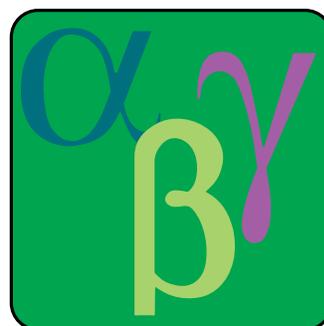
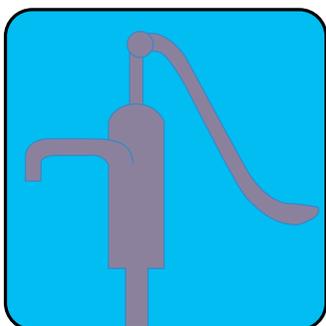
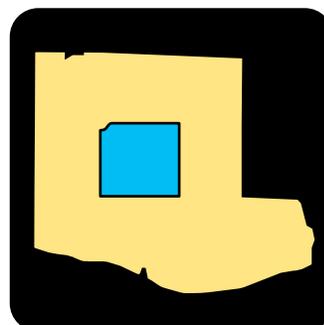
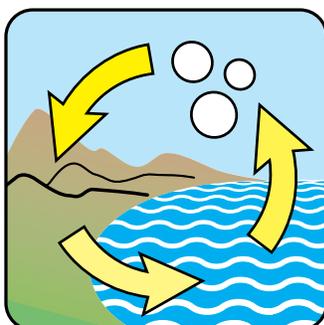
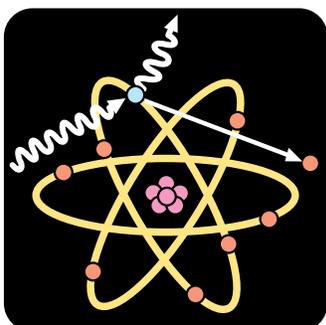
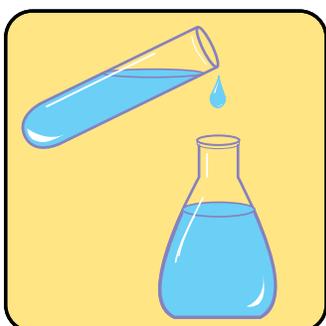
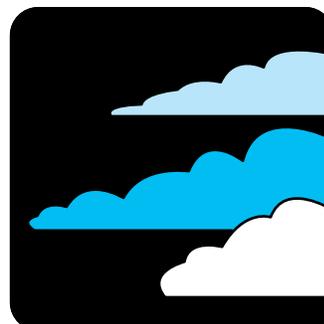


# Environmental Report 1994





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# Environmental Report 1994

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

This report is prepared for the U.S. Department of Energy (DOE) by the Environmental Protection Department (EPD) at the Lawrence Livermore National Laboratory (LLNL). The results of LLNL's environmental monitoring and compliance effort and an assessment of the impact of LLNL operations on the environment and the public are presented in this publication.

To produce a more readable and useful document for our diverse readership—including regulators, scientists and engineers, educators, the media, public interest groups and interested citizens—we have departed from the format used in previous years and divided this report into two volumes. The first describes LLNL's environmental impact and compliance activities and features descriptive and explanatory text, summary data tables, and plots showing data trends. The summary data include measures of the center of data, their spread or variability, and their extreme values. The first volume contains the Executive Summary and the Compliance Summary; it features individual chapters on monitoring of air, sewage, surface water, ground water, soil and sediment, vegetation and food-stuff, and environmental radiation; and it contains chapters on site overview, environmental program information, ground water protection, compliance self-monitoring, radiological dose assessment, and quality assurance. Information on both the Livermore site and Site 300 are presented in each chapter.

The second volume, supporting Volume 1 summary data, is essentially a detailed data report that provides the individual data points, where applicable. Some summary data are also included in Volume 2, and more detailed accounts are given of sample collection and analytical methods.

Volume 1, which is self-contained and can be read without access to Volume 2, contains all information of interest to most of our readers. Volume 1 will be distributed as usual, but Volume 2 will only be sent upon request; a card for this purpose is included on the last page of Volume 1.

As in last year's annual report, data are presented in *Système International* (SI) units. In particular, the primary units we use for radiological results are becquerels and sieverts for activity and dose, respectively, with curies and rem used secondarily ( $1 \text{ Bq} = 2.7 \times 10^{-11} \text{ Ci}$ ;  $1 \text{ Sv} = 100 \text{ rem}$ ). Units are discussed in the introduction of Chapter 12, Radiological Dose Assessment, in Volume 1.

This document is the responsibility of the Operations and Regulatory Affairs Division of EPD.

Monitoring data were obtained through the combined efforts of the Environmental Monitoring Section, the Nuclear Chemistry Division, the Radiological Analytical Sciences laboratory, and the Hazards Control Department of LLNL. Special recognition is deserved for the dedication and professionalism of the technicians who carried out environmental monitoring—David Ahre, Paris E. Althouse, Gary A. Bear, David L. Graves, Marion Heaton, Renee Needens, Terrance W. Poole, Donald G. Ramsey, Rebecca J. Ward, and Rhonda L. Welsh—and to the data management personnel—Nina Hankla, Jennifer Clark, Karen Schumacher, Kimberly A. Stanford, and Connie Wells. Special thanks also to Judith L. Kelly for initial preparation of Appendix A and collation and distribution of drafts.

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## **Introduction**

Lawrence Livermore National Laboratory (LLNL), a U.S. Department of Energy (DOE) facility operated by the University of California, serves as a national resource of scientific, technical, and engineering capability. The Laboratory's mission focuses on nuclear weapons and national security, and over the years has been broadened to include areas such as strategic defense, energy, the environment, biomedicine, technology transfer, the economy, and education. The Laboratory carries out this multifaceted mission in compliance with local, state, and federal environmental regulatory requirements. It does so with the support of the Environmental Protection Department, which is responsible for environmental monitoring and analysis, hazardous waste management, environmental restoration, and ensuring compliance with environmental laws and regulations.

LLNL comprises two sites: the Livermore site and Site 300. The Livermore site occupies an area of 3.28 square kilometers on the eastern edge of Livermore, California. Site 300, LLNL's experimental testing site, is located 24 kilometers to the east in the Altamont Hills, and occupies an area of 30.3 square kilometers. Environmental monitoring activities are conducted at both sites as well as in surrounding areas.

This summary provides an overview of LLNL's environmental activities in 1994, including radiological and nonradiological sampling and surveillance monitoring, remediation, assessment of radiological releases and doses, and determination of the impact of LLNL operations on the environment and public health.

## **Environmental Monitoring Results**

During 1994, the Environmental Protection Department sampled air, sewage effluent, ground water, surface water, soil, vegetation and foodstuffs, and measured environmental radiation. More than 17,200 environmental samples were taken and 21,500 analyses conducted for more than 236,000 analytes. The last number compares to 190,000 for the previous year.

LLNL's sampling networks undergo constant evaluation; changes are made, as necessary, to ensure adequate, cost-effective monitoring of all media potentially affected by LLNL operations. Once samples are collected, they are analyzed for radioactive and nonradioactive substances using standard methods such as analytical procedures approved by the U.S. Environmental Protection Agency (EPA), special systems such as the continuous monitoring system for Livermore



site sewage, or special analytical techniques designed to measure very low levels of radionuclides. Environmental radiation is also measured directly using dosimeters.

The amount of radioactivity released from LLNL during 1994 was slightly less than in 1993 and was below the range of earlier years. The most significant radiological effluent for the Livermore site continues to be tritium, the radioactive isotope of hydrogen. The primary source of tritium emissions is Building 331, the Tritium Facility. Routine Livermore site operations released a total of  $5.1 \times 10^{12}$  Bq (137 Ci) of tritium to the atmosphere in 1994; of that,  $2.8 \times 10^{12}$  Bq (77 Ci) was in the form of tritiated water. In 1993 the total emissions were  $8.77 \times 10^{12}$  Bq (177 Ci). By contrast, levels of tritium emissions in 1991 and previous years were above  $37 \times 10^{12}$  Bq (1,000 Ci). The Tritium Facility has significantly reduced its tritium operations except for inventory reduction and cleanup activities. Tritium values measured in surface water, rainwater, and runoff were low in 1994, comparable to levels the previous year and consistent with a generally decreasing historical trend. Measured values for tritium in air and vegetation in 1994 were not statistically different from those in 1993.

At Site 300, the dominant radioactive effluent is depleted uranium, which contains isotopes with atomic weights 238, 235, and 234 in the weight percentages 99.8, 0.2, and 0.0005, respectively. The primary sources of these emissions were experiments on the firing tables adjacent to Buildings 801 and 851, resulting in estimated releases of  $2.8 \times 10^9$  Bq ( $7.6 \times 10^{-2}$  Ci),  $3.6 \times 10^7$  Bq ( $9.7 \times 10^{-4}$  Ci), and  $2.6 \times 10^8$  Bq ( $7.1 \times 10^{-3}$  Ci) for the three isotopes, respectively. These emissions are a little more than twice those in 1993 but within the range of variation seen from year to year due to changes in the level of operations at the firing tables.

To determine whether Site 300 operations are affecting the measured levels of uranium, we analyzed the ratio of uranium-238 to uranium-235. Natural uranium contains uranium-238, -235, and -234 in the weight percentages 99.274, 0.72, and 0.0057. The observed ratio of the 238 and 235 isotopes, therefore, can reveal whether LLNL operations have added uranium-238 to the environment at Site 300. The ratios of airborne particulate uranium deviated from the natural ratio during two months (October and December) of 1994, indicating the presence of airborne uranium-238 from Site 300 operations. The measured concentrations of uranium-238, however, are only a small fraction (16/100,000) of the regulatory exposure guideline of  $0.03 \mu\text{g}/\text{m}^3$ .

Particulate matter in air is monitored for beryllium and for radionuclides, including plutonium and uranium isotopes. Most of the radioactivity detected is from naturally occurring radionuclides and global fallout from historical nuclear weapons testing by the world's nuclear powers. Plutonium from fallout and past



programmatic activity is found at low levels around the perimeter of the Livermore site. Plutonium from fallout only is detected at even lower levels at Site 300. The highest average plutonium value was measured at a location on the Livermore site near Building 531. The median concentration there was  $1.7 \times 10^{-13}$  Bq/mL of air ( $4.5 \times 10^{-24}$  Ci/mL), a small fraction (23/100,000) of the regulatory exposure guideline of  $7.4 \times 10^{-10}$  Bq/mL of air ( $2 \times 10^{-20}$  Ci/mL).

A special study of plutonium in Big Trees Park in the City of Livermore began in 1994. During a 1993 EPA investigation of plutonium in soils in the southeast quadrant of the Livermore site, EPA personnel collected a soil sample at Big Trees Park about two kilometers to the west to serve as a background sample. This soil sample showed plutonium at higher concentration than expected from global fallout for this region. The park was resampled by EPA, LLNL, and the California Department of Health Services (DHS). The results confirmed the finding of plutonium, but all results are below the EPA's preliminary remediation goal for residential exposure to plutonium. The EPA and DHS concur that there is no regulatory concern or significant impact on human health or the environment.

Discharges of radioactive and hazardous materials to the combined sanitary and industrial sewer at the Livermore site are controlled by limiting the use of those materials, implementing engineering controls, and routing discharged material to retention tanks for later characterization and treatment. Flow-proportional samples of discharged wastewater are regularly collected and analyzed to assure that LLNL's sewage effluent meets the requirements of the permit granted by the City of Livermore. In addition, effluent is monitored continuously for pH, selected metals, and radioactivity. Should concentrations be detected above warning levels, LLNL's sewer diversion system is automatically activated. The diversion system captures all but the first few minutes of wastewater flow that causes an alarm, thereby protecting the Livermore Water Reclamation Plant (LWRP) and minimizing any required cleanup. In 1994, there were two releases, involving methylene chloride and zinc, that slightly exceeded discharge limits for release of materials to the sanitary sewer system. The results of the effluent monitoring program demonstrate the success of LLNL's discharge control programs.

Water sampling and analysis are a large part of the LLNL surveillance monitoring effort. The waters monitored include lakes, streams, rainfall, tap water, storm water runoff, drinking water-supply wells, and ground water monitoring wells. The samples are analyzed for gross alpha and gross beta radiation, tritium, and nonradioactive pollutants, including solvents, metals, and pesticides. Median activities for gross alpha and gross beta radiation in surface water samples for the Livermore site and Livermore Valley in 1994 were less than 10% of the drinking water maximum contaminant level (MCL). Storm



water gross alpha and gross beta were well below MCLs, with the exception of samples collected November 5 at one location (GRNE) that is upstream and off the Livermore site. The origin of the elevated readings has not been determined. Livermore site rainfall has exhibited elevated tritium activities in the past, but during 1994, measurements were far below the 740 Bq/L (20,000 Ci/L) MCL established by the EPA for drinking water; the highest activity measured was 12% of the MCL. Tritium values for surface and drinking water samples were less than 1% of the drinking water standard.

The Ground Water Protection Management Program at LLNL is a multifaceted effort to eliminate or minimize adverse impacts of Laboratory operations on ground water. It also aims to determine the extent and understand the impact of past activities, remediate adversely affected areas, and monitor current operations. Ground water monitoring at the Livermore site investigates contamination according to the Federal Facility Agreement for the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA). LLNL conducts ground water monitoring at Site 300 under three programs: one to meet regulatory commitments established for site-specific CERCLA investigations, a second consisting of routine compliance monitoring around landfill and wastewater surface impoundment units, and a third to perform surveillance monitoring in and around the site to register the impacts, if any, of current operations.

LLNL routinely monitors ground water wells in the Livermore Valley and at Site 300, to complement the extensive CERCLA monitoring activities associated with known areas of ground water contamination. Tritium, as well as other radioisotopes and a wide range of inorganic and organic constituents of potential concern, are measured. Tritium measurements in 21 wells in the Livermore Valley all showed very low values compared to the EPA MCL for drinking water; the highest measured value was 15.7 Bq/L (424 pCi/L), which is approximately 2% of the standard (occurring in a nondrinking water source). The overall trend of tritium is downward in Livermore Valley ground waters; the mean tritium activity in these wells has declined more than 50% in the past six years. The principal processes causing this decline are the natural decay of tritium (12.3-year half-life), declining tritium emissions from the Livermore site, and dilution of older ground water with younger recharge water. Tritium in Livermore Valley drinking water is at a very low and safe level, amounting to less than 1% of the MCL. At Site 300 and adjacent properties in the Altamont Hills, ground water monitoring shows that no on-site or off-site drinking water wells were impacted by activities at Site 300 in 1994 and indicate that environmental impacts of both past and present activities are minimal beyond the site boundaries. LLNL will continue to determine the nature and extent of contamination by continued sampling, data analysis, and transport analysis.



Area vegetation and foodstuffs are monitored for their tritium content. The tritium concentrations taken near the Livermore site were greater than those taken from more distant locations. The tritium concentrations were the same as those reported in 1993, within measurement uncertainty. As in the past, the tritium concentrations in Livermore Valley wines analyzed in 1994 are slightly above those for wines tested from Europe and other locations in California; however, even the highest detected value, 8.0 Bq/L (216 pCi/L), is just over 1% of the amount California allows in drinking water. This amount is nearly the same as the highest value for 1993, 8.25 Bq/L (223 pCi/L).

In 1994, soil samples from the Livermore site and Site 300, and arroyo sediment samples from storm water drainage channels at the Livermore site, were analyzed for radionuclides and beryllium. All measured values for 1994 were consistent with historical data and generally showed background values.

LLNL maintains a network of direct radiation monitors, using thermoluminescent dosimeters (TLDs) for gamma radiation. In 1994, TLD measurements at the Livermore-site perimeter averaged 0.72 mSv (72 mrem) and, at the Site 300 perimeter, averaged 0.88 mSv (88 mrem). Both are within the range of background levels for the two sites. The Laboratory also maintained a network of neutron monitors developed at LLNL for neutron radiation, but these monitors have deteriorated. Because neutron measurements for the past decade have shown only background levels, and because data indicate that it is not necessary, neutron monitoring will be discontinued in 1995 to save the cost of replacing the measurement devices.

### **Radiological Impact Assessment**

The primary DOE radiation standards for protection of the public are 1 mSv/y (100 mrem/y) effective dose equivalent for prolonged exposure, and 5 mSv/y (500 mrem/y) effective dose equivalent for occasional exposure. These limits are based on the dose to the maximally exposed individual in an uncontrolled area, delivered via all pathways. The EPA radiation dose standard, which applies to air emissions only, is promulgated under Section 112 of the Clean Air Act, and defined in Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) under 40 CFR 61. It limits to 0.1 mSv/y (10 mrem/y) the whole-body effective dose equivalent to members of the public from airborne releases caused by DOE activities. Additionally, EPA requires continuous monitoring of individual emission points that have potential unabated emissions of 1  $\mu$ Sv/y (0.1 mrem/y) or more.

The EPA NESHAPs standard is small, and the doses caused by radionuclides released from LLNL are smaller still, compared to levels of natural exposure to radioactivity. As a result, it is difficult to use measurements alone to distinguish between LLNL-contributed radiation in the environment and that due to other

sources, to prove compliance with the standard. Therefore, we use mathematical models to calculate potential doses to the public for compliance demonstrations based on measured or calculated releases of radionuclides to air and water. The models implement EPA's approved dosimetry and dispersion models, which contain conservative assumptions that are expected to result in calculated doses larger than ones actually received by members of the public.

Radiological dose-assessment modeling runs using EPA-mandated computer models, actual LLNL meteorology, population distributions appropriate to the two sites, and 1994 radionuclide inventory and monitoring data were conducted for every emission point at the Livermore site and Site 300. The total potential dose calculated for point-source (stack) emissions for a hypothetical person having the greatest possible exposure at the Livermore site in 1994 was 0.42  $\mu\text{Sv}$  (0.042 mrem) and, from diffuse-source (area) emissions, was 0.23  $\mu\text{Sv}$  (0.023 mrem). Summing these contributions yields a total dose of 0.65  $\mu\text{Sv}$  (0.065 mrem) for the Livermore site.

Compared to data of previous years, the total potential dose for 1994 is practically the same as the 1993 value of 0.66  $\mu\text{Sv}$  (0.066 mrem), slightly below the 1992 value of 0.79  $\mu\text{Sv}$  (0.079 mrem), and well below the dose values of 2.34  $\mu\text{Sv}$  (0.234 mrem) and 2.40  $\mu\text{Sv}$  (0.240 mrem) reported for 1991 and 1990, respectively. Reduced emissions from the Tritium Facility account for much of this decline.

The dose to a person having the greatest possible exposure at Site 300 during 1994 was calculated to be 0.81  $\mu\text{Sv}$  (0.081 mrem). Explosive tests at the Building 801 and Building 851 firing tables accounted for all of the point source dose of 0.49  $\mu\text{Sv}$  (0.049 mrem), while a source representing resuspension of both naturally-occurring and LLNL-contributed uranium in surface soils throughout the site was responsible for nearly all of the diffuse sources total of 0.32  $\mu\text{Sv}$  (0.032 mrem). In comparison, the Site 300 total dose values in recent years were 0.37  $\mu\text{Sv}$  (0.037 mrem) in 1993, 0.21  $\mu\text{Sv}$  (0.021 mrem) in 1992, 0.44  $\mu\text{Sv}$  (0.044 mrem) in 1991, and 0.57  $\mu\text{Sv}$  (0.057 mrem) in 1990.

The doses to the maximally exposed public individual from Livermore site and Site 300 emissions amount to less than 1% of the EPA NESHAPs standard. These doses are a small fraction (about 1/4,000) of the doses received by these populations from natural background radiation. Thus, the potential radiological doses from LLNL operations in 1994 were well within regulatory standards and were very small compared to doses from natural background radiation sources.



## Environmental Compliance Activities

LLNL works to ensure that its operations have limited environmental impacts and comply with environmental laws and federal, state, and local regulatory guidelines. Many activities related to water, air, waste, waste reduction, community "right to know," and other environmental issues were addressed in 1994.

Both the Livermore site and Site 300 are Superfund sites under CERCLA and are undergoing remedial activities. The proposed technique for cleaning up ground water at the Livermore site consists of managed ground water extraction and surface treatment. Contaminated sediments in the unsaturated zone are treated, as appropriate, by extracting fuel hydrocarbons or volatile organic compounds (VOCs) by vacuum-induced venting and treatment of the vapors. EPA and local and state agencies have approved this plan. In 1994, ground water was treated at five facilities to capture and control the off-site spread of contaminated ground water: Treatment Facility A treated more than 87 million liters of ground water, removing and destroying about 5.6 kilograms of VOCs; Treatment Facility B treated about 30 million liters of ground water, removing and destroying about 2.7 kilograms of VOCs; Treatment Facility C treated about 10.6 million liters of ground water, removing 1.2 kilograms of VOCs; and Treatment Facility F treated approximately 15 million liters of ground water, and removed about 300 liters liquid-volume-equivalent of gasoline from the subsurface. Construction of Treatment Facility D was completed on July 13, 1994, and 0.34 million liters of ground water were processed, removing 0.3 kilograms of VOCs.

The Superfund activities at Site 300 are at an earlier stage: LLNL completed a sitewide remedial investigation report during 1994, compiling all ground water and soil investigation information for the entire site, and assessing potential hazards to human health and the environment resulting from contamination of soil, sediment, and ground water. Treatment activities have begun in the General Services Area (GSA) at Site 300. During 1994, 82 million liters of ground water in the eastern GSA were treated to remove about 0.74 kilograms of VOCs. Similar results were obtained in treatments in the central GSA, and proof of system testing was conducted at the Building 834 Complex.

The Laboratory's Chemical Exchange Warehouse (CHEW) program, started in November 1993 with the goal of reducing the disposal of chemicals as hazardous waste, was continued in 1994. This pollution prevention program finds ways of collecting, identifying, storing, and reusing chemicals. Twenty-five percent of the volume of unused chemicals turned into the program is being recycled for additional use.



LLNL continues to perform all activities necessary to comply with clean air and clean water requirements. In 1994, the Bay Area Air Quality Management District issued 71 permits to operate, 396 letters of exemption, and 164 permit renewals for the Livermore site, and conducted five days of on-site inspections. The San Joaquin Valley Unified Air Pollution Control District issued seven permits to operate, two letters of exemption, and 25 permit renewals for Site 300, and conducted three days of on-site inspections. LLNL has permits for discharge of treated ground water, industrial and sanitary sewage, and storm water. Site 300 has additional permits for inactive landfills; cooling tower discharges; operation of the sewer lagoon, septic tanks, and leach fields; and discharge of treated ground water. The Laboratory complies with all requirements for self-monitoring and inspections associated with these permits.

LLNL has one endangered species, *Amsinckia grandiflora* (large-flowered fiddleneck), which is found at Site 300. On April 7, 1994, LLNL personnel counted 1,606 mature plants in the natural population of *Amsinckia*, up from 301 plants observed in 1993. The increase in population is a direct result of the use of grass-selective herbicides to reduce competition from exotic grasses in the area. LLNL personnel also counted 248 mature plants in one of two experimental populations. Work on all populations will continue through 1995.

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## Conclusion

LLNL is committed to protecting the environment and ensuring that its operations are conducted in accordance with applicable federal, state, and local laws and regulations. The current techniques used at the Laboratory for environmental monitoring are very sensitive, allowing detection at extremely low levels of constituents. The combination of environmental and effluent monitoring, source characterization, and computer modeling show that radiological doses to the public caused by LLNL operations are less than 1% of regulatory standards and are about 4,000 times smaller than the doses received from background radiation. The analytical results and evaluations generally show a decrease in contaminant levels, reflecting both decreased operations and the responsiveness of the Laboratory in controlling pollutants. In summary, the results of the 1994 environmental monitoring and modeling programs demonstrate that the environmental impacts of LLNL are minimal and pose no threat to the public or the environment.



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## Introduction

Climate and geography play primary roles in how the environment is affected by human actions. Dispersal of particles of air, for example, is influenced by wind patterns and rainfall, which in turn are influenced by geographical characteristics. Similarly, the dispersal of ground water is constrained by the particular geology of the site. Thus, data on wind, rainfall, geological, and geographical characteristics are used to calculate the effects that operations at LLNL might have on the surrounding environment. Some history and a description of these data help us understand the relationship of the Laboratory to its climatic and geographic setting.

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## Operations

The mission of LLNL is to serve as a national resource in science and engineering, with a special responsibility for nuclear weapons. Laboratory activities focus on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education. The Laboratory's mission is dynamic and has been broadened over the years to meet new national needs.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, and medical departments—necessary to support its operations and nearly 10,000 personnel. At the Livermore site, food service, banking, and limited shopping services are available on site. At Site 300, services include a cafeteria in the General Services Area.

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## Location

LLNL consists of two main facilities—the main laboratory site located in Livermore, California (Livermore site), and the Experimental Test Facility (Site 300) located near Tracy, California (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

Over 40 years ago, LLNL was founded on the site of a former U.S. Navy training base. At that time, the location was relatively isolated, being approximately 1.6 kilometers from the Livermore city limits. Over the years, Livermore evolved from a small town of fewer than 7,000 people to its present population of nearly 63,000. The economy diversified from primarily agricultural to include light industry and business parks. Within the last few years, low-density, single-family residential development has begun to fill the formerly vacant fields, bringing the city limits of Livermore to LLNL's western boundary.

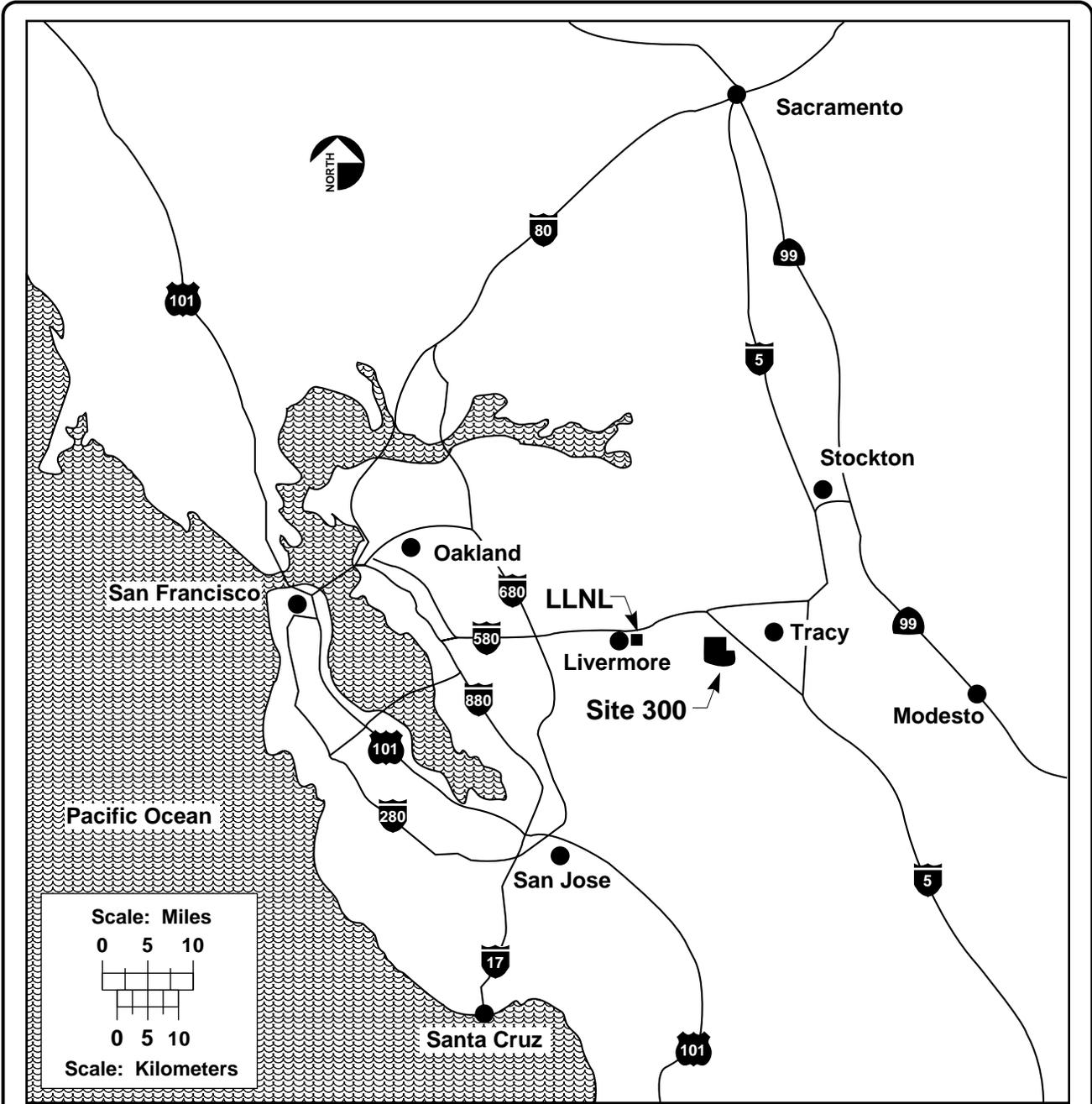


Figure 1-1. Locations of LLNL Livermore site and Site 300.

LLNL's Livermore site occupies an area of 3.28 square kilometers, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories, California (Sandia, California), operated by Martin-Marietta under DOE contract. Sandia, California provides research and development associated with nuclear weapons systems engineering, as well as



related national security tasks. Although their primary missions are similar, LLNL and Sandia, California are separate facilities, each with its own management and each reporting to a different DOE operations office.

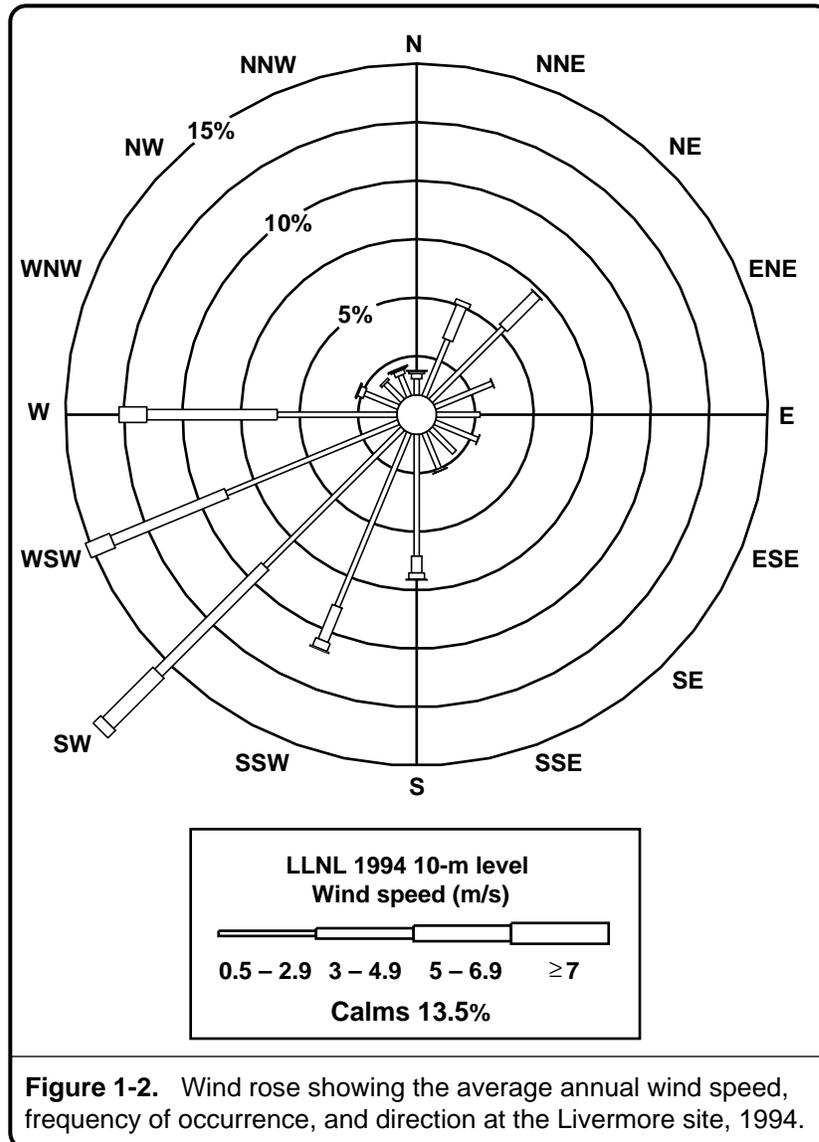
To the south of LLNL, there are also some low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards; a business park lies to the southwest. Farther south, property is primarily open space or rural ranchettes, with some agricultural use. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills of the intercoastal range that defines the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare parcel of open space to the northeast has been rezoned to allow development of a center for industry.

Site 300, LLNL's Experimental Test Site, is located 24 kilometers east of the Livermore site in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 square kilometers. It is in close proximity to two other testing facilities: Physics International operates a testing facility that is adjacent and to the east of Site 300, and SRI International operates another facility, located approximately 1 kilometer south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills northwest of the site. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 42,000), located 10 kilometers to the northeast.

## Meteorology

Meteorological data (including wind speed, wind direction, rainfall, and temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. The mean annual temperature for 1994 was 15°C. Temperatures range from -5°C during predawn winter mornings to 40°C during summer afternoons.

Both rainfall and wind exhibit strong seasonal patterns. Annual wind data for the Livermore site are given in **Figure 1-2** and **Table 1-1**. These data show that the prevailing winds are from the west and southwest, accounting for 45% of the wind pattern. These wind patterns are dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. The wind blows from the northeast primarily during the winter storm season. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months. The highest and lowest annual rainfalls on record are 782 millimeters and 138 millimeters. In 1994, the Livermore site received 307 millimeters of rain.



The meteorological conditions at Site 300, while generally similar to the Livermore site, are modified by higher elevation and more pronounced relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-3** and **Table 1-2**. The data show that these winds are more consistently from the west-southwest and reach greater speeds than at the Livermore site. The increased wind speed and elevation of much of the site result in afternoon temperatures that are typically lower than those for the Livermore site. Rainfall for 1994 was 217 millimeters.



**Table 1-1.** Wind rose for Livermore site during 1994 at the 10-meter level.

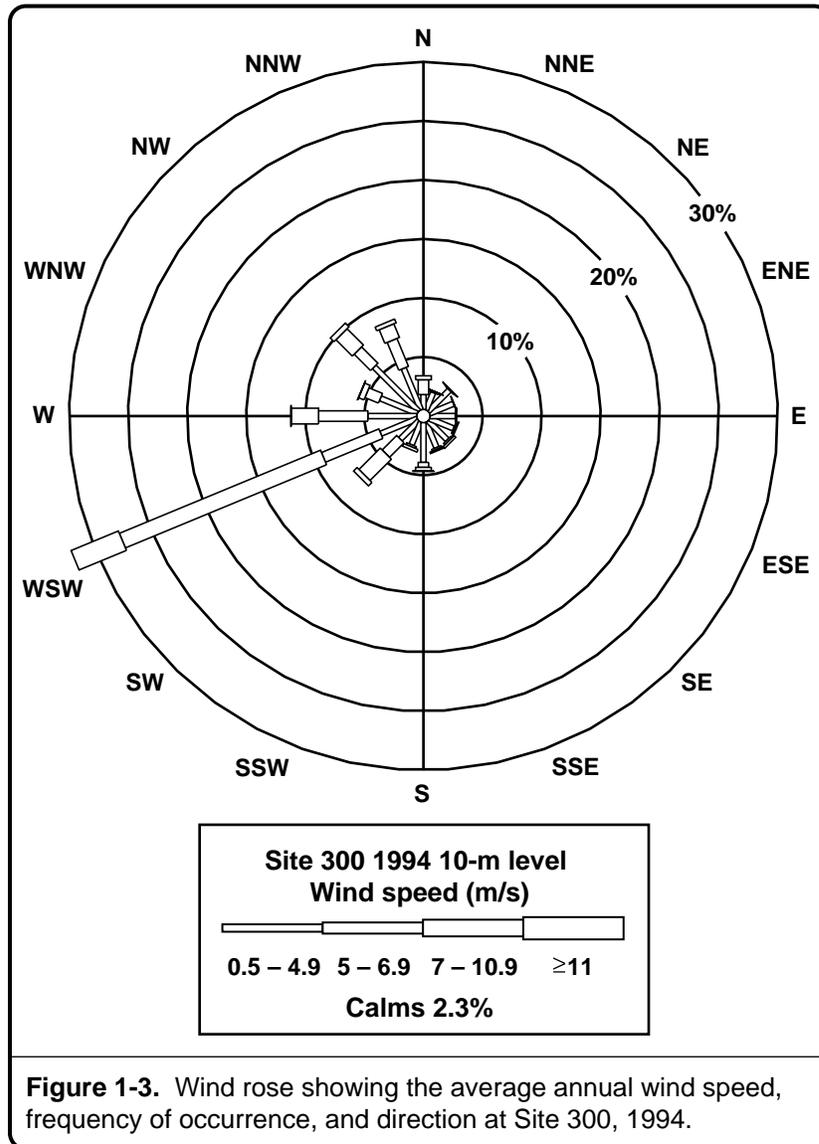
Direction	Livermore Site					
	Wind Speed (m/s)					Total
	0.0-0.4	0.5-2.9	3.0-4.9	5.0-6.9	≥7.0	
NNE	0.84	2.62	1.55	0.21	0.00	5.2
NE	0.84	4.40	2.00	0.01	0.00	7.3
ENE	0.84	2.65	0.01	0.00	0.00	3.6
E	0.84	1.86	0.00	0.00	0.00	2.7
ESE	0.84	1.97	0.01	0.00	0.00	2.8
SE	0.84	1.43	0.00	0.00	0.00	2.3
SSE	0.84	1.65	0.10	0.01	0.00	2.7
S	0.84	5.20	0.72	0.27	0.03	7.1
SSW	0.84	8.02	1.58	0.37	0.06	10.9
SW	0.84	8.32	6.43	3.04	0.45	19.1
WSW	0.84	7.95	5.27	1.11	0.00	15.2
W	0.84	5.11	5.57	1.18	0.00	12.7
WNW	0.84	1.55	0.25	0.06	0.00	2.7
NW	0.84	1.04	0.09	0.00	0.00	2.0
NNW	0.84	0.97	0.20	0.05	0.05	2.1
N	0.84	0.69	0.22	0.10	0.03	1.9
<b>Total<sup>(a)</sup></b>	<b>13.5</b>	<b>55.4</b>	<b>24.0</b>	<b>6.4</b>	<b>0.6</b>	<b>100.0</b>

<sup>a</sup> Totals are adjusted for round-off error.

**Table 1-2.** Wind rose for Site 300 during 1994 at the 10-meter level.

Direction	Site 300					
	Wind Speed (m/s)					Total
	0.0-0.4	0.5-4.9	5.0-6.9	7.0-10.9	≥11.0	
NNE	0.14	1.60	0.06	0.06	0.01	1.9
NE	0.14	2.55	0.03	0.05	0.01	2.8
ENE	0.14	2.20	0.01	0.03	0.00	2.4
E	0.14	2.14	0.03	0.08	0.00	2.4
ESE	0.14	2.19	0.14	0.08	0.00	2.6
SE	0.14	2.29	0.16	0.20	0.00	2.8
SSE	0.14	2.33	0.15	0.13	0.00	2.8
S	0.14	3.37	0.42	0.29	0.05	4.3
SSW	0.14	2.07	0.17	0.23	0.00	2.6
SW	0.14	2.21	1.73	2.56	0.42	7.1
WSW	0.14	3.35	5.25	18.42	4.34	31.5
W	0.14	4.15	4.17	2.32	0.02	10.8
WNW	0.14	3.38	1.24	0.49	0.01	5.3
NW	0.14	5.34	1.96	1.95	0.44	9.8
NNW	0.14	3.82	2.56	1.25	0.34	8.1
N	0.14	1.27	1.25	0.34	0.00	3.0
<b>Total<sup>(a)</sup></b>	<b>2.3</b>	<b>44.3</b>	<b>19.3</b>	<b>28.5</b>	<b>5.6</b>	<b>100.0</b>

<sup>a</sup> Totals are adjusted for round-off error.



**Geology**

**Topography**

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley, the most prominent valley in the Diablo Range, is an east-west trending structural and topographic trough that is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays, at an average thickness of about 100 meters. The valley is approximately 25 kilometers long and averages 11 kilometers in width. The valley floor is at its highest elevation of



220 meters along the eastern margin and gradually dips to 92 meters at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow only during the rainy season.

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation ranges from approximately 150 meters at the southeast corner of the site to approximately 538 meters in the northwestern portion.

## Hydrogeology

### Livermore Site

The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several recent and continuing investigations. Detailed discussions of these investigations can be found in Stone and Ruggieri (1983); Carpenter et al. (1984); Webster-Scholten and Hall (1988); and Thorpe et al. (1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District, Zone 7, the agency responsible for ground water management in the Livermore Valley basin (San Francisco Bay RWQCB 1982).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley ground water basin, an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain ground water levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the depth to the water table varies from about 8 to 40 meters. **Figure 1-4** shows a contour map of water table elevations (meters above mean sea level) for the Livermore-site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-4** are generally maintained. At the eastern edge of the Livermore site, ground water gradients (change in vertical elevation per unit of horizontal distance) are relatively steep,



but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Ground water flow under most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of ground water recovery and remediation in the southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 meters per day (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an average ground water velocity estimate of 20 meters per year (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

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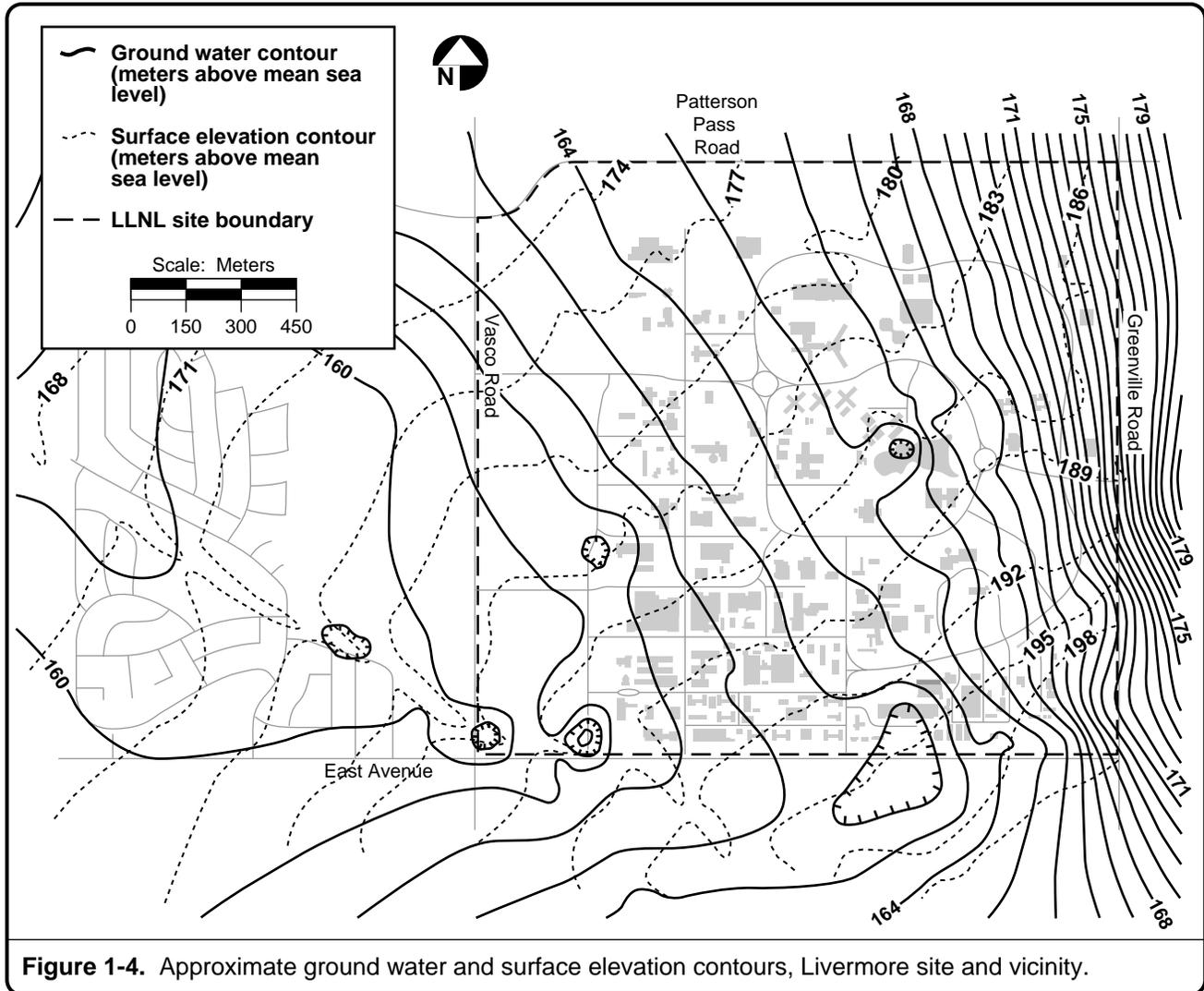
## Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most ground water occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable layers; normally they are discontinuous and highly localized. Because water quality generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

Fine-grained siltstone and claystone interbeds may confine the ground water and act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, ground water in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, ground water in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly sandstone, stratigraphically near the base of the formation, contains confined water. Wells located in the western part of the General

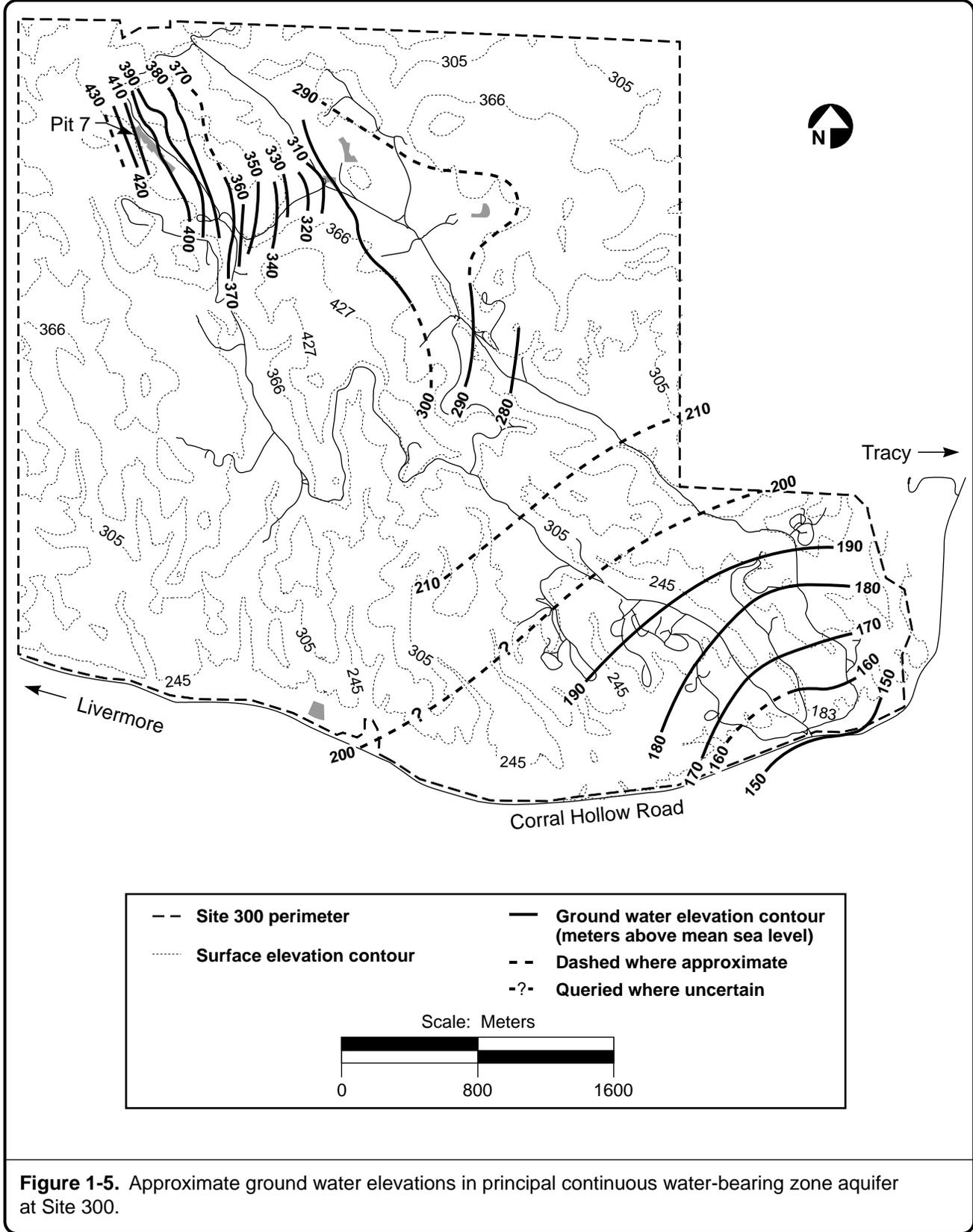


**Figure 1-4.** Approximate ground water and surface elevation contours, Livermore site and vicinity.

Services Area are completed in this aquifer and are used to supply drinking and process water.

**Figure 1-5** shows the elevation contours for water in the regional aquifer at Site 300. This map of the piezometric surface (the elevation to which water rises in a well that penetrates a confined or unconfined aquifer) is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock, or where permeable bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high



**Figure 1-5.** Approximate ground water elevations in principal continuous water-bearing zone aquifer at Site 300.



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evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Further information on the hydrology of both the Livermore site and Site 300 can be found in the ground water protection information in Chapter 8.

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## Summary

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationship with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year additional information is gained to allow us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, soil, ground water, and vegetation—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each medium used to monitor the environment.



## 2. Compliance Summary



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### Introduction

During 1994, Lawrence Livermore National Laboratory (LLNL) participated in numerous environmental activities to comply with regulatory and internal requirements and Department of Energy (DOE) orders. Activities related to waste, water, air, waste reduction, community “right to know,” and other environmental issues were addressed at both the Livermore site and Site 300. Documents addressing these and other environmental issues are available for public viewing at the LLNL Visitors Center and the Livermore Public Library. A summary of the permit activity related to these environmental activities for the calendar year 1994 is presented in **Table 2-1**.

### Department of Energy Tiger Team and Tiger Team Progress Assessment

DOE conducted a Tiger Team Assessment of LLNL environmental, safety, and health (ES&H) programs in 1990. In November 1992, DOE conducted a follow-up Tiger Team Progress Assessment, concluding that, “LLNL management recognizes the importance that the Secretary of Energy places on ES&H excellence and has responded with improvements in all ES&H areas.” Although work remains to be done to address concerns in several areas, these concerns do not diminish the significance of the progress made since the 1990 Tiger Team Assessment.

In July 1993, LLNL submitted a Draft Action Plan to DOE in response to the Tiger Team Progress Assessment; this plan is still under review. Once the action plan is approved, the actions may be incorporated as an addendum to the original Tiger Team Action Plan.

LLNL continues to undertake those activities identified in its original seven-year Tiger Team Action Plan, and significant progress has been made towards the 581 subtasks identified in it. Action items have been prioritized and are funded within budget constraints. As of December 31, 1994, 84% of these subtasks have been completed, 1% are on schedule, and 8% are considered late; 38 low-priority subtasks (the remaining 7%) have not been funded. The majority of the late subtasks are late because of funding limitations. LLNL is also working with DOE to close those open action items that have been preempted by new and different requirements.

## 2. Compliance Summary



**Table 2-1.** Summary of permits.

Type of Permit	Livermore Site	Site 300
Air	164 permits (various equipment)	39 permits (various equipment)
Water	<p>WDR Order No. 88-075</p> <p>WDR Order No. 91-091, NPDES Permit No. CA0029289</p> <p>WDR Order No. 91-13-DWQ (as amended by Order No. 92-12-DWQ) NPDES General Permit No. CAS000001</p> <p>WDR Order No. 92-08-DWQ NPDES General Permit No. CAS000002 Site ID No. Bldg. 132 2015300881</p>	<p>WDR Order No. 93-100 (amended 80-184)</p> <p>WDR Order No. 94-131 NPDES Permit No. CA0081396 (amended WDR Order No. 82-105 and replaced WDR Order No. 91-13-DWQ as amended by WDR Order No. 92-12-DWQ, NPDES General Permit No. CAS000001)</p> <p>WDR Order No. 85-188 NPDES Permit No. CA0082651</p> <p>WDR Order No. 92-08-DWQ NPDES General Permit No. CAS000002 Site ID No. 5B39S303589 Doall Road Construction Project</p>
Hazardous waste	<p>ISD CA2890012584</p> <p>DTSC Permit No. 2-13640 for disposal of extremely hazardous waste</p> <p>Authorization to perform Waste Resin Mixing in Unit CE231-1 and Unit CE443-1 under Condition Exemption tier</p>	<p>Part B CA2890090002</p> <p>Docket HWCA 92/93-031 Open Burning of Explosives Waste</p>
Sewer	Discharge Permit Nos. 1250 (94-95), 1508G (94-95), and 1510G (94-95)	
Tanks	Fees paid for 28 tanks	Fees paid for 7 tanks
Other	FFA, ground water investigation/remediation; ACEHS medical waste permits for treatment and storage	FAA ground water investigation/remediation

Permit numbers are based on actual permitted units maintained and renewed by LLNL during 1994.



### Comprehensive Environmental Response, Compensation and Liability Act/Superfund Amendment and Reauthorization Act, Title I

LLNL has several projects that are under the jurisdiction of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)/Superfund Amendment and Reauthorization Act (SARA), Title 1. These include the Livermore Site Ground Water Project, the Site 300 Environmental Restoration Program, and community relations.

### Livermore-Site Ground Water Project

The Ground Water Project (GWP) complies with provisions specified in a Federal Facility Agreement entered into by the Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (RWQCB). As required by the agreement, the project addresses compliance issues through investigations of potential contamination source areas (such as suspected old release sites, solvent handling areas, and leaking underground tank systems), continued monitoring of ground water, and remediation.

### Required Documentation

In 1994, DOE/LLNL submitted 19 CERCLA documents for the Livermore site and conducted community activities. Recipients of these CERCLA documents included EPA, RWQCB, DTSC, Community Work Group Information Repositories, and Tri-Valley Citizens Against a Radioactive Environment (CAREs). The final version of *Remedial Design Report No. 3 for Treatment Facilities C and F* (Berg et al. 1994a) was issued on March 1, 1994, according to the revised schedule presented in the *Remedial Action Implementation Plan* (Dresen et al. 1993). With regulatory and community concurrence, the *Remedial Action Implementation Plan* schedule was revised on July 20, 1994, to add Remedial Design Report No. 6 (for the Building 518 vadose zone), and change the issue dates for Remedial Design Reports Nos. 4 and 5. In conjunction with the revised *Remedial Action Implementation Plan* schedule, a consensus statement was signed by the LLNL Livermore Site Remedial Program Managers that established cleanup priorities. *Remedial Action Implementation Plan No. 6 for the Building 518 Vapor Treatment Facility* (Berg et al. 1994b) was issued on schedule on November 30, 1994. The draft version of *Remedial Action Implementation Plan No. 5 for Treatment Facilities G-1 and G-2* (Berg et al. 1995) was distributed for review on schedule to the regulatory agencies and the community on December 1, 1994. In addition, in 1994, DOE/LLNL also issued the following reports: the January through December 1994 *Ground Water Project Monthly Progress Reports*; the March, June, and September 1994 *Ground Water Project Quarterly Progress Reports* (MacDonald



et al., 1994; Hoffman et al. 1994b; Hoffman et al. 1994c, respectively); and the *LLNL Ground Water Project 1993 Annual Report* (Hoffman et al. 1994a).

### Treatment Facilities

Treatment Facility A (TFA) has been operating since September 1989. TFA treated more than 87 million liters of ground water during 1994, removing and destroying approximately 5.6 kilograms (3.6 liters) of volatile organic compounds (VOCs). About 371 million liters have been treated, removing 46 kilograms (29 liters) of VOCs since TFA began operating. (See **Figure 2-1** for the locations of treatment facilities.) Treated waters from TFA are discharged into the recharge basin.

Treatment Facility B (TFB) has been operating since October 1990; TFB treated about 32 million liters of ground water in 1994, removing and destroying approximately 2.7 kilograms (1.7 liters) of VOCs. More than 87 million liters have been treated, removing 9 kilograms (5.7 liters) of VOCs since TFB began operating. TFB's treated waters are discharged into a drainage ditch feeding into Arroyo Las Positas.

Treatment Facility C (TFC) has been operating since October 1993. In 1994, a total of 1.2 kilograms (0.76 liters) of VOCs was removed from approximately 11 million liters of ground water treated at TFC. Treated waters from TFC are discharged into Arroyo Las Positas.

Ground water and vapor extracted from the Treatment Facility F (TFF) Area subsurface continued to have elevated temperatures due to the Dynamic Underground Stripping Project conducted at the site in early 1993. In December 1994, extracted ground water temperatures averaged about 48°C. TFF treated approximately 15 million liters of ground water containing a volume-weighted average concentration of fuel hydrocarbons (FHCs) of about 2,900 parts per billion (ppb). This is equivalent to about 57 liters liquid-volume-equivalent of gasoline removed. In addition, TFF extracted about 230 million liters of vapor containing a volume-weighted FHC concentration of about 210 parts per million (ppm) by volume, for about 240 liters liquid-volume-equivalent of gasoline removed. Therefore, the total liquid-volume-equivalent of gasoline removed from the TFF subsurface during 1994 was about 300 liters. The TFF gasoline removal rate has declined steadily throughout the year as recoverable gasoline in the Gasoline Spill Area is removed. Treated waters from TFF are discharged into the sanitary sewer.

Construction of Treatment Facility D (TFD) began on February 28, 1994, and was completed on July 13, 1994. TFD was activated on July 14, 1994, and operation

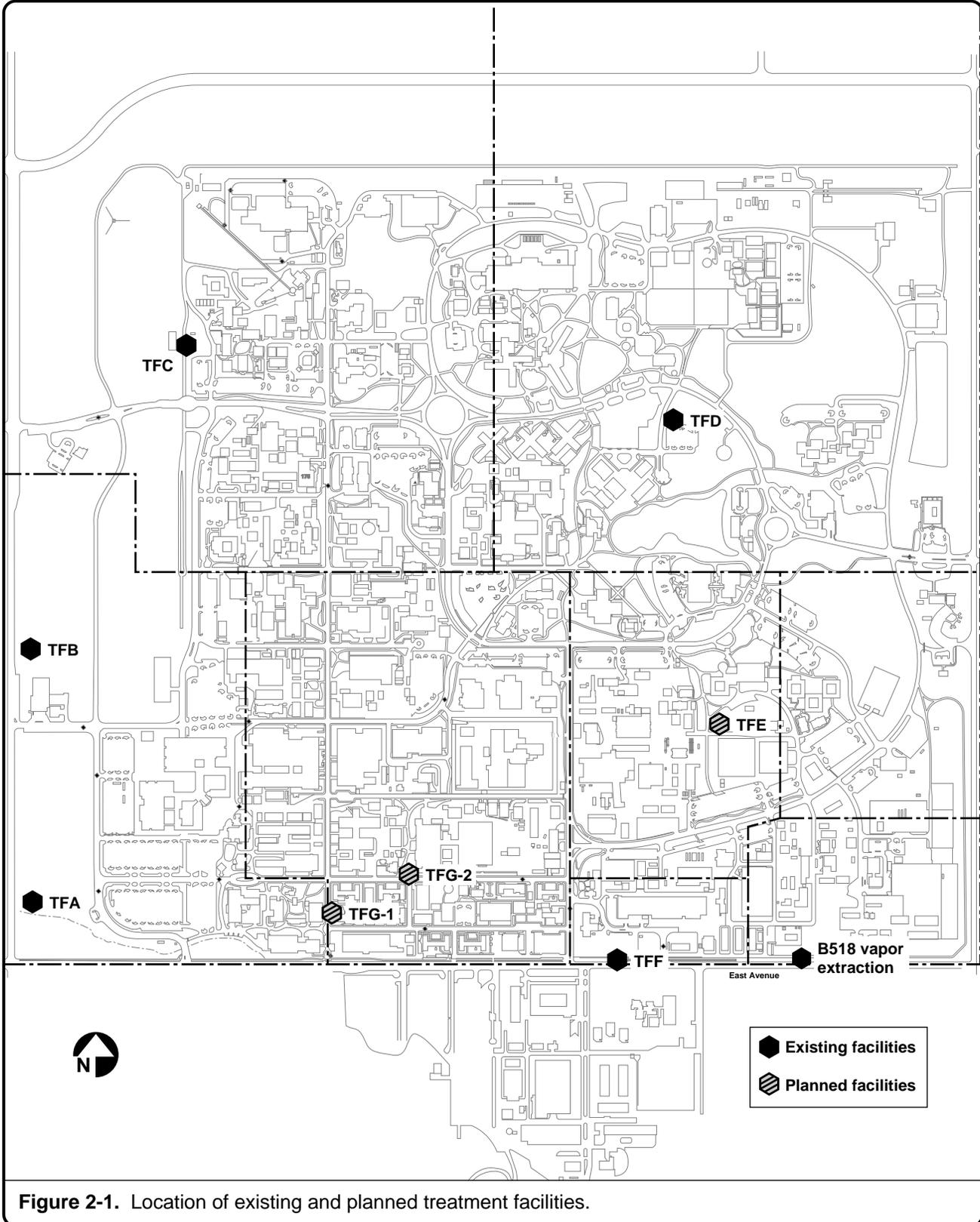


Figure 2-1. Location of existing and planned treatment facilities.



began on September 15, 1994. In 1994, TFD processed about 0.3 million liters of ground water containing about 0.3 kilograms (0.19 liters) of VOCs. The treated water was discharged to the Drainage Retention Basin.

In 1994, LLNL completed design of the vapor extraction system concrete pad for the Building 518 area. The system is scheduled to begin operation on September 29, 1995.

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### Community Relations

The Livermore Site Community Work Group includes representatives from the community at large, local real estate, wine growers, City of Livermore, Tri-Valley CAREs, EPA, RWQCB, and DTSC. This group met five times in 1994 to discuss topics including Remedial Design Report No. 6; the proposed Livermore Site Restoration Activities Priority List and revised Remedial Action Implementation Plan schedule; comparison of ground water treatment technologies for the Trailer 5475 Area; the baseline risk assessment in the Remedial Investigation report (Thorpe et al. 1990); DOE budget status; the Arroyo Pipeline extension; and organizational issues (e.g., the Community Work Group Operations and Mission Statement). Other community relations activities in 1994 included meeting periodically with Tri-Valley CAREs and its technical advisors, distributing the Environmental Community Letter, maintaining the Information Repositories and the Administrative Record, conducting tours of the site environmental activities, and staffing a telephone information line for public and news media inquiries. In November, a ribbon-cutting event marked the startup of TFD. The event was attended by Community Work Group representatives, a representative from Congressman Bill Baker's office, and DOE/LLNL officials and staff.

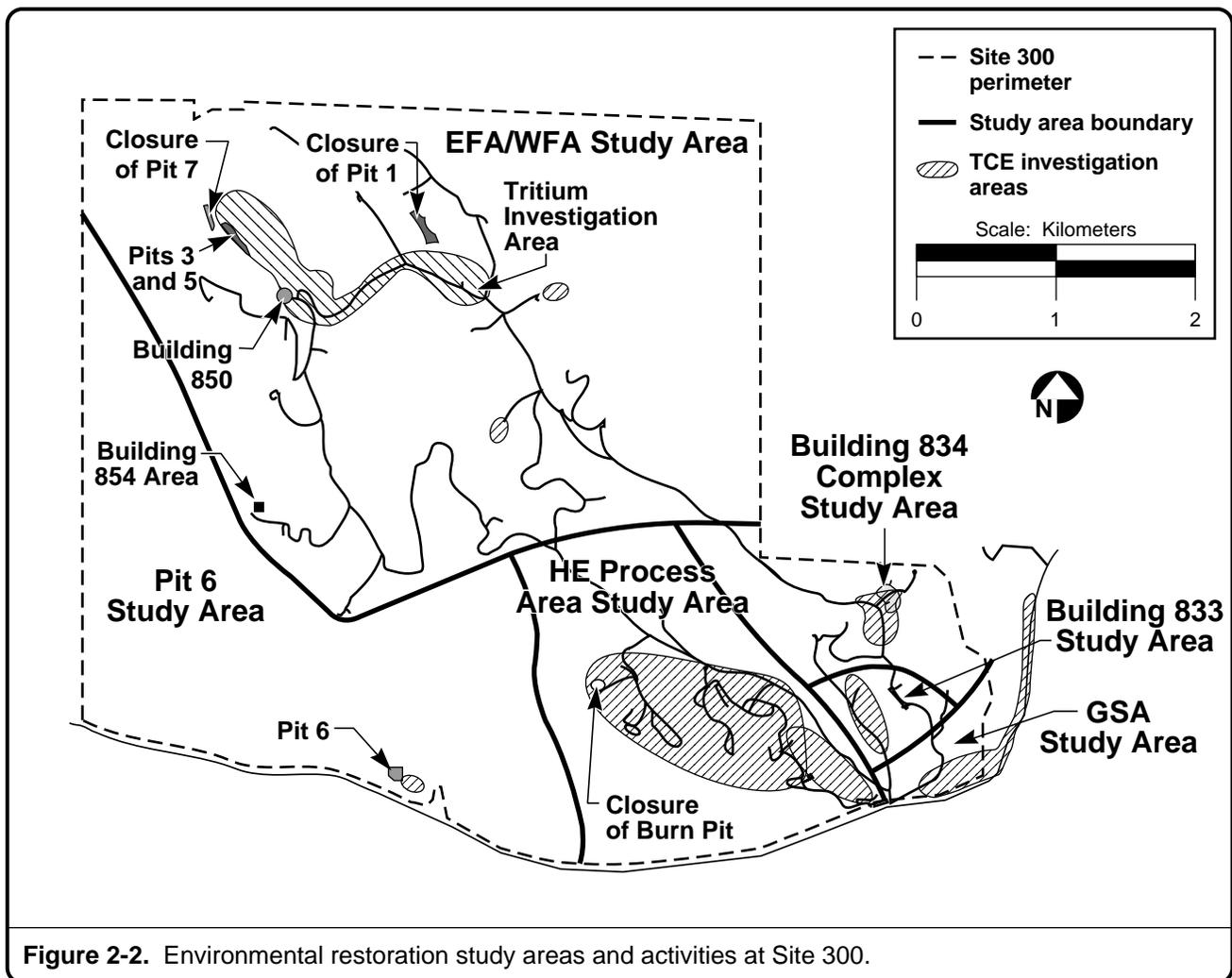
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### Site 300 Environmental Restoration Program

At Site 300, ongoing remedial investigations, feasibility studies, and remedial actions are being performed as a part of the Environmental Restoration Program. Site 300 investigations and remedial actions are conducted under the joint oversight of the EPA, Central Valley RWQCB, and DTSC under the authority of a Federal Facility Agreement for the site (there are separate agreements for Site 300 and the Livermore site). Ground water investigations began in 1981 under the regulatory authority of the Central Valley RWQCB. In August 1990, Site 300 was placed on EPA's National Priorities List under CERCLA. In June 1992, the DOE and LLNL negotiated a Federal Facility Agreement that describes the ground water and soil investigations to be conducted and specifies reporting due dates.

The study areas and constituents of concern at Site 300 include: (1) General Services Area (GSA)—VOCs, primarily trichloroethene (TCE), in soil, rock, and

ground water; (2) Building 834 Complex—TCE in soil, rock, and ground water; (3) High Explosives (HE) Process Area—VOCs, primarily TCE and high-explosive compounds (primarily cyclotetramethyltetramine and 1,3,5-trinitro-1,3,5-triazine in soil, rock, and ground water); (4) East and West Firing Areas—tritium, VOCs (primarily TCE), and depleted uranium in soil, rock, and ground water; (5) Pit 6 Area—VOCs, primarily TCE, in soil, rock, and ground water; and (6) Building 833 Area—TCE in soil and rock (**Figure 2-2**). These study areas roughly correspond to the programmatic areas at Site 300.



### Documentation

Before Site 300 was placed on the National Priorities List, a number of draft remedial investigation and feasibility study reports were completed for the study areas. The draft remedial investigation reports include detailed discussions of the environment, geology and hydrogeology, environmental risk of any



chemicals encountered, and assessment of the potential hazard or risk to public health and safety. The draft feasibility study reports include proposals for remedial action alternatives with cost estimates under several conditions, from no action to full remediation. These reports were submitted to regulatory agencies for consideration of appropriate choices for remediation.

In mid-1991, the regulatory agencies requested that LLNL prepare a sitewide remedial investigation report to replace the previously submitted area-specific individual draft remedial investigation reports. The *Final Site-Wide Remedial Investigation Report* (Final SWRI report; Webster-Scholten 1994) was submitted to EPA, Central Valley RWQCB, and DTSC during 1994. The Final SWRI report is organized by study areas that roughly correspond to the areas covered by the individual remedial investigation reports. It is a compilation of all ground water and soil investigation information for the entire site and contains an assessment of potential human health and ecological hazards or risks resulting from contamination of soil, sediment, and ground water. New feasibility study reports have been or will be prepared for portions of the individual study areas, termed operable units, where the Final SWRI report or more recent studies indicate that unacceptable potential hazards or risks exist.

During 1994, LLNL submitted the *Final Feasibility Study Reports for the Building 834 and Pit 6 Operable Units* (Landgraf 1994; Devany et al. 1994) and the draft proposed plan for remedial actions at the Building 834 operable unit (Landgraf et al. 1994) to the regulatory agencies; the latter report describes the planned remedial strategy.

LLNL is currently working with DOE and the regulatory agencies to streamline the Site 300 CERCLA process by reducing the number of documents and by agreeing on a suitable remediation strategy for each operable unit that can be presented in an engineering evaluation/cost analysis (EE/CA) report. Each remedial action would then be performed as a removal action. The public would be able to comment at public meetings.

Although LLNL is renegotiating CERCLA deliverables and schedules to hasten cleanup, current milestone dates for draft feasibility study reports for the pertinent operable units within their respective study areas are: the GSA operable unit, May 15, 1995 (already submitted); the Building 815 operable unit (HE Process Area study area), December 1, 1995; and the Building 850/Pits 3 and 5 operable unit (East and West Firing Area study area), February 15, 1996. Additional feasibility study or EE/CA reports may be prepared if investigative activities planned at the Building 832 Canyon area (Building 833 study area) and the Building 854, Building 812, and Sandia Test Site areas (East and West Firing Area study area) indicate unacceptable risks or hazards. During 1994, LLNL



submitted characterization plans for these sites to the regulatory agencies in preparation for these investigations.

### General Services Area

This study area is located in the southeastern corner of Site 300. Since 1982, LLNL has conducted an intensive investigation in the GSA and off-site areas to locate VOC release points and to define the vertical and horizontal distribution of VOCs, primarily TCE and tetrachloroethene (PCE), in the soil, rock, and ground water. According to the Final SWRI report and draft remedial investigation (McIlvride et al. 1990) reports, VOCs in excess of drinking water maximum contaminant levels (MCLs) have been identified in the shallow ground water beneath the GSA in two localities. Two small plumes occur in the central section of the study area, and one plume occurs in the eastern section in the gravels of Corral Hollow Creek. An air-sparging ground water treatment unit that removes VOCs from the eastern GSA ground water began operation in June 1991 as a CERCLA Removal Action and was operated throughout 1994. The total volume of water treated here through December 1993 was about 110 million liters; 2.8 kilograms (0.79 liters) of VOCs were removed from the water. The treated ground water was discharged off site to the Corral Hollow Stream Channel. During 1994, an additional 82 million liters of ground water in the eastern GSA were treated to remove approximately 742 grams of VOCs. Before cleanup was initiated, this plume extended about 1,200 meters off site; it now extends about 300 meters off site.

