10

Soil and Sediment Monitoring

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Introduction

The soil and sediment monitoring analysis that Lawrence Livermore National Laboratory performed in 1999 included work in four areas: surface soil in the Livermore Valley and at Site 300, sediment at the Livermore site, vadose zone soils at the Livermore site, and a special study at Big Trees Park in the City of Livermore.

Soil is weathered material, mainly composed of disintegrated rock and organic material, that sustains growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. Department of Energy (DOE) guidance for environmental monitoring states that soil should be sampled to determine if there is measurable, long-term buildup of radionuclides in the terrestrial environment and to estimate environmental radionuclide inventories (U.S. Department of Energy 1991). The guidance recommends monitoring for radionuclides specific to a particular operation or facility as well as those that occur naturally. Particulate radionuclides are of major interest in the LLNL soil monitoring program because airborne particulate releases are the most likely pathway for LLNL-induced soil contamination.

Sediments are defined, for the purposes of this chapter, as finely divided, solid materials that have settled out of a liquid stream or standing water. The accumulation of radioactive materials in sediment could lead to exposure of humans through their ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source (U.S. Department of Energy 1991). However, the LLNL Livermore site and Site 300 do not have habitats for aquatic species that are consumed by people, nor do they have surface drainage that directly feeds drinking water supplies.

Soils in the vadose zone—the region below the land surface where the soil pores are only partially filled with water—are collected in arroyo channels at the Livermore site as part of the Ground Water Protection Management Program (GWPMP). Infiltration of natural runoff through arroyo channels is a significant source of ground water recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley ground water basin (Webster-Scholten 1994). Soils in the shallow vadose zone are collected and analyzed to

provide information about possible constituents that may be dissolved as runoff water infiltrates through the arroyo to the ground water.

In addition to the soil, sediment, and vadose zone soil sampling conducted on an annual basis, LLNL may also conduct special sampling to address areas of interest or concern, as in the case of Big Trees Park in Livermore. During previous sampling at this park in 1993 and 1995, plutonium had been detected at concentrations above fallout background. Continuing the work initiated by soil sampling at Big Trees Park in 1998, LLNL and the Agency for Toxic Substances Disease Registry (ATSDR) published reports summarizing the analytical results for soil samples collected at the park.

Sampling Locations

Since 1971, surface soil sampling in the vicinity of the LLNL Livermore site and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. These samples have been analyzed for plutonium and gamma-emitting radionuclides, such as depleted uranium that is used in some explosive tests at Site 300. The inclusion of other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) and the long-lived fission product, cesium-137, provides background information and baseline data on global fallout from historical aboveground nuclear weapons testing. In addition, LLNL analyzes Site 300 soils for beryllium because it is a potentially toxic metal used at this site. Soils in the Livermore vicinity were analyzed for beryllium from 1991 to 1994. However, analysis for beryllium was discontinued at the Livermore site in 1995 because beryllium was never measured above background values.

Surface soil samples are collected at 19 locations in the Livermore Valley (**Figure 10-1**) and 15 locations at or near Site 300 (**Figure 10-2**). The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the Livermore Water Reclamation Plant (LWRP), are also sampled.

Site 300 soil sampling locations are established around firing tables and other areas of potential soil contamination. PRIM location was added to the sampling program in 1998 to correspond with air sampling conducted at that location. The PRIM site is downwind of Site 300 and sufficiently close to the Site 300 boundary to potentially be affected by

