6. Terrestrial Monitoring

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Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, vegetation, and wine, and the absorbed gamma radiation dose at ground-level receptors from terrestrial and atmospheric sources. LLNL also monitors the abundance of distribution of rare plants and the protection of special habitats onsite.

The LLNL terrestrial radioactivity-monitoring program is designed to measure any changes in environmental levels of radioactivity. All monitoring activities follow U.S. DOE guidance criteria. On-site monitoring activities detect radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation and is used to compare the impact of operations.

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air (see Chapter 4). Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota is calculated using a screening model that requires knowledge of radionuclide concentrations in soils and surface water, which is explained under the *Biota Dose* section below.

Sampling for all media is conducted according to written, standardized procedures summarized in Gallegos (2012).

LLNL also monitors the abundance, distribution, and ecological requirements of plant and wildlife species, and conducts research relevant to the protection of rare plants and animals. Monitoring and research of biota on LLNL property is conducted to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

6.1 Soil Monitoring

The number of soil sampling locations is as follows:

Livermore Site—7 (see **Figure 6-1**)

Livermore Valley—10, including 3 at the LWRP (see **Figure 6-2**)

Site 300—12 (see **Figure 6-3**)

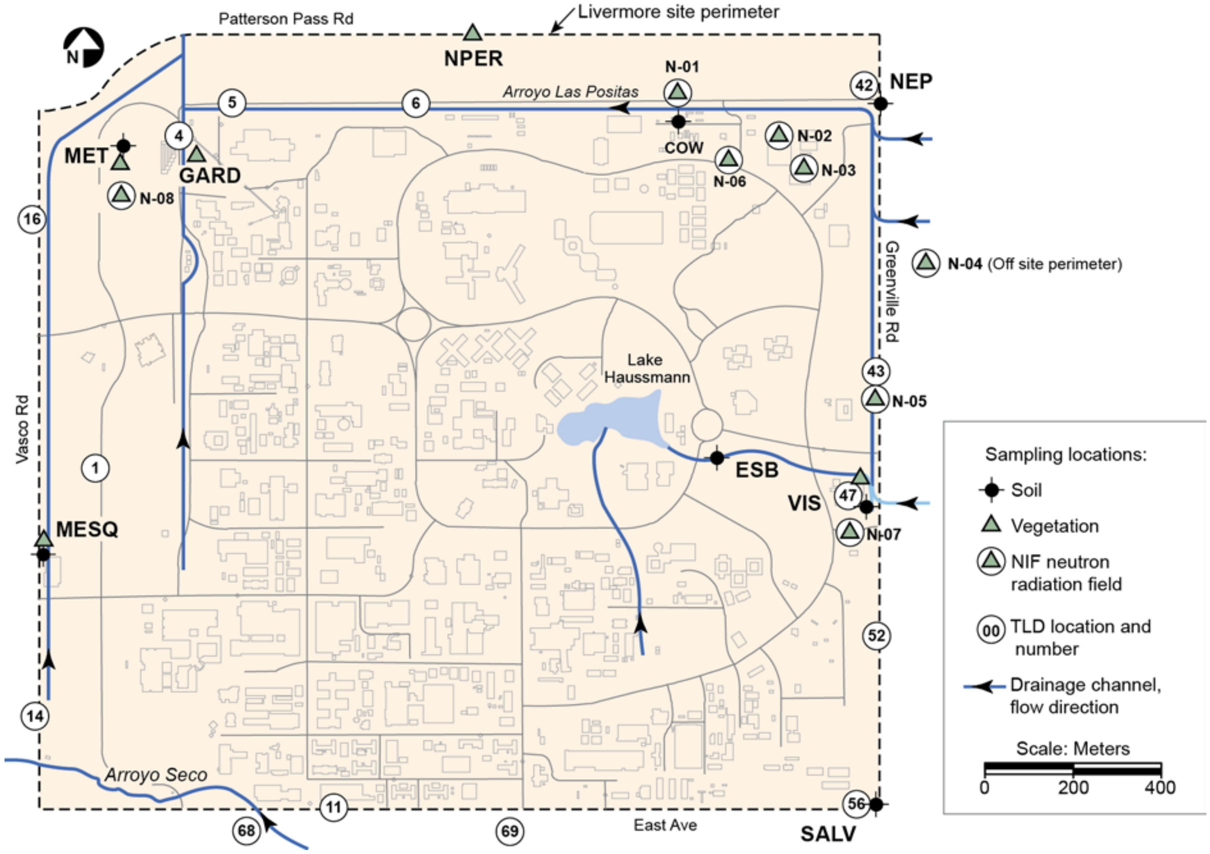

Figure 6-1. Soil and vegetation sampling locations and TLD locations, Livermore Site.

These locations were selected to represent both background concentrations (distant locations unlikely to be affected by LLNL activities) and areas that have the potential to be affected by LLNL operations. Sampling locations also include areas with known contaminants, such as the LWRP and around explosives testing areas at Site 300.

Surface soil samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-m squares are chosen from which to collect the sample. Each sample is a composite consisting of 10 subsamples that are collected at the corners and center of each square using an 8.25-cm-diameter, stainless steel core sampler.

Additional samples are collected for tritium, gross alpha, gross beta, and metals analyses. At four sample locations a 15-cm deep sample is taken for tritium analysis at one of the subsample grid points; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis.

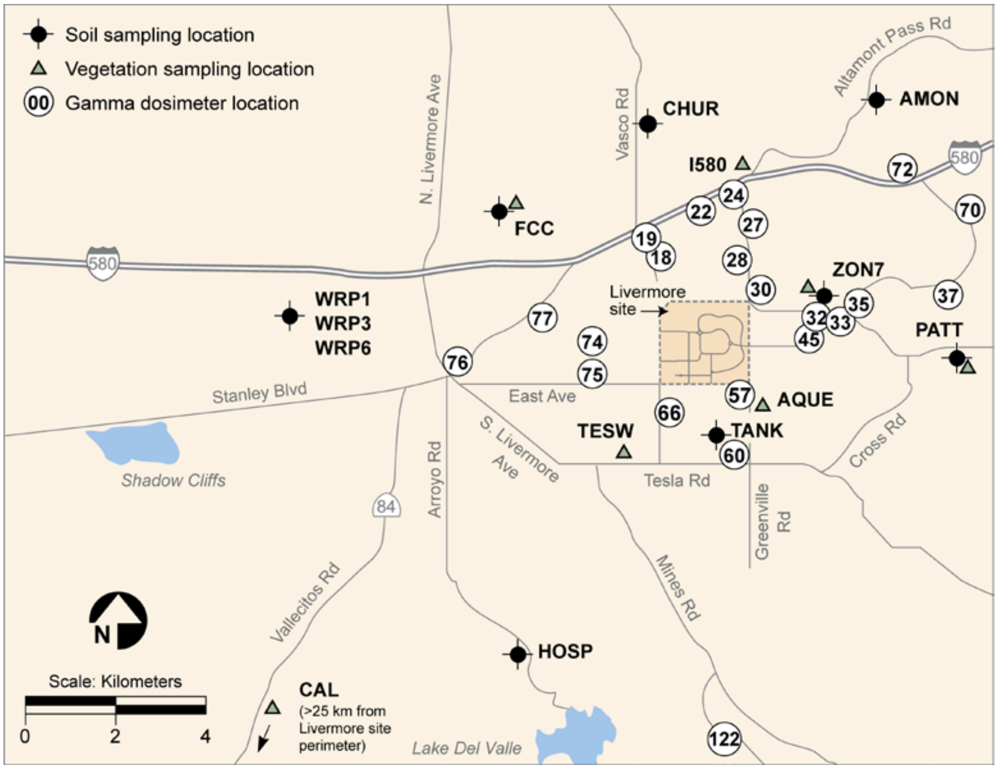

Figure 6-2. Soil and vegetation sampling locations and TLD locations, Livermore Valley.

