants of former outdoor dog pens consisting of asphalt and gravel occupy the remaining 5% of

the Site. The owners of the land and the buildings on the Site are the Regents of the University of California.

The land within a one-mile radius of LEHR is owned privately or by UC Davis, and is mainly used for animal research, agriculture, and recreation. Immediately to the north, east, and west of LEHR are UC Davis research facilities. The privately owned lands within one mile to the south and east of LEHR include rural residences and crop land. Approximately 75% of the surrounding land in the general vicinity of LEHR is used for agriculture. Major crops include fruits, nuts, and grains. Approximately 40% of the agricultural land in the vicinity is irrigated, and some of the nearby lands are used for cattle grazing (DOE, 1988). The agricultural data required for CAP88-PC are listed in Table 3.

1.2 Source Description

The only source of radionuclide air emissions at the Site in 2009 was diffuse emissions from the Eastern Dog Pens (EDPs) area (Figure 2). There are no point sources of radionuclide emissions at the Site.

The EDPs area is located along the southern boundary of LEHR (Figure 2) and overlies UC Davis Landfill Number 2. Historically, this area contained 96 outdoor pens that were used to house dogs involved in the former Ra-226 and Sr-90 research activities at LEHR. The pens were constructed of concrete curbs and chain-link fencing, contained above-grade shelters, and were partly covered by asphalt and partly covered by gravel. Low levels of Sr-90 and Ra-226 are known to have been released at the EDPs in excreta from the dogs to the floor of the pens and to the concrete curbing. Because the floor areas covered by gravel provided no impermeable barrier between the gravel and the underlying soil, it is possible that the gravel and soil remaining at the EDPs is contaminated with these radionuclides.

Removal of the dog pens began in 1996, when the above-grade structures and interior chain-link fencing were removed, properly packaged, and shipped to the DOE Hanford site for disposal. In fall 2007 (September 13 through October 24), the exterior chain-link fencing and concrete curbing were removed, and the area was re-graded. Currently, only at-grade weathered asphalt and gravel remain.

In 2009, the EDPs area was a potential source of airborne radionuclide emissions due to entrainment by wind of soil particles from areas where soil is exposed. The EDPs emissions are "fugitive" emissions, by definition, because they were not released through an actively ventilated air stream (US EPA, 2004). There were no activities, construction or otherwise, that caused additional emissions. Input parameters required for CAP88-PC that pertain to the Eastern Dog Pens as an emissions source are provided in Table 4.

The radionuclides detected at activity concentrations greater than background in soil at the EDPs, and for this report assumed to be emitted to the atmosphere, are listed with their highest

measured activity concentrations in Table 5. It is assumed that the radionuclides detected in soil at concentrations greater than background are present in fugitive dust at the same concentrations.

Three conservative assumptions are made to estimate the activity concentrations of the radionuclides in soil: 1) the activity concentrations listed in Table 5 are the highest detected concentrations in soil at the EDPs; 2) background activity concentrations were not subtracted from these measured activity concentrations even though part of the total concentrations can be attributed to background in most cases; and 3) the activity concentrations were also not corrected to account for attenuation due to radioactive decay, although all of the soil samples were collected before 2000. The activity concentrations of radionuclides in soil from the EDPs area are from samples collected during the 1999 EDPs investigation (Weiss, 1999), which is the only CERCLA investigation that was conducted in this area.

2. AIR EMISSION DATA

2.1 Point Sources

As discussed in Section 1, there were no point sources of radionuclide emissions at the Site in 2009.

2.2 Diffuse Sources

The EDPs were the only diffuse source of radionuclide emissions present at the Site in 2009; emissions from this area were due to wind erosion of surface soil. No excavation or other ground-disturbing activities were conducted at any DOE areas during calendar year 2009. The following discussion pertains to the estimation of radionuclide emissions as respirable particles, defined as those particles 10 micrometers (PM_{10}) in diameter or smaller.

2.2.1 Estimating Radionuclide Emissions due to Wind Entrainment of Surface Soil

To estimate the emissions from wind erosion of radionuclides, a two-step calculation is used. First, a general emission rate for respirable particles is calculated for the area (Equation [Eq.] 1). The equation used for this calculation assumes that the source area is an "unlimited reservoir" of erodible soil, and that the emission rate is a function of percent of vegetation, soil conditions, and meteorological conditions. Secondly, radioactivity emission rates for each radionuclide at the source area are calculated (Eq. 3).

The general-emission equation is found in the US EPA's guidance document *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites* (Cowherd et al., 1985):

$$E_{10} = 0.036 \times (1 - V) \times \left(\frac{[u]}{u_t}\right)^3 \times F(x) \qquad \text{(Eq. 1)}$$

where,

E_{10} = annual average PM_{10} emission rate per unit contaminated surface, grams per square meter-hour [g/(m^2-hr)];

V = fraction of contaminated surface vegetative cover (assumed zero for worst-case bare soil);

$[u]$	=	mean annual wind speed (= 2.4 m/s at Sacramento Executive Airport in 2009);
u_t	=	threshold value of wind speed at height of wind instrument (= 715 cm per second [cm/s]), as discussed below;
$F(x)$	=	function plotted in Figure 4-3 (= 3.82E-2) of Cowherd et al., 1985; and
x	=	$0.866\ u_t/[u]$ = dimensionless wind-speed ratio (= 2.58).

The fraction of contaminated surface vegetative cover was conservatively assumed to be zero (i.e., bare soil) to calculate a worst-case value. The mean annual wind speed is taken from the Sacramento Executive Airport (NCDC, 2010), which is the nearest meteorological station to LEHR with wind sensors.