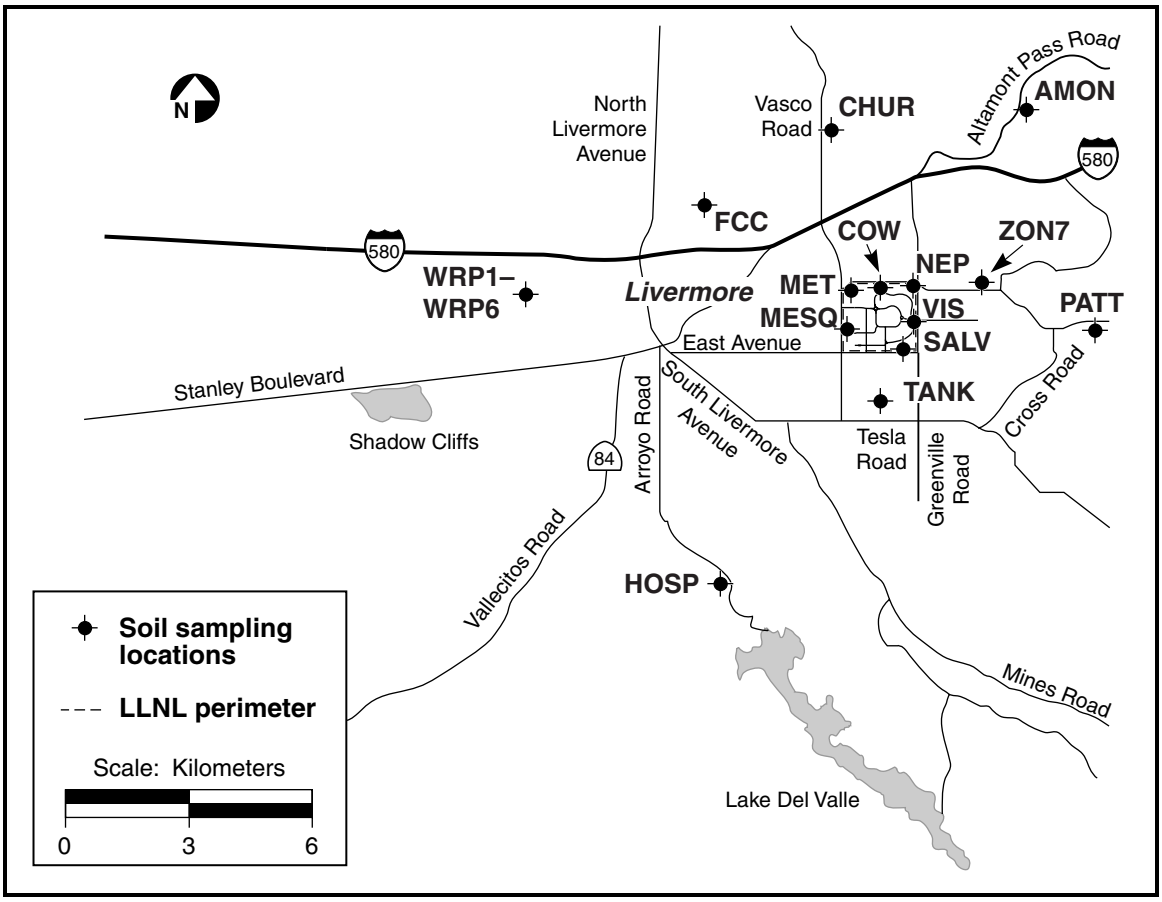

Figure 10-1. Surface soil sampling locations, Livermore Valley, 1999.

Site 300 operations. Approximately 10% of locations are sampled in duplicate; two identical samples are collected at each location chosen for this sampling. All soil and sediment sampling locations have permanent location markers for reference.

Similarly, sediment samples have been collected from selected arroyos and other drainage areas at and around the Livermore site since 1988; these locations largely coincide with selected storm water sampling locations (see Chapter 7). The number of sediment sampling locations was reduced in 1994 to correspond to reductions in storm water sampling locations. Although ALPO was added as a new sediment sampling location in 1997, it was not sampled in 1997, 1998, or 1999 because the location was continually under water from releases upstream of the Livermore site. Sediment sampling locations have not been established at Site 300. The drainage courses at Site 300 are steep, causing flowing water to scour the drainages, so that sediment is not deposited. Because of these conditions, sediment sampling at Site 300 is not warranted.