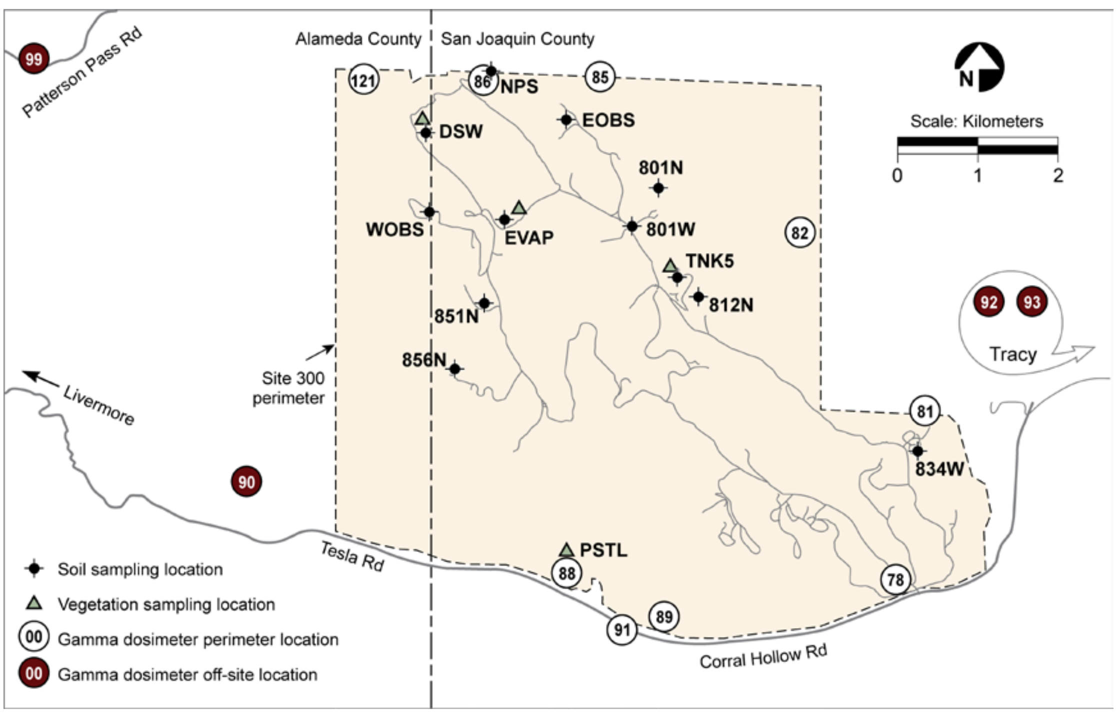

Figure 6-3. Soil and vegetation sampling locations and TLD locations, Site 300 and offsite.

In 2013, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides; samples at selected locations were analyzed for tritium, gross alpha, and gross beta. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium.

Prior to radiochemical analysis, the surface soil is dried, sieved, ground, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectrometry. Other sample aliquots (300 g) are analyzed by gamma spectrometry using a high-purity germanium (HPGe) detector for a suite of radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. Tritium is analyzed by liquid scintillation counting. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry.

6.1.1 Radiological Monitoring Results

The 2013 data on the concentrations of radionuclides in surface soil from the Livermore Valley sampling locations are provided in **Appendix A**, **Section A.8**.

The concentrations and distributions of all observed radionuclides in soil for 2013 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Slightly higher values at and near the Livermore Site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste. Sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore Site, shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2013 was 0.35 mBq/dry g (9.5×10^{-3} pCi/dry g). Elevated levels of plutonium-239+240 resulting from an estimated 1.2×10^{9} Bq (32 mCi) plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at LWRP sampling locations in 2013. The highest detected plutonium-239+240 value at the LWRP in 2013 was 10 mBq/dry g (2.7×10^{-1} pCi/dry g). In addition, americium-241 was detected in one LWRP sample at a concentration of 5.0 mBq/dry g (1.4×10^{-1} pCi/dry g) and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

The highest detected value for tritium in 2013 (16 Bq/L [432 pCi/L]) was at location ESB, which is downwind of the Tritium Facility. This value is consistent with measured tritium emissions associated with the Tritium Facility's operations, as described in **Chapter 4**. All tritium concentrations were within the range of previous data.

The soils data for Site 300 for 2013 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2013 lie within the ranges reported in previous years. At the majority of the sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.00725. There is significant uncertainty in calculating the ratio due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. In 2013, the highest measured values for uranium-235 and uranium-

238 in a single sample were 0.0.049 µg/g (0.0039 Bq/g or 0.11 pCi/g) and 9.5 µg/g (0.12 Bq/g or 3.2 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample was 0.0053, which at the upper end range of analytical uncertainty is consistent with the ratio for natural occurring uranium; at the lower end range of the analytical uncertainty, the presence of depleted uranium is indicated. Depleted uranium values at Site 300 result from the previous use of depleted uranium in atmospheric explosive experiments.

6.1.2 Nonradiological Monitoring Results

Nonradiological monitoring for beryllium at Site 300 is sampled at all locations (see **fig. 6-3**). The beryllium results for soils at Site 300 were within the ranges reported since sampling began in 1991. The highest value in 2013, 1.1 mg/kg, was found in an area that has historically been used for explosives testing. This value is much lower than the 110 mg/kg detected in 2003. The range of results reflects the varied concentrations of beryllium in the soil from previous explosives testing.

6.1.3 Environmental Impact on Soil

6.1.3.1 Livermore Site

Routine surface soil sample analyses indicate that the impact of LLNL operations on this medium in 2013 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts or could not be measured above detection limits.

The highest value for plutonium-239+240 in 2013 (10 mBq/dry g [0.27 pCi/dry g]), measured at LWRP, is 2.1% of the National Council on Radiation Protection (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999).