The threshold value of wind speed at the height of the wind instrument is calculated by Eq. 2:

$$u_t = u_{friction} \times \left(\frac{1}{0.4}\right) \times \left(\ln \frac{z}{z_0}\right) \qquad \text{(Eq. 2)}$$

where,

u_t	=	threshold value of wind speed at height of wind instrument;
$u_{friction}$	=	threshold friction velocity (= 50 cm/s);
z	=	height of wind instrument (20 feet = 610 cm); and
z_o	=	emission source-area roughness height (= 2 cm).

Cowherd et al. recommend a procedure for determining the threshold friction velocity based on surface-soil sieve-analysis data. Because no surface-soil sieve-analysis data were available for the Site, a conservative threshold friction velocity of 50 cm/s was selected, following the example in Cowherd et al. (1985) for a rural emergency-response application (Application No. 1). This velocity is based on a particle-size mode of 500 µm. The two-cm roughness height represents a value between the ranges for a plowed field and grasslands (Cowherd et al., 1985). The resulting value of u_t is 715 cm/s.

The result of Eq. 1, using the Site- and 2009-specific data, is 5.16E-05 g/m^2-hr (gram(s) per square meter-hour).

To determine the radioactivity emission rate for each radionuclide, the general emission rate is multiplied by the area over which the radionuclide-bearing soil is exposed, the time during which the soil is exposed, and the activity concentration of the radionuclide in the soil:

$$E_{area} = E_{10} \times A_{area} \times \left(24\ {}^{hr}\!/_{day} \times 365\ {}^{days}\!/_{year}\right) \times C_{rad} \times \left(10^{-12}\ {}^{curies}\!/_{picocurie}\right) \qquad \text{(Eq. 3)}$$

where,

E_{area}	=	annual average PM_{10} emission rate for the potential radionuclide-emission diffuse source, curies per year (Ci/yr);
E_{10}	=	annual average PM_{10} emission rate per unit contaminated surface, g/(m^2-hr);
A_{area}	=	surface area of potential radionuclide-emission diffuse source, m^2; and
C_{Rad}	=	maximum value of the measured surface-soil radionuclide concentrations, picocuries per gram (pCi/g).

The surface area of the EDPs area, 3,900 square meters (m^2), was determined using a scaled map of the Site (Figure 2). The highest measured (non-decay-corrected) activity concentrations for any point in the EDPs area are conservatively assumed to be uniformly distributed across the whole EDPs area. The activity concentrations in the fugitive dust are assumed to be equal to the activity concentrations measured in soil. Table 5 reports the activity concentrations of radionuclides in the soil and the resulting radioactivity emission rates for each radionuclide as determined by Eq. 3.

3. DOSE ASSESSMENTS

3.1 Description of Dose Model

Compliance with the NESHAPs radiation-dose limits for diffuse-source emissions was assessed using the US EPA computer code CAP88-PC, Version 1.0. CAP88-PC calculates radiation dose from atmospheric diffusion, and was used to calculate dose from radionuclides in wind-emitted dust.

CAP88-PC was used to calculate the EDE to individual receptors at various distances from the EDPs. The area-source algorithm employed by CAP88-PC, Version 1.0, assumes the distance from an area source to a receptor is measured as the distance from the centroid of the area source to the receptor (US EPA, 1992). For the Site CAP88-PC modeling, the distance from an area source to a receptor is measured as the approximate distance from the centroid of the area source to the outdoor individual or building where the indoor receptor is located. Doses were calculated for potential receptors in buildings at LEHR and receptors immediately outside of LEHR (Table 7).

Based on the CAP88-PC model output, the maximally exposed individual (MEI) at LEHR is a worker at the Geriatrics Buildings Numbers 1 and 2, receiving an EDE of 2.8E-04 mrem/yr (Figure 2, Table 7).

A "population" CAP88-PC run was executed to model the collective population dose from fugitive dust emission from the Site during the course of the year for receptors within a distance of 80 kilometers (km) of the Site, as specified by DOE guidance. Using geographical information system software, the area within 80 km of the Site was split into 128 sectors by dividing the area into eight 10-km-wide rings and sixteen compass directions. The collective population dose was calculated as the average radiation dose to an individual in each sector, multiplied by the number of individuals in that sector, and summed for all sectors. The population of each sector was estimated by multiplying the surface area of the sector by the population density of the county or counties occupied by that sector. The populations of the counties were obtained from the 2009 Annual Population Estimates Program of the Unites States Census Bureau (US Census Bureau, 2010). The total estimated population within 80 km of LEHR is approximately 3,670,000.

The results of the CAP88-PC population run are presented in Appendix A. The estimated collective population dose for 2009 was 1.2E-05 person-rem per year.

Supplemental information required by DOE (DOE, 1994b) is included in Section 6.

3.2 Summary of Input Parameters

The input parameters for the CAP88-PC runs are provided in Tables 2 through 6. As noted above, doses were conservatively calculated assuming that the maximum concentrations (not corrected for background) of the observed radiological surface- and shallow-soil contamination for the EDPs area were present across the entire potential radionuclide emission diffuse source area. The US EPA-recommended particulate-resuspension rate model was used to calculate the fugitive dust emission rates.

The Sacramento area wind file included with the CAP88-PC computer code was used for the modeling. The average annual wind speeds recorded at Sacramento Executive Airport were used to calculate particle-emission rates, as described above. Use of the Sacramento wind data is appropriate because the Site is near Sacramento (approximately 15 miles), the geography is similar, there are no intervening geographical anomalies, and a compatible meteorological data file from a closer air station is not available.