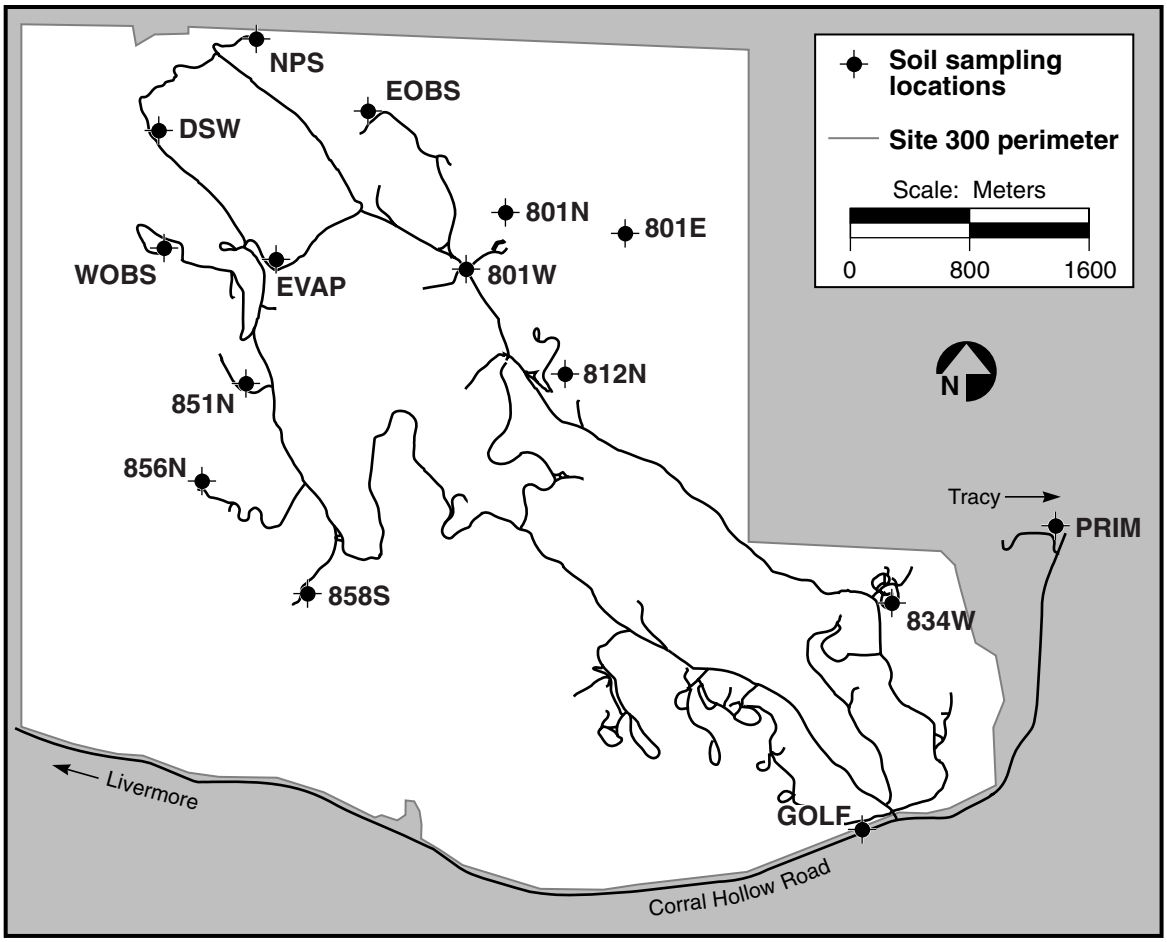

Figure 10-2. Site 300 surface soil sampling locations, 1999.

Vadose zone soil sampling has been conducted since 1996. These sampling locations correspond to the same selected storm water sampling locations as the sediment sampling locations (see **Figure 10-3**). The collocation of sampling for these three media facilitates comparison of analytical results. As with sediment samples, vadose zone samples are not collected at Site 300.

Methods

Surface soil, sediment, and vadose zone soil sampling is conducted according to written, standardized procedures (Tate et al. 1999). Soil samples are collected from undisturbed areas near permanent location markers. These areas generally are level, free of rocks, and unsheltered by trees or buildings. All surface soil samples are collected from the

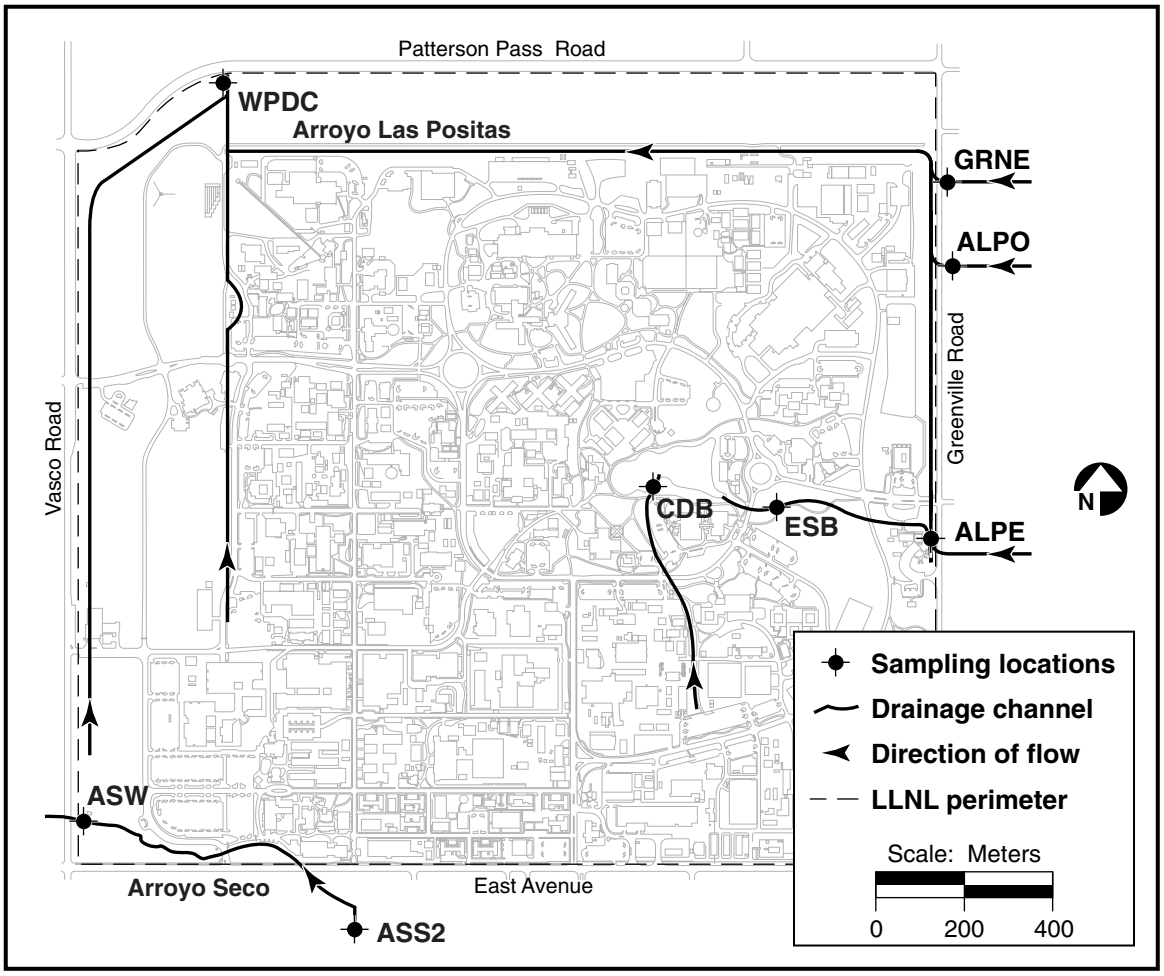

Figure 10-3. Sediment and vadose zone sampling locations on or near the Livermore site, 1999.