LLNL has investigated the presence of radionuclides in local soils frequently over the years including possible impacts of the distribution to the public of sludge contaminated by the 1967 plutonium release (see Table 6-5 in the *Environmental Report 2006* [Mathews et al. 2007] for a list of previous studies). The studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern. In fact, the concentrations are of such low levels of health concern that the Agency for Toxic Substances and Disease Registry (ATSDR) (2003) strongly recommended against further study of local soils for the purpose of identifying locations where plutonium-contaminated sludge from the 1967 release may remain.

6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2013 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables. They result from the fraction of the firing table operations that dispersed depleted uranium from historical testing. The highest measured uranium-235 concentration was 0.0.049 µg/g (0.0039 Bq/g or 0.11 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (8.2 µg/g [0.65 Bq/g or 17.5 pCi/g]). The highest measured uranium-238 concentration was 9.5 µg/g (0.12 Bq/g or 3.2 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]).

In 2008, a Remedial Investigation/Feasibility Study was submitted for the Building 812 operating unit (OU) (Taffet et al. 2008). This Investigation/Feasibility Study specifies the nature and extent of contamination, risk assessment, and remedial alternatives for CERCLA cleanup of the site (see **Chapter 7**). In 2011, ERD began characterization as a means to address soil and groundwater contamination cleanup in the Building 812 OU. However, further characterization activities may be necessary and may therefore delay remediation. See **Chapter 7** for further details regarding this project.

6.2 Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore Site (see **Figure 6-1**) and in the Livermore Valley (see **Figure 6-2**) are divided for comparison into the following three groups:

- Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are on-site or less than 1 km from the Livermore Site perimeter.
- Intermediate locations (I580, PATT, TESW, and ZON7) are in the Livermore Valley and 1 to 5 km from the Livermore Site perimeter.
- Far locations (FCC and CAL) are more than 5 km from the Livermore Site perimeter; FCC is about 5 km away and CAL is more than 25 km away. Both locations are generally upwind of the Livermore Site.

Tritium in vegetation due to LLNL operations is most likely to be detected at the Near and Intermediate locations and is highly unlikely to be detected at the Far locations.

Site 300 has four monitoring locations for vegetation (PSTL, TNK5, DSW, and EVAP) (see **Figure 6-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. At the other two locations, TNK5 and PSTL, the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Vegetation is sampled and analyzed quarterly. Water is extracted from vegetation by freeze-drying and analyzed for tritiated water (HTO) using liquid scintillation techniques.

Wines for sampling in 2013 were purchased from a supermarket in Livermore. The wines represent the Livermore Valley, two other regions of California, and the Rhone Valley in France. Wines were prepared for sampling using a method that separates the water fraction from the other components of the wine and were analyzed using an ultra-low-level scintillation counter.

6.2.1 Vegetation Monitoring Results

Median and mean concentrations of tritium in vegetation based on samples collected at the Livermore Site, in the Livermore Valley, and Site 300 in 2013 are shown in **Table 6-1**. (See

Appendix A, **Section A.9**, for quarterly tritium concentrations in plant water). The highest mean tritium concentration for 2013 was 4.3 Bq/L at the Near location VIS located on the east-central perimeter of the Livermore Site. For Site 300, the highest mean concentration for 2013 was 37 Bq/L at EVAP located in an area where the groundwater is contaminated with tritium.

Median concentrations of tritium in vegetation at sampling locations at the Livermore Site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-4**). Median concentrations at the far locations have been below the detection limit of approximately 2.0 Bq/L since 1993. Median concentrations at the Intermediate locations have been below the detection limit since 1998, except in 2002 when the median concentration was 2.3 Bq/L. Median concentrations at the near locations have been at or slightly above the detection limit since 2003.

At Site 300, the median concentrations of tritium in vegetation at locations PSTL and TNK5 were below the detection limit. The median concentration of tritium in vegetation at EVAP was 8.3 Bq/L.

6.2.2 Wine Monitoring Results

Tritium concentrations in wines purchased in 2013 are shown in **Table 6-2**. The highest concentration in a Livermore Valley wine is 4.7 Bq/L (127 pCi/L) from a wine made from grapes harvested in 2011. The highest concentration in a California (other than the Livermore Valley) wine is 3.0 Bq/L (81 pCi/L) from a wine made from grapes harvested in 2009. The highest concentration in a Rhone Valley (France) wine is 4.4 Bq/L (120 pCi/L) from a wine made from grapes harvested in 2010.

Analysis of the wines purchased annually since 1977 have typically demonstrated the following relationship between the Livermore Valley, California, and the Rhone Valley wines: Tritium concentrations in the Rhone Valley wines are typically higher than tritium concentrations in the Livermore Valley wines. Tritium concentrations in the California (other than the Livermore Valley) wines are typically lower than tritium concentrations in the Livermore Valley wines.

Table 6-1. Median and mean concentrations of tritium in plant water for the Livermore Site, Livermore Valley, and Site 300 sampled in 2013. The table includes mean annual ingestion doses calculated for 2013.

Sampling locations		Concentration of tritium in plant water (Bq/L) Median	Mean	Mean annual ingestion dose (a) (nSv/y)
NEAR (on-site or <1 km from Livermore Site perimeter)	AQUE	1.9	4.0	20
	GARD	1.9	1.7	<10(b)
	MESQ	2.4	3.2	16
	MET	1.2	2.1	10
	NPER	1.6	2.5	12
	VIS	4.6	4.3	21
INTERMEDIATE (1–5 km from Livermore Site perimeter)	I580	2.6	2.3	11
	PATT	1.0	0.86	<10(b)
	TESW	2.1	2.8	14
	ZON7	3.9	4.0	20
FAR (>5 km from Livermore Site perimeter)	CAL	0.62	0.57	<10(b)
	FCC	1.1	1.2	<10(b)
Site 300	DSW(c)	(d)	1.6	(e)
	EVAP(c)	8.3	37	(e)
	PSTL	1.2	1.6	(e)
	TNK5	0.05	0.44	(e)

(a) Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-3**.

(b) When concentrations are less than the detection limit (about 2.0 Bq/L), doses can only be estimated as being less than the dose at that concentration.

(c) Plants at these locations are rooted in areas of known subsurface contamination.

(d) Median not calculated because only three values are available for DSW.

(e) Dose is not calculated because there is no pathway to dose to the public.

The Livermore Valley wines represent vintages from 2010, 2011 and 2012; the California wines represent vintages from 2007 and 2011; and the Rhone Valley wines represent vintages from 2010 and 2012. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. In 2013, decay-corrected concentrations for Livermore Valley wine samples ranged from 2.5 to 5.4 Bq/L; for the two California wine samples, 3.0 and 4.3 Bq/L; and for the two Rhone Valley wine samples, 4.6 and 5.4 Bq/L.