The two plumes of VOCs in ground water in the central GSA are present in alluvium and shallow bedrock and in deeper bedrock. Construction of an air-sparging ground water treatment and vapor extraction unit for a CERCLA Removal Action to remove VOCs from the central GSA ground water and soil vapor was completed in 1993. During 1993, ground water extraction and treatment began, and about 440,000 liters of ground water containing 1,700 grams (129 liters) of VOCs were treated. During 1994, an additional 463,000 liters of ground water containing 650 grams of VOCs were treated. The treated ground water was collected and discharged as a batch in a remote on-site location. Pilot soil vapor extraction and treatment of VOCs began in 1993; 2.4 kilograms (0.44 liters) of VOCs were removed. During 1994, an additional 5.7 kilograms (3.9 liters) were extracted and treated by carbon adsorption. Soil vapor extraction and treatment are ongoing.

Following additional investigations conducted during 1993–1994 to better define the extent of ground water contamination, work on the draft feasibility study report began in 1994, and was submitted to the regulatory agencies on May 15, 1995.



### Building 834 Complex

The Building 834 Complex is located in the east-central portion of Site 300. An isolated, perched aquifer that contains TCE in excess of the MCL of 5 ppb has been defined and reported in the Final SWRI report, *Draft Remedial Investigation and Feasibility Study for the Lawrence Livermore National Laboratory Site 300 Building 834 Complex* (Bryn et al. 1990), and The *Final Feasibility Study Report for the Building 834 Operable Unit* (Landgraf et al. 1994). Techniques have been evaluated and pilot-tested to remove TCE vapor from the vadose zone above the water table and from the shallow perched water. Water was extracted by pumping from extraction wells and from soil vapor extraction wells under vacuum. Pilot remediation began during 1993 at the Building 834 Complex, where about 300 kilograms (200 liters) of TCE have been removed from the unsaturated sediment soil vapor and ground water by extraction and treatment. Ground water has been treated by air sparging. Vapor-phase TCE has been treated by carbon adsorption; successful experiments have been conducted at Building 834 for the breakdown of TCE with ultraviolet-light flash lamps and an electron beam accelerator. During 1993, the pilot extraction system was upgraded in preparation for a CERCLA Removal Action, which began in 1994. Proof-of-system testing was conducted during 1994.

During 1994, LLNL submitted the Final Feasibility Study Report (Landgraf et al. 1994) and the Draft Proposed Plan (LLNL 1994) for the Building 834 Complex to the regulatory agencies. The proposed remedial strategy for the operable unit is ground water and soil vapor extraction and treatment. LLNL is pursuing an interim Record of Decision (ROD) to promote the use of innovative technologies such as surfactants for enhanced removal of VOCs by soil vapor and ground water extraction.

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### HE Process Area

During field investigations of ground water, concentrations of TCE above MCLs and low concentrations of the high-explosive compound 1,3,5-trinitro-1,3,5-triazine were discovered in two perched water-bearing zones within the HE Process Area near Buildings 815 and 817 (Crow and Lamarre 1990; Webster-Scholten 1994). Discharges of rinse water from buildings within the HE Process Area historically have been disposed of in unlined lagoons adjacent to the processing buildings. Use of these lagoons was terminated in 1985; the lagoons were closed and capped with impermeable clay in 1989. Sporadic, but generally low, concentrations of high-explosive compounds, metals, and VOCs were identified in the vadose zone beneath some of the lagoons, but these contaminants have not migrated to the underlying ground water (Webster-Scholten 1994). During 1994, additional investigations were conducted in the study area,

and the full extent of the contamination has been determined. The feasibility study for the Building 815 operable unit has been put on hold pending renegotiation although the draft feasibility study is scheduled for submittal to the regulatory agencies on December 15, 1995.

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### East and West Firing Areas

Debris from explosive tests historically conducted in this study area in the northern part of Site 300 was disposed of in adjacent landfill pits; these landfill pits are designated Pits 1 and 2 in the East Firing Area (EFA), and Pits 3, 4, 5, and 7, collectively termed the Pit 7 Complex, in the West Firing Area (WFA). In 1981, the Hazardous Waste Assessment study of the hydrology, geology, and ground water chemistry associated with Site 300 landfills was initiated. As part of this project, monitoring wells were installed at the landfills, and a program of periodic ground water monitoring was initiated. In 1984, tritium activities in water from four of the wells rose above the California MCL for drinking water, which is 740 Bq/L (20,000 pCi/L).

A tritium investigation was initiated, and two areas where tritium occurs in ground water above background activities and MCLs have been delineated: (1) the Pit 7 Complex, and (2) the area of Building 850, Doall Road, and Elk Ravine in the East and West Firing Areas. **Figure 2-3** shows the distribution of tritium in ground water for October 1994. The Final SWRI report indicates that, for this second area, tritium was released to the subsurface by percolation of rainfall runoff and dust control water through contaminated Building 850 firing table gravels to ground water. In the first area, tritium was released to ground water from Pits 3 and 5 (in the Pit 7 Complex) by heavy winter rains in 1982–1983, 1986–1987, and 1991–1992 and the resulting rising water tables. Computer modeling of the transport and fate of the tritium indicates that by the time the tritiated water from sites of known ground water contamination reaches the Site 300 boundary, the tritium will have decayed to near background activities. Details of the remedial investigation for the East and West Firing Areas are discussed in the Final SWRI report.

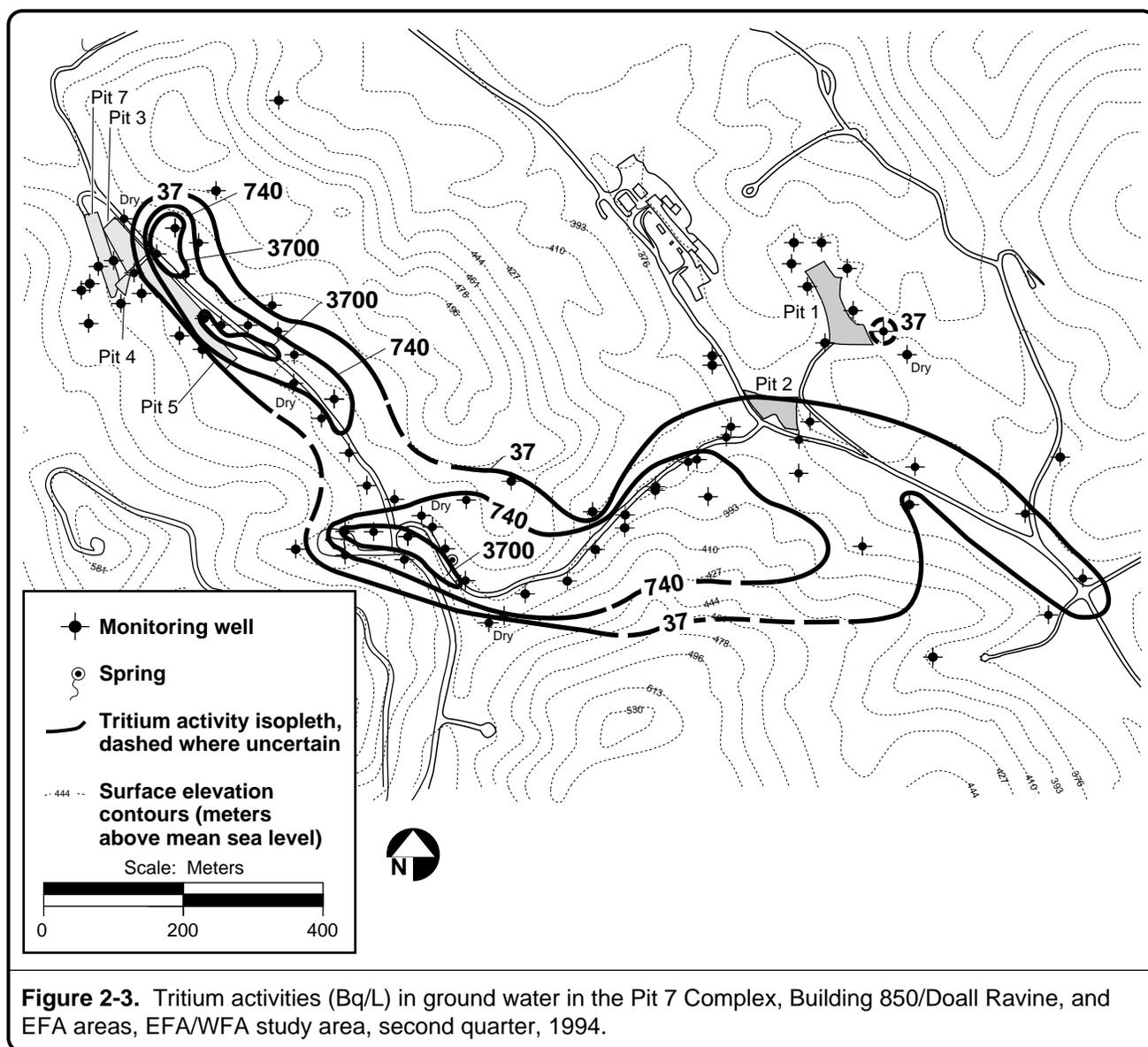
Past monitoring has also revealed trace amounts of TCE in ground water near the Pit 7 Complex (from Pit 5) and at Building 801. Freon-113 at concentrations far below the California maximum contaminant level of 1.2 ppm is present near Pit 1 and is the result of spills at Building 865 (Advanced Testing Accelerator).

During 1994, total uranium activities in excess of the state MCL of 0.74 Bq/L (20 pCi/L) continued to be measured in samples from several ground water monitoring wells at the Pit 7 Complex; several of these wells yielded samples bearing isotopic ratios indicative of depleted uranium. Conversely, samples of

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ground water from several wells in the area contain uranium activities in excess of the state MCL but bear natural uranium isotopic signatures. Analyses of ground water samples from several wells adjacent to Building 850 also indicate depleted uranium signatures; these samples are not in excess of the state MCL for uranium. Additional field work was conducted at Building 850 and Pits 3 and 5 to define the nature and extent of uranium isotopes, polychlorinated biphenyls (PCBs), dioxins and furans, and VOCs in soil, rock, and ground water. These chemical results are being integrated into the risk assessment for the operable unit. The draft final feasibility study for the Building 850/Pits 3 and 5 operable unit is on hold pending schedule negotiations but is currently scheduled for completion by February 15, 1996.





Characterization plans for the Building 854, Building 812, and Sandia Test Site portions of the East and West Firing Areas were submitted to the regulatory agencies during 1994. The characterization work outlined will be performed during 1995–1998.

During December 1992, LLNL completed the capping of landfill Pits 1 and 7. This work was conducted under an LLNL Resource Conservation and Recovery Act (RCRA) closure plan previously approved by DTSC; the legal date of closure was February 12, 1993. The primary components of the closure design are a closure cover system, surface water control system, and subsurface water control system. Quarterly and annual inspection and maintenance of the RCRA landfill caps continues.

During 1994, LLNL properly sealed and abandoned water supply Well 1, which was screened across several water-bearing zones that contained elevated tritium activities.

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### **Pit 6 Area**

The Final SWRI report and *Draft Remedial Investigation of Landfill Pit 6* (Taffet 1990) discuss the small plume of TCE (in excess of MCLs) in ground water that discharges to the surface at small springs at the southeastern edge of the Pit 6 area. The source of the plume is the Pit 6 landfill. Due to natural volatilization of affected ground water at the springs, concentrations of VOCs in the plume have been declining since 1992. The *Final Feasibility Study Report for the Pit 6 Operable Unit* (Devany et al. 1994) was released in 1994 and discusses options for remediation in this area.

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### **Building 833 Area**

Low concentrations of TCE and associated VOCs have been detected in shallow soils and sediments (to a depth of 15 meters) beneath the Building 833 Area. During the remedial investigation of the Building 833 area, VOC concentrations of up to 1,800 micrograms per liter of water were detected in ground water in two boreholes. Results of the investigation were published in the Final SWRI report and in the *Draft Remedial Investigation of the Building 833 Area* (Webster-Scholten et al. 1991). Although past investigations documented in the Final SWRI report do not indicate risk or hazard above acceptable levels, additional investigation began in 1994 at the Building 832 Canyon portion of the study area. This investigation is scheduled for completion during 1996. Remedial actions will be evaluated if unacceptable risk or hazard is indicated at the Building 832 Canyon area.



### Community Relations

The Site 300 Environmental Restoration Division (ERD) CERCLA project maintains open communication with the surrounding communities of Tracy and Livermore. During September 1994, ERD distributed the second Site 300 Environmental Restoration Fact Sheet (Heffner 1994) to over 250 concerned citizens, regulatory agencies, and elected officials. The fact sheet was also distributed to LLNL main site and Site 300 employees. ERD also distributed the Environmental Community Letter to the public; this circular contains information about Site 300 investigation and cleanup activities. In April 1994, LLNL sent a letter that described the Building 834 Interim Treatment CERCLA Removal Action (ground water and soil vapor extraction and treatment) to the same 250 or so people on the community relations mailing list (Heffner 1994). Other community relations activities conducted during 1994 included beginning dialogue with Tri-Valley CAREs, maintenance of the information repositories and administrative records, Site 300 tours for scientists and students from universities and local public schools, and support for off-site private well sampling activities.

### Superfund Amendment and Reauthorization Act of 1986, Title III

Title III of SARA is known as the Emergency Planning and Community Right-to-Know Act (EPCRA). It requires owners or operators of facilities that have certain hazardous chemicals on site to provide information on the storage and use of those chemicals to organizations responsible for emergency response planning. In California, chemical inventory information is provided to the California Chemical Emergency Planning and Response Commission and the local administering agency. Executive Order 12856, signed by President Clinton on August 3, 1993, directs all federal agencies not only to comply with the chemical inventory requirements of EPCRA but also to participate in the SARA 313 Toxic Release Inventory Program beginning in calendar year 1994.

LLNL's ChemTrack is an important tool for improving the overall management of hazardous materials at LLNL. It tracks chemical inventories at LLNL through the use of bar codes, laser scanners, and customized software, and enhances LLNL's ability to obtain toxic release information necessary to complete SARA 313 submittals. ChemTrack currently has an inventory of nearly 200,000 chemical containers ranging from 210-liter drums to gram-quantity vials.

ChemTrack includes a chemical locating service that allows LLNL researchers to find and share chemicals. This minimizes the purchase of new chemicals, thereby reducing procurement costs and the generation of hazardous waste. In addition, ChemTrack data is being used by various LLNL organizations to provide for improved emergency response planning and management of Material Safety Data Sheets, to more closely track specific high-hazard chemicals and other regulated substances, and as a screening tool for conducting preliminary hazard analyses of selected LLNL facilities.



### Resource Conservation and Recovery Act

RCRA provides the framework at the federal level for regulating the generation and management of solid wastes, including wastes designated as hazardous. Similarly, the California Hazardous Waste Control Act (HWCA) sets requirements for managing hazardous wastes in California. RCRA and HWCA also regulate hazardous waste treatment, storage, and disposal facilities, including permit requirements.

In January 1993, the California Legislature made extensive changes in the laws governing the treatment and storage of hazardous wastes. The changes established five levels, or tiers, of permitting for hazardous waste treatment and storage activities, and they reduced the regulatory requirements for many storage and treatment activities that required a hazardous waste permit under state authorization but not under federal laws.

During 1993, LLNL continued discussions with the DTSC regarding classification of LLNL's waste accumulation areas (WAAs). These negotiations resulted in a January 1994 verbal agreement to allow the WAAs to revert to 90-day "generator" storage units provided LLNL ensures that storage in the WAAs does not exceed 90 days and that the aggregate volume in storage at any one time in the WAAs does not exceed 189,000 liters. This agreement was incorporated into the RCRA Parts A and B permit application, which was revised in March 1994 and submitted to DTSC.

### Hazardous Waste Reports for 1993 and 1994

The 1993 federal report (biennial report) for both the Livermore site and Site 300 are required under 40 CFR 262.41, 264.75, and 265.75. These reports were completed and delivered to EPA on April 28, 1994, by the adjusted deadline. The annual reports, which cover 1994 waste-handling information, were completed and submitted to DTSC by their adjusted April 30, 1995, deadline. The annual reports are required under 22 CCR 66264.75.

Both reports are maintained on file at LLNL and comprise four forms. The Identification and Certification form provides general facility information, including addresses, contacts, and general waste minimization information. The Generation and Management form includes "cradle-to-grave" tracking of each waste stream category. The Waste Received form includes descriptions and quantities of wastes that were received from off-site facilities (Site 300 and the Livermore Airport), and the Process System form includes waste quantities treated by each waste management unit on site. DTSC will add two new forms to the 1994 annual report: one covering closure/post closure estimates, and another to document waste cessation within permitted facilities.

## 2. Compliance Summary



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Hazardous Waste Permits	<p>The Livermore-site hazardous waste storage and treatment management units continue to operate under interim status provisions (ISD CA2890012584). Waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction).</p> <p>Because RCRA program authorization was delegated to the State of California in 1992, LLNL now works solely with DTSC in obtaining a hazardous waste permit for the Livermore site. After LLNL submitted the Part A permit application revision on December 18, 1992, and the Part B permit application revision on April 30, 1993, DTSC asked LLNL to make additional modifications to both parts of the permit application. Accordingly, newly revised applications were submitted to DTSC on March 1, 1994.</p> <p>The Site 300 Building 883 hazardous waste container storage area (CSA) continues to operate under the provisions of the Part B permit (Part B CA28990090002) issued by EPA and DTSC in November 1989. A Class 1 modification to the permit was approved in July 1994 to correct a violation noted in the March 31, 1992 Report of Violation issued by DTSC and to update the permit due to personnel changes. A permit renewal application for the Building 883 CSA was submitted in May 1994 and is still being reviewed by DTSC.</p> <p>The Building 829 Open Burn Facility for explosives waste continues to operate under an enforcement order received from DTSC in September 1993. Two new facilities have been proposed for Site 300, and Part B permit applications have been submitted for each facility. One is an explosives waste storage facility that augments the storage capability at the Building 883 CSA by providing a separate dedicated facility to store explosives waste. The other facility is a new Open Burning/Open Detonation Facility (the Explosives Waste Treatment facility, EWTF) that will replace the existing Building 829 Open Burn Facility.</p>
Extremely Hazardous Waste Permit	<p>Permit No. 2-13640 is required, pursuant to 22 CCR 67430.1, to transport extremely hazardous waste to an off-site hazardous waste disposal facility. As a condition of the permit, LLNL must prepare a list of extremely hazardous wastes (including concentration, quantity, packaging, proposed hauler, disposal facility, and proposed method of disposal), and submit it to DTSC two weeks before shipping any such waste. This permit must be renewed annually; the application for renewal was submitted in August 1994.</p>
Hazardous Waste Transport Registration	<p>This registration is required, pursuant to 22 CCR 66263.10, to transport hazardous wastes over public roads (e.g., from one LLNL site to another). Conditions for registration include annual inspections of transport vehicles and</p>

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trailers by the California Highway Patrol, special training and annual physical examinations for drivers, and annual submission of lists of transport vehicles and trailers to DTSC. The registration was renewed by DTSC in November 1994.

### Medical Waste Permit

LLNL generates several types of medical wastes (previously identified as infectious wastes). In July 1991, LLNL registered with the Alameda County Environmental Health Services as a large-quantity generator of medical waste, and submitted an application for a medical waste treatment permit for the Livermore site. The registration and application contained detailed information concerning the management and treatment of medical wastes generated by LLNL's biomedical research, Center for Chemical Forensics, and health services facilities, as well as medical wastes generated at Site 300. The treatment permit was issued in August 1991 and is valid through July 1996. The registration is issued annually and is currently valid through July 1995.

The Alameda County Department of Environmental Health conducted an inspection of LLNL's medical waste generator and treatment facilities on August 18, 1994. No violations were noted at any of the facilities.

### Inspections of Hazardous Waste Management Facilities

From May 16–18, 1994, DTSC Region 2 inspected all four Hazardous Waste Management (HWM) facilities (Areas 612, 514, 233, and 693), the Building 231 hydrogen-fluoride (HF) scrubber, 13 WAAs, three workplace accumulation areas (WPAAs), aboveground retention Tank 231-R2A1, hazardous waste storage Tank 406-R1A1, the Fleet Maintenance and Transportation Group's registered hazardous waste hauling vehicles, and two conditionally exempt (CE) resin-mixing units. Also on May 18, 1994, DTSC reviewed the following types of records: inspections, hazardous waste manifests, land disposal restriction notifications, interim status document, and conditionally exempt treatment unit operating logs, contingency plans, and training records.

On June 1, 1994, DTSC held an on-site close-out meeting and delivered a Field Report of Violation listing seven alleged violations and the Tiered Permitting Verification Inspection Report listing one alleged violation. LLNL responses to the violations include correcting an improperly marked label, remarking a hazardous waste hauling vehicle, revising the inspection form for Building 419, shipping a container to a HWM facility for storage, and ensuring an employee received his annual training. LLNL disagreed with a portion of an alleged violation requiring Land Disposal Restriction notification.

DTSC conducted an inspection of the Site 300 hazardous waste facilities on December 6–7, 1994. No violations were noted during the inspection.



### Waste Accumulation Areas

In December 1994, there were 43 WAAs in operation at LLNL: 42 at the Livermore site and one at the Livermore Airport. Environmental Protection Department personnel performed over 950 WAA walkthroughs at the Livermore site and the Livermore Airport during 1994. The walkthroughs are informal checks of items such as capacity, labeling, and secondary containment; formal inspections of these items are conducted by personnel in the programs using the WAA.

There were five WAAs that were taken out of service, and one WAA was reclassified as a hazardous waste retention tank system at Site 300 during 1994. This left a total of seven operational WAAs at Site 300 in December of 1994. Environmental Protection Department personnel performed over 250 WAA walkthroughs at Site 300 during 1994.

### Underground Storage Tank Management

LLNL manages its underground storage tanks (USTs) through the use of underground tank permits, tank integrity testing, closure and leak documentation, the Tank Upgrade Project, remedial activities, and inspections. Those topics are discussed in the following sections.

### Underground Tank Permits

Underground tanks contain diesel fuel, gasoline, waste oil, and potentially contaminated wastewater; aboveground tanks contain diesel fuel, insulating oil, TCE, and contaminated wastewater. Some of the wastewater systems are a combination of underground storage tanks and aboveground storage tanks. **Table 2-2** tabulates tank status as of December 31, 1994.

The number of USTs requiring tank permit fees during all or part of 1994 at the Livermore site decreased by five, from 33 in 1993 to 28 in 1994. The 28 tanks for which fees were paid consisted of the 24 permitted USTs noted in the table, along with four additional tanks that were either removed or replaced with aboveground storage tanks (ASTS) in 1994. A total of 10 USTs need to be upgraded by the 1988 deadline. Four of the 24 permitted USTs consisted of diesel tanks that were replaced with double-walled underground tanks with leak detection.

At the end of 1994, Site 300 had a total of five underground petroleum product tanks in service: four diesel storage tanks and one gasoline storage tank. Eight diesel USTs were closed in 1994; five of these eight were replaced with ASTS, while one was replaced with an UST. The two remaining diesel USTs were closed without replacement. In addition, the two gasoline USTs that were removed in 1993 were replaced by a single UST in 1994. Fees were paid for seven tanks during 1994, including the five permitted USTs noted in the table and two tanks that were removed in 1994 and replaced with aboveground storage tanks.

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**Table 2-2.** Status of In-service tanks, December 31, 1994.

Tank Type	Livermore Site			Site 300		
	Permitted	No Permits Required	Total	Permitted	No Permits Required	Total
<b>Underground Storage Tanks</b>						
Petroleum						
Diesel	8	0	8	4	0	4
Gas	2	0	2	1	0	1
Oil	1	0	1	0	0	0
Wastewater	13	63	76	0	10	10
<b>Subtotal</b>	<b>24</b>	<b>63</b>	<b>87</b>	<b>5</b>	<b>10</b>	<b>15</b>
<b>Aboveground Storage Tanks</b>						
Diesel	0	27	27	0	12	12
Wastewater	7 <sup>(a)</sup>	87	94	0	15	15
<b>Subtotal</b>	<b>7</b>	<b>114</b>	<b>121</b>	<b>0</b>	<b>27</b>	<b>27</b>
<b>TOTAL</b>	<b>31</b>	<b>177</b>	<b>208</b>	<b>5</b>	<b>37</b>	<b>42</b>

<sup>a</sup> These seven tanks are situated at the LLNL Treatment, Storage, and Disposal Facility and are generated under interim status as part of the RCRA Part B permit application.

### Tank Integrity Testing

Under the tank leak-tightness testing program, hazardous waste and hazardous product USTs are tested to determine structural integrity in accordance with requirements established in state and federal regulations. The underground portions of tank systems are tested (as a whole or by component parts) using methods that may include precision tests, dye tests, helium-injection detection, and hydrostatic tests. All leak-tightness test results for regulated systems are provided to Alameda County Environmental Health Services or San Joaquin County Public Health Services. Two diesel fuel USTs at the Livermore site and three diesel fuel USTs at Site 300, which have capacities in excess of 7,600 liters, were tested on a monthly basis throughout the year. The results of the testing were forwarded to the respective regulatory agencies.

Seven diesel USTs at the Livermore site and four diesel USTs at Site 300 were tested in 1994 as part of the state and federal requirements for annual testing of single-walled USTs. The two gasoline USTs at Site 300 were not tested in 1994 because they were removed in March of 1994.

On December 20, 1993 at the Livermore site, holes were discovered on the top of an underground storage tank while it was being removed. Although the tank had been tested and certified to be product tight on December 8, 1993, it was determined that the holes had existed for some time and were present during the tank test. This information prompted an appraisal of the tank tester's method



and procedures. It was discovered that the tester had modified the state-certified procedure, eliminating the standpipe that is used to provide constant head pressure while testing. Upon further investigation, it was discovered that this modified procedure was used on other tanks in 1993. A total of 17 tanks were retested by another state-certified tank tester to ensure validity of all test data. The situation was reported to DOE as an off-normal occurrence. Retesting was completed on January 12, 1994, and all of the tanks that were retested were leak tight. Both the Alameda County Health Agency and San Joaquin Public Health Agency were notified of these findings.

### Closure and Leak Documentation

Closure requirements for hazardous USTs include the preparation and approval of a closure plan for the system, quarterly reports if leaks have been identified, and a report upon completion of closure activities. The closure plans must include a detailed review of the uses of the tank, a sampling plan, a site plan, and other information to verify that no environmental contamination has occurred or, if it has occurred, to ensure its cleanup.

A total of 48 closure plans were prepared in 1994 for tank systems (or portions of systems) that were taken out of service, previously removed (but not officially closed), or expected to be removed from service. Thirty of these closure plans—for hazardous product, hazardous waste, or mixed-waste tank systems—were approved by regulatory agencies. The 18 remaining closure plans were prepared and approved for nonhazardous waste tank systems as a part of LLNL's best management practices.

Upon completion of closure activities, closure reports for hazardous product, hazardous waste, and mixed waste USTs must be submitted to the regulatory agencies for review and approval. Twenty-four closure reports for hazardous product USTs were submitted to regulatory agencies for review in 1994. Twenty-three of these closure reports received county approval in 1994; one is pending approval in 1995. There were two closure reports prepared in 1994 for above-ground hazardous product tanks as a part of LLNL's best management practices.

In 1994, LLNL submitted unauthorized release (leak)/contamination site reports to the regulatory agencies for 10 petroleum USTs. Unauthorized release/contamination from five diesel USTs, three located at the Livermore site and two at Site 300, were discovered based on soil sample results. The results indicated diesel contamination. Three unauthorized release reports, all at Site 300, were initiated during the actual removal of the tank. Contamination was based on both visual certification and the presence of a strong diesel odor. One unauthorized release report was initiated after a helium test indicated that a hole was present in the gasket area of the manway. This tank was replaced with an above-ground storage tank. The final unauthorized release/contamination was

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indirectly associated with the two gasoline USTs that were located at Site 300. During the excavation of these two tanks, the city water supply line was ruptured, and water filled the excavation.

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### Tank Upgrade Project

In fiscal year 1992, LLNL received funding for four years to upgrade or close approximately 126 tanks in accordance with existing local, state, and federal tank regulations or to decrease the potential for environmental contamination as the result of a release from a tank or its appurtenances. These tanks include wastewater retention tanks (for nonhazardous, hazardous, mixed, and radioactive waste) and product retention tanks (for petroleum products). In fiscal year 1993, additional funding was granted to provide overflow and spill protection to aboveground oil-filled electrical equipment (e.g., transformers) and additional aboveground petroleum tanks, resulting in a revised total of 214 tanks or transformers being closed or upgraded. In 1994, the remaining nonhazardous tank systems were dropped from the overall scope, reducing the number of tanks and transformers to 158. As of December 1994, construction was completed for 56 tanks, construction is in progress for 43 tanks, design was completed for 102 tanks, and design is in progress for 52 tanks.

Closure and corrective action reports were submitted to San Joaquin County in 1994 on the removal of underground fuel supply tanks at Buildings 827, 829, 834, 836, 865, 871, and 879. Cleanup of the associated contaminated gravels and soils was documented in these reports.

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### Remedial Activities

In 1994, data continued to be collected to evaluate the tritium activities in the Building 292 Area subsurface, where tritiated rinse water leaked from an UST. Tritium activities fluctuated between about 260 and 1,370 Bq/L (7,000 and 37,000 pCi/L) during 1994. The tritium activity trend followed the ground water elevation trend throughout the year with the tritium activity above the 740 Bq/L (20,000 pCi/L) drinking water standard.

The data collected for the Building 292 Area have been incorporated into a vadose zone computer model to provide estimates of tritiated moisture movement within the subsurface. The model has been verified with experimental results, and work is in progress to assign values to locations where there are no measured data.

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### Inspections

For every installation and closure of hazardous waste, mixed waste, and hazardous product USTs, there is an inspection in which a representative from Alameda County Environmental Health Services (for the Livermore site) or San Joaquin County Public Health Services (for Site 300) participates. For 1994,



there were 17 inspections by the former and 16 inspections by the latter. There were no notices of violation or notices of deficiency received as a result of any of these inspections.

In December 1994, the San Joaquin County Public Health Services performed a sitewide inspection of the five remaining in-use underground storage tanks at Site 300. All five systems are doubly contained and continuously monitored for leak tightness. All other Site 300 underground fuel storage tanks systems have been closed and not replaced, or replaced with aboveground tank systems. When the inspection was completed, LLNL received an "Underground Tank Official Inspection Report" dated December 27, 1994, indicating there were no violations.

### National Environmental Policy Act

The National Environmental Policy Act (NEPA—42 U.S.C. 4321 et seq.) establishes federal policy for protecting environmental quality. The major method for achieving established NEPA goals is the requirement of an Environmental Impact Statement (EIS) for any major federal or federally funded project that may have significant impact on the quality of the human environment. If the need for an EIS is not clear, or if the project does not meet DOE's criteria for requiring an EIS, an Environmental Assessment (EA) is prepared. A Finding of No Significant Impact is issued when the EIS is determined to be unnecessary.

Certain groups of actions that do not have a significant effect on the environment either individually or cumulatively can be categorically excluded from more in-depth NEPA review (i.e., preparation of either an EA or EIS). DOE NEPA implementing procedures identify those categorical exclusions. If a proposed project does not clearly fit one of the exclusion categories, an Action Description Memorandum is prepared to determine which type of assessment document may be needed.

### Environmental Assessments Submitted to DOE

In 1994, LLNL prepared 30 categorical exclusion documents for DOE review to comply with NEPA. DOE issued no Findings of No Significant Impact in 1994 for the EAs submitted earlier for DOE determination. Two draft EAs for proposed projects were submitted to DOE in 1994 for NEPA determination.

The *Draft Environmental Assessment for the Mixed Waste Management Facility (MWMF; Khan 1994)* addressed the potential impacts from construction and operation of a facility that will demonstrate potential technologies for treating DOE mixed waste on a pilot scale. Based on the results of this research, certain of the technologies may be adopted later by DOE for treatment of mixed wastes throughout DOE's facilities. DOE is currently reviewing this draft EA.

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*Draft Environmental Assessment for the Site 300 Explosives Waste Treatment Facility (EWTF; McDowell 1994)* addressed the potential impacts of constructing and operating up-to-date replacement facilities for treating explosives wastes and explosives-contaminated wastes at Site 300. DOE is currently reviewing this draft EA.

### Floodplain Management and Wetland Protection

Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), both dated May 24, 1977, require each federal agency to issue or amend existing procedures to ensure that the agency evaluates the potential effects of any action it may take in a floodplain (Order 11988), and to consider wetland protection in its decision-making (Order 11990). DOE's policy (10 CFR 1022) is to implement these Executive Orders through existing NEPA review procedures. LLNL applies the requirements of the DOE wetlands/floodplains policy and procedures through the NEPA review process for each proposed LLNL action. In accordance with DOE policy, a separate public notice and floodplain/wetlands assessment may be required for certain proposed actions and would be prepared if no EA- or EIS-level NEPA documentation incorporating such assessments had been prepared. In 1994, there were no proposed LLNL actions that required such separate DOE assessments.

### California Environmental Quality Act

The California Environmental Quality Act (CEQA—California Public Resources Code Sections 21000 et seq.) establishes state policy for protecting environmental quality. The goals of CEQA are achieved by requiring local and state agencies to assess the potential environmental impacts of proposed actions for which they may have a decision-making role. This is done through the preparation of an Initial Study, which leads to issuance of a Negative Declaration or a requirement to prepare an Environmental Impact Report (EIR). An EIR may also be prepared directly for projects that may have significant environmental impacts.

No Initial Study or EIR documents were prepared by the University of California (UC) in 1994 on proposed projects for which the UC was the decision-making or lead agency.

In November 1992, UC and LLNL made a commitment to implement 67 mitigation measures identified by the 1992 EIS/EIR (*Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (U.S. Department of Energy and University of California 1992a,b) and to provide annual reports on their implementation. The measures are being implemented in accordance with the approved 1992 Mitigation Monitoring and Report Program, and the first annual report was published in March 1994.



### Endangered Species Acts and Sensitive Natural Resources

As a federal facility within California, LLNL must meet the requirements of both the U.S. Endangered Species Act and the California Endangered Species Act as they pertain to endangered or threatened species and other species of special concern that may exist or are known to exist at the LLNL sites. For example, in implementing the Mitigation Monitoring and Reporting Program in 1994, biological assessment surveys were performed for special-status species at 42 Site 300 project construction (ground disturbance) areas. Presence data for the San Joaquin kit fox (*Vulpes macrotis mutica*), American badger (*Taxidea taxus*), and burrowing owl (*Speotyto cunicularia*) were collected at each project location, and other applicable mitigation measures were implemented when required.

During 1994, no active San Joaquin kit fox dens were discovered, but seven potential dens were found. One occupied American badger den was discovered, and 40 unoccupied dens were identified. Five active burrowing owl dens were discovered, and two potential dens were identified. In addition, several animal species not previously observed were recorded on site, and two new blue elderberry bush locations were delineated. **Table 2-3** lists those special-status animal species previously not known to occur on LLNL property, but first observed in 1994.

**Table 2-3.** Additional special-status species observed in 1994 at LLNL.

Species	Location	Federal Status	State Status
Long-eared owl ( <i>Asio otus</i> )	Site 300	—	Species of Special Concern
Double-crested cormorant ( <i>Phalacrocorax auritus</i> )	Livermore site	—	Species of Special Concern
Ferruginous hawk ( <i>Buteo regalis</i> )	Livermore site, Site 300	Candidate (II)	Species of Special Concern
Swainson's hawk ( <i>Buteo swainsoni</i> )	Site 300	—	Threatened
Merlin ( <i>Falco columbarius</i> )	Site 300	—	Species of Special Concern

In the fall of 1992, LLNL investigators began a project to establish two new experimental populations of the large-flowered fiddleneck (*Amsinckia grandiflora*), a federally listed endangered plant species, into a portion of its designated critical habitat at Site 300. The investigators are also studying the causes of the species decline. This work is funded through a Laboratory Directed Research and Development grant and is being conducted in collaboration with Mills College (representing the California Department of Fish and Game) and UC Davis, with the approval of the U.S. Fish and Wildlife Service.



Researchers from Mills College and UC Davis made numerous trips to Site 300 between October 1993 and May 1994 to work with LLNL personnel on both the experimental and natural populations. The natural populations are located adjacent to the Building 858 Drop Tower (known as the Drop Tower population), and at a site one canyon to the west, which is known as the Draney Canyon population. The experimental populations are located near the Drop Tower natural population. On April 7, 1994, LLNL personnel counted 1,606 mature plants in the Drop Tower population, up from the 301 plants observed in 1993. This increase is a direct result of the use of grass-selective herbicides to reduce competition from the exotic grasses in the area. On April 19, 1994, LLNL personnel counted 16 mature plants in the Draney Canyon population.

The census information was provided to the California Department of Fish and Game. Only one of the two experimental populations contained adult plants. This population had a total of 248 mature plants; however, this was primarily a result of additional seeding and transplantation. Work on this experimental population will continue through 1995, at which point it will be allowed to naturally rejuvenate.

### **National Historic Preservation Act**

The National Historic Preservation Act, as amended through 1992, contains two primary sections that apply to federally operated and funded installations such as LLNL; Sections 110 and 106. Section 110 sets forth the broad affirmative responsibilities for balancing agency missions with cultural values. Its purpose is to ensure that historic preservation is fully integrated into federal agency programs. Section 106 (36 CFR 800) requires federal agencies to take into account the effects their projects may have on "historic properties" (cultural resources), and they must allow a reasonable time period for the Advisory Council on Historic Preservation to comment.

Consultation with the State Historic Preservation Office began in 1994 with an immediate goal of developing an interim programmatic agreement. This document will enable DOE/OAK and LLNL to implement temporary compliance measures for federal cultural resource management while the Cultural Resource Management Plan is developed. Overview documentation of past cultural resource management activities was also submitted to the DOE Oakland Operations Office and the State Historic Preservation Office. In the interim, cultural resource management reviews of project activities are conducted in accordance with federal and state standards, and the LLNL archaeologist performs surveys on a project-by-project basis.



LLNL participated in the following activities and initiatives in 1994:

- Performed the Shovel Test Project for the residential portion of the Carnegie Site at Site 300.
- Established an Archaeological Laboratory that contains facilities for mapping, photography, program and project electronic database management, artifact accessioning, and archival storage.
- Prepared an archival slide presentation on the 1890–1918 historic period of Corral Hollow Canyon for public outreach.
- Conducted a meeting between research-oriented archaeologists and Laboratory scientists on April 26, 1994, to present research investigations and explore common areas and mutual interests with a view towards future partnerships.

### **Clean Water Act and State Programs—Waste Discharge Requirements**

Preserving clean water is the subject of local, state, and federal regulations. The National Pollutant Discharge Elimination System (NPDES) under the Federal Clean Water Act establishes permit requirements for discharges into navigable waterways. In addition, the State of California requires permits, known as Waste Discharge Requirements (WDR) for any discharges of wastes that could adversely affect the beneficial uses of waters of the state. The RWQCBs are responsible for issuing and enforcing both permit types. The Livermore Water Reclamation Plant requires permits for wastewater discharges to the city sanitary sewer system. Finally, the California Department of Fish and Game requires streambed alteration agreements for any work that may disturb or impact rivers, streams, or lakes.

LLNL does not currently have any projects subject to permitting under Section 404 (wetlands) of the Clean Water Act, administered by the Army Corps of Engineers.

### **Ground Water and Surface Water Discharge Permits**

WDR Order No. 88-075, issued by the San Francisco Bay RWQCB, pertains to activities undertaken to investigate and remediate contaminants in ground water at the Livermore site. The order allows treated ground water that meets specified standards to be discharged to specified areas on DOE property. LLNL also holds an NPDES permit (CA0029289, WDR Order No. 91-091) for treated ground water discharged to the ground, storm drains, arroyos, injection wells, and infiltration trenches at the Livermore site. The treated ground water is from ground water investigation monitoring wells and ground water treatment facilities. As adopted into the CERCLA Record of Decision, LLNL follows the substantive requirements of CA0029289 as applicable, relevant, and appropriate requirements. The administrative requirements of this permit are no longer



followed, including reporting, payment of fees, and permit renewal. The self-monitoring programs required by this permit and the CERCLA Record of Decision are described in Chapter 13 on Compliance Self-Monitoring. Analytical results are presented in the *LLNL Ground Water Project 1993 Annual Report* (Hoffman et al. 1994a) submitted under CERCLA.

The Livermore site also discharges storm water associated with industrial activities under the California General Industrial Storm Water Activity NPDES Permit issued by the State Water Resources Control Board and implemented by the RWQCBs. On March 27, 1992, LLNL submitted a Notice of Intent to the State Water Resources Control Board, applying for coverage to discharge storm water associated with industrial activity under the General Industrial Activity permit. The general industrial activity permit became effective October 1, 1992. In addition, LLNL continued construction operations for the Building 132 project at the Livermore site and applied for coverage of this activity under the California General Construction Activity Storm Water NPDES Permit. The Notice of Intent for this project was submitted to the State Water Resources Control Board on September 30, 1992. The self-monitoring programs required by these permits and associated analytical results are detailed in Chapters 6 and 13, and are submitted annually to the San Francisco Bay RWQCB.

Storm water from LLNL's Central Drainage Basin is discharged under the authority of the CERCLA Record of Decision through the reference to WDR Order No. 91-091. The self-monitoring agreement submitted to the San Francisco Bay RWQCB for discharges from the Central Drainage Basin and associated analytical results are discussed in Chapter 13.

Site 300 discharges storm water associated with industrial activity, routine blow-down water from three cooling towers, and emergency blowdown water from 14 additional cooling towers under NPDES Permit No. CA0081396, WDR Order No. 94-131. WDR Order No. 82-105 for discharges from cooling towers was rescinded, and coverage of storm water discharges associated with industrial activities, excluding construction activities under WDR Order No. 91-13-DWQ (California General Industrial Storm Water Activity NPDES Permit), was replaced with the adoption of this order renewing and amending CA0081936. Routine cooling tower blowdown discharges from the 14 cooling towers were engineered to percolation pits and discharge to these pits under a Waiver of Waste Discharge Requirements issued by the Central Valley RWQCB on February 6, 1995. The self-monitoring program for storm water discharges and associated analytical results are detailed in Chapters 6 and 13. The cooling tower self-monitoring program and associated analytical results are detailed in Chapter 13. Analytical data for this permit for both storm water and cooling tower discharges are reported annually to the Central Valley RWQCB.



Notices of termination of coverage under the general construction activity permits were submitted to the Central Valley RWQCB for the Site 300 Roadway Improvement Project and closure of landfill Pits 1 and 7. A notice of termination was also submitted to the Central Valley RWQCB for coverage of Site 300 under the general industrial activity storm water permit. LLNL submitted a Notice of Intent for coverage under the general construction activity storm water permit for the Site 300 Doall Road Project on June 17, 1994. Construction was completed, and the site stabilized on December 29, 1994. The Notice of Termination of coverage for this project under the general construction activity permit was submitted to the Central Valley RWQCB on February 8, 1995.

Site 300 operates under three additional permits and two substantive requirement agreements issued by the Central Valley RWQCB: WDR Order No. 93-100 pertains to ongoing post-closure monitoring requirements for landfill Pits 1 and 7; WDR Order No. 85-188 is a permit for operation of the domestic sewer lagoon, domestic septic tanks and associated leach fields, and the Class II surface impoundments for high-explosives rinse waters, chemistry building wastewaters, and photo process rinse waters. A revised report of waste discharge to update WDR Order No. 85-188 was submitted at the request of the Central Valley RWQCB on June 29, 1994. The Central Valley RWQCB is reviewing the permit application and should issue new waste discharge requirements in 1995. The self-monitoring programs for WDR Order Nos. 93-100 and 85-188 and associated analytical results are described in Chapter 7, Routine Ground Water Monitoring, and reported to the Central Valley RWQCB in quarterly and annual reports.

WDR Order No. 91-052 (NPDES Permit No. CA0082651) is a permit to discharge treated ground water from the eastern GSA ground water treatment facility to Corral Hollow Creek. Two ground water treatment facilities at Site 300 (central GSA and Building 834) operate under substantive requirements issued by the Central Valley RWQCB and agreed to by LLNL as part of the CERCLA process. The substantive requirements for these facilities include proof-of-system and full-scale operation evaluations of the hardware, monitoring of physical properties in the subsurface and influent and effluent chemical concentrations, and regular reporting to the regulatory agencies. The self-monitoring programs for the ground water treatment permit and substantive requirements are also discussed in Chapter 13. Analytical results are reported quarterly to the Central Valley RWQCB in the LLNL Site 300 ground water program reports.

Both the Livermore site and Site 300 are implementing Storm Water Pollution Prevention Plans that were adopted in May 1994. The Storm Water Monitoring Programs were implemented by January 1, 1993, as required by the California General Industrial Activity Permit. The Site 300 Storm Water Monitoring Program was updated July 1994 as required in WDR Order No. 94-131. LLNL



submitted a technical report to the Central Valley RWQCB to obtain coverage of nonstorm water discharges under an NPDES permit for discharges discovered during LLNL's investigation of drain connections. A permit application is being prepared for nonstorm water discharges at the Livermore site for 1995 submittal to the San Francisco Bay RWQCB. This is necessary to meet Storm Water Pollution Prevention Plans certification requirements for both the Livermore site and Site 300.

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### Inspections

The San Francisco Bay RWQCB inspected the Livermore site on October 20, 1994, for compliance with the Construction and Industrial Storm Water programs. There were no findings of violations resulting from this inspection. The Central Valley RWQCB met with LLNL staff on October 12, 1994, to gain a better understanding of discharges for which permit applications had been submitted, as well as to view the area of cooling tower sludge deposition near Building 865.

### Wastewater Permits

A Wastewater Discharge Permit from the Livermore Water Reclamation Plant (LWRP) provides for the continued discharge of LLNL sanitary and industrial effluent to the city sewer system. Permit No. 1250 (93-94) was in effect from September 1993 through September 1994, and renewal Permit No. 1250 (94-95) is effective from September 1994 to September 1995. Under the provisions of this permit, LLNL conducts a self-monitoring program at its outfall into the Livermore sewer system. Daily and monthly effluent sampling are performed to satisfy permit compliance requirements. The daily samples are composited to represent weekly values. The monitoring results of the total LLNL effluent are reported monthly to the LWRP. LLNL is seeking an EPA exemption from continued compliance with the Categorical Standards; therefore, the need for self-monitoring of categorical processes, as well as semiannual reports, has been suspended by the LWRP until further notice.

The self-monitoring program, including a discussion of analytical results for this wastewater discharge, is detailed in Chapters 5 and 13. LLNL received one Notice of Violation from the LWRP for a discharge of wastewater containing methylene chloride in January 1994 for exceeding the discharge limit for total toxic organics.

LLNL renewed two discharge permits by the LWRP for discharges of treated ground water to the sanitary sewer during 1994: (1) ground water discharge Permit No. 1508G (94-95) for discharge of sewerable waste from TFF and



(2) ground water discharge Permit No. 1510G (94-95) for an ERD sitewide treatability study. Discharges from TFF to the sanitary sewer are monitored quarterly and reported semiannually to the LWRP. Discharges to the sanitary sewer are monitored for the sitewide treatability study and reported annually. The self-monitoring programs and the associated analytical results documenting compliance with the self-monitoring provisions of these permits are detailed in Chapter 13.

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### Inspections

LWRP personnel spent two days on site during 1994 (in August and November) inspecting and sampling pretreatment discharges. There were no Notices of Violation issued by the LWRP as a result of these inspections.

### Streambed Alteration Agreements

Three streambed alteration agreements were issued by the California Department of Fish and Game for construction and maintenance projects impacting the natural drainage at Site 300. A one-time agreement was issued for modifications to Doall Road. A five-year maintenance agreement was issued for removal from Corral Hollow Creek of vegetative growth resulting from the discharge of treated ground water from the eastern GSA treatment facility (Site 300). A one-time agreement was issued for the installation of a storm water sampling device in Corral Hollow Creek. A streambed alteration agreement application was submitted to the Department of Fish and Game on December 22, 1994, to extend a fire trail across Elk Ravine. This agreement was issued in February 1995.

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### Inspections

California Department of Fish and Game personnel inspected Site 300 in May 27, 1994, to determine the need for a streambed alteration agreement for proposed work associated with the Doall Road upgrade project.

California Department of Fish and Game personnel also inspected Site 300 in December 1994 to determine the need for a streambed alteration agreement for proposed installation of the storm water sampling device.

### Clean Air Act/Air Quality Management Activities

Air permits are obtained from the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and from the San Joaquin Valley Unified Air Pollution Control District for Site 300. In 1994, the former issued 71 permits to operate, 396 letters of exemption, and 164 permit renewals for the Livermore site.



In 1994, the latter issued seven permits to operate, two letters of exemption, and 25 permit renewals for Site 300.

### Inspections

The BAAQMD conducted five days of inspections at the Livermore site during 1994. No Notices of Violation were issued.

The San Joaquin Valley Unified Air Pollution Control District conducted three days of inspection at Site 300 during 1994. No Notices of Violations were issued.

### National Emission Standards for Hazardous Air Pollutants

In August 1993, DOE and EPA signed a Federal Facility Compliance Agreement whereby LLNL would undertake measures to demonstrate compliance with National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radionuclide emissions (Radionuclide NESHAPs, 40 CFR 61, Subpart H). The agreement contained a compliance schedule, required quarterly reporting, and documented the work that LLNL needed to perform to demonstrate compliance with these regulations. EPA notified DOE and LLNL in April 1994 that all requirements of the agreement had been met and that LLNL had demonstrated compliance with NESHAPs regulations.

The applicable NESHAPs regulations require that all potential sources of radionuclide air emissions be evaluated to determine the possible effective dose equivalent to the maximally exposed individual member of the public (MEI). These evaluations may include modeling based on radionuclide inventory data, measurements of the emissions, or both. Compliance with two dose limits must be evaluated. First, the sum of all effective dose equivalents to the MEI from all radionuclide emissions to air must not exceed 100  $\mu\text{Sv}/\text{y}$  (10 mrem/y). Second, all emission points with the potential for unmitigated emissions resulting in any effective dose equivalent greater than 1  $\mu\text{Sv}/\text{y}$  (0.1 mrem/y) must have continuous monitoring systems that meet the requirements stated in the regulations.

The 1994 NESHAPs annual report (Surano et al. 1995) reported to DOE and EPA the total calculated sitewide MEI effective dose equivalents for the Livermore site and Site 300 as 0.65  $\mu\text{Sv}/\text{y}$  (0.065 mrem/y) and 0.81  $\mu\text{Sv}/\text{y}$  (0.081 mrem/y), respectively. The reported doses include contributions from both point sources and diffuse sources. Modeling was based on monitoring data and on a comprehensive LLNL-wide radionuclide inventory. The totals are well below the 100  $\mu\text{Sv}/\text{y}$  (10 mrem/y) dose limits defined by the NESHAPs regulations. The details of these data are included in this report (see Chapter 12). The total calculated 1994 MEI effective dose equivalents for the Livermore site and Site 300 are comparable to those reported for 1993, when the effective dose equivalent values were 0.66  $\mu\text{Sv}/\text{y}$  (0.066 mrem/y) for the Livermore site and 0.37  $\mu\text{Sv}/\text{y}$  (0.037 mrem/y) for Site 300.



LLNL is committed to maintain continuous monitoring of Building 331, Building 332, and the hardened portion of Building 251. Continuous monitoring already exists in these buildings. They and five other buildings, where continuous monitoring systems are in place, will continue to be monitored. Inspections of these sampling systems indicated that representative sampling is being performed.

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### **Toxic Substance Control Act**

Toxic Substance Control Act (TSCA) regulations affecting the Livermore site are those that regulate the storage and disposal of PCBs and asbestos wastes. The PCB annual report, required under 40 CFR 761.180, is a record of PCB-containing equipment in service, taken out of service, or disposed of during the year. At LLNL, equipment containing PCBs is used in a totally enclosed manner until the equipment is taken out of service, at which time it is removed to HWM for disposal at an approved site. In addition, LLNL conducts research and development activities using PCBs. Statistics for PCBs compiled in 1994 are kept on file, available for EPA inspection. Asbestos wastes are reported in the Hazardous Waste Report, which is required by DTSC under 22 CCR 66264.75.

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### **Current Issues and Actions**

The Environmental Management Assessment, conducted last summer by DOE's Office of Environmental Audit, found LLNL's environmental communications exemplary. The report stated that all levels of Laboratory management and staff exhibited a high level of commitment to environmental excellence.

Several areas were singled out as "exceptional" by the DOE, including the Laboratory's emergency preparedness planning and response program, the Laboratory's internal communications program (for effectively conveying awareness of environmental issues), and the Laboratory's environmental planning program.

The report identified eight minor deficiencies having to do with DOE's organizational structure. Most of these had previously been identified by LLNL and DOE Oakland Operations Office, and corrective actions have been planned or completed.

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### **Chemical Exchange Warehouse**

A new program at LLNL is aimed at reducing the disposal of chemicals as hazardous waste. This program is known as the Chemical Exchange Warehouse (CHEW) program. In the past, a good fraction of the hazardous waste disposal resulted from unused chemicals. Today, the CHEW program provides a method of collecting, identifying, storing, and finding a new use for the materials. The CHEW program is finding a new home for at least 25% of the available chemicals

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and returning 25% of that volume to be recycled for additional use. The savings are estimated to offset the transportation and storage costs after program startup.

### Building Drain Repair Project

In fiscal year 1994, LLNL received approval from DOE to redirect \$2.1 million of sanitary sewer rehabilitation funds to the Building Drain Repair Project. This project was charged with performing sitewide repair activities identified by the Building Drain Investigation Project and preparing regulatory permits to comply with the NPDES Storm Water requirements imposed by the RWQCBs. Drains discharging to improper destinations are removed or redirected in accordance with current mandated regulatory requirements. Over 200 repairs were identified at the Livermore site, and about 80 were identified at Site 300.

A major portion of this project involved assessing each of the drain discharges to ground to determine if it should be permitted or repaired. Once the assessments for over 25,000 drain sources were completed, along with the necessary field verification and database entry, the permitting and repair process began. All permit and repair work must be completed by the September 30, 1995, regulatory deadline. This work is being driven by the Porter-Cologne Water Quality Control Act, NPDES Stormwater Requirements for Industrial Facilities enacted in 1991. Once this project has been completed, building drain management will become the responsibility of Plant Engineering. All future drain additions and modifications will be tracked with a drain permit system as an infrastructure management function. Environmental drain discharge guidance support will continue to be the responsibility of the Environmental Protection Department (EPD).

### Environmental Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations, including the 5000 series of DOE Orders: DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information; and DOE Order 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements. DOE Order 5000.3B, effective February 22, 1993, provides guidelines to contractor facilities regarding categorization and reporting of environmental occurrences to DOE. The order divides occurrences into three categories: emergencies, unusual occurrences, and off-normal occurrences. DOE Order 232.1, which will replace DOE Order 5000.3B, is being drafted.

EPD responds to all reports of spills or other environmental occurrences through a well-established reporting process. EPD has established a seven-day-a-week, 24-hour-a-day, on-call, rotational position called the Environmental Duty Officer (EDO), who can be reached by pager or by cellular phone at any time. Environmental analysts and the EDO cooperate in providing advice on immediate cleanup and monitoring necessary to protect the environment; in evaluating reporting

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requirements; and deciding with LLNL management on the process for notifying local, state, and federal regulatory agencies. The EPD's response to environmental occurrences is part of the larger LLNL On-Site Emergency Response Organization that also includes representatives from Hazards Control, Health Services, Plant Engineering, Public Affairs, Safeguards and Security, and Site 300.

EPD responded to 24 incidents that required agency notification during the 1994 calendar year. Three of the incidents were categorized as unusual occurrences according to the DOE Order 5000.3B implementing procedures; the others were reported as off-normal occurrences. (Any incident that requires notification of an environmental regulatory agency is considered an off-normal occurrence.) None of the incidents, summarized in **Table 2-4**, caused any adverse impact to human health or the environment. Agencies notified of the incidents described above included DOE, Alameda County Department of Health Services, San Joaquin County Public Health Services, San Francisco RWQCB, the Central Valley RWQCB, LWRP, National Response Center, and the Office of Emergency Services.

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**Table 2-4.** Tabulation of environmental occurrences, 1994.

Date <sup>(a)</sup>	Occurrence Category	Description
Jan 3	Off-normal	Approximately 7,200 liters of low-conductivity water was discharged to the storm water drainage system as a result of a leak in the low-conductivity water system in Building 191. The Fire Department responded, installed a sump pump in the basement of Building 191, and began pumping the water into the storm water drainage system that led to the Arroyo Las Positas. Because of unknown potential contaminants in the water and a possibility that the water left the Livermore site, the San Francisco Bay RWQCB was notified.
Jan 6	Off-normal	Analytical soil sample results from the 241-D1U1 tank removal indicated the presence of diesel fuel in the native soil. As required per Title 23, California Underground Storage Tank Regulation, the local agency was notified.
Jan 7	Off-normal	Holes were discovered on the top of an underground diesel tank, 241-D1U1, which had been tested and certified to be leak tight. Investigation revealed the state-certified test procedure had been modified by the tank tester, which caused erroneous readings. This incorrect procedure was also used on other tanks, including tanks at Site 300; therefore, Alameda County Health Agency and San Joaquin County Public Health Agency were notified.
Jan 12–13	Off-normal	LLNL personnel performed a helium injection/detection test on 231-D1U1. Results of the helium testing indicated that there was a leak in the gasketed area on the manway cover, a possible leak in the gasketed area of the lower gasket of the manway, and that the supply and return lines did not leak. The tank was pumped out and emptied the following day. It has since been replaced with an aboveground storage tank.
Jan 18	Unusual	The Permits and Regulatory Affairs Group received a Report of Violation from DTSC following an inspection at Site 300 on November 15–16, 1992. The inspection noted violations of inadequate/lack eyewash and safety shower at Building 805. There was also inadequate identification of wastes on a hazardous waste label at Building 879. An Report of Violation constitutes an unusual occurrence.
Feb 2	Off-normal	The monthly compliance sampling indicated that LLNL had exceeded discharge limits for total toxic organics. The allowable limit was 1.0 ppm, and the reportable result concentration was 1.5 ppm. The reporting requirements specify 24-hour notification to the LWRP.
Feb 7	Off-normal	A release of wastewater containing zinc above the limit imposed by LLNL's Wastewater Discharge Permit was registered by an alarm at Building 196 on January 29, 1994, and was reported by the Water Guidance and Monitoring Group to the LWRP. Zinc was present at 3.3 mg/L, as compared to the discharge limit of 3.0 mg/L.
Feb 10	Off-normal	A contaminant, 1,2-dichloroethane (1,2-DCA) was detected in routine monthly water sampling on November 22, 1993, from Well 20. Split-sample analytical results received on January 4, 1994, based on two different EPA methods, indicated 0.6 µg/L and 1.0 µg/L of 1,2-DCA. The Department of Health Services regulations set the maximum contaminant levels for 1,2-DCA at 0.5 µg/L.
Mar 11	Off-normal	During removal of an underground diesel tank at Building 827, diesel fuel was observed spilling out of the bottom of the tank and into the excavation pit. Approximately 40 liters of fuel was released into the pit. A San Joaquin County Public Health Services inspector was present at the time of the release; therefore, no additional verbal notification was necessary.
Mar 17	Off-normal	An excavation to prepare for the removal of the two 38,000-liter gasoline tanks, 879-G1U1 and 879-G2U1, at Building 879 resulted in the rupture of the city water supply to Building 879. Approximately 11,000 liters of water were pumped from the excavation.

## 2. Compliance Summary



**Table 2-4.** Tabulation of environmental occurrences, 1994 (continued).

Date <sup>(a)</sup>	Occurrence Category	Description
Mar 18	Off-normal	Analytical results from rain water collected on February 23, 1993, and stored until December 1993 were received and indicated elevated tritium levels in a rain water sample from the Building 343 area. The incident was reportable because the sample analysis indicated a release exceeding historical data.
Mar 18	Off-normal	Soil analytical results from the 836-D1U1 tank removal were received and indicated an exceeded level of TPH-D in the backfill. Under Title 23, California Underground Storage Tank Regulation, any amount detected is considered an unauthorized release; therefore, the local agency was notified.
Mar 23	Off-normal	A 1,250-liter "Tuff" tank filled with 50% solution hydrogen peroxide was found leaking while still sitting in the delivery truck at Building 411. Because LLNL had not yet accepted the shipment, the California Highway Patrol (CHP) was contacted. The CHP issued multiple citations. The inspection revealed a few ounces were released onto the top of the container, which was caused by a loose lid. The shipper secured the lid, cleaned the top of the container before the shipment was accepted.
May 18	Off-normal	Soil sample results from a transformer spill that had occurred on April 18, 1994, indicated TPH-D levels of 26,000 mg/kg. It was estimated that 120 liters of oil from transformer on the south side of Trailer 1601 (<1 ppm PCBs) was released to the ground while being moved by a crane. Because the cleanup was not completed immediately, the incident became reportable to the San Francisco Bay RWQCB.
Jun 22	Unusual	The subcontractor for the Building 132 South Road project broke a 20-centimeters water line while excavating the area south of Building 131. Plant Engineering estimated the volume of water released at 170,000 liters. In February 1994, LLNL entered into agreement with the San Francisco Bay RWQCB regarding these types of releases. The agreement stated that releases of any material that leave LLNL discharge points or any discharge that might impact ground water must be reported immediately.
Jul 1	Off-normal	The Water Guidance and Monitoring Group reported to the Central Valley RWQCB statistical evidence for a release for two constituents of concern. Arsenic in concentration of 0.02 mg/L was found in wells downgrade of Site 300's landfill Pit 1; vanadium in concentration of 0.05 mg/L was found in one well downgrade of Site 300's landfill Pit 7.
Jul 1	Off-normal	Soil analytical results from the 805-D1U1 and 827-D2U1 tank removals were received and indicated an exceeded level of TPH-D in the backfill. Analyses indicated 7.4 mg/kg TPH-D from the 805-D1U1 and 11.0 mg/kg TPH-D from the 827-D2U1 samples. Under Title 23, California Underground Storage Tank Regulation, any amount detected is considered an unauthorized release; therefore, the local agency was notified.
Jul 27	Off-normal	While removing the underground fuel tank, 834-D1U1, adjacent to Building 871 an odor of diesel fuel was evident. The odor of diesel indicated a release to the environment. In addition, the odor of diesel fuel was discovered in a ground water monitoring well, approximately 5 meters away from the tank. The local agency was on site at the discovery of this release.
Aug 12	Off-normal upgraded to Unusual on Aug 24	The cooling tower sludge analysis from Site 300 had levels of zinc at 26,000 ppm. Building 865 has had its sludge removed annually since 1980. The prior maintenance practice was to dispose of the removed sludge on the ground. The total threshold limit concentration for zinc in Title 22 CCR is 5,000 ppm. The Central Valley RWQCB was notified of this finding.
Oct 20	Off-normal	Diesel contamination was discovered during a underground fuel tank removal at Building 865. The local agency was on site at the discovery of this release.

## 2. Compliance Summary



**Table 2-4.** Tabulation of environmental occurrences, 1994 (concluded).

Date <sup>(a)</sup>	Occurrence Category	Description
Nov 28	Off-normal	A pump failure, apparently caused by a gasket failure, discharged approximately 190 liters of water, which entered the storm drainage system. The pump was used to circulate hot water that contains a corrosion inhibitor at concentrations of 500–1,000 ppm. The inhibitor contains nitrous acid, sodium salt molybdix acid, and disodium salt. Since the release was not potable and could not be cleaned up, the release was reportable to San Francisco Bay RWQCB.
Dec 6	Off-normal	Shipment papers for a radioactive material being shipped from DOE Ann Arbor to Reynolds Electrical & Engineering Co., Mercury, Nevada had not been filled out properly. The manifest was prepared by LLNL Hazardous Waste Management and did not include the letters "RQ" as required for each hazardous substance.
Dec 12	Off-normal	A spill of 594 kilograms of nondispersable solid uranium-238 metal ingots was released from a tractor trailer onto the concrete sidewalk. All of the uranium metal including the container packaging was recovered. The spill location was on Avenue B, southwest of Building 241.
Dec 29	Off-normal	The Tank Assessments and Guidance Group received analytical data indicating that soil removed during the removal of the underground diesel tank 152-D1U1 was contaminated with 4,500 mg/kg TPH-D.

<sup>a</sup> The date indicated is the date the occurrence is categorized, not the date of its discovery.



### 3. Environmental Program Information



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#### **Introduction**

LLNL is committed to environmental compliance and accountability. During the course of each year, the Environmental Protection Department (EPD) monitors the environment surrounding the Livermore site and Site 300 through a sampling and analysis program. In 1994, over 17,000 samples were taken, and more than 236,000 analytes were analyzed. This effort, which is conducted in accordance with DOE Orders 5400.1, 5400.5, 5484.1, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), has four purposes: (1) to assess the effectiveness of pollution control programs, (2) to assess compliance with applicable environmental laws and regulations, (3) to evaluate the impact of operations on the environment, and (4) to support CERCLA investigations and cleanup. Data are gathered from air, sewage, ground water, surface water, soil, vegetation, foodstuff, and environmental radiation samples. The type of samples collected at a specific location depends on the site and the potential pollutants to be monitored. Details on the monitoring activities can be found for each environmental medium in the specific chapters of this report. In addition, a special study of tritium in rain and storm water runoff is documented in Chapter 6, Surveillance Water Monitoring. Summary information on monitoring activities can be found in Chapter 12, Radiological Dose Assessment, and Chapter 13, Compliance Self-Monitoring.

Although its monitoring activities are quite comprehensive, EPD's main mission is to work with LLNL programs to ensure that operations are conducted in a manner that limits environmental impacts and are in compliance with regulatory guidelines. The specific activities required by environmental statutes were described in the preceding chapter. This chapter describes the divisions comprising EPD and the activities they carry out as mandated by DOE, environmental regulations, and/or LLNL management.

#### **Environmental Protection Department**

As the Laboratory's environmental support organization, EPD prepares and maintains LLNL environmental plans and guidelines, informs management about pending changes in environmental regulations pertinent to LLNL, represents LLNL in day-to-day interactions with regulatory agencies, assesses the effectiveness of pollution control programs, and monitors the environment to determine the impact of LLNL operations. EPD also helps LLNL programs to

### 3. Environmental Program Information



manage and minimize hazardous, radioactive, and mixed wastes; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; and responds to emergencies in order to minimize and assess any impact on the environment and the public.

Training is an important component of EPD's work. EPD provides LLNL employees with training on environmentally related topics and improves their ability to comply with environmental regulations. Training tasks address both specialized training for environmental professionals in EPD and training in a variety of environmental topics for employees at all levels throughout LLNL.

The four operating divisions in EPD, described below, include: Operations and Regulatory Affairs Division (ORAD), Hazardous Waste Management Division (HWM), Environmental Restoration Division (ERD), and Environmental Monitoring and Analysis Division (EMAD). EPD has also established Environmental Support Teams, composed of various environmental discipline specialists from the four divisions, which work with LLNL staff to identify and address compliance issues.

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#### Operations and Regulatory Affairs Division

The six groups that comprise ORAD specialize in environmental compliance and provide laboratory programs with information to make more informed environmental decisions. Each group makes a specific contribution toward the compliance and environmental goals of the University of California and DOE.

ORAD drafts the environmental permits for federal, state, and local agencies; tracks chemical inventories; prepares National Environmental Policy Act (NEPA) documents and conducts related field studies; provides guidance to programs on environmental issues; operates the pollution prevention and recycling programs; teaches numerous environmental training courses; and operates the underground storage tank assessment program.

LLNL programs are supported by four Environmental Support Teams. Each team includes representatives from each environmental specialty and each group within ORAD. These teams evaluate existing operations and provide guidance on environmental regulations and DOE orders for existing and proposed projects. Each environmental support team assists programs in planning, implementing, and operating projects and their environmental requirements. When permits are obtained from regulatory agencies, Environmental Support Teams aid the program in evaluating the permit conditions and implementing recordkeeping requirements. ORAD also provides the liaison between LLNL and regulatory agencies conducting inspections.

### 3. Environmental Program Information



ORAD responds to environmental emergencies such as spills and assigns a specially trained Environmental Duty Officer (EDO). Training includes simulated accidents to provide the staff with the experience of working together to resolve environmental issues within the regulatory structure. EDOs are on duty 24 hours a day and coordinate with LLNL's Hazards Control Team and other first responders or environmental specialists.

#### Hazardous Waste Management Division

All hazardous, radioactive, and mixed wastes generated at all LLNL facilities are managed by HWM in accordance with state and federal regulations. HWM processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer.

As part of its waste management activities, HWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas (WAAs) located near the waste generator to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for shipment of waste meet the specifications of the U.S. Department of Transportation (DOT) and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. HWM prepares numerous reports, including the annual and biennial hazardous waste reports required by the state and federal environmental protection agencies. HWM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans.

In 1994, HWM completed and implemented a new waste data management system and a system to automate control of existing tank treatment units; completed the HWM Safety Analysis Report and submitted it to DOE for approval; resumed shipments of low-level waste (LLW) to the Nevada Test Site (NTS); developed new waste treatment methodologies; implemented computer-based DOT training for the HWM Division; and activated laboratory operations within Building 612 for waste verification.

#### Environmental Restoration Division

ERD was established to evaluate and remediate contaminated soil and ground water resulting from past hazardous materials handling and disposal, and from leaks and spills that have occurred at the Livermore site and Site 300, both prior to and during LLNL operations. At both the Livermore site and Site 300, ERD investigates field sites to characterize the existence, extent, and impact of contamination. ERD evaluates and develops various remediation technologies, makes recommendations, and implements actions for site restoration. ERD is responsible for managing remedial activities, such as soil removal and ground

### 3. Environmental Program Information



water extraction, and for assisting in closing inactive facilities in a manner designed to prevent environmental contamination.

In dealing with CERCLA compliance issues, ERD plans, directs, and conducts assessments to determine both the impact of such releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment. ERD is responsible for interacting with the community. Several public meetings are held each year as required in the ERD CERCLA Community Relations Plans. To comply with CERCLA ground water remedial actions at the Livermore site, ERD has designed and constructed five ground water treatment facilities and associated pipeline networks and wells. At Site 300, ERD has designed and implemented two soil vapor/ground water extraction and treatment systems and one ground water extraction and treatment system. ERD has also capped two inactive mixed-waste landfills. ERD is actively designing, testing, and applying innovative remediation and assessment technologies to contaminant problems at the Livermore site and Site 300.

#### Environmental Monitoring and Analysis Division

The effluent monitoring, surveillance monitoring, and modeling functions of EMAD cover a number of environmental media and include sampling and analysis, risk assessment, impact modeling and analysis, and reporting. EMAD is responsible for monitoring the environmental effects, both radiological and nonradiological, of effluent streams of air, sewage, storm water runoff, and wastewater. The monitoring is performed by sampling point-source discharges in accordance with federal regulations. EMAD works with other LLNL programs to prepare storm water pollution prevention plans, eliminate illicit wastewater discharges, and provide regulatory guidance and permitting assistance on storm water/wastewater issues. The surveillance, effluent, and compliance monitoring program includes direct radiation monitoring; radiological and nonradiological monitoring of air, soil, water, ground water, vegetation, and foodstuff; as well as meteorological monitoring.