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. Sediments are collected annually from drainages at and around the LLNL Livermore site after the cessation of spring runoff. Samples to be analyzed for particulate radionuclides are collected from the top 5 cm of soil; samples to be analyzed for tritium are collected 5–15 cm deep to obtain sufficient water in the sample for analysis. Vadose zone soil samples are collected at 30–45 cm deep for metals analysis, and at 45–65 cm deep for semi-volatile organic compound analysis.

In 1999, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Analysis of Site 300 soil samples for plutonium was discontinued in 1997 because plutonium has not been used at the site, and sample results have continuously been at background levels since sampling was begun in 1972. Sediment samples collected at the Livermore site were analyzed for plutonium and gamma-emitting radionuclides and tritium. Vadose zone samples were analyzed for total and soluble metals and for semi-volatile organic compounds.

Prior to radiochemical analysis, surface soil and sediment samples are dried, ground, sieved, and homogenized. The samples are analyzed by LLNL's Chemistry and Materials Science Environmental Services (CES) laboratory. The plutonium content of a 100-g sample aliquot is determined by alpha spectroscopy. Other sample aliquots (300 g) are analyzed for more than 150 radionuclides by gamma spectroscopy using a high-purity germanium (HPGe) detector (Hall and Edwards 1994a, b, and c). The 10-g subsamples for beryllium analyses are sent to a contract analytical laboratory and are analyzed by graphite-furnace atomic absorption spectroscopy. For sediment samples collected for tritium analyses, CES uses freeze-drying techniques to recover water from the samples and determines the tritium content of the water by liquid-scintillation counting. Vadose zone soil samples are analyzed by a contract laboratory. The analytical methods include the toxicity characteristic leaching procedure (TCLP, EPA Method 8240) for semi-volatile organic compounds, and soluble metals and total metals by EPA Methods 200.7, 245.2, 7471A, and 6010B. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

Livermore Valley Surface Soil Results

Table 10-1 presents summary data on the concentrations of plutonium-239+240, plutonium-238, americium-241, cesium-137, potassium-40, thorium-232, uranium-235, and uranium-238 in surface soils from the Livermore Valley sampling locations. Complete data for 1999 soil and sediment sampling are presented in Table 10-1 of the Data Supplement.

The concentrations and distributions of all observed radionuclides in soil for 1999 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. The ratio of uranium-235 to uranium-238 generally reflects the natural ratio of 0.7%; however, there is significant uncertainty in the uranium-235/uranium-238 ratio because of the difficulty in measuring small quantities of uranium-238 by gamma spectroscopy.

Table 10-1. Summary of surface soil and sediment radioanalytical data, 1999.

Analyte and location	Detection frequency[a]	Median	IQR[b]	Maximum
^{238}Pu (µBq/dry g)				
Livermore Valley soils	12/13	2.7	3.0	22.8
LWRP[c] soils	6/6	108	130	354
Livermore site sediments	4/7	5.0	23.6	211
$^{239+240}$Pu (µBq/dry g)				
Livermore Valley soils	13/13	72.5	51	507
LWRP soils	6/6	2150	2230	6960
Livermore site sediments	7/7	84	382	2180
^{137}Cs (mBq/dry g)				
Livermore Valley soils	12/13	1.6	1.9	6.1
LWRP soils	6/6	1.1	1.4	4.0
Livermore site sediments	5/7	0.5	0.4	1.3
Site 300 soils	15/15	3.2	2.6	5.6
^{40}K (Bq/dry g)				
Livermore Valley soils	13/13	0.466	0.067	0.581
LWRP soils	6/6	0.359	0.040	0.407
Livermore site sediments	7/7	0.466	0.052	0.529
Site 300 soils	15/15	0.440	0.087	0.574
^{232}Th (µg/dry g)[d]				
Livermore Valley soils	13/13	7.5	1.2	9.2
LWRP soils	6/6	7.2	0.6	7.8
Livermore site sediments	7/7	5.9	2.0	8.6
Site 300 soils	15/15	10.2	2.5	14.2
^{235}U (µg/dry g)[e]				
Livermore Valley soils	13/13	0.020	0.005	0.024
LWRP soils	6/6	0.018	0.002	0.020
Livermore site sediments	7/7	0.016	0.006	0.024
Site 300 soils	15/15	0.025	0.012	0.148
^{238}U (µg/dry g)[f]				
Livermore Valley soils	13/13	1.6	0.5	2.5
LWRP soils	6/6	2.0	0.2	2.2
Livermore site sediments	6/7	1.9	0.8	2.7
Site 300 soils	15/15	2.3	2.1	71.3

Table 10-1. Summary of surface soil and sediment radioanalytical data, 1999 (concluded).