4. COMPLIANCE ASSESSMENT

Point-Source Effective Dose Equivalent:	None
Diffuse-Source Maximum Effective Dose Equivalent:	2.8E-04 millirem per year [mrem/yr] (2.8E-06 millisieverts [mSv] per yr) (about 0.003% of the 10 mrem/yr standard).
Location of On-Site Maximally Exposed Individual:	Geriatrics Buildings Numbers 1 and 2

4.1 Certification

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

Signature: Robert D. Devany Date: June 21, 2010
Robert Devany
Principal Hydrogeologist

Signature: M.Kothari Date: June 21, 2010
Vijendra Kothari
DOE-LEHR Project Manager

5. ADDITIONAL INFORMATION

In 2009, no construction or modifications were completed at the DOE areas at LEHR.

As required in the memorandum of understanding for facilities that were exempt from having to submit an application to the US EPA for construction or modifications, the following information is provided for the Site:

- **Provide a brief description of the construction or modification project and an estimate of potential doses to the public.**

  There were no construction or modification projects completed at the Site in 2009.

- **Identify any unplanned releases of radionuclides to the atmosphere.**

  There were no unplanned releases of radionuclides to the atmosphere during 2009.

- **Results of the dose assessment associated with the diffuse-source emissions from the facility.**

  As noted in Sections 1 and 2, there are currently no point sources of radionuclide emissions at the Site. The only potential sources of radionuclide emissions remaining at the Site are diffuse sources of fugitive dust. The results of the dose assessment associated with the diffuse-source emissions from the Site are presented in Section 3 and Table 7. The total EDE to the on-site MEI from diffuse-source emissions was estimated to be 2.8E-04 mrem/yr (2.8E-06 mSv/yr), far below the 10 mrem/yr standard.

6. SUPPLEMENTAL DOE INFORMATION

- **Provide an estimate of collective dose equivalent for 2009 releases.**

  The collective population dose for calendar year 2009 emissions to the population within an 80-km distance of the Site is estimated to be 1.2E-05 person-rem per year.

- **Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61.**

  The Site is in compliance with Subparts Q and T of 40 CFR part 61, which provide standards for radon emissions from 1) radium-containing materials, and 2) tailings and residual radioactive material due to the processing of uranium ores, respectively. Radium-containing material was not stored at the Site by DOE in 2009, and radium-containing material that had been disposed of at the Site that could emit radon above the Subpart Q standard has been removed. Uranium ores were not processed at the Site.

- **Provide information on radon-220 emissions from sources containing uranium-232 and thorium-232, where emissions potentially can exceed 0.1 mrem/yr to the public, or 10% of the non-radon dose to the public.**

  There are no uranium-232 or thorium-232 sources stored at the Site.

- **Provide information on radon-222 emissions from non-disposal/non-storage sources where emissions potentially can exceed 0.1 mrem/yr to the public, or 10% of the non-radon dose to the public.**

  There are no non-disposal or non-storage sources of radon-222 located at the Site.

- **Give the number of emission points subject to the continuous monitoring requirements of Section 61.93(b) of 40 CFR, the number of these emission points that do not comply with Section 61.93(b) requirements and the cost of upgrades. Describe site periodic confirmatory measurement plans. Indicate the status of the quality assurance program described by Appendix B, Method 114.**

  There are no point-source emissions at the Site that require continuous monitoring according to Subpart H of 40 CFR.

7. TERMINATION OF REPORTING

As mentioned in Section 1, above, this is the final NESHAPs annual report for the DOE areas at LEHR, as specified in the ROD (DOE, 2009). The ROD presents facts and analysis supporting selection of a remedy for the Site under CERCLA. As such, the ROD documents the assessment and cleanup activities that were conducted under CERCLA, including site characterization, decontamination and decommissioning, completion of removal actions at the DOE areas, and human health and ecological risk assessments. The ROD also provides a record that DOE and US EPA agree that monitoring and reporting for compliance with the NESHAPs regulations will cease upon adoption of the ROD, and that the site is not a significant source of radionuclides in air emissions (DOE, 2009). The ROD was adopted and signed by US EPA and DOE in late 2009.

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TABLES

Table 1. Dose Estimates to Maximally Exposed Members of the Public, Laboratory for Energy-related Health Research, 1999-2009

Calendar Year	Effective Dose Equivalent to Maximally Exposed Individual (millirem(s) per year)	Document Reference
1999	1.35E-3	Weiss, 2000
2000	7.52E-4	Weiss, 2001
2001	1.0E-3	Weiss, 2002
2002	3.8E-4	Weiss, 2003
2003	1.4E-3	Weiss, 2004
2004	1.6E-3	Weiss, 2005
2005	5.9E-4	Weiss, 2006
2006	5.8E-2	Weiss, 2007
2007	8.1E-2	Weiss, 2008
2008	5.1E-4	Weiss, 2009
2009	2.8E-4	This document

Table 2. Meteorological Input Parameters for CAP88-PC

Parameter	Value	Notes
Wind file	SAC0320.WND	supplied with CAP88-PC
Annual precipitation (centimeters)	40.1	total precipitation in Davis, California in 2009[1]
Temperature (degrees Celsius)	16.2	average temperature in Davis, California in 2009[1]
Height of lid (meters)	1,000	CAP88-PC default