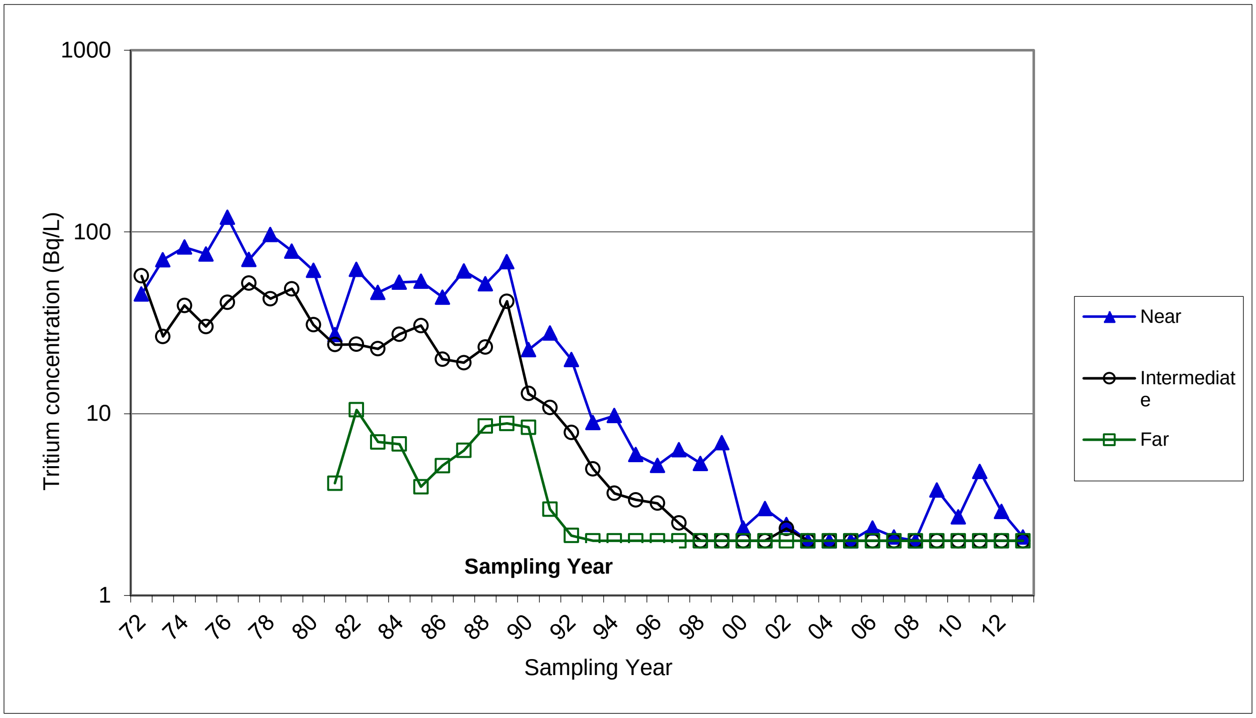

Figure 6-4. Median tritium concentrations in Livermore Site and Livermore Valley plant water samples, 1972 to 2013.

Table 6-2. Tritium in retail wine, 2013[a, b].

Sample	Concentration by area of production (Bq/L)		
	Livermore Valley	**California**	**Europe**
1	3.0 ± 0.70	2.6 ± 0.82	4.2 ± 0.72
2	3.6 ± 0.71	3.0 ± 0.83	4.4 ± 0.73
3	2.1 ± 0.67		
4	3.0 ± 0.70		
5	4.7 ± 0.88		
6	3.1 ± 0.84		
Dose (nSv/y)[c]	5.7	3.6	5.3

(a) Radioactivity is reported here as the measured concentration and an uncertainty (±2σ counting error).

(b) Wines from a variety of vintages were purchased and analyzed for the 2013 sampling. Concentrations are those measured in March or April 2014.

(c) Calculated based on consumption of 52 L wine per year at maximum concentration. Doses account for contribution of OBT as well as of HTO.

6.2.3 Environmental Impact on Vegetation and Wine

6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-1**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 6-3** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2013, was 21 nSv (2.1 µrem).

Table 6-3. Bulk transfer factors used to calculate inhalation and ingestion doses (in µSv) from measured concentrations in air, vegetation, and drinking water.

Exposure pathway	Bulk transfer factors[(a)] times observed mean concentrations
Inhalation and skin absorption	0.21 × concentration in air (Bq/m^3)
Drinking water	0.013 × concentration in drinking water (Bq/L)
Food ingestion	0.0049 × concentration in vegetation (Bq/kg); factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk

(a) See Sanchez et al. (2003), Appendix C, for the derivation of bulk transfer factors.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, “the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this” (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2013, including OBT, is 42 nSv/y (4.2 µrem/y). This maximum dose is about 1/71,000 of the average annual background dose in the United States from all natural sources and about 1/240 the dose from a panoramic dental x-ray. Ingestion doses of Site 300 vegetation were not calculated because neither people nor livestock ingest vegetation at Site 300.

6.2.3.2 Wine

For Livermore Valley wines purchased in 2013, the highest concentration of tritium (4.7 Bq/L [127 pCi/L]) was just 0.64% of the EPA’s standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2013 would have resulted in a dose of 40 nSv/y (4.0 µrem/y). A more realistic dose estimate, based on moderate drinking (one liter per week) [(1)] at the mean of the Livermore Valley wine concentrations (3.3 Bq/L [88 pCi/L]) would have been 4.0 nSv/y (0.40 µrem/y).

(1) Moderate consumption is higher than the average consumption of wine in California (15.7 L/yr) (Avalos 2005).

(2) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. The dose coefficient for HTO is 1.8×10^{-11} Sv/Bg per the International Commission on Radiological Protection (1996).

Both doses explicitly account for the added contribution of OBT.[2]

The potential dose from drinking Livermore Valley wines in 2013, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/250 of a single dose from a panoramic dental x-ray.

6.3 Biota Dose

In 2013, the radionuclides measured and modeled that contributed to individual and collective doses were tritium and plutonium- 239+240 at the Livermore Site and uranium-234, uranium-235, and uranium-238 at Site 300. All radionuclides measured at the Livermore Site and Site 300 was used to assess dose to biota in 2013.

6.3.1 Estimate of Dose to Biota

Biota (flora and fauna) also needs to be protected from potential radiological exposure from LLNL operations because their exposure pathways are unique to their environment (e.g., a burrowing animal may be exposed by contaminated soil). Thus, LLNL calculates potential dose to biota from LLNL operations according to *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (U.S. DOE 2002) and by using the RESRAD-BIOTA computer code, a tool for implementing DOE’s graded approach to biota dose evaluation.

Limits on absorbed dose to biota are 10 mGy/d (1 rad/d) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial animals. At LLNL in 2013, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium (HTO), potassium-40, plutonium-238, plutonium-239, thorium-232, uranium-235, and uranium-238, as well as plutonium-239 based on gross alpha and strontium-90 based on gross beta.