Analyte and location	Detection frequency[a]	Median	IQR[b]	Maximum
^{3}H (Bq/L extracted water)[g]				
Livermore site sediments	4/7	4.5	—(i)	75.1
^{241}Am (mBq/dry g)[h]				
LWRP soils	2/6	<1.1	—(i)	2. 9
Be (mg/kg)[j]				
Site 300 soils	15/15	0.6	0.2	2.5

a Detection frequency = the fraction of samples having a measured value above the detection limit.

b IQR = Interquartile range; the difference between the top of the third and the top of the first quartiles of the data.

c LWRP = Livermore Water Reclamation Plant.

d Thorium-232 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 247.3, and pCi/dry g can be determined by dividing by 9.15.

e Uranium-235 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 12.5, and pCi/dry g can be determined by dividing by 0.463.

f Uranium-238 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 80.3, and pCi/dry g can be determined by dividing by 2.97.

g Only sediment samples are analyzed for tritium.

h Americium-241 is detected only in LWRP soil samples.

i IQR is not calculated because of high incidence of reported values below detection limits.

j Only Site 300 samples are analyzed for beryllium.

Plutonium has, in the past, been detected at levels above background at ZON7, the off-site soils sampling location near the LLNL Livermore site and in the prevailing downwind direction. Because of the high level of variability inherent in the measurement of soils, we do not always find plutonium above background levels at this location. In 1999, as in 1994 through 1998, plutonium-239+240 was detected at background levels, 156 µBq/dry g (4.2×10^{-3} pCi/dry g), at location ZON7. Since 1973, soil samples in this area have generally shown plutonium-239+240 values that are higher than background, and location VIS, one of the on-site locations upwind of ZON7, did exhibit a plutonium-239+240 value slightly above background, 507 µBq/dry g (1.4×10^{-2} pCi/dry g), in 1999. The slightly higher values at and near the Livermore site have been attributed to historic operations, which included the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant (Silver et al. 1974). LLNL no longer operates the solar evaporators or engages in any other open-air treatment of plutonium-containing waste. Nonetheless, plutonium-239+240 from historic operations is carried off site by resuspension of soil by wind. Similarly, 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 first observed in soils near LWRP during the early 1970s, and were again detected at LWRP sampling locations. As in 1997 and 1998, americium-241 was detected in LWRP samples; it is most likely caused by the natural decay of the trace concentrations of plutonium-241 that were present in the release.

Historical plots of median plutonium-239+240 concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site, at Site 300, and at LWRP are shown in **Figure 10-4**. Livermore Valley upwind and Site 300 concentrations have remained relatively constant since monitoring began and generally are indicative of worldwide fallout. Greater variation can be noted in the downwind concentration data, which in 1999 included sampling locations VIS, PATT, NEP, COW, and ZON7, compared with the upwind and historic Site 300 data. The concentrations of plutonium at the downwind locations reflect resuspension of low-level plutonium contamination from soils in the southeast quadrant of the Livermore site. Greater variability in plutonium-239+240 is seen in samples from LWRP. Because the plutonium-239+240 is likely to be present in discrete particles, the random presence or absence of the particles dominates the measured plutonium-239+240 in any given sample.

Livermore Site Sediment Results

Table 10-1 presents summary data on radionuclides detected in the sediment samples; a complete presentation of 1999 sediment data is found in Table 10-1 of the Data Supplement. The levels of plutonium-239+240 were generally at background concentrations, reflective of worldwide fallout. The moderately higher values at sampling locations CDB and ESB (see **Figure 10-3**) than the values at other locations may be attributed to historic activities in the southeast quadrant at LLNL; these locations are both in drainages for that area. Most other radionuclides were detected at levels similar to those reported from 1988 through 1998: cesium-137, a fission product, was found at worldwide background concentrations; potassium-40, thorium-232, uranium-235, and uranium-238—naturally occurring radionuclides—were detected at background concentrations. Tritium concentrations were within the range of previous data. Tritium in sediments was evaluated for differences upwind and downwind of the Livermore site for all data collected from 1988 to 1999. A statistically significant difference was found using the Tukey-Kramer honestly significant difference (HSD) test, with the downwind sediment samples having higher measured concentrations than the upwind sediment samples. Tritium in sediments will continue to be evaluated.