Note:
[1] Davis WSW weather station

Table 3. Agricultural Input Parameters for CAP88-PC

Parameter	Value	Notes
Source type	Rural	CAP88-PC default
Food production		
Vegetable		
Fraction home produced	0.7	CAP88-PC default
Fraction from assessment area	0.3	CAP88-PC default
Fraction imported	0	CAP88-PC default
Milk		
Fraction home produced	0.399	CAP88-PC default
Fraction from assessment area	0.601	CAP88-PC default
Fraction imported	0	CAP88-PC default
Beef		
Fraction home produced	0.442	CAP88-PC default
Fraction from assessment area	0.558	CAP88-PC default
Fraction imported	0	CAP88-PC default
Beef cattle density (number per square kilometer)	8.81E-02	CAP88-PC default for California
Milk cattle density (number per square kilometer)	2.85E-02	CAP88-PC default for California
Land fraction cultivated for vegetable crops	0.25	Site-specific parameter that was applied to CAP88-PC for the 1995 Radionuclide Air Emissions Annual Report (PNL, 1996)

Table 4. Source Input Parameters for CAP88-PC

Parameter	Value	Notes
Source type	Area	
Number of sources	1	The Eastern Dog Pens area is one contiguous area
Height (meters)	0	The Eastern Dog Pens area is relatively flat
Area (square meters)	3,900	Calculated from scaled map (Figure 2)
Plume rise	Zero	Plume rise is zero for each Pasquill stability category

Table 5. Radionuclides Potentially Released from Soil to Air, Eastern Dog Pens Area

Radionuclide[1]	Highest Measured Activity Concentration (pCi/g)	Potential radioactivity-emission rate due to entrainment by wind, assuming highest measured activity concentration[2] (Ci/yr)	Size[3] (μm)	Class[4]
Bismuth-212	0.415	7.32E-10	1	Week
Bismuth-214	0.572	1.01E-09	1	Week
Cesium-137[5]	0.191	3.37E-10	1	Day
Lead-214	0.607	1.07E-09	1	Day
Strontium-90	0.164	2.89E-10	1	Day
Thallium-208	0.219	3.86E-10	1	Day
Thorium-228	1.54	2.72E-09	1	Year
Thorium-230	1.26	2.22E-09	1	Year
Thorium-232[5]	1.39	2.45E-09	1	Year
Thorium-234	0.89	1.57E-09	1	Year
Tritium	1.21	2.13E-09	0	Gas
Uranium-235	0.0383	6.76E-11	1	Year

Notes:
[1]The radionuclides included on this list are those for which at least one detected result in soil from the Eastern Dog Pens was at an activity concentration greater than background.
[2]See discussion in text for calculations of emission rate.
[3]CAP88-PC default particle size.
[4]CAP88-PC default lung-retention class.
[5]Did not include whole decay chain in CAP88-PC model because nuclides were measured directly.

Abbreviations:

Ci/yr	curies per year
pCi/g	picocuries per gram
μm	micrometer

Table 6. CAP88-PC Model Run Specifications and Options

Run type	Specifications
Individual	Distances between source and receptors, in meters, are 94, 132, 143, 150, 155, 165, 180, 187, 500, 1000
Population	Population file is 09LEHR.POP

Options	Value
Generate genetic effects?	Yes
Create Dose and Risk Factor file?	Yes
Create Concentration Table file?	Yes
Create Chi/Q Table file?	Yes

Table 7. Modeled Effective Dose Equivalents to Potentially Exposed Members of the Public

Receptor location[1]			
Description	UC Davis Building Number	Distance and direction from Eastern Dog Pens[2]	Effective dose equivalent[3] (mrem/yr)
Geriatrics Buildings Nos. 1 and 2	H-292 and H-293	94 m N	**2.8E-04**
Specimen Storage Building	H-216	132 m WNW	1.4E-04
Inter-Regional Project No. 4 Building	H-217	143 m WNW	1.2E-04
Clinical Pathology	H-215	150 m WNW	1.1E-04
Cellular Biology Laboratory	H-294	155 m NNW	1.2E-04
Animal Hospital Buildings Nos. 1 and 2	H-219 and H-218	165 m NW	9.4E-05
UC Davis Building E of LEHR Site	N/A	180 m E	1.7E-05
Main Office	H-213	187 m NW	7.3E-05
Off-Site Receptor W of LEHR Site	N/A	500 m W	8.2E-06
Off-Site Receptor S of Putah Creek	N/A	1,000 m S	1.7E-06

Notes:
[1]The list of receptor locations is in order of distance from the source.
[2]The distance from an area source to a receptor is defined by CAP88-PC as the distance from the centroid of the area source to the receptor (US EPA, 1992). For the CAP88-PC modeling at the Site, the distance from an area diffuse source to a receptor is measured as the approximate distance from the centroid of the diffuse source to the centroid of the building assumed to house the receptor.
[3]The effective dose equivalent to the potentially exposed member of the public is taken as the maximum modeled dose within a 45° sector in the direction and at the distance indicated. For example, the dose 94 m north of the Eastern Dog Pens area would be the maximum modeled dose within the sector bounded by 94 m NNE and 94 m NNW. See Appendix A for the modeled results for each distance and direction. Value in **bold face** is the modeled dose to the maximally exposed individual.