In the 2013 LLNL assessment, the maximum concentration of each radionuclide measured in soil and the storm water run-off samples were used in the dose screening calculations for the terrestrial and aquatic fractions respectively. This approach resulted in an assessment that is extremely conservative, given that the maximum concentrations in the media are distributed over a large area. It accounts for the exposure at both the Livermore Site and Site 300 individually and no plant or animal would likely be exposed to both simultaneously.

In the RESRAD-BIOTA code, each radionuclide in each medium (e.g., soil, sediment, and surface water) is assigned a Biota Concentration Guide (BCG). Measured radionuclide concentrations in the soil and water media are divided by the BCG, and the resulting fractions (concentration ratios) for each nuclide and medium are summed as a ratio for the fraction affecting the aquatic animals and terrestrial plants and animals of each ecosystem (aquatic and terrestrial) and presented in **Table 6.3**. For aquatic and riparian animals, the sum of the fractions for water exposure is added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), then the site has passed the screening analysis for protection of the biota.

At the Livermore Site in 2013, the sum of the water fractions for the Aquatic and Riparian animal are 6.15×10^{-2} due to the contribution from storm water runoff. The sum of the soil fraction for the terrestrial animal and plant was 4.38×10^{-1}, primarily due to gross beta with the remainder due to Cs-137, and K-40. The predominant concentrations of radioactivity measured in the aquatic ecosystem were due to gross alpha with a ratio of concentration to BCG of 2.17×10^{-2} for the aquatic animal and the gross beta ratio of concentration to BCG of 3.98×10^{-2} for the riparian animal.

At Site 300 in 2013 soil fraction for the terrestrial animal was 1.27×10^{-1} with a total ratio of 1.27×10^{-1} for the ecosystem based solely on soil measurements as there was no run-off sampling of storms at Site 300 for 2013. The dose to biota at Site 300 is primarily due to natural potassium-40 in the soil with a ratio of 1.19×10^{-1} and the remainder primarily Cs-137, Th-232, and U-238.

Table 6-4. Biota dose summary.

Biota Dose Concentration Ratio				
	Aquatic Animal	**Riparian Animal**	**Terrestrial Plant**	**Terrestrial Animal**
Livermore Site	2.17×10^{-2}	3.98×10^{-2}	(NA)	4.38×10^{-1}
Sum of Ratio For Ecosystem	Water 6.15×10^{-2}		Soil 4.38×10^{-1}	
Site 300	(NA)	(NA)	(NA)	1.27×10^{-1}
Sum of Ratio For Ecosystem	Water (NA)		Soil 1.27×10^{-1}	

6.4 Ambient Radiation Monitoring

LLNL's ambient radiation monitoring program compares changes in the natural radiation field that may be attributable to LLNL operations to long-term averages. By sampling at enough locations in the surrounding community, the variance in the natural background from season to season and the variance from location to location is measured and compared to a five-year trend. The long-term trend analysis allows any radiation field effects from operations to be readily recognized. Evaluation of long-term averages reduces the effects of uncontrollable variance due to seasonal effects.

The eight background locations for the National Ignition Facility (NIF) neutron radiation field dosimeters are shown in **Figure 6.1**, designated by N-# e.g., N-01. Data from these dosimeters in 2013 were below detection limits of this dosimeter type of 100 μSv (10 mrem). NIF TLDs are deployed monthly.

6.4.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thulium-activated calcium sulfate ($CaSO_4$: Tm), to measure environmental gamma exposure.

The Panasonic UD-810 contains two-elements of lithium borate ($^{7}Li_2{}^{11}B_4O_7$), one-element of lithium borate ($^{6}Li_2{}^{10}B_4O_7$), and one-element of $CaSO_4$: Tm. This composition with lead filtration is specially designed to absorb the energy of slow neutrons. With a 10-mR sensitivity, locations sited for this network include both near-field and far-field locations. Packaging of the dosimeters is done as described below for the rest of the TLD network, with the exception that the dosimeter once sealed in the Mylar protective package is submersed in a water bath. This enables fast-neutrons of energy ranging greater than (>) 0.5 MeV to be absorbed by the hydrogen in water to thermal-neutron energy range of 0.025 eV to 0.1 eV, obtaining thermal equilibrium with their surroundings. The ^{10}B composition has a very high neutron capture cross-section of 3837 barn (which thereby increases the geometric target nuclei probability of the (n,α) ^{7}Li reaction), 1 barn = 1×10^{-24} cm^2.

The TLD measurements are corrected in the following way for reporting: the results of the TLD measurement process are normalized to 90-day quarters from their actual exposure period, and the measurement units are converted from absorbed exposure units to reported dose units. These corrections allow the TLDs measurements to be representative of external exposure to the public at these sample locations. Comparisons are made for LLNL perimeter locations to those of the Livermore Valley (background locations) for the purposes of determining an elevated radiation field. Similar comparisons are made for TLDs at Site 300 and nearby locations.

TLD crystals absorb ionizing energy by trapping this energy. A solid-state physical process controls the energy trapping during crystal ionization. Electron–hole (vacancy) pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy released in the form of light emission upon heating in the reading process is proportional to the TLD's absorbed dose. Comparative dose is reported relative to the calibrated standard of cesium-137 gamma energy of 662 keV. The calculated result of the TLD exposure is then reported in the SI unit of Sievert (Sv) from the measured dose in milli-roentgen (mR).

In order to see any deviation in the dose trend over a five-year period, each site-wide location quarterly average is plotted for each year. These site-wide quarterly averages for each year are shown with their respective five-year average and associated error (the measured location's quarterly average is the average of the four quarterly measurements; and the site-wide quarterly average is the average of all the location quarterly averages).

The results of these comparisons of the Livermore Site to Livermore Valley and Site 300 to the Site 300 vicinity (which includes the City of Tracy), are shown in **Table 6-4.**

A true representation of local site exposure and any dose contribution from LLNL operations is obtained through a quarterly deployment cycle. TLDs are deployed at a height of 1 m, adhering to regulatory guidance.

For the purpose of reporting comparisons, data are reported with the dose in milli-sievert (mSv; 1 mSv = 100 mrem).

Table 6-5. Average quarterly ambient radiation doses (mSv) with standard deviations and numbers of samples (standard deviation, N), 2009 – 2013.

Dose (mSv)					
Location	**2009**	**2010**	**2011**	**2012**	**2013**
Livermore Site	0.147 (0.009, 55)	0.138 (0.007, 55)	0.142 (0.009, 54)	0.141 (0.008, 56)	0.145 (0.009, 56)
Livermore Valley	0.145 (0.013, 86)	0.137 (0.012, 86)	0.141 (0.014, 85)	0.141 (0.014, 88)	0.140 (0.030, 88)
Site 300	0.173 (0.012, 36)	0.165 (0.010, 34)	0.168 (0.014, 34)	0.157 (0.040, 36)	0.173 (0.015, 36)
Site 300 Vicinity and Tracy	0.164 (0.012, 16)	0.154 (0.010, 15)	0.159 (0.014, 16)	0.158 (0.012, 16)	0.161 (0.014, 16)

6.4.2 Gamma Monitoring Results

Figure 6-5 represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore Site perimeter, Livermore Valley, Site 300 and Site 300 environs. Tabular data for each sampling location are provided in **Appendix A**, **Section A.9**.