The EMAD analytical laboratory supports LLNL waste generators and HWM in performing chemical and radiological analysis to identify, characterize, and certify waste for proper disposal. Risk assessment and impact modeling and analysis are part of this work.

EMAD is responsible for producing this annual Environmental Report and for radionuclide effluent reporting and compliance demonstration under the National Emission Standards for Hazardous Air Pollutants (NESHAPs) of the Clean Air Act. EMAD is responsible for producing the quarterly ground water report and annual ground water report for the Central Valley Regional Water Quality Control Board (RWQCB); the semiannual wastewater report; and a

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number of other documents, including those dealing with wastewater management for regulatory compliance, permit applications, monitoring reports, and compliance plans.

During 1994, the four operating divisions in EPD included ORAD, HWM, ERD, and EMAD. In early 1995, EPD reorganized, moving the functions of EMAD into ORAD and the Chemistry and Materials Science Directorate.

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#### Self-Monitoring Programs

At both the Livermore site and Site 300, a number of self-monitoring programs are required by the permits and regulations governing projects and activities. The National Pollution Discharge Elimination System (NPDES) permits require self-monitoring of storm water discharges associated with industrial activity (covered under the California General Industrial Activity Storm Water Permit) and of construction projects that are 2 hectares and greater (covered under the General Construction Activity Storm Water Permit).

Self-monitoring of pretreated, nondomestic, industrial-source wastewater is required at both sites by the Livermore Water Reclamation Plant, under the authority of the San Francisco Bay RWQCB, for wastewater that will be discharged from LLNL into the City of Livermore sewer system. The standards for pretreated water are defined in 40 CFR 403.

Self-monitoring is required at the Livermore site by the San Francisco Bay RWQCB for discharge of treated ground water to a percolation pond, to the surface drainage system, or for on site reuse. Similarly, self-monitoring programs at Site 300 are required by permits issued by the Central Valley RWQCB for discharges of cooling tower blow down water to surface waters, for discharges of treated ground water from the eastern General Services Area (GSA) treatment facility, and for monitoring of landfills at the site. In addition, self-monitoring programs are dictated by substantive requirements (under CERCLA) issued by the Central Valley RWQCB for discharges of treated ground water from the central GSA treatment facility and the Building 834 treatment facility.

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#### Waste Minimization and Pollution Prevention Awareness Plan

The combined *Waste Minimization and Pollution Prevention Awareness Plan* (Celeste 1994) was prepared in accordance with DOE Order 5400.1. It was originally issued on May 31, 1991, updated on May 31, 1992, and revised in April 1994. Since then several significant changes in regulatory requirements have affected Laboratory operations. Some changes include: California passed a law requiring reporting of recycled non-RCRA wastes; the California Hazardous Waste Management and Source Reduction Review Act led LLNL to identify its

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largest hazardous waste streams, select waste minimization options for them, and make a commitment to implement them; the Pollution Prevention Act of 1990 required significant modifications to the existing LLNL hazardous waste data reporting procedures; and the Land Ban placed new restrictions on the generation of mixed wastes.

Other changes resulted from new definitions, requirements, and restrictions. These include the reduction by DOE of the level of radioactivity that defines waste as radioactive or mixed; new offset requirements for local air emissions that have increased the difficulty of obtaining air permits; an Executive Order issued in September 1991 that requires new emphasis on the use of recycled materials by all federal facilities; California's increased restrictions on the quantities of nonhazardous wastes that may be disposed of in landfills; and the directives by the DOE Secretary to participate in the EPA 33/50 program to reduce emissions of 17 priority chemicals, submit progress reports on the program, phase out Class I ozone-depleting chemicals by the end of 1995, and submit progress reports on this phase-out.

LLNL is continuing to address these changes and to follow the strategies proposed in the original 1991 *Waste Minimization and Pollution Prevention Awareness Plan*. The plan includes the following three actions: first, each Laboratory program is continuing to conserve resources, minimize waste generation, and prevent pollution. This includes creating incentives for pollution prevention; developing specific goals and schedules for waste minimization activities; promoting the use of nonhazardous materials; substituting, reformulating, modifying, managing, and/or recycling waste materials to achieve minimal adverse effects; targeting policies, procedures, or practices that may be barriers to waste minimization; and integrating and coordinating waste generators and waste managers on waste minimization issues. The second action is to enhance communication of waste minimization goals and ideas. This has involved developing and implementing employee pollution prevention awareness activities, including regular articles in *Newsline* (the LLNL biweekly newspaper) or other periodicals. It also includes collecting and disseminating waste minimization information through technology transfer and outreach and through presentations at conferences and internal LLNL meetings. The third action involves characterizing waste streams and developing a baseline of waste generation data.

LLNL conducted a number of activities in support of the plan, continued to communicate management's commitment to curtail pollution, and publicized the goals of pollution prevention through posters and articles in *Newsline* and the *Pollution Prevention Advisor*. LLNL conducted formal training on pollution prevention and on the responsibilities of waste generators. Pollution prevention displays and handouts are regularly presented during Earth Week at Earth Day fairs, and at an on-site Energy Fair. Environmental Alerts (one-page flyers) were

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published and distributed to all LLNL employees, conveying information on environmental concerns, possible solutions, recommended practices, and pertinent environmental regulatory issues. Changes and additions to regulatory requirements, new technologies, and management changes related to environmental issues continued to be conveyed in 1994 by the environmental analysts assigned to specific site areas.

#### Pollution Prevention Activities

LLNL prepared the *Annual Report on Waste Generation and Waste Minimization Progress* (Celeste 1994) for DOE in October 1994. The Laboratory also submitted a report to Alameda County concerning recycling of non-RCRA hazardous wastes, which described LLNL's waste minimization achievements and successes.

LLNL's operating contract now includes waste minimization and pollution prevention performance measures. In 1994, reductions of 5% for three specific streams and a 10% reduction in the aggregate total were established. The three specific streams are discussed below.

Contaminated gravel and debris from the firing tables at Site 300 are generated as a result of explosive testing. The segregation of debris from gravel, administrative controls, and material substitution of nonhazardous for hazardous material, when possible, has reduced this waste stream from 95 metric tons in 1993 to 77 metric tons in 1994 (1 metric ton =  $10^3$  kilograms). Additionally, a new gravel washer has been purchased to allow the reuse of gravel and reduce this waste stream. The gravel washer is scheduled to be on-line in 1995.

Aqueous liquids from the paint shop spray booth have been significantly reduced by improving the process. A microseparator has been installed to separate the spray paint solids from the water, which allows the reuse of the water in the spray booth. The total wastewater for 1994 was 8.7 metric tons compared to 11.7 metric tons for 1993, a reduction of about 27%. There should only be about one 55-gallon (208-liter) drum of solid paint sludge generated per year from now on.

Spent aqueous coolant wastes are generated from machine tools when the coolant becomes unusable. A product recovery system was installed to separate the tramp oils and solids from the water/oil emulsion, which is then reused. This waste stream has been reduced from 32.7 metric tons in 1993 to 24.5 metric tons in 1994. A portable recycling unit is being evaluated to process hazardous machine coolant wastes in small machine shops that do not justify the expense of a large, permanently installed unit. The portable recycler filters out particulates and coalesces tramp oils, and may extend the coolant life from one month to as much as seven months.

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LLNL has begun to differentiate routine from nonroutine waste generation. Nonroutine wastes include remediation projects and construction projects. We have established a soil management program to maximize the reuse of soil on site instead of shipping the soil to a landfill.

Reduction of waste is a continuing effort at LLNL. A significant part of this effort has been to reduce hazardous organic solvents that are disposed of as liquid hazardous waste or that may evaporate into the air. The Pollution Prevention Group solicits from LLNL programs parts that are currently cleaned with solvents such as chlorofluorocarbons (CFCs) or halogenated hydrocarbons. After cleaning with alternative solvents, they are returned to the programs with suggestions for alternative solvent use. To date, approximately 25 shops or laboratories on site have converted to environmentally friendly chemistries in their cleaning operations.

A contamination analysis sensor is currently being developed to measure the cleaning performance of different solvents in near-real time, which will help redesign cleaning processes to be more efficient and present less environmental risks. The sensor will be field-tested in the aerospace and electronics industry in the coming year.

LLNL is now recycling its ethanol laser dye solution and its CFCs off site. The reprocessed CFCs are sent back to LLNL for reuse. Laser users are also experimenting with the use of carbon dioxide snow and pellet sprays for precision cleaning of optics, electronics, and other assemblies. After cleaning, the carbon dioxide sublimates, leaving no solvent waste.

Many LLNL programs and directorates have recently implemented significant pollution prevention technologies. The Electronics Engineering Department has improved pollution control at its Rapid Prototype Facility (RPF), one of several on-site electronics fabrication facilities. Aqueous solvents and alternative cleaning equipment have decreased air emission and hazardous waste sources. In addition, dilute nitric acid has replaced chromium-based desmutting, and cyanide has been eliminated from conversion-coating operations for metal finishing. Plant Engineering has replaced a CFC degreaser in its instrument shop with a triple-rinse aqueous system, cutting CFC use by 1,500 liters per year.

Chlorinated solvents in the Engineering Directorate's machine shops have been largely replaced with nonhazardous cleaners. Engineering's electroplating shop has evaluated alternatives to hexavalent chromium plating and is using a dialysis unit to recycle nickel from electrolyte plating baths. The shop has also installed equipment for recycling aqueous detergent-based cleaning chemicals.

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LLNL continues to operate a successful Chemical Exchange Warehouse (CHEW) to receive, temporarily store, and track excess usable chemicals in order to make them available to other users. By reusing chemicals, the hazardous waste stream is lessened, thereby reducing chemical procurement and disposal costs. LLNL has also shipped over 380 metric tons of hazardous material for recycling in 1994.

#### Materials Recycling

In 1994, 314 metric tons of paper (including destroyed classified and nonclassified paper wastes) were collected and recycled. In 1994 LLNL's wood recycling (410 metric tons), excess food donation (0.96 metric tons), toner cartridge recycling (2.01 metric tons), composting, and Buy Recycle programs continued to grow.

In the second of two nonhazardous waste stream assessments, LLNL sampled and categorized solid wastes from more than 25 dumpsters according to their types. Total paper waste constituted approximately 50% (by weight) of the material sampled. The paper waste was categorized as white paper, cardboard, newsprint, colored paper, coated paper, computer (green bar) paper, and paper towels. Quantities of white paper observed during the assessment indicated that the white paper recycling program is successful, but there is a need for additional awareness programs that would increase participation even more. These 1993 findings were the basis of the expansions discussed below.

Cardboard comprised the largest single waste stream category. LLNL will implement full-site collection in 1995. In addition, LLNL expanded the paper recycling program to include colored paper. Non-LLNL phone book recycling was expanded to a full-year program in 1994.

LLNL maintains a Buy Recycle Committee in response to Executive Order 12873 that mandates federal facilities to increase use of recycled materials. LLNL Stores now carry white photocopier and printer paper containing 50% recycled fiber content (with 10–25% post-consumer waste), refillable bottles that replace aerosol cans, aqueous-based correction fluid, low alkalinity dishwashing compound, rechargeable batteries, and refurbished laser printer toner cartridges. The Technical Information Department demonstrated that recycled paper could be used in most copiers and laser printers, resulting in acceptance by many other departments.

Property Management's Donation Utilization and Sales (DUS) Group has a project to divert scrap material from being dumped into landfills and make it available for LLNL reuse at no cost to the programs. The most common types of reuse items are moving boxes, wooden pallets, box pallets, office supplies and furniture, and general hardware, such as nuts, bolts, and screws. Scrap metals that are not picked up for reuse are sold under term contracts, as are tires, cardboard, telephone books, electronic scrap, and destroyed/baled classified

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paper. In 1994, programs were implemented to recycle magazines and newspapers, and DUS recycled over 1,190 metric tons of scrap material. DUS is working closely with the Pollution Prevention Group to explore new avenues of recycling. In 1994, DUS's Education Program donated over \$5 million worth of excess equipment (under DOE guidelines) to schools around the state.

LLNL received a certificate of appreciation from DOE in 1994 commending the Laboratory's contribution to pollution prevention.

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#### **Building Inspections**

Formal, detailed building inspections for each LLNL facility are conducted based on a schedule established by the Facility Manager and the appropriate Environmental Safety and Health (ES&H) team. The ES&H teams are made up of health, safety, and environmental discipline specialists who assist LLNL to maintain compliance with ES&H requirements.

The inspections scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of WAAs, potential release pathways to the environment (e.g., storm and sanitary sewer drains), hazardous product storage areas, wastewater retention systems, operating equipment (e.g., vacuum pumps, transformers, capacitors, and baghouses), and laboratory and machine shop areas. An inspection report is prepared for a program or department, and follow-up checks are conducted to ensure implementation of recommendations or corrections. Walkthrough inspections are conducted on an as-needed basis. During 1994, the ES&H teams conducted 122 formal building inspections at the Livermore site. At Site 300, the team conducted nine formal building inspections. EPD conducted 10 audits of the HWM facilities at the Livermore site and 10 audits of the HWM facilities at Site 300.

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#### **Waste Accumulation Area Inspections**

Program representatives conducted inspections at least weekly at all WAAs to ensure that WAAs are operated in compliance with regulatory requirements. An inspection checklist is completed, and corrective actions are implemented. In addition, EPD conducted biweekly, routine checks at all WAAs to help ensure that programs manage their WAAs and wastes in compliance with state and federal requirements. Chapter 2 provides additional inspection information under the subsection on Waste Accumulation Areas.

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#### **Spill Response**

Investigation, sampling, and evaluation of all spills and leaks that are potentially hazardous to the environment are conducted when necessary. The spill response process includes identifying the spill or leak, shutting off the source (if safe to do so), eliminating ignition sources, contacting appropriate emergency personnel, cordoning off the area, containing the spill or leak, absorbing and neutralizing

### 3. Environmental Program Information



the spill or leak, assisting in cleanup of the spill or leak, determining if a spill or leak must be reported to regulatory agencies, and verifying that cleanup (including decontaminating and replenishing spill equipment) is complete. Environmental analysts also provide guidance to the programs on preventing spill recurrence.

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#### Spill Reporting

Under authority of the *San Francisco Bay Water Quality Control Plan*, the San Francisco Bay RWQCB requires a report of all releases to the ground or surface waters that are not specifically allowed in permits. LLNL negotiated a spill reporting procedure with the San Francisco Bay RWQCB to replace an existing requirement to report minor spills. The procedure identifies what types of spills must be reported and when the spills are considered to be of so little consequence that records can be kept on file rather than reported. If a spill of a reportable quantity of material occurs or one that is not contained, the appropriate agencies are contacted immediately.

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#### Site Evaluations Prior to Construction

Soil and debris from construction sites are sampled and analyzed for potential contamination. Soil is disposed of according to established procedures, based on analytical results. During 1994, environmental analysts conducted preconstruction site evaluations for 96 construction projects.

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#### Environmental Training

Major efforts are ongoing to provide LLNL employees with training on environmental topics aimed at improved compliance. Training tasks address both specialized training for environmental professionals and training in a variety of environmental topics for employees at all levels throughout LLNL. Courses presented by EPD's Training Section are listed in **Table 3-1**.

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**Table 3-1.** EPD training courses.

Advanced Environmental Law and Regulation	Packaging Operations
Air Source Management	Placarding: Hazardous Waste Transport
Asbestos Hazards (HWM)	Radioactive Materials
Chemical Compatibility	RCRA Facility Management
Emergency Response Briefing—Removal	RCRA Operations
Environmental Law and Regulation	Safety
General Awareness/Familiarization	SARA/OSHA Refresher Training
Hazardous Waste Generation and Certification	SARA/OSHA Supervisory Training
Hazardous Waste Sampling	SARA/OSHA Training 24 Hour
Hazardous Waste Transportation	SARA/OSHA Training 40 Hour
Identification of Hazardous Material	Separation for Highway Transport
Labeling of Packages	Shipping Papers
Low-Level Waste Certification Overview	Spill Prevention, Control, and Countermeasures
Low-Level Waste Generation and Certification	TRU Waste Generation and Certification
Marking of Packages	Unique Moves
NEPA Overview	Waste Accumulation Area Operations
Overview of Environmental Law and Regulation	Waste Accumulation Area Overview



Paula J. Tate  
Arthur H. Biermann

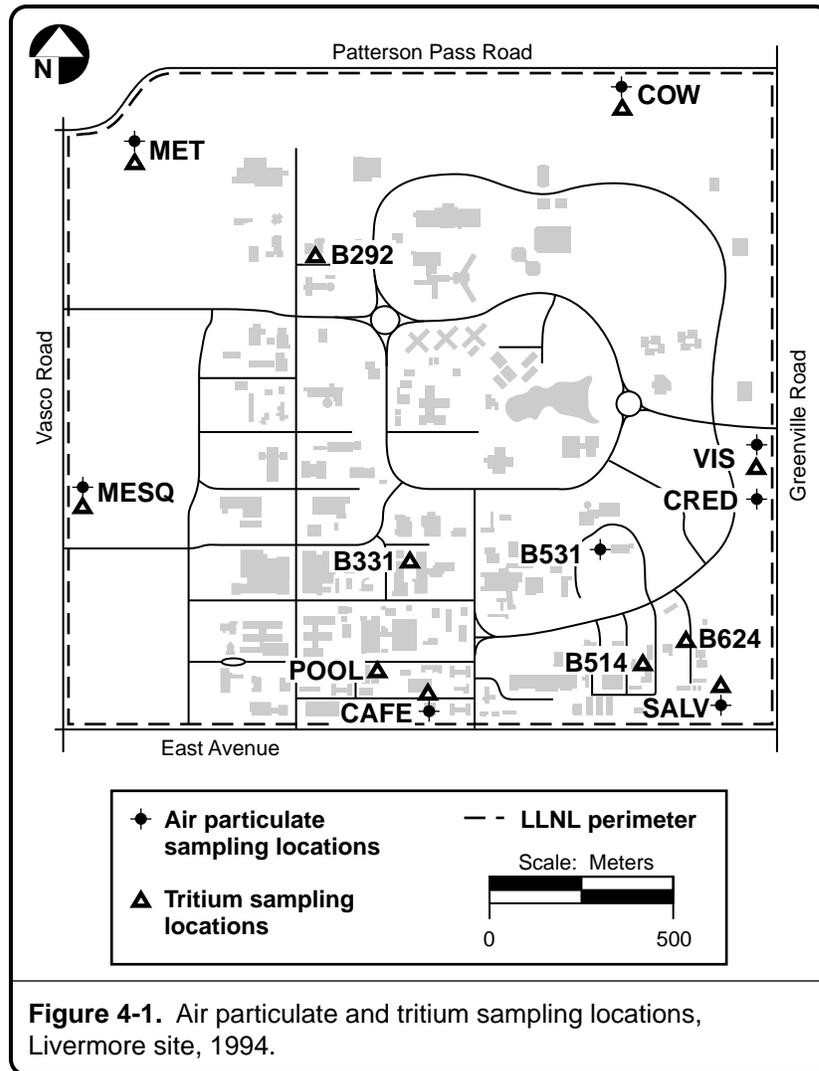
### Introduction

Air surveillance and air effluent monitoring are performed to evaluate compliance with local, state, and federal regulations, and to ensure that human health and the environment are protected from hazardous and radioactive air emissions. LLNL complies with local, state, and federal environmental air quality laws and DOE regulations including 40 CFR 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act; and DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) is the guidance for implementing DOE Orders 5400.1 and 5400.5. Other laws governing air quality include 22 CCR 67264.700 and 66265.710, Environmental and Compliance Monitoring, and the California Air Toxics “Hot Spots” Information and Assessment Act of 1987 (AB2588). In general, LLNL analyzes for most constituents at levels that are far below regulatory standards in order to determine any environmental impact.

LLNL monitors ambient air to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations, what the concentrations are, and what the trends are in the LLNL environs. In addition, LLNL conducts air effluent monitoring at atmospheric discharge points of some facilities to determine the actual emissions from individual facilities and to confirm the operation of emission control systems. Air monitoring involves measurement of particles collected on filters or of vapor chemically trapped on a collection medium. Concentrations of various airborne radionuclides (including particles and tritiated water vapor) and beryllium are measured at the Livermore site, Site 300, at off-site locations throughout the Livermore Valley, and at an off-site location in Tracy. Point sources as well as diffuse, or nonpoint sources, are monitored to fulfill NESHAPs requirements.

### Methods

For air surveillance monitoring, LLNL maintains eight continuously operating, high-volume, air particulate samplers on the Livermore site (**Figure 4-1**), ten in the Livermore Valley (**Figure 4-2**), eight at Site 300, and one in Tracy (**Figure 4-3**). One sampling location, LCCY, was removed in July of 1994 because of vandalism problems. The samplers are positioned to ensure reasonable probability that any significant concentration of particulate effluents from LLNL operations will be detected. Geographical details of particulate sampling locations are outlined in a written procedure in Appendix A of the *Environmental Monitoring Plan* (Tate et al. 1995).



**Figure 4-1.** Air particulate and tritium sampling locations, Livermore site, 1994.

LLNL also maintains 11 continuously operating airborne tritium samplers on the Livermore site (**Figure 4-1**) and five samplers in the Livermore Valley (**Figure 4-2**). Four of the Livermore site locations (B331, B292, B514, and B624) monitor diffuse source emissions. The tritium sample locations are detailed in Appendix A of the *Environmental Monitoring Plan*.

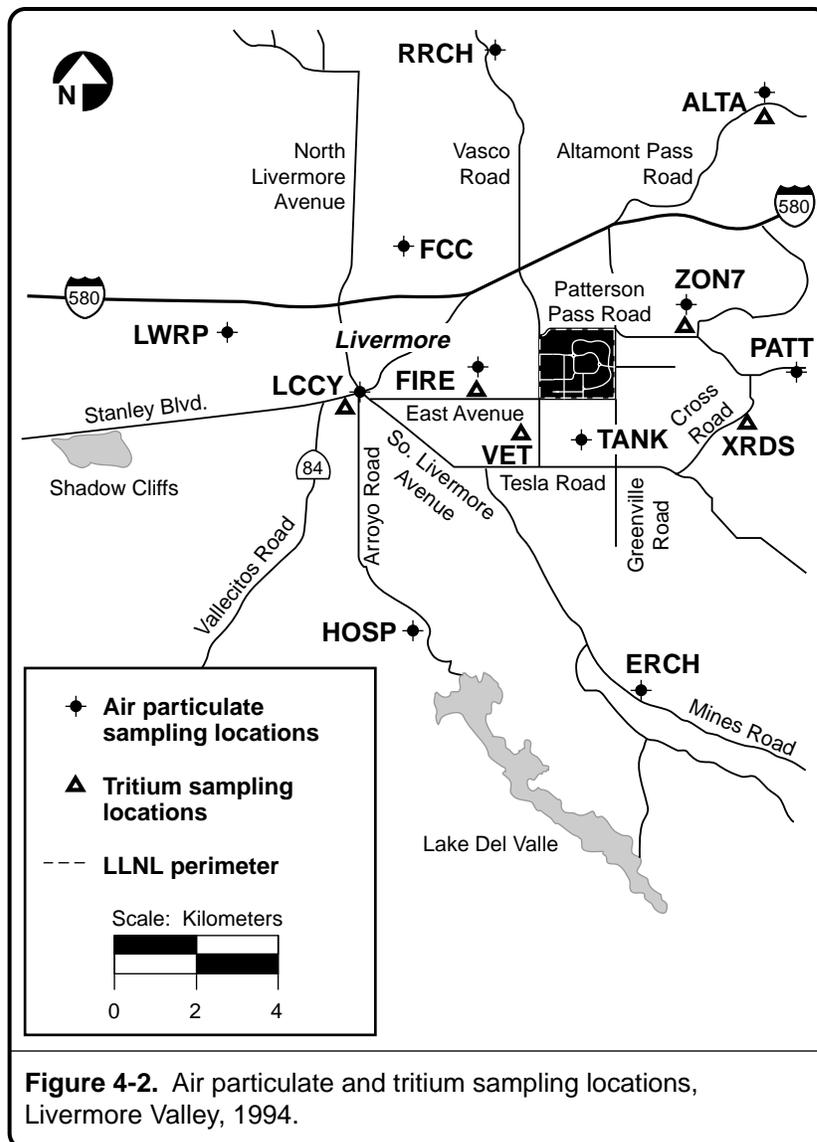
Particulate filters are changed each week at all locations, and tritium samples are changed every two weeks. Replicate samples are processed to confirm the results obtained from the samplers. In addition, duplicate quality control (QC) samplers are operated for two months in parallel with the permanent sampler at a given site.

As outlined in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991),

## 4. Air Monitoring



gross alpha and gross beta air filter results are used only as trend indicators; specific radionuclide analysis is done for plutonium, uranium, and all gamma emitters. All analytical results are reported as a measured concentration per volume of air, or at the minimum detection limit (MDL) when no activity is detected. In all cases, the MDL is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that may be or are present in the air sample. Particle size distributions are not determined because the estimated effective dose equivalent to the maximally exposed individual is well below the 0.01 mSv (1 mrem) allowable limit. Further details of the surveillance monitoring methods are included in Volume 2, Chapter 4.



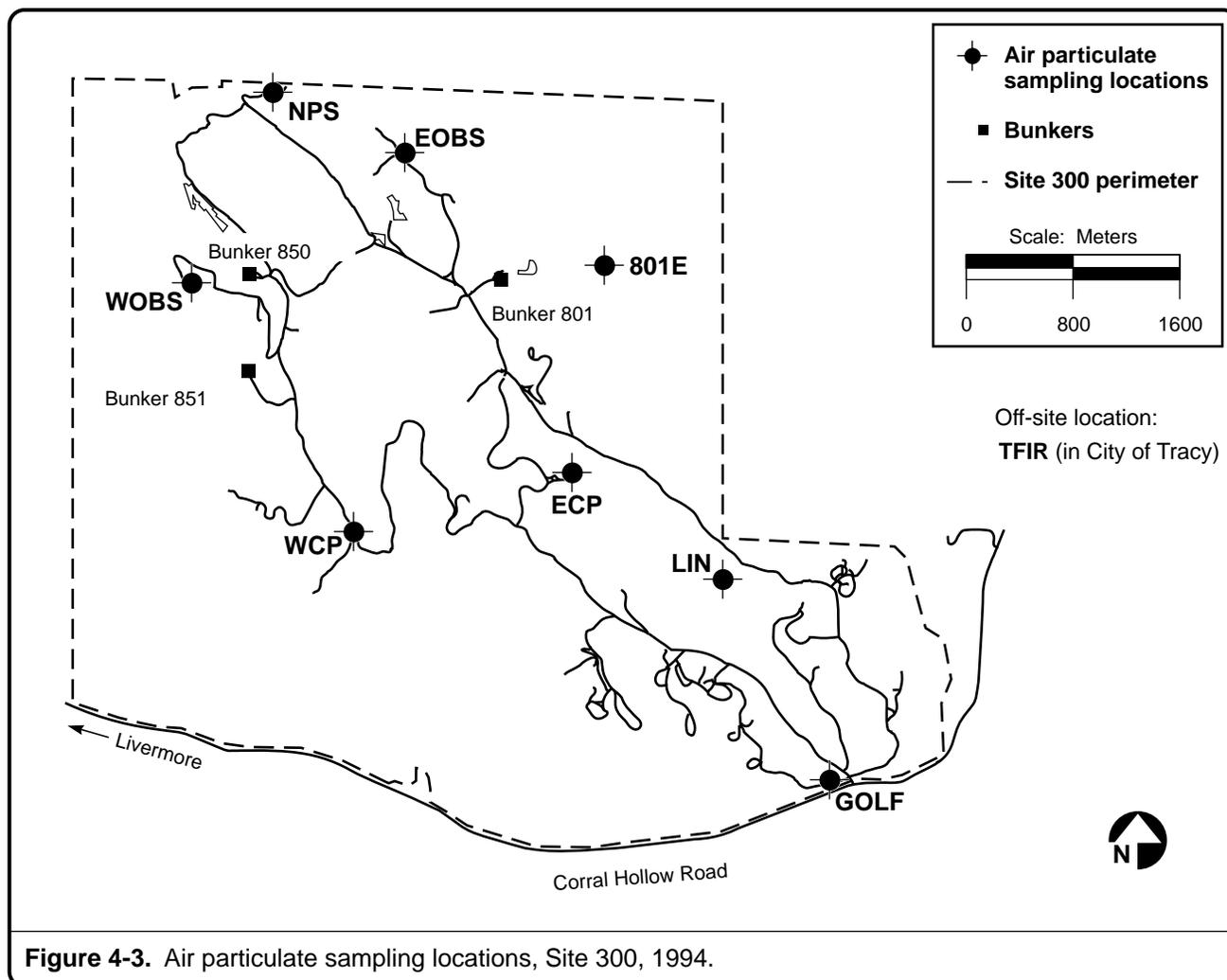


Figure 4-3. Air particulate sampling locations, Site 300, 1994.

For air effluent monitoring, LLNL maintains 92 radionuclide sampling systems on air exhausts at eight facilities at the Livermore site. These systems are listed in **Table 4-1** along with the analytes of interest, the type of sampler, and the number of samplers and discharge points monitored. Sampling for particles containing radionuclides is conducted in seven of the facilities; sampling for tritium is conducted in one facility. All sampling systems operate continuously. Samples are changed weekly or biweekly depending on the facility. Air samples for particulate emissions are extracted downstream of high efficiency particulate air (HEPA) filters and prior to the discharge point to the atmosphere. Particles in the extracted air are collected on sample filters and analyzed for gross alpha and beta activity. Tritium is collected using molecular sieves. In addition to sample collection for environmental reporting, some facilities have real-time monitors at discharge points to provide faster notification in the event of a release of radioactivity. Further details of LLNL air effluent sampling systems are included in Chapter 4 of the *Environmental Monitoring Plan*.



**Table 4-1.** Air effluent sampling locations and systems.

Building	Facility	Analytes	Sample Type	Number of Samplers	Number of Discharge Points	
175	Mars	Gross $\alpha, \beta$ on particles	Filters	6	6	
231	Vault	Gross $\alpha, \beta$ on particles	Filter	1	1	
251	Heavy elements	Unhardened area	Gross $\alpha, \beta$ on particles	Filters	44	55 <sup>(a)</sup>
		Hardened area	Gross $\alpha, \beta$ on particles	CAM <sup>(b)</sup>	4	
331	Tritium	Tritium	Ionization chamber <sup>(b)</sup>	4	4	
		Gaseous tritium/tritiated water vapor	Molecular sieves	4	2	
332	Plutonium	Gross $\alpha, \beta$ on particles	CAM <sup>(b)</sup>	12	11	
		Gross $\alpha, \beta$ on particles	Filters	12	11	
419	Decontamination	Gross $\alpha, \beta$ on particles	Filters	2	2	
490	Laser isotope separation	Gross $\alpha, \beta$ on particles	Filters	4	4	
491	Laser isotope separation	Gross $\alpha, \beta$ on particles	Filters	1	1	

Note: "CAM" denotes Eberline continuous air monitors.

<sup>a</sup> Alternate blower system measured by the same sampler.

<sup>b</sup> Alarmed systems.

The need for continuous air effluent monitoring at other air discharge points that can potentially release radionuclides to the atmosphere is evaluated according to the NESHAPs regulations. The evaluation is based on estimated releases using radionuclide inventories specific to individual discharge points and does not take into account reduction by emission control systems (according to the regulations). As reported in the *LLNL NESHAPs 1994 Annual Report* (Surano et al. 1995), no additional locations were identified that require continuous monitoring. In fact, many of the existing sampling systems now in place (**Table 4-1**) are not required; however, LLNL has continued to operate these systems as a best-management practice.

### Results

This section discusses the air monitoring results at the Livermore site and at Site 300.



**Table 4-2** shows the monthly gross alpha and gross beta detection frequency, median, interquartile range (IQR), and maximum for all Livermore Valley, Livermore-site perimeter, and Site 300 sampling locations. (See Volume 2, Tables 4-1 and 4-2, for a weekly summary of Livermore Valley and Livermore-site perimeter gross alpha and gross beta concentrations in air.) Negative values are not considered detections. The monthly median gross alpha and gross beta concentrations in air are plotted in **Figures 4-4** and **4-5**, respectively. The gross beta results seem to be much more variable and higher during the fall and winter. This apparent seasonal pattern is similar to 1992 and 1993 data. The values reported for gross alpha and gross beta activities are similar to those observed in previous years and show no significant differences between samples taken at the Livermore-site perimeter, Livermore Valley, and Site 300. Most of the gross alpha determinations were at or near the detection limit of the method. Typical gross alpha activity for the Livermore Valley is  $-4.7 \times 10^{-12}$  Bq/mL ( $-1.3 \times 10^{-22}$  Ci/mL) and for the Livermore-site perimeter is  $-3.9 \times 10^{-12}$  Bq/mL ( $-1.1 \times 10^{-22}$  Ci/mL). Approximately 56% of the gross alpha values are negative. The negative values occur because the background of the devices used to analyze the filters is higher than the amount of activity on the filters. Typical gross beta activity for the Livermore Valley is  $4.1 \times 10^{-10}$  Bq/mL ( $1.1 \times 10^{-20}$  Ci/mL) and  $4.5 \times 10^{-10}$  Bq/mL ( $1.2 \times 10^{-20}$  Ci/mL) for the Livermore-site perimeter. The primary sources of observed alpha and beta activity are the naturally occurring radioisotopes of uranium and thorium and their decay products.

**Table 4-3** shows a summary of gamma-emitting radionuclide concentrations in air that contribute to the activity in the Livermore-site perimeter samples. (See Volume 2, Table 4-4 for monthly gamma data.) Of the nuclides tabulated,  $^7\text{Be}$ ,  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ra}$ , and  $^{228}\text{Th}$  occur naturally. The primary source of  $^{137}\text{Cs}$  is long-term global fallout and fallout resuspension.

In addition to providing baseline data on global fallout, analysis of these radionuclides enables LLNL to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL. The Derived Concentration Guides (DCGs) for these radionuclides are also shown in **Table 4-3**. For air, DCGs specify the concentrations of radionuclides that could be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent (DOE Order 5400.5). (Chapter 12 on Radiological Dose Assessment provides an explanation of this and other units of dose.) Finally, the fraction of the DCGs is presented. These values demonstrate the low levels of gamma activity present in air at the Livermore-site perimeter.

## 4. Air Monitoring



**Table 4-2.** Gross alpha and gross beta (Bq/mL) in air particulate samples summarized by month, 1994.

	Detection Frequency	Monthly Median	Interquartile Range	Maximum
<b>Livermore Valley</b>				
<b>Gross alpha</b>				
Jan	21/38	$2.8 \times 10^{-12}$	$2.6 \times 10^{-11}$	$8.8 \times 10^{-11}$
Feb	36/43	$4.7 \times 10^{-11}$	$6.8 \times 10^{-11}$	$1.8 \times 10^{-10}$
Mar	22/51	$-1.0 \times 10^{-11}$	$3.2 \times 10^{-11}$	$1.0 \times 10^{-10}$
Apr	17/41	$-6.3 \times 10^{-12}$	$1.4 \times 10^{-11}$	$1.0 \times 10^{-10}$
May	18/39	$-6.1 \times 10^{-12}$	$3.4 \times 10^{-11}$	$1.3 \times 10^{-10}$
Jun	13/54	$-2.9 \times 10^{-11}$	—(a)	$7.7 \times 10^{-11}$
Jul	15/38	$-2.2 \times 10^{-11}$	$2.5 \times 10^{-11}$	$1.1 \times 10^{-10}$
Aug	17/39	$-4.9 \times 10^{-12}$	$1.9 \times 10^{-11}$	$1.1 \times 10^{-10}$
Sep	29/49	$1.4 \times 10^{-11}$	$2.5 \times 10^{-11}$	$1.3 \times 10^{-10}$
Oct	11/37	$-2.4 \times 10^{-11}$	$2.3 \times 10^{-11}$	$7.4 \times 10^{-11}$
Nov	19/36	$2.2 \times 10^{-12}$	$4.1 \times 10^{-11}$	$8.9 \times 10^{-11}$
Dec	18/46	$-1.4 \times 10^{-11}$	$2.6 \times 10^{-11}$	$1.0 \times 10^{-10}$
<b>Gross beta</b>				
Jan	38/38	$1.1 \times 10^{-9}$	$1.1 \times 10^{-9}$	$2.7 \times 10^{-9}$
Feb	43/43	$4.4 \times 10^{-10}$	$6.0 \times 10^{-10}$	$2.2 \times 10^{-9}$
Mar	51/51	$4.4 \times 10^{-10}$	$1.6 \times 10^{-10}$	$6.6 \times 10^{-10}$
Apr	41/41	$2.7 \times 10^{-10}$	$1.2 \times 10^{-10}$	$6.4 \times 10^{-10}$
May	39/39	$2.5 \times 10^{-10}$	$1.7 \times 10^{-10}$	$4.6 \times 10^{-10}$
Jun	54/54	$3.1 \times 10^{-10}$	$1.9 \times 10^{-10}$	$5.4 \times 10^{-10}$
Jul	38/38	$2.6 \times 10^{-10}$	$2.0 \times 10^{-10}$	$6.7 \times 10^{-10}$
Aug	39/39	$3.5 \times 10^{-10}$	$1.1 \times 10^{-10}$	$5.4 \times 10^{-10}$
Sep	49/49	$8.0 \times 10^{-10}$	$5.9 \times 10^{-10}$	$1.2 \times 10^{-9}$
Oct	37/37	$7.5 \times 10^{-10}$	$6.6 \times 10^{-10}$	$3.1 \times 10^{-9}$
Nov	36/36	$3.7 \times 10^{-10}$	$2.3 \times 10^{-10}$	$9.7 \times 10^{-10}$
Dec	46/46	$5.7 \times 10^{-10}$	$3.5 \times 10^{-10}$	$1.2 \times 10^{-9}$
<b>Livermore Perimeter</b>				
<b>Gross alpha</b>				
Jan	9/22	$-3.3 \times 10^{-11}$	$1.0 \times 10^{-11}$	$1.0 \times 10^{-10}$
Feb	16/21	$3.6 \times 10^{-11}$	$8.4 \times 10^{-11}$	$1.1 \times 10^{-10}$
Mar	12/28	$-6.7 \times 10^{-12}$	$3.6 \times 10^{-11}$	$1.3 \times 10^{-10}$
Apr	9/24	$-1.3 \times 10^{-11}$	$1.3 \times 10^{-11}$	$1.3 \times 10^{-10}$
May	13/24	$5.4 \times 10^{-12}$	$2.5 \times 10^{-11}$	$9.5 \times 10^{-11}$
Jun	11/27	$-1.7 \times 10^{-11}$	$2.9 \times 10^{-11}$	$7.4 \times 10^{-11}$
Jul	10/22	$-2.8 \times 10^{-12}$	$4.2 \times 10^{-11}$	$1.0 \times 10^{-10}$
Aug	15/24	$5.3 \times 10^{-12}$	$3.4 \times 10^{-11}$	$1.4 \times 10^{-10}$
Sep	14/30	$-2.1 \times 10^{-12}$	$3.6 \times 10^{-11}$	$1.1 \times 10^{-10}$
Oct	9/23	$-1.8 \times 10^{-11}$	$1.8 \times 10^{-11}$	$4.8 \times 10^{-11}$
Nov	14/24	$7.3 \times 10^{-12}$	$3.8 \times 10^{-11}$	$1.0 \times 10^{-10}$
Dec	9/29	$-1.5 \times 10^{-11}$	$1.2 \times 10^{-11}$	$6.6 \times 10^{-11}$

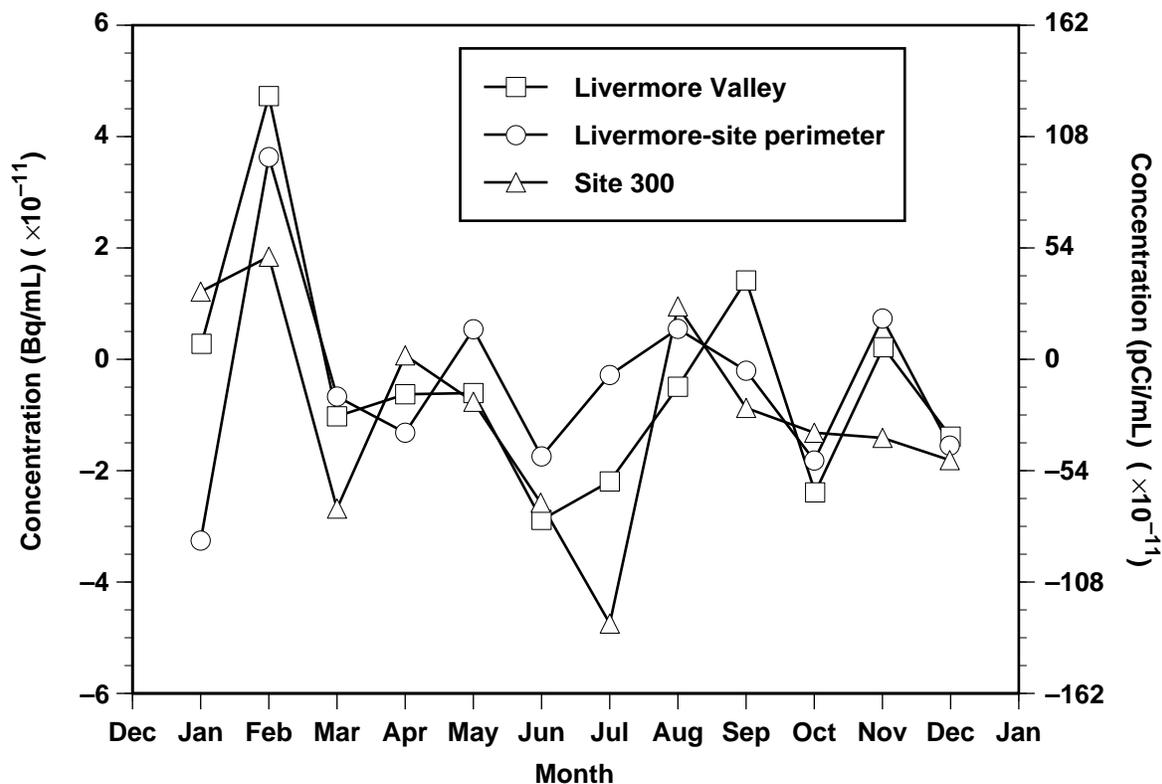
## 4. Air Monitoring



**Table 4-2.** Gross alpha and gross beta (Bq/mL) in air particulate samples summarized by month, 1994 (concluded).

	Detection Frequency	Monthly Median	Interquartile Range	Maximum
<b>Livermore Perimeter (continued)</b>				
<b>Gross beta</b>				
Jan	22/22	$1.6 \times 10^{-9}$	$1.3 \times 10^{-9}$	$3.7 \times 10^{-9}$
Feb	21/21	$4.7 \times 10^{-10}$	$4.4 \times 10^{-10}$	$1.8 \times 10^{-9}$
Mar	28/28	$4.7 \times 10^{-10}$	$1.3 \times 10^{-10}$	$6.7 \times 10^{-10}$
Apr	24/24	$3.0 \times 10^{-10}$	$1.4 \times 10^{-10}$	$5.3 \times 10^{-10}$
May	23/24	$2.5 \times 10^{-10}$	$2.0 \times 10^{-10}$	$5.4 \times 10^{-10}$
Jun	27/27	$2.9 \times 10^{-10}$	$1.4 \times 10^{-10}$	$6.3 \times 10^{-10}$
Jul	22/22	$3.2 \times 10^{-10}$	$1.9 \times 10^{-10}$	$6.7 \times 10^{-10}$
Aug	24/24	$4.0 \times 10^{-10}$	$2.0 \times 10^{-10}$	$6.8 \times 10^{-10}$
Sep	30/30	$7.5 \times 10^{-10}$	$4.9 \times 10^{-10}$	$1.4 \times 10^{-9}$
Oct	23/23	$5.8 \times 10^{-10}$	$9.1 \times 10^{-10}$	$2.1 \times 10^{-9}$
Nov	24/24	$3.6 \times 10^{-10}$	$3.1 \times 10^{-10}$	$7.2 \times 10^{-10}$
Dec	29/29	$6.5 \times 10^{-10}$	$4.3 \times 10^{-10}$	$1.1 \times 10^{-9}$
<b>Site 300</b>				
<b>Gross Alpha</b>				
Jan	19/34	$1.2 \times 10^{-11}$	$4.3 \times 10^{-11}$	$8.6 \times 10^{-11}$
Feb	27/36	$1.8 \times 10^{-11}$	$4.8 \times 10^{-11}$	$1.5 \times 10^{-10}$
Mar	10/43	$-2.7 \times 10^{-11}$	— <sup>(a)</sup>	$1.3 \times 10^{-10}$
Apr	19/36	$7.0 \times 10^{-13}$	$1.8 \times 10^{-11}$	$6.6 \times 10^{-11}$
May	13/36	$-7.6 \times 10^{-12}$	$2.4 \times 10^{-11}$	$6.6 \times 10^{-11}$
Jun	10/44	$-2.6 \times 10^{-11}$	— <sup>(a)</sup>	$9.6 \times 10^{-11}$
Jul	7/35	$-4.7 \times 10^{-11}$	— <sup>(a)</sup>	$6.7 \times 10^{-11}$
Aug	21/35	$9.3 \times 10^{-12}$	$3.1 \times 10^{-11}$	$1.0 \times 10^{-10}$
Sep	18/44	$-1.2 \times 10^{-12}$	$2.8 \times 10^{-11}$	$1.3 \times 10^{-10}$
Oct	13/36	$-1.3 \times 10^{-11}$	$9.9 \times 10^{-12}$	$7.5 \times 10^{-11}$
Nov	10/36	$-1.4 \times 10^{-11}$	$1.9 \times 10^{-12}$	$5.8 \times 10^{-11}$
Dec	14/40	$-1.8 \times 10^{-11}$	$1.2 \times 10^{-11}$	$1.3 \times 10^{-10}$
<b>Gross Beta</b>				
Jan	34/34	$9.7 \times 10^{-10}$	$1.2 \times 10^{-9}$	$3.1 \times 10^{-9}$
Feb	36/36	$3.8 \times 10^{-10}$	$4.9 \times 10^{-10}$	$2.3 \times 10^{-9}$
Mar	43/43	$3.6 \times 10^{-10}$	$1.4 \times 10^{-10}$	$6.8 \times 10^{-10}$
Apr	36/36	$2.6 \times 10^{-10}$	$1.8 \times 10^{-10}$	$6.3 \times 10^{-10}$
May	36/36	$2.9 \times 10^{-10}$	$2.5 \times 10^{-10}$	$5.4 \times 10^{-10}$
Jun	44/44	$3.6 \times 10^{-10}$	$1.4 \times 10^{-10}$	$6.7 \times 10^{-10}$
Jul	35/35	$4.4 \times 10^{-10}$	$1.7 \times 10^{-10}$	$7.0 \times 10^{-10}$
Aug	35/35	$4.5 \times 10^{-10}$	$1.9 \times 10^{-10}$	$8.2 \times 10^{-10}$
Sep	44/44	$8.0 \times 10^{-10}$	$5.2 \times 10^{-10}$	$1.2 \times 10^{-9}$
Oct	36/36	$7.8 \times 10^{-10}$	$8.2 \times 10^{-10}$	$2.0 \times 10^{-9}$
Nov	36/36	$3.9 \times 10^{-10}$	$3.3 \times 10^{-10}$	$1.1 \times 10^{-9}$
Dec	40/40	$5.0 \times 10^{-10}$	$3.6 \times 10^{-10}$	$1.5 \times 10^{-9}$

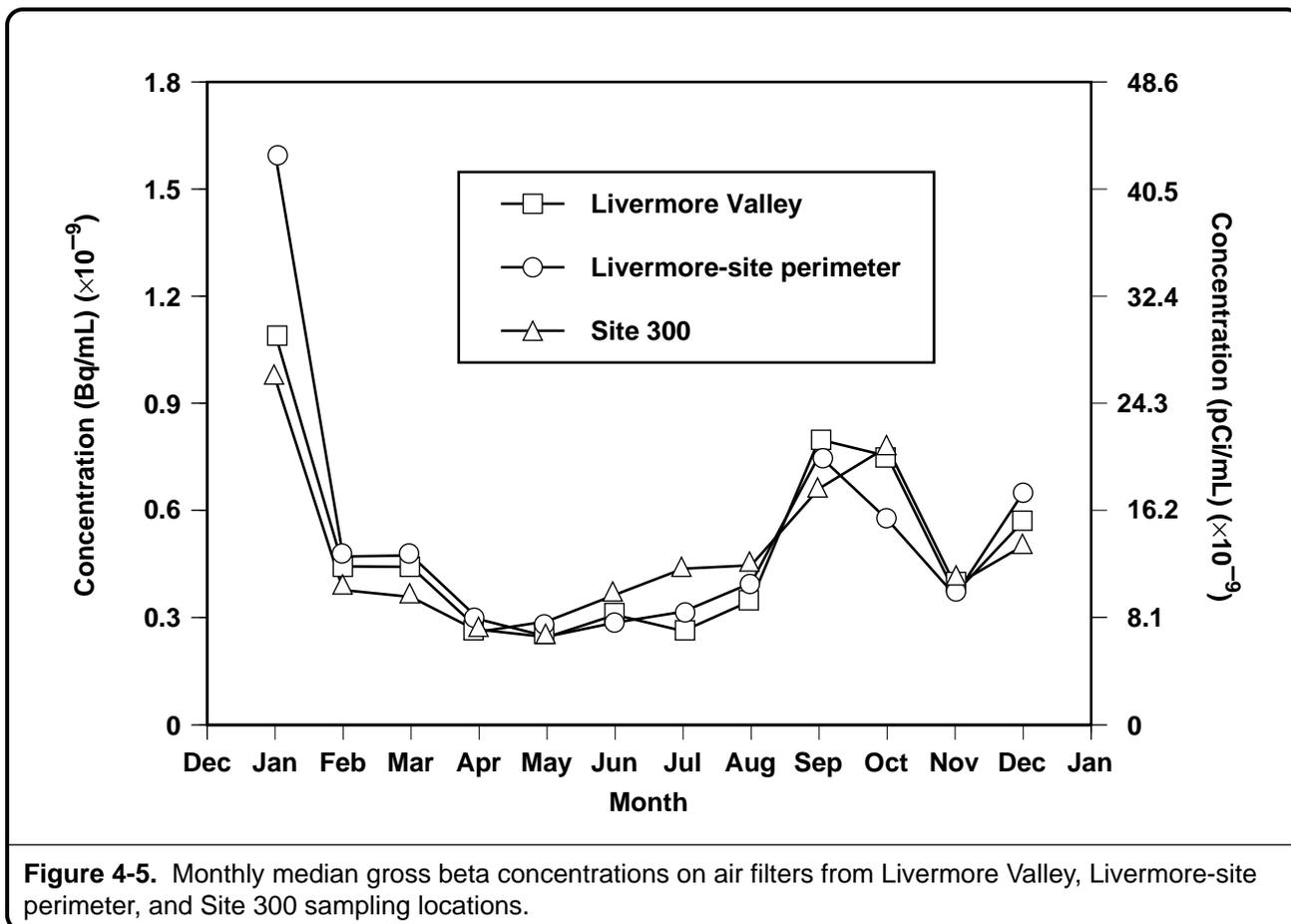
<sup>a</sup> Interquartile range not calculated. See Chapter 14, Quality Assurance.



**Figure 4-4.** Monthly median gross alpha concentrations on air filters from Livermore Valley, Livermore-site perimeter, and Site 300 sampling locations.

**Table 4-4** shows the detection frequency, median, IQR, maximum, and fraction of DCG for concentration of plutonium on air filter samples collected in the Livermore Valley. (See Volume 2, Table 4-6 for monthly data.) The highest off-site median concentration of  $^{239}\text{Pu}$  occurred at the Livermore Water Reclamation Plant (LWRP). Soils near the LWRP contain some detectable plutonium, principally resulting from sludge-spreading operations following an estimated  $1.2 \times 10^9$  Bq (32 mCi) release to the sewer in 1967 (see Chapter 9, Soil and Sediment Monitoring). Resuspension of these soils probably accounts for the slightly higher average  $^{239}\text{Pu}$  in air concentrations observed. However, the median observed value is  $<0.0001$  of the DCG.

**Table 4-4** also shows the concentrations of airborne  $^{239}\text{Pu}$  on air filter samples from the Livermore-site perimeter. (See Volume 2, Table 4-7 for monthly data.) The August sample for location CAFE, which is on the south perimeter of the Livermore site, registered the highest concentrations of  $^{239}\text{Pu}$  in air of all perimeter sampling locations. The concentration reported for this sample,



$3.4 \times 10^{-13}$  Bq/mL ( $9.1 \times 10^{-24}$  Ci/mL), represents 0.0005 of the DCG. The annual median concentration of  $^{239}\text{Pu}$  at location CAFE was  $3.4 \times 10^{-14}$  Bq/mL ( $9.2 \times 10^{-25}$  Ci/mL). No other statistically significant differences between locations or samples were noted, and the overall  $^{239}\text{Pu}$  levels were similar to those reported in 1993.

**Figure 4-6** shows the annual median concentrations of  $^{239}\text{Pu}$  for locations SALV (on-site) and FCC (off-site) from 1982 to 1994. Location FCC represents a typical upwind background location, and SALV represents the perimeter location having the highest annual average for most of this 13-year period. The higher values in the past at SALV may be attributed to historical activities at LLNL.

In June 1991, two air particulate sampling locations (B531 and CRED) were added as part of a special study to investigate the somewhat elevated levels of plutonium in air and surface soil in the southeast quadrant of the Livermore site (see Chapter 9, Soil and Sediment Monitoring, for general background on this



**Table 4-3.** Gamma activity on air filters, Livermore-site perimeter and Site 300, 1994.

	(10 <sup>-9</sup> Bq/mL)	(10 <sup>-12</sup> Bq/mL)					
	<sup>7</sup> Be	<sup>40</sup> K	<sup>137</sup> Cs	<sup>22</sup> Na	<sup>226</sup> Ra	<sup>228</sup> Ra	<sup>228</sup> Th
<b>Livermore Perimeter</b>							
Median	4.61	<7.07	<0.24	<0.26	<0.47	<1.07	<0.64
Interquartile range	1.45	<24.62	— <sup>(a)</sup>				
Maximum	6.14	27.08	0.48	0.63	1.85	3.52	1.39
Median fraction of DCG <sup>(b)</sup>	3.1 × 10 <sup>-6</sup>	<2.1 × 10 <sup>-7</sup>	<1.6 × 10 <sup>-8</sup>	<7.0 × 10 <sup>-9</sup>	<1.3 × 10 <sup>-5</sup>	<9.7 × 10 <sup>-6</sup>	<4.3 × 10 <sup>-4</sup>
<b>Site 300</b>							
Median	5.11	<4.37	<0.15	<0.48	<0.33	<0.59	<0.41
Interquartile range	2.57	— <sup>(a)</sup>	— <sup>(a)</sup>	<0.67	— <sup>(a)</sup>	— <sup>(a)</sup>	— <sup>(a)</sup>
Maximum	7.77	14.17	0.51	1.00	1.27	1.86	1.22
Median fraction of DCG <sup>(b)</sup>	3.4 × 10 <sup>-6</sup>	<1.3 × 10 <sup>-7</sup>	<1.0 × 10 <sup>-8</sup>	<1.3 × 10 <sup>-8</sup>	<9.0 × 10 <sup>-6</sup>	<5.3 × 10 <sup>-6</sup>	<2.8 × 10 <sup>-4</sup>
<b>DCG<sup>(b)</sup> (Bq/mL)</b>	1.5 × 10 <sup>-3</sup>	3.3 × 10 <sup>-5</sup>	1.5 × 10 <sup>-5</sup>	3.7 × 10 <sup>-5</sup>	3.7 × 10 <sup>-8</sup>	1.1 × 10 <sup>-7</sup>	1.5 × 10 <sup>-9</sup>

<sup>a</sup> No measure of dispersion calculated. See Chapter 14, Quality Assurance.

<sup>b</sup> Derived Concentration Guide.

study). These sampling locations are now part of our routine monitoring network and provide data for diffuse source dose assessments. **Table 4-4** shows the median concentrations of airborne <sup>239</sup>Pu at these two locations. (See Volume 2, Table 4-8 for monthly data.) The median concentration of 1.7 × 10<sup>-13</sup> Bq/mL (4.5 × 10<sup>-24</sup> Ci/mL) at location B531 is higher than the median concentration for any of the other air particulate sampling locations but is still only 0.0002 of the DCG.

The median <sup>235</sup>U and <sup>238</sup>U concentrations in air samples from the Livermore-site perimeter are shown in **Table 4-5**. (See Volume 2, Table 4-10 for monthly data.) The maximum measured concentrations of <sup>238</sup>U are less than 0.0004 of the DCG (DOE Order 5400.5). All <sup>235</sup>U/<sup>238</sup>U median ratios are as expected for naturally occurring uranium; however, monthly data in Volume 2 shows some unexpected <sup>235</sup>U/<sup>238</sup>U ratios for natural uranium around the Livermore-site perimeter. The cause of these apparent depleted and enriched uranium ratios is not known, but they have occurred sporadically in the past.

## 4. Air Monitoring



**Table 4-4.** Plutonium activity on air filters (in  $10^{-15}$  Bq/mL), 1994.

Sampling Location <sup>(a)</sup>	Detection Frequency	Median	Interquartile Range	Maximum	Median Fraction of DCG <sup>(b)</sup>
<b>Livermore Valley</b>					
TANK	11/12	3.53	6.05	12.91	$4.8 \times 10^{-6}$
ZON7	10/12	7.38	9.90	16.61	$1.0 \times 10^{-5}$
FCC	7/12	1.33	7.15	64.75	$1.8 \times 10^{-6}$
HOSP	8/12	3.34	7.67	16.84	$4.5 \times 10^{-6}$
LWRP	10/12	11.08	33.1	65.86	$1.5 \times 10^{-5}$
FIRE	8/12	4.22	10.46	29.12	$5.7 \times 10^{-6}$
TFIR	9/12	5.92	8.58	19.31	$8.0 \times 10^{-6}$
ALTA	7/12	2.13	6.08	43.66	$2.9 \times 10^{-6}$
ERCH	10/12	6.64	10.71	34.11	$9.0 \times 10^{-6}$
LCCY	3/6	2.93	7.66	18.50	$4.0 \times 10^{-6}$
RRCH	8/12	3.48	9.72	11.84	$4.7 \times 10^{-6}$
PATT	7/12	4.02	7.97	41.81	$5.4 \times 10^{-6}$
<b>Livermore-Site Perimeter</b>					
SALV	12/12	18.59	7.38	37.37	$2.5 \times 10^{-5}$
MESQ	12/12	23.07	6.56	63.64	$3.1 \times 10^{-5}$
CAFE	12/12	34.08	10.78	338.9	$4.6 \times 10^{-5}$
MET	12/12	21.70	14.74	50.69	$2.9 \times 10^{-5}$
VIS	12/12	22.31	14.34	62.16	$3.0 \times 10^{-5}$
COW	12/12	23.27	10.84	48.47	$3.1 \times 10^{-5}$
<b>Diffuse On-Site Sources</b>					
B531	12/12	166.0	346.7	521.7	$2.2 \times 10^{-4}$
CRED	10/12	10.27	13.79	38.11	$1.4 \times 10^{-5}$
<b>Site 300</b>	12/12	4.31	3.74	11.80	$5.8 \times 10^{-6}$

<sup>a</sup> See Figures 4-1, 4-2, and 4-3 for sampling locations. Location TFIR is in Tracy.

<sup>b</sup> DCG =  $7.4 \times 10^{-10}$  Bq/mL for  $^{239}\text{Pu}$  activity in air ( $2 \times 10^{-14}$   $\mu\text{Ci/mL}$ ).



**Table 4-5.** Uranium activity on air filters, 1994.

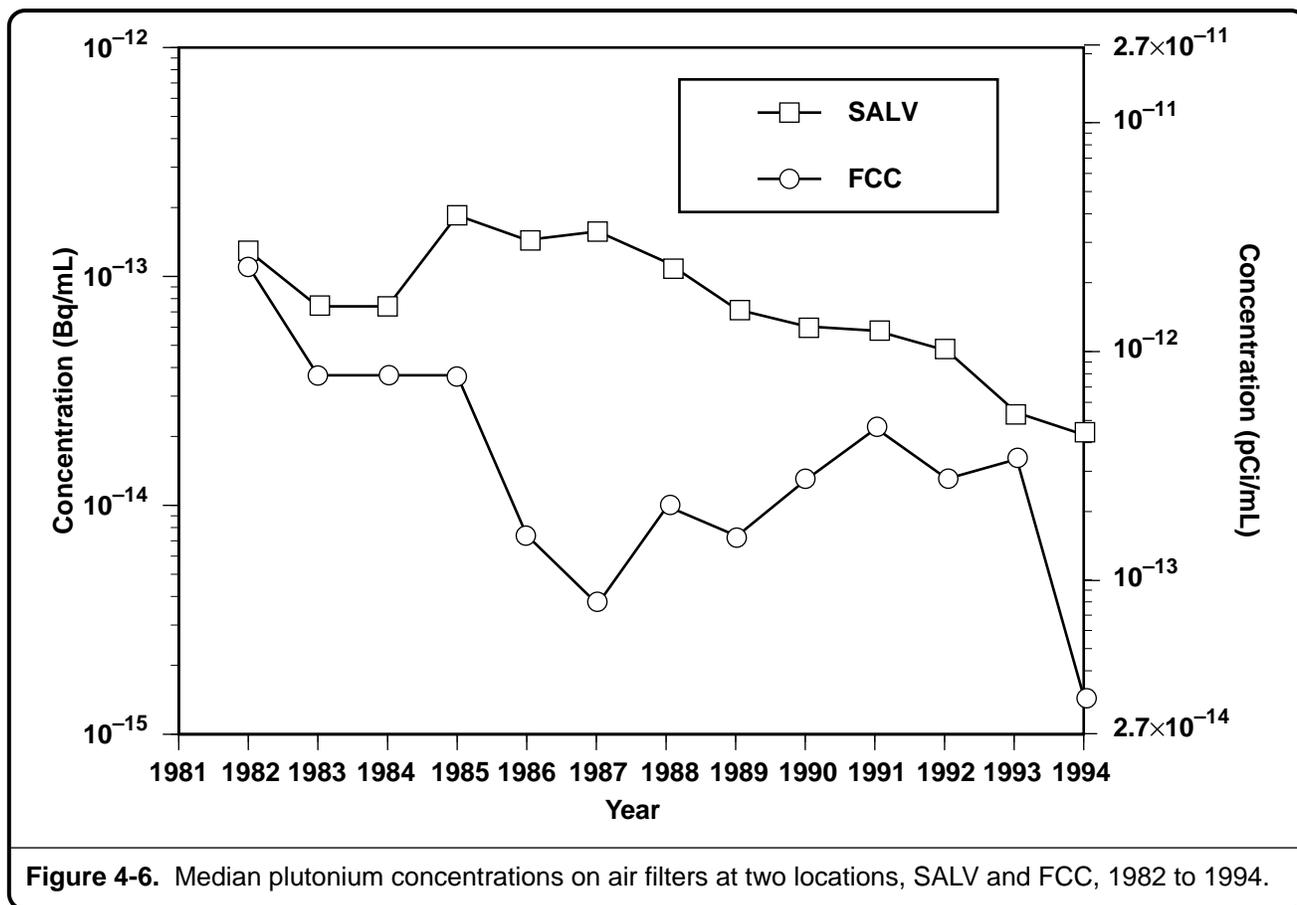
Sampling Location <sup>(a)</sup>	Uranium-238 <sup>(b)</sup> [10 <sup>-5</sup> µg/m <sup>3</sup> ]	Uranium-235 <sup>(c)</sup> [10 <sup>-7</sup> µg/m <sup>3</sup> ]	Uranium-235/238 <sup>(d)</sup> [10 <sup>-3</sup> ]
<b>Livermore Perimeter</b>			
SALV			
Median	3.50	3.36	7.34
Interquartile range	3.63	3.01	1.17
Maximum	9.78	7.02	
Median fraction of DCG	1.2 × 10 <sup>-4</sup>	7.1 × 10 <sup>-6</sup>	
MESQ			
Median	4.32	3.17	7.15
Interquartile range	2.74	2.28	0.46
Maximum	9.00	6.93	
Median fraction of DCG	1.4 × 10 <sup>-4</sup>	6.7 × 10 <sup>-6</sup>	
CAFE			
Median	5.45	3.88	7.13
Interquartile range	3.42	2.68	0.27
Maximum	11.60	8.39	
Median fraction of DCG	1.8 × 10 <sup>-4</sup>	8.2 × 10 <sup>-6</sup>	
MET			
Median	3.65	2.60	7.16
Interquartile range	3.29	2.55	0.54
Maximum	8.86	7.03	
Median fraction of DCG	1.2 × 10 <sup>-4</sup>	5.5 × 10 <sup>-6</sup>	
VIS			
Median	3.28	2.39	7.30
Interquartile range	1.62	1.18	0.23
Maximum	7.96	5.64	
Median fraction of DCG	1.1 × 10 <sup>-4</sup>	5.1 × 10 <sup>-6</sup>	
COW			
Median	5.06	3.72	7.22
Interquartile range	3.96	2.80	0.34
Maximum	10.80	7.64	
Median fraction of DCG	1.7 × 10 <sup>-4</sup>	7.9 × 10 <sup>-6</sup>	
<b>Site 300</b>			
Site 300 composite			
Median	4.84	2.90	6.72
Interquartile range	4.61	2.49	1.00
Maximum	50.0	21.0	
Median fraction of DCG	1.6 × 10 <sup>-4</sup>	6.2 × 10 <sup>-6</sup>	

<sup>a</sup> See Figures 4-1 and 4-3 for sampling locations.

<sup>b</sup> DCG = 0.3 µg/m<sup>3</sup> for <sup>238</sup>U activity in air.

<sup>c</sup> DCG = 0.047 µg/m<sup>3</sup> for <sup>235</sup>U activity in air.

<sup>d</sup> Naturally occurring uranium has a <sup>235</sup>U/<sup>238</sup>U ratio of 7.1 × 10<sup>-3</sup>. Maximum not computed for <sup>235</sup>U/<sup>238</sup>U ratio.



**Table 4-6** shows the median concentrations of tritiated water vapor for the Livermore Valley sampling locations. (See Volume 2, Table 4-12 for biweekly data for each location.) The highest annual median concentration was observed at location ZON7. At approximately  $4.4 \times 10^{-8}$  Bq/mL ( $1.2 \times 10^{-18}$  Ci/mL), this concentration represents 0.00001 of the DCG. The highest biweekly concentration was observed in December at VET. If it were a yearly average, this concentration,  $1.4 \times 10^{-7}$  Bq/mL ( $3.8 \times 10^{-18}$  Ci/mL), would be 0.00004 of the DCG. The 1994 tritium values generally are similar to those reported last year.

**Table 4-6** also shows the median concentrations of tritiated water vapor that were observed at the Livermore-site perimeter sampling locations. (See Volume 2, Table 4-13 for biweekly data.) The highest annual median concentration was observed at location POOL, which was  $1.5 \times 10^{-7}$  Bq/mL ( $4.1 \times 10^{-18}$  Ci/mL), or 0.00004 of the DCG.

Diffuse sources of tritium on the Livermore site are monitored at air tritium sampling locations B331, B292, B514, and B624. **Table 4-6** shows the median concentrations of tritiated water vapor for these sampling locations. (See



**Table 4-6.** Tritium in air (in  $10^{-9}$  Bq/mL), 1994.

Sampling Location <sup>(a)</sup>	Detection Frequency	Median	IQR <sup>(b)</sup>	Maximum	Median Fraction of DCG <sup>(c)</sup>	Median Dose (mSv) <sup>(d)</sup>
<b>Livermore Valley</b>						
ZON7	25/26	44.2	21.3	109.9	$1.2 \times 10^{-5}$	$9.5 \times 10^{-6}$
ALTA	15/24	<15.4	— <sup>(e)</sup>	30.8	$<4.2 \times 10^{-6}$	$3.3 \times 10^{-6}$
LCCY	7/8	16.3	3.6	32.1	$4.4 \times 10^{-6}$	$3.5 \times 10^{-6}$
FIRE	11/24	<15.2	<23.3	55.5	$<4.1 \times 10^{-6}$	$3.3 \times 10^{-6}$
XRDS	18/25	<18.5	<34.7	79.9	$<5.0 \times 10^{-6}$	$4.0 \times 10^{-6}$
VET	17/24	35.1	<58.7	142.5	$9.5 \times 10^{-6}$	$7.5 \times 10^{-6}$
<b>Livermore Perimeter</b>						
SALV	24/24	116.7	100.0	283.1	$3.2 \times 10^{-5}$	$2.5 \times 10^{-5}$
MESQ	19/25	43.3	51.5	115.4	$1.2 \times 10^{-5}$	$9.3 \times 10^{-6}$
CAFE	26/26	91.9	78.3	175.0	$2.5 \times 10^{-5}$	$2.0 \times 10^{-5}$
MET	21/26	29.6	28.3	105.5	$8.0 \times 10^{-6}$	$6.4 \times 10^{-6}$
VIS	26/26	91.4	54.1	178.3	$2.5 \times 10^{-5}$	$2.0 \times 10^{-5}$
COW	24/25	52.5	35.2	114.7	$1.4 \times 10^{-5}$	$1.1 \times 10^{-5}$
POOL	25/25	151.7	78.1	239.4	$4.1 \times 10^{-5}$	$3.3 \times 10^{-5}$
<b>Diffuse On-Site Sources</b>						
B292	22/22	239.4	230.8	555.0	$6.5 \times 10^{-5}$	$5.1 \times 10^{-5}$
B331	26/26	688.2	598.5	1576.2	$1.9 \times 10^{-4}$	$1.5 \times 10^{-4}$
B514	25/26	122.7	67.0	214.2	$3.3 \times 10^{-5}$	$2.6 \times 10^{-5}$
B624	25/25	651.2	333.0	1380.1	$1.8 \times 10^{-4}$	$1.4 \times 10^{-4}$

<sup>a</sup> See Figures 4-1 and 4-2 for sample locations.

<sup>b</sup> Interquartile range.

<sup>c</sup> DCG =  $3.7 \times 10^{-3}$  Bq/mL ( $1 \times 10^{-7}$   $\mu$ Ci/mL).

<sup>d</sup> 1 mSv = 100 mrem.

<sup>e</sup> Interquartile range not calculated. See Chapter 14, Quality Assurance.

Volume 2, Table 4-14 for biweekly data.) The highest median concentration was observed at location B331. This concentration was  $6.9 \times 10^{-7}$  Bq/mL ( $1.9 \times 10^{-17}$  Ci/mL) and represents 0.0002 of the DCG. The highest biweekly tritium concentration,  $1.6 \times 10^{-6}$  Bq/mL ( $4.3 \times 10^{-17}$  Ci/mL), was observed in June. If it were a yearly average, this concentration would represent 0.0004 of the DCG.



The B331 location is near the Tritium Facility (Building 331), which has ceased operations except for inventory reduction and cleanup activities. During this process, tritium-contaminated equipment slated for disposal is stored in a waste accumulation area and sent to Hazardous Waste Management facilities. During 1994, outgassing from such waste processing released an estimated  $0.11 \times 10^{12}$  Bq/L (3 Ci) of tritium to the atmosphere outside of Building 331.

The B292 location is near an underground retention tank that had previously leaked (see the section on Tank Systems Management in Chapter 2 of the 1993 Environmental Report for information regarding the B292 area).