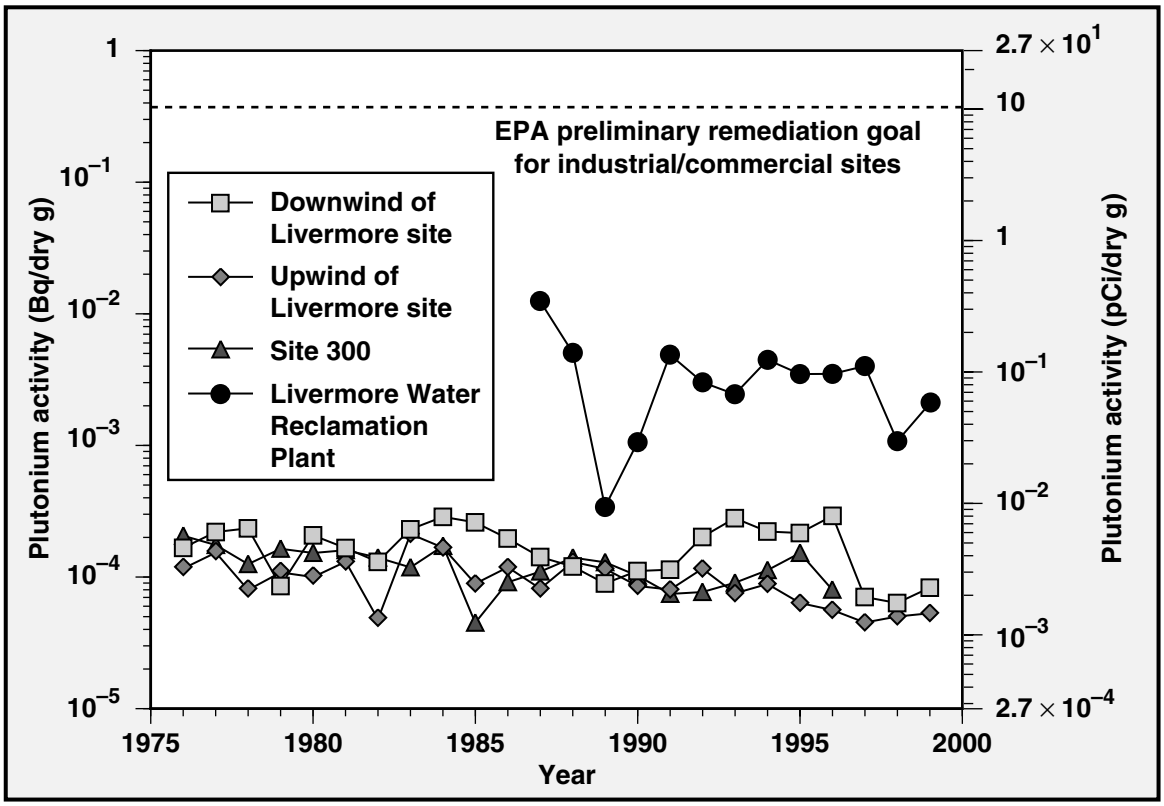

Figure 10-4. Median plutonium-239+240 activities in surface soils, 1976–1999. Upwind and downwind designations are relative to the center of the Livermore site.

Livermore Site Vadose Zone Soil Results

Analytical results for vadose zone soil samples are compared with soil reuse standards developed by LLNL and the San Francisco Bay Regional Water Quality Control Board (RWQCB) (Folks 1997, Marshack 1991). Metals background concentrations are based on naturally occurring levels in the soil, considering first the results for total metals and then the soluble metals test. There are no background levels for organic compounds or tritium. Soils containing materials at levels above background still may not adversely affect the ground water. If a metal exceeds both the total and soluble background values, or if there are any detected organic compounds or tritium, the designated level methodology (DLM) (i.e., application of a simple attenuation factor and specific water quality objectives) is used to determine the soluble levels of contaminants that would not adversely impact ground water beyond its beneficial uses. (Background and DLM de minimis values are presented in Tables 10-3 to 10-5 in the Data Supplement.)

All analytical results for organic compounds were below detection limits. All total metals concentrations were below background (see Tables 10-6 to 10-8 in the Data Supplement). Tritium results from the sediment sampling were evaluated by the DLM method and were all below de minimis levels (see the Data Supplement, Table 10-1).

Site 300 Results

Table 10-1 presents summary data on the concentrations of cesium-137, potassium-40, thorium-232, uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; a complete presentation of 1999 soils data for Site 300 is found in Table 10-2 of the Data Supplement. The concentrations and the distributions of all observed radionuclides in Site 300 soil for 1999 lie within the ranges reported in all years since monitoring began. The ratio of uranium-235 to uranium-238 generally reflects the natural ratio of 0.7%. Historical trends of uranium-238 concentrations from both the Livermore Valley and Site 300 are shown in **Figure 10-5**. Median values have remained relatively constant for both places. The highest values at Site 300 result from the use of depleted uranium in explosive experiments.

Environmental Impact

This section discusses the environmental impacts of operations at the LLNL Livermore site and Site 300 inferred from soil, sediment, and vadose zone soil monitoring.

Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 1999 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 of 7.0 mBq/dry g (0.19 pCi/dry g) for plutonium-239+240 measured at LWRP during 1999 represents 1.9% of the Environmental Protection Agency (EPA) preliminary remediation goal for commercial or industrial sites of 0.37 Bq/dry g (10 pCi/dry g) (U.S. Environmental Protection Agency 1991). Statistical analysis shows no general increase or decrease in plutonium-239+240 values with time. Moreover, all measured concentrations, regardless of location and year, have been a small fraction of the EPA preliminary remediation goal (shown in **Figure 10-4** for comparison). LLNL

sampling of surface soil, sediment, and vadose zone soil will continue on an annual basis.