Abbreviations:

°	degrees
E	east
LEHR	Laboratory for Energy-related Health Research
NW	northwest
mrem/yr	millirem(s) per year
N	north
N/A	not applicable
NNW	north by northwest
m	meters
No(s).	number(s)
S	south
UC Davis	University of California, Davis
W	west
WNW	west by northwest

FIGURES

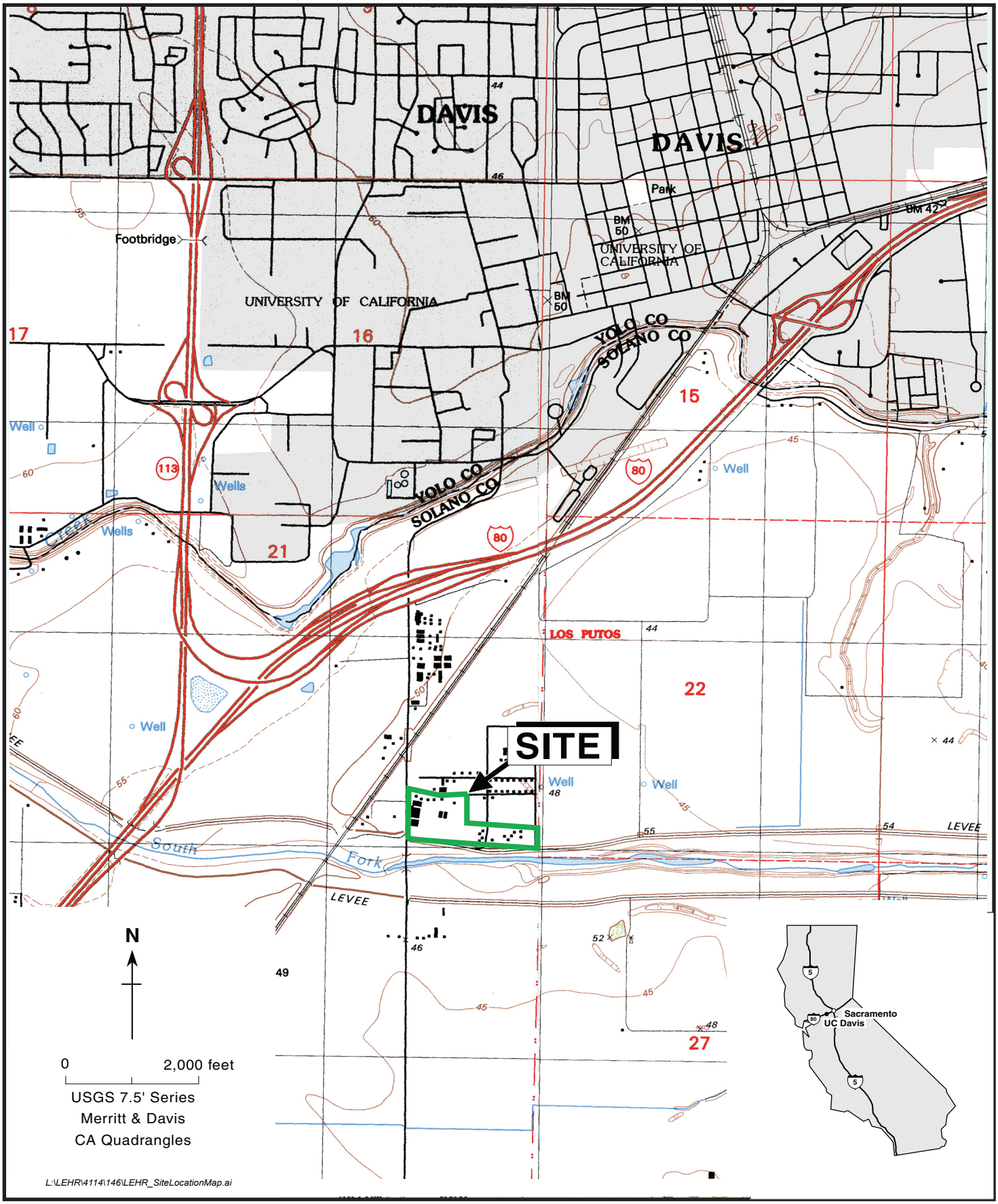

Figure 1. LEHR Location Map, University of California, Davis

Weiss Associates

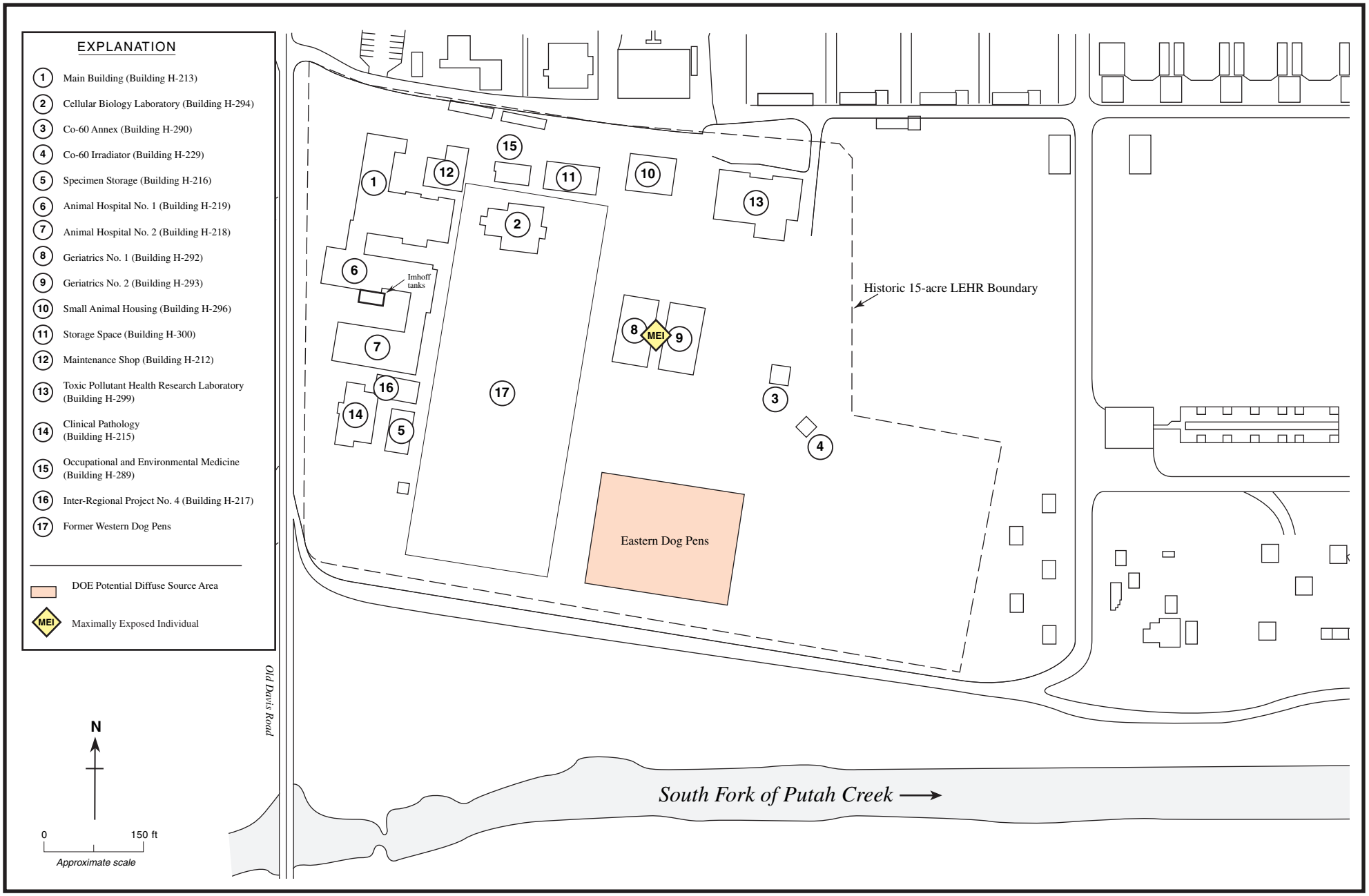

Figure 2. DOE Potential Diffuse-Source Area and Location of Maximally Exposed Individual

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6/21/10

APPENDIX A

CAP88-PC OUTPUT RESULTS

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

Non-Radon Individual Assessment
Apr 18, 2010 1:59 pm

Facility: LEHR
Address:
City: Davis
State: CA Zip:

Source Category: area
Source Type: Area
Emission Year: 2009

Comments: wind-entrained dust, individual run

Dataset Name: EDPind
Dataset Date: Apr 18, 2010 1:58 pm
Wind File: WNDFILES\SAC0320.WND

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	9.47E-07
BREAST	9.79E-07
R MAR	1.65E-04
LUNGS	1.66E-03
THYROID	9.49E-07
ENDOST	2.05E-03
RMNDR	2.75E-06

EFFEC	2.82E-04

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)