The B624 location is situated in the Building 612 yard, which is dedicated to hazardous waste, radioactive waste, and mixed waste management activities. The yard consists of several areas where waste containers that are outgassing tritium are stored outdoors. The 1994 median concentrations at B292 and B624 are lower than the median concentrations in 1993.

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### Beryllium in Air

The median concentrations of airborne beryllium for the Livermore-site perimeter sampling locations are shown in **Table 4-7**. (See Volume 2, Table 4-15 for monthly data.) The highest value of  $17.4 \text{ pg/m}^3$  occurred in the October composite at location COW. The median concentration is 0.00065 of the monthly ambient concentration limit of  $10,000 \text{ pg/m}^3$  established by the Bay Area Air Quality Management District (BAAQMD).

**Figure 4-7** is a plot of the median beryllium concentration at the Livermore-site perimeter from 1974 through 1994. The overall median concentration was calculated to be 0.002 of the ambient concentration guide. Unless there is a change in LLNL's operations, it is expected that the beryllium levels will remain unchanged.

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### Site 300

#### Airborne Radioactivity

Most gross alpha determinations at Site 300 were at or near the analytical limit of detection for the method. **Table 4-2** shows the monthly gross alpha and gross beta detection frequency, median, IQR, and maximum for sampling locations at Site 300. (See Volume 2, Table 4-3 for monthly data.) The monthly median gross alpha and gross beta concentrations are shown in **Figures 4-4** and **4-5**. The Site 300 gross beta results show a similar pattern to that of the Livermore-site results. Typical gross alpha activity is  $-1.0 \times 10^{-11} \text{ Bq/mL}$  ( $-2.7 \times 10^{-22} \text{ Ci/mL}$ ).



**Table 4-7.** Beryllium on air filters (in  $\text{pg}/\text{m}^3$ ), Livermore-site perimeter and Site 300, 1994.

Sampling Location <sup>(a)</sup>	Detection Frequency	Median	Interquartile Range	Maximum
<b>Livermore Perimeter</b>				
SALV	11/12	<4.9	<12.3	14.5
MESQ	12/12	4.9	7.3	14.9
CAFE	12/12	7.8	7.0	17.1
MET	12/12	4.6	7.9	12.6
VIS	12/12	3.7	5.8	10.8
COW	12/12	6.5	8.0	17.4
<b>Site 300</b>				
EOBS	11/12	4.8	<8.2	10.7
ECP	11/12	<4.6	<9.8	10.4
WCP	12/12	4.6	7.8	14.1
LIN	11/12	6.4	<11.1	18.4
GOLF	12/12	6.6	8.5	16.7
TFIR	12/12	9.2	10.5	24.1
NPS	11/12	<4.4	<8.8	10.5
WOBS	11/12	<5.0	<8.5	11.3
801E	12/12	6.5	14.7	27.7

<sup>a</sup> See Figures 4-1 and 4-3 for sampling locations.

Typical gross beta activity is  $4.4 \times 10^{-10}$  Bq/mL ( $1.2 \times 10^{-20}$  Ci/mL). The primary sources of observed gross alpha and gross beta activity are naturally occurring radioisotopes of uranium and thorium and their decay products.

**Table 4-3** lists the annual median activities, IQR, the fraction of the DCG, as well as the DCGs, of gamma-emitting radionuclides in samples from Site 300 and Tracy. (See Volume 2, Table 4-5 for monthly data.) All these radionuclides were measured at concentrations significantly below the DCGs. Of the nuclides tabulated,  $^7\text{Be}$ ,  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ra}$ , and  $^{228}\text{Th}$  are naturally occurring. The primary source of  $^{137}\text{Cs}$  normally is long-term global fallout and resuspension.

**Table 4-4** shows the median concentration of  $^{239}\text{Pu}$  on air filter samples collected from Site 300. (See Volume 2, Table 4-9 for monthly data.) The highest concentration of  $^{239}\text{Pu}$  was observed in the August composite at a level of  $1.2 \times 10^{-14}$  Bq/mL ( $3.2 \times 10^{-25}$  Ci/mL, or 0.00002 of the DCG). **Table 4-5** shows the median concentration of  $^{238}\text{U}$ , and  $^{235}\text{U}$  and the  $^{235}\text{U}/^{238}\text{U}$  ratio on air samples from Site 300. (See Volume 2, Table 4-11 for monthly data.) The highest concentration of  $^{238}\text{U}$  was observed in the October composite at a level of

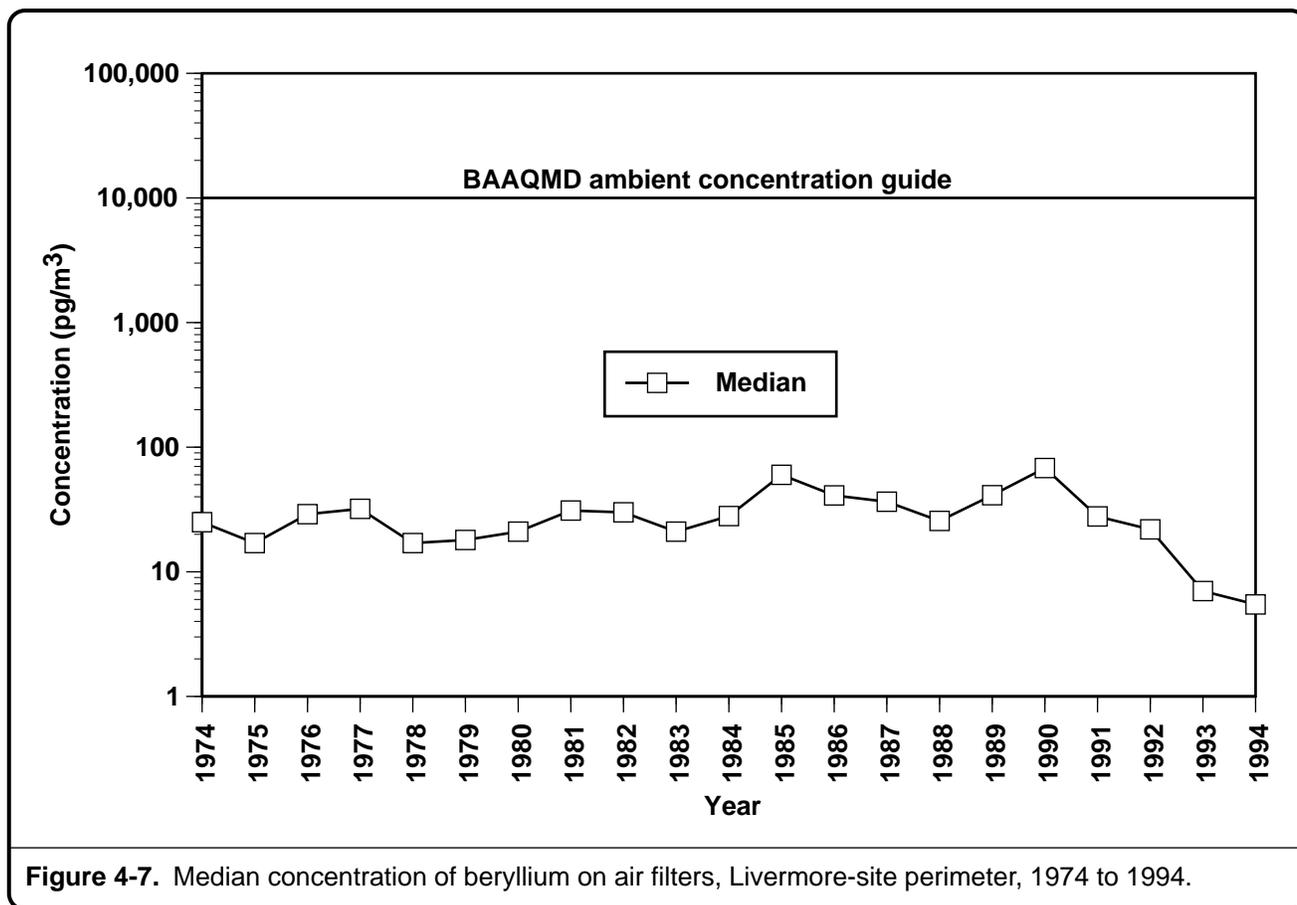


Figure 4-7. Median concentration of beryllium on air filters, Livermore-site perimeter, 1974 to 1994.

$5.0 \times 10^{-4} \mu\text{g}/\text{m}^3$  (0.0017 of the DCG). The highest concentration of  $^{235}\text{U}$  was observed in the October composite at a level of  $1.5 \times 10^{-6} \mu\text{g}/\text{m}^3$  (0.00003 of the DCG). No other significant differences between locations or samples were noted. The overall levels were essentially the same as those reported in previous years.

The ratio of  $^{235}\text{U}$  to  $^{238}\text{U}$  can be used as an indicator of the source of the uranium. Both  $^{235}\text{U}$  and  $^{238}\text{U}$  occur naturally in the area, but only 0.7% of the naturally occurring uranium is  $^{235}\text{U}$ , and the remainder is  $^{238}\text{U}$ . Because Site 300 operations use depleted uranium that contains very little  $^{235}\text{U}$ , it follows that if the ratio remains constant and near 0.7% (within the limit of sampling and analytical error), then the  $^{238}\text{U}$  measured is from natural sources. The  $^{235}\text{U}/^{238}\text{U}$  ratio for October and December show statistically significant deviations from the natural ratio, indicating the presence of airborne depleted uranium from Site 300 operations. The measured concentrations of  $^{238}\text{U}$  for 1994, however, are only 0.00016 of the DCG (DOE Order 5400.5). The  $^{235}\text{U}/^{238}\text{U}$  ratio for September indicates unrealistic levels of  $^{235}\text{U}$ . A ratio of this magnitude would imply operations involving  $^{235}\text{U}/^{238}\text{U}$  ratios much higher than are actually used.



Because the September results were so unusual, reanalysis of the sample was requested. The reanalysis indicates naturally occurring concentrations of  $^{235}\text{U}$  and  $^{238}\text{U}$ .

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### Beryllium in Air

The detection frequency, median, IQR, and maximum concentrations of airborne beryllium for the Site 300 sampling locations are shown in **Table 4-7**. (See Volume 2, Table 4-16 for monthly data.) The highest beryllium concentration of  $27.7 \text{ pg/m}^3$  occurred in August at location 801E. The concentration median is 0.0007 of the federal ambient concentration limit, which is  $10,000 \text{ pg/m}^3$ .

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### Environmental Impact

The environmental impacts from radioactive and nonradioactive effluents are described in this section.

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### Radioactive Effluents

Most of the tritium discharged to the atmosphere by LLNL in 1994 came from the Tritium Facility (Building 331). In 1994, operations there released a total of  $5.1 \times 10^{12} \text{ Bq}$  (137 Ci) of tritium to the atmosphere. Of this, approximately  $2.8 \times 10^{12} \text{ Bq}$  (76 Ci) were released as tritiated water (HTO). The remaining tritium was elemental tritium gas (HT). The highest single biweekly stack emission from the facility was  $1.7 \times 10^{11} \text{ Bq}$  (4.7 Ci), of which  $9.3 \times 10^{10} \text{ Bq}$  (2.5 Ci) was HT. This stack emission was measured between January 11–18, 1994. Sandia National Laboratories, California, released  $3.4 \times 10^{12} \text{ Bq}$  (91 Ci) of HTO and  $1.5 \times 10^{12} \text{ Bq}$  (4 Ci) of HT in 1994. Once released to the environment, the potential dose from tritium gas is approximately 25,000 times lower than a dose from a comparable release of tritiated water. Therefore, the tritiated hydrogen gas did not contribute significantly in calculations of the overall dose.

The potential for the release of radionuclides to the air from all discharge points from operations involving the use of radioactive materials is evaluated according to 40 CFR 61.93 of the NESHAPs regulations. This evaluation, performed on an annual basis, uses radionuclide inventories and monitoring data along with EPA-accepted release factors for operations and EPA-suggested reduction factors for emission control devices to estimate the potential release for each individual discharge point. Results have been published in LLNL NESHAPs 1994 Annual Report (Surano et al. 1995). An abbreviated-isotope summary of measured and calculated emissions for 1994 is presented in **Table 4-8**. The total estimated release from both point and diffuse sources for all isotopes used at LLNL was  $5.5 \times 10^{12} \text{ Bq}$  (150 Ci). Tritium emissions account for 95% of the total estimated emissions. Emissions from point sources are 97% of the total emissions. A complete isotope listing of calculated emissions appears in Volume 2, Table 4-17.



**Table 4-8.** Calculated radioactive air emissions from the Livermore site for 1994.

Radionuclide <sup>(a)</sup>	Calculated Emissions <sup>(b)</sup> (Bq)	Radionuclide	Calculated Emissions <sup>(b)</sup> (Bq)
<sup>3</sup> H (HTO) <sup>(c)</sup>	$2.99 \times 10^{12}$	<sup>232</sup> Th	$4.81 \times 10^3$
<sup>238</sup> U	$1.16 \times 10^6$	<sup>244</sup> Cm	$2.20 \times 10^3$
<sup>241</sup> Am	$1.16 \times 10^5$	<sup>15</sup> O	$8.51 \times 10^{10}$
<sup>234</sup> U	$3.17 \times 10^5$	<sup>239</sup> Pu	$1.22 \times 10^3$
<sup>235</sup> U	$4.84 \times 10^4$	<sup>243</sup> Cm	$7.70 \times 10^2$
Gross alpha <sup>(d)</sup>	$1.14 \times 10^4$	<sup>233</sup> U	$1.18 \times 10^3$
<sup>13</sup> N	$1.63 \times 10^{11}$	<sup>32</sup> P	$1.99 \times 10^7$
<sup>63</sup> Ni	$1.07 \times 10^9$	<sup>226</sup> Ra	$6.29 \times 10^3$
<sup>228</sup> Th	$9.62 \times 10^3$	<sup>3</sup> H (HT) <sup>(c)</sup>	$2.23 \times 10^{12}$
<b>Total</b>			<b><math>5.47 \times 10^{12}</math></b>

- <sup>a</sup> Radionuclides have been ordered by weighting the emissions according to the inhalation dose rate conversion factor for the isotope.
- <sup>b</sup> Calculated emissions are estimates made according to NESHAPs 40 CFR 61.93 except those noted as measured. Values are considered to be conservative.
- <sup>c</sup> Includes measured emissions.
- <sup>d</sup> Gross alpha activity is reported in inventories where specific isotopic content is not determined.

Operations involving tritium at facilities other than the Tritium Facility had estimated releases totaling  $0.18 \times 10^{12}$  Bq (4.8 Ci) of HTO during 1994. The diffuse tritium sources at B292, B331, B514, and B624 have a localized effect; no elevated tritium concentrations were detected at the site perimeter or off site.

Estimated releases of the short-lived radionuclides <sup>13</sup>N and <sup>15</sup>O from Building 194 (the electron-positron linear accelerator) totaled  $2.5 \times 10^{11}$  Bq (6.7 Ci). Releases of <sup>3</sup>H and <sup>13</sup>N and <sup>15</sup>O radioactive effluents at LLNL during the 13-year period from 1981 through 1994 are shown in **Table 4-9**. The radioactive atmospheric emissions from these LLNL operations during 1994 are generally lower than previous years. (Note, in 1992 the Building 194 accelerator that generated <sup>13</sup>N and <sup>15</sup>O was not in operation.)

Analysis of air effluent samples for particulate emissions from facilities with monitoring (Buildings 175, 231, 251, 332, 419, 490, and 491) indicate air concentrations of alpha activity near or less than the MDL. Use of zero values for MDL data can be justified based on facility knowledge, use of tested multiple-stage HEPA filters, and isotopic analysis of filters. Isotopic analyses of the alpha activity of selected samples having values above the MDL have indicated the presence of activity from natural-occurring radon progeny such as polonium. Projecting MDL values for actual emissions, the estimated annual emissions of alpha activity associated with particles from the Livermore site yields  $5.9 \times 10^5$  Bq ( $1.6 \times 10^{-5}$  Ci). The MDL-projected emissions have been substituted



**Table 4-9.** Radioactive airborne effluent releases from the Livermore site, 1981 through 1994.

Year	Airborne Effluents			
	<sup>3</sup> H (GBq) <sup>(a)</sup>	<sup>3</sup> H (Ci) <sup>(a)</sup>	<sup>13</sup> N and <sup>15</sup> O (GBq) <sup>(b)</sup>	<sup>13</sup> N and <sup>15</sup> O (Ci) <sup>(b)</sup>
1981	96,900	2,619	12,700	344
1982	74,520	2,014	21,600	584
1983	120,100	3,245	31,600	855
1984	272,100	7,354	3,000	81
1985	81,550	2,204	19,200	520
1986	46,400	1,254	4,180	113
1987	101,800	2,751	2,300	62
1988	147,400	3,983	1,100	30
1989	109,200	2,952	1,600	42
1990	47,430	1,282	1,800	48
1991	41,140	1,112	440	12
1992	6,550	177	0	0
1993	8,770	237	259	7
1994	5,070	137	248	7

<sup>a</sup> The tritium values reported are from Building 331 only. Additionally, an estimated 180 GBq were released during 1994 from other operations and diffuse sources.

<sup>b</sup> Estimated emissions from Building 194.

in screening calculations estimating dose; the total dose to the public attributable to LLNL operations is not significantly altered by these screening calculations.

The concentrations of radionuclides measured around Site 300 and in the City of Tracy were well below all standards and, except for uranium isotopes, reflect background or naturally occurring levels of these chemicals. The <sup>235</sup>U/<sup>238</sup>U ratios in October and December are less than the ratio of naturally occurring concentrations of these isotopes, which suggests the presence of LLNL-induced depleted uranium in air samples from Site 300. These kinds of results can occur when tests using depleted uranium are conducted at Site 300. Estimated emissions from Site 300 operations that involve radioactive materials are calculated using inventories according to the NESHAPs regulations. Estimated releases of radionuclides for 1994 were  $4.4 \times 10^{10}$  Bq (1.2 Ci) of which  $2.8 \times 10^9$  Bq ( $7.6 \times 10^{-2}$  Ci) were <sup>238</sup>U. Calculated emissions for Site 300 are presented in **Table 4-10**.



**Table 4-10.** Estimated radioactive air emissions from Site 300 for 1994.

Radionuclide	Quantity <sup>(a)</sup> (Bq)	Quantity <sup>(a)</sup> (Ci)
<sup>3</sup> H	$4.19 \times 10^{10}$	1.13
<sup>234</sup> U	$2.63 \times 10^8$	$7.10 \times 10^{-3}$
<sup>235</sup> U	$3.59 \times 10^7$	$9.70 \times 10^{-4}$
<sup>238</sup> U	$2.81 \times 10^9$	$7.60 \times 10^{-2}$
<b>Total</b>	<b><math>4.50 \times 10^{10}</math></b>	<b>1.22</b>

<sup>a</sup> Emissions are estimated according to NESHAPs 40 CFR 61.93.

All LLNL operations with measured and estimated radionuclide releases to the atmosphere and those with the potential to discharge radionuclides are evaluated for their potential impact to the public (see Chapter 12 on radiological dose assessment).

### Nonradioactive Effluents

The concentrations of beryllium at both sites can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 part per million (ppm) of beryllium, and the air of the Livermore area and Central Valley typically contains 10 to 100  $\mu\text{g}/\text{m}^3$  of particulates. Using a value of 50  $\mu\text{g}/\text{m}^3$  for an average dust load and 1 ppm for beryllium content of dust, an airborne beryllium concentration of 50  $\text{pg}/\text{m}^3$  can be calculated. The overall annual medians for the Livermore site and Site 300 are 5.5  $\text{pg}/\text{m}^3$  and 5.1  $\text{pg}/\text{m}^3$ , respectively. These data are well below standards and do not indicate the presence of a threat to the environment or public health.

The estimated releases from exempt and permitted sources of air pollutants at the Livermore site can be compared to the most recent estimated 1994 daily release of air pollutants for the entire Bay Area. For example, the total emissions of oxides of nitrogen released in the Bay Area is approximately 444 metric tons per day compared to an estimate for LLNL releases of 0.065 metric tons per day (0.00015 of total Bay Area emissions). The BAAQMD estimate for reactive organic emissions is at 753 metric tons/day, versus Livermore site's estimated releases of 0.037 metric tons/day (0.00005 of total Bay Area emissions) in 1994.

**Table 4-11** lists the estimated LLNL 1994 total releases for organic precursor and nonprecursor compounds, chlorofluorocarbons (an organic nonprecursor), and other LLNL airborne emissions.

Certain operations at Site 300 require permits from San Joaquin Valley Unified Air Pollution Control District. The total estimated air emissions during 1994 from operations (permitted and exempt air sources) at Site 300 are given in **Table 4-11**.

## 4. Air Monitoring



**Table 4-11.** Nonradioactive air emissions, Livermore site and Site 300, 1994.

Pollutant	Estimated Releases (metric tons/day)	
	Livermore Site	Site 300
Carbon monoxide	0.0109	0.00097
Chlorofluorocarbons	0.00477	0.000005
Organic compounds	0.0358	0.00155
Oxides of nitrogen	0.0646	0.00142
Oxides of sulfur	0.001	0.000045
Particulates	0.0092	0.00234





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### **Introduction**

In 1994, the Livermore site discharged approximately 1.1 million liters per day of wastewater to the City of Livermore sewer system, an amount that constitutes less than 6% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories, California (Sandia, California), which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system. The wastewater contains sanitary sewage and industrial effluent and is discharged in accordance with permit requirements and the City of Livermore Municipal Code.

The effluent is processed at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management Program, the treated sanitary wastewater is transported out of the valley through a pipeline and discharged into San Francisco Bay. A small portion of the treated effluent is used for summer irrigation of the adjacent municipal golf course. Sludge from the treatment process is disposed of in sanitary landfills.

LLNL receives water from two suppliers. LLNL's primary water source is the Hetch-Hetchy Aqueduct. Secondary or emergency water deliveries are taken from the Alameda County Flood Control and Water Quality Conservation District Zone 7. This water is a mixture of ground water and water from the South Bay Aqueduct of the State Water Project. Water quality parameters for the two sources are obtained from the suppliers and are used to evaluate compliance with the discharge permit conditions that limit changes in water quality between receipt and discharge.

Administrative and engineering controls at the Livermore site effectively prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Waste generators receive training on proper waste handling. Environmental Protection Department (EPD) reviews facility procedures and inspects processes for inappropriate discharges. Retention tanks are used to collect wastewater from processes that might release contaminants in quantities sufficient to disrupt operations at the LWRP. Finally, to verify the success of training and control equipment, wastewaters are sampled and analyzed not only at the significant points of generation, as defined by type and quantity of contaminant generated, but also at the point of discharge to the municipal sewer system.

To ensure the integrity of the wastewater collection system, LLNL recently has pursued an aggressive assessment and rehabilitation program. During 1992 and 1993, all building drains that could be identified were tested to determine their



points of discharge. Identified deficiencies, considered to be illicit connections, were classified and are being corrected; major deficiencies were immediately remedied. The retention tank infrastructure at LLNL is undergoing comprehensive evaluation and rehabilitation. Finally, preparatory to relining with a synthetic sock, the major laterals of the sanitary sewer system have been videotaped and evaluated. Major line failures have been repaired. The relining work was completed in 1994.

For facilities with installed retention tank systems, collected wastewater is discharged to the sanitary sewer only if laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). LLNL has developed internal discharge guidelines for specific sources and operations to ensure that sewer effluent for the entire site complies with LLNL's waste discharge permit. If pollutant levels exceed permissible concentrations, the wastewater is treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or it is shipped to an off-site treatment or disposal facility. Liquids containing radioactivity are handled on site and may be treated using processes that reduce the activity to levels well below DOE Order 5400.5 requirements.

LLNL's sanitary sewer discharge permit requires continuous monitoring of the effluent flow rate and pH. A flow-proportional composite sampler collects samples that are analyzed for metals, radioactivity, toxic chemicals, and water quality parameters. In addition, the outflow to the municipal collection system is sampled continuously and analyzed in real-time for conditions that may upset the LWRP treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for pH (as mentioned above), selected metals, and radioactivity. If concentrations above warning levels are detected, an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control and, since July 1990, automatically notifies the LWRP in the event that contaminants are detected. Trained staff respond to all alarms to evaluate the cause.

Two major upgrades were made to the continuous monitoring system in the last quarter of 1994. First, the centrifugal sampling pumps were replaced with a vortex-impeller sampling pump. The new pump is markedly more reliable in providing a continuous sampling stream. Secondly, the electrical system was rewired. The result of the rewiring is a significantly more dependable and maintainable electrical system.

On the basis of the continuous monitoring data, during 1994 there was one release of a metallic contaminant above the warning levels (see the Environmental Impact section of this chapter) and no releases of corrosive or radioactive contaminants that warranted a sewer diversion. This is consistent with the results for 1993, when no such releases were detected, and contrasts markedly with the



results for 1991 and 1992, when 15 and 13 such releases, respectively, were detected.

In 1991, LLNL completed construction of a diversion system that is automatically activated when the monitoring system sounds an alarm. The diversion system ensures that all but the first few minutes of the affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any required cleanup. Up to 775,000 liters of potentially contaminated sewage can be held pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if the liquid is not hazardous or after the contamination level is adjusted, depending on analytical results), shipped for off-site disposal, or treated at LLNL's Hazardous Waste Management Facility. All diverted sewage in 1994 was returned to the sanitary sewer.

In 1991, LLNL completed the implementation of a system of satellite monitoring stations that operates in conjunction with the sewer monitoring system (Figure 5-1). The satellite monitoring stations are positioned at strategic locations within the main sewer system to help pinpoint the on-site area from which a release might have originated. Each station consists of an automatic sampler that collects samples on a time-proportional basis. If there is a release, these samples are analyzed. However, early in 1994, all but two (86B and 51A) of the satellite monitoring stations were taken off-line until the equipment used in routine maintenance of the stations can be ergonomically reengineered.

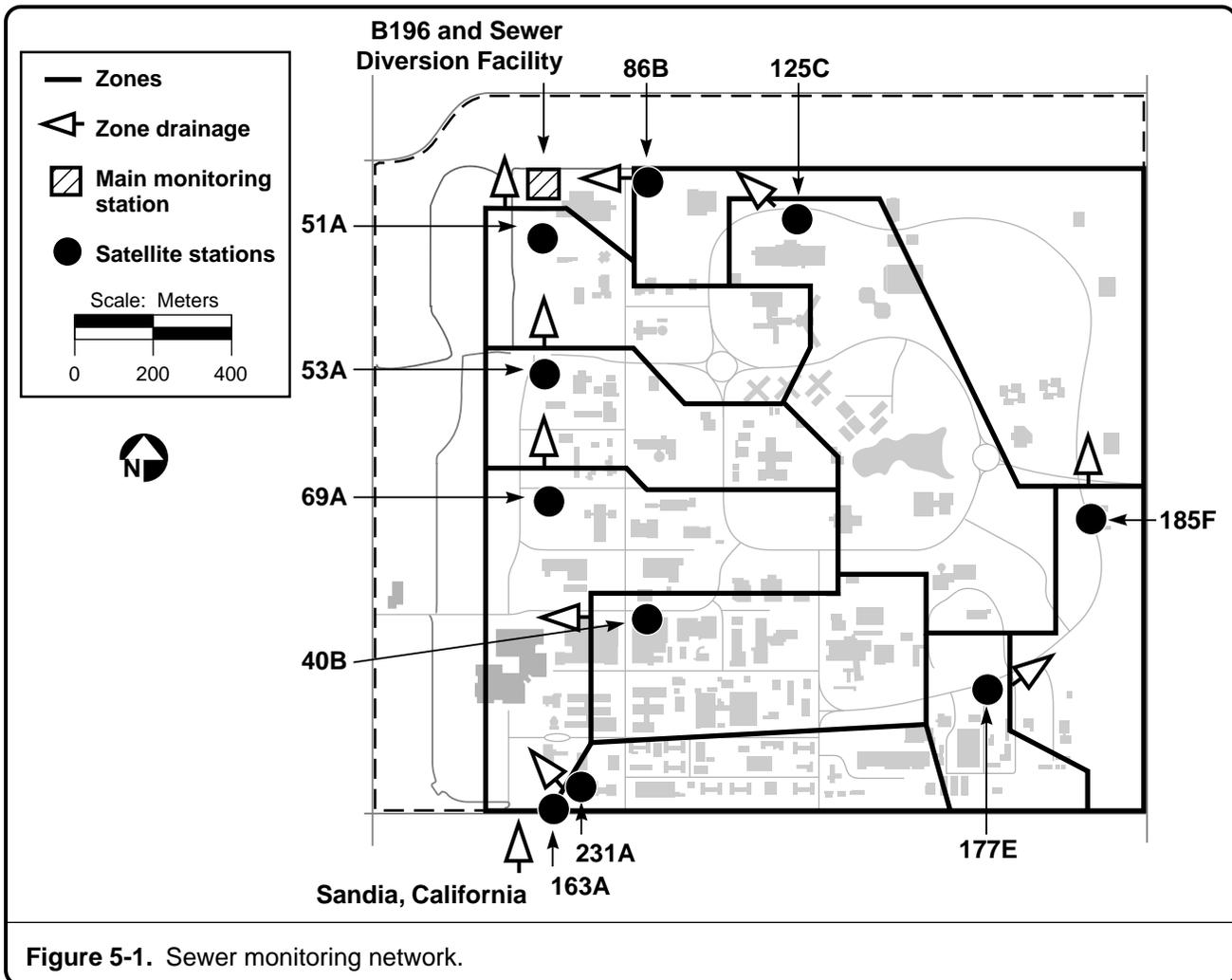
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### Methods

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for 4 seconds for every 3785 liters of effluent. Aliquots of this composite are transferred to polyethylene bottles and submitted for analysis. Treated effluent from LWRP is collected daily by LWRP employees. The daily 500-milliliter aliquots are composited in one gallon polyethylene bottles, which are collected weekly by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge once a week.

Standard quality control and quality assurance procedures are followed. When each sewage field sample is collected, it is labeled with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies that sample during analysis.

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the Livermore-site and LWRP effluents is analyzed for  $^{137}\text{Cs}$  and  $^{239}\text{Pu}$  using ion-exchange and gamma or alpha spectroscopy (respectively). Weekly composites of LLNL effluent are analyzed for metals. In addition, composite samples from the LWRP digesters are analyzed



monthly for gross radioactivity and metals; composites of the monthly samples are analyzed quarterly for plutonium, cesium, and gamma-emitting radionuclides.

Water quality parameters and organic compounds are also monitored. Once each month, a 24-hour composite sample and an instantaneous grab sample of the LLNL sewage effluent are subjected to an extensive set of analyses. These analyses include parameters specified on LWRP's National Pollutant Discharge Elimination System permit, including metals, nutrients, pesticides, and priority pollutants. The federal priority pollutants are measured using EPA Methods 608, 624, and 625 to establish baseline information for these parameters. As part of this monthly sampling program, four oil and grease grab samples are acquired at 4-hour intervals during the day. The analytical results are averaged to obtain a representative measure of the daily oil and grease concentration.



Samples were collected at the point where specified metal finishing and electrical (and electronic) component processes are discharged to assure compliance with EPA categorical pretreatment discharge limits for those processes. The results are reviewed in Chapter 13, Compliance Self-Monitoring.

Three changes in the sampling program were made in 1994. In January, to minimize confined space access by sampling personnel, LLNL modified its monthly instantaneous grab sampling procedure. These samples are collected from the vault entrance using a portable sampler, instead of entering the vault to collect from the sewage stream with either a collimated water sampler (coliwasa) or a grab sample dipper. This change was implemented as a health and safety measure after determining that analytical results for the new sampling protocol were consistent with historical discharge characteristics. Secondly, from January through November, LLNL's secondary contractor for environmental analytical services performed the Biological Oxygen Demand analysis. This analytical test was shifted from primary to secondary analytical contractor while the primary analytical contractor resolved quality control issues with the Biological Oxygen Demand analysis. Finally, in September, pursuant to a LWRP request, LLNL began to measure the federal priority pollutants using EPA Methods 608, 624, and 625, instead of EPA Methods 624 and 625.

### Radioactivity in Sewage Results

Determination of the total radioactivity released as tritium, alpha emitters, and beta emitters is based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever is higher (see **Table 5-1**). The combined releases of tritium, alpha, and beta radiation is 5.0 GBq (GBq = gigabequerels =  $10^9$  Bq), or 0.14 curie (Ci). The total is based on the results shown in **Table 5-1**, reduced by reported Sandia, California tritium releases of 2.2 GBq (0.06 Ci). The annual average concentration of tritium in LLNL sanitary sewer effluent was 0.011 Bq/mL (0.65 pCi/mL).

The concentrations of  $^{239}\text{Pu}$ ,  $^{137}\text{Cs}$ , and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 5-2**. The tritium numbers

**Table 5-1.** Estimated total radioactivity in sanitary sewer effluent, LLNL, 1994.

Radioactive Emitter	Estimate Based on Effluent Concentration (GBq) <sup>(a)</sup>	Limit of Sensitivity (GBq) <sup>(a)</sup>
Tritium	6.9 <sup>(b)</sup>	4.4
Alpha radiation	0.094	0.092
Beta radiation	0.22	0.084

<sup>a</sup> GBq =  $10^9$  Bq or 0.027 Ci.

<sup>b</sup> 6.9 GBq includes 4.7 GBq from LLNL plus 2.2 GBq from Sandia, California.

## 5. Sewage Monitoring



**Table 5-2.** Various radionuclides in sanitary sewer effluents, LLNL and LWRP, 1994.

Month	<sup>3</sup> H (mBq/mL)		<sup>137</sup> Cs (μBq/mL)		<sup>239</sup> Pu (nBq/mL)		<sup>239</sup> Pu (mBq/dry g)
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge <sup>(a)</sup>
January	4.5 ± 0.3	<5.6	1.1 ± 0.4	<0.6	1130 ± 110	0.5 ± 13.9	
February	2.1 ± 0.2	<5.5	< 0.69	<0.6	360 ± 50	2 ± 6	
March	6.0 ± 0.4	<5.2	1.8 ± 0.4	<0.7	520 ± 80	-5 ± 11	1.9 ± 0.1
April	26 ± 1	<5.2	1.2 ± 0.4	<0.4	1000 ± 110	2 ± 10	
May	6.0 ± 0.5	<5.1	1.4 ± 0.5	<0.7	420 ± 60	5 ± 9	
June	3.9 ± 0.3	<5.2	1.1 ± 0.5	<0.6	90 ± 30	5 ± 5	0.44 ± 0.04
July	9.8 ± 0.7	<5.2	1.3 ± 0.4	<0.3	290 ± 50	6 ± 8	
August	5.1 ± 0.4	<4.9	1.5 ± 0.3	<0.5	190 ± 40	-6 ± 6	
September	28 ± 1	<4.9	<0.61	<0.4	210 ± 40	7 ± 9	1.2 ± 0.1
October	4.1 ± 0.3	<5.0	0.9 ± 0.3	<0.5	670 ± 80	0.3 ± 6.6	
November	20 ± 1	<5.1	0.9 ± 0.5	<0.4	560 ± 70	-4 ± 7	
December	5 ± 1	<5.0	1.0 ± 0.4	<0.6	270 ± 50	-1 ± 8	1.0 ± 0.1
<b>Median</b>	<b>6.0</b>	<b>&lt;5.1</b>	<b>1.1</b>	<b>&lt;0.5</b>	<b>390</b>	<b>1</b>	<b>1.1</b>
<b>Interquartile range</b>	<b>12.0</b>	<b>—<sup>(b)</sup></b>	<b>0.5</b>	<b>—<sup>(b)</sup></b>	<b>330</b>	<b>7</b>	<b>0.5</b>
<b>pCi/mL<sup>(c)</sup></b>							<b>pCi/dry g<sup>(c)</sup></b>
<b>Median</b>	<b>0.16</b>	<b>&lt;0.14</b>	<b>2.9 × 10<sup>-5</sup></b>	<b>&lt;14 × 10<sup>-6</sup></b>	<b>11 × 10<sup>-6</sup></b>	<b>0.3 × 10<sup>-7</sup></b>	<b>0.03</b>
<b>Interquartile range</b>	<b>0.32</b>	<b>—<sup>(b)</sup></b>	<b>1.2 × 10<sup>-5</sup></b>	<b>—<sup>(b)</sup></b>	<b>9 × 10<sup>-6</sup></b>	<b>1.8 × 10<sup>-7</sup></b>	<b>0.01</b>
<b>Annual Total Discharges by Radioisotope</b>							
	<b><sup>3</sup>H<sup>(d)</sup></b>		<b><sup>137</sup>Cs</b>		<b><sup>239</sup>Pu</b>		<b>Total</b>
<b>Bq/y</b>	<b>4.7 × 10<sup>9</sup></b>		<b>4.6 × 10<sup>5</sup></b>		<b>1.9 × 10<sup>5</sup></b>		<b>4.7 × 10<sup>9(c)</sup></b>
<b>Ci/y<sup>(c)</sup></b>	<b>0.13</b>		<b>1.3 × 10<sup>-5</sup></b>		<b>5.2 × 10<sup>-6</sup></b>		<b>0.13</b>
<b>Fraction of limit</b>							
<b>DOE</b>	<b>1.6 × 10<sup>-5</sup></b>		<b>2.0 × 10<sup>-6</sup></b>		<b>1.1 × 10<sup>-6</sup></b>		<b>1.9 × 10<sup>-5</sup></b>
<b>10 CFR</b>	<b>0.026</b>		<b>1.3 × 10<sup>-5</sup></b>		<b>—</b>		<b>—</b>

Note: Radionuclide results are reported ±2σ; see Chapter 14, Quality Assurance.

<sup>a</sup> Sludge from LWRP digesters is dried before analysis. The resulting data indicate the plutonium concentration of the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

<sup>b</sup> Due to the large number of nondetections, the interquartile range is omitted. See Chapter 14, Quality Assurance.

<sup>c</sup> 1 Ci = 3.7 × 10<sup>10</sup> Bq

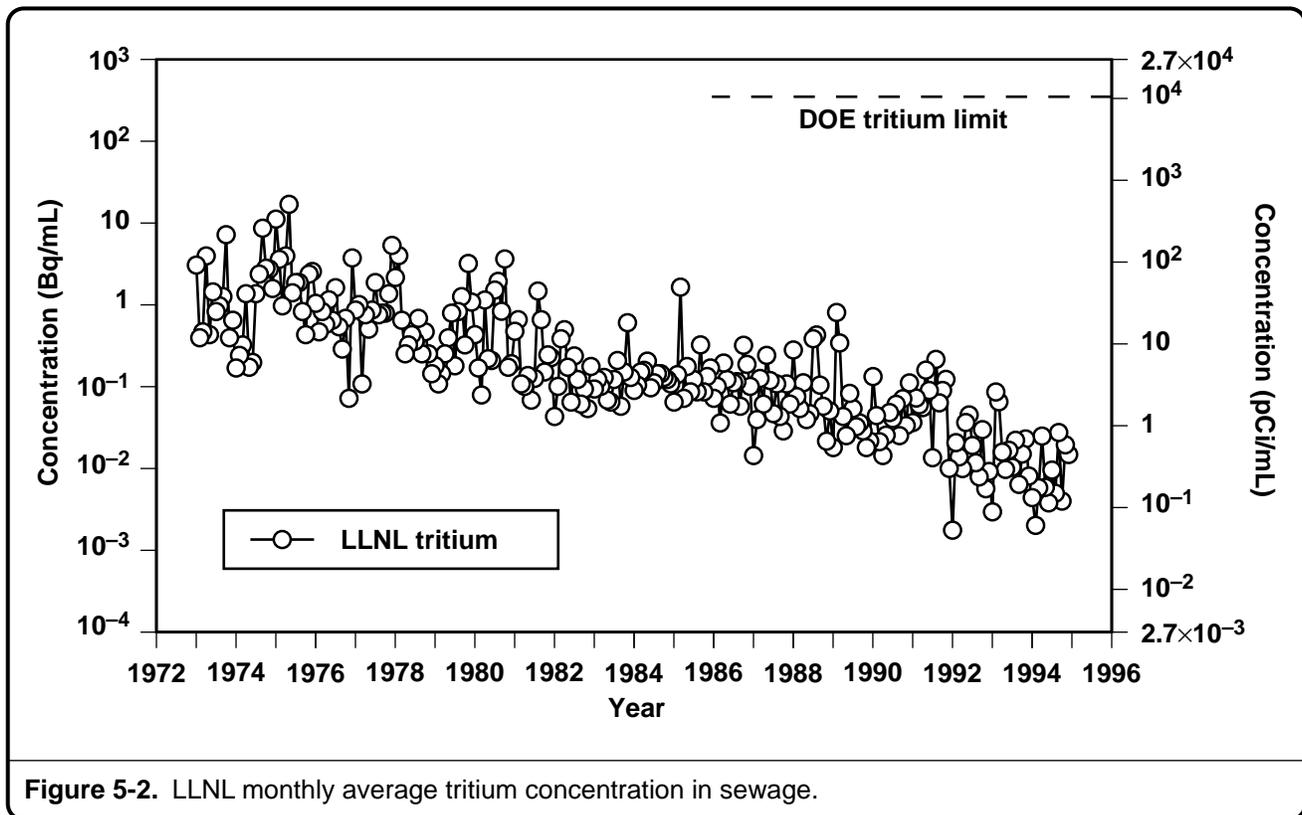
<sup>d</sup> Not including Sandia, California discharges of 2.2 × 10<sup>9</sup> Bq (0.0586 Ci).



are based on the flow-weighted average of the individual daily sample results for a given month. The plutonium and cesium numbers are the direct result of analysis of monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. At the bottom of the table, the total activity released is given by radioisotope. This was calculated by multiplying each sample result by the total flow volume over which the sample was collected, and summing up over all samples. The total activity released for each radioisotope is a conservative value; the limit of sensitivity was used in the calculation when the limit of sensitivity was greater than the actual activity reported.

The historical trend in the monthly average concentration of tritium is shown in **Figure 5-2**. Also included in the figure is the DOE tritium limit (370 Bq/mL), discussed in the Environmental Impact section of this chapter. The trend plot in **Figure 5-2** is indicative of a well-controlled tritium discharge that is not necessarily driven by site inventory.

**Figure 5-3** shows the average monthly plutonium and cesium concentrations in sewage since 1985. The annual average concentration of  $^{137}\text{Cs}$  was  $1.1 \mu\text{Bq/mL}$  ( $3.0 \times 10^{-5}$  pCi/mL); the annual average  $^{239}\text{Pu}$  concentration was  $0.46 \mu\text{Bq/mL}$  ( $1.2 \times 10^{-5}$  pCi/mL).



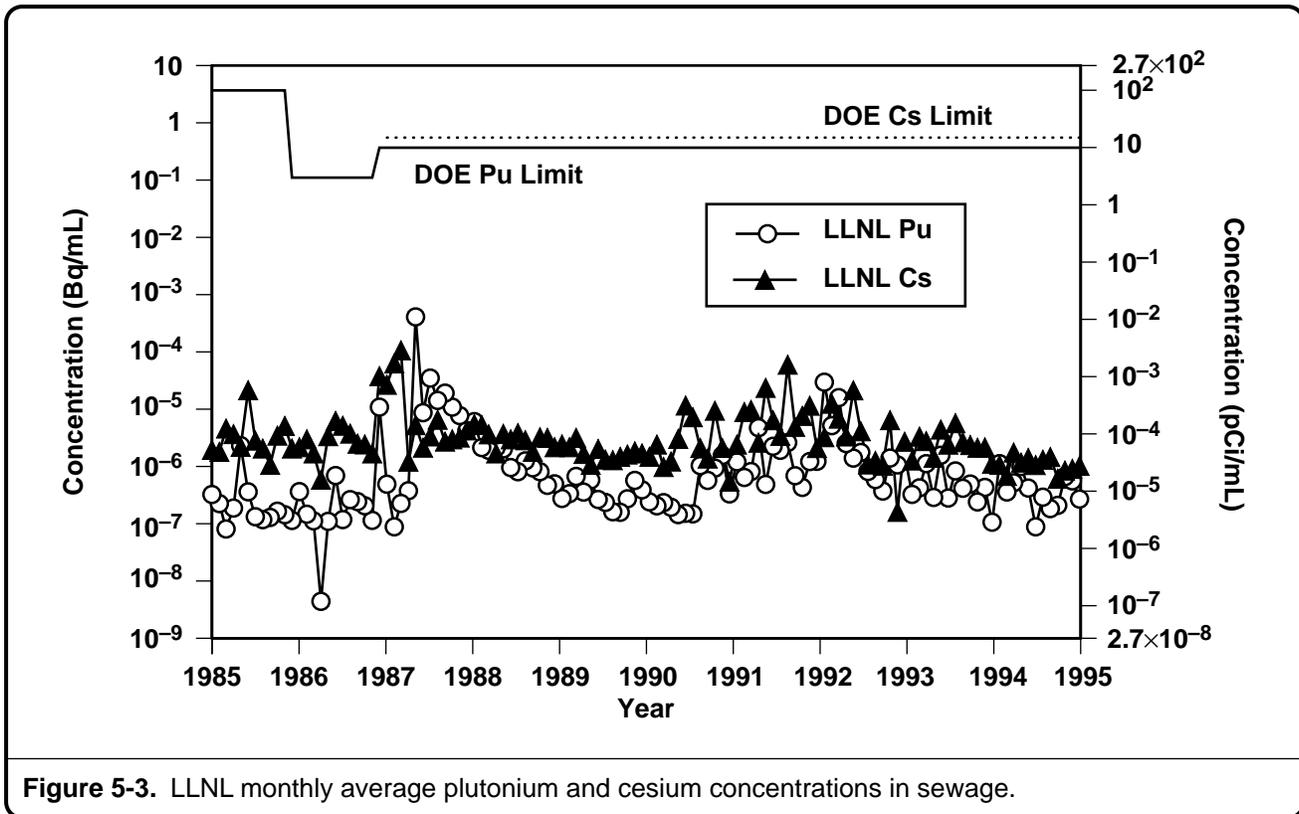


Figure 5-3. LLNL monthly average plutonium and cesium concentrations in sewage.

### Nonradioactive Pollutants in Sewage Results

In July 1993, LLNL changed its primary nonradiological analytical laboratory. The transition between laboratories resulted in some fluctuation in the analytical limits of detection and minor inconsistencies in the reported suite of analytes; the majority of the fluctuations and inconsistencies were resolved by the end of the first quarter of 1994.

**Table 5-3** presents monthly average metal concentrations in LLNL's sanitary sewer effluent. The averages were obtained by a flow-proportional weighting of the results from analysis of the weekly composite samples and the 24-hour composites collected each month. Each result was weighted by the total flow volume for the period during which the sample was collected. The results are quite typical of the values seen during previous years, with the exception of arsenic. The arsenic results are discussed below in the Environmental Impact section.

Results of monthly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 5-4**. Note that—although the samples were analyzed for bromide, carbonate alkalinity (as  $\text{CaCO}_3$ ), hydroxide alkalinity as ( $\text{CaCO}_3$ ), nitrate (as N), beryllium, cyanide, and the full suite of organochlorine pesticides—those analytes were not detected in any sample acquired during 1994, and so are not presented in the table. The

## 5. Sewage Monitoring



results are quite typical of those seen in previous years, with the exceptions of oil and grease and the purgeable-extractable pollutants.

**Table 5-3.** Metals discharged to sanitary sewer system (in mg/L), 1994 summary.

Month	Ag	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
January	0.009	0.47	0.0046	<0.0005	0.0031	0.024	0.07	3.30	0.0007	0.007	0.013	0.28
February	0.010	1.41	0.0040	<0.0005	<0.0029	0.021	0.07	2.27	0.0010	0.013	0.012	0.26
March	0.009	0.31	0.0023	<0.0005	0.0022	0.012	0.09	1.02	0.0006	0.007	0.012	0.16
April	0.010	0.70	0.0024	<0.0005	<0.0050	0.013	0.07	1.28	0.0006	0.008	0.013	0.17
May	0.012	0.40	0.0037	<0.0005	<0.0050	0.017	0.08	1.63	0.0009	0.006	0.019	0.16
June	0.013	0.42	0.0044	<0.0005	<0.0050	0.020	0.10	1.31	0.0006	0.008	0.018	0.18
July	0.011	0.52	0.0042	<0.0005	<0.0050	0.013	0.13	1.11	0.0007	0.006	0.026	0.19
August	<0.010	0.58	0.0057	<0.0005	<0.0050	0.013	0.10	0.96	0.0004	0.006	0.019	0.15
September	<0.010	0.45	0.0039	<0.0005	<0.0050	0.012	0.12	1.11	0.0003	0.006	0.033	0.20
October	<0.010	0.30	0.0032	<0.0005	<0.0050	0.012	0.07	0.85	0.0003	0.007	0.015	0.16
November	<0.010	0.23	0.0035	<0.0005	<0.0050	0.018	0.06	0.87	0.0007	0.006	0.007	0.13
December	0.010	0.27	0.0022	<0.0005	<0.0050	0.010	0.06	0.77	0.0002	0.006	0.010	0.12
<b>Median</b>	<b>&lt;0.010</b>	<b>0.44</b>	<b>0.0036</b>	<b>&lt;0.0005</b>	<b>&lt;0.0050</b>	<b>0.013</b>	<b>0.08</b>	<b>1.11</b>	<b>0.0006</b>	<b>0.007</b>	<b>0.014</b>	<b>0.17</b>
<b>IQR</b>	<b>0.001</b>	<b>0.22</b>	<b>0.0014</b>	— <sup>(a)</sup>	— <sup>(a)</sup>	<b>0.006</b>	<b>0.03</b>	<b>0.45</b>	<b>0.0003</b>	<b>0.001</b>	<b>0.007</b>	<b>0.04</b>
<b>DCL<sup>(b)</sup></b>	<b>0.2</b>	— <sup>(c)</sup>	<b>0.06</b>	— <sup>(c)</sup>	<b>0.14</b>	<b>0.62</b>	<b>1.0</b>	— <sup>(c)</sup>	<b>0.01</b>	<b>0.61</b>	<b>0.2</b>	<b>3.0</b>
<b>Fraction of DCL</b>	<b>0.05</b>	— <sup>(c)</sup>	<b>0.06</b>	— <sup>(c)</sup>	<b>0.04</b>	<b>0.02</b>	<b>0.08</b>	— <sup>(c)</sup>	<b>0.06</b>	<b>0.01</b>	<b>0.07</b>	<b>0.06</b>

<sup>a</sup> Due to the large number of nondetects, the interquartile range could not be calculated for these analytes. See Chapter 14, Quality Assurance.

<sup>b</sup> Discharge Concentration Limit (City of Livermore Ordinance 13.32).

<sup>c</sup> No established limit for analyte.

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**Table 5-4.** Positively detected parameters in LLNL sanitary sewer effluent, 1994.

Positively Detected Parameter	Detection <sup>(a)</sup> Frequency	Minimum	Maximum	Median	IQR <sup>(b)</sup>
<b>Physical and Chemical (mg/L)</b>					
Biochemical oxygen demand	12/12	75	300	140	73
Chemical oxygen demand	12/12	120	630	335	133
Solid settling rate (mL/L/h)	11/11	2	28	17	11
Total dissolved solids (TDS)	12/12	190	290	250	40
Total suspended solids (TSS)	12/12	51	220	115	56
Volatile solids	11/11	11	160	63	42
Bicarbonate alkalinity (as CaCO <sub>3</sub> )	12/12	110	200	160	60
Total alkalinity (as CaCO <sub>3</sub> )	12/12	110	200	160	60
Chloride	12/12	31	95	45	14
Sulfate	12/12	11	37	17	13
Nitrite (as N)	1/12	<0.1	<5	<0.5	—
Ammonia nitrogen (as N)	11/12	<0.1	51	34	16
Total Kjeldahl nitrogen	11/11	30	63	44	15
Total phosphorus (as P)	12/12	0.079	11	3.4	2.6
Ortho-phosphate	3/3	9.6	19	12	4.7
Aluminum	10/12	<0.2	1.1	<0.30	0.22
Arsenic	5/12	<0.002	0.005	<0.002	—
Cadmium	2/12	0.0019	<0.005	<0.005	—
Calcium	12/12	7.9	25	14	3.5
Chromium	7/12	<0.01	0.042	<0.014	0.0055
Copper	12/12	0.059	0.26	0.077	0.019
Iron	12/12	0.42	2.7	0.89	0.43
Lead	12/12	0.0076	0.046	0.013	0.0055
Magnesium	12/12	2.0	4.7	3.0	1.4
Mercury	7/12	<0.0002	0.0014	<0.0003	0.00038
Nickel	6/12	<0.005	0.01	<0.005	—
Potassium	11/12	<0.5	19	<15	2.8
Selenium	3/12	<0.002	0.003	<0.002	—
Silver	6/12	0.0072	0.055	<0.010	—
Sodium	12/12	25	48	38	8.5
Zinc	12/12	0.094	0.34	0.185	0.045
<b>Organic Compounds (mg/L)</b>					
Oil and grease	12/12	6.9	274	21	6.6
Phenolics	5/12	<0.01	<0.05	<0.013	—
Total organic carbon (TOC)	12/12	29	96	46	23

**Table 5-4.** Positively detected parameters in LLNL sanitary sewer effluent, 1994 (concluded).

Positively Detected Parameter	Detection <sup>(a)</sup> Frequency	Minimum	Maximum	Median	IQR <sup>(b)</sup>
<b>Purgeable/Extractable Pollutants (EPA Methods 624 and 625, µg/L)</b>					
Acetone	8/12	<10	770	<52	57
Benzoic acid	4/12	<50	<500	<63	—
Benzyl alcohol	5/12	<20	<200	<30	—
Bis(2-ethylhexyl)phthalate	9/12	<10	<100	<12.5	10.75
Chloroform	12/12	7.4	29	11	4.5
Di-n-butylphthalate	3/12	<10	150	<10	—
Diethylphthalate	1/12	<10	<100	<10	—
m- and p-Cresol	1/12	<10	<100	<10	—
Methylene chloride	1/12	<1	1500	<1	—
Phenol	1/12	<10	<100	<10	—
Styrene	7/12	<1	170	<1	27
Toluene	1/12	<1	3.1	<1	—
Trichloroethene	2/12	<0.5	1.9	<0.5	—

<sup>a</sup> The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

<sup>b</sup> Where the detection frequency is less than 50%, the interquartile range is omitted.

### Environmental Impact of Radioactivity in Sewage

During 1994, there were no inadvertent releases that exceeded any discharge limits for release of radioactive materials to the sanitary sewer system.

In 1990, DOE suggested that radiological releases to the sanitary sewer comply with local and state regulations. The most stringent of these limits was applied by Title 17 of the California Code of Regulations. As a federal facility, LLNL is formally exempt from the requirements of state regulations but follows those requirements under the guidance of DOE. Title 17 contained a limit on discharges of radioactivity in sewage of 37 GBq (1 Ci) each year; it also listed limits on the daily, monthly, and annual concentration for each specific radionuclide. In 1994, Title 17 was repealed and the discharge requirements of Title 17 were replaced with those found in Title 10 of the Code of Federal Regulations, Part 20. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci); in addition, it specifies that the discharge material must be soluble and lists limits on monthly concentrations.

**Table 5-5** summarizes the discharge requirements of Title 10. Because Title 10 permits and therefore applies to only soluble discharges, and because the plutonium in LLNL effluent is in the insoluble form, there is no applicable discharge requirement for <sup>239</sup>Pu. This assumption is supported by the



**Table 5-5.** Sewer discharge release limits for  $^3\text{H}$ ,  $^{137}\text{Cs}$ , and  $^{239}\text{Pu}$ .

	$^3\text{H}$	$^{137}\text{Cs}$	$^{239}\text{Pu}$
10 CFR 20 concentrations used to establish release limits	370 Bq/mL	0.37 Bq/mL	NA <sup>(a)</sup>
10 CFR 20			
Monthly	185 GBq	13 GBq	—
Yearly	185 GBq <sup>(b)</sup>	37 GBq <sup>(c)</sup>	—
DOE annualized discharge limit for application of BAT <sup>(d)</sup>	370 Bq/mL	0.56 Bq/mL	0.37 Bq/mL

<sup>a</sup> 10 CFR 20 imposes a discharge limit for soluble  $^{239}\text{Pu}$  released. Evidence supports the insolubility of LLNL's plutonium discharges. Refer to the Environmental Impact section of this chapter.

<sup>b</sup> 10 CFR 20 imposes a 185-GBq (5-Ci) limit for the tritium radiation released.

<sup>c</sup> 10 CFR 20 imposes a 37-GBq (1-Ci) combined limit on the total of all radiation released (excluding tritium and  $^{14}\text{C}$ , which have separate 10 CFR 20 limits of 185 GBq and 37 GBq, respectively); i.e., the total release of all isotopes must not exceed 37 GBq. If a total of 37 GBq of a particular isotope were released during the year, this would require that no other isotopes be released.

<sup>d</sup> The DOE annualized discharge limit for application of Best Available Technology (BAT) is five times the Derived Concentration Guide (DCG; ingested water) for each radionuclide released.

experience during the recent sewer system evaluation, when increased cleaning led to higher plutonium concentrations in LLNL sewage (Gallegos et al. 1993). This indicates that the bulk of plutonium discharged is liberated from deposits on the sewer pipes, which are, by their nature, insoluble.

**Table 5-5** also includes the total activity that could have be discharged by LLNL during a given period (monthly and annually) assuming the 1994 average monthly flow rate. As the table clearly demonstrates, the Title 10 concentration limits for tritium for facilities such as LLNL that generate wastewater in large volumes are overridden by the limit on total tritium activity discharged during a single year. In 1994, the total LLNL tritium release was 2.6% of the corresponding Title 10 limit. Total LLNL releases (**Table 5-1**), in the form of alpha and beta emitters (excluding tritium), were 0.85% of the corresponding Title 10 limit.

DOE has also established criteria for the application of Best Available Technology to protect public health adequately and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each specific radionuclide that is discharged to publicly-owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeds its concentration limit, LLNL would be required to improve discharge control measures until concentrations were again below the DOE limits. **Table 5-5** presents the DCGs for the specific radioisotopes of most interest at LLNL.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 0.000030 (that is, 0.0030%) of the DOE DCG (and the Title 10 limit); the annual



average concentration of  $^{137}\text{Cs}$  was 0.000020 of the DOE DCG (and 0.000030 of the Title 10 limit); and the annual average  $^{239}\text{Pu}$  concentration was 0.000012 of the DOE DCG. The combined discharges were therefore 0.000033 of the DCG. As discussed earlier in this section, when calculating the contribution from plutonium, the plutonium in LLNL effluent is assumed to be in the insoluble form (the DCG for soluble forms of plutonium is 70 times less than the DCG for insoluble plutonium).

LLNL also compares annual discharges against historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-6** summarizes the radioactivity in liquid effluent released over the past ten years. During 1994, a total of 6.9 GBq (0.19 Ci) of tritium was discharged to the sanitary sewer. This is the combined release from the Livermore site and from Sandia, California, whose records account for 2.2 GBq (0.06 Ci) of this amount; LLNL therefore released 4.7 GBq (0.13 Ci), an amount that is well within environmental protection standards and is less than the range reported in the past. Note that DOE did not suggest compliance with the 37 GBq limit of Title 17 until 1990.

**Figure 5-3** summarizes the  $^{239}\text{Pu}$  monitoring data over the past ten years. The historical levels observed since 1985 are approximately  $0.37 \mu\text{Bq/mL}$  ( $1 \times 10^{-5}$  pCi/mL), with the exception of a peak in 1987. Even this peak is well below the applicable DOE DCG. Historically, levels generally are one-millionth (0.000001) of that limit. The greatest part of the plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge, which is dried and disposed of at a landfill. The plutonium concentration observed in 1994 sludge (**Table 5-2**),

**Table 5-6.** Radioactive liquid effluent releases from the Livermore site, 1985–1994.

Year	Liquid Effluents (GBq)	
	$^3\text{H}$ (LLNL and Sandia, California)	$^{239}\text{Pu}$
1985	133	$1.8 \times 10^{-4}$
1986	74	$5.5 \times 10^{-4}$
1987	52	$2.6 \times 10^{-2}$
1988	56	$8.1 \times 10^{-4}$
1989	59	$1.8 \times 10^{-4}$
1990 <sup>(a)</sup>	25	$2.3 \times 10^{-4}$
1991	32	$6.1 \times 10^{-4}$
1992	8	$1.9 \times 10^{-3}$
1993	12.6	$2.6 \times 10^{-4}$
1994	6.9	$1.9 \times 10^{-5}$

<sup>a</sup> Year that DOE first suggested compliance with the 37-GBq (1-Ci) limit of California Title 17.



1.1 mBq/dry g (0.03 pCi/dry g), is more than 400 times lower than the proposed EPA guideline for unrestricted use of soil (480 mBq/dry g).

As first discussed in the *Environmental Report for 1991* (Gallegos et al. 1992a), plutonium and cesium concentrations were slightly elevated during 1991 and 1992 over the lowest values seen historically. As was established in 1991, the overall upward trend is related to sewer cleaning with new, more-effective equipment. During 1993, as utility personnel worked to complete an assessment of the condition of the sewer system, cleaning activity around the site was less extensive, resulting in slightly lower plutonium and cesium concentrations in LLNL effluent. During 1994, in conjunction with the installation of the synthetic sock lining in the sewer system, the cleaning activity around the site was more extensive than in 1993. However, by the end of 1993, the new sewer cleaning equipment had been used on LLNL's entire sewer system; this has been reflected in 1994 by the continuation of the slightly lower plutonium and cesium concentrations that were observed in the 1993 effluent.

### Environmental Impact of Nonradioactive Liquid Effluents

**Table 5-3** presents monthly average metal concentrations in LLNL's sanitary sewer effluent. At the bottom of the table, the annual average concentration for each metal is compared to the discharge limit. The metals that approached closest to the discharge limits were copper and lead at 8% and 7%, respectively, of the discharge concentrations.

Although arsenic concentrations were well below discharge limits, the slightly elevated levels first seen during the summer of 1992 continued through 1994. As first discussed in the *Environmental Report for 1993* (Gallegos et al. 1994), the elevated arsenic levels were the subject of an extended investigation during 1993. The conclusion of the 1993 investigation was that the ground water restoration operation at a gas pad seemed to account for the majority of the observed arsenic. The gas pad cleanup operation continued in 1994, and the slightly elevated arsenic levels of 1993 continued in 1994.

**Table 5-4** presents the results of monthly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent. The results are quite typical of those seen in previous years, with the exceptions of oil and grease and the purgeable-extractable pollutants.

As a whole, the reduced concentrations of oil and grease observed in 1993 continued in 1994. (The overall oil and grease concentrations are substantially reduced from levels in 1992, when LLNL received a Notice of Violation for grease discharges. As a result of this incident, LLNL adopted the LWRP's suggested changes in sampling protocol and implemented improvements in the design of grease abatement measures in use at LLNL cafeterias.) The exception



to the substantial reduction in oil and grease concentrations is observed in the maximum value (274 mg/L) for 1994; however, this result was not confirmed with analysis of a duplicate sample. Nonetheless, EPD conducted seminars on proper food-handling and disposal practices for the employees of the LLNL cafeterias.

Overall, the results for the purgeable-extractable pollutants are typical of those seen in prior years. However, there are two notable exceptions. The first exception is for styrene. Styrene was not detected in previous years but was observed in approximately 60% of the 1994 monthly samples. We attribute the presence of styrene to the relining of the sewer system with synthetic socks. The detection of styrene occurred during the relining work, and the resin-impregnated synthetic socks contain styrene. The second exception is for methylene chloride. In a monthly sample for January 1994, there was a sufficient concentration of methylene chloride to cause LLNL to exceed the effluent pollutant limitations of its sewer permit and receive a Notice of Violation. As a result of this incident, the LWRP suggested additional EPA Method 624 sampling (methylene chloride is in the suite of compounds analyzed for in EPA Method 624) that could demonstrate that the single monthly instantaneous grab sample was not representative of that entire month's discharge profile. In response to the LWRP's suggestion, LLNL collects two EPA Method 624 samples on the day of the monthly sample collection; the sample collected earliest in the day is submitted for analysis, and the later sample is held pending the analytical results for the earlier sample.

The continuous monitoring system detected one inadvertent discharge during 1994 (as compared to 0 and 13 such discharges in 1993 and 1992, respectively); this incident was reported to the LWRP and DOE. Specifically, in January 1994, the continuous monitoring system detected a brief discharge of zinc above alarm limits. The instantaneous concentration was 3.3 mg/L, and the average concentration for the 31-hour period containing the release was 0.6 mg/L, as compared to 3.0 mg/L, the effluent pollutant limit for zinc contained in LLNL's sewer permit. The estimated duration of the incident was 25 minutes. Since this incident lasted more the five minutes, the Sewer Diversion Facility was activated to contain the remainder of the release. (If a release lasted as long as 24 hours, concentrations above the effluent pollutant limit could disrupt treatment plant operations or cause the treated wastewater to exceed allowable concentration limits for discharge to the San Francisco Bay.) Later analysis of the diverted effluent showed that the average concentration of zinc was sufficiently low to allow release of the wastewater back to the sanitary sewer. This incident did not represent a threat to the integrity of the operations at the LWRP.

Through investigation of the zinc discharge incident, it was determined that the source of the zinc was from the cooling tower sludge released to the sanitary

## 5. Sewage Monitoring

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sewer during cooling tower cleanout. As a result of this zinc discharge incident, the method for cleaning cooling tower has been modified to further minimize the introduction of the sludge into the sanitary sewer system.

The sewage monitoring data for 1994 reflect the success of LLNL's discharge control program in preventing any significant impact on the operations of the City's treatment plant. The results demonstrate good compliance with the effluent pollutant limitations of LLNL's sewer permit, and are generally consistent with values seen in the past.

## 6. Surface Water Monitoring



Erich R. Brandstetter  
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### Introduction

Lawrence Livermore National Laboratory performs surface water monitoring at the Livermore site, in surrounding regions of the Livermore Valley, and at Site 300 and vicinity in the nearby Altamont Hills. At the first two locales, LLNL monitors reservoirs and ponds, the LLNL swimming pool, rainfall, tap water, and storm water runoff. At Site 300 and vicinity, surface water monitoring encompasses rainfall and storm water runoff. Results for the spring at Site 300 are reported in Chapter 7 (Routine Ground Water Monitoring) because the spring water is more representative of its ground water source than it is of surface water. The water samples are analyzed for radionuclides, explosives, total organic carbon, total organic halides, total suspended solids, conductivity, pH, chemical oxygen demand, oil and grease, metals, minerals, anions, and a wide range of organic compounds.

Surface water monitoring is driven by the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) and DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*. LLNL also complies with the Federal Clean Water Act and changes in Section 402 of this Act, which led to LLNL's revision of the storm water monitoring program during 1993.

Rainwater monitoring is called for in DOE Order 5400.1, which states:

Representative meteorological data are required at DOE facilities to support environmental monitoring activities. This information is essential to characterize atmospheric transport and diffusion conditions in the vicinity of the DOE facility and to represent other meteorological conditions (e.g., precipitation, temperature, and atmospheric moisture) that are important to environmental surveillance activities such as air quality and radiation monitoring.

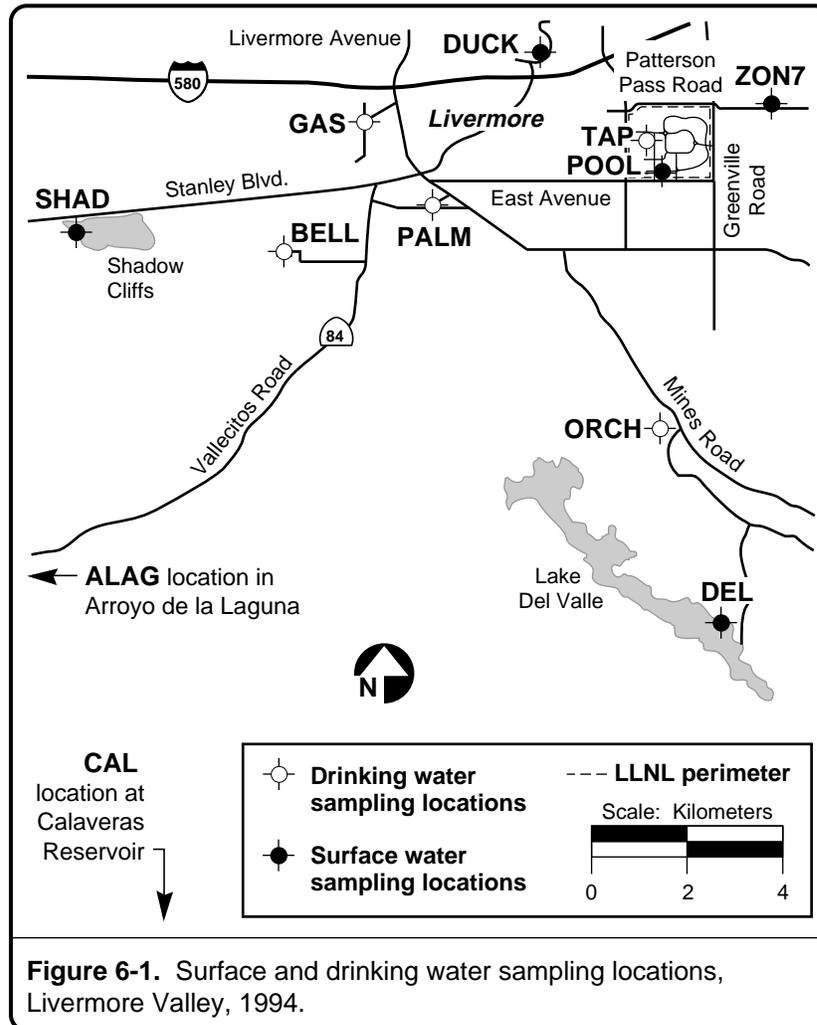
### Water Sampling Methods

A description of water sampling methods for surface water and rainfall follows.

#### Surface Water

Surface and drinking water near the Livermore site and in the Livermore Valley (**Figure 6-1**) are sampled according to procedures EMP-W-L and EMP-W-S

## 6. Surface Water Monitoring



(Tate et al., 1995). Sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water sources; BELL, GAS, PALM, and ORCH are drinking water outlets. LLNL samples these locations quarterly for gross alpha, gross beta, and tritium. The on-site swimming pool and drinking water source (POOL and TAP; **Figure 6-1**) are also sampled, as described above, for gross alpha, gross beta, and tritium. POOL is sampled monthly, TAP quarterly.