The difference in the doses at the Livermore Site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 contains higher levels of naturally occurring thorium that provides the higher external radiation dose.

6.4.3 Environmental Impact from Laboratory Operations

TLD measurements for 2013 indicate there were no detectable elevations in the ambient radiation field as a result of LLNL operations. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in Tabl**e 6-5**, the annual average gamma radiation dose for the Livermore Site perimeter and the Livermore Valley from 2008 to 2012 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.

6.5 Special Status Wildlife and Plants

Special status wildlife and plant monitoring at LLNL focuses on species considered to be rare, threatened, or endangered (including species listed under the federal or California Endangered

Species Acts); species considered of concern by the California Department of Fish and Wildlife [CDFW] and the USFWS; and species that require inclusion in NEPA.

The California red-legged frog (*Rana draytonii*), a threatened species, is known to occur at the Livermore Site (see **Figure 6-5**). Because California tiger salamanders (*Ambystoma californiense*) have been observed within 1.1 km of the Livermore Site, portions of the Livermore Site are considered potential upland habitat for the California tiger salamander. There is no known historic or occupied breeding habitat for the California tiger salamander at the Livermore Site.

Five species that are listed under the federal Endangered Species Act (ESA) are known to occur at Site 300—the California tiger salamander, California red-legged frog, Alameda whipsnake (*Masticophus lateralis euryxanthus),* valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have historically occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California-endangered Willow Flycatchers (*Empidonax traillii*) have also been observed at Site 300. The willow flycatcher is not known to nest at Site 300.

Current and historic observations of the five listed species, a California Fully Protected Species (White-tailed Kite [*Elanus leucurus*]), and two avian California Species of Special Concern (Western Burrowing Owl [*Athene cunicularia*] and Tricolored Blackbird [*Agelaius tricolor*]) at Site 300 are shown in **Figures 6-6** and **6-7**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix C**. A similar list has not been prepared for the Livermore Site.

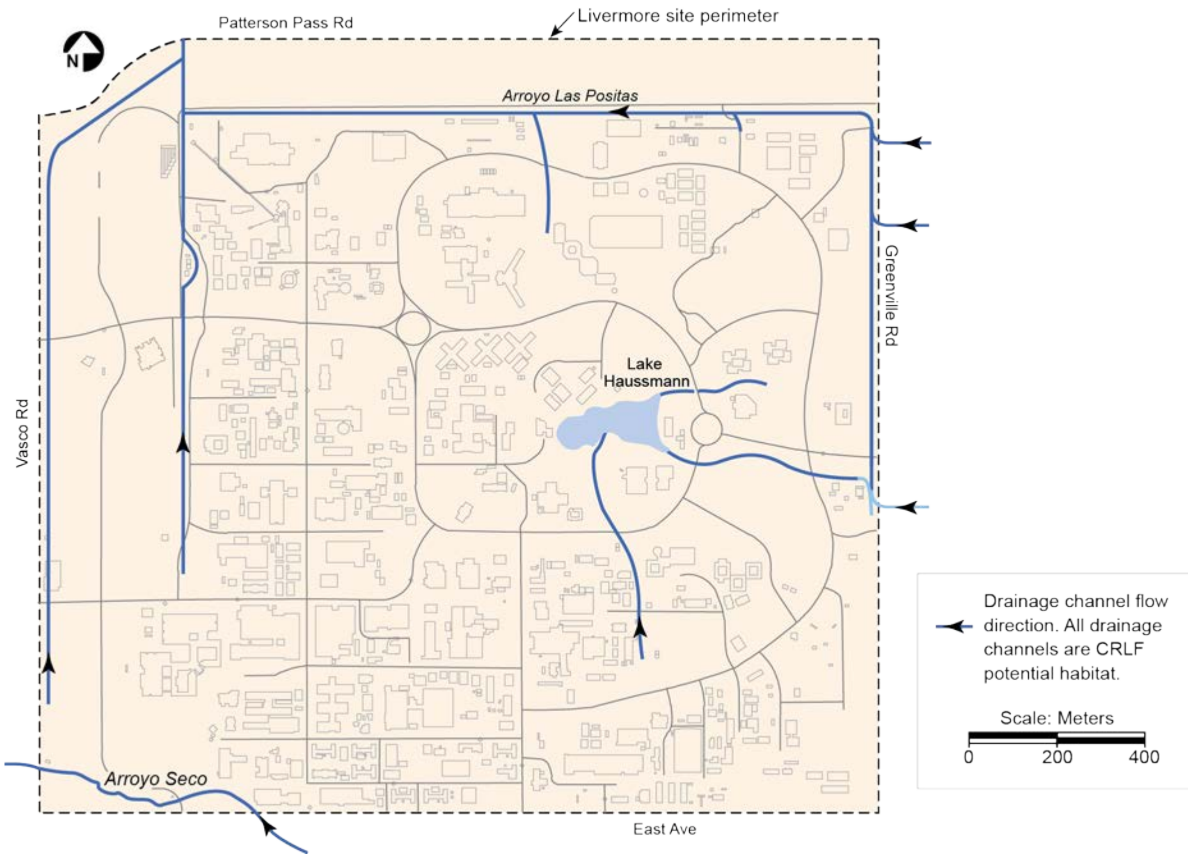

Figure 6-5. Potential California red-legged frog aquatic habitat, Livermore Site.

Including the federally endangered large-flowered fiddleneck, five rare plant species and three uncommon plant species are known to occur at Site 300. The five rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*), the round-leaved filaree *(California macrophylla),* the diamond-petaled California poppy (*Eschscholzia rhombipetala*)—all have a California Rare Plant Rank (CRPR) of 1B (CNPS 2014). Adobe navarretia (*Navarretia nigelliformis* ssp. *radians*) was found to occur at Site 300 during the 2009 through 2012 biological review completed in January of 2014 (Paterson and Woollett 2014). These species are considered rare and endangered throughout their range. The location of these four rare plant species at Site 300 is shown in **Figure 6-7**.

The three uncommon plant species—California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*)—have a CRPR of 4 (CNPS 2014). Past surveys have failed to identify any rare plants on the Livermore Site (Preston 1997, 2002).