INGESTION	2.29E-06
INHALATION	2.80E-04
AIR IMMERSION	2.60E-10
GROUND SURFACE	3.08E-08
INTERNAL	2.82E-04
EXTERNAL	3.10E-08
TOTAL	2.82E-04

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
BI-212	3.26E-09
BI-214	1.83E-10
CS-137	3.88E-08
PB-214	1.52E-10
SR-90	1.11E-07
TL-208	9.90E-11
TH-228	9.06E-05
TH-230	7.36E-05
TH-232	1.17E-04
TH-234	1.50E-08
H-3	1.85E-10
U-235	1.15E-06
TOTAL	2.82E-04

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	1.44E-10
BONE	9.42E-11

	A.SUM
THYROID	1.73E-13
BREAST	1.52E-12
LUNG	2.84E-09
STOMACH	1.23E-12
BOWEL	1.74E-12
LIVER	6.23E-12
PANCREAS	8.59E-13
URINARY	7.04E-13
OTHER	1.05E-12
TOTAL	3.10E-09

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	1.02E-11
INHALATION	3.09E-09
AIR IMMERSION	6.30E-15
GROUND SURFACE	7.05E-13
INTERNAL	3.10E-09
EXTERNAL	7.12E-13
TOTAL	3.10E-09

NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk
BI-212	4.19E-14
BI-214	2.12E-14
CS-137	1.01E-12
PB-214	2.60E-14
SR-90	1.86E-12
TL-208	2.43E-15
TH-228	1.82E-09
TH-230	6.04E-10
TH-232	6.57E-10
TH-234	5.13E-13
H-3	5.01E-15
U-235	1.52E-11
TOTAL	3.10E-09

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)

A.SUM
(All Radionuclides and Pathways)