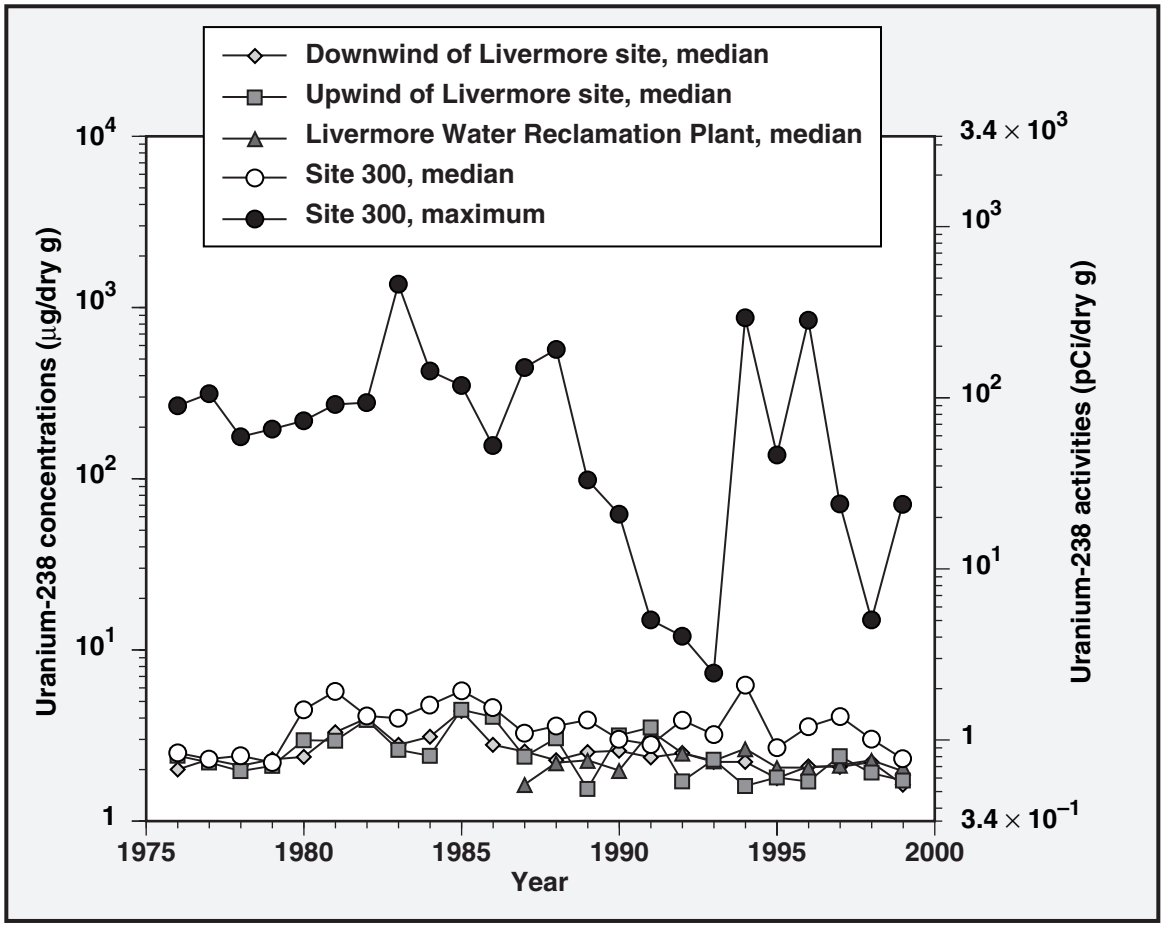

Figure 10-5. Uranium-238 concentrations in surface soils, 1976–1999.

Site 300

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 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 occur near active and inactive firing tables at Buildings 801 and 812, from a small fraction of the operations at the firing table that disperse depleted uranium.

Big Trees Park

During the 1993 EPA investigation of plutonium in soils present in the southeast quadrant of the LLNL Livermore site, EPA personnel collected a soil sample at Big Trees Park in Livermore to obtain a background sample. This soil sample showed plutonium at a concentration higher than what is expected from global fallout for this region. The park was resampled by the EPA, LLNL, and the California Department of Health Services (DHS) in 1995. (Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Table 10-2**.)

Table 10-2. Special soil studies.

Year	Subject	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999
2000	Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling	Agency for Toxic Substances Disease Registry 2000

As reported in MacQueen (1995), samples from 13 of the 16 locations sampled at the park during 1995 had plutonium concentrations consistent with background levels found throughout the Bay Area. These levels were 1/600 to 1/10,000 of the EPA's risk-based preliminary remediation goal (PRG) for plutonium for residential areas of 0.09 Bq/dry g (2.5 pCi/dry g) (U.S. Environmental Protection Agency 1991). Background values were found in all sandboxes, school grounds, and picnic areas, and under the large eucalyptus trees for which the park is named. Samples from two locations had plutonium concentrations slightly above background levels but were still 1% to 2% of the EPA's risk-based preliminary remediation goal for plutonium for residential areas. The four samples

collected in 1995 near the 1993 EPA sampling location had results above background, with the highest concentration at this location, 0.038 Bq/dry g (1.02 pCi/dry g), being 40% of the PRG.