### Rainfall

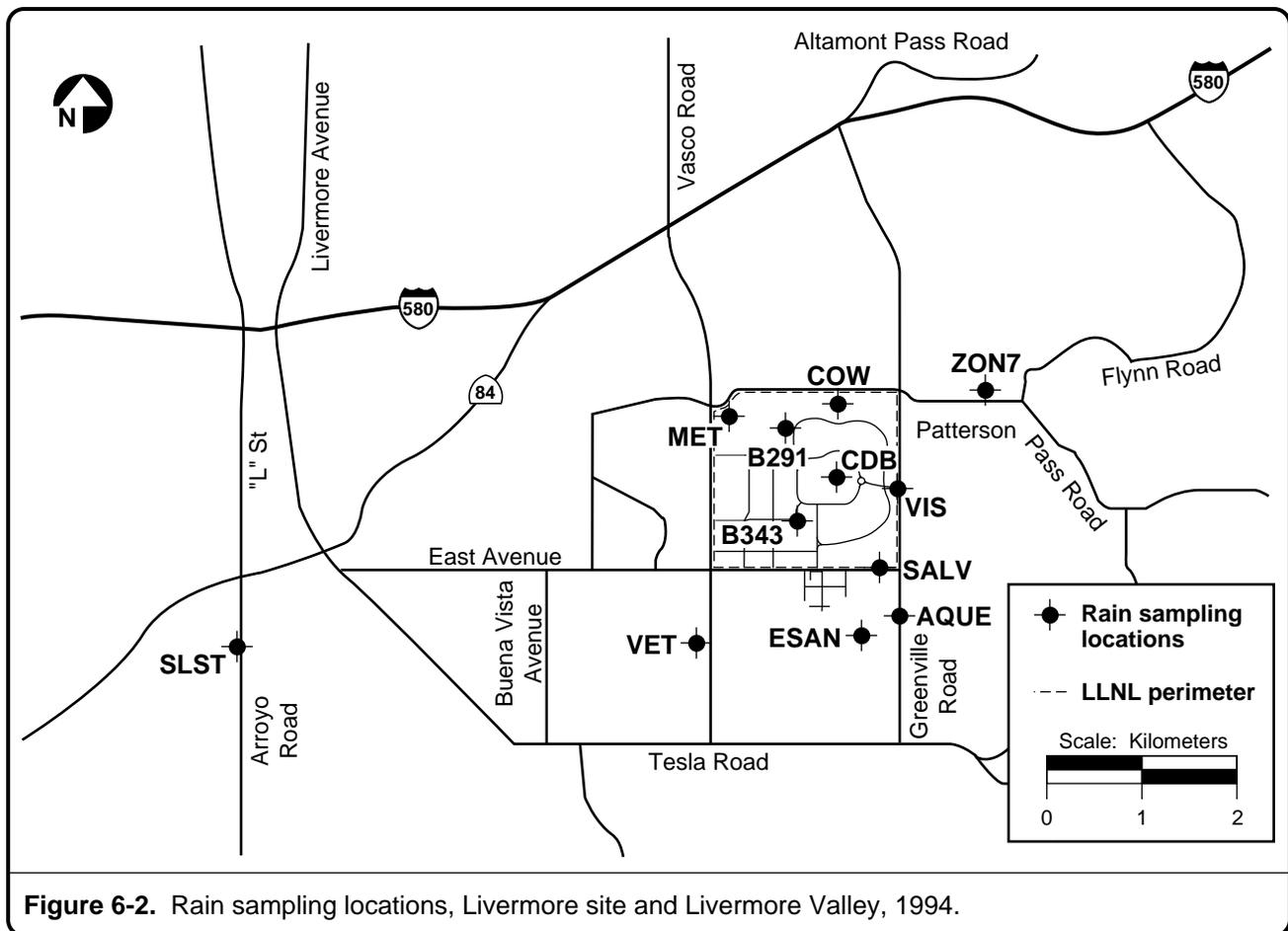
Rainfall is sampled according to written procedures EMP-RA-L and EMP-RA-S (Tate et al. 1995). The tritium activity measured in Livermore Valley rainfall results primarily from atmospheric emissions of tritiated water vapor (HTO) from stacks at LLNL's Tritium Facility (Building 331), and Sandia National Laboratories, California's (Sandia, California's) former Tritium Research

## 6. Surface Water Monitoring



Laboratory. No experiments using tritium were conducted at either of these facilities during 1994. HTO emissions resulted from continuing cleanup activities at both locations. The total measured atmospheric emission of HTO from these facilities in 1994 was 6.2 TBq (168 Ci). Of this amount, LLNL released 2.8 TBq (76 Ci).

The rain sampling station locations are shown on map in **Figure 6-2**. The fixed stations are positioned around the two main HTO sources so as to record a wide spectrum of tritium activities in rainfall, from the maximum expected down to background levels. Previous analyses of tritium activity at 19 rain sampling locations, covering 53 rain events from October 1990 through December 1992, showed that activity levels decreased to background levels beyond 4 kilometers from the two main sources. Therefore, in 1993, as a cost-cutting measure, eight of the more distant background locations were eliminated from the 19-station network.



## 6. Surface Water Monitoring

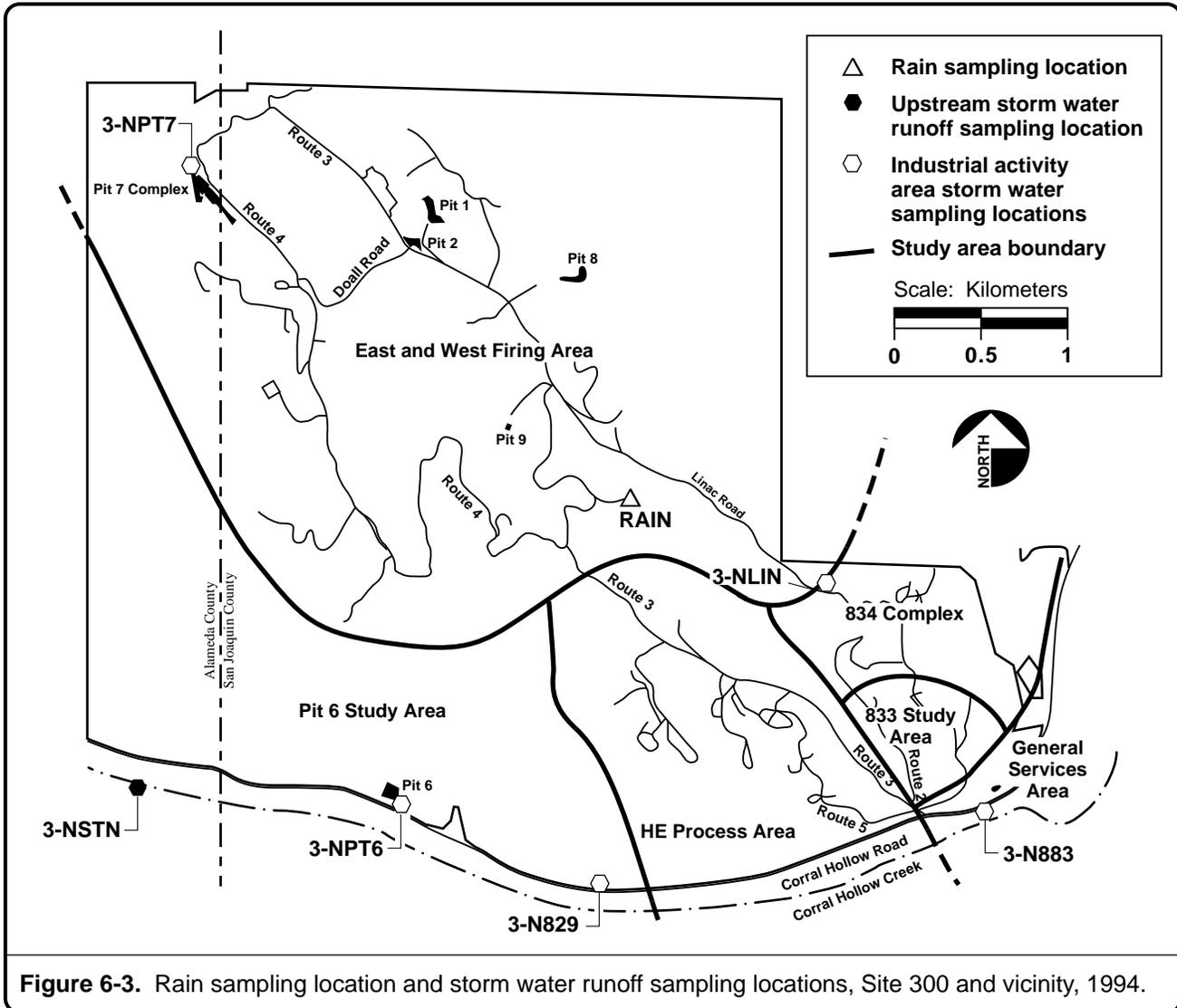


Winds measured at LLNL during rain events are predominantly from the southwest quadrant and totaled 49% of the 1994 wind field. Winds from the northwest, northeast, and southeast quadrants accounted for 16%, 21%, and 14%, respectively, during rain events. One station, located west-southwest of LLNL, is used to determine upwind background levels of tritium activity in rainfall. This station is identified as SLST on **Figure 6-2**. ZON7 is the most distant downwind station. Nine additional rain sampling locations were designed to monitor rainfall close to the primary sources. Stations were placed at various compass directions to provide adequate coverage of wind directions expected during rain events. However, in October 1994, a new rain sampling station (VET) was established southwest of LLNL to fill a potential directional gap in rain-sampling coverage (**Figure 6-2**).

One central location is used to collect rainfall for tritium activity measurements at LLNL's Experimental Test Site (Site 300; **Figure 6-3**). Rain samples are collected monthly from Site 300 during the rainy season. Over the past 23 years, 151 measurements of rainfall samples collected at this location give a maximum tritium activity of only 9.1 Bq/L (246 pCi/L), a median of 2.3 Bq/L (62 pCi/L), and an interquartile range of 2.2 Bq/L (60 pCi/L). The tritium activity measured in rainfall at Site 300 is not distinguishable from atmospheric background over the past 23 years.

### Storm Water

Storm water runoff monitoring provides a broad measure of the efficacy of LLNL operational procedures that prevent, contain, and remediate inadvertent spills of hazardous wastes or products onto the ground at the Livermore site and Site 300. LLNL first monitored storm water runoff at the Livermore site in 1975. This monitoring network, originally designed to detect pesticides, expanded in 1990 to cover new locations and additional water quality parameters (i.e., radioactivity, metals, and additional organic compounds). Additional changes during 1993 complied with the National Pollutant Discharge Elimination System General Industrial Activities Storm Water Permit (NPDES General Permit). In October 1993, also in response to the NPDES General Permit, LLNL established a new storm water monitoring program at Site 300. The current list of analyses requested for storm water samples is given in **Table 6-1**. A wide range of activities is conducted at the Livermore site so it is necessary to monitor storm water for the potential impacts of these activities. In addition, due to flow patterns at the site, storm water at sampling locations includes components from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. Therefore, it is necessary to analyze storm water for a wide range of constituents at the Livermore site. In contrast, storm water at Site 300 is sampled at locations that target specific activities, and a smaller range of analyses is needed.



**Figure 6-3.** Rain sampling location and storm water runoff sampling locations, Site 300 and vicinity, 1994.

About one-fourth of the storm water runoff generated within the Livermore site drains into the Drainage Retention Basin (**Figure 6-4**), a lined depression turned into a man-made lake through the collection of runoff and treated ground water. The remainder of the site drains either directly or eventually into two arroyos by way of storm sewers and ditches. The two arroyos drain from east to west. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas, diverted from its natural course, follows the northeastern and northern boundaries of the site and exits the site at the northwest corner.

In 1994, the Livermore site storm water sampling network consisted of six locations (**Figure 6-4**). Five locations characterize storm water either entering (influent: ALPE, GRNE, and ASS2) or exiting (effluent: WPDC and ASW) the

## 6. Surface Water Monitoring



**Table 6-1.** Requested analyses for storm water samples.

Livermore Site	Site 300
pH	pH
Total suspended solids	Total suspended solids
Specific conductance	Specific conductance
Oil and grease	Total organic carbon
Total organic carbon	Gross alpha and beta
Gross alpha and beta	Tritium
Tritium	Uranium
Chemical oxygen demand	Total organic halides
General minerals	Explosives
Anions	
Metals	
EPA Method 624	
EPA Method 625	
Drinking water pesticides	

Livermore site. Location CDB characterizes runoff from the southeastern quadrant of the Livermore site entering the Drainage Retention Basin (DRB).

The Site 300 storm water sampling network, begun in 1994, also consisted of six locations (**Figure 6-3**). One location (NSTN) was selected to characterize storm water runoff typical of the region, unaffected by Site 300 activities. The remaining five locations were selected to characterize storm water runoff potentially affected by specific Site 300 activities.

Storm water sampling occurred on seven dates during 1994. LLNL obtained samples from all six Livermore site locations on January 24, April 25, and November 5. Samples were collected from some Site 300 locations on February 7, May 5 and 6, and December 14. Typically, a given storm will not produce runoff at all Site 300 locations because Site 300 receives relatively little rainfall and is largely undeveloped. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff occurs.

### Results

This section presents the monitoring results for radioactivity and other constituents in surface water, drinking water, and storm water at the Livermore site, Livermore Valley, and Site 300 and vicinity.

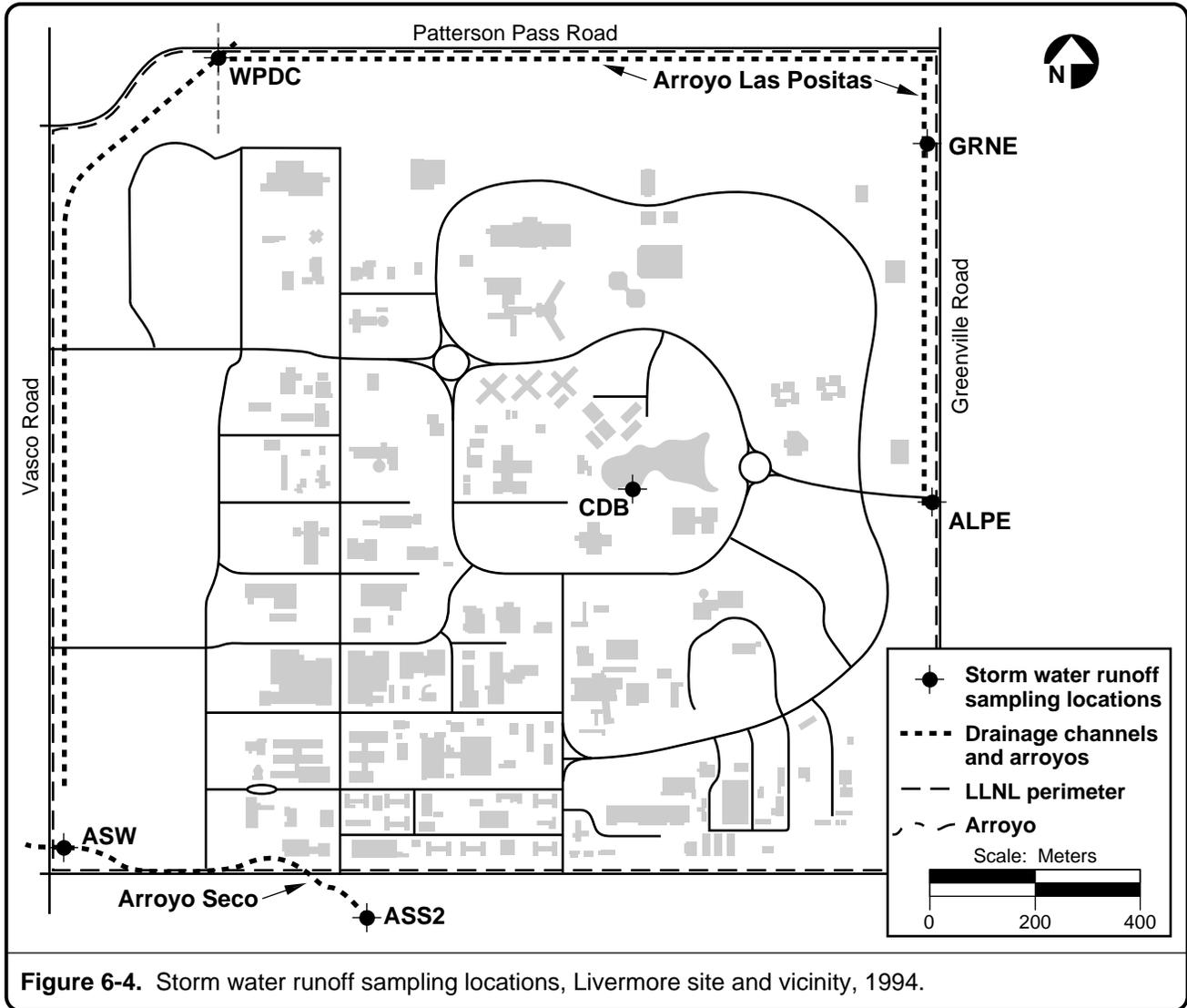


Figure 6-4. Storm water runoff sampling locations, Livermore site and vicinity, 1994.

Livermore Site and Livermore Valley Radioactivity in Surface Water

**Gross Alpha and Gross Beta**

Median activities for gross alpha and gross beta radiation in surface water samples (detailed data are in Table 6-1, Volume 2) are generally less than 10% of the drinking water maximum contaminant levels (MCLs; 0.56 Bq/L or 15 pCi/L, gross alpha; 1.85 Bq/L or 50 pCi/L, gross beta); however, the maximum activity detected for gross alpha (0.3 Bq/L; 8.2 pCi/L) was over 50% of its MCL.

Three of the initial analyses for gross beta radiation resulted in activities above the MCL of 1.85 Bq/L. Of those, the analyses for DUCK and PALM during the

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**Table 6-2.** Annual statistics for radioactivity in surface and drinking waters (in Bq/L).

Summary Statistics	Tritium	Gross Alpha	Gross Beta
<b>Maximum Contaminant Level (MCL) Bq/L</b>	740	0.56	1.85
<b>All locations, including POOL</b>			
Number of samples	56	56	56
Minimum	0.414	-0.121	0.014
Maximum	5.957	0.303	10.027 (0.11)
Median	1.093	0.027	0.120
Interquartile range	1.928	0.075	0.121
<b>All locations, except POOL</b>			
Number of samples	44	44	44
Minimum	0.414	-0.121	0.014
Maximum	2.982	0.303	10.027 (0.11)
Median	0.803	0.028	0.109
Interquartile range	0.718	0.072	0.079
<b>POOL only</b>			
Number of samples	12	12	12
Minimum	3.182	-0.047	0.02
Maximum	5.957	0.295	0.326
Median	4.514	0.021	0.197
Interquartile range	1.658	0.127	0.107
<b>Surface waters only</b>			
Number of samples	24	24	24
Minimum	0.503	-0.121	0.014
Maximum	2.982	0.303	6.068 (0.017)
Median	1.215	0.026	0.119
Interquartile range	1.333	0.069	0.100
<b>Off-site drinking waters only</b>			
Number of samples	16	16	16
Minimum	0.414	-0.009	0.062
Maximum	1.395	0.266	0.223
Median	0.753	0.041	0.096
Interquartile range	0.337	0.110	0.048
<b>On-site TAP only</b>			
Number of samples	4	4	4
Minimum	0.507	0.007	0.028
Maximum	0.855	0.06	2.209 (0.021)
Median	0.736	0.033	0.08
Interquartile range	0.126	0.028	0.615

Note: Values in parentheses are the results of recounts for original sample results that gave values inconsistent with historical data.

## 6. Surface Water Monitoring



second quarter resulted in gross beta activities of 6.1 and 10.0 Bq/L (164 and 271 pCi/L), respectively. Upon recounting, the analytical laboratory arrived at activities of 0.017 and 0.11 Bq/L (0.45 and 2.9 pCi/L), respectively. Likewise, the original fourth quarter analysis at TAP (LLNL's on-site drinking water) resulted in an activity of 2.2 Bq/L (60 pCi/L), slightly above the MCL for gross beta radiation; recounted activities for gross beta were 0.021 Bq/L (0.58 pCi/L).

LLNL is now in the process of auditing and checking the quality of the analytical laboratory to see if samples could be contaminated from higher level samples; however, this process is not yet complete. Historically, gross alpha and gross beta radiation have fluctuated generally around laboratory detection limits and display no apparent trends (Figures 6-5 and 6-6).

Storm water gross alpha and gross beta samples are listed in Table 6-3. Because there were only three storm events sampled at each site in 1994, the entire data set is presented. Storm water gross alpha and gross beta were well below MCLs, except for samples collected November 5 at GRNE. Because GRNE is an influent location, the gross alpha and gross beta sources were upstream and off the

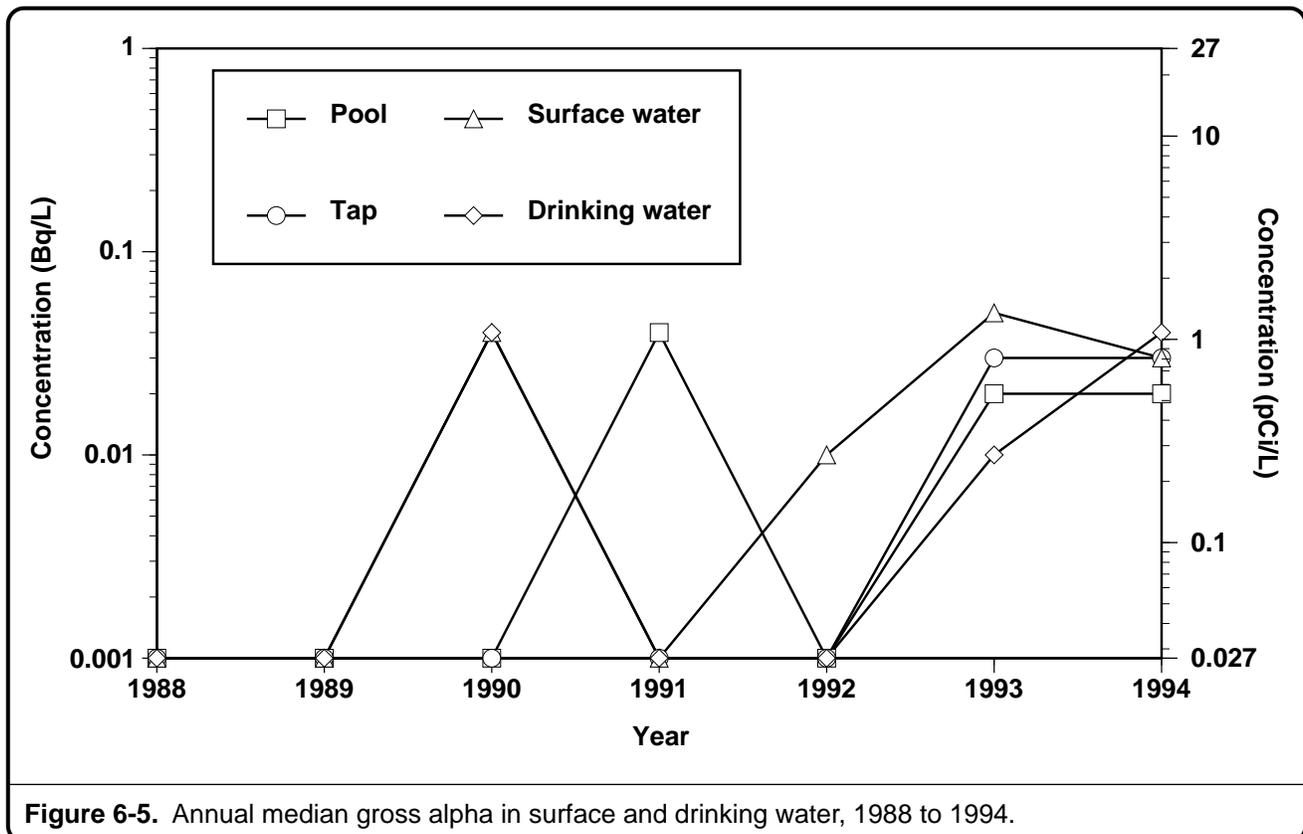


Figure 6-5. Annual median gross alpha in surface and drinking water, 1988 to 1994.

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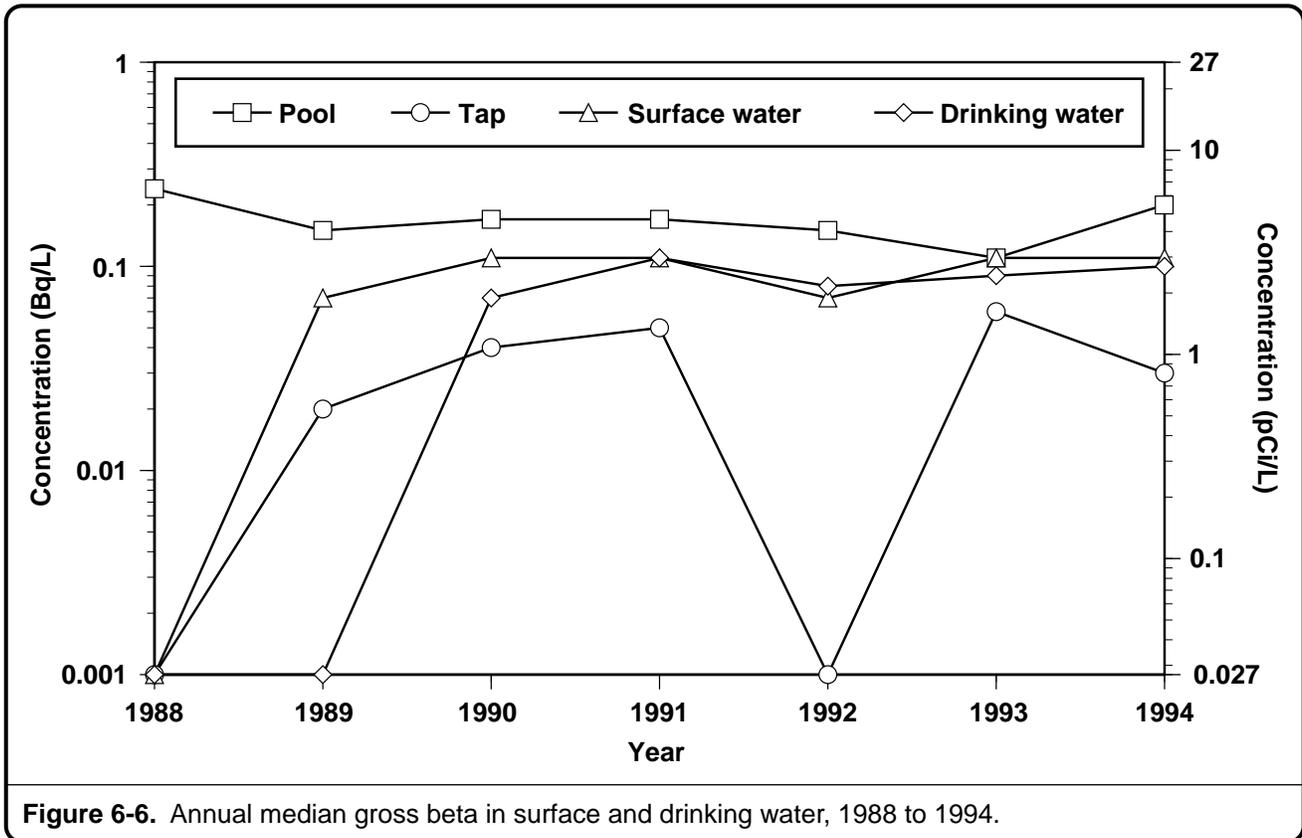


Figure 6-6. Annual median gross beta in surface and drinking water, 1988 to 1994.

Livermore site. The origin of this off-site source is unknown. Because the analytical laboratory did not retain the sample, it was not possible to reanalyze the sample or conduct an isotopic analysis for this event. LLNL procedures have been updated (see below) to ensure that, if another high result is obtained, sufficient sample will be available for further analysis.

In order to investigate possible sources for the November 5 GRNE gross alpha and gross beta, 1994 air particulate gross alpha and gross beta sampling was examined in detail. Air particulate sampling locations ZON7 and PATT are in the area upgradient of storm water location GRNE. If either of these locations exhibited abnormally high gross alpha or gross beta levels, it would indicate a source via the air pathway. Figure 6-7 compares ZON7 and PATT monthly median air particulate gross alpha with the monthly median for all Livermore Valley locations. All values are very low, near the detection limit of the method. Thus, although the gross alpha level PATT seems high in November, it is within the variation expected at such low levels.

## 6. Surface Water Monitoring



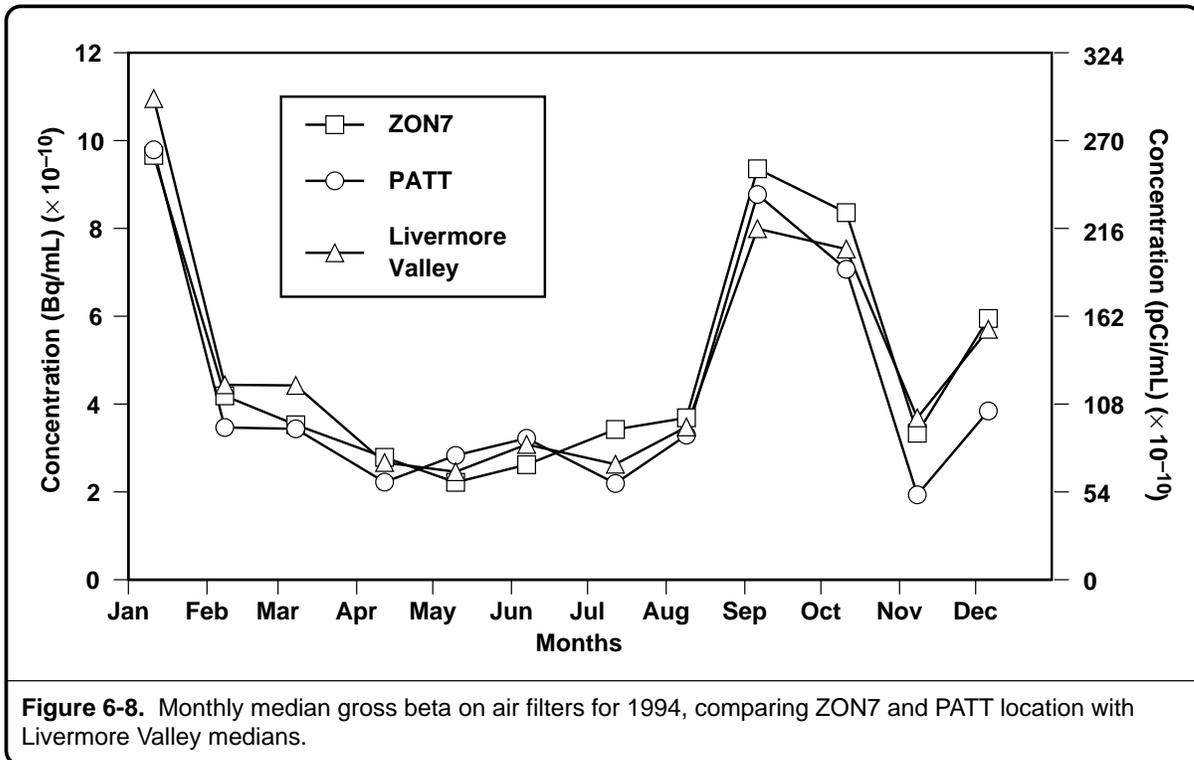
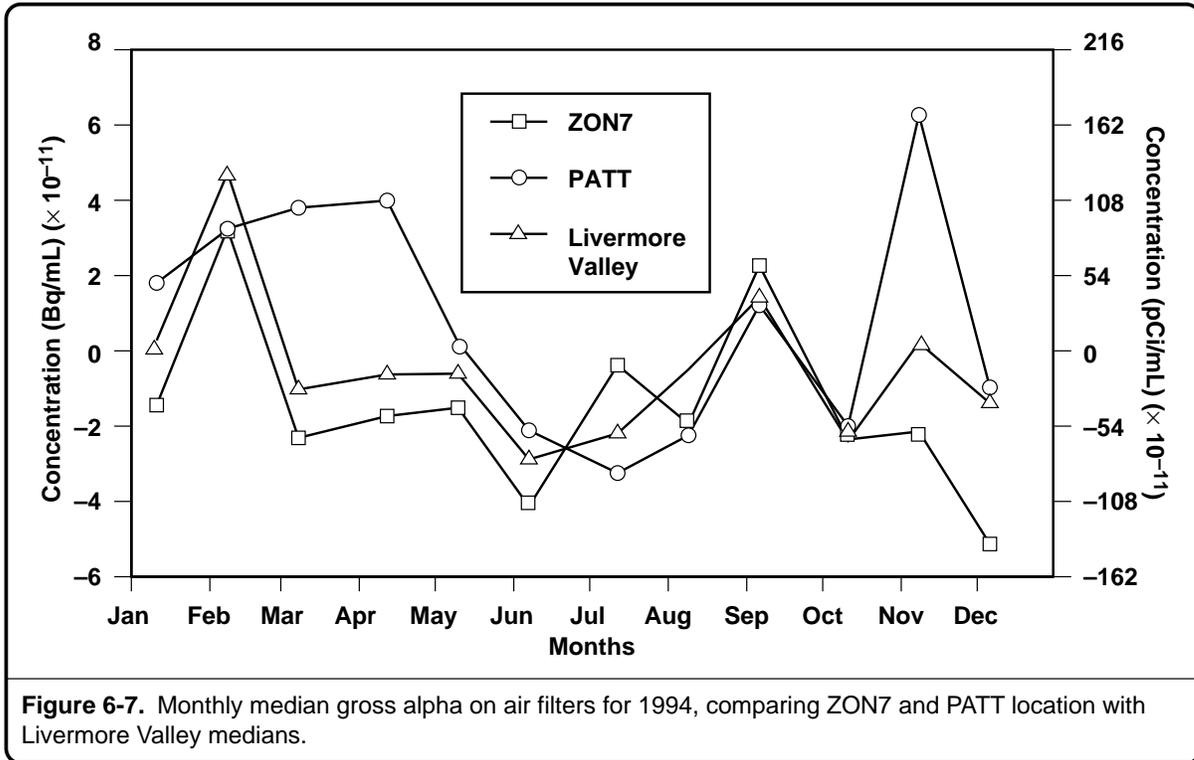
**Table 6-3.** Radioactivity in storm water runoff at LLNL (in Bq/L), 1994.

Location	Date	Tritium	Gross Alpha	Gross Beta
ALPE	Jan 24	3.522 ± 1.927	0.327 ± 0.113	0.537 ± 0.052
	Apr 25	3.959 ± 2.249	0.063 ± 0.006	0.154 ± 0.020
	Nov 5	2.357 ± 1.845	0.072 ± 0.044	0.160 ± 0.045
ASS2	Jan 24	1.839 ± 1.839	0.070 ± 0.009	0.192 ± 0.011
	Apr 25	2.168 ± 2.168	0.026 ± 0.005	0.044 ± 0.020
	Nov 5	17.945 ± 2.333	0.030 ± 0.027	0.041 ± 0.034
ASW	Jan 24	2.627 ± 1.902	0.081 ± 0.011	0.222 ± 0.012
	Apr 25	2.139 ± 2.139	0.040 ± 0.006	0.137 ± 0.019
	Nov 5	25.530 ± 2.527	0.024 ± 0.027	0.121 ± 0.043
CDB	Jan 24	17.501 ± 2.328	0.142 ± 0.012	0.221 ± 0.011
	Apr 25	8.880 ± 2.415	0.042 ± 0.006	0.323 ± 0.019
	Nov 5	2.142 ± 1.825	0.074 ± 0.035	0.089 ± 0.036
GRNE	Jan 24	3.667 ± 1.929	0.226 ± 0.022	0.326 ± 0.014
	Apr 25	2.135 ± 2.135	0.226 ± 0.010	0.844 ± 0.022
	Nov 5	1.809 ± 1.809	8.362 ± 2.294	6.623 ± 1.184
WPDC	Jan 24	12.247 ± 2.180	0.147 ± 0.014	0.256 ± 0.012
	Feb 7	7.733 ± 1.848	0.069 ± 0.031	0.289 ± 0.022
	Apr 25	2.646 ± 2.201	0.159 ± 0.009	0.433 ± 0.022
	Nov 5	4.107 ± 1.897	0.078 ± 0.035	0.142 ± 0.040

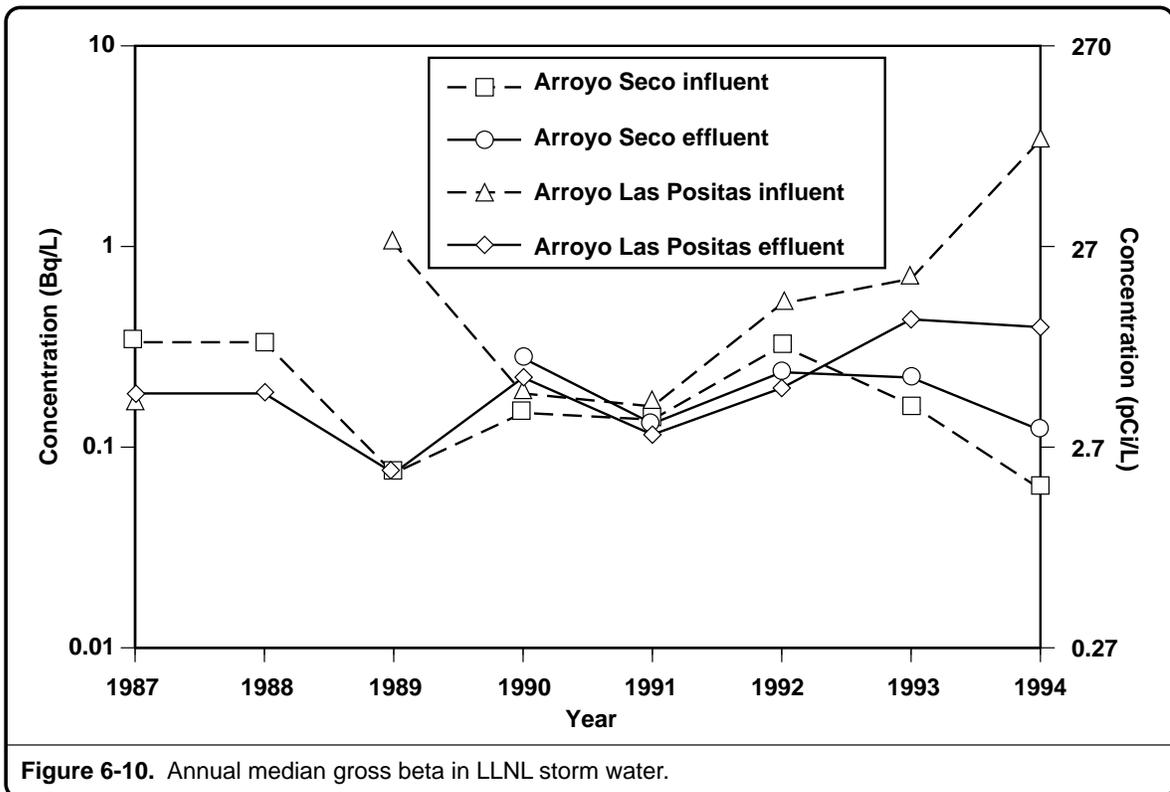
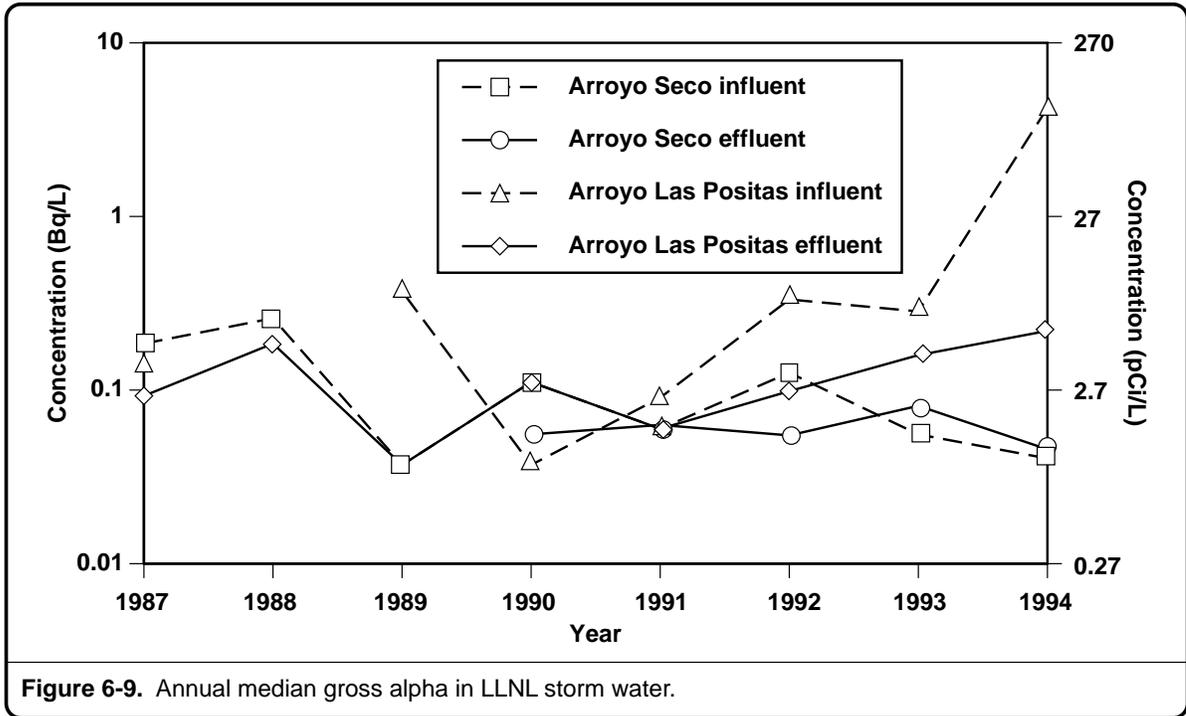
**Figure 6-8** is the same plot for air particulate gross beta. The ZON7 and PATT locations exhibit the same pattern as the Livermore Valley median—sometimes slightly less than the Livermore Valley median—sometimes slightly greater, with no large deviations. Investigation of these locations indicated that there is no pattern in the 1994 air particulate gross alpha and gross beta sampling that would tie the GRNE result to airborne emissions from LLNL (see Chapter 4, Air Monitoring). Contemporaneous storm water gross alpha and gross beta measurements at WPDC (the LLNL outfall location) were at levels typical for that location and less than one-third of the MCL.

**Figures 6-9 and 6-10** show the historical trend in storm water gross alpha and gross beta, respectively. In these figures and other storm water historical trend figures in this chapter, all available data for the influent and effluent locations of the two runoff pathways through the LLNL site have been aggregated. Also, data have been aggregated on a wet season basis—that is, October of one year through May of the next—rather than on a calendar year basis. Thus, data on storm plots labeled 1993 actually represent October 1993 through May 1994, and

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## 6. Surface Water Monitoring





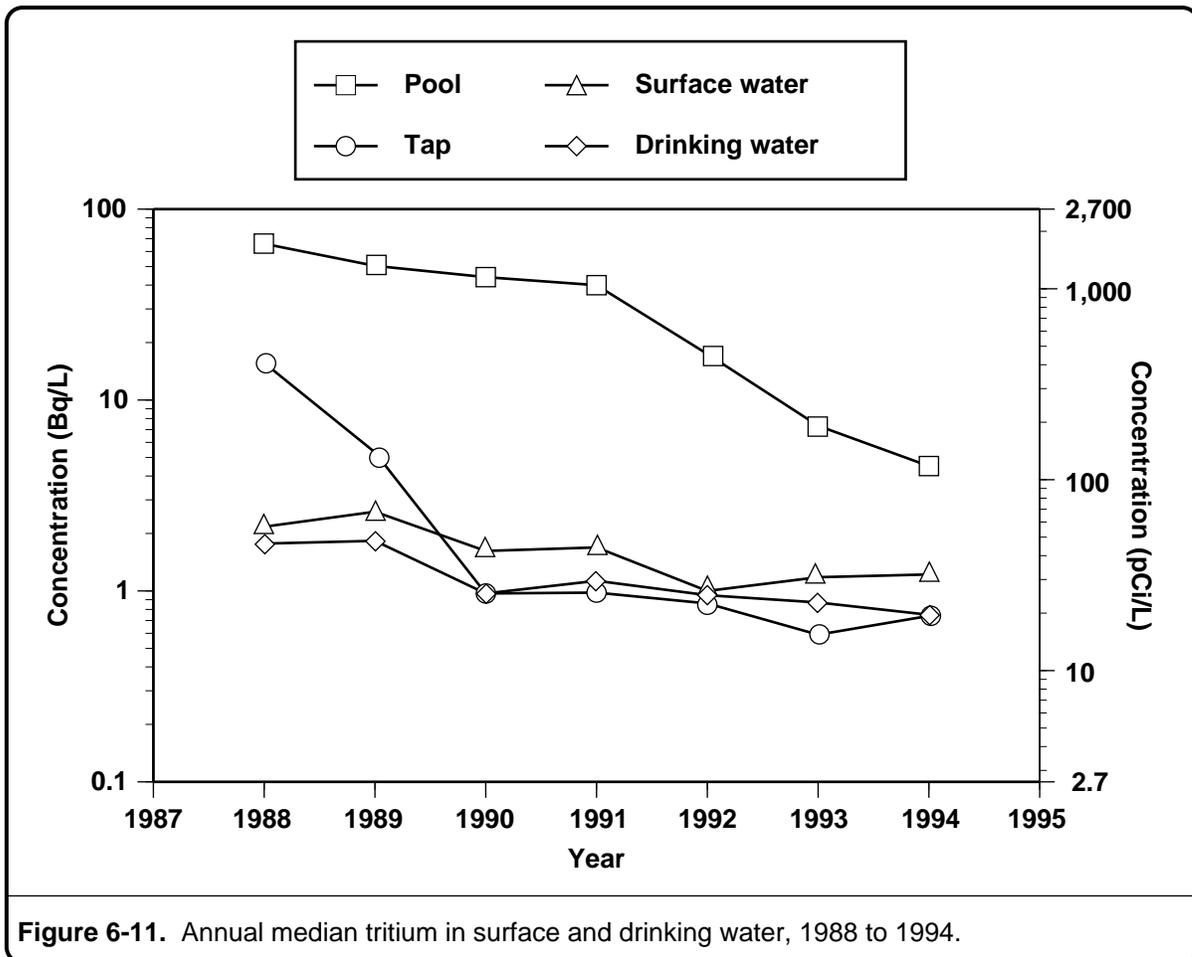
data labeled 1994 represent October through December 1994 (a partial wet season, pending collection of 1995 data). Finally, plots include all available storm water influent/effluent data for each constituent. The Arroyo Seco pathway shows no discernible pattern. Gross alpha, and, to a lesser extent, gross beta results seem to be increasing slightly at the influent locations on the Arroyo Las Positas pathway. This is reflected, to a lesser degree, in the results at the Arroyo Las Positas effluent locations. In order to better investigate any future results that may be inconsistent with historical data, LLNL has instituted a procedure of archiving storm water samples from all influent locations. If another high gross alpha or gross beta result is obtained, we will conduct an isotopic analysis using the archived water, an important first step in determining the nature of the source.

### Tritium

Median tritium activity (0.8 Bq/L or 21.7 pCi/L) and the maximum tritium activity (2.982 Bq/L or 80.6 pCi/L) at surface and drinking water locations in the Livermore Valley (excluding POOL) were much less than 1% of the drinking water MCL (**Table 6-2**). Water in the LLNL swimming pool had the highest median value and individual measurement. The median activity for tritium at POOL for 1994 was 4.51 Bq/L (122 pCi/L), compared to 7.4 Bq/L (200 pCi/L) in 1993, with both values 1% or less of the drinking water MCL. The highest single observation for POOL was 5.96 Bq/L (161 pCi/L), compared to 10.25 Bq/L (277 pCi/L) in 1993.

Tritium activities in the POOL have decreased from 1988 (the beginning of monitoring for tritium) to 1994 (**Figure 6-11**). The decrease in tritium activities has been most marked since 1991, the last year with significant tritium emissions from Building 331, the Tritium Facility, located very near to the POOL. Median tritium activities in the on-site TAP have also decreased with time since 1988. Tritium activities in the off-site surface waters and drinking waters have decreased very gradually, almost imperceptibly on a logarithmic scale (**Figure 6-11**).

Tritium activities measured in rainfall at the LLNL site and vicinity are shown in **Table 6-4**. The Livermore site rainfall has exhibited elevated tritium activities in the past (Gallegos et al. 1994). During 1994, however, measurements of tritium activity in rainfall were all far below the 740 Bq/L (20,000 pCi/L) MCL established by the EPA for drinking water. Rainfall samples were collected on January 25, March 25, April 11, April 26, May 9, and November 7, 1994. The highest activity measured was 91 Bq/L (2460 pCi/L). This activity was recorded in a sample collected from station ESAN on March 25, 1994. This station is 0.3 kilometers east of the former Tritium Research Laboratory at Sandia, California, and 1.1 kilometers southeast of LLNL's Building 331.



As expected, the stations in the prevailing downwind directions and closest to the sources showed the highest median tritium activities in rain. For LLNL Building 331 sources and stations, these were stations B343 (28.5 Bq/L; 770 pCi/L), CDB (16.7 Bq/L; 450 pCi/L), and B291 (14.6 Bq/L; 390 pCi/L). The stations most affected by the source at Sandia, California were SALV (12.2 Bq/L; 330 pCi/L), ESAN (11.7 Bq/L; 320 pCi/L), and AQUE (10.4 Bq/L; 280 pCi/L). As expected from the results of past years, the lowest medians were for the prevailing upwind station SLST (1.8 Bq/L; 50 pCi/L), the station MET (1.8 Bq/L; 50 pCi/L), and the most distant downwind station ZON7 (3.4 Bq/L; 90 pCi/L). Station VET, newly established in October 1994, recorded the highest tritium activity (19.4 Bq/L; 520 pCi/L) for the rainfall samples collected on November 7.

This result has prompted the reestablishment in 1995 of three previously discontinued rain sampling stations to the south and southwest of LLNL that historically showed very low tritium activities. The additional stations are needed to determine the extent of tritium activity in rainfall to the southwest of LLNL and Sandia, California.

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**Table 6-4.** Tritium in rain (in Bq/L), Livermore site and Livermore Valley, 1994.

Sampling Location	Jan 25	Mar 25	Apr 11	Apr 26	May 9	Nov 7	Median
<b>On-site</b>							
B343	32.7 ± 2.7	18.1 ± 2.3	38.5 ± 3.2	24.2 ± 2.5	44.0 ± 2.6	3.4 ± 1.8	28.5
CDB	14.0 ± 2.2	8.1 ± 2.0	22.0 ± 2.7	19.4 ± 2.7	22.4 ± 2.2	1.8 ± 1.8	16.7
B291	14.8 ± 2.2	14.5 ± 2.2	18.6 ± 2.6	15.6 ± 2.3	13.7 ± 2.2	1.8 ± 1.8	14.6
VIS	7.4 ± 2.1	7.9 ± 2.0	10.8 ± 2.4	7.2 ± 2.0	6.0 ± 1.7	1.8 ± 1.8	7.3
SALV	12.7 ± 2.2	30.4 ± 2.6	9.6 ± 2.1	53.7 ± 3.2	11.8 ± 1.9	1.8 ± 1.8	12.2
MET	2.4 ± 2.4	1.7 ± 1.7	3.1 ± 2.2	1.8 ± 1.8	1.5 ± 1.5	1.7 ± 1.7	1.8
COW	6.0 ± 2.0	1.8 ± 1.8	9.0 ± 2.4	3.6 ± 1.9	5.4 ± 1.7	1.7 ± 1.7	4.5
<b>Off-site</b>							
ESAN	8.6 ± 2.0	91.0 ± 3.8	20.3 ± 2.7	14.7 ± 2.6	7.8 ± 1.8	1.9 ± 1.9	11.7
AQUE	7.3 ± 2.0	— <sup>(a)</sup>	13.8 ± 2.5	13.5 ± 2.2	— <sup>(a)</sup>	1.7 ± 1.7	10.4
ZON7	2.3 ± 1.9	3.4 ± 1.9	3.4 ± 2.2	7.4 ± 2.0	5.1 ± 1.7	1.8 ± 1.8	3.4
SLST	1.8 ± 1.8	1.8 ± 1.8	1.7 ± 1.7	1.7 ± 1.7	1.5 ± 1.5	1.8 ± 1.8	1.8
VET	— <sup>(b)</sup>	19.4 ± 2.4	— <sup>(c)</sup>				

<sup>a</sup> Rain collected at this location was not sufficient to produce a sample.

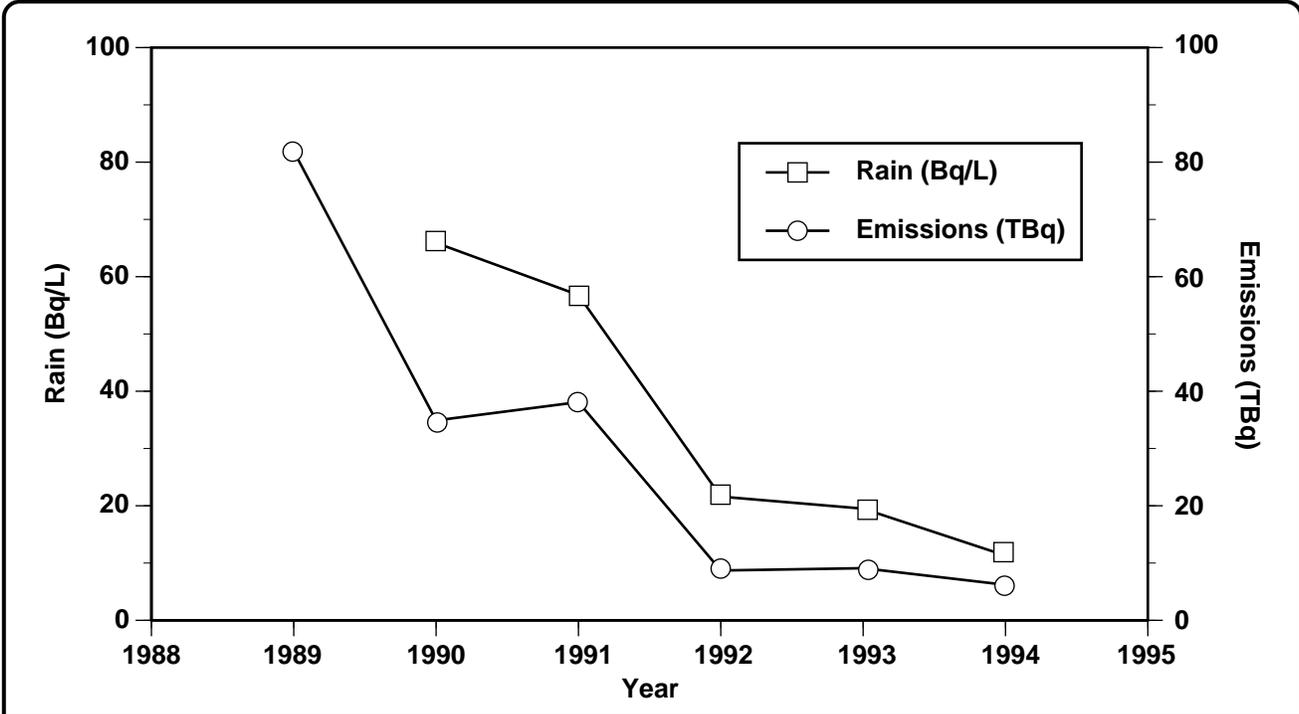
<sup>b</sup> Location VET was added towards the end of the year; therefore, data are only available for November 7.

<sup>c</sup> Because there is only one data point the median is not listed.

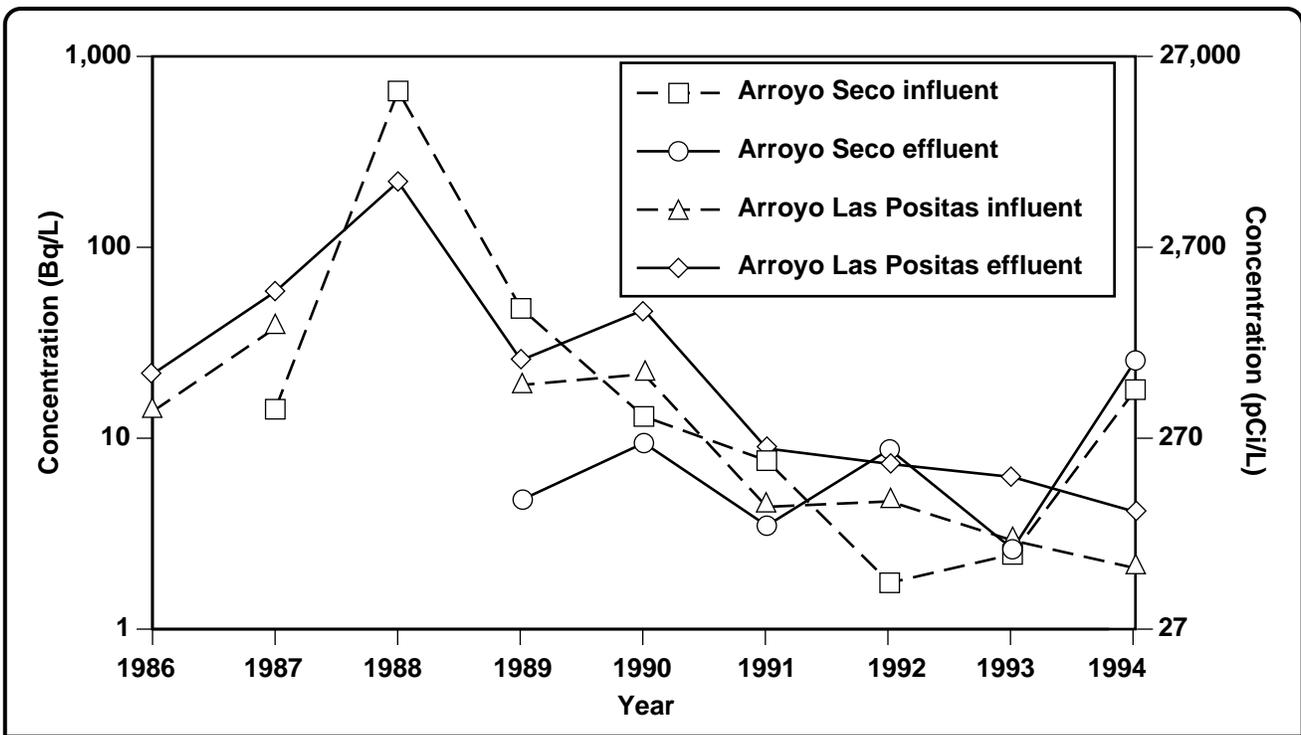
The trend of tritium activity in rainfall at the Livermore site has been downward during the past five years. This decrease mirrors the downward trend in total HTO emissions from LLNL's Tritium Facility and Sandia, California's former Tritium Research Laboratory. These trends are shown in **Figure 6-12**. Values for the median rain tritium activity shown in **Figure 6-12** are derived from the six on-site rain sampling locations that historically have given the highest activities. These locations are B343, B291, CDB, SALV, VIS, and COW (**Figure 6-2**). A nearly six-fold decrease in total HTO emissions has occurred since 1991, from 34.9 TBq (943 Ci) down to 6.2 TBq (168 Ci). This decrease is mirrored by a nearly six-fold decrease in median tritium activity measured in rainfall on site at LLNL (65.9 Bq/L down to 11.3 Bq/L, or 1780 pCi/L down to 300 pCi/L).

As with tritium levels in rainfall, tritium levels in storm water runoff were low; the overall median was 3.5 Bq/L (95.1 pCi/L), or less than 0.5% of the drinking water MCL (**Table 6-3**). The highest tritium activity measured in storm water runoff during 1994 was 25.5 Bq/L (689 pCi/L) at location ASW, about 3.5% of the drinking water MCL. The historical trend (**Figure 6-13**) indicates generally decreasing tritium levels in storm water.

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**Figure 6-12.** Trends of median tritium activity in rain and total stack emissions of HTO by LLNL and Sandia, California, 1989 to 1994.



**Figure 6-13.** Annual median tritium concentrations in LLNL storm water.

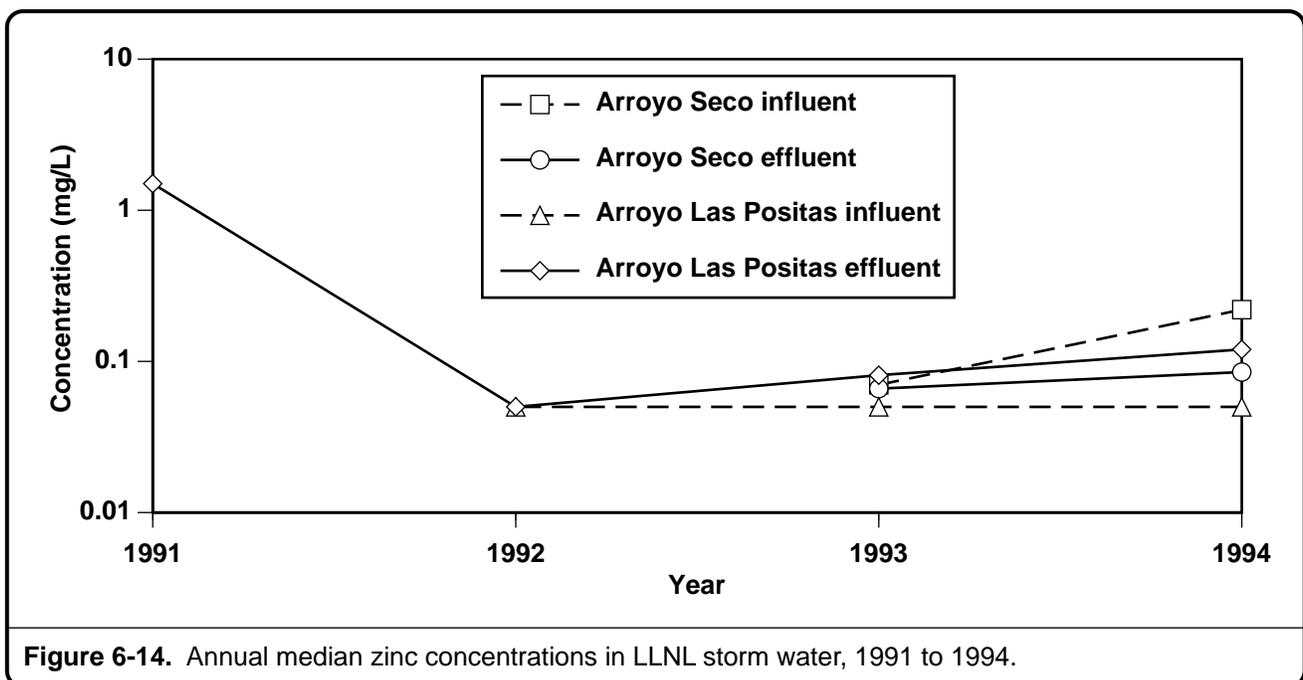
## 6. Surface Water Monitoring



### Livermore Site and Livermore Valley, Nonradioactive Pollutants in Storm Water

Storm water sample results were compared to EPA MCLs and Ambient Water Quality Criteria (AWQC), as summarized in *A Comparison of Water Quality Goals* (Marshack 1991). In addition, Livermore site results were compared to criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin Region*, January 17, 1995 revision; and Site 300 results were compared to criteria listed in *The Water Quality Control Plan for the California Regional Water Quality Control Board Central Valley Region*, Second Edition, 1992 (Basin Plans). If a result exceeded a Basin Plan criterion, that criterion was compared to the Marshack criteria. If, then, a Marshack criterion was equal to or more stringent than the Basin Plan criterion, only the Marshack criterion was used for comparison. Although three sets of criteria apply, the Marshack criteria are the most stringent for LLNL results, and only Marshack criteria are discussed below. (Complete storm water results are presented in Table 3, Volume 2.)

Sample results for zinc in storm water exceeded the AWQC (0.054 mg/L) in 11 samples, but were well below the MCL (50 mg/L). In general, zinc levels at influent locations were equal to or greater than corresponding effluent locations, indicating a probable off-site source. The only exception to this was the April 24 storm, in which zinc at WPDC (0.081 mg/L) was just above the AWQC and was below the analytical laboratory reporting limit (0.05 mg/L) at the corresponding influent locations. In addition, zinc at the on-site location (CDB) was above the AWQC for all three storms monitored, with a maximum level of 0.14 mg/L. The available historical data (Figure 6-14) indicate a slight increase in zinc levels over the past three years.

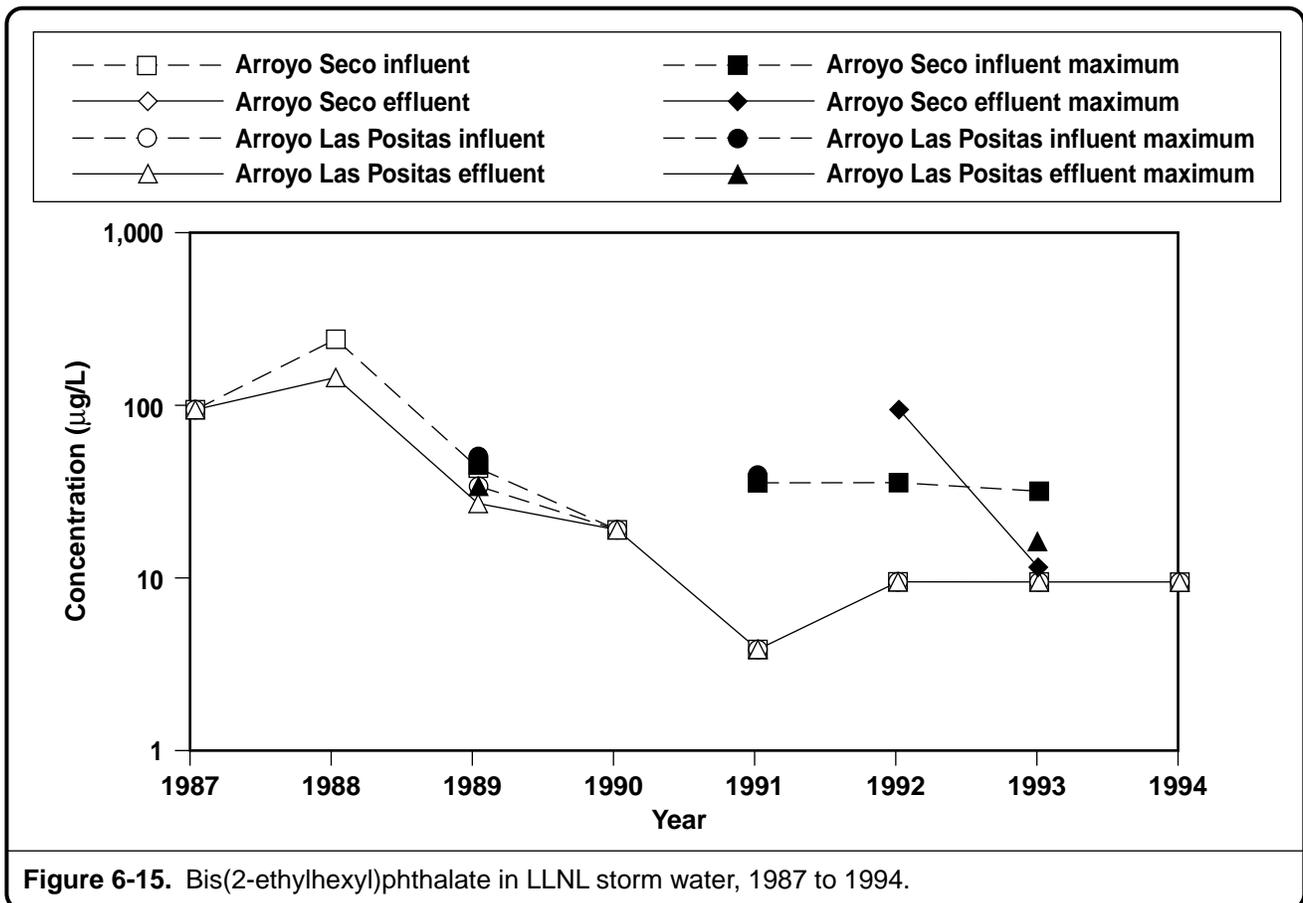


## 6. Surface Water Monitoring



Bis(2-ethylhexyl)phthalate was detected once (17 parts per billion) at location WPDC, and in excess of the MCL (4 parts per billion). This plasticizer is ubiquitous in the environment and is known to be used on site (LLNL Waste-water Discharge permit application, 1993–1994). Historically, it is detected at most once or at twice per year at any given location. Therefore, the historical trend plot (open symbols in **Figure 6-15**) is actually more reflective of changes in the reporting levels than of changes in the actual bis(2-ethylhexyl)phthalate level. A plot of maximum detected bis(2-ethylhexyl)phthalate (solid symbols in **Figure 6-15**) shows that maximum levels have remained relatively unchanged. If the data used to generate a particular median were all below reporting levels, the maximum is not shown.

**Table 6-5** lists nonradioactive constituents found above comparison criteria in Livermore site storm water. **Table 6-3**, Volume 2, contains all information in **Table 6-5** except criteria. Zinc and bis(2-ethylhexyl)phthalate were, at times, above their respective water quality criteria at effluent locations, and pH results for one storm event were slightly below the minimum of the MCL range. In addition, criteria were exceeded at influent or on-site locations but not at



## 6. Surface Water Monitoring



corresponding effluent locations for total alkalinity, total dissolved solids, arsenic, beryllium, chloride, chromium, selenium, sulfate, and 2,4-D.

**Table 6-5.** Storm water nonradioactive parameters exceeding relevant comparison criteria.

Constituent	Criteria	Date	Location	Concentration (mg/L)
pH	6.5–8.5 (MCL)	11/5/94	ASS2	6.2
			ASW*	6.1
			ALPE	6.4
			WPDC*	6.4
			CDB	6.0
Total alkalinity (as CaCO <sub>3</sub> )	200 (AWQC)	1/24/94	ALPE	290
Total dissolved solids	500 (MCL)	1/24/94	ALPE	1,500
Arsenic	0.05 (MCL)	4/25/94	CDB	0.074
Beryllium	0.004 (MCL)	4/25/94	GRNE	0.0031
			CDB	0.0012
Chloride	250 (MCL)	1/24/94	ALPE	380
Chromium	0.05 (MCL)	4/25/94	GRNE	0.079
Selenium	0.01 (MCL)	4/25/94	CDB	0.015
Sulfate	250 (MCL)	1/24/94	ALPE	320
Zinc	0.054 (AWQC)	1/24/94	ASS2	0.056
			CDB	0.084
		4/25/94	ASW*	0.066
			ASS2	0.07
			CDB	0.096
			WPDC*	0.081
		11/5–6/94	ASW*	0.085
			ASS2	0.22
			ALPE	0.12
			CDB	0.14
WPDC*	0.12			
Bis(2-ethylhexyl)phthalate	0.004 (MCL)	4/25/94	WPDC*	0.017
2,4-D	0.07 (MCL)	4/25/94	ALPE	0.072

\*Effluent locations

MCL = Maximum contaminant level

AWQC = Ambient water quality criteria

## 6. Surface Water Monitoring



Organic constituents detected in 1994 but below comparison criteria were acetone (three observations), 2-butanone (one observation), chloromethane (one observation), 1,3-dichlorobenzene (two observations), 1,2-dichloroethane (three observations), 2,4,5-TP (Silvex, one observation), and trichloroethene (one observation).

### Site 300 Radioactivity in Surface Water

Rainfall at the semiarid Site 300 was only sufficient to provide a total of three samples. The samples were collected during the first, second, and fourth quarters of 1994. The measured tritium activities were 0.50 Bq/L, 0.66 Bq/L, and 0.66 Bq/L (13.5, 17.8, and 17.8 pCi/L), respectively. These activities are indistinguishable from atmospheric background activity.

The highest observed tritium in Site 300 storm water runoff (**Table 6-6**) was 1.4 Bq/L (37.8 pCi/L), less than 0.2% of the drinking water MCL of 740 Bq/L (20,000 pCi/L). The maximum gross beta level observed in Site 300 storm water runoff (1.5 Bq/L, or 41 pCi/L) was also below the applicable MCL (1.85 Bq/L, or 50 pCi/L). Gross alpha radiation measured at location NPT7 on May 6 (0.69 Bq/L, or 18.6 pCi/L) was just above the drinking water MCL (0.56 Bq/L, or 15 pCi/L). The gross alpha level in the next storm water sample from that location (0.073 Bq/L, or 2.0 pCi/L, on December 15), however, was approximately one-tenth that of the previous sample, and well below the MCL. One sample at the off-site location (NSTN) was also above the gross alpha MCL, at 1.59 Bq/L (43 pCi/L).