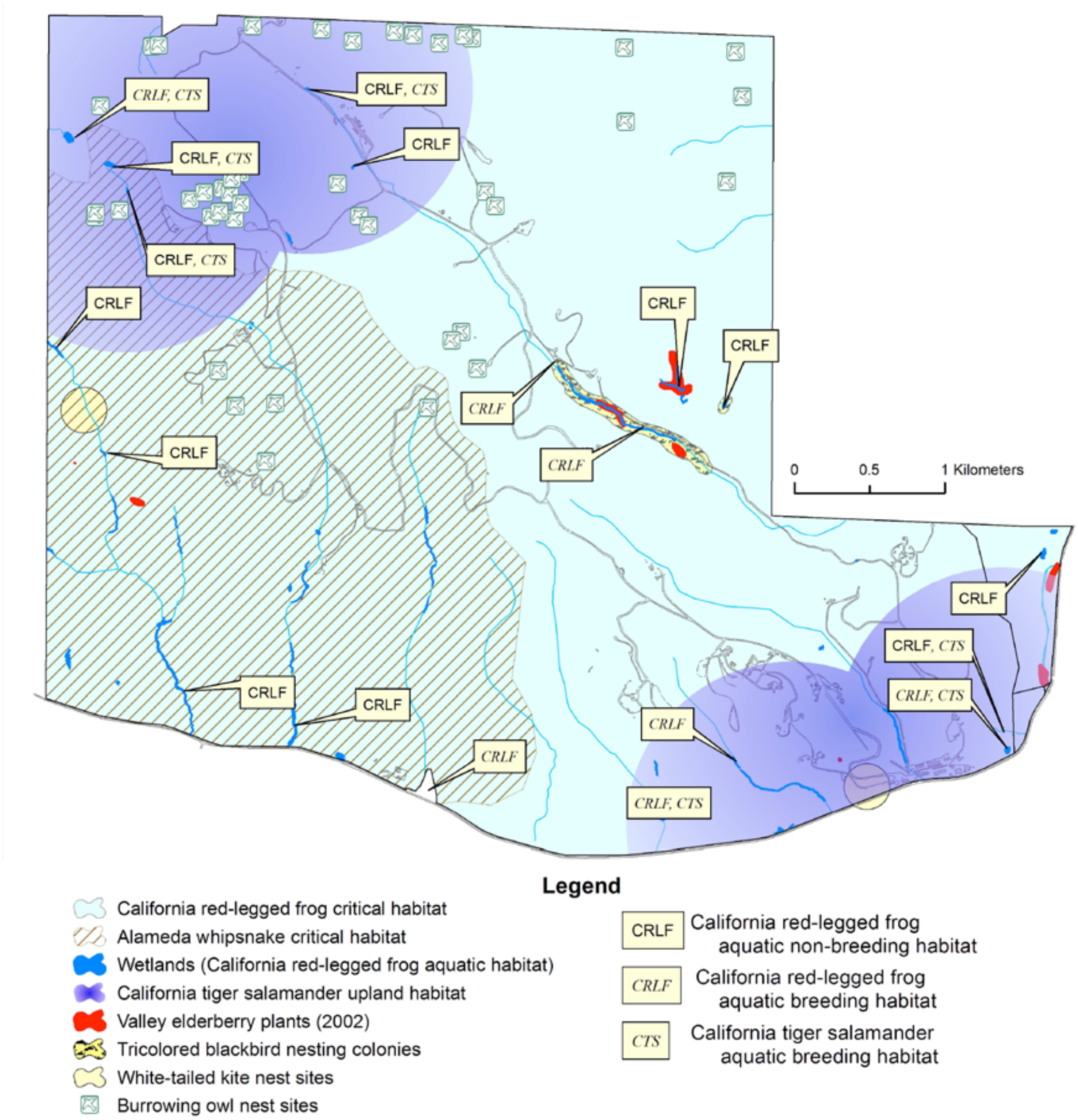

Figure 6-6. Distribution of special status wildlife, Site 300.

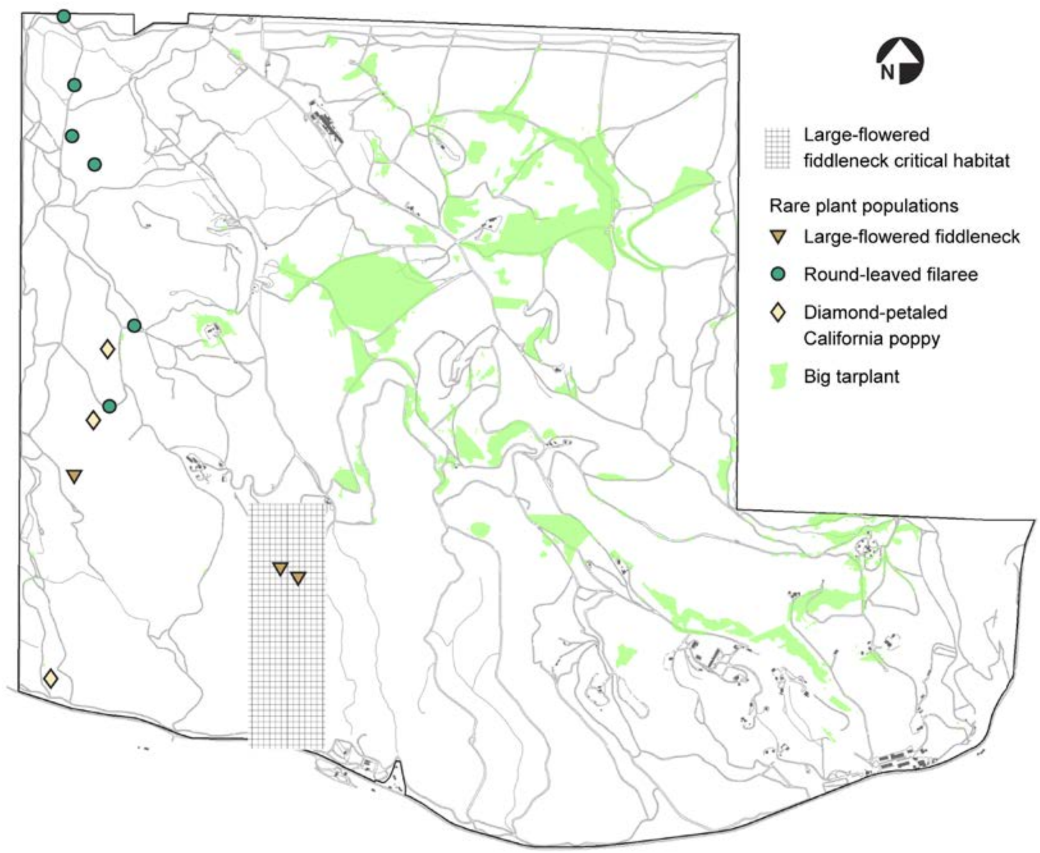

Figure 6-7. Distribution of special status plants, Site 300.

6.5.1 Habitat Enhancement Projects and Compliance Activities

6.5.1.1 Elk Ravine Habitat Enhancement Pools

In late August 2005, LLNL implemented a habitat enhancement project for California red-legged frogs at Site 300 in accordance with a 2002 USFWS biological opinion (BO) and ACOE and RWQCB permits. California red-legged frogs were translocated to the new habitat enhancement pools in February and March of 2006. Monitoring demonstrated that California red-legged frogs successfully reproduced in these pools in 2006 through 2012.