Based on the 1995 work, both the EPA and the California DHS concurred that there was no regulatory concern from any of the sample results, that there was no significant lifetime cancer risk resulting from the low concentrations of plutonium-239+240 in the soil samples, and that there was no unacceptable risk to human health or the environment.

In 1997, the ATSDR (which had contracted with the California DHS, Environmental Health Investigations Branch, to conduct a health consultation for plutonium) held a public meeting on the subject of plutonium at Big Trees Park. At this meeting, the regulatory agencies restated that, although the levels of plutonium at Big Trees Park were not a health concern, they were interested in knowing how the plutonium got to the park and the vertical extent of contamination at the park. The regulatory agencies determined that these questions warranted further investigation. ATSDR issued a draft report discussing these questions in 1998 and the final report in May 1999.

On the basis of the 1998 draft report, LLNL volunteered to conduct additional sampling and analysis to investigate how plutonium got to the park and to work with the regulatory agencies to ensure public concerns were addressed. In August and September 1998, more than 300 additional soil samples were collected at Big Trees Park. The sampling strategy was based on choosing sampling locations and analytes to provide (1) data to better determine the vertical and lateral extent of plutonium in soils at Big Trees Park, (2) data at locations and depths that are believed to be unique to each of three plutonium distribution pathways, (3) data at areas of public concern, and (4) additional data for locations previously identified as exhibiting above-background plutonium concentrations in soil.

The results of the 1998 sampling effort have provided much more information about the vertical and lateral extent of plutonium levels in soil at Big Trees Park. The results clearly show no systematic distribution of plutonium at depth. Of the 130 samples collected deeper than 10 cm to characterize the vertical extent of contamination, only four had concentrations of plutonium-239+240 above background levels determined from historic surveillance sampling. The results for samples collected to evaluate the lateral extent of contamination clearly show an increased level of plutonium along the park's northern boundary, where the ornamental trees are planted (Gallegos et al. 1999).

The results can also be used to draw conclusions about the route of transport of the plutonium to the park. Three routes to the park were investigated: (1) water-borne,

plutonium-contaminated sediments transported via Arroyo Seco, which cuts across the southwestern corner of the Livermore site and flows past Big Trees Park on its northern boundary; (2) plutonium-contaminated sewage sludge used as a soil amendment for planting the ornamental trees along the northern boundary of the park; and (3) aerial distribution of releases from the LLNL Plutonium Facility. The results for the samples collected to investigate the water-borne hypothesis were nearly all below detection limits. Because the concentrations of plutonium-239+240 were so low in these samples, the water-borne hypothesis is considered to be unlikely. In addition, annual surveillance monitoring of the arroyo shows no residual of past releases or evidence of recent release.

The sewage sludge hypothesis is based on the fact that from the early 1960s to the mid-1970s, the LWRP distributed sewage sludge to the public for use as soil amendments. The probable source of plutonium in the sludge is LLNL releases to the sanitary sewer, with the largest single release occurring in 1967. It is also known that the ornamental trees were planted in a row along the northern border of the park next to the arroyo some time between 1972 and 1975. Ten trees along the northern boundary of the park were selected for sampling. Paired with each tree location was another location at least 1 m beyond the irrigation berm that surrounds each tree. The results from these samples clearly show elevated levels of plutonium in samples taken near the trees but only background levels outside the tree wells. This distribution of plutonium at the park supports the theory that contaminated sewage sludge was used to fertilize trees at the northern border of the park.

In January 2000, ATSDR issued a report presenting that agency's evaluation of the data obtained as a result of the 1998 sampling (Agency for Toxic Substances Disease Registry 2000). The ATSDR concluded:

> The most credible pathway by which plutonium radioisotopes reached Big Trees Park was the application of plutonium contaminated sewage sludge as a soil amendment. This is based on a comparison of the concentrations of both plutonium and heavy metals collected from within tree wells to the concentrations present outside the tree wells. Although there is an elevated concentration of plutonium in the park, the levels are below the levels of health concern set by EPA (Region IX preliminary remediation goals; less than a risk of one in a million) and below the recommended levels which NCRP [National Council on Radiation Protection] has set for requiring additional activities. No other pathway appears to be a viable pathway for the presence of plutonium in the park.

Impact

The results of this extensive sampling effort demonstrate that the plutonium is not present at Big Trees Park, Livermore, at a level of health concern. All sample results were less than the PRG and were less than values measured as the result of previous sampling efforts at the park. The highest sample concentration from the 1998 sampling effort was 0.029 Bq/dry g (0.79 pCi/dry g) plutonium-239+240, well below the residential PRG of 0.093 Bq/dry g (2.5 pCi/dry g). Again, EPA, California DHS, and ATSDR concur that there is no unacceptable risk to human health or the environment from the levels of plutonium at the park.