**Table 6-6.** Radioactivity in storm water runoff at Site 300 (in Bq/L), 1994.

Location	N883		NPT7		NSTN
	May 6	Dec 14	May 6	Dec 15	May 6
Tritium	0.296 ± 0.992	1.339 ± 1.339	1.014 ± 1.014	1.399 ± 1.399	0.648 ± 0.984
Gross alpha	0.196 ± 0.017	0.046 ± 0.006	0.69 ± 0.038	0.073 ± 0.010	1.595 ± 0.067
Gross beta	0.429 ± 0.030	0.119 ± 0.010	0.747 ± 0.044	0.239 ± 0.011	1.532 ± 0.056
Uranium-234	0.003 ± 0.001	0.011 ± 0.009	0.063 ± 0.003	0.021 ± 0.007	0.115 ± 0.003
Uranium-235	-0.002 ± 0.001	0.003 ± 0.005	0.002 ± 0.001	0.001 ± 0.002	0.005 ± 0.001
Uranium-238	0.0004 ± 0.001	0.009 ± 0.007	0.069 ± 0.003	0.019 ± 0.007	0.123 ± 0.004

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### Site 300 Nonradioactive Pollutants in Storm Water

There were two pH readings in Site 300 storm water runoff (**Table 6-7**) outside of the MCL range (6.5 to 8.5); a pH of 6.1 was measured at location N883 on May 6, and a pH of 9.4 was measured at NPT7 on December 14. All other nonradioactive constituents and parameters were comparable to or below those measured at the background location (NSTN) in Corral Hollow Creek. The only Site 300 values higher than the background location were within the uncertainty of the test, with two total organic carbon readings of 14 mg/L at location N883, compared to 13 mg/L at NSTN.

**Table 6-7.** Site 300 storm water runoff, nonradioactive parameters, 1994.

Parameters	Storm Date	N883	NPT7	STN
Total organic halides (mg/L)	Feb 7	<0.01	<0.01	— <sup>(a)</sup>
	May 6	0.016	0.024	0.1
	Dec 14	0.038	0.059	— <sup>(a)</sup>
Total organic carbon (mg/L)	Feb 7	5	4	— <sup>(a)</sup>
	May 6	14	10	13
	Dec 14	14	10	— <sup>(a)</sup>
Total suspended solids (mg/L)	Feb 7	9	880	— <sup>(a)</sup>
	May 6	19	550	2,100
	Dec 14	62	40	— <sup>(a)</sup>
pH (units)	Feb 7	6.6	8.1	— <sup>(a)</sup>
	May 6	6.1	7.7	7.6
	Dec 14	6.5	9.4	— <sup>(a)</sup>
Specific conductance (µmhos/cm)	Feb 7	15	110	— <sup>(a)</sup>
	May 6	30	130	830
	Dec 14	24	280	— <sup>(a)</sup>

<sup>a</sup> There was not sufficient rainfall to produce runoff at location STN on February 7 and December 14 so no data are available for STN on these dates.

### Environmental Impact

Tritium activities in off-site drinking waters (as well as the on-site TAP location) were all well below the drinking water MCL; they are in the approximate range of the estimated background levels (the background ranges from 3–4 Bq/L or 80–110 pCi/L). The potential impact of such tritium in drinking water supplies was estimated by using the effective dose equivalent (EDE). Appendix B presents the method used to calculate dose. Of all off-site drinking waters measured, the maximum tritium activity, 1.4 Bq/L (38 pCi/L), occurred at location

## 6. Surface Water Monitoring



GAS (at a service station) sampled on July 13, 1994. The EDE to an adult who ingested two liters of this tap water per day for one year would be 0.017  $\mu\text{Sv}$  (1.7  $\mu\text{rem}$ ), which is approximately 0.002% of the DOE standard allowable dose of 1.0 mSv/yr (100 mrem/yr). All other off-site waters, if ingested at the 2-liter-per-day rate, would result in even lower EDEs. The data from waters sampled during 1994 and the estimated potential maximal dose demonstrates a negligible impact of LLNL operations on valley waters resulting from releases of tritium to the atmosphere.

The environmental impact of tritium measured in rainfall samples from LLNL, Sandia, California, the Livermore Valley, and Site 300 was negligible. The highest tritium activity measured in a 1994 rainfall sample was 91 Bq/L (2460 pCi/L). This activity is only 12% of the 740 Bq/L limit established for drinking water by the EPA. The EDE to an adult who ingested two liters of this rain per day for one year would be 0.001 mSv (0.1 mrem), which is 0.1% of the DOE standard allowable annual dose of 1.0 mSv (100 mrem).

Storm water runoff contained levels of zinc and bis(2-ethylhexyl)phthalate that were, at times, above their respective water quality criteria at effluent locations. No other constituent at Livermore-site storm water effluent locations were observed above a regulatory limit. In addition, pH results for one storm event were slightly below the minimum of the MCL range. At Site 300, measurements at effluent locations indicated one gross alpha reading and two pH readings outside of MCLs. Although some 1994 storm water results were above criteria, there is no evidence that indicates any impact to off-site biota.



## 7. Routine Ground Water Monitoring



Eric Christofferson

### Introduction

To complement extensive Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) monitoring activities associated with known areas of ground water contamination, LLNL routinely monitors additional ground water wells in the Livermore Valley and at the Experimental Test Site (Site 300) in the Altamont Hills. Routine ground water monitoring consists of surveillance monitoring and compliance monitoring. Areawide surveillance monitoring is directed by DOE Orders 5400.1 and 5400.5. Additionally, DOE provides direction on radiological effluent monitoring in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991). LLNL determines the number and locations of sampling wells, the constituents to be monitored, and the frequency of sampling for surveillance monitoring purposes. This allows LLNL to devise a comprehensive, cost-effective monitoring program.

Fewer compliance ground water monitoring options are available to LLNL. Compliance monitoring requirements at Site 300 are specifically prescribed in Waste Discharge Requirement (WDR) permits issued by the Central Valley Regional Water Quality Control Board (RWQCB). The WDRs specify the wells to be monitored, the constituents to be measured, the frequency of measurement for each constituent, and the frequency and form of required reports. The Site 300 ground water compliance monitoring data that are summarized in this chapter were previously submitted to the Central Valley RWQCB and other interested federal agencies in four quarterly reports and one annual report (Christofferson et al. 1994a, 1994b, 1994c, 1995a, and 1995b).

LLNL routinely measures tritium in ground water throughout the Livermore Valley and at Site 300. Ground waters are sampled from water-supply wells and from wells that are used only for monitoring purposes. Additional potential contaminants to ground water are monitored at Site 300, where compliance monitoring is associated with two landfills, Pits 1 and 7, closed under the Resource Conservation and Recovery Act (RCRA), and with two connected surface impoundments, where process water is allowed to evaporate. The primary objective of compliance monitoring at Site 300 is the earliest possible detection of any release of contaminants to the ground water from the closed landfills and the process water impoundments. Compliance monitoring is accomplished by measuring specified constituents of concern and general contaminant indicator parameters. The sampled ground waters come from specific networks of wells upgradient and downgradient from the landfills and the process-water impoundments. Additionally, leachate collection systems beneath the process water impoundments are inspected weekly for the presence of water.

## 7. Routine Ground Water Monitoring



Surveillance monitoring at Site 300 uses both on-site and off-site wells. Depending on their location and purpose, well waters at Site 300 are sampled monthly, quarterly, or annually and are analyzed for gross radioactivity, certain radioisotopes, and a wide range of nonradioactive inorganic and organic chemicals.

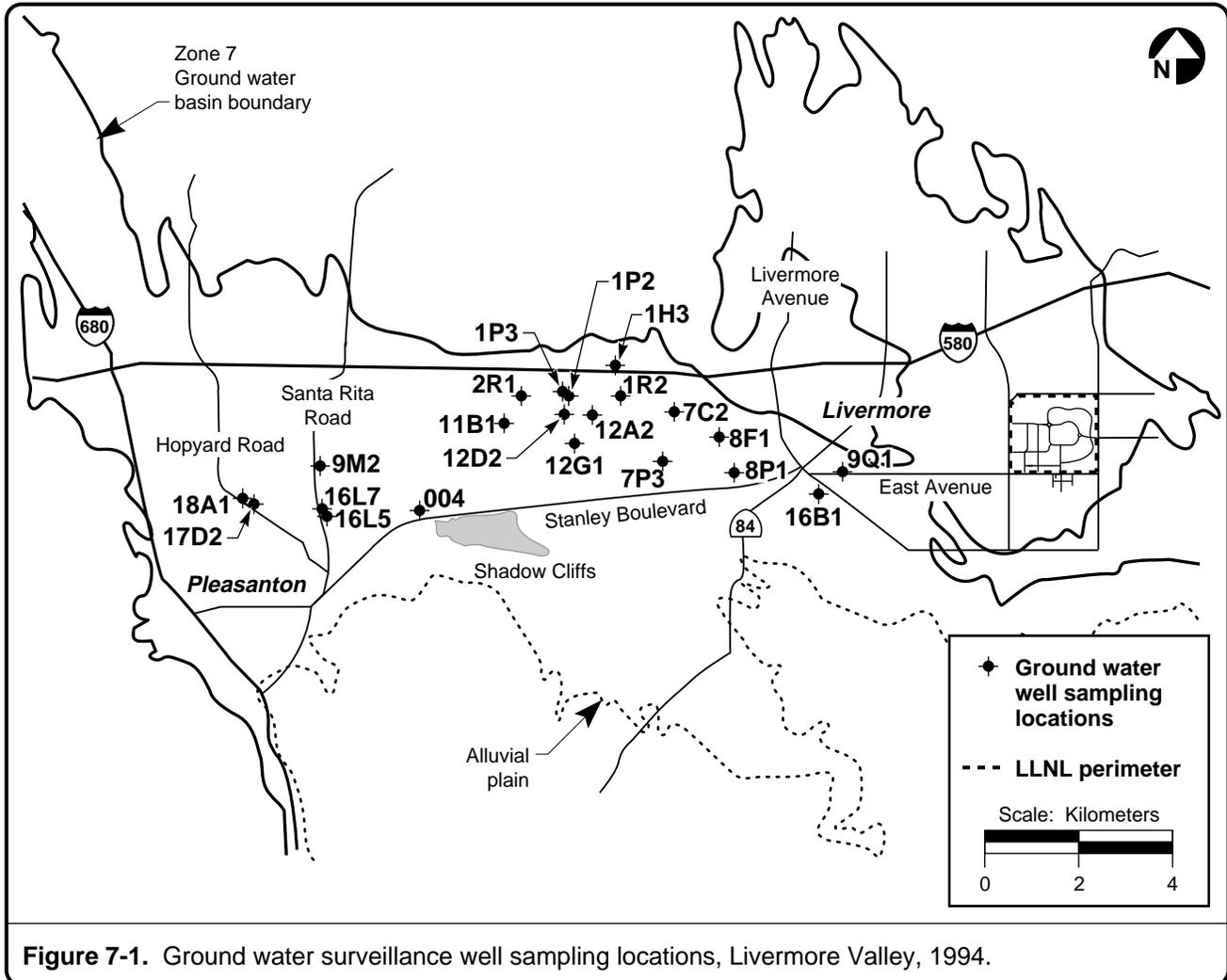
### Surveillance Monitoring of the Livermore Valley

Rain and storm water runoff in the Livermore Valley recharge local aquifers. Rain and runoff contain small amounts of tritium from natural sources, from past atmospheric nuclear weapon tests, and from atmospheric emissions from LLNL and Sandia National Laboratories, California (see Chapter 4 on Air Monitoring for further discussion on air emissions). During 1994, approximately 8% of the sewage water treated at the City of Livermore Water Reclamation Plant (LWRP), amounting to 558 million liters (147 million gallons), was used to irrigate nearby municipal land, including a public golf course. This reclaimed water contained low levels of tritium from natural sources and from permitted operational releases to the sanitary sewer system by LLNL and Sandia, California (total radionuclides in liquid effluents are limited to  $3.7 \times 10^{10}$  Bq [1 Ci] per year; see Chapter 5 for details of sanitary sewer releases).

LLNL is located near the eastern end of the Livermore Valley. The valley floor slopes westward, which directs surface stream flow and ground water flow generally to the west from LLNL. Since 1977, annual tritium measurements have been made on water samples collected from monitoring wells and drinking water wells that are hydrologically downgradient from LLNL to determine the impact of tritium migration into the ground from rain, from the LWRP irrigation water, and from storm water runoff that flows through the Arroyo Las Positas and recharges local aquifers (**Figure 7-1**).

**Figure 7-1** shows the locations of 21 ground water wells in the Livermore Valley that were sampled and analyzed for tritium during the third quarter of 1994. The wells are all downgradient to the west of LLNL and are located within the Alameda County Zone 7 Flood Control and Water Conservation District. Ten of the wells monitor ground water beneath municipal land near the LWRP, where reclaimed water is used for irrigation. Five drinking water-supply wells serving the City of Livermore were sampled, and six serving the City of Pleasanton were sampled.

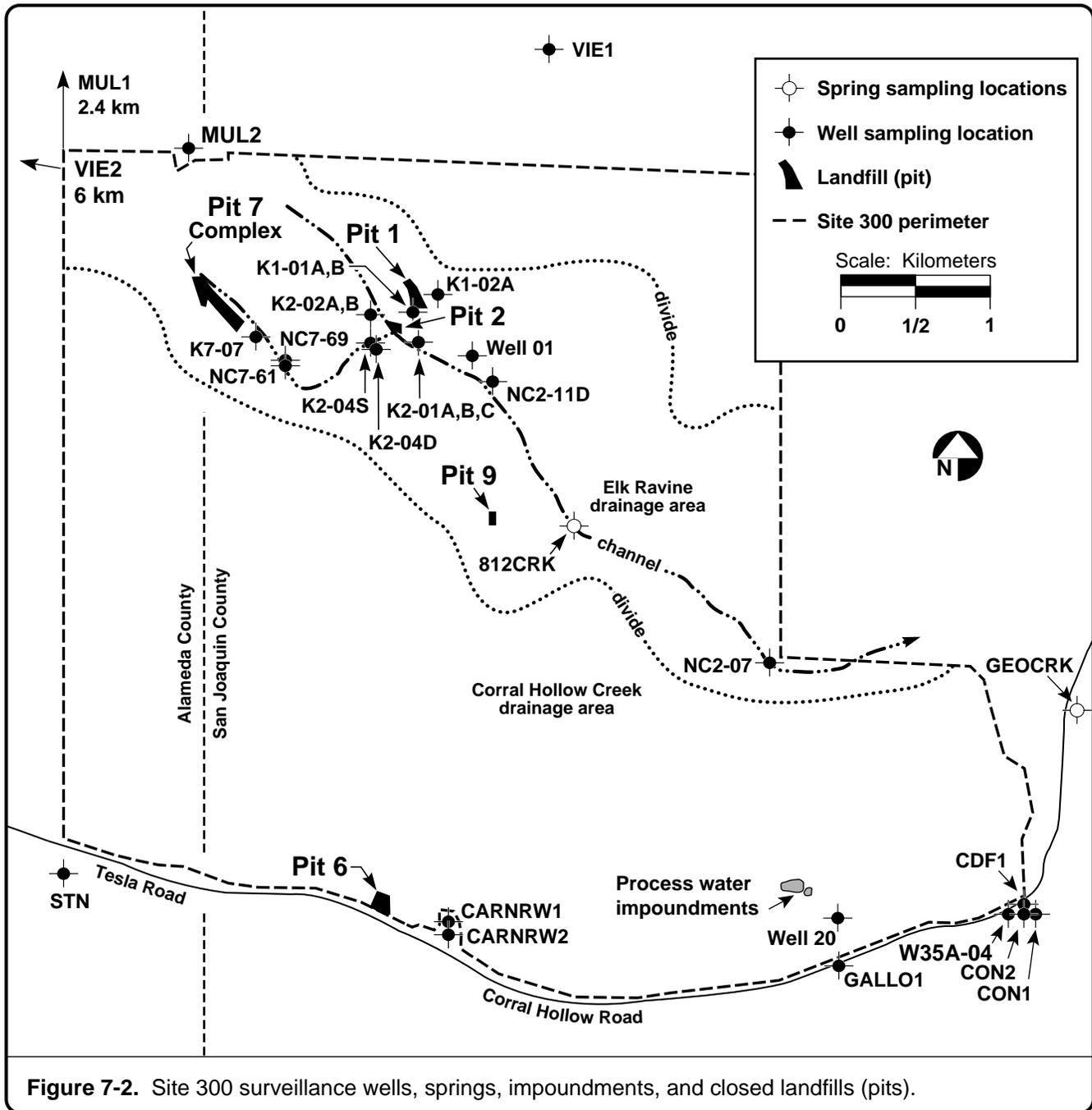
## 7. Routine Ground Water Monitoring



### Compliance Ground Water Monitoring at Site 300

The LLNL Experimental Test Site, known as Site 300, is located in the Altamont Hills approximately 15 kilometers southwest of the city of Tracy. Compliance ground water monitoring at Site 300 is governed by WDR Order Nos. 85-188 and No. 93-100 (Central Valley RWQCB 1985; 1993) and a RCRA post-closure monitoring plan (Rogers/Pacific Corporation 1990). Compliance monitoring involves analyses of water samples drawn from 23 wells associated with two closed landfills and two active process water impoundments. **Figure 7-2** shows the closed landfills (pits), the two process water surface impoundments, and all of the on-site and off-site surveillance wells. A brief description of these areas and associated wells follows. A more complete description of the stratigraphy and hydrogeologic conditions at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994), hereafter referred to as the Final SWRI report.

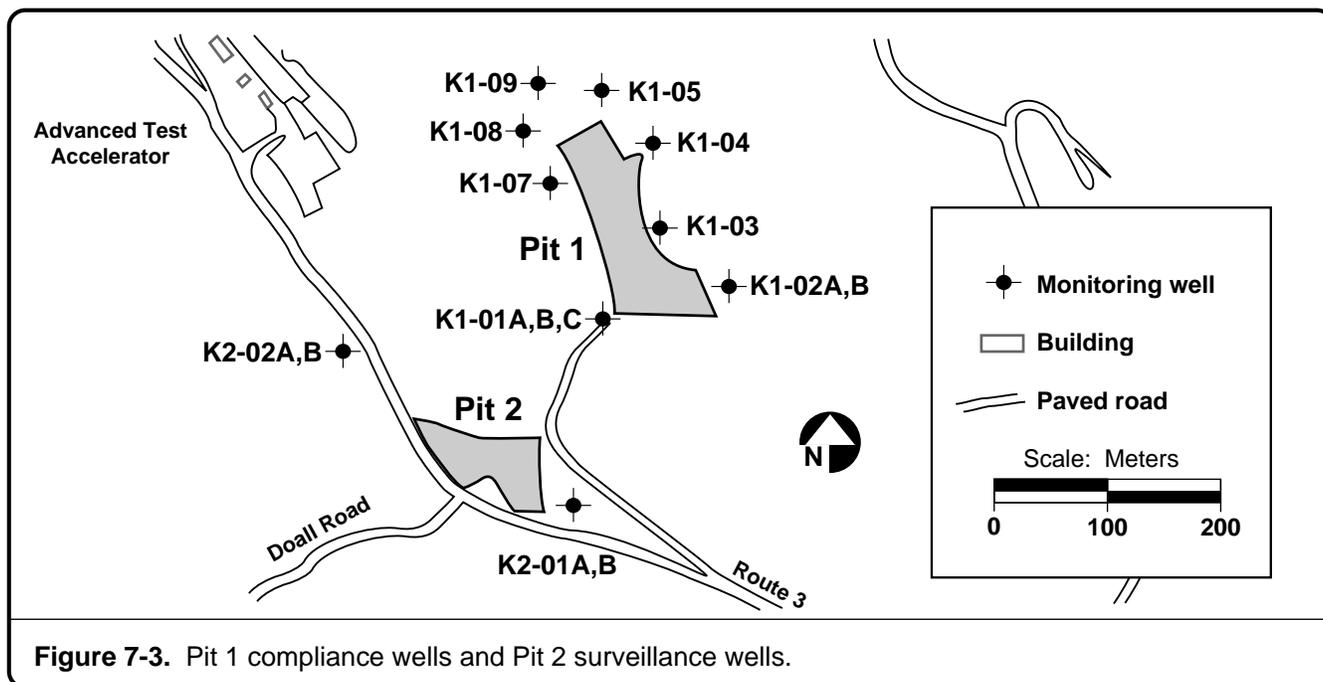
## 7. Routine Ground Water Monitoring



### Pit 1 Area

**Figure 7-3** shows the locations of Pit 1, the monitoring wells, an adjacent inactive landfill identified as Pit 2, and the Advanced Test Accelerator (ATA) in Building 865. Pit 1 lies in the upper part of the Elk Ravine drainage area at an elevation of 330 meters above sea level. Although the test site is in a semiarid locale, intense rainfall does occur. In order to combat erosion, rain runoff from the pit cap and surrounding area is collected in a concrete channel that encircles

## 7. Routine Ground Water Monitoring



the pit. The outfall is at the southwest corner of Pit 1 where surface runoff flows to Elk Ravine. Subsurface water flow beneath Pit 1 is east-northeasterly and generally follows the dip of the underlying sedimentary rocks. Compliance monitoring Wells K1-01C and K1-07 are hydrologically upgradient from Pit 1; K1-02B, K1-03, K1-04, and K1-05 are downgradient; and K1-08 and K1-09 are cross-gradient. Pit 2 is hydrologically upgradient from Pit 1 with respect to subsurface water flow, although it is downslope from Pit 1 with respect to rain runoff into Elk Ravine. The ATA is upgradient from Pit 1 monitoring wells K1-05, K1-08, and K1-09.

The Pit 1 monitoring wells are completed near or at the contact between the Tertiary Neroly Formation lower blue sandstone member and the underlying mid-Miocene Cierbo Formation consisting of claystones and siltstones. The Tertiary Neroly and Cierbo sedimentary rock formations contain the main water-bearing strata beneath the test site.

Pit 1 ground water samples were analyzed for constituents fulfilling the requirements of WDR Order No. 93-100 and a post-RCRA-closure monitoring plan (Rogers/Pacific Corporation 1990). Measurements were performed for water table elevation; total dissolved solids (TDS); specific conductance; temperature; pH; metals; high-explosive compounds [cyclotetramethyltetramine (HMX), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and trinitrotoluene (TNT)]; general minerals; total organic carbon (TOC); total organic halides (TOX); radioactivity (gross alpha and gross beta); the radioisotopes tritium ( $^3\text{H}$ ), radium ( $^{226}\text{Ra}$ ), uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ), and thorium ( $^{228}\text{Th}$  and  $^{232}\text{Th}$ );

## 7. Routine Ground Water Monitoring



herbicides and pesticides (EPA Methods 615 and 608); purgeable organic compounds (EPA Method 624); and extractable organic compounds (EPA Method 625). See Table 7-4, Volume 2, for the list of analyses for Pit 1 required by WDR Order No. 93-100. See Tables 7-1 and 7-2, Volume 2, for a complete list of methods used, analytes measured, and reporting limits.

### Pit 7 Complex Area

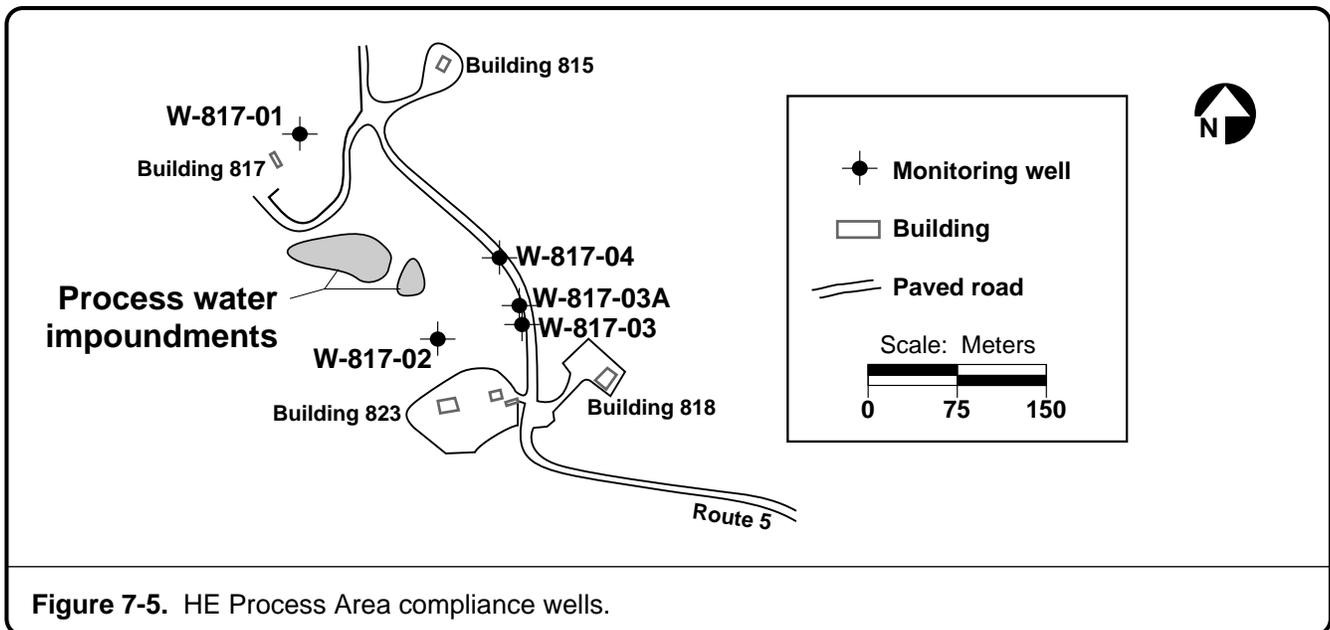
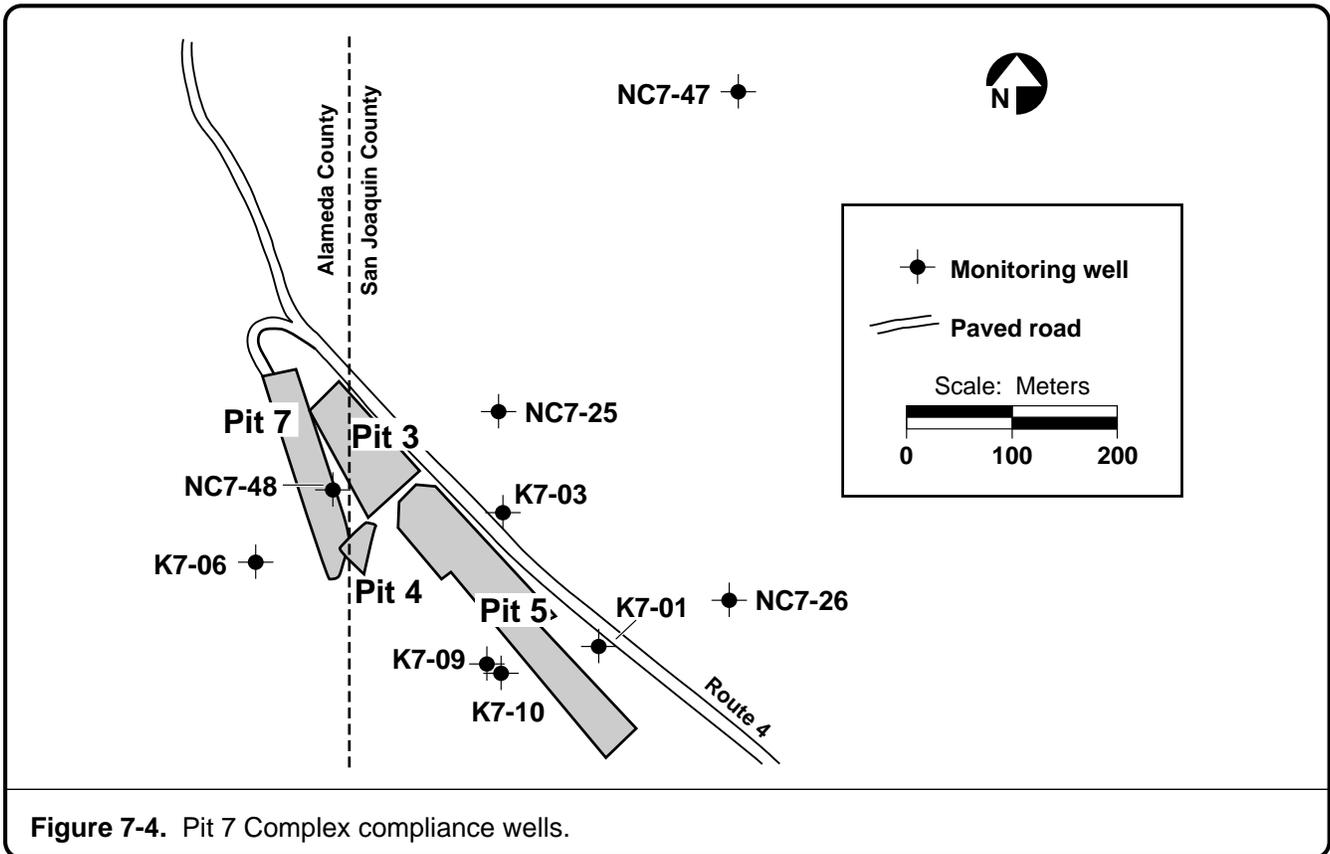
Nine wells monitor the Pit 7 Complex that consists of three inactive landfills (Pits 3, 4, and 5), and one RCRA-closed landfill (Pit 7; **Figure 7-4**). The complex of closed landfills lies in the uppermost reaches of the Elk Ravine drainage area at an elevation of 425 meters. To combat erosion and to reduce local recharge, rain runoff from the Pit 7 cap is collected in several concrete channels. Pit 7 is nearly encircled by a concrete channel that collects rain runoff from the pit cap and directs it southeasterly into the Elk Ravine drainage system. A second concrete channel was constructed on the west side of Pit 7. Runoff entering this northerly directed diversion channel is sheet flow that develops on the hill slope immediately to the west of the Pit 7 landfill. Subsurface water can flow in two directions through this area. With sufficient seasonal rainfall, a shallow, unconfined, southeastward flow can develop in the unconsolidated surficial Quaternary alluvial deposits. The predominant ground water flow, however, is east-northeasterly within the underlying Tertiary sedimentary rocks of the Neroly and Cierbo formations that dip east-northeast in this area. With respect to Pit 7 and the predominant flow direction, Well K7-06 is upgradient, Wells K7-09 and K7-10 are cross-gradient, and Wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are completed in the lower blue sandstone of the Tertiary Neroly Formation that underlies much of the Pit 7 Complex. The remaining wells are completed at the base of, or below, the Neroly and within the claystone and sandstone mid-Miocene Cierbo Formation.

Pit 7 ground water samples were analyzed for constituents fulfilling the requirements of WDR Order No. 93-100 and the monitoring plan for the post-RCRA closure. Measurements were performed for water table elevation; TDS; specific conductance; temperature; pH; metals; general minerals; the radioisotopes tritium ( $^3\text{H}$ ), radium ( $^{226}\text{Ra}$ ), uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ), and thorium ( $^{228}\text{Th}$  and  $^{232}\text{Th}$ ); high-explosive compounds (HMX, RDX, and TNT); and a wide range of organic chemicals.

### High Explosives Process Area

**Figure 7-5** shows the portion of the High Explosives (HE) Process Area that includes two process-water impoundments, five compliance monitoring wells, and Buildings 815 and 817. Compliance monitoring of the two impoundments is specified in permit WDR Order No. 85-188, issued by the Central Valley RWQCB (1985). Beneath both process water impoundments in **Figure 7-5** are systems

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## 7. Routine Ground Water Monitoring



of perforated pipes. The primary purpose of the pipes is leak detection. In addition to the leak detection system, four compliance monitoring wells are completed in the underlying Neroly upper blue sandstone, a water-bearing formation. A fifth compliance monitoring well, W-817-03A, is completed at shallow depth in a nonmarine formation, consisting of unconsolidated sediments and sedimentary rocks, that locally overlies the Neroly Formation. The overlying formation contains a perched water-bearing zone that is very restricted laterally and vertically. The direction of water flow in both formations is approximately southeasterly. Well W-817-01 is an upgradient well with respect to the impoundments. Wells W-817-02, -03, -03A, and -04 are downgradient wells.

Ground water samples were collected quarterly during 1994 from the five compliance monitoring wells in the B-817 HE Process Area. Samples from the four deeper wells completed in the Neroly upper blue sandstone formation were analyzed for metals, general minerals, TOC, TOX, pH, specific conductance, high-explosive compounds (HMX, RDX, and TNT), volatile organic compounds (VOCs), and tritium. Samples from the shallow well W-817-03A were analyzed for VOCs, high-explosive compounds, and tritium.

### Surveillance Ground Water Monitoring at Site 300

Thirty-five ground water wells and several springs are monitored at Site 300 as part of the ground water surveillance program (**Figure 7-2**). Twenty-three wells are on site and 12 are off site. One spring, designated GEOCRK, is located off site in the Corral Hollow Creek arroyo. Methods of sampling and analysis are the same for compliance and surveillance monitoring wells, but the constituents of concern and the frequency of sampling may differ. Three of the 12 off-site surveillance wells are located north of Site 300, where the Altamont Hills slope down to the San Joaquin Valley. One well, designated VIE2, is located in the Altamont Hills approximately 6 kilometers west of Site 300 in the upper reaches of the Livermore Valley watershed. The remaining eight off-site surveillance wells are located adjacent to Site 300 on the south in the Corral Hollow Creek drainage area. Twelve of the 23 on-site surveillance wells monitor three inactive landfills (closed pits). Six wells monitor Pit 6 (**Figure 7-6**). Four wells monitor Pit 9 (**Figure 7-7**). Three multiple completion wells monitor Pit 2 (**Figure 7-3**). Nine of the 10 remaining surveillance wells and one spring, designated 812CRK, are strewn along the system of fault-marked ravines and arroyos that comprise the Elk Ravine drainage area (**Figure 7-2**). Well 20 is a production well that provides potable water to Site 300 (**Figure 7-2**). The wells are described below. A more complete description of the stratigraphy and the hydrogeologic conditions can be found in the Final SWRI report (Webster-Scholten 1994).

## 7. Routine Ground Water Monitoring

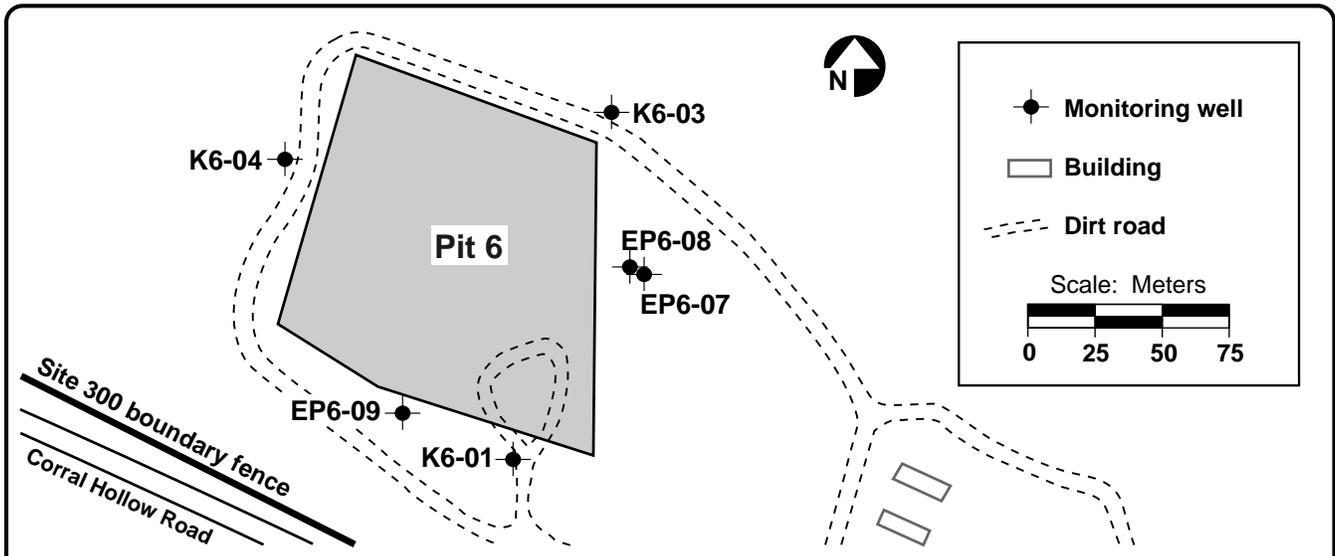


Figure 7-6. Pit 6 surveillance wells.

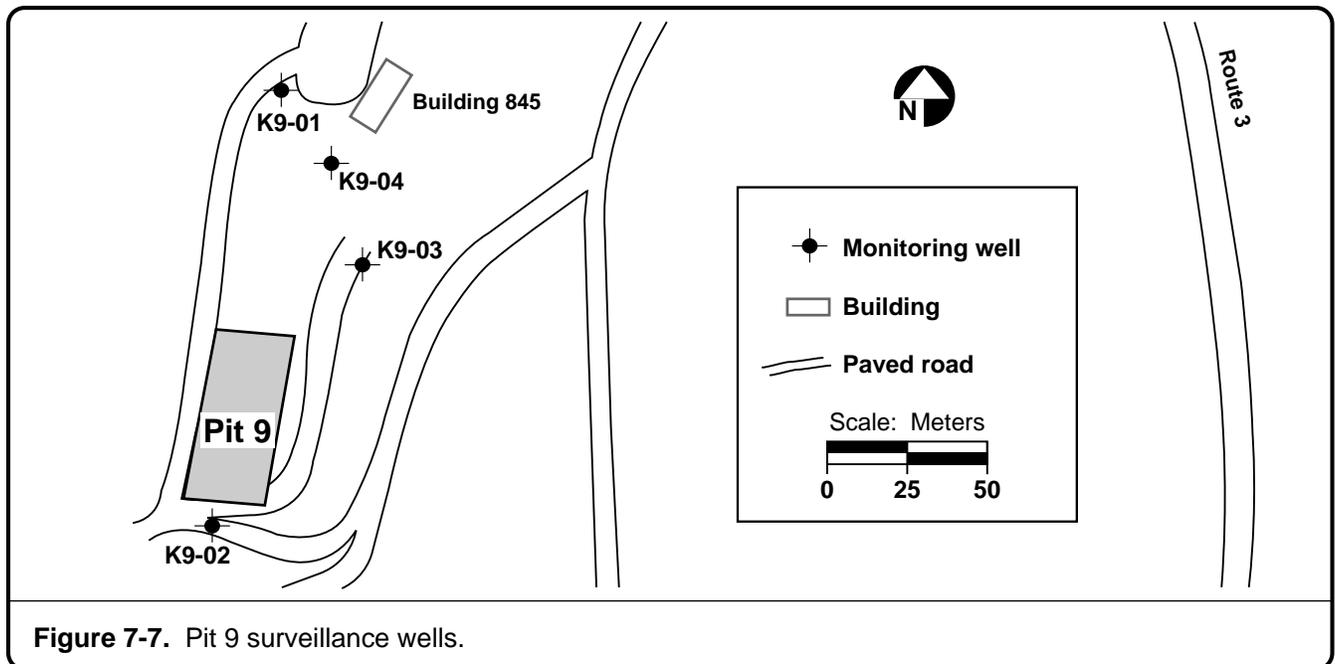


Figure 7-7. Pit 9 surveillance wells.

### Pit 2

The inactive Pit 2 landfill lies in the upper portion of Elk Ravine at 320 meters above sea level (Figure 7-3). Surface runoff from the pit area is southerly into Elk Ravine. Subsurface water flow beneath the pit is east-northeasterly following the dip of the underlying Neroly and Cierbo sedimentary rocks. Multiple completion Well K1-01, shown in Figure 7-3, is completed at three separate depth

## 7. Routine Ground Water Monitoring



intervals in the claystone and sandstone mid-Miocene Cierbo Formation. It contains three Barcad sampling devices. Each Barcad samples a discrete water-bearing zone within the Cierbo Formation. The deepest of the three zones is sampled by Barcad K1-01A, the intermediate zone by Barcad K1-01B, and the upper zone, which is an upgradient monitoring point for Pit 1, by Barcad K1-01C. Surveillance monitoring Wells K2-01 and K2-02 are hydrologically cross-gradient from Pit 2. These are also multiple completion wells and are fitted with Barcad sampling devices. Barcads K2-01A, K2-02A, and K2-02B are completed in the Cierbo Formation. Barcad K2-01B is completed in the lower blue sandstone of the Tertiary Neroly Formation that overlies the Cierbo Formation.

Samples from the Barcad-fitted multiple completions were taken quarterly during 1994 and were analyzed for various metals; radioactivity (gross alpha and gross beta); and the radioisotopes tritium ( $^3\text{H}$ ), radium ( $^{226}\text{Ra}$ ), and uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ).

### Pit 9

Inactive landfill Pit 9 is centrally located within Site 300 at an elevation of 340 meters above sea level. Surface runoff from Pit 9 flows northeastward into Elk Ravine. Subsurface ground water flow is also east-northeasterly in the lower blue sandstone of the Neroly Formation. Surveillance monitoring Well K9-02 is hydrologically upgradient from Pit 9. Wells K9-01, K9-03, and K9-04 are downgradient. Well K9-02 is completed and screened in the Neroly lower blue sandstone at its contact with the underlying Cierbo Formation. Wells K9-01, K9-03, and K9-04 are completed and screened in the Cierbo Formation, just below its contact with the Neroly Formation.

Pit 9 surveillance monitoring Wells K9-01, K9-02, and K9-03 were sampled and analyzed once during 1994 for general contaminant indicator parameters, general minerals, metals, radioactivity, radioisotopes, and a wide range of organic compounds, including pesticides and herbicides. Because Well K9-04 contained little water, it was analyzed only for uranium isotopes.

### Elk Ravine Drainage Area

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown on **Figure 7-2**. This semiarid area collects rare surface runoff into arroyos from inactive landfill Pits 1, 2, 3, 4, 5, 7, 8, and 9. Surface runoff from the Pit 7 Complex area flows southeastward to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit. At the northeastern end of Doall Ravine, the runoff combines with channeled runoff from the ATA area. From this confluence point, the arroyo trends southeasterly within Elk Ravine. Near Well NC2-07, channeled runoff turns easterly away from the trend of the Elk Ravine fault and flows off site for approximately

## 7. Routine Ground Water Monitoring



2 kilometers to its confluence with Corral Hollow Creek. Except for Doall Ravine, the arroyos traverse and follow faults, especially the extensive Elk Ravine Fault that may provide conduits to the underlying water-bearing Neroly strata. For this reason, ground waters from wells that lie within this drainage network are monitored. The monitored wells are (from highest to lowest elevation within the drainage area) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, NC2-12D (replaced Well 01), NC2-11D, and NC2-07. The 812CRK sampling location is a natural spring, also known as Spring 6. It is located in the main Elk Ravine arroyo on the Elk Ravine Fault. Individual wells are discussed below.

Well K7-07 is a shallow well, completed and screened in the upper Neroly lower blue sandstone and the overlying Quaternary alluvium. The well was dry during 1994. Wells NC7-61 and NC7-69 are completed and screened in and sample separate water-bearing zones beneath the upper reach of Doall Ravine, downstream from Well K7-07. Well NC7-61 is completed and screened in the shallower Neroly Formation lower blue sandstone, and Well NC7-69 is completed and screened in the deeper Cierbo Formation. Wells K2-04D and K2-04S and Barcad K2-01C are located near the join between Elk Ravine and Doall Ravine. They are all completed and screened in the upper Neroly Formation lower blue sandstone. Wells NC2-12D and NC2-11D are located in Elk Ravine below its join with Doall Ravine. Well 01, originally a drinking water well and then an emergency fire-suppression well, was completed and screened in the Neroly Formation lower blue sandstone. Well 01 was properly sealed and abandoned in 1994 after third-quarter samples were taken. An adjacent well, NC2-12D, replaced Well 01 for surveillance purposes and was sampled during the fourth-quarter of 1994. Well NC2-11D is completed at the boundary between the Cierbo and the overlying Neroly formations. The farthest downstream on-site well in the Elk Ravine drainage area is Well NC2-07. It is completed in the Neroly Formation lower blue sandstone.

Ground water samples from all wells were analyzed for various metals, including beryllium, radioactivity (gross alpha and gross beta), tritium, and VOCs (EPA Method 601). Due to limited sample water for analysis, Well NC2-07 was not analyzed for metals. Samples from Wells NC7-61 and NC7-69 were additionally analyzed for uranium isotopes ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ). Samples from Wells K2-04D, K2-04S, and K2-01C were additionally analyzed for nitrogen compounds. The Spring 812CRK samples were analyzed for metals, gross alpha, gross beta, and tritium.

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### Pit 6

The closed Pit 6 landfill is positioned along the southern boundary of Site 300 at an elevation of 210 meters above sea level (**Figure 7-2**). It lies in Quaternary terrace deposits above and north of the Corral Hollow Creek floodplain. The Tertiary Neroly Formation sedimentary rocks underlie the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flow beneath the pit is also southward, following the south-dipping sedimentary rocks of the Neroly Formation. However, the direction of the subsurface flow changes from south to southeast beneath the southern margin of the landfill where the Carnegie Fault has brought vertically dipping strata on the south into contact with gently dipping strata on the north. A deposit of terrace gravel fills a southeasterly trending trough within the vertically dipping strata immediately south of the landfill and acts as a channel for the ground water after it passes beneath Pit 6.

Six wells comprise the surveillance monitoring network at closed landfill Pit 6 (**Figure 7-7**). Well K6-03 is hydrologically upgradient from Pit 6 and is completed and screened in the gently southward dipping Tertiary Neroly sedimentary rocks. Wells K6-04, EP6-07, and EP6-08 are hydrologically cross-gradient from Pit 6 and are also completed and screened in the south-dipping Neroly sedimentary rocks. The completion interval of Well K6-04 extends upwards into the Quaternary terrace deposits. Wells EP6-09 and K6-01 are hydrologically downgradient from Pit 6 and are completed and screened in the vertically dipping Tertiary sedimentary rocks.

Ground water samples from the Pit 6 surveillance wells were analyzed for metals; general minerals; organic compounds, including VOCs (EPA Method 601), herbicides (EPA Method 615), and pesticides (EPA Method 608); the general contamination indicator parameters pH, specific conductivity, TOC, and TOX; radioactivity (gross alpha and gross beta); and the radioisotopes tritium ( $^3\text{H}$ ), radium ( $^{226}\text{Ra}$ ), and uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ).

### Well 20

This well supplied potable water at Site 300 during 1994. It is a deep, high-production well that is completed in the Tertiary Neroly Formation lower blue sandstone. The well can produce up to 1,500 liters of water per minute. Additional geologic and hydrogeologic information regarding Well 20 is contained in the Final SWRI report (Webster-Scholten 1994). Quarterly samples taken from this drinking water production well during 1994 were analyzed for the metals beryllium, chromium, copper, and lead; for gross alpha and gross beta radioactivity; and for tritium. Monthly well samples were also taken and analyzed for VOCs using EPA Method 502.2 or 524.2.

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### Off-Site Supply Wells

Twelve off-site potable water-supply wells near Site 300 were tested during 1994 as part of the Site 300 surveillance monitoring program. Four wells—MUL1, MUL2, VIE1, and VIE2—lie to the north of Site 300. Wells CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1 STN, and W-35A-04 are located to the south of the test site (**Figure 7-2**).

Six wells were sampled quarterly during 1994. Of these, CARNRW1 and CON2 were tested for VOCs only (EPA Method 601), while CARNRW2, CDF1, CON1, and GALLO1 were tested for a large suite of inorganic and organic compounds. The remaining six wells—MUL1, MUL2, STN, VIE1, VIE2, and W-35A-04—were tested once during 1994 for a large suite of inorganic and organic compounds. All wells, except CARNRW1 and CON2, were tested at least once during 1994 for high-explosive compounds (HMX, RDX, and TNT), radioactivity (gross alpha and gross beta), and tritium.

### Results

This section presents the results of measurements in Livermore Valley wells, Site 300 Pit 1 area, Pit 7 Complex area, HE Process Area, Pit 2, Pit 9, Elk Ravine drainage area Pit 6, water-supply Well 20, and off-site supply wells.

### Livermore Valley Wells

Tritium measurements of water samples collected once during 1994 from 21 wells in the Livermore Valley are given in the following **Table 7-1**. Tritium in all well samples was very low compared to the 740 Bq/L (20,000 pCi/L) maximum contaminant level (MCL) established for drinking water by the EPA. As in previous years, the highest tritium measured, 15.7 Bq/L (424 pCi/L), was in a water sample from the irrigation monitoring Well 11B1. Tritium in Well 11B1 has decreased 33% since 1991, when it was 23.4 Bq/L (630 pCi/L).

The overall trend of tritium is downward in Livermore Valley ground waters. In 1989, the mean (arithmetic average) well tritium was 5.4 Bq/L (145 pCi/L). By mid-1994, the mean activity had dropped by more than 50% to 2.5 Bq/L (68 pCi/L). The mean well tritium for the past six years is plotted in **Figure 7-8**, together with a plot of total measured annual tritiated water (HTO) emissions to the atmosphere by LLNL and Sandia, California. (Note that in **Figure 7-8** that the tritium per liter in the ground water is about ten trillion times smaller than the annual atmospheric emissions.) Two processes are operating on the tritium in the ground water: natural decay of tritium and mixing of old ground water with younger recharge water. In a closed system, tritium decreases naturally by 50% each half-life of 12.3 years. However, tritium decreased 50% in the Livermore Valley open ground water system in 6 years. The additional decrease, over that expected by decay, is due to dilution of older ground water by younger ground water containing less tritium. Dilution provides the connection between the downward trend in ground water tritium and the downward trend in tritium

## 7. Routine Ground Water Monitoring



emissions shown on **Figure 7-8**. If atmospheric emissions continue to decrease, then tritium in ground waters will also continue to decrease. Tritium in Livermore Valley drinking water is at a very low and safe level, amounting to less than 1% of the MCL.

**Table 7-1.** Tritium activity in Livermore Valley wells (in Bq/L), 1994.

Well No.	Activity	Percent of MCL
<b>LWRP</b>		
1H3	0.43 ± 0.09	0.06
1P2	3.50 ± 0.20	0.47
1P3	0.57 ± 0.11	0.08
1R2	1.79 ± 0.15	0.24
2R1	3.56 ± 0.17	0.48
7C2	2.68 ± 0.17	0.36
11B1	15.69 ± 0.50	2.12
12A2	3.51 ± 0.17	0.47
12D2	6.22 ± 0.24	0.84
12G1	4.96 ± 0.20	0.67
<b>Mean</b>	<b>4.29</b>	<b>0.58</b>
<b>Standard deviation</b>	<b>4.39</b>	
<b>Livermore</b>		
7P3	0.06 ± 0.06	0.00
8F1	1.25 ± 0.13	0.17
8P1	1.69 ± 0.13	0.23
9Q1	1.14 ± 0.14	0.15
16B1	0.77 ± 0.13	0.10
<b>Mean</b>	<b>0.98</b>	<b>0.13</b>
<b>Standard deviation</b>	<b>0.61</b>	
<b>Pleasanton</b>		
9M2	0.88 ± 0.15	0.12
4	1.14 ± 0.14	0.15
16L5	1.08 ± 0.15	0.15
16L7	1.62 ± 0.17	0.22
17D2	0.09 ± 0.09	0.01
18A1	0.28 ± 0.13	0.04
<b>Mean</b>	<b>0.85</b>	<b>0.11</b>
<b>Standard deviation</b>	<b>0.57</b>	

## 7. Routine Ground Water Monitoring

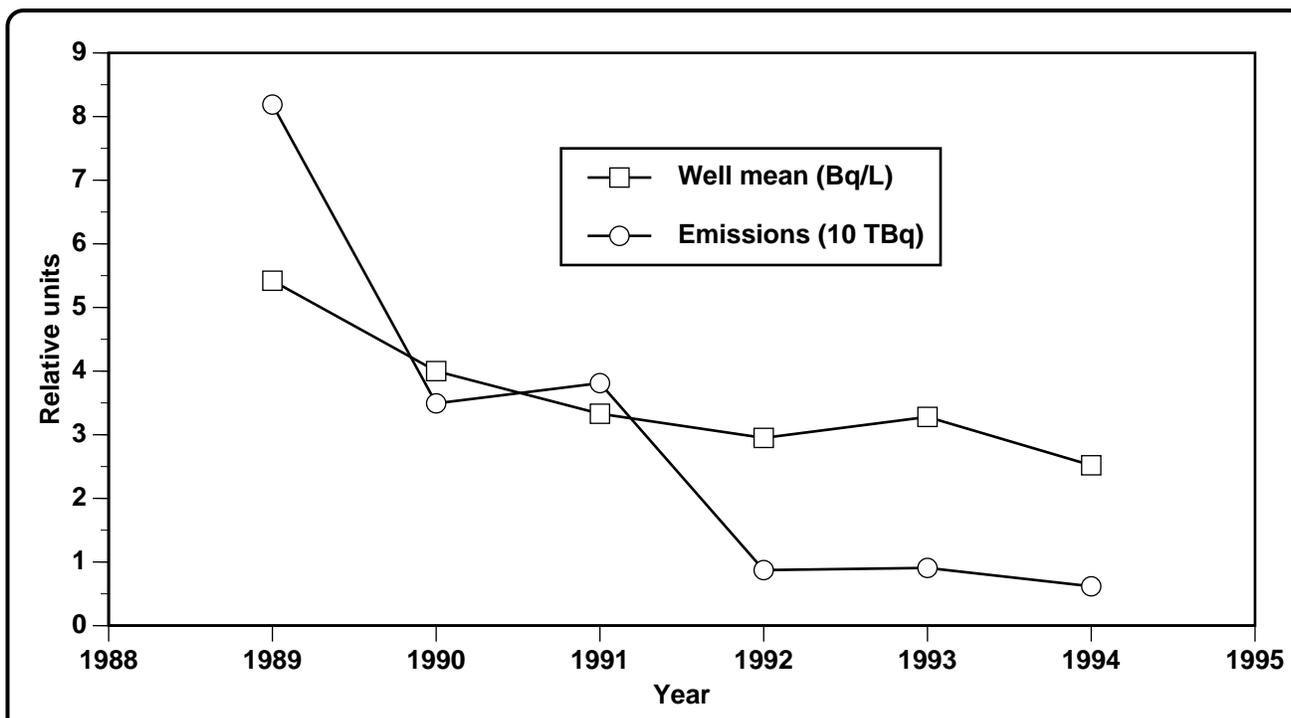


Figure 7-8. Trends of tritium in Livermore Valley wells and atmospheric emissions, 1989 to 1994.

### Site 300 Pit 1 Area

In compliance with the reporting requirements under WDR Order No. 93-100, LLNL notified the Central Valley RWQCB of “statistically significant evidence of a release” of arsenic and total dissolved solids (TDS) from Pit 1. In addition to arsenic, samples from Pit 1 downgradient monitoring Well K1-02B contained significantly more TDS than did the upgradient wells. Measurements of arsenic in Pit 1 ground water samples made during 1994 exceeded the 0.02 mg/L concentration limit for arsenic specified in WDR Order No. 93-100 (see Table 7-4, Volume 2). [Note: the concentration limit is a statistically determined number that is equal to the average background (upgradient) concentration plus approximately three standard deviations. It is not related to the 0.05 mg/L MCL for arsenic established for drinking water by the EPA.]

Additional analyses and measurements indicate that no releases of chemicals from Pit 1 to ground water occurred during 1994, and it is improbable that Pit 1 has released arsenic to ground water since measurements began in 1987 for the following reasons:

- The arsenic increase of 1994 was observed in both upgradient and downgradient well water samples (Christofferson et al. 1994a, 1994b). A release from the pit could not have produced the observed concentration increase in the upgradient well samples.

## 7. Routine Ground Water Monitoring



- The phenomenon was short lived. Arsenic concentration decreased below the concentration limit in both upgradient and downgradient well samples during the third quarter and showed the same low levels during the fourth quarter of 1994.
- Analysis of variance (ANOVA) of the arsenic data revealed that differences in arsenic concentrations between upgradient and downgradient well water samples were not significant during the period when the concentration limit was exceeded (Christofferson et al. 1994b, 1994c).

Therefore, the varying concentration of arsenic observed during 1994 in the Pit 1 area ground water samples was probably due to natural causes or measurement calibration errors, but not a release of arsenic from Pit 1.

It is also improbable that elevated TDS in water samples taken from Pit 1 Well K1-02B indicates a release of chemicals from Pit 1. The mean concentration of TDS is about 15% higher in water samples from Well K1-02B than in water samples from the remaining Pit 1 monitoring wells. However, the major contributors to TDS are calcium, magnesium, and sulfate; natural constituents that come from sources in the sedimentary rocks along the water flow path. Most likely, the elevated TDS in Well K1-02B samples represents the variability of natural sources of calcium, magnesium, and sulfate within the sedimentary rocks that underlay this area. Well K1-02B water samples contain sufficiently more calcium, magnesium, and sulfate than the other Pit 1 monitoring wells to account for the relatively elevated TDS measurements.

Tritium increased in ground water samples from downgradient monitoring Well K1-02B from 1989 to 1993, when it peaked at 130 Bq/L (3500 pCi/L). The maximum activity measured during 1994 was 123 Bq/L (3325 pCi/L). Pit 1 is not the source of the tritium. Rather, it correlates with a plume of tritium-bearing ground water that is moving slowly into the Pit 1 area from a source about 1 kilometer to the southwest at the Building 850 firing table (Webster-Scholten 1994). The plume primarily contributes tritium to downgradient monitoring Well K1-02B samples, but tritium in samples from the monitoring wells closest to K1-02B, upgradient Well K1-01C and downgradient Well K1-03, both show tritium elevated above background levels (see Table 7-5, Volume 2). Increased tritium in water samples from Well K1-01C is evidence for a tritium source outside of Pit 1.

During 1994, the compound 1,1,2-trichloro-1,2,2-trifluoroethane, known as Freon-113, was detected far below the California State Action Level of 1200 µg/L in ground water samples from Wells K1-05, K1-08, and K1-09. However, Pit 1 has no record of Freon disposal. The Pit 1 wells that yield ground water samples containing this Freon compound are also downgradient from the ATA Building 865 (**Figure 7-3**) where a Freon spill to ground is known to have

## 7. Routine Ground Water Monitoring



occurred. The history of Pit 1 monitoring well measurements shows Freon increasing in Well K1-09 four years before a similar increase was seen in Well K1-05. This delay in Freon reaching the well near Pit 1, K1-05, indicates that the source is outside of Pit 1 in the direction of the ATA.

Gross alpha, gross beta, total uranium, radium, and tritium activities measured in water samples taken from Pit 1 compliance monitoring wells were all low and were indicative of natural background levels.

An impermeable cap was installed over Pit 1 in 1992. The purpose of the cap is to assure that waste material buried in the pit will be contained. Despite some initial data to the contrary, additional measurements and analyses made during 1994 demonstrate that this landfill has not leached detectable concentrations of any chemicals to ground water.

A complete table of measurements conducted on ground water samples taken from Pit 1 compliance monitoring wells during 1994 is presented in Volume 2 (Table 7-5).

### Pit 7 Complex Area

The monitoring data for 1994 continue to show tritium from a release to ground water known to have occurred in 1983 from Pit 3 (Webster-Scholten 1994). The release resulted from higher-than-normal rainfall that infiltrated the pit during the 1982–1983 wet season. Although a few measurements made during 1994 constitute statistical evidence of a past release of vanadium from Pit 7 to the ground water, the data generally do not indicate the release of any constituent of concern from Pit 7 since 1992 when an impermeable cap was constructed over the pit. The RCRA cap was designed to prevent the release of any chemicals from the closed Pit 7 landfill due to rain infiltration.

In 1994, through ground water monitoring of the Pit 7 Complex area, LLNL discovered statistical evidence of a release of vanadium from Pit 7. LLNL submitted a 7-day letter report to the Central Valley RWQCB when vanadium was first detected above the 0.05 mg/L CL at 0.06 mg/L in a first quarter 1994 ground water sample from Well NC7-47, the most distant downgradient monitoring well in the network (Christofferson et al. 1994a). Subsequently, vanadium was detected above the concentration limit at 0.12 mg/L in a fourth quarter ground water sample from Well NC7-48, the downgradient monitoring well nearest Pit 7 (Christofferson et al. 1995a).

Vanadium occurs naturally in ground waters at highly variable background concentrations of up to 0.17 mg/L at Site 300 and up to 0.27 mg/L in the Central Valley (Webster-Scholten 1994). The background (upgradient) monitoring well for Pit 7, Well K7-06, is near the ground water recharge area. It taps relatively

## 7. Routine Ground Water Monitoring



fresh ground water that contains less than 0.05 mg/L of vanadium (Table 7-6, Volume 2). The detection of vanadium in water samples from the farthest and nearest downgradient wells, but not from the intermediate-distance monitoring wells, strongly implies that the vanadium in the most distant well samples is from natural sources. The ground water most likely continues to dissolve additional vanadium from the sedimentary rocks along its flow path beneath the Pit 7 Complex area. A progressive increase of vanadium in the ground water from natural sources along the flow path cannot be distinguished from vanadium coming from the landfill; therefore, vanadium cannot be relied on, by itself, to indicate a release from the landfill.

Tritium activities during 1994 continued above the 740 Bq/L MCL in ground water samples from downgradient monitoring Wells K7-01, K7-03, and NC7-25. The highest tritium measured in 1994 was 10,027 Bq/L (271,000 pCi/L) in a third-quarter sample from monitoring Well NC7-25. This activity is about 14 times the MCL. However, none of the wells in this area are used to produce water for human or animal consumption.

Total uranium activity in downgradient monitoring Well NC7-25 exceeded the drinking water MCL of 0.74 Bq/L (20 pCi/L) for the first three quarters of 1994. The highest total uranium activity measured during 1994 was 0.95 Bq/L (26 pCi/L) in a second-quarter sample. This activity is equal to 1.3 times the MCL. A full uranium characterization for the Pit 7 Complex area (including Pits 3 and 5) will be completed during 1995. Initial analytical results give a natural uranium isotopic signature for the uranium in Well NC7-25 samples. The uranium characterization includes ground water sampling and analysis for uranium and uranium isotopes, additional sampling and uranium analysis of soil and rock, fate and transport modeling, and a risk assessment.

A complete table of measurements conducted on ground water samples taken from Pit 7 compliance monitoring wells during 1994 is presented in Table 7-6, Volume 2.

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### HE Process Area

Leak detection systems, consisting of perforated pipes, are installed between the inner and outer liners of the two Class II process water surface impoundments in the HE Process Area. The systems are installed above an impermeable layer of clay that has been graded to provide optimum capture and removal of any leachate by the perforated pipes should any leak occur in the liners of the evaporation ponds. The pipe outfalls are checked weekly for the presence of any leachate water. No leachate water was observed during 1994. Water has been observed only once in previous years when a seal in the pipe connecting the two evaporation ponds leaked a small amount of leachate.

## 7. Routine Ground Water Monitoring



In addition to the leachate monitoring effort, LLNL is required to conduct quarterly analyses of ground water samples taken from a network of nearby monitoring wells. A complete table of measurements conducted during 1994 on ground water samples taken from the surface impoundment compliance monitoring wells is presented in Table 7-7, Volume 2. Water samples drawn during 1994 from these wells all exhibited levels of arsenic, selenium, and nitrate near or above drinking water MCLs (Webster-Scholten 1994).

The high arsenic and selenium concentrations are natural and result from the dissolution of arsenopyrite and mafic minerals from the volcanoclastic-rich Neroly upper sandstone (Webster-Scholten 1994; Raber and Carpenter 1983). The highest arsenic value measured was 66  $\mu\text{g}/\text{L}$  in downgradient Wells W-817-02 and W-817-04. The drinking water MCL for arsenic is 50  $\mu\text{g}/\text{L}$ . Background concentrations of arsenic range up to 220  $\mu\text{g}/\text{L}$  at Site 300. The highest selenium value measured was 94  $\mu\text{g}/\text{L}$  in Well W-817-02. This is nearly twice the EPA 50  $\mu\text{g}/\text{L}$  drinking water MCL for selenium. Background concentrations of selenium range up to 13,000  $\mu\text{g}/\text{L}$  in the region. The highest nitrate value measured as nitrogen was 25  $\text{mg}/\text{L}$  in Well W-817-04, which is 2.5 times the EPA drinking water MCL for nitrate measured as nitrogen. The origin of the nitrate is uncertain. Background concentrations of nitrate range up to 20  $\text{mg}/\text{L}$  (as nitrogen) at Site 300. No drinking water wells are located in this area.

As expected from historical data, trichloroethylene (TCE) continued to be above the MCL of 5  $\mu\text{g}/\text{L}$  in ground water samples from the downgradient monitoring Wells W-817-03, W-817-03A, and W-817-04. A sample from shallow Well W-817-03A showed the highest value of 42  $\mu\text{g}/\text{L}$ , approximately eight times the 5  $\mu\text{g}/\text{L}$  drinking water MCL. The source of the TCE is upgradient of the surface impoundments at Building 815. The levels of TCE measured in samples taken from the HE Process Area compliance monitoring wells are consistent with the map of TCE concentrations described in the Final SWRI report for the HE Process Area (Webster-Scholten 1994). Cis-1,2-dichloroethene was detected at a concentration of 2.7  $\mu\text{g}/\text{L}$  in a water sample from Well W-817-03A, below the 6  $\mu\text{g}/\text{L}$  MCL for this compound.

The high-explosive compound RDX was observed in all water samples drawn from upgradient Well W-817-01. Obviously, the source of the RDX in upgradient Well W-817-01 cannot be the process water impoundments. The highest RDX value measured during 1994 was 113  $\mu\text{g}/\text{L}$ . A maximum concentration limit for RDX has not been set.

Tritium, the single radiological parameter monitored in the Building 817 HE Process Area compliance network wells, was at background levels (1.7 Bq/L) in samples from all five network monitoring wells.

## 7. Routine Ground Water Monitoring



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A complete table of measurements conducted on ground water samples taken from HE Process Area compliance monitoring wells during 1994 is presented in Table 7-7, Volume 2.

### Pit 2

Of the metals, arsenic, barium, iron, lead, and selenium were measured above detection limits. The highest arsenic value was 0.068 mg/L in a sample from Barcad K2-02A. This value is 1.4 times the drinking water MCL for arsenic. The highest barium value was 0.053 mg/L in a sample from Barcad K1-01B and is 5% of the drinking water MCL for barium. Iron was detected in a sample from Barcad K2-02B. The value, 0.14 mg/L, is 50% of the secondary (esthetic) drinking water MCL for iron. No primary MCL for iron has been established. The highest lead value was 0.0037 mg/L in a sample from Barcad K2-01B, which is 7% of the drinking water MCL for lead. The highest selenium value was 0.0046 mg/L in a sample from Barcad K1-01A, which is 9% of the drinking water MCL for selenium. The metal levels are all within the range of natural background concentrations found in the ground water at Site 300 (Webster-Scholten 1994).

The radioactivity and radioisotope measurements show only low background levels for gross alpha, gross beta, radium, tritium, and uranium isotopes. However, although tritium activities in samples from Barcad K2-01B are very low, they are approximately three times the activities measured in samples taken from the other six Barcads in this area. This relatively elevated activity probably defines the boundary of the plume of tritium-bearing water flowing into the Pit 2 area from a source 1 kilometer to the west near Building 850 in the West Firing Area (Webster-Scholten 1994). The incursion of this tritium-bearing water into the Pit 2 and Pit 1 area is also seen in Pit 1 Barcad K1-02B ground water samples (Table 7-5, Volume 2, ). The plume appears to be confined to the lower blue sandstone within the Neroly Formation in the vicinity of Pit 2 and Pit 1.

The results of analyses made on ground water samples from seven Pit 2 surveillance monitoring wells during 1994 are given in Table 7-8, Volume 2.

### Pit 9

The Well K9-04 sample was analyzed only for uranium isotopes. All of the organic compounds for which LLNL performed an analysis were below reporting limits. All metals, general minerals, and radioisotope measurements were indistinguishable from normal background levels. None of the measurements indicates that Pit 9 released any chemicals to the ground water during

1994. The results of analyses made on ground water samples from Pit 9 surveillance monitoring wells during 1994 are given in Table 7-9, Volume 2.

## 7. Routine Ground Water Monitoring



### Elk Ravine Drainage Area

Routine ground water monitoring in the Elk Ravine drainage area included analyses of samples from the wells listed below. Detailed analyses on ground water samples from the Elk Ravine drainage area surveillance monitoring wells during 1994 are given in Table 7-10, Volume 2.

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#### Well K7-07

Well K7-07 was dry during 1994. No water could be obtained for analysis.

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#### Wells NC7-61 and NC7-69

All analyses for beryllium, chromium, copper, and lead in samples from these two wells resulted in no detections. No VOCs (EPA Method 601) were detected in either well.

Of the radioactivity and radioisotope measurements, only Well NC7-61 samples showed elevated tritium. The mean of four quarterly tritium measurements, 7560 Bq/L (204,000 pCi/L), is about 10 times the drinking water MCL for tritium. This tritium-bearing water in the Neroly lower blue sandstone comes from the West Firing Area near Building 850 and is described in the Final SWRI report (Webster-Scholten 1994). Tritium in the underlying Cierbo Formation was very low. The marked difference in tritium between these two wells suggests that the two water-bearing zones are not interconnected in this area.

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#### Wells K2-04D, K2-04S, and K2-01C

As in past years, gross alpha measurements in Barcad K2-01C exceeded the 0.555 Bq/L (15 pCi/L) drinking water MCL. Uranium isotopic measurements made on water samples from Well K2-01C show that the elevated alpha activity results from natural uranium in the ground water.

Elevated tritium was measured in all three wells. The tritium level in Well K2-04D was approximately equal to half the drinking water MCL; the level in Well K2-04S was approximately equal to the MCL; and the level in Well K2-01C was approximately one-fourth the 740 Bq/L (20,000 pCi/L) MCL. These wells lie within the plume of tritium-bearing ground water in the Neroly lower blue sandstone that extends beneath Doall Ravine to Elk Ravine and Pit 1. The source of the plume is near Building 850 in the West Firing Area (Webster-Scholten 1994).

Nitrate measurements in water samples from Wells K2-04D and K2-04S exceeded the drinking water MCL for nitrate by 50%. Elevated nitrate levels are

## 7. Routine Ground Water Monitoring



common in Site 300 ground waters, including the previously discussed HE Process Area, but their origin is still uncertain.

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### Wells 01, NC2-12D, and NC2-11D

Metals and VOCs (EPA Method 601) were not detected in samples taken from these three wells. Both gross alpha and gross beta radioactivity measurements were far below drinking water MCLs. Only tritium was elevated in the samples from these wells. When it was closed in late 1994, tritium in Well 01 samples had increased to 295 Bq/L (7,970 pCi/L) from 222 Bq/L (6,000 pCi/L) in 1992. Tritium in a fourth quarter 1994 sample from Well NC2-12D was 142 Bq/L (3,830 pCi/L). Tritium increased in Well NC2-11D from 68.6 Bq/L (1,850 pCi/L) in 1992 to a mean of 87.7 Bq/L (2,370 pCi/L) in 1994. These wells are located within the plume of tritium-bearing ground water that is moving slowly southeastward in the Neroly Formation beneath Elk Ravine.