Direction	Distance (m) 94	132	143	150	155	165	180
N	2.8E-04	1.6E-04	1.4E-04	1.3E-04	1.2E-04	1.1E-04	9.2E-05
NNW	2.6E-04	1.3E-04	1.1E-04	9.6E-05	9.0E-05	7.9E-05	6.6E-05
NW	2.6E-04	1.4E-04	1.2E-04	1.1E-04	1.1E-04	9.4E-05	7.9E-05
WNW	2.1E-04	1.1E-04	9.4E-05	8.6E-05	8.0E-05	7.1E-05	6.0E-05
W	1.4E-04	7.5E-05	6.5E-05	5.9E-05	5.5E-05	4.9E-05	4.1E-05
WSW	7.5E-05	3.4E-05	2.8E-05	2.5E-05	2.3E-05	2.0E-05	1.7E-05
SW	4.5E-05	2.2E-05	1.8E-05	1.6E-05	1.5E-05	1.3E-05	1.1E-05
SSW	5.6E-05	2.4E-05	2.0E-05	1.7E-05	1.6E-05	1.4E-05	1.2E-05
S	1.1E-04	5.6E-05	4.9E-05	4.4E-05	4.2E-05	3.7E-05	3.1E-05
SSE	1.3E-04	7.3E-05	6.4E-05	5.9E-05	5.6E-05	5.0E-05	4.2E-05
SE	9.2E-05	4.6E-05	3.9E-05	3.5E-05	3.3E-05	2.9E-05	2.4E-05
ESE	5.8E-05	2.7E-05	2.3E-05	2.0E-05	1.9E-05	1.7E-05	1.4E-05
E	5.6E-05	2.9E-05	2.5E-05	2.2E-05	2.1E-05	1.9E-05	1.6E-05
ENE	8.2E-05	3.6E-05	2.9E-05	2.6E-05	2.3E-05	2.0E-05	1.7E-05
NE	1.5E-04	8.3E-05	7.2E-05	6.7E-05	6.3E-05	5.6E-05	4.7E-05
NNE	2.2E-04	1.1E-04	9.0E-05	8.1E-05	7.5E-05	6.6E-05	5.6E-05

Direction	Distance (m) 187	500	1000
N	8.6E-05	1.3E-05	3.5E-06
NNW	6.2E-05	9.3E-06	2.5E-06
NW	7.3E-05	1.1E-05	3.0E-06
WNW	5.5E-05	8.2E-06	2.2E-06
W	3.8E-05	5.7E-06	1.6E-06
WSW	1.6E-05	2.4E-06	7.4E-07
SW	1.0E-05	1.7E-06	5.5E-07
SSW	1.1E-05	1.7E-06	5.6E-07
S	2.9E-05	4.5E-06	1.3E-06
SSE	3.9E-05	6.1E-06	1.7E-06
SE	2.3E-05	3.5E-06	1.0E-06
ESE	1.3E-05	2.0E-06	6.5E-07
E	1.5E-05	2.3E-06	7.1E-07
ENE	1.6E-05	2.5E-06	7.7E-07
NE	4.4E-05	6.7E-06	1.9E-06
NNE	5.2E-05	8.0E-06	2.2E-06

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

Distance (m)

A.SUM

Direction	94	132	143	150	155	165	180
N	3.1E-09	1.7E-09	1.5E-09	1.4E-09	1.3E-09	1.2E-09	1.0E-09
NNW	2.9E-09	1.4E-09	1.2E-09	1.1E-09	9.8E-10	8.7E-10	7.3E-10
NW	2.8E-09	1.5E-09	1.3E-09	1.2E-09	1.2E-09	1.0E-09	8.7E-10
WNW	2.4E-09	1.2E-09	1.0E-09	9.4E-10	8.8E-10	7.8E-10	6.5E-10
W	1.6E-09	8.3E-10	7.1E-10	6.5E-10	6.1E-10	5.4E-10	4.5E-10
WSW	8.2E-10	3.8E-10	3.1E-10	2.8E-10	2.5E-10	2.2E-10	1.9E-10
SW	4.9E-10	2.4E-10	2.0E-10	1.8E-10	1.7E-10	1.5E-10	1.2E-10
SSW	6.1E-10	2.7E-10	2.2E-10	1.9E-10	1.7E-10	1.5E-10	1.3E-10
S	1.2E-09	6.2E-10	5.3E-10	4.9E-10	4.6E-10	4.1E-10	3.4E-10
SSE	1.4E-09	8.0E-10	7.0E-10	6.5E-10	6.2E-10	5.5E-10	4.6E-10
SE	1.0E-09	5.0E-10	4.3E-10	3.9E-10	3.6E-10	3.2E-10	2.7E-10
ESE	6.4E-10	3.0E-10	2.5E-10	2.2E-10	2.1E-10	1.8E-10	1.5E-10
E	6.1E-10	3.1E-10	2.7E-10	2.5E-10	2.3E-10	2.0E-10	1.7E-10
ENE	9.0E-10	3.9E-10	3.2E-10	2.8E-10	2.6E-10	2.2E-10	1.9E-10
NE	1.7E-09	9.1E-10	7.9E-10	7.3E-10	6.9E-10	6.2E-10	5.2E-10
NNE	2.4E-09	1.2E-09	9.9E-10	8.9E-10	8.3E-10	7.3E-10	6.1E-10

	Distance (m)		
Direction	187	500	1000
N	9.4E-10	1.4E-10	3.7E-11
NNW	6.8E-10	1.0E-10	2.7E-11
NW	8.0E-10	1.2E-10	3.2E-11
WNW	6.1E-10	9.0E-11	2.4E-11
W	4.2E-10	6.2E-11	1.6E-11
WSW	1.7E-10	2.5E-11	7.1E-12
SW	1.1E-10	1.7E-11	5.0E-12
SSW	1.2E-10	1.8E-11	5.1E-12
S	3.2E-10	4.8E-11	1.3E-11
SSE	4.3E-10	6.6E-11	1.8E-11
SE	2.5E-10	3.8E-11	1.0E-11
ESE	1.4E-10	2.1E-11	6.2E-12
E	1.6E-10	2.4E-11	6.7E-12
ENE	1.7E-10	2.6E-11	7.5E-12
NE	4.8E-10	7.3E-11	2.0E-11
NNE	5.7E-10	8.7E-11	2.3E-11