6.5.1.2 Pool M2

In 2006, 2010, and 2011, Pool M2 filled and California tiger salamanders were able to successfully reproduce at this location. In 2007, 2008, 2009, 2012, and 2013 the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pool. An additional habitat enhancement project was conducted at the Pool M2 in 2013. The clay liner of this pool was augmented in the fall of 2013 in an effort to limit infiltration or loss of water through the bottom of the pool.

6.5.1.3 Oasis and Round Valley Pools

In 2006, LLNL completed culvert replacement projects at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails cross intermittent drainages. The Round Valley project included the creation of a pool upstream of the project area in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for protected amphibian species. These projects were completed under the USFWS BO for maintenance and operations of Site 300 and ACOE and RWQCB permits. The Round Valley pool did not receive enough water during the 2007 through 2012 winters to pool and afford potential breeding habitat for amphibians.

An additional habitat enhancement project was conducted at the Round Valley Pool in 2012. The clay liner of this pool was augmented in the fall of 2012 in an effort to limit infiltration or loss of water through the bottom of the pool.

6.5.1.4 Power Pole Modifications for Migratory Bird Protection

To minimize adverse impacts to migratory birds, Site 300 implemented an avian protection policy to support avian-friendly transmission lines, insulators, power poles and other features that are designed to minimize collision and electrocution fatalities of birds of prey. Between June and November 2011, seven power poles onsite caused bird of prey deaths by electrocution.

Five of the seven poles received multiple perch deterrents, gray pvc triangles that were designed to fully discourage perching birds of prey on the crossarm arrays (and withstand the ambient UV rays). Additionally, to allow alternative, safe perch sites for birds, non-energized poles (stand-alone) with crossarm arrays in multiple directions were placed within roughly 25 feet of the original pole. Poles were purchased that lacked chemical treatments and were at least 6 feet taller in stature than the original pole (to support the viewshed perspective of the birds). No additional birds of prey have been electrocuted on these power poles since the modifications were performed.

6.5.2 Invasive Species Control Activities

Invasive species control is an important part of LLNL’s effort to protect special status species at both sites. Prevention of the downstream dissemination of invasive species is also important to protect native species throughout our region. The bullfrog *(Lithobates catesbeiana)* is a significant threat to California red-legged frogs at the Livermore Site, and the feral pig (*Sus scrofa*) threatens California numerous protected habitat types at Site 300. The exotic fish, largemouth bass *(Micropterus salmoides)*, has also historically occurred in Lake Haussmann at the Livermore Site.

At the Livermore Site, bullfrog control measures were implemented between May through September of 2013. Bullfrog control measures included dispatching adults and removing egg masses in Lake Haussmann and Arroyo Las Positas. To remove bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in September of 2013 by temporarily halting groundwater discharges to the arroyo.

6.5.3 Surveillance Monitoring

6.5.3.1 Wildlife Monitoring and Research

Nesting Bird Surveys. Nesting bird surveys ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed kites frequently nest in the trees along the north, east, and south perimeters of the Livermore Site. At Site 300 in 2013, two red-tailed hawk pairs received protected buffer zones around their respective nest tree to avoid impacts relative to the annual prescription burn.

California Red-Legged Frog Nocturnal Surveys. LLNL continued nocturnal visual surveys for California red-legged frogs in Lake Haussmann and Arroyo Las Postias. No egg masses were observed in Arroyo Las Positas in 2013. Despite this, adult California red-legged frogs were observed in Arroyo Las Positas and Lake Haussmann in 2013.

6.5.3.2 Rare Plant Research and Monitoring

Large-Flowered Fiddleneck. This species is currently known to exist naturally in only two locations—at the Site 300 Drop Tower and on nearby conservation property owned by the Contra Costa Water District. A third population occurs in Draney Canyon at Site 300, but no large-flowered fiddleneck have been observed at this location since a landslide that occurred at the population site in 1997. The Drop Tower and Draney Canyon native population contained no large-flowered fiddleneck plants in 2013.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. LLNL maintains the experimental population by periodically planting large-flowered fiddleneck seeds in established plots within the population. The size of the experimental population fluctuates as a result of these seed bank enhancement efforts.

In November of 2012, 100 large-flowered fiddleneck seeds were planted in each of the 20 plots in the experimental population, and the experimental population contained 715 large-flowered fiddleneck plants at flowering in 2013. These plants are a result of seeds produced from plants present in the population in 2012 and previous years and the 2012 seed bank enhancement efforts.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September through November of 2013. It is estimated that between 46,000 and 158,000 individual big tarplants occurred at Site 300 in 2013. While this species is extremely rare throughout its range, it can be abundant at Site 300, especially in or near areas where prescribed burns are routinely conducted and where wildfires have occurred. As is typical with annual plant species, the abundance of big tarplant varies greatly between years depending on environmental conditions. For example in 2009, the Site 300 big tarplant population was estimated to contain no more than 22,000 individual plants while up to 214,000 big tarplants were found at Site 300 in 2010.

Diamond-Petaled California Poppy. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in Contra Costa and San Luis Obispo Counties. Currently three populations of this species are known to occur at Site 300; these population locations are referred to as Site 1, Site 2, and Site 3.

The most recently discovered population, Site 3, is the largest and typically contains the largest population of this rare species. As with the big tarplant and other annual plants, the number of diamond-petaled California poppy plants present in these populations is expected to vary from year to year.

A spring census of these three populations has been conducted annually between 2000 and 2013. During this time, the largest diamond-petaled California poppy populations were observed in 2012. Between 20,000 and 45,000 diamond-petaled California poppies were observed at Site 300 in 2012. The relatively large diamond-petaled California poppy population in 2012 was likely attributable to annual grass cover in 2012, which was much less dense than average. The number of diamond-petaled California poppies observed in 2011 was the lowest seen since surveys began (a total of only 46 plants). A census of the three Site 300 populations was conducted in April 2013. A total of approximately 10,850 diamond-petaled California poppies were observed at Sites 1, 2, and 3 during 2013.

Round-Leaved Filaree. Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of the site. This species thrives in the disturbed soils of the annually graded fire trails at Site 300, but also occurs in grasslands. Of the six known Site 300 populations, four occur on fire trails and two occur in grasslands. Only two of the six round-leaved filaree populations were surveyed in 2013 due to drought conditions. These two populations combined were estimated to contain 1,809 plants in 2013.

6.5.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2013, LLNL has been able to avoid impacts to special status wildlife and plants. Habitat enhancement, avian protection, and invasive species control efforts resulted in benefits to protected species. LLNL continues to monitor and maintain several restoration sites, habitat enhancements, and conservation set asides that are beneficial to native plants and animals at the Livermore Site or Site 300 and ensures the protection of listed and special status species.

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