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### 812CRK

There were no detections of the four metals in all samples from this spring in the Elk Ravine arroyo. Measurements for gross alpha, gross beta, and tritium were all low and were indistinguishable from background levels at Site 300.

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### Well NC2-07

No organic constituents of concern were detected in the samples taken in 1994. Gross alpha and gross beta measurements were low and cannot be distinguished from background levels in the Neroly Formation. Tritium measurements were also very low. This well presently lies downgradient from the slowly moving plume of tritium-bearing ground water, discussed above.

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### Pit 6

Of the metals analyzed in Pit 6 well samples, arsenic, barium, manganese, and selenium were detected at concentrations consistent with natural levels in the area ground water (Webster-Scholten 1994). Two rare detections of beryllium at extremely low levels in samples from Wells K6-01 and K6-03 were followed by no detections in scheduled samples taken six months later.

Of all the organic compounds analyzed for, only the solvent TCE was detected in one monitoring well. The MCL for TCE in drinking water is 5 µg/L. The highest value measured was 9 µg/L in a ground water sample from Well EP6-09. The TCE concentration is down sharply from a high of 18 µg/L measured in 1993. Well EP6-09 lies within a shallow, elongated plume of water that is known

## 7. Routine Ground Water Monitoring



to contain TCE. The plume extends only 100 meters east of Pit 6. The extent of TCE in the Pit 6 area is fully described in the Final SWRI report (Webster-Scholten 1994).

All of the radioactivity and radioisotope measurements of ground water samples from the Pit 6 area wells in 1994 were at low levels that are indistinguishable from natural background levels. No measurement was above the EPA drinking water MCL. The results of analyses made on ground water samples from Pit 6 surveillance monitoring wells during 1994 are given in Table 7-11, Volume 2.

### Water-Supply Well 20

No metals of concern were detected in Well 20 water samples during 1994. Radioactivity and tritium measurements of these samples in 1994 gave very low values that are indistinguishable from natural background levels. The results of analyses made on ground water samples from Well 20 during 1994 are given in Table 7-12, Volume 2.

On one occasion during 1994, the solvent 1,2-dichloroethane (1,2-DCA) was detected in a water sample from Well 20 at a concentration of 2.5 µg/L, equal to five times the State of California MCL of 0.5 µg/L. Further sampling and analysis done by LLNL during early 1994 traced the 1,2-DCA to the hydrochloric acid used to preserve the water sample. After removing this source of contamination, 11 subsequent monthly analyses of water samples using EPA Method 502.2 showed Well 20 samples to be free of 1,2-DCA.

### Off-Site Supply Wells

No inorganic compounds were detected above primary MCLs in any of the off-site monitoring wells and only two inorganic compounds, sulfate and manganese, were detected above their secondary (aesthetic) MCLs. Two wells, STN and CON1, exceeded the 250 mg/L EPA secondary drinking water MCL for sulfate. Two wells, CON1 and MUL2, exceeded the secondary MCL of 50 µg/L for manganese. High concentrations of sulfate and manganese occur naturally in ground water in the Altamont Hills (Webster-Scholten 1994).

As in the past, low levels of trihalomethanes were detected in water samples from Well CARNRW2 during 1994. The compounds result from water chlorination. Although the tap used to obtain water samples is upstream from the chlorinating mechanism, some reverse flow probably occurs when the well pump is off.

Trichloroethene was reported near the reporting limit of 0.2 µg/L in five water samples from surveillance Well GALLO1 during 1994. Three similarly low detections were seen in samples from this well during 1993. The GALLO1 well is hydrologically upgradient from identified areas of TCE contamination at Site 300

## 7. Routine Ground Water Monitoring



(Webster-Scholten 1994). The trace of organic solvents in samples from this well more likely comes from an unknown source in the Corral Hollow Creek floodplain not associated with Site 300.

Of all off-site radioactivity measurements conducted during 1994, only one exceeded an MCL. Samples from surveillance Well STN showed gross alpha readings above the 0.555 Bq/L (15 pCi/L) drinking water MCL. Measurements of gross alpha in samples from this well ranged from 0.7 to 1.4 Bq/L (14 to 43 pCi/L). This well is located in the Corral Hollow Creek floodplain and is hydrologically upgradient from Site 300. Using mass spectroscopy methods, LLNL has determined the primary source of the gross alpha activity to be natural uranium (0.9 Bq/L or 24 pCi/L). All radioactivity measurements in samples from the remaining off-site surveillance wells gave very low values that are statistically equivalent to natural background levels in the Site 300 area.

The results of analyses made on ground water samples from off-site surveillance monitoring wells during 1994 are given in Table 7-13, Volume 2. Wells CARNRW1 and CON2 were sampled once in 1993 and analyzed for VOCs only. Because no volatiles were detected, these wells are not listed in Table 7-13, Volume 2.

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### Environmental Impacts

The environmental impacts in the Livermore Valley and at Site 300 are presented below.

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#### Livermore Valley

Tritium is at a very low and safe level in Livermore Valley drinking water. The highest tritium measured in a sample from a drinking water well serving the City of Livermore during 1994 was 1.7 Bq/L (46 pCi/L; Well 8P1). This activity is only 0.2% of the 740 Bq/L (20,000 pCi/L) drinking water MCL. The highest tritium measured in a sampled drinking water well serving the City of Pleasanton during 1994 was 1.6 Bq/L (44 pCi/L; Well 16L5). We calculated the maximum annual environmental impact of 1.7 Bq/L in terms of effective dose equivalent (EDE) based on an individual who ingested two liters of this water every day and who showered with this water for 15 minutes every day during 1994. The total water ingested was 730 liters during 1994. The total water inhaled while showering during 1994 was 4 liters. Total ingestion equals 1,240 Bq (33,500 pCi), and total inhalation equals 7 Bq (180 pCi). Using the dose conversion factors contained in Appendix B, the EDE for ingested tritium is 0.000022 mSv (0.0022 mrem), and the EDE for tritium inhaled while showering is 0.000002 mSv (0.00002 mrem). The inhalation dose is a hundred times smaller than the ingested dose, and the ingested dose is negligible, equal to only 0.02% of the EPA standard allowable annual dose of 0.1 mSv (10 mrem).

## 7. Routine Ground Water Monitoring



### Site 300

Ground water monitoring at Site 300 and adjacent properties in the Altamont Hills leaves little doubt that the impacts of past and present LLNL activities are minimal on ground water beyond the site boundaries. Except for tritium contamination at the site, which is predicted to disappear naturally by decay (Webster-Scholten 1994), solvent contamination of aquifers beneath the site is roughly comparable to the potential contamination from a typical neighborhood gas station that operated over the same number of years. Several analyses of ground water samples from Pit 1 and Pit 7 monitoring wells became minor issues of compliance during 1994 under WDR Order No. 93-100. However, the particular analytes of concern for Pit 1 correlate either with naturally occurring elements such as arsenic, or with sources outside the pit, such as tritium and Freon. Ground water data from Pit 1 indicate that the RCRA-closed landfill did not release any potential contaminants to the ground water during 1994.

Under the WDR Order No. 93-100 permit, several analyses of vanadium in ground water samples from Pit 7 monitoring wells constituted statistical evidence of noncompliance. Vanadium, like arsenic, also occurs naturally in ground water in the Altamont Hills. None of the Pit 7 Complex monitoring data point to a release of any potential contaminants from Pit 7 to ground water during 1994.

During 1994, tritium activities in three Pit 7 downgradient monitoring wells continued to exceed the U.S. and California drinking water MCL of 740 Bq/L (20,000 pCi/L). Fate and transport modeling of the tritium-bearing ground water plume indicates that the tritium will disappear by decay to a level far below the MCL by the time it reaches the Site 300 boundary (Webster-Scholten 1994). None of the on-site tritium-bearing ground water is used for irrigation or for consumption by animals and people; therefore, it presents no health risk.

Depleted uranium (99.8%  $^{238}\text{U}$ ) has been detected in ground water samples from several monitoring wells in the vicinity of the Pit 7 Complex. Depleted uranium is less radioactive than naturally occurring uranium. The higher concentration of natural uranium in the ground water at Site 300 had previously masked the presence of the depleted uranium. Apparently, Pits 5 and 7 were sources of depleted uranium before Pit 7 was capped in 1992. A study of uranium at Site 300 will be completed in 1995.

Because concentration limits for several constituents of concern as specified in WDR Order No. 93-100 were exceeded during 1993 and 1994, LLNL established an evaluation monitoring and assessment program for the Pit 7 and Pit 1 areas. LLNL will continue to determine the nature and extent of barium, lead, tritium, uranium isotopes, and vanadium adjacent to Pit 7 and arsenic adjacent to Pit 1 by sampling ground water from additional wells and by conducting additional chemical analyses. This work is being transferred from RCRA compliance to

## 7. Routine Ground Water Monitoring

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CERCLA compliance. Monitoring data will be integrated into this effort. If LLNL confirms that hazardous substances are or were released from Pits 1 or 7, LLNL will conduct further fate and transport analysis and a risk assessment. If these assessments indicate that the risks and/or hazards posed by these substances are significant, as defined by CERCLA, corrective actions for the appropriate landfill(s) will be incorporated into the CERCLA process. Results of this work will be transmitted to the CERCLA Remedial Project Managers.

No on-site or off-site drinking water wells were impacted by LLNL activities at Site 300 during 1994. The 1,2-DCA measured in a sample from Well 20 in January 1994, was traced to the hydrochloric acid used to preserve the water sample. The surveillance monitoring data contained in Tables 7-5 through 7-13, Volume 2, demonstrate that the on-site and off-site radiological and non-radiological impacts of LLNL operations at Site 300 were negligible during 1994.

## 8. Ground Water Protection Management Program



*Richard A. Brown  
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### **Introduction**

LLNL's Ground Water Protection Management Program is a multifaceted effort to eliminate or minimize adverse impacts of Laboratory operations on ground water, determine the extent and understand the impact of past activities, remediate adversely affected areas, and monitor current operations.

DOE Order 5400.1 requires all DOE facilities to prepare a plan that describes the site's ground water regime; describes programs to monitor the ground water and monitor and control potential sources of ground water contamination; and describes areas of known contamination and remediation activities. Ground water surveillance and compliance monitoring at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills is carried out as required by DOE Orders, by written agreement with the California Environmental Protection Agency (Cal-EPA), and by permits and other requirements from the California Regional Water Control Boards (RWQCBs). This monitoring can be divided into two general types: that carried out under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and other surveillance monitoring driven mainly by DOE Order 5400.1. Much of the ground water monitoring at the Livermore site and Site 300 is carried out under CERCLA restoration efforts. This monitoring is fully described in documents issued by the Site 300 Restoration Project and Livermore site Ground Water Project (see Appendix A).

### **Ground Water Regime**

The ground water regime at the Livermore site and at Site 300 is described in the following sections.

#### **Livermore Site**

##### **Physiographic Setting**

The Livermore Valley, which is the most prominent valley within the Diablo Range, is an east-west trending structural and topographic trough bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays with an average thickness of about 100 meters. The valley is approximately 25 kilometers long and averages 11 kilometers in width. The valley floor is 220 meters at its highest elevation along the eastern margin and gradually dips to 92 meters at the southwest corner. The major streams dissecting the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow only during the rainy season.

## 8. Ground Water Protection Management Program

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### Livermore Valley Ground Water Basin

The Livermore Valley Ground Water Basin lies within the Diablo Range, which reaches a maximum elevation of 1,160 meters in the tributary watershed. Including the uplands and valley floor, the ground water basin encompasses 17,000 hectares. The prominent streams, all of which are ephemeral, include Arroyo del Valle, Arroyo Las Positas, Arroyo Seco, Arroyo Mocho, Alamo Creek, South San Ramon Creek, and Tassajara Creek. Arroyo del Valle and Arroyo Mocho drain the largest areas and are the largest streams. These streams all flow toward the valley floor and then westward until they converge at Arroyo de la Laguna, which flows southward out of the valley into the Sunol Valley Ground Water Basin.

The Livermore Valley ground water system can be described as a sequence of semiconfined aquifers. Ground water moves downslope from the perimeter (the valley uplands) toward the longitudinal axis of the valley. It then flows in a generally westward direction toward the southwest portion of the basin. From this point, the ground water flows south into the Sunol Valley Ground Water Basin. However, since 1945, heavy draft from the area has eliminated any sub-surface outflow from the Livermore Valley Ground Water Basin.

The Livermore Formation, with an average thickness of about 1,000 meters and an area of approximately 250 square kilometers, has an available storage capacity significantly greater than that of the overlying alluvium, which averages only about one-tenth the thickness. However, the alluvium is considerably more permeable and is, therefore, the principal water-producing formation for most of the valley (San Francisco RWQCB 1982). The largest quantities of ground water are produced in the central and western portions of the Livermore Valley, where the valley fill is thickest.

The quality of ground water in the Livermore Valley Ground Water Basin is generally a reflection of the surface water that recharges the aquifers. The chemical character ranges from an excellent quality sodium, magnesium, or calcium bicarbonate to a poor quality sodium chloride water. In the eastern part of the valley, the poor quality sodium chloride ground water is indicative of the recharge waters from Altamont Creek, which drains the marine sediments to the east of the valley. High concentrations of naturally occurring dissolved minerals, especially boron, in the eastern part of the valley render the ground water unsuitable for irrigation purposes. Infiltration of wastewater or fertilizers applied to crop lands causes locally elevated levels of nitrates (San Francisco Bay RWQCB 1982). Areas with rapid infiltration rates are limited to the larger stream courses of Arroyo del Valle, Arroyo Mocho, and, to a lesser extent, Arroyo Las Positas.

## 8. Ground Water Protection Management Program

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### Surface Drainage

The natural drainage at the Livermore site has been altered by construction activities so that the current northwest flow of Arroyo Seco and the north-then-west flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 kilometers to the west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west to eventually merge with Arroyo Mocho. An abandoned stream channel is visible on air-photo maps of the site east of the present alignment of Arroyo Seco (Carpenter 1984). A Central Drainage Basin for storm water diversion and flood control was constructed near Building 551 and collects surface water runoff from the Arroyo Las Positas drainage. This was lined in 1990 to prevent infiltration in this area. The gentle 0.5°-to-1° northwest slope of the ground surface (not composed of drainage ways) suggests Holocene deposition by streams flowing northwest from the south and east. Actual ground elevations range from 170 to 200 meters above mean sea level.

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### Hydrogeology

Sediment types at the Livermore site can be grouped into four categories, based on dominant particle size by volume: clay, silt, sand, and gravel. The hydrostratigraphic units of concern at the site are part of the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation. These strata comprise the upper section of strata at the site and vary from approximately 60 meters thick on the eastern part of the site to 120 meters thick on the west. Ground water flow is primarily in sand and gravel lenses and channels, bounded by the less permeable clay and silt.

Based on borehole lithologic data, a series of buried sand and gravel-filled stream channels have been identified at the site. The sand and gravel deposits, which are highly permeable, are present in narrow bands at the site and are interpreted as braided stream deposits, similar to strata deposited by the present day Arroyo Mocho. Sand and gravel deposits do not exceed about 30% of the section anywhere at the Livermore site.

The permeable sediments of the Upper Livermore Formation at the Livermore site are vertically separated by the horizontally extensive, low permeability silt and clay of the Lower Member of the Livermore Formation, which comprise a regional confining layer.

The depth to ground water ranges from over 40 meters in the southeast corner of the site to 10 meters in the northwest and 12 meters in the northeast corners (Thorpe et al. 1990). Ground water levels respond to climate and resource use.

## 8. Ground Water Protection Management Program



Decreases in ground water use from the 1960s to 1985 caused the water table to rise. Heavy rains caused a rise in 1986, 1993, and 1994, and droughts caused a decline in 1987 through 1991.

Ground water recharge at the Livermore site primarily consists of controlled releases from the South Bay Aqueduct and direct rainfall. Recharge enters primarily through the arroyos and, until its lining in 1990, the Drainage Retention Basin.

Ground water flow at the Livermore site is generally westward. The gradient is steepest near the northeast (about 0.15 meter/meter) and southeast corners of the site and decreases to about 0.002 meter/meter west of the site. The downward vertical gradient at the Livermore site ranges from 0.25 meter/meter on the east side to 0.3 meter/meter on the west side.

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### Subsurface Migration Off Site

The conceptual model presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) suggests that ground water generally flows towards two destinations from the Livermore site. Ground water from the north half flows west and northwest and eventually discharges to Arroyo Las Positas near First Street in Livermore, about two kilometers northwest of the Livermore site. Ground water from the southern half flows generally westward toward the gap between the Mocho I and Mocho II subbasins, about two kilometers west of the Livermore site. Ground water velocities at the Livermore site average about 15 to 20 meters (49 to 66 feet) per year. In the area of the gap, the magnitude and direction of ground water flow is uncertain; investigations are under way to determine if ground water from the Livermore site (Mocho I subbasin) migrates westward into the Mocho II subbasin, where several City of Livermore water-supply wells are located.

Site 300

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### Geology

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The elevation ranges from approximately 150 meters above sea level at the southeast corner of the site to approximately 538 meters in the northwestern portion.

The Altamont Hills, in which Site 300 is located, are part of the Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The southern boundary of the Altamont Hills is locally well

## 8. Ground Water Protection Management Program



defined by the abrupt rise in the terrain as the Franciscan Complex core of the Diablo Range emerges south of the Tesla Fault.

The Neroly Formation is the principal hydrologic unit within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (Webster-Scholten 1994). The total thickness of the Neroly Formation beneath Site 300 appears to vary from about 140 meters to more than 150 meters. The lower portion of the section is thicker beneath the southerly part of Site 300, whereas the upper portion is thickest beneath the northeastern portion of Site 300.

The active floodplain of Corral Hollow Creek lies along the southern boundary of Site 300, underlying portions of the western and eastern General Services Area. The floodplain also makes small incursions into Site 300 in the vicinity of closed landfill Pit 6. Floodplain alluvium consists primarily of coarse cobble and boulder-bearing gravel derived from Franciscan sources, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, may locally influence ground water flow within the site and have therefore been studied as part of LLNL's CERCLA investigations.

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### Hydrogeology

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most ground water occurs in the Miocene Neroly Formation upper blue sandstone and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present in the Plio-Pleistocene nonmarine unit, where it occurs as perched water-bearing zones beneath hilltops in the Building 833 and Building 834 areas, and more extensively in the High Explosives (HE) Process Area. The perched water-bearing zone at Building 833 is ephemeral. Fine-grained siltstone and claystone interbeds act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers, but is generally unconfined elsewhere.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock, or where bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, thus

## 8. Ground Water Protection Management Program



creating the perched water-bearing zones at Buildings 833 and 834. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300 (north of the east-west trending Patterson anticline), bedrock ground water flows generally northeast, except where it is locally influenced by ground water in alluvium-filled ravines. In the southern half of the site, bedrock ground water flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

At Site 300, some ground water bodies are regional in extent, such as the Neroly lower sandstone and Cierbo aquifers; others occur as isolated, discontinuous, water-bearing zones underlying hilltops. Ground water is also locally present in alluvial terrace deposits and valley fill.

Ground water in the Neroly lower sandstone aquifer is unconfined in much of the northwestern part of Site 300. In the southern HE Process Area, several flowing artesian wells are present. The elevation of the potentiometric surface in some flowing wells is about 5 meters above ground level, or about 1 meter higher than in the shallower Neroly upper sandstone aquifer.

The Cierbo Formation is saturated beneath Doall Ravine, the Building 851 Area, and the southern part of the East Firing Area. This formation is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas; this may be the result of swelling clays in pore spaces.

### Ground Water Monitoring

Several ground water monitoring programs are in place at the two Laboratory sites and in the surrounding area; their purposes constitute their primary differences. One is to determine impacts from current and ongoing activities; another is to determine if there is contamination from past practices and to remediate it.

#### Livermore-Site Ground Water Monitoring

Surveillance monitoring carried on in the Livermore Valley and on the Livermore site includes both surface and ground water monitoring (see Chapters 6 and 7 of this report). Surface water monitoring is important for ground water protection because contaminants from surface water can reach ground water. Surface water monitoring at the Livermore site includes storm water monitoring and monitoring of nearby surface and domestic waters for radioactive constituents. The storm water monitoring network may be especially crucial in times of significant storm events that might transport pollutants into the permeable sediments at the

## 8. Ground Water Protection Management Program



bottoms of the arroyos, particularly Arroyo Seco. (Chapter 6 contains details of all surface water monitoring networks.)

The ground water monitoring network that supports the Livermore-site remediation effort was initially established to identify and delineate any ground water contamination that may have originated from the Livermore site. Over the years, monitoring has included a good spatial sampling of the entire site plus the off-site areas related to contaminant plumes that have migrated from the site. In every case, wells were drilled to establish a clean zone beyond the limits of measurable contaminants, both vertically and horizontally. Boreholes and monitoring wells were also placed to establish the sources of the contaminants. Over 400 wells are in the regularly monitored network. **Figure 8-1** shows all monitoring wells, piezometers, extraction wells, and treatment facilities as of December 1994.

When a well is initially installed, a comprehensive suite of analyses is performed to establish the baseline conditions for ground water from that well. Follow-on analyses provide data on remedial activities so sampling can be limited to analytes of concern. The primary ground water contaminants at both the Livermore site and Site 300 are volatile organic compounds (VOCs) and tritium. While these comprise the main analytes of concern, analyses for chromium, physical parameters, and pH are also requested on many samples.

Ground water samples are collected quarterly for 18 months from newly installed monitoring wells and piezometers. This sampling schedule may be changed as the distribution of contaminants in ground water changes. The sampling frequency is determined by evaluating the overall and recent (past 18 months) histories of each well. Wells exhibiting little change [ $<10$  parts per billion (ppb) per year] will be sampled annually, wells exhibiting moderate change ( $>10$  ppb and  $<30$  ppb per year) will be sampled semiannually, and wells showing large changes ( $>30$  ppb per year) will be sampled quarterly.

LLNL has designed a surveillance monitoring program to detect possible releases from the mixed-waste storage areas in the southeastern portion of LLNL. This program consists of four background and four downgradient monitoring wells and is being implemented in 1995; these wells were chosen to monitor the uppermost aquifers within that area. First-year monitoring efforts will be used to establish baseline conditions for future monitoring. This surveillance monitoring effort will be reported in the *Environmental Report for 1995*.

This surveillance monitoring program will be reevaluated on an ongoing basis to identify areas of potential concern that may warrant further monitoring (see Chapter 10, *Environmental Monitoring Plan*, Tate et al. 1995, for further details).





## 8. Ground Water Protection Management Program



Monitoring the ground water at any significant distance from the Livermore site is not required because of the slow ground water velocities. Tritium surveillance monitoring of Livermore Valley ground water-supply wells downgradient from LLNL to date has not detected significant migration of tritiated waters (see Chapter 7 for further information).

Pump-and-treat remediation is under way at several locations on the Livermore site (Hoffman et al. 1995). Five ground water treatment facilities are presently operational, and four additional facilities are planned (**Figure 8-1**). Monitoring of the extracted ground water and the capture area surrounding the extraction wells is done by measuring ground water level drawdown in nearby monitoring wells and piezometers. Particular attention is paid to the ground water cone of depression surrounding the pumping wells and the changes in contaminant concentrations resulting from the pump-and-treat effort (see Chapters 2 and 13).

### Site 300 Ground Water Monitoring Program

Water monitoring at Site 300 can be divided into three types—surveillance, compliance, and remedial action. As with the Livermore site, the purpose of the remedial monitoring is to support the investigations and restoration activities associated with CERCLA compliance and cleanup.

As with remedial monitoring at the Livermore site, when initially drilled, a general suite of analyses is performed on each new monitoring well. The results of these analyses, as well as historical information concerning suspected contaminants in the area, are used to determine the continuing monitoring program. Wells without measurable contaminants and located in areas with no history of contaminant usage are sampled at least once a year. Wells in areas with known contaminants but with generally stable conditions are sampled at least twice a year. In regions where significant changes in contaminant concentrations are either observed or predicted (e.g., at the leading edge of the plume), quarterly sampling has been established. The depth to ground water is also measured quarterly unless special circumstances make it impractical to measure a particular well.

The surveillance monitoring program supports 35 ground water wells—23 on-site, including a drinking water-supply well, and 12 off-site—and two springs (see **Figure 7-2** in Chapter 7). Analytes to be monitored are chosen in accordance with current understanding of the ground water quality in the area and to determine the impact, if any, of LLNL operations at the site. The wells are currently sampled primarily for metals, radioactivity, and organic compounds. Details of this network and data for 1994 can be found in Chapter 7 of this report.

The compliance monitoring program ensures that LLNL meets its sampling, analysis, and reporting requirements, which are spelled out in permits and state

## 8. Ground Water Protection Management Program



and federal regulations (other than CERCLA requirements). Currently, the monitoring program is designed to meet the requirements of the closure and post-closure plans for landfill Pits 1 and 7 (Rogers/Pacific Corporation 1990), Waste Discharge Requirements (WDR) Order No. 85-188, and WDR Order No. 93-100. Details of this network and results for 1994 can be found in Chapter 7 of this report.

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### Areas of Contamination

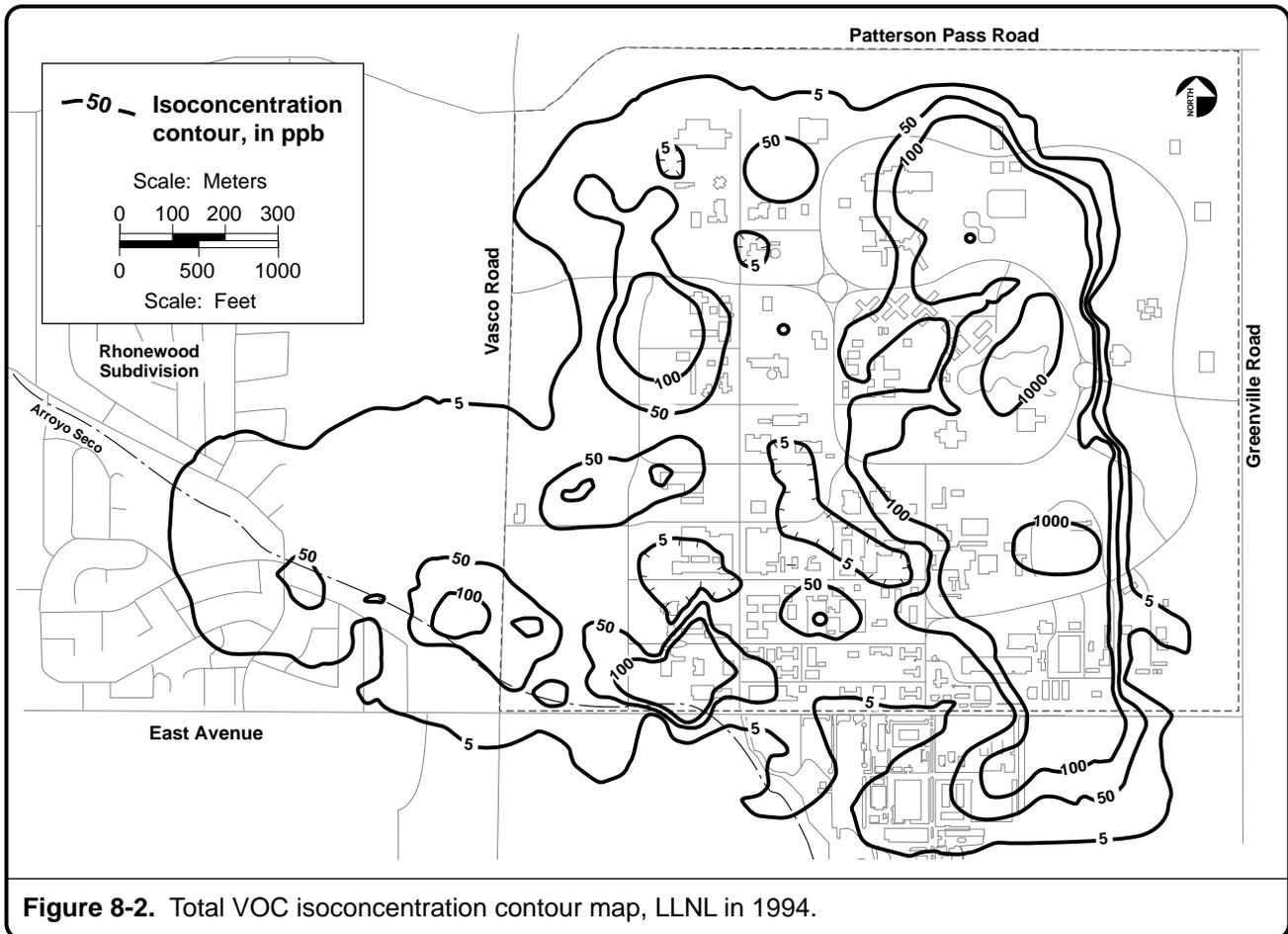
The areas of contamination at the Livermore site and Site 300 are discussed below.

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### Livermore Site

The Livermore site is on the National Priority List for sites requiring environmental restoration in accordance with CERCLA and the Superfund Amendments and Reauthorization Act. In light of this, extensive investigations have been performed to identify contamination from past practices that has affected or could affect the ground water underlying the Livermore site. Detailed descriptions of these findings are available in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and in the *CERCLA Feasibility Study Report for Lawrence Livermore National Laboratory Livermore Site* (Isherwood et al. 1990). Additionally, Ground Water Project (GWP) progress reports were issued monthly, quarterly, and annually by DOE/LLNL in 1994 (see Chapter 2 for additional information). The *Record of Decision for Lawrence Livermore National Laboratory Livermore Site* (Ziagos 1992) became effective on August 5, 1992. This document presents the selected remedial actions for the LLNL Livermore site and was agreed upon by the EPA, San Francisco Bay RWQCB, and California Department of Toxic Substances Control (DTSC).

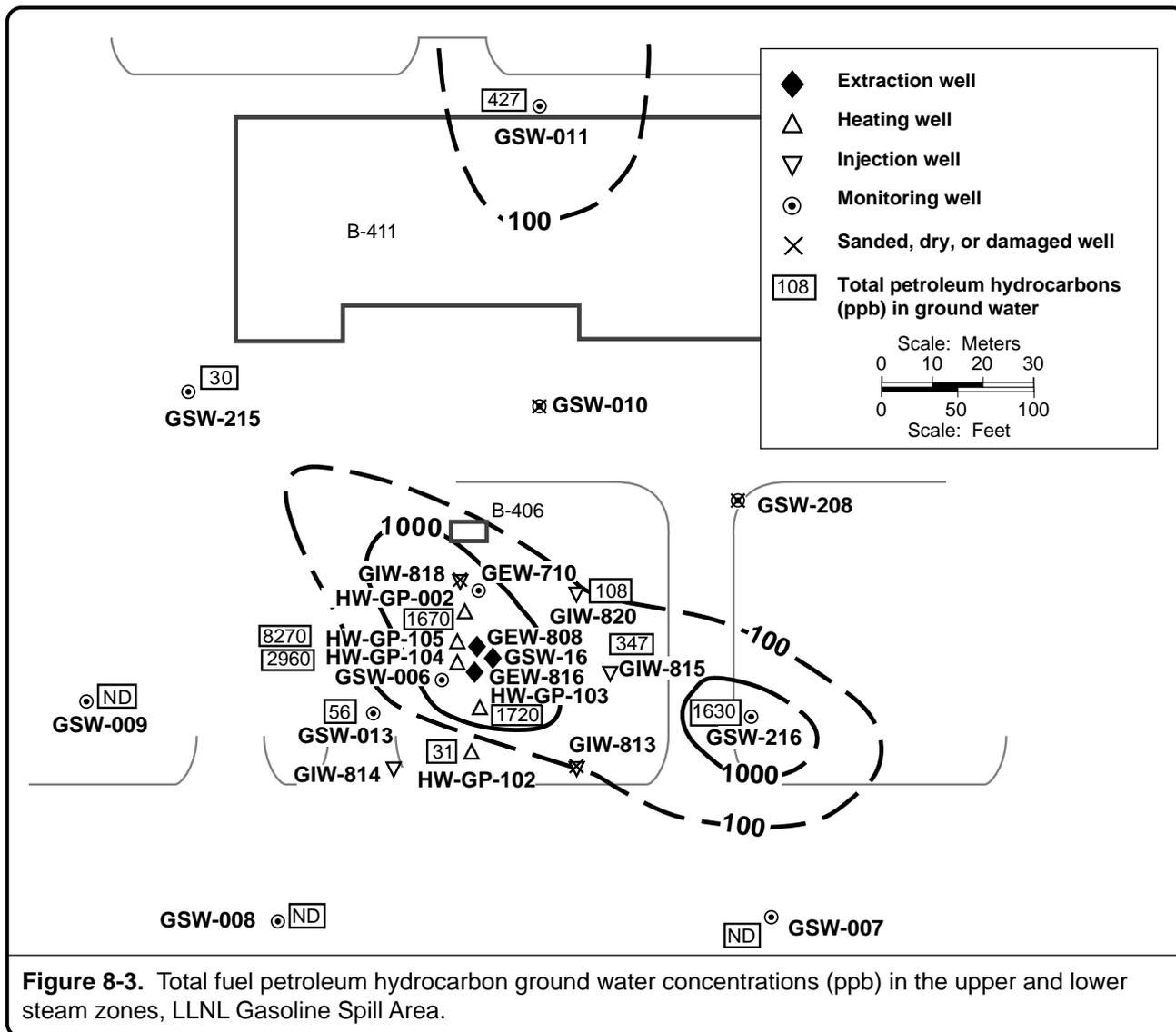
Currently VOCs, predominantly trichloroethene (TCE) and tetrachloroethene (PCE), exist in the ground water beneath about 85% of the Livermore site in relatively low concentrations. The contamination is believed to have started when the site was used as a Naval maintenance base during World War II. The calculated total volume of undiluted VOCs is about 800 liters; Treatment Facilities A, B, C, and D have removed a total of nearly 40 liters of those undiluted VOCs from the on-site ground water since the startup of the facilities (Hoffman et al. 1995). The VOCs are found in ground water plumes varying from 1 to 30 meters thick, but seldom found at depths greater than 70 meters. During 1994, the highest measured ground water concentrations of VOCs (excluding fuel hydrocarbons) were between 1–5 parts per million (ppm) of TCE found in under 2% of the over 400 wells; PCE concentrations did not exceed 1 ppm during 1994. The isoconcentration contours for total VOCs as of December 1994 are shown in **Figure 8-2**.



The concentration of TCE in the unsaturated sediment is receiving special attention in two specific areas. Near Building 518, the TCE concentration reached a maximum of about 6 ppm at a depth of 7 meters. This TCE probably originated from surface spills or leaking drums in the post-Navy operations era. The area surrounding Trailer 5475 was formerly used for landfills and surface impoundments (these areas were excavated and restored in 1983–1985). Total VOC concentrations of up to 5 ppm are found in the unsaturated sediments in this area. Treatment facilities are planned for both of these areas (see Chapter 2).

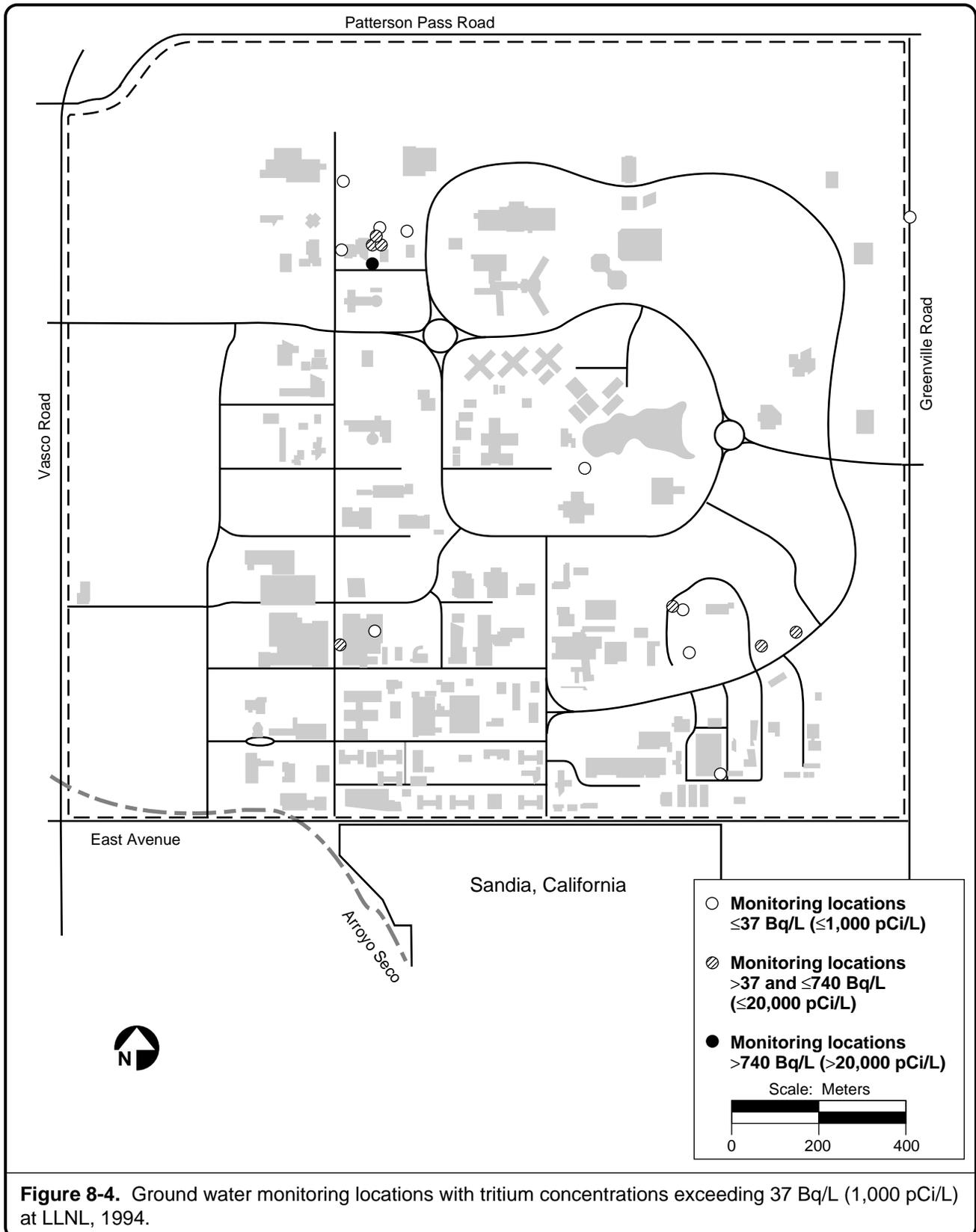
Fuel hydrocarbon contamination is isolated to the area affected by a 66,000-liter leaded gasoline spill that occurred during the U.S. Navy era and subsequent LLNL operation. The fuel tank was removed from service and subsequently abandoned in place in 1979. **Figure 8-3** shows the extent of the contamination after remediation efforts during 1993 and 1994. By December 1994, Treatment Facility F is estimated to have removed nearly half of the total estimated quantity of the gasoline spill (Hoffman, et al. 1994; 1995).

## 8. Ground Water Protection Management Program



Tritium above the maximum contaminant level (MCL) of 740 Bq/L (20,000 pCi/L) is found in only one well (in the Building 292 area). However, tritium is found at levels considered elevated at several locations during 1994, mostly around Building 292 and Trailer 5475 (Figure 8-4). These two areas have unsaturated sediments with tritium concentrations that are also elevated. The source for the Building 292 contamination was a retention tank that leaked during the period that the facility housed the Rotating Target Neutron Source (information about release of tritium to air from this source is provided in Chapter 4, Air Monitoring). In the Trailer 5475 area, the source of the tritium is believed to be leakage from a lined solar evaporation pond used in the 1950s and 1960s.

## 8. Ground Water Protection Management Program



## 8. Ground Water Protection Management Program



### Site 300

Site 300 is also on the EPA National Priority List for sites requiring environmental restoration in accordance with CERCLA. Extensive investigations have been performed to identify and delineate contamination from past practices that has affected or could affect the soil, rock, and ground water underlying LLNL Site 300. Detailed descriptions of these activities and findings are available in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Final SWRI report; Webster-Scholten 1994). The remediation work at Site 300 has not reached the same stage as that at the Livermore site so some areas of possible contamination are still under investigation. (Chapter 2 gives further information on CERCLA remediation activities at Site 300.)

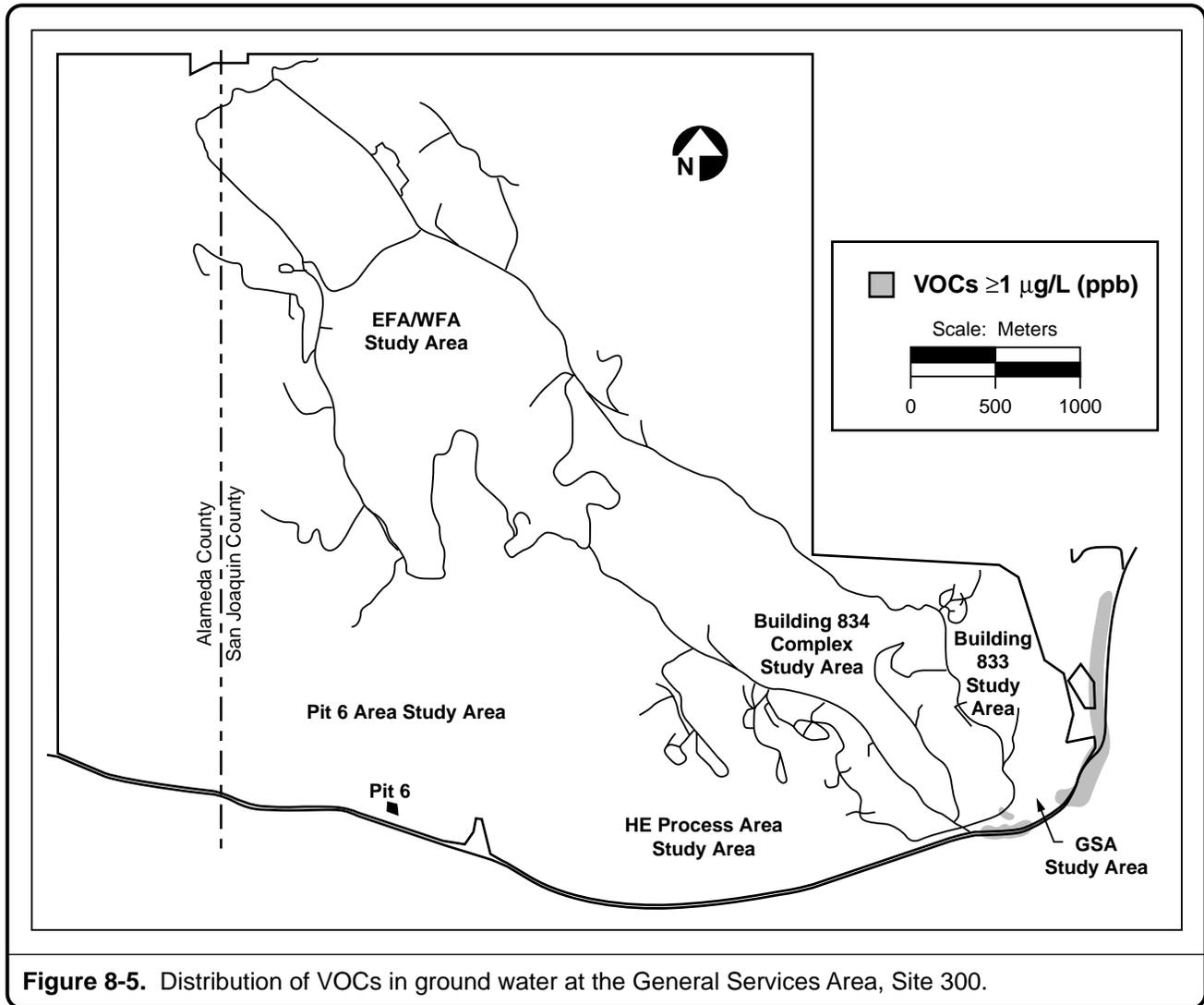
VOCs, primarily TCE, have been detected in the ground water and unsaturated sediments at Site 300. The main areas of concern are predominantly in the southeast portion of the site (**Figure 8-5**). Contaminants in ground water have extended off site from the General Services Area (GSA), which houses the administrative buildings, crafts and mechanical shops, fuel and vehicle repair shops, cafeteria, and main parking. VOCs in excess of the MCLs for TCE and PCE have been identified in the shallow ground water beneath the GSA at two locations: (1) two small plumes occur in the central area, and (2) one plume occurs in the eastern area and the gravels of Corral Hollow Creek, a seasonal arroyo running along the southern border of Site 300. TCE is also present in the Building 833 and Building 834 areas, the HE Process Area, and downgradient of closed landfill Pit 6. Minor detections of TCE have been seen in the East and West Firing Areas (in wells downgradient from closed Pit 7 and the Building 801/Pit 8 area).

Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) has been detected in wells downgradient from the closed Advanced Test Accelerator where Freon-113 was spilled to ground in the past. This is discussed further in Chapter 7 on Routine Ground Water Monitoring.

Discharges of rinse water from buildings within the HE Process Area were historically disposed of in unlined lagoons near the buildings. LLNL no longer uses the lagoons, and they have been closed and capped. However, high-explosive compounds and metals have been detected in the unsaturated sediments beneath some of the lagoons. High-explosive compounds and TCE have been detected in ground water within two perched water-bearing zones beneath the HE Process Area.

Tritium has been identified in ground water from three release sites in the northern portion of Site 300: Pit 3, Pit 5, and the Building 850 firing table. These plumes of tritium in ground water occur in the northern West Firing Area, in Doall Ravine, and in Elk Ravine in the East Firing Area.

## 8. Ground Water Protection Management Program



**Figure 8-5.** Distribution of VOCs in ground water at the General Services Area, Site 300.

The tritium from Pit 3 was released into the ground water when abnormally high water levels flooded landfills; direct infiltration may also have occurred. Tritium was released from the Building 850 firing table due to percolation of rainwater and dust suppression water through the ground surface of the table to ground water.

The ratio of the isotopes  $^{235}\text{U}$  to  $^{238}\text{U}$  found in nature is about 0.007. The by-product of the enrichment process of  $^{235}\text{U}$  is depleted uranium—uranium with a lower proportion of  $^{235}\text{U}$  and a mass ratio of less than 0.065. Depleted uranium has been detected in a number of wells downgradient of Pit 7, Pit 5, and Building 850—the three release sites of depleted uranium at Site 300. Studies have determined its extent in soil, rock, and ground water; it is less extensive than tritium. (See Chapter 7 for more detail.)

## 8. Ground Water Protection Management Program



Results from monitoring wells surrounding Pits 1 and 7 have shown statistically significant evidence of release of some constituents of concern and possible changes in ground water quality. LLNL has reported data for  $^{235}\text{U}$  and specific conductivity for Pit 1; and barium, tritium,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ , specific conductivity, pH, and lead for Pit 7. LLNL is required to report “statistically significant evidence of release” based on a comparison of upgradient and downgradient well chemical results and historical monitoring data. LLNL will perform further investigations under CERCLA to determine if the results indicate releases from the pits. The capping of the pits, completed in 1992, eliminates infiltration from the surface, thereby diminishing the rate of potential release of any material from the pits. (See Chapter 7 for further information on Site 300 ground water.)

### Waste Minimization/ Pollution Prevention Activities

LLNL beneficially reuses excess construction soils on site if they do not pose a potential threat to beneficial uses of ground water supplies as defined by the local California RWQCB. At a CERCLA site such as LLNL, regulatory agencies usually require that the cleanup level for contaminants be background. The background level for synthetic VOCs, which are the primary contaminants at LLNL, is no contamination (zero concentration). As a result, LLNL selected an alternative method to allow reuse of soils with minimal levels of VOCs. The Designated Level Methodology (DLM), developed by Jon Marshack (Marshack 1991) of the Central Valley was approved for use by both the Central Valley and the San Francisco Bay RWQCB.

We also developed *de minimis* concentrations for VOC-contaminated soils based on the DLM (Isherwood 1994) that have formally been approved by the San Francisco Bay RWQCB for use at the Livermore site. Any soils with VOC contamination below these *de minimis* concentrations can now be reused at the Livermore site. The approval of these levels for VOCs will eliminate the need to landfill most construction soils that could be reused on site. This also ensures that LLNL construction activities add no unacceptable pollution to the ground water beneath the site. *De minimis* concentrations for VOC-contaminated soils have also been developed for Site 300 and submitted to the Central Valley RWQCB (Isherwood 1993); formal approval for use of these concentrations at Site 300 has not yet been received.

The next major project is to update natural background concentrations for trace metals in soils. This work is under way and should be completed in time to report in the *Environmental Report for 1995*.

### Remediation Activities

CERCLA and other remediation activities—including the Tank Upgrade Project, the Sanitary Sewer Rehabilitation Project, and the Building Drain Investigation—are discussed below.

## 8. Ground Water Protection Management Program



CERCLA

### Livermore Site

An extensive investigation of the remediation options for the contaminated areas discussed above is summarized in the *CERCLA Feasibility Study for Lawrence Livermore National Laboratory Livermore Site* (Isherwood et al. 1990). The *Record of Decision for Lawrence Livermore National Laboratory Livermore Site* (ROD; Ziagos 1992) documents the remedial options selected for implementation. The selected remedies for ground water contamination involve pumping the ground water for surface treatment by a combination of ultraviolet-light hydrogen peroxide, air stripping, and granulated activated carbon. The selected remedies for contaminants in the unsaturated zone are vacuum-induced venting with surface treatment of the vapors by catalytic oxidation or activated-carbon filtration. The goal of the remedial action is to clean the ground water to the levels specified in the applicable, relevant, and appropriate requirements developed for this project and outlined in the ROD. A description of the remediation efforts during 1994 can be found in Chapter 2.

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### Site 300

The investigations and preparations for remediation at Site 300 have not progressed as far as those at the Livermore site. The Final SWRI report (Webster-Scholten 1994) was accepted by the regulators. This report compiles all ground water and soil investigation information for Site 300 and contains an assessment of the potential human health and ecological hazards or risks resulting from contamination of soil, sediment, and ground water. Feasibility studies are being prepared for the individual study areas where an unacceptable risk or hazard exists. During 1994, LLNL submitted the *Final Feasibility Study Report for the Building 834 Operable Unit Lawrence Livermore National Laboratory Site 300* (Landgraf et al. 1994), the *Final Feasibility Study Report for the Pit 6 Operable Unit* (Devany et al. 1994), and the *Proposed Plan for Remediation of the Lawrence Livermore National Laboratory Site 300 Building 834 Area Final Draft* (Landgraf et al. 1994) to the regulatory agencies. Current milestone dates for Final Feasibility Study reports are: GSA on May 1, 1995; HE Process Area on December 1, 1995; and Building 850/Pits 3 and 5 on February 15, 1996. A description of the remediation efforts in 1994 can be found in Chapter 2. LLNL, DOE, EPA, DTSC, and the Central Valley RWQCB are at present working to reengineer the CERCLA process to speed up cleanup at portions of Site 300 requiring it.

LLNL properly sealed and abandoned water-supply Well 1 at Site 300. This well was screened across several water-bearing zones that contained elevated tritium activities and, therefore, had the potential to cross-contaminate the aquifers.

## 8. Ground Water Protection Management Program



### Other Remedial Programs

Leaking underground and aboveground tanks, transformers, sanitary sewer pipes, building drain pipes, dry wells, and cooling tower discharges to ground can potentially supply significant quantities of contaminants to the soils and to the ground water. The projects and studies described below are LLNL's 1994 efforts to eliminate or minimize discharges that could adversely impact ground water and/or surface water supplies.

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#### Tank Upgrade Project

The Tank Upgrade Project has included the closure and accompanying soil cleanup of 27 petroleum product underground storage tank (UST) systems with minor to moderate amounts of vadose zone contamination in their immediate vicinity. The suspected cause of contamination in the majority of these tank systems was overspill during filling operations. A total of 74 USTs and 48 above-ground or on-ground storage tanks (whose contents are hazardous product and hazardous/nonhazardous waste) will be closed, replaced, or upgraded as part of this project. Approximately 36 pieces of oil-containing equipment (transformers and sectional switches) will also be upgraded with secondary containment, accompanied by appropriate soil cleanup. As of December 1994, construction was completed for 56 tanks, construction was in progress for 43 tanks, design was completed for three tanks not yet under construction, design was in progress for 52 tanks, and four systems remain to be designed.

Closure and corrective action reports were submitted to San Joaquin County in 1994 on the removal of underground fuel supply tanks at several buildings at Site 300. Seventeen underground and one aboveground tank systems were closed and cleaned up (as required) in an earlier Tank Systems Upgrade Project. (See Chapter 2 for further information.)

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#### Sanitary Sewer Rehabilitation Project

The objective of the Sanitary Sewer Rehabilitation Project is to investigate the condition of, and rehabilitate, the sanitary sewer system at the Livermore site. Over 9,000 meters of sewer line were examined to identify areas where lines were off-set, joints were separated, or a portion of a line was either punctured or had collapsed. The major line breaks and disruptions have been repaired by excavation and pipe replacement. Smaller problems (e.g., line off-sets and cracks) were identified in sufficient numbers to determine that *in situ* lining of over 6,000 meters of piping in the system would be the most cost-effective repair. This lining effort has been completed and will reduce, to an acceptable level, exfiltration from the sewer pipes into the surrounding sediments and, possibly, into the ground water. It will also reduce infiltration of rain water into the sewerage system.

## 8. Ground Water Protection Management Program

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### Building Drain Investigation

The Building Drain Investigation, completed in 1992, identified deficiencies in wastewater discharge systems that must be repaired or permitted. If, after examination of the process and sampling and analysis, the discharger did not have a significant impact to the environment, LLNL applied for permits to continue the discharge. Examples of this type of discharge are water from testing of emergency showers and eye-washes and condensate from air conditioners. LLNL is in the process of removing or rerouting the discharge to the sanitary sewer or a retention tank in cases where there may be a significant impact on the environment, including the possibility of ground water contamination.

LLNL submitted a technical report to amend an existing National Pollutant Discharge Elimination System (NPDES) permit at Site 300 to include the non-storm water discharges not covered by another permit on August 1, 1994. A NPDES permit application was submitted to the San Francisco Bay RWQCB on March 23, 1995.

Once the respective regional boards act on the submitted information, LLNL will be required to certify that all discharges are in accordance with environmental regulations. The elimination of discharges that release industrial wastewater to ground will reduce the possibility that contaminants in the wastewater could reach the ground water. Permits issued by the regional boards should establish effluent limits and operating conditions that will protect surface and ground water quality.

In the past two years, LLNL has completed extensive investigations of the sanitary sewer system at the Livermore site and of the building drain systems at both sites. As might be expected at a site with most of its infrastructure over 30 years old, closed-circuit television testing revealed cracks, breaks, and off-set joints in the sanitary sewer system. Exfiltration could have taken place at each of these locations. Repairs were prioritized based on an evaluation and ranking of the problems by an outside contractor. The worst portions of the system have been repaired, and much of the system has been lined to reduce leakage from it. When repairs required excavation, soil samples were taken and analyzed to determine if exfiltration released contaminants into the soil. When necessary, soil from the excavations was removed and disposed of at a properly certified landfill. Further details of this effort are given in the last section of this chapter.

From 1992–1994, LLNL tested over 25,000 drain discharges to determine the location of all nonstorm water discharges to ground or storm sewer systems. The discharge points of the drains were identified through dye testing, smoke testing, and methods as simple as flushing popcorn down the line and watching for its appearance at a downstream manhole. Deficiencies that posed a significant or

## 8. Ground Water Protection Management Program



immediate threat to ground water have been eliminated, and LLNL is in the process of removing or repairing these deficiencies. Eleven discharges that could have affected human health or significantly affected the environment were stopped immediately upon detection. The remaining deficiencies were categorized and identified to facility management and DOE Oakland Operations Office staff. Note that remaining deficiencies do not pose a significant, immediate threat to ground water quality.

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### Dry Wells and Disposal Lagoons

At Site 300, dry wells and disposal lagoons have been primary points of wastewater release to the environment, including potentially to the ground water. The dry wells and lagoons received wastewater and other liquids from various buildings and test cells by piping or lined trenches. Dry wells were typically filled with gravel and were generally not very deep (often less than 2 meters). Disposal lagoons were often earthen depressions with no metal or concrete sides. Most disposal lagoons were constructed in permeable soil and almost never had standing water. Some disposal lagoons were partially filled with gravel. In a few instances, drainage ditches appear to have been used as disposal lagoons.

Forty-eight dry wells and disposal lagoons were identified in the initial remediation investigation in the 1980s. By 1989, the majority of these dry wells and disposal lagoons were permanently removed from service. Soil and rock samples have been collected and analyzed at most dry wells and disposal lagoons; some dry wells have been excavated. Details of the dry wells and disposal lagoons are presented in the Final SWRI report (Webster-Scholten 1994).

During the recent efforts to repair or permit deficiencies identified by the Building Drain Investigation, approximately 13 dry wells were identified as still being in use. We are working to determine if there are discharges to any of these wells and how to close them. Since wastewaters discharged into these drywells might reach ground water, LLNL is working to discontinue their use, thereby assuring that any constituents that are present cannot reach the ground water.

In the past, landfills were in use at Site 300 to accept debris from high-explosive testing and other experiments. Except for Pits 1 and 7, all the landfills were closed prior to 1980 and did not require closure under RCRA. In 1988, LLNL also ceased operations of these landfill Pits 1 and 7 and began the closure process. Both were capped in 1992, and LLNL began post-closure activities under the submitted post-closure monitoring plan (Rogers/Pacific Corporation 1990). LLNL applied for and received a permit specifying Waste Discharge Requirements (WDR Order No. 93-100) and defining the monitoring and reporting requirements. Monitoring of wells surrounding Pits 1 and 7, under

## 8. Ground Water Protection Management Program



permit WDR Order No. 93-100, has resulted in LLNL reporting statistically significant evidence of release of some constituents of concern, and several monitoring parameters indicate changes in the ground water quality. Further investigations will be completed under CERCLA to determine if the results are due to releases from the pits. It is expected that the capping of the pits, completed in 1992, has eliminated infiltration from the surface, thereby diminishing the rate of potential release of any material from the pits.

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### Cooling Towers

Twenty-three cooling towers are operated at Site 300 to cool buildings and equipment. Of these, six discharge wastewater to septic tanks. In the past, 17 towers discharged wastewater to on-site surface drainage courses. During the latter part of 1994, LLNL installed engineered percolation pits for 14 of the 23 cooling towers. Construction of all the percolation pits was completed by December 1994. The RWQCB issued a waiver from Waste Discharge Requirements when it was determined that the cooling tower discharges into the percolation pits would not adversely affect the receiving water.

The Central Valley RWQCB issued the new permit expanding the pH range for the remaining cooling towers discharging to surface water drainage courses because of the low threat imposed by the cooling towers on the surface waters. The new permit was issued on May 20, 1994. (For further information on the cooling tower discharges, see Chapter 13.)

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### Registration of Disposal Systems

In January 1995, LLNL registered 52 subsurface wastewater disposal systems at Site 300, meeting EPA's definition of Class 5 injection wells under the Safe Drinking Water Act regulations. These disposal systems included: septic systems designed to serve more than 20 people or accepting industrial wastewater, such as boiler blowdown, active and inactive dry wells, the cooling tower percolation pits, and a sewage overflow percolation pond. EPA final permit regulations for Class 5 were expected in March 1995; however, EPA staff note that these final regulations will be indefinitely delayed. This registration is designed to inform EPA of the types of nonhazardous wastewater discharges injected into substrata above drinking water aquifers so that a determination can be made as to the risk of such discharges. EPA may require additional information, establish discharge limitations, or require elimination of discharges that pose a risk to the drinking water aquifers.

## 8. Ground Water Protection Management Program

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### Summary

It is LLNL's policy to operate in a manner that does not adversely affect the environment. Past material-handling activities and practices have resulted in ground water contamination. LLNL is working closely with local, state, and federal regulatory agencies, with input from the public, to develop and implement efficient, cost-effective ways to remediate the contamination. LLNL is also looking at its current and future operations to prevent possible negative impacts to ground water. Through ongoing plans, LLNL is working to remove sources of concern and to implement protection against accidental impacts.





### Introduction

Soil is weathered material, mainly composed of disintegrated rock and organic material, that is suitable for growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. DOE guidance for environmental monitoring (U.S. Department of Energy 1991) 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. The guidance specifies that radionuclides in use at the facility as well as those that occur naturally should be monitored. 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. To evaluate current conditions, LLNL samples recent sediments in storm drainage channels and the two arroyos on site. The accumulation of radioactive materials in sediment could lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source (U.S. Department of Energy 1991). Note, however, that the 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.

Since 1971, surface soil sampling in the vicinity of the 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, which is occasionally used in high-explosives tests at Site 300. The inclusion of other gamma-emitting naturally occurring nuclides ( $^{40}\text{K}$ ,  $^{232}\text{Th}$ , and  $^{235}\text{U}$ ) and the long-lived fission product  $^{137}\text{Cs}$  provides background information and baseline data on global fallout.

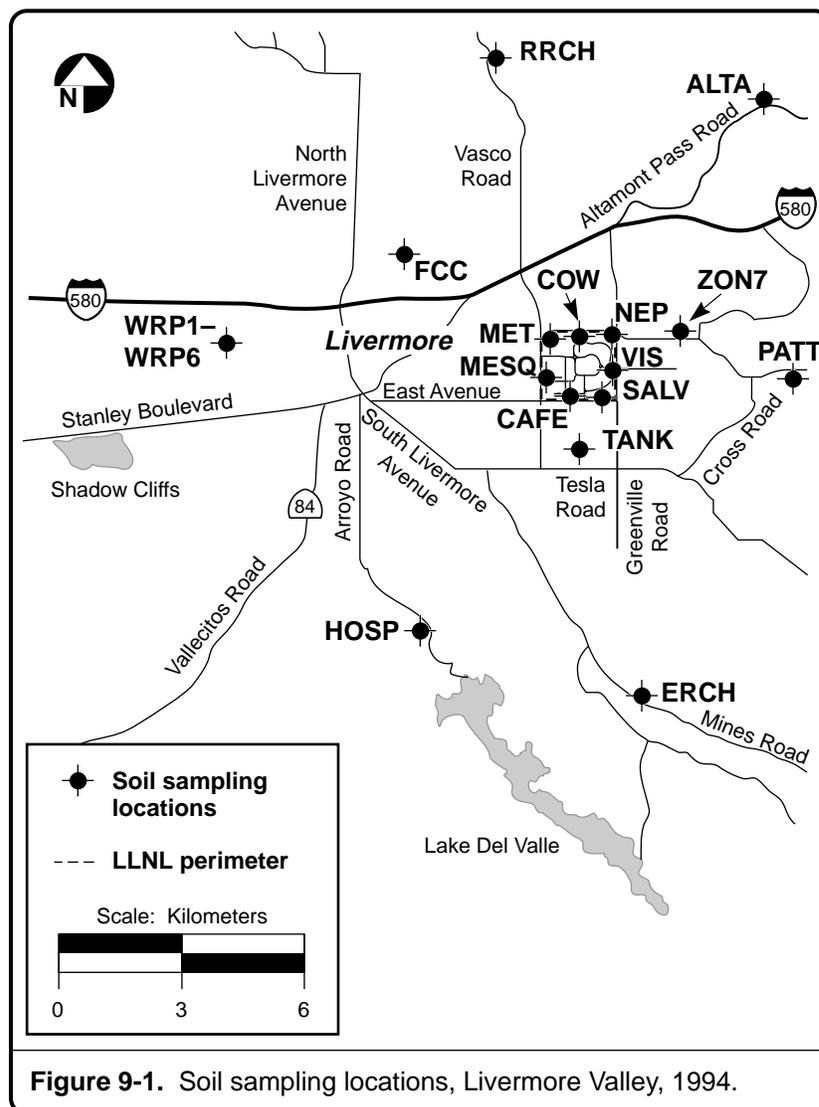
Similarly, sediment samples have been collected from selected arroyos and other drainage areas at and around the Livermore site since 1988; these locations largely coincide with selected storm water sampling locations. The number of sediment sampling locations was reduced in 1994 to correspond to reductions in storm water sampling locations. In addition, in 1991, LLNL began analyzing

## 9. Soil and Sediment Monitoring



surface soil samples for beryllium, a potentially toxic metal used at both the Livermore site and Site 300.

Location maps for soil and sediment sampling conducted during 1994 are provided in **Figures 9-1** through **9-3**. 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. In general, Site 300 soil sampling locations were established around firing tables and other areas of potential soil contamination. Arroyo and drainage channel sediment sampling locations were chosen to coincide with major Livermore-site storm water drainages. All soil and sediment sampling locations have permanent location markers for reference.



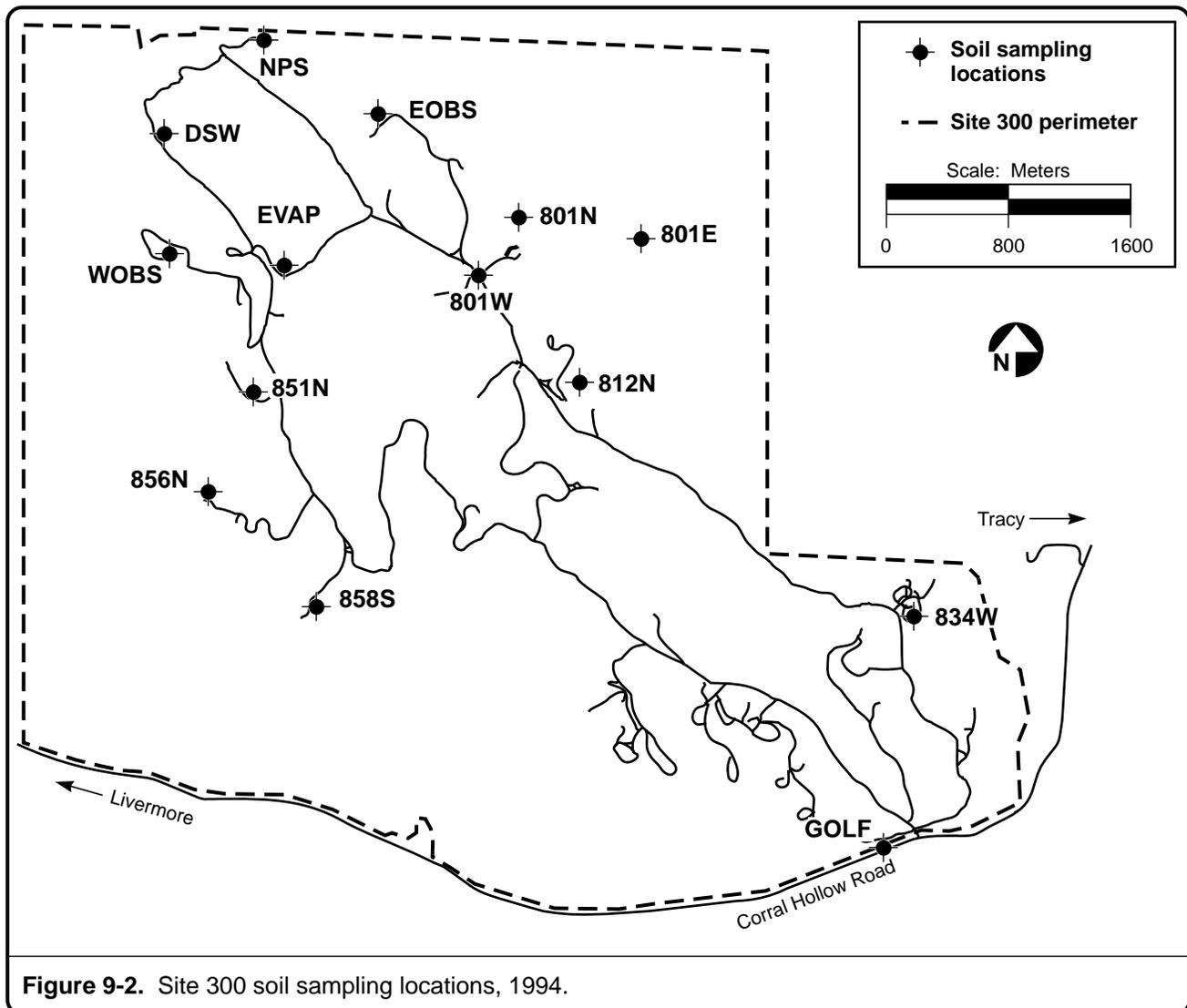
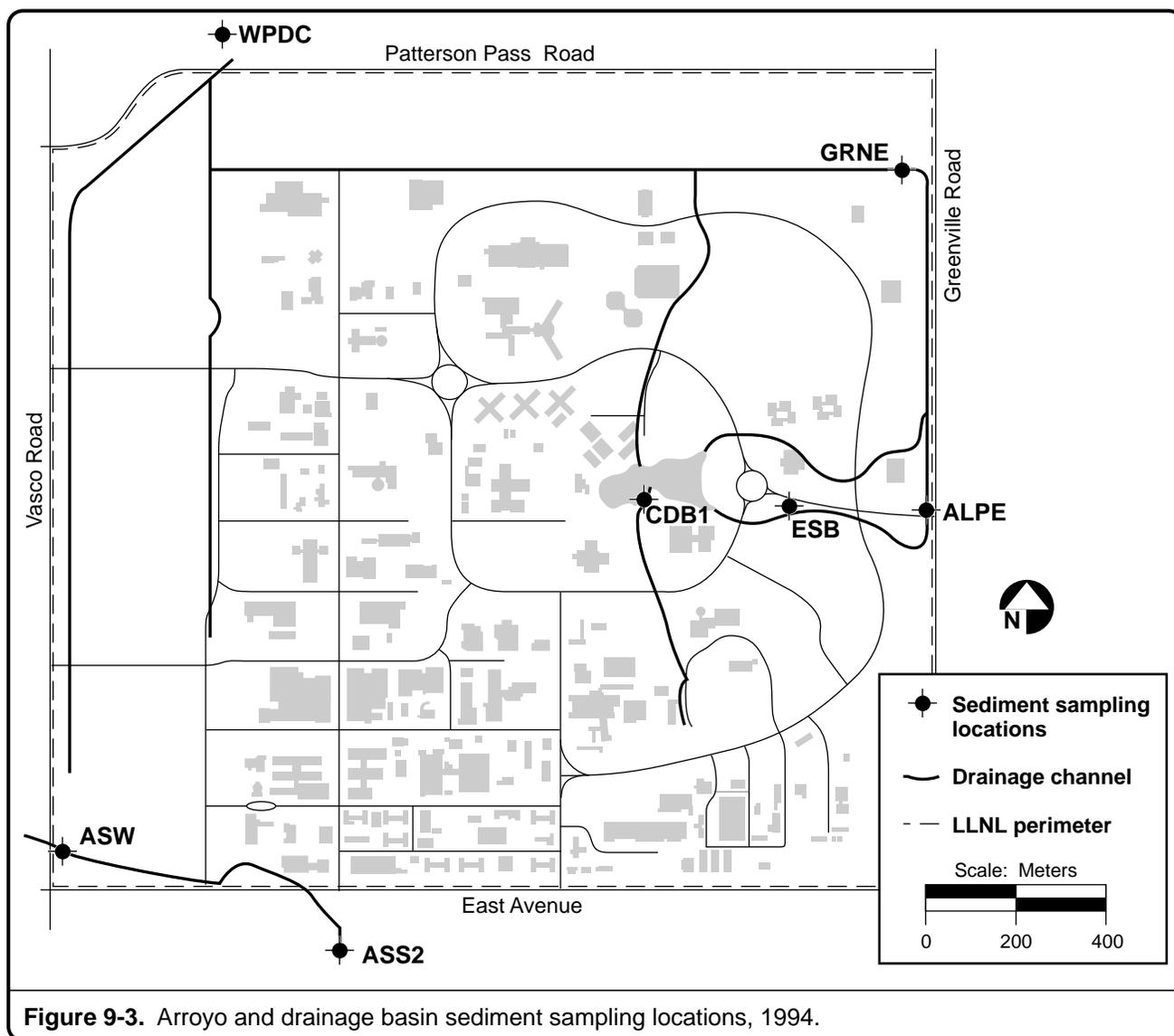


Figure 9-2. Site 300 soil sampling locations, 1994.