♀

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

S Y N O P S I S R E P O R T

Non-Radon Population Assessment
Apr 18, 2010 1:59 pm

Facility: LEHR
Address:
City: Davis
State: CA Zip:

Effective Dose Equivalent (mrem/year)
2.27E-07

At This Location: 5000 Meters North
Source Category: area
Source Type: Area
Emission Year: 2009

Comments: wind-entrained dust, population run

Dataset Name: EDPpop
Dataset Date: Apr 18, 2010 1:58 pm
Wind File: WNDFILES\SAC0320.WND
Population File: POPFILES\09LEHR.POP

♀

MAXIMALLY EXPOSED INDIVIDUAL

Location Of The Individual: 5000 Meters North
Lifetime Fatal Cancer Risk: 2.49E-12

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)	Collective Population (person-rem/y)
GONADS	7.54E-10	4.16E-08
BREAST	7.81E-10	4.33E-08
R MAR	1.33E-07	7.07E-06
LUNGS	1.34E-06	6.91E-05
THYROID	7.53E-10	4.17E-08
ENDOST	1.65E-06	8.75E-05
RMNDR	2.23E-09	1.38E-07
EFFEC	2.27E-07	1.18E-05

FREQUENCY DISTRIBUTION OF LIFETIME FATAL CANCER RISKS

Risk Range	Number of People	Number of People In This Risk Range Or Higher	Deaths/Year In This Risk Range	Deaths/Year In This Risk Range Or Higher
1.0E+00 TO 1.0E-01	0	0	0.00E+00	0.00E+00
1.0E-01 TO 1.0E-02	0	0	0.00E+00	0.00E+00
1.0E-02 TO 1.0E-03	0	0	0.00E+00	0.00E+00
1.0E-03 TO 1.0E-04	0	0	0.00E+00	0.00E+00
1.0E-04 TO 1.0E-05	0	0	0.00E+00	0.00E+00
1.0E-05 TO 1.0E-06	0	0	0.00E+00	0.00E+00
LESS THAN 1.0E-06	3674832	3674832	1.83E-09	1.83E-09

RADIONUCLIDE EMISSIONS DURING THE YEAR 2009

Nuclide	Class	Size	Source #1 Ci/y	TOTAL Ci/y
BI-212	W	1.00	7.3E-10	7.3E-10
BI-214	W	1.00	1.0E-09	1.0E-09
CS-137	D	1.00	3.4E-10	3.4E-10
PB-214	D	1.00	1.1E-09	1.1E-09
SR-90	D	1.00	2.9E-10	2.9E-10
TL-208	D	1.00	3.9E-10	3.9E-10
TH-228	Y	1.00	2.7E-09	2.7E-09
TH-230	Y	1.00	2.2E-09	2.2E-09
TH-232	Y	1.00	2.4E-09	2.4E-09
TH-234	Y	1.00	1.6E-09	1.6E-09
H-3	*	0.00	2.1E-09	2.1E-09
U-235	Y	1.00	6.8E-11	6.8E-11

B.SYN

SITE INFORMATION

Temperature: 16 degrees C
Precipitation: 40 cm/y
Mixing Height: 1000 m

SOURCE INFORMATION

Source Number: 1

Source Height (m): 0.00
Area (sq m): 3.90E+03

Plume Rise Pasquill Cat:	A	B	C	D	E	F	G
Zero:	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AGRICULTURAL DATA

	Vegetable	Milk	Meat
Fraction Home Produced:	0.700	0.399	0.442
Fraction From Assessment Area:	0.300	0.601	0.558
Fraction Imported:	0.000	0.000	0.000

Beef Cattle Density: 8.81E-02
Milk Cattle Density: 2.85E-02
Land Fraction Cultivated for Vegetable Crops: 2.50E-01

POPULATION DATA

	Distance (m)						
Direction	5000	15000	25000	35000	45000	55000	65000
N	1507	4425	7374	9495	10187	10205	14453
NNW	1501	4420	7366	10312	11412	2578	1963
NW	1537	4420	7365	10311	13264	14533	9377
WNW	1709	4431	7364	10024	12132	14235	11615
W	3599	8866	10989	9856	11630	14208	19168
WSW	3626	10879	18126	13750	12662	14208	26623

B.SYN

SW	3626	10879	18127	23653	31909	29152	42694
SSW	3626	10879	18130	25382	31053	49700	127658
S	3631	10893	18154	25596	49220	113943	136579
SSE	3624	7314	16909	54045	68245	57738	60701
SE	2809	4420	26576	72013	61039	41381	46309
ESE	2184	5008	41192	74464	95812	111903	73728
E	2077	8445	51720	74461	95816	117052	43582
ENE	1899	4452	47146	74463	84074	71773	12821
NE	1650	4475	50727	37364	16141	19320	22827
NNE	1525	4420	13669	8154	10633	12507	12976

	Distance (m)
Direction	75000
N	16875
NNW	2621
NW	3858
WNW	7641
W	29816
WSW	33879
SW	56087
SSW	157374
S	157595
SSE	63542
SE	53430
ESE	22094
E	8925
ENE	11584
NE	20892
NNE	12847