### Methods

Soil and sediment sampling is conducted according to written, standardized procedures (Tate et al. 1995, Appendix A). Soil samples are collected from undisturbed areas near the permanent sampling location marker. These areas generally are level, free of rocks, and are unsheltered by trees or buildings. All samples are collected from the top 5 centimeters of soil because surface deposition from the air is the primary pathway for potential contamination. Quality control samples are submitted with each batch of soil samples. At locations chosen for duplicate sampling, two identical samples are collected.

Samples of recent sediment are collected annually from drainages at and around the Livermore site after the cessation of spring runoff. For 1994, samples were



**Figure 9-3.** Arroyo and drainage basin sediment sampling locations, 1994.

analyzed for radionuclides and beryllium. Critical evaluation of the sediment monitoring program for heavy metals and organic compounds in 1994 did not yield sufficient evidence of contamination to warrant further yearly sampling (Tate et al. 1995). LLNL staff will continue to explore the need for sediment sampling for heavy metals and organic compounds as new regulations are developed or as LLNL operations change.

Soils and sediment samples are delivered on the day of collection to LLNL's Radiation Analytical Sciences (RAS) laboratory for analyses. Soil samples are dried, ground, sieved, and blended. The plutonium content of a sample aliquot is determined by alpha spectroscopy (Hall and Edwards 1994). Other sample aliquots (300 grams) are analyzed for more than 150 radionuclides by gamma



spectroscopy, using a high-purity germanium (HPGe) detector (Hall and Edwards 1994). The 10-gram subsamples for beryllium analyses are sent to a contract analytical laboratory and are analyzed by graphite-furnace atomic absorption spectroscopy. For samples collected for tritium analyses, RAS uses freeze-drying techniques to recover water from the samples, and determines the tritium content of the water by liquid-scintillation counting. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

### Livermore Valley Results

Table 9-1 presents summary data on the concentrations of  $^{239+240}\text{Pu}$ ,  $^{40}\text{K}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{232}\text{Th}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ , in surface soils from the Livermore Valley sampling locations. The complete data for 1994 soils and sediment sampling is presented in Table 9-1, Volume 2, of this report. The concentrations and distributions of all observed radionuclides in soil for 1994 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. The ratio of  $^{235}\text{U}$  to  $^{238}\text{U}$  reflects the natural ratio of 0.7%; however, there is uncertainty in the  $^{235}\text{U}/^{238}\text{U}$  ratio due to the difficulty in measuring  $^{238}\text{U}$  by gamma spectroscopy.

As in 1991,  $^{239+240}\text{Pu}$  was detected at background levels— $0.22 \times 10^{-3} \text{ Bq/g}$  ( $6.1 \times 10^{-3} \text{ pCi/g}$ )—at location ZON7. Since 1973, soil samples in this area have generally shown  $^{239+240}\text{Pu}$  values that are higher than background. The slightly higher values at 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 any other open air treatment of plutonium-containing waste. Nonetheless,  $^{239+240}\text{Pu}$  from historic operations is carried off site by resuspension of soil and other particles by wind. Similarly, elevated levels of  $^{239+240}\text{Pu}$ , resulting from an estimated  $1.2 \times 10^9 \text{ Bq}$  (32 mCi) plutonium release to the sewer in 1967 and first observed in soils near LWRP during the early 1970s, again were detected at LWRP sampling locations.

Of all the factors that could effect the measured activity of  $^{239+240}\text{Pu}$  in soils, the particle size of the  $^{239+240}\text{Pu}$  levels may be the most significant. The radioactivity of a particle is proportional to the third power of the diameter of the particle; e.g., a particle 10 times bigger than a second particle is 1,000 times as radioactive. Using the equation from Sill (1971)—Activity (Bq) =  $0.01202 \times \text{Number of particles} \times (\text{Diameter of particles})^3$ —and, for the sake of discussion, assuming one particle per gram of soil, the geometric mean of historical plutonium results from the Livermore Valley ( $1.17 \times 10^{-4} \text{ Bq/g}$ ) suggests that the average particle size is

## 9. Soil and Sediment Monitoring



**Table 9-1.** Summary of soils and sediment analytical data, 1994.

Analyte and Location	Detection Frequency	Median	IQR <sup>(a)</sup>	Maximum
<b><sup>239+240</sup>Pu (10<sup>-3</sup> Bq/dry g)</b>				
Livermore Valley soils	15/15	0.09	0.20	0.64
LWRP soils	6/6	4.4	9.6	38
Livermore site sediments <sup>(b)</sup>	6/6	0.10	1.3	2.1
Site 300 soils	14/14	0.11	0.08	0.25
<b><sup>137</sup>Cs (10<sup>-3</sup> Bq/dry g)</b>				
Livermore Valley soils	14/15	3.1	1.6	10
LWRP soils	6/6	3.6	3.8	5.9
Livermore site sediments <sup>(b)</sup>	5/6	0.93	0.7	1.5
Site 300 soils	14/14	4.5	3.1	9.3
<b><sup>40</sup>K (Bq/dry g)</b>				
Livermore Valley soils	15/15	0.459	0.11	0.599
LWRP soils	6/6	0.427	0.037	0.455
Livermore site sediments <sup>(b)</sup>	6/6	0.481	0.053	0.492
Site 300 soils	14/14	0.498	0.12	0.662
<b><sup>232</sup>Th (μg/dry g)<sup>(c)</sup></b>				
Livermore Valley soils	15/15	6.5	1.4	8.4
LWRP soils	6/6	6.8	0.6	7.7
Livermore site sediments <sup>(b)</sup>	6/6	5.9	1.3	8.4
Site 300 soils	14/14	9.6	1.3	44
<b><sup>235</sup>U (μg/dry g)<sup>(d)</sup></b>				
Livermore Valley soils	12/15	0.025	0.009	0.032
LWRP soils	6/6	0.027	0.012	0.036
Livermore site sediments <sup>(b)</sup>	4/6	<0.019	— <sup>(e)</sup>	0.028
Site 300 soils	12/14	0.029	0.014	1.8
<b><sup>238</sup>U (μg/dry g)<sup>(f)</sup></b>				
Livermore Valley soils	6/15	2.2	— <sup>(e)</sup>	3.8
LWRP soils	5/6	2.7	1.0	3.5
Livermore site sediments <sup>(b)</sup>	2/6	<2.0	— <sup>(e)</sup>	3.4
Site 300 soils	9/14	3.4	6.4	870

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**Table 9-1.** Summary of soils and sediment analytical data, 1994 (concluded).

Analyte and Location	Detection Frequency	Median	IQR <sup>(a)</sup>	Maximum
<b><sup>3</sup>H (Bq/L extracted water)<sup>(g)</sup></b> Livermore site sediments	5/6	3.1	9.4	20
<b><sup>60</sup>Co (10<sup>-3</sup> Bq/dry g)<sup>(h)</sup></b> LWRP soils	2/6	<0.1	— <sup>(e)</sup>	0.5
<b>Be (mg/kg)<sup>(i)</sup></b> Livermore Valley soils	15/15	0.50	0.28	1.2
LWRP soils	6/6	0.64	0.25	0.80
Site 300 soils	14/14	1.5	0.65	42

<sup>a</sup> IQR = interquartile range.

<sup>b</sup> Location WPDC could not be sampled because water was flowing through the drainage channel.

<sup>c</sup> 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.

<sup>d</sup> 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.

<sup>e</sup> IQR could not be calculated.

<sup>f</sup> 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.

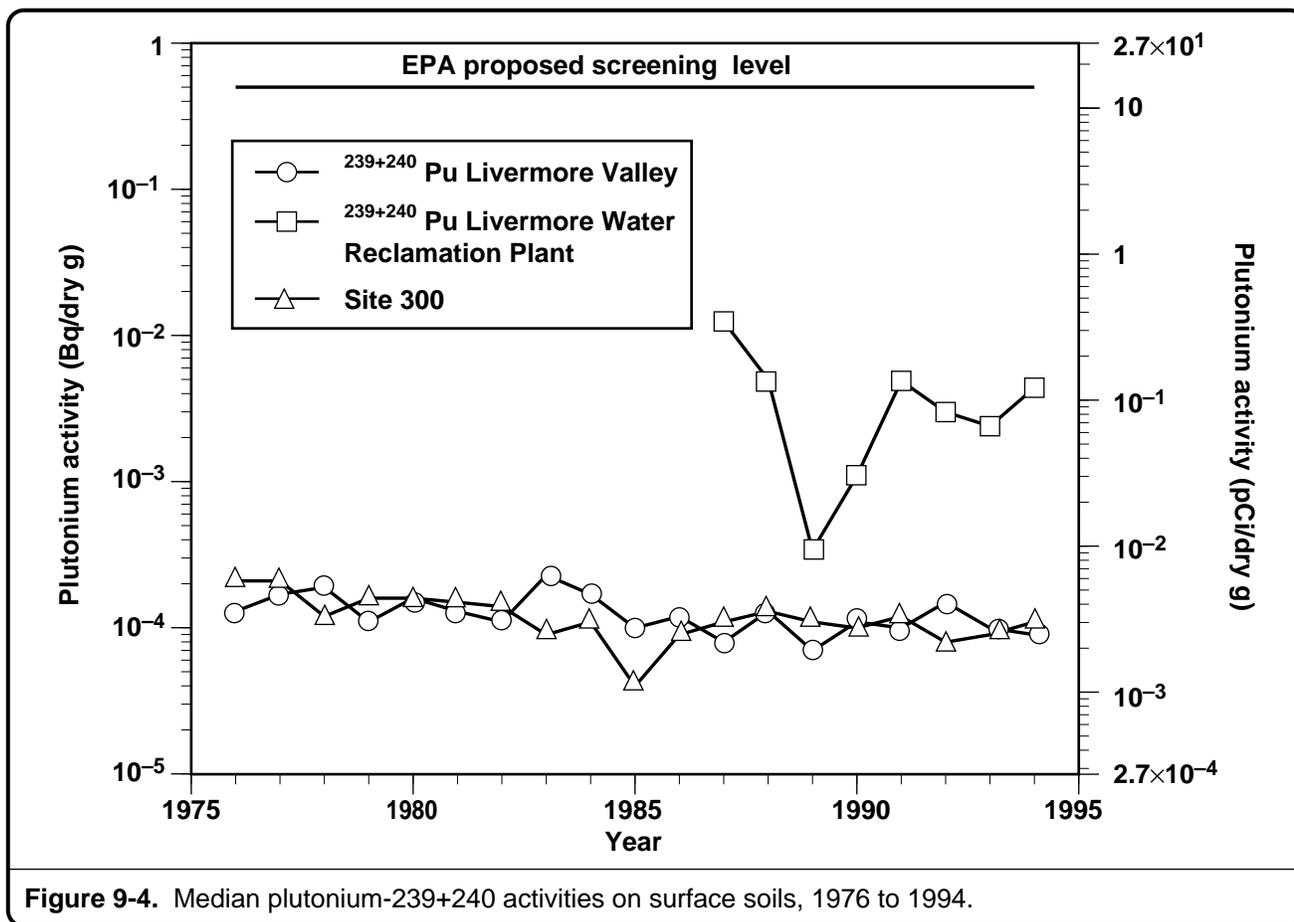
<sup>g</sup> Tritium (<sup>3</sup>H) analysis is only conducted on sediment samples.

<sup>h</sup> Cobalt-60 is only detected in LWRP soil samples.

<sup>i</sup> Beryllium analysis is only conducted on soils samples; the analysis is a chemical, not a radiochemical analysis.

0.21 micron. A particle twice as large as the average particle (0.41 micron) would result in a measured activity of  $9.4 \times 10^{-4}$  Bq/g, eight times the average; in contrast, it would take eight 0.21-micron particles to result in the same measured activity. Consequently, the presence of a larger than average particle will cause a disproportionately large analytical result.

Historical plots of average <sup>239+240</sup>Pu concentrations in soil in the Livermore Valley, at Site 300, and at LWRP are shown in **Figure 9-4**. Livermore Valley and Site 300 concentrations have remained relatively constant over the past ten years and generally are indicative of worldwide fallout (locations VIS and ZON7 at the Livermore site show activities greater than background). Greater variability in <sup>239+240</sup>Pu is seen at LWRP. Six samples are being evaluated to determine the median at LWRP. The <sup>239+240</sup>Pu is likely to be present in discrete particles, so the presence or absence of the particles will dominate the measured <sup>239+240</sup>Pu in any given sample.



**Figure 9-4.** Median plutonium-239+240 activities on surface soils, 1976 to 1994.

As in 1991 to 1993, low levels of  $^{60}\text{Co}$  were detected at the LWRP. While there is  $^{60}\text{Co}$  in use at the Livermore site, it is only present in gram quantities in three facilities (Buildings 151, 194, and 514) or in sealed sources. Low levels of  $^{60}\text{Co}$ , on the order of  $0.0037 \text{ Bq/g}$  ( $0.1 \text{ pCi/g}$ ), have also been detected intermittently in sewage sludge samples. If the Livermore site were the source of  $^{60}\text{Co}$ , this activity of  $^{60}\text{Co}$  in the sludge would translate into about  $1.5 \times 10^{-6} \text{ Bq/mL}$  ( $40 \times 10^{-6} \text{ pCi/mL}$ ) in the effluent leaving the site, which is below the detection limits of current analytical methods. This level is also well below the DOE effluent limit of  $0.925 \text{ Bq/mL}$  ( $25 \text{ pCi/mL}$ ). The reader should note that LLNL is not the only contributor to the waste stream that arrives at the LWRP and that  $^{60}\text{Co}$  is used in a variety of medical, technical, and research applications. It is not possible to determine if LLNL is the source of  $^{60}\text{Co}$  at LWRP. However, it can be concluded that LLNL controls on the release of  $^{60}\text{Co}$  are sufficient to ensure that LLNL activities do not adversely affect LWRP operations.

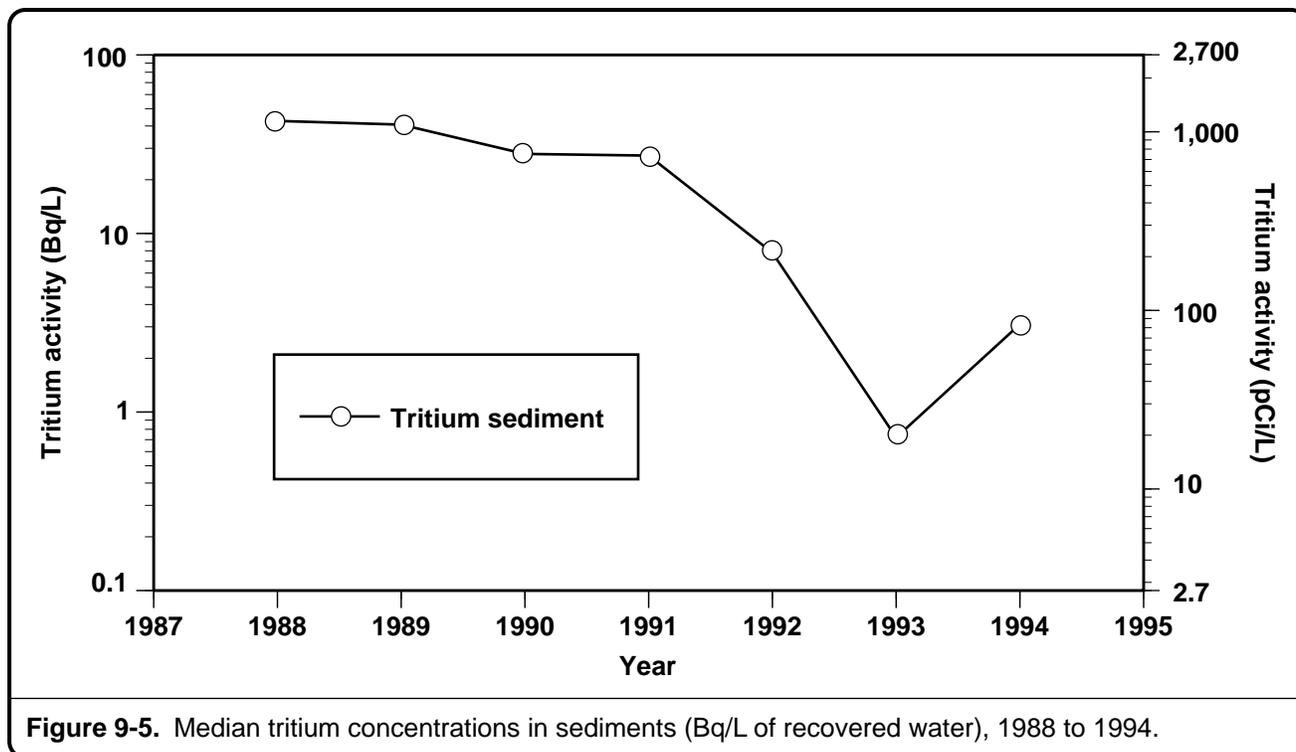
**Table 9-1** shows data on the concentrations of beryllium in surface soils from Livermore Valley sampling locations. Beryllium levels in soil samples from the Livermore Valley were comparable to the normal range of background

## 9. Soil and Sediment Monitoring



concentrations (Wilber 1980). Beryllium analysis for Livermore Valley soils will be discontinued in 1995. The few LLNL operations that use beryllium are HEPA filtered. In addition, sampling data to date have shown no evidence of beryllium contamination in the Livermore Valley (Tate et al. 1995). Should beryllium usage change, LLNL's environmental monitoring staff would reevaluate the need for beryllium monitoring in soils.

**Table 9-1** presents summary data on radionuclides detected in the sediment samples; a complete presentation of 1994 sediment data is found in Table 9-1, Volume 2, of this report. The levels of  $^{239+240}\text{Pu}$  were generally at background concentrations, reflective of worldwide fallout. The higher values at CDB1 and ESB 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 1991:  $^{137}\text{Cs}$ , a fission product, was found at worldwide background concentrations; and  $^{40}\text{K}$ ,  $^{232}\text{Th}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ —naturally occurring radionuclides—were detected at background concentrations. Tritium concentrations were below those reported from 1988 through 1992, but above those for 1993. Median tritium values are shown in **Figure 9-5** and show a general decline since measurement began. In 1993, the sediment sampling procedure was changed so that samples were collected 5 cm deep, rather than 15 cm deep; both 1993 and 1994 samples were



**Figure 9-5.** Median tritium concentrations in sediments (Bq/L of recovered water), 1988 to 1994.



collected at the shallower depth. The effect of the change in sampling depth, if any, on measured activities is not clear; nonetheless, it appears from the **Figure 9-5** that tritium values for 1993 were unusually low compared to all other years. Tritium in sediments will continue to be evaluated.

### Site 300 Results

**Table 9-1** presents summary data on the concentrations of  $^{239+240}\text{Pu}$ ,  $^{40}\text{K}$ ,  $^{137}\text{Cs}$ ,  $^{232}\text{Th}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$  in soil from the Site 300 sampling locations; a complete presentation of 1994 soils data for Site 300 is found in Table 9-1, Volume 2, of this report. The concentrations and distributions of all observed radionuclides in Site 300 soil for 1994 lie within the ranges reported in all years since monitoring began, and, with one exception discussed below, reflect naturally occurring concentrations. The ratio of  $^{235}\text{U}$  to  $^{238}\text{U}$  reflects the natural ratio of 0.7%.

Historical trends of  $^{238}\text{U}$  concentrations from both the Livermore Valley and Site 300 are shown in **Figure 9-6**. Median values have remained relatively constant for both places. The highest values at Site 300 are caused by the use of depleted uranium in high-explosive tests.

One sample from a region near a firing table (812N) had substantially higher than background concentrations of  $^{238}\text{U}$  and beryllium. To investigate the elevated  $^{238}\text{U}$  and beryllium result at 812N, LLNL personnel resampled the original sampling location as well as four additional locations about 5 meters north, south, east, and west of the original 1994 sampling location. The results of this investigation are shown in **Table 9-2**. The highest value of 870  $\mu\text{g/g}$  of  $^{238}\text{U}$  is the same order of magnitude as a high  $^{238}\text{U}$  value found at that location in 1988 (570  $\mu\text{g/g}$ ) (**Figure 9-6**). The  $^{235}\text{U}/^{238}\text{U}$  ratios, at 0.2%, confirm the presence of depleted uranium; the ratio in naturally occurring material is 0.7%. Beryllium analyses have only been conducted since 1991, so there is less historic data for comparison of beryllium results. The 1994 results for beryllium at 812N are well above the previous highest beryllium result in 1992, which was 2.5 mg/kg at location 801N. The samples for the 812 area also showed elevated levels of  $^{232}\text{Th}$ ; these 1994 results are similar to, but higher than,  $^{232}\text{Th}$  results for environmental samples in the 812 area for 1987 (20  $\mu\text{g/g}$ ) and 1988 (18  $\mu\text{g/g}$ ). As with beryllium, there is limited historic data for  $^{232}\text{Th}$  at Site 300; the  $^{232}\text{Th}$  results have only been reported since 1987. The results for beryllium and  $^{238}\text{U}$  in the Building 812 area are confirmed in previous reports published as part of the Site 300 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) restoration project (Lamarre et al. 1989c; Webster-Scholten 1994). Further investigation of this area is planned during CERCLA restoration.

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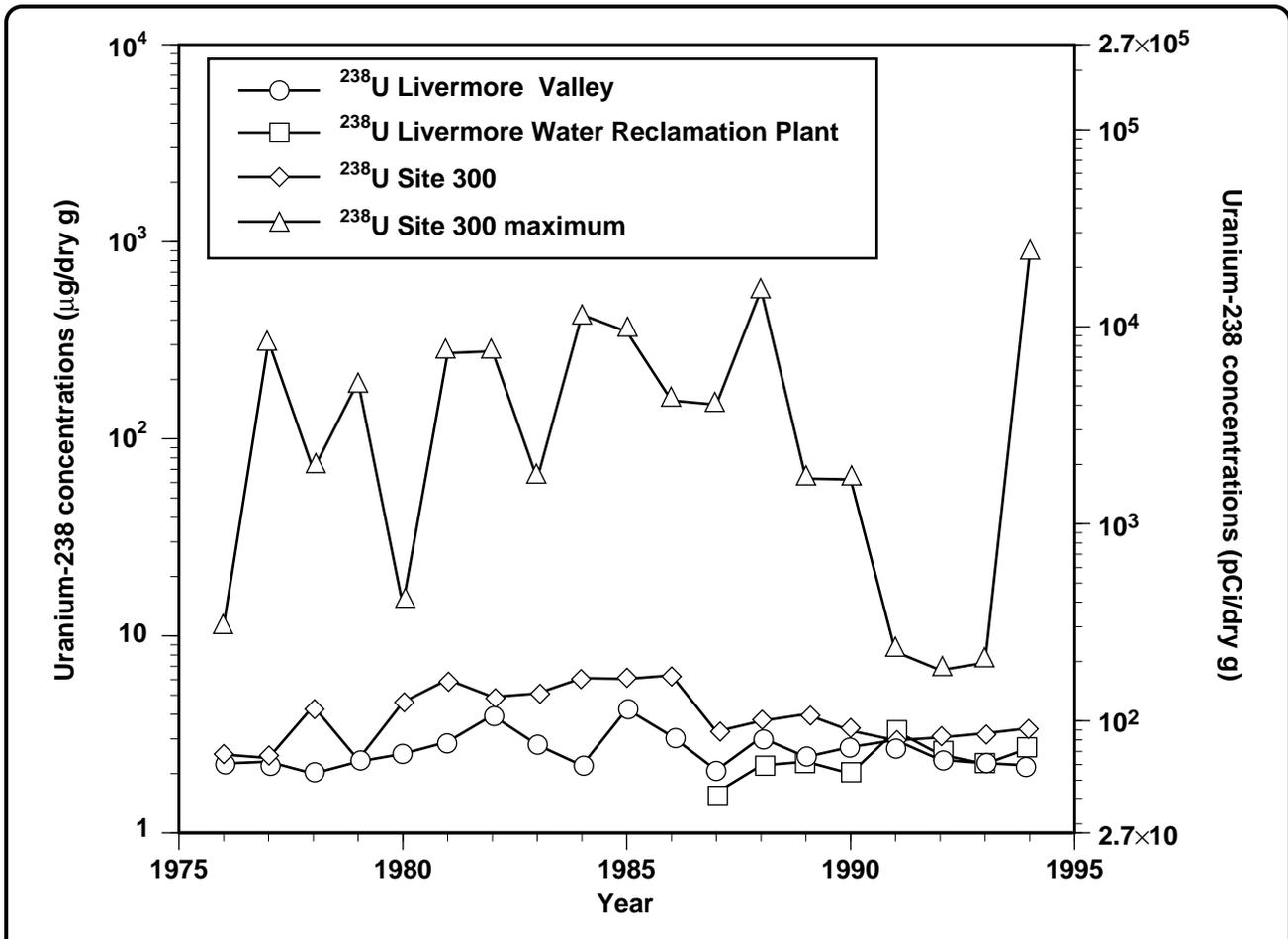


Figure 9-6. Median uranium-238 concentrations in surface soils, 1976 to 1994.

Table 9-2. Sample results for location 812N for 1994.

	Beryllium (mg/kg)	<sup>238</sup> U (µg/dry g)	<sup>235</sup> U (µg/dry g)	Ratio <sup>235</sup> U/ <sup>238</sup> U	<sup>232</sup> Th (µg/dry g)
<b>Original sample</b>	42	870	1.8	0.002	44
Rerun of original	240	780	1.8	0.002	—(a)
<b>Resample</b>					
Original location	23	260	0.56	0.002	26
East of original	9.3	400	0.89	0.002	35
North of original	11	420	0.89	0.002	41
South of original	38	470	1.0	0.002	33
West of original	14	420	0.9	0.002	32

<sup>a</sup> Sample not analyzed for <sup>232</sup>Th.

## 9. Soil and Sediment Monitoring



### Environmental Impact

This section discusses the environmental impacts at the Livermore site and Site 300.

### Livermore Site

Routine soil and sediment sample analyses indicate that the impact of LLNL operations on these media in 1994 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations, in trace amounts, or could not be measured above detection limits.

The highest value of  $38 \times 10^{-3}$  Bq/g (1.0 pCi/g) for  $^{239+240}\text{Pu}$  measured at LWRP during 1994 represents 7.6% of the proposed EPA surface soil screening level of 7,400 Bq/m<sup>2</sup> (0.2  $\mu\text{Ci}/\text{m}^2$ ), or 0.5 Bq/g (13 pCi/g), assuming average Livermore Valley soil densities of 1.5 g/cm<sup>3</sup> and a potential resuspension depth of 1.0 cm. (Areas that do not exceed the screening level are generally said to be in compliance and need no further investigation for possible remediation.) The proposed EPA screening level for surface soil contamination was derived from conservative assumptions and mathematical models that considered both the inhalation and ingestion pathways (42 Federal Register 230 1977; U.S. Environmental Protection Agency 1977, 1978). Statistical analysis shows that all LWRP  $^{239+240}\text{Pu}$  soils data are lognormally distributed, and there is no general increase or decrease in  $^{239+240}\text{Pu}$  values with time. Moreover, all measured concentrations, regardless of location and year, have been a small fraction of the proposed EPA screening level, which is shown in **Figure 9-4** for comparison.

In addition, evaluation of the soils and sediment monitoring program (Tate et al. 1995) has shown that LLNL nonradiological impacts on sediment and airborne releases of beryllium are not sufficient to warrant continued sampling. Sampling of soils for radiological materials will continue on an annual basis.

### Site 300

With the exception of elevated concentrations of  $^{238}\text{U}$ , Be, and possibly  $^{232}\text{Th}$ , at location 812N, the concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are representative of background or naturally occurring levels. In 1988, contaminated gravel from the firing table at Building 812 was removed to on-site landfills, and measured values for samples from this location have generally not exhibited elevated levels of  $^{238}\text{U}$  and beryllium. The elevated results for  $^{238}\text{U}$  and beryllium indicate that areas outside the firing table may be contaminated by firing table debris. The investigation planned as part of the Site 300 CERCLA restoration efforts will clarify the nature and extent of the contamination in this area.

## 9. Soil and Sediment Monitoring



### Special Studies

LLNL was involved with two special studies of soils in 1994: Plutonium in the Soil in the Southeast Quadrant of Livermore Site and Plutonium in the Soil in Big Trees Park, Livermore. The results of these studies follow.

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#### Plutonium in Soil, Southeast Quadrant of Livermore Site

From 1962 to 1976, solar evaporation trays were located in the southeast quadrant of LLNL. The trays were approximately 6 meters  $\times$  6 meters  $\times$  3 meters deep, constructed of concrete coated with polyamide epoxy paint, and lined with polyvinylchloride or polyethylene liners. Plutonium-containing liquid waste was put in these trays to reduce by evaporation the total volume of disposable waste (Buerer 1983).

In 1991, in response to a Tiger Team comment, 195 surface soil samples were collected and analyzed for plutonium in the southeast quadrant of LLNL. None of the samples were above the interim EPA guidance for Superfund remediation for commercial/industrial sites (0.51 Bq/g or 13.7 pCi/g). The highest level detected was 0.11 Bq/g (3 pCi/g). In 1993, EPA decided to resample the areas with levels above the global fallout for further conformation and to sample locations to the west of the 1991 sampling locations to assure the boundary of the area of interest had been appropriately set.

The highest plutonium values in the 1993 study were 0.32 Bq/g (8.6 pCi/g) at a depth of 0.01 meters and 0.45 Bq/g (12.2 pCi/g) at a depth of 0.05 meters. These values are higher than the highest value found in the 1991 study. Comparison of the 1993 data with the data from 1991 and a previous study from 1974, shows that plutonium activities have remained substantially the same (Gallegos et al. 1994).

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#### Plutonium in Soil, Big Trees Park, Livermore

During the 1993 EPA investigation of plutonium in soils in the southeast quadrant of the 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 EPA, LLNL, and the California Department of Health Services (DHS) in 1995. The results confirmed the finding of plutonium, with all the results below the EPA's health protective screening level for residential exposure. The EPA and DHS concur that there is no regulatory concern or significant impact on human health and the environment.



## 10. Vegetation and Foodstuff Monitoring



*Gretchen M. Gallegos  
Kris A. Surano*

### **Introduction**

Because vegetation can be a biological end point for pollutants originally released to the soil, air, or liquids, the sampling and analysis of native vegetation can provide information about the presence and movement of radionuclides in the environment. Vegetation can contribute a radiation dose to humans directly through ingestion or indirectly through human ingestion of the products from animals that have consumed it. DOE guidance states that periodic sampling and analysis of vegetation should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment (U.S. Department of Energy 1991).

Since 1972, vegetation and foodstuff sampling in the vicinity of LLNL and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity, to evaluate any increase in radioactivity that might have resulted from LLNL operations, and to calculate potential human doses resulting from direct and indirect ingestion of these products. During 1994, LLNL collected and analyzed samples of native vegetation and wine. In previous years, LLNL collected samples of goat milk and honey but discontinued this because samples became very hard to obtain and the potential doses from those products were very low. By 1993, only one local farm raised goats (and those goats were not kept to produce milk), and only two local honey samples could be acquired. Potential human doses from the remaining foodstuffs—vegetation and wine—are calculated using the monitoring data and dose models presented in Appendix B.

Tritium is the nuclide of major interest in the LLNL vegetation and foodstuff monitoring program because LLNL has historically released tritium to the air both accidentally and in the course of routine operations. Tritium is likely to move into the environment as tritiated water and can be assimilated easily into vegetation and foodstuff. It can contribute to human radiation dose burdens if it is inhaled or ingested directly or indirectly. Although other radionuclides are used at LLNL, our assessments show that only tritium could be present in vegetation in detectable concentrations.

### **Methods**

Our methods for monitoring vegetation and wine are presented in the following sections.

## 10. Vegetation and Foodstuff Monitoring



### Vegetation

LLNL collects vegetation samples, usually annual grasses, quarterly from fixed locations in the Livermore Valley, San Joaquin Valley, San Ramon Valley, and Site 300, and then analyzes them for tritium. A sampling location designated GARD was added in 1994 at the Livermore site. Location maps are provided in **Figures 10-1** and **10-2**. These locations have been selected so samples would represent vegetation from: (1) locations near LLNL that could be affected by LLNL operations, (2) background locations where vegetation was similar to that growing near LLNL but was unlikely to be affected by LLNL operations, and (3) areas of known or suspected LLNL-induced contamination.

All vegetation sampling is conducted according to written and approved standardized procedures (Tate et al. 1995). Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Garcia and Failor 1993).

### Wine

Wine is the most important agricultural product in the Livermore Valley, representing an approximately \$30-million annual industry. Data since monitoring began have indicated that although tritium concentrations in all wines are low, Livermore Valley wines contain statistically more tritium than do their California counterparts.

Three types of wine samples were collected and analyzed for tritium concentrations: wine produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California outside the Livermore Valley, and wines produced from grapes grown in Europe (France, Germany, and Italy). The latter two groups were divided into eight and thirteen wine-producing regions, respectively, and were used as comparative samples.

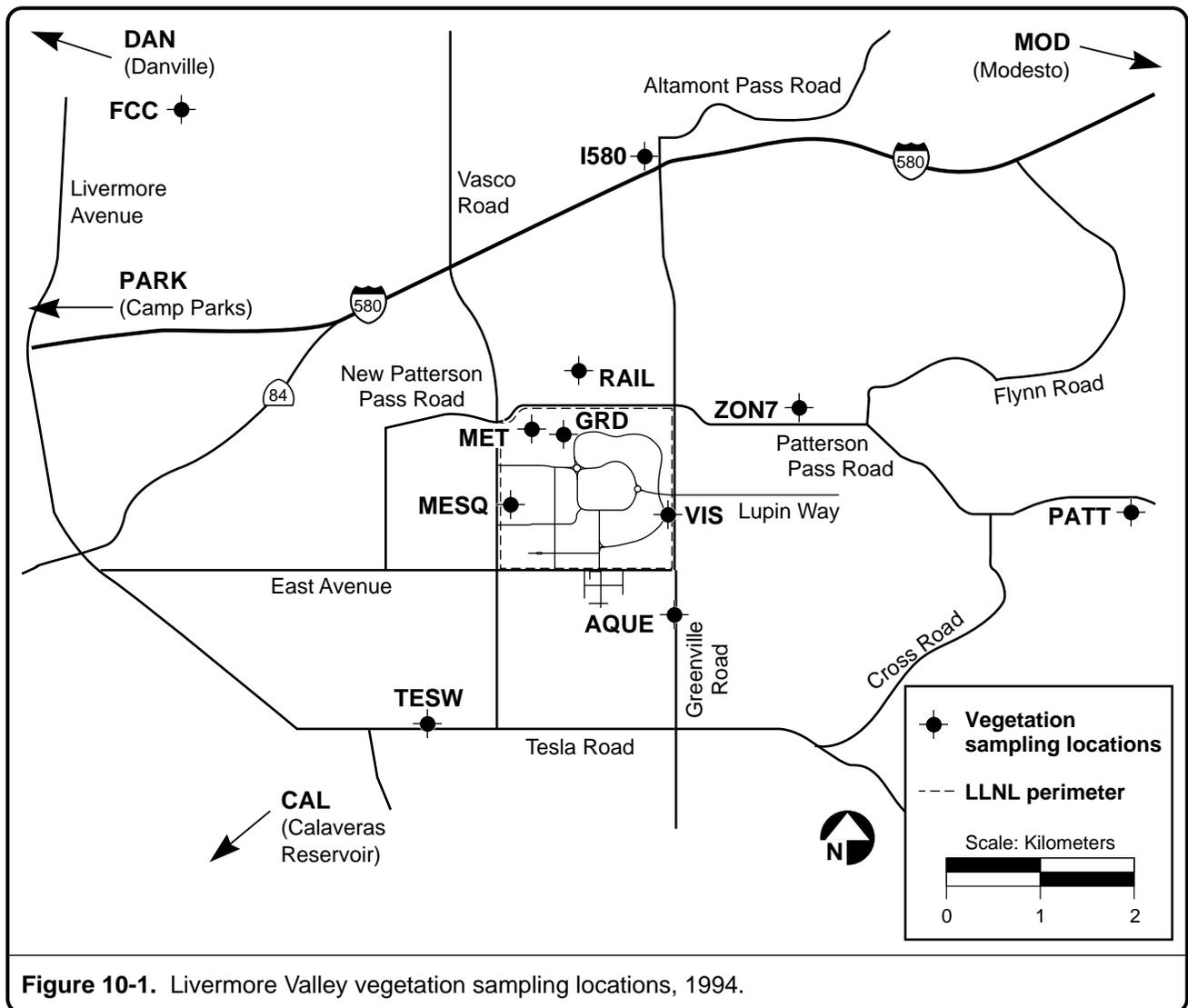
The wine samples were purchased from local retailers in a variety of vintages and reflect the body of wines locally available to the general public during 1994. The resulting analytical data can be used to estimate the potential tritium dose received by consumers during the year of purchase. The 1994 sampling data cannot, however, be used to indicate how LLNL's operations affected wines produced in 1994. Some time—in some cases, several years—will have elapsed between the harvest of the grapes and the release of the vintage. However, wine sample data can be decay-corrected to its original tritium concentrations (given the number of months that have elapsed between wine production and LLNL analysis) to determine trends and to help determine the impact of LLNL operations during a particular vintage year.

The wine samples were submitted for analysis unopened to avoid airborne tritium contamination. Wines were analyzed for tritium using  $^3\text{He}$  mass spectrometry in the LLNL Nuclear Chemistry Noble Gas Mass Spectrometry

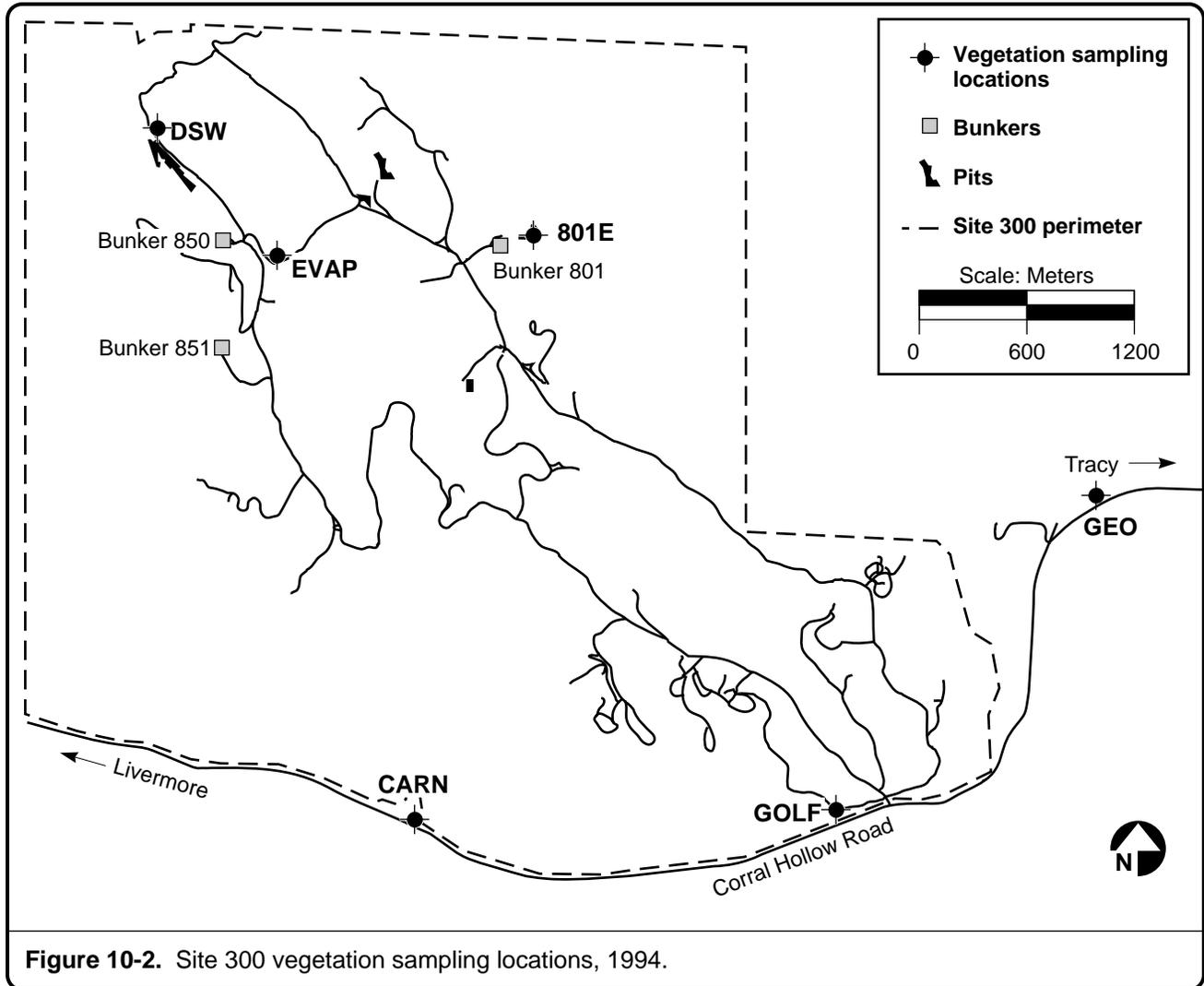
## 10. Vegetation and Foodstuff Monitoring



Laboratory (Surano et al. 1991). We used this highly sensitive method for our wine analysis so that we could determine differences in the tritium content of the samples. Had less sensitive methods been used, such as those employed by commercial analytical laboratories, the tritium content of all samples would be near or below detection limits and no differences would be apparent. Approximately 10% of the total complement of wines were sampled in duplicate to comply with quality assurance protocols.



## 10. Vegetation and Foodstuff Monitoring



### Results

The results of vegetation and foodstuff monitoring for the Livermore site and Site 300 are presented below.

### Livermore

#### Vegetation

**Table 10-1** shows summary tritium data for vegetation collected in the Livermore-site vegetation monitoring program in 1994 (the individual sampling values are presented in Volume 2 of this document). In general, the 1994 tritium levels in vegetation were unchanged from levels measured in 1993 and were lower than levels found in years prior to 1993.

## 10. Vegetation and Foodstuff Monitoring



**Table 10-1.** Tritium in vegetation (in Bq/L), 1994.<sup>(a)</sup>

Location	Detection Frequency	Median	Interquartile Range	Maximum	Dose ( $\mu\text{Sv/y}$ ) <sup>(b)</sup> Median	Dose ( $\mu\text{Sv/y}$ ) <sup>(b)</sup> Maximum
Livermore site near locations	20/22	8.5	13.0	47	0.041	0.226
Livermore site intermediate locations	12/16	4.0	5.6	19	0.019	0.092
Livermore site far locations	3/20	<1.7	— <sup>(d)</sup>	3.2	<0.008	0.015
Location DSW at Site 300 <sup>(c)</sup>	1/4	<1.9	— <sup>(d)</sup>	340	<0.009	1.636
Location EVAP at Site 300 <sup>(c,e)</sup>	2/2 <sup>(e)</sup>	30	— <sup>(d)</sup>	57	0.14	0.276
All other locations at LLNL Site 300	0/16	<1.8	— <sup>(d)</sup>	<2.1	<0.009	0.010

<sup>a</sup> See Figures 10-1 and 10-2 for sampling locations.

<sup>b</sup> Dose calculated based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk is derived from livestock fed on grasses with the same concentration of tritium. See Appendix B, Methods of Dose Calculations.

<sup>c</sup> Sampling location in known area of contamination.

<sup>d</sup> Insufficient data to calculate interquartile range.

<sup>e</sup> During the third and fourth quarters, sampling location EVAP was inaccessible due to construction. See Chapter 14, Quality Assurance.

The vegetation locations were put into three groups for statistical evaluation:

- **Near**—locations at or within one kilometer of the Livermore-site perimeter. Near locations include AQUE, RAIL, GARD, MESQ, MET, and VIS.
- **Intermediate**—locations in the Livermore Valley removed from the site (1 to 5 kilometers from the Livermore-site perimeter) but close enough and often downwind so that they are still potentially under the influence of tritium releases at the site. The intermediate locations were I580, TESW, ZON7, and PATT.
- **Background**—locations unlikely to be affected by LLNL operations. Three of the background locations (MOD, DAN, and CAL) are more than 25 kilometers away. The other two (FCC and PARK) are in the Livermore Valley but are greater than 5 kilometers from the Livermore site and are generally upwind so they are unlikely to be affected by LLNL operations.

The changes in tritium levels between 1993 and 1994 for the vegetation from each of the Near, Intermediate, and Far groups were statistically insignificant.

Because the data for tritium in vegetation were lognormally distributed, the means of the logarithms were compared, using the Tukey-Kramer honestly significant difference (HSD) test. This evaluation showed a significant difference among all three groups, that is, the Near values are significantly different from

## 10. Vegetation and Foodstuff Monitoring

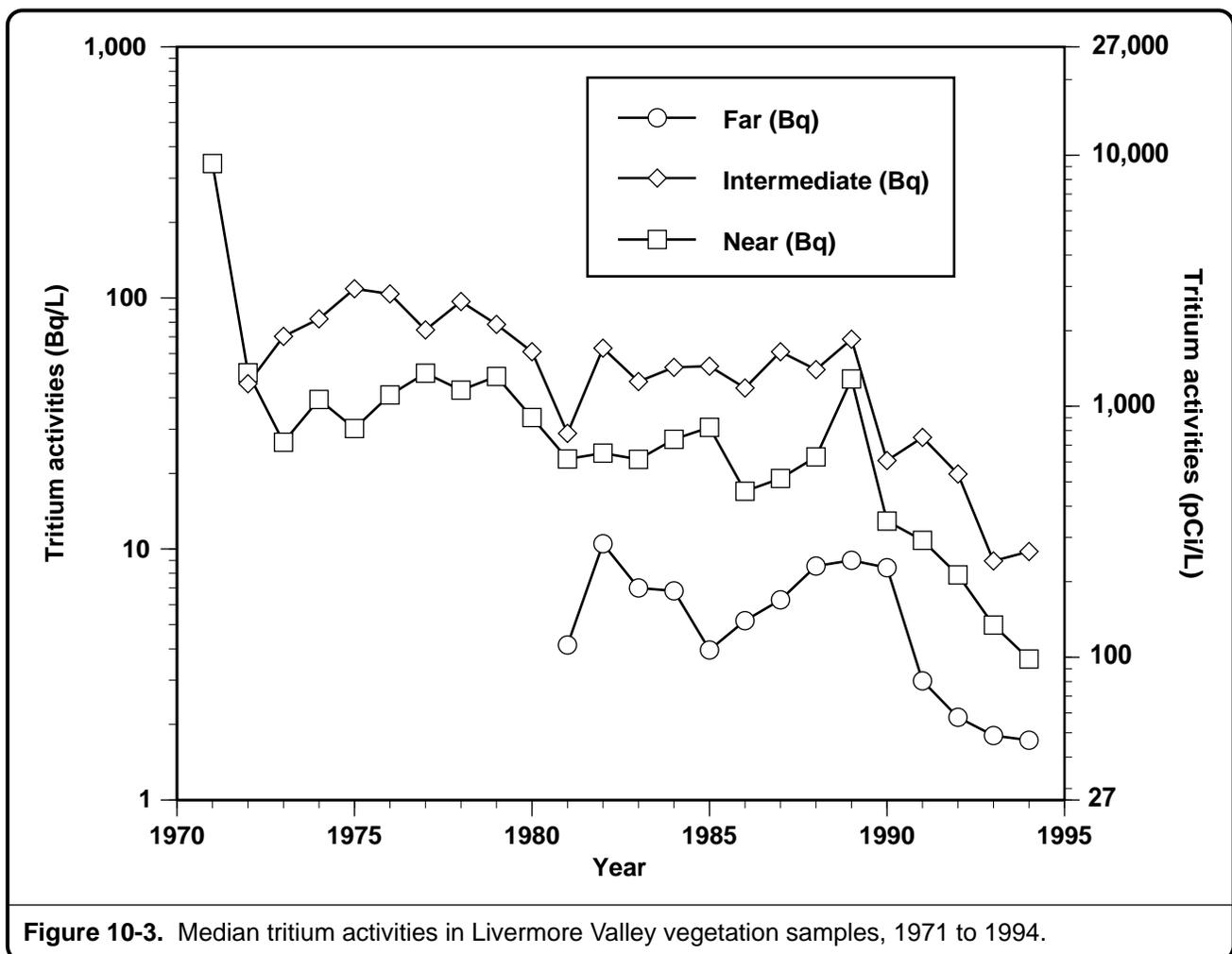


Intermediate, which in turn are significantly different from the Far values.

**Figure 10-3** shows the historic averages for the three groups. The highest tritium results for individual vegetation sampling locations were found at AQUE and VIS. These locations are downwind of Sandia National Laboratory, Livermore, and the Livermore site and historically have had higher values than other locations.

### Wine

The results from the 1994 wine tritium analyses are shown in **Table 10-2**. Tritium concentrations were within the range of those reported in previous years, and they remained low in wines from all areas.



**Figure 10-3.** Median tritium activities in Livermore Valley vegetation samples, 1971 to 1994.

## 10. Vegetation and Foodstuff Monitoring



**Table 10-2.** Tritium (Bq/L) in retail wine, 1994.<sup>(a)</sup>

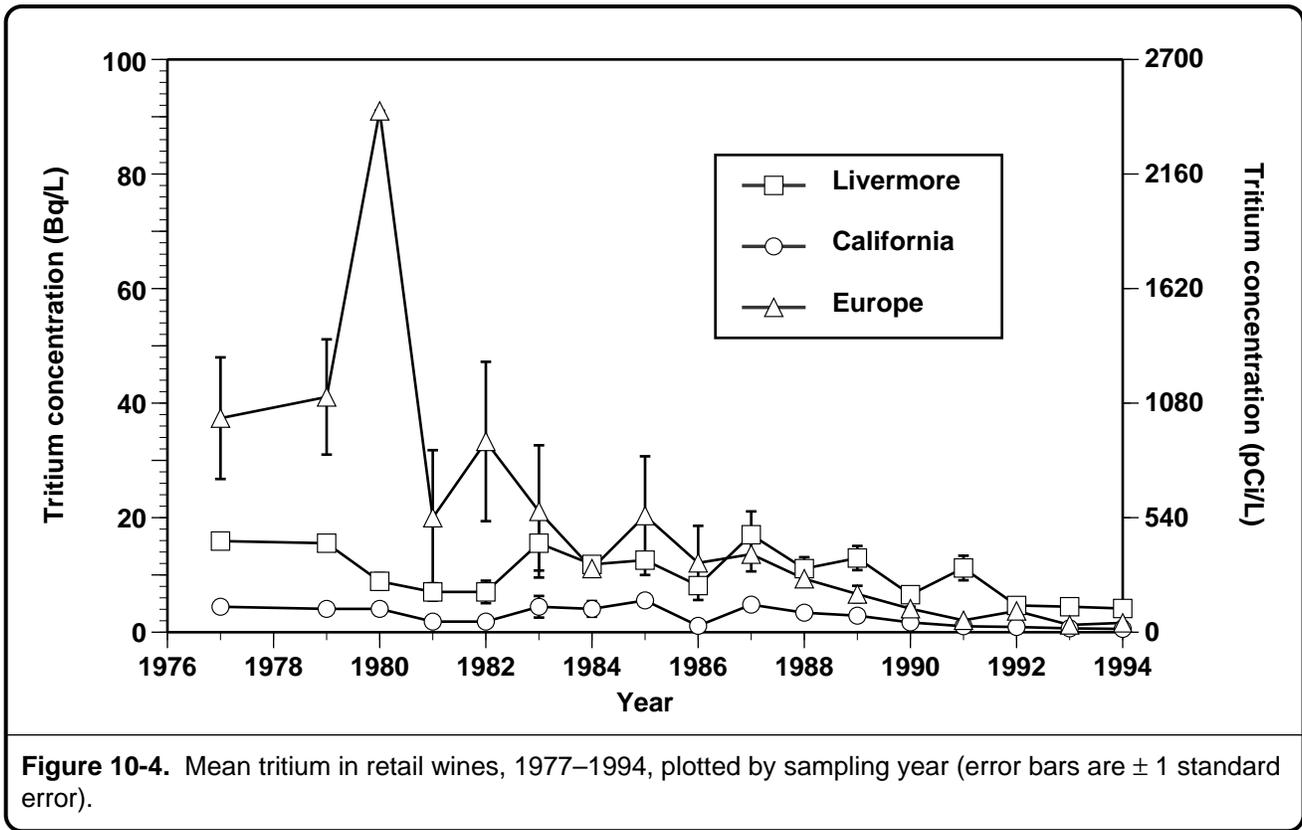
	Livermore Valley	California	Europe
Detection frequency	12/12	6/6	4/4
Median	3.60	0.55	1.60
Interquartile range	1.21	0.08	0.38
Mean	4.14	0.57	1.63
Standard deviation	1.81	0.10	0.36
Maximum	8.02	0.68	2.05

<sup>a</sup> Wines from a variety of vintages were purchased and analyzed during 1994. The concentrations shown are not decay-corrected to vintage year.

The data for the 1994 sampling year were analyzed using analysis of variance (ANOVA). The statistical analyses showed that the mean tritium concentration of the Livermore wines sampled was statistically greater than that of both the California (other than Livermore) wines and European wines sampled. The statistical analyses also indicated that there was no significant difference between the means of European and California wines sampled. Multiple comparison tests indicated that the mean levels of the 1994 sampling year data from all areas were not statistically different from those reported for the 1992 and 1993 sampling years. **Figure 10-4**, which shows the results of the wine analyses by sampling year since monitoring began, also shows that 1994 tritium concentrations are among the lowest for all Livermore wines since monitoring began.

Regression analyses and ANOVA of the wine data (when decay-corrected) grouped by vintage year showed tritium concentrations have statistically decreased for all areas since monitoring began, and since 1980. However, the drop in concentrations leveled off for European wines in 1987–1988, in 1990 for Livermore wines, and in 1991 for California wines.

Livermore wines, examined by vintage year, had statistically greater tritium concentrations since 1980 than both European and California wines. This is particularly apparent since 1986 (**Figure 10-5**). However, while vintage wines from Europe exhibited statistically higher tritium concentrations than vintage wines from California from 1980 to 1985, data from more recent vintage years are not statistically different. This indicates that the three distinct data sets discussed in previous annual reports no longer exist; Livermore wines, when decay-corrected and grouped by vintage year, contain higher tritium concentrations than either European or California wines similarly grouped, while European and California wines contain statistically identical concentrations.

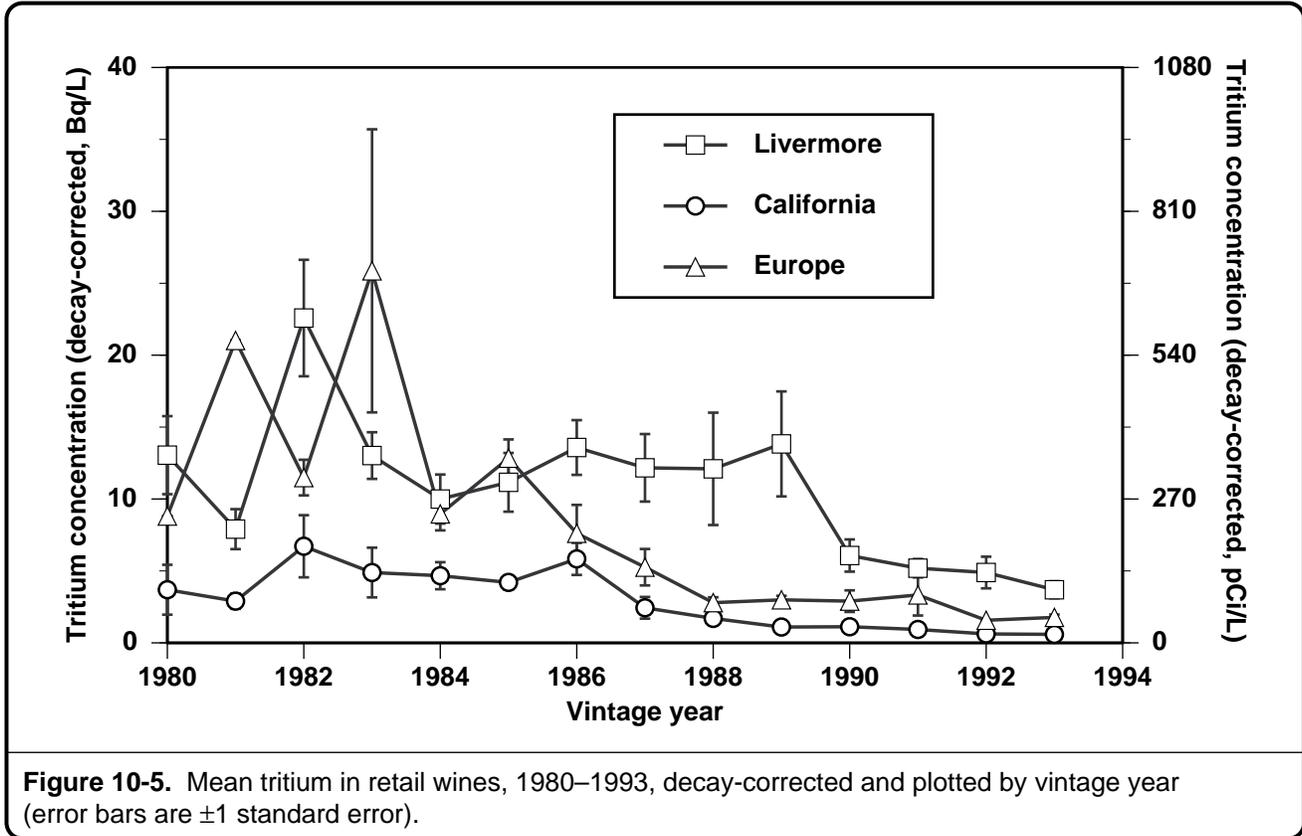


Site 300

## Vegetation

**Table 10-1** shows summary tritium data for vegetation collected at Site 300 during 1994. Historic values for tritium at Site 300 sampling locations are shown in **Figure 10-6**. Of the six sampling locations at Site 300, four yield results at or near the detection limits. Two locations, EVAP and DSW, yield results above background. Because of construction in the area, the EVAP location could only be sampled twice in 1994. The analytical results for this location were not remarkably higher than for previous years; however, the median is higher because only two samples could be obtained.

As was the case in 1992 and 1993, vegetation samples from location DSW contained the highest tritium values detected. Tritium has been observed in the vegetation of the DSW sampling location since 1971; it is in an area presently being investigated under CERCLA for tritium contamination of ground water. This sampling location is adjacent to a landfill that contains debris contaminated with tritium from past experiments. The landfill area is under continued investigation for tritium in soil and ground water, as described in reports published as part of LLNL's Environmental



Restoration Program (Lamarre 1989a, 1989b, and 1989c; Taffet et al. 1989a and 1989b; Taffet et al. 1991; Carlsen 1991a and 1991b; and Webster-Scholten 1994). In the past, purge water from samples of ground water monitoring wells was released to the ground at this location. This practice has been discontinued, and LLNL will continue to monitor vegetation in this area to determine whether the change in purge water deposition affects tritium activities in vegetation samples. The location EVAP is near a spring where ground water flows near the surface and evaporates. Some of the ground water near this location arises near the Building 850 firing table where tritium is released to soil (Surano et al. 1995). Consequently, higher than background levels of tritium are measured in vegetation in this area. Evaluation of the 1994 data using the Tukey-Kramer HSD test on the logarithms of the data yielded no significant differences among the locations; however, location DSW and EVAP are significantly different from all other locations when all historic data are evaluated.

## Environmental Impact

The environmental impacts of LLNL operations on vegetation and foodstuff monitoring are small and are presented below for the Livermore site and Site 300.

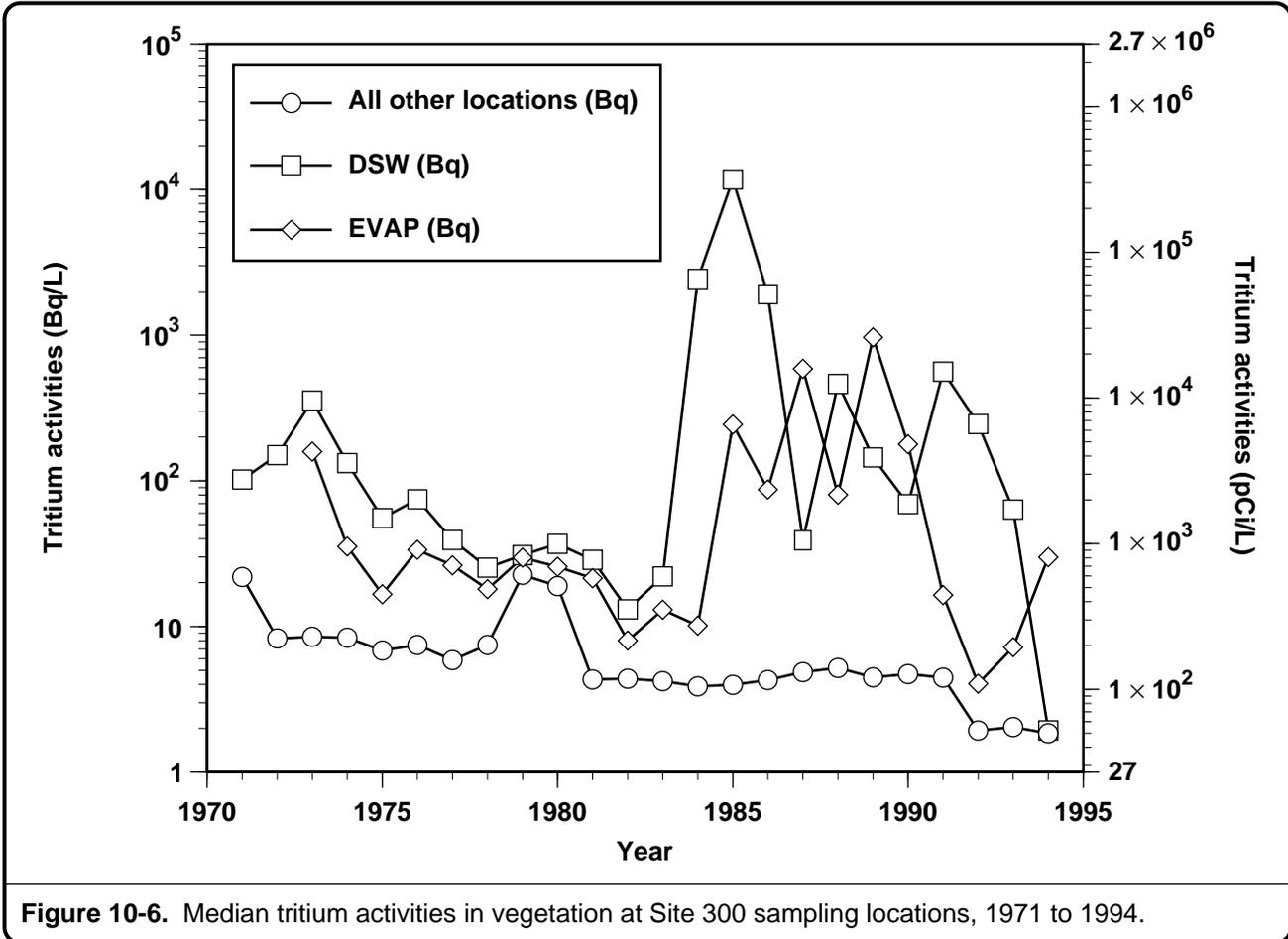


Figure 10-6. Median tritium activities in vegetation at Site 300 sampling locations, 1971 to 1994.

## Livermore Site

LLNL impacts on vegetation in the Livermore Valley remained minimal in 1994. The effective dose equivalents shown in **Table 10-1** were derived using the dose conversion factors provided by DOE (U.S. Department of Energy 1988) and the dose pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). Appendix B provides a detailed discussion of dose calculation methods. The dose from tritium in vegetation is based on the conservative assumptions that an adult's diet consists exclusively of vegetables with the measured tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration. These assumptions are conservative because most vegetables consumed directly by an adult will not contain tritium at the levels reported (the tritium levels will actually be much less), nor will the livestock actually consume vegetation with the reported levels of tritium. Based on these conservative assumptions, the maximum potential dose (from ingestion of affected vegetation) for 1994 for the Livermore site is 0.23  $\mu$ Sv (0.023 mrem).

## 10. Vegetation and Foodstuff Monitoring



There are no health standards for radionuclides in wine. However, all the wine tritium levels were far below drinking water standards. In fact, even the highest detected Livermore Valley value (8.0 Bq/L or 220 pCi/L) represents only 1.1% of the California drinking water standard (740 Bq/L or 20,000 pCi/L). Doses from wine consumption can be calculated according to methods for water ingestion, which are detailed in Appendix B.

The corresponding annual dose of the highest detected 1994 Livermore Valley tritium value in wine (8.0 Bq/L or 220 pCi/L) is 0.10  $\mu$ Sv (0.010 mrem), based on the extremely conservative assumption that wine is consumed in the same quantities as water (730 liters per year or 2 liters per day). Using a more realistic wine consumption factor (52 liters per year or 1 liter per week of wine from a single area), and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.0037  $\mu$ Sv (0.00037 mrem), from European wine would be 0.0014  $\mu$ Sv (0.00014 mrem), and from California wine would be 0.0005  $\mu$ Sv (0.00005 mrem). Compared with an annual background dose of approximately 3000  $\mu$ Sv (300 mrem), which includes radon, and a 100- $\mu$ Sv (10-mrem) dose from a typical chest x-ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Therefore, although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

### Site 300

In general, LLNL impacts on vegetation at Site 300 for 1994 were insignificant. Tritium levels found in the Site 300 vegetation were comparable to those observed in previous years. With the exception of vegetation from previously identified sites of contamination, the levels were low, near the limits of detection. The areas where tritium is known to be present in the subsurface soil are well delineated and localized.

The calculated maximum potential annual dose from vegetation at DSW, based on the maximum value of 340 Bq/L (9200 pCi/L), is 1.6  $\mu$ Sv (0.16 mrem). This dose, which was not actually received by anyone, is about two orders of magnitude less than a chest x-ray (Shleien and Terpilak 1984). This calculation uses the same conservative pathway modeling assumptions, as described above. In actuality, this dose never would be received because vegetation at Site 300 is not consumed by people or by grazing livestock. In comparison, the calculated potential annual dose from vegetation at all other locations at Site 300 had a median value of <0.009  $\mu$ Sv (<0.0009 mrem; the value is a "less than" value because all measured tritium levels were less than the detection limit). Tritium levels in vegetation at Site 300 will continue to be monitored.



# 11. Environmental Radiation Monitoring



*Barbara C. Fields  
Kris A. Surano*

## Introduction

Many types of radioisotopes are used at LLNL, including transuranics, biomedical tracers, tritium, and mixed fission products for general research and nuclear weapons research. In accordance with federal regulations, DOE Orders 5400.1 and 5400.5, and Title 17, California Code of Regulations, Section 30250, LLNL monitors direct gamma radiation to establish background radiation levels in its vicinity and to determine the environmental radiological impact of its operations. Gamma radiation results from natural background sources of geologic/terrestrial or cosmic origin, or from man-made sources, such as fallout from past nuclear weapons testing and any contribution from LLNL operations.

Because environmental radiological monitoring is used as one measure of the potential direct radiation dose the public receives as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for its Livermore-site perimeter, the Livermore Valley, and the Site 300 perimeter. Both gamma and neutron radiation have been measured at the Livermore-site perimeter since 1973. A direct environmental radiation monitoring program was implemented at Site 300 in 1988. Gamma radiation is measured using thermoluminescent dosimeters (TLDs) that provide a measure of the total amount of gamma radiation at a particular location. Neutron radiation that may be generated from fusion facilities and particle accelerators is measured using modified Anderson-Braun rem meters.

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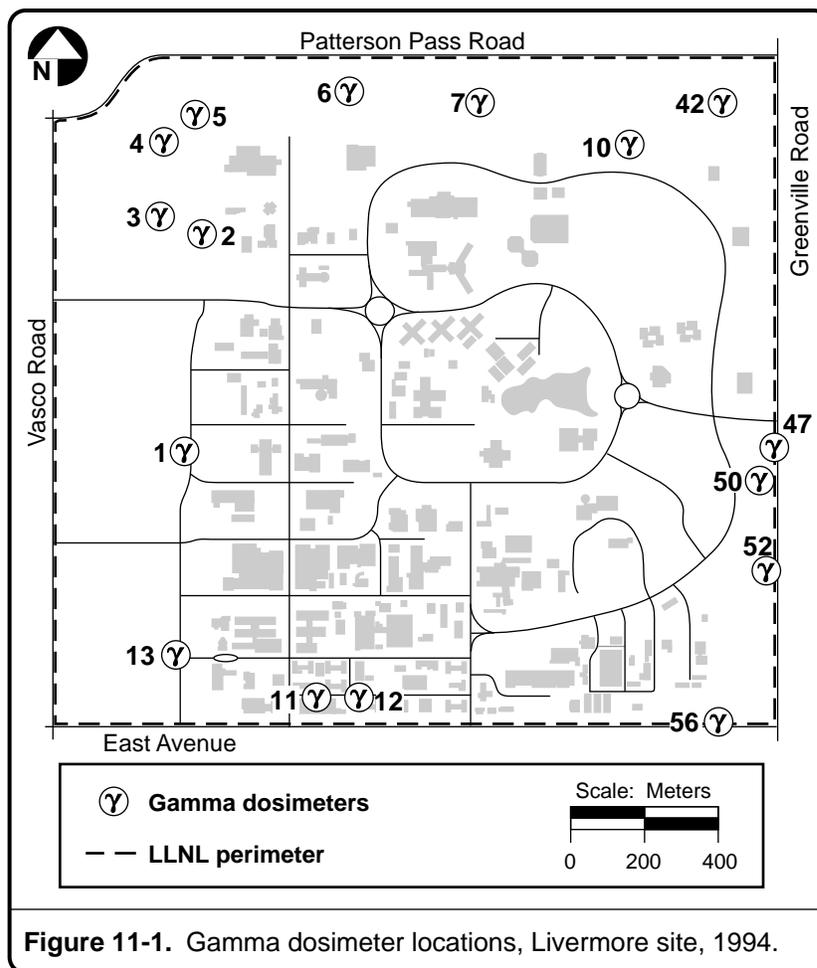
## Monitoring Locations

External doses from gamma radiation are monitored at 16 Livermore-site perimeter locations (as shown in **Figure 11-1**), and 48 Livermore Valley locations (**Figure 11-2**). These off-site locations are used for background comparison with perimeter locations. Similarly, there are 12 perimeter monitoring locations at Site 300 (**Figure 11-3**) and two locations in the nearby City of Tracy. Six additional locations, also shown in **Figure 11-3**, were added in 1993 in areas near Site 300 as a special study. Neutron monitoring locations were discontinued as of January 1, 1995, as discussed below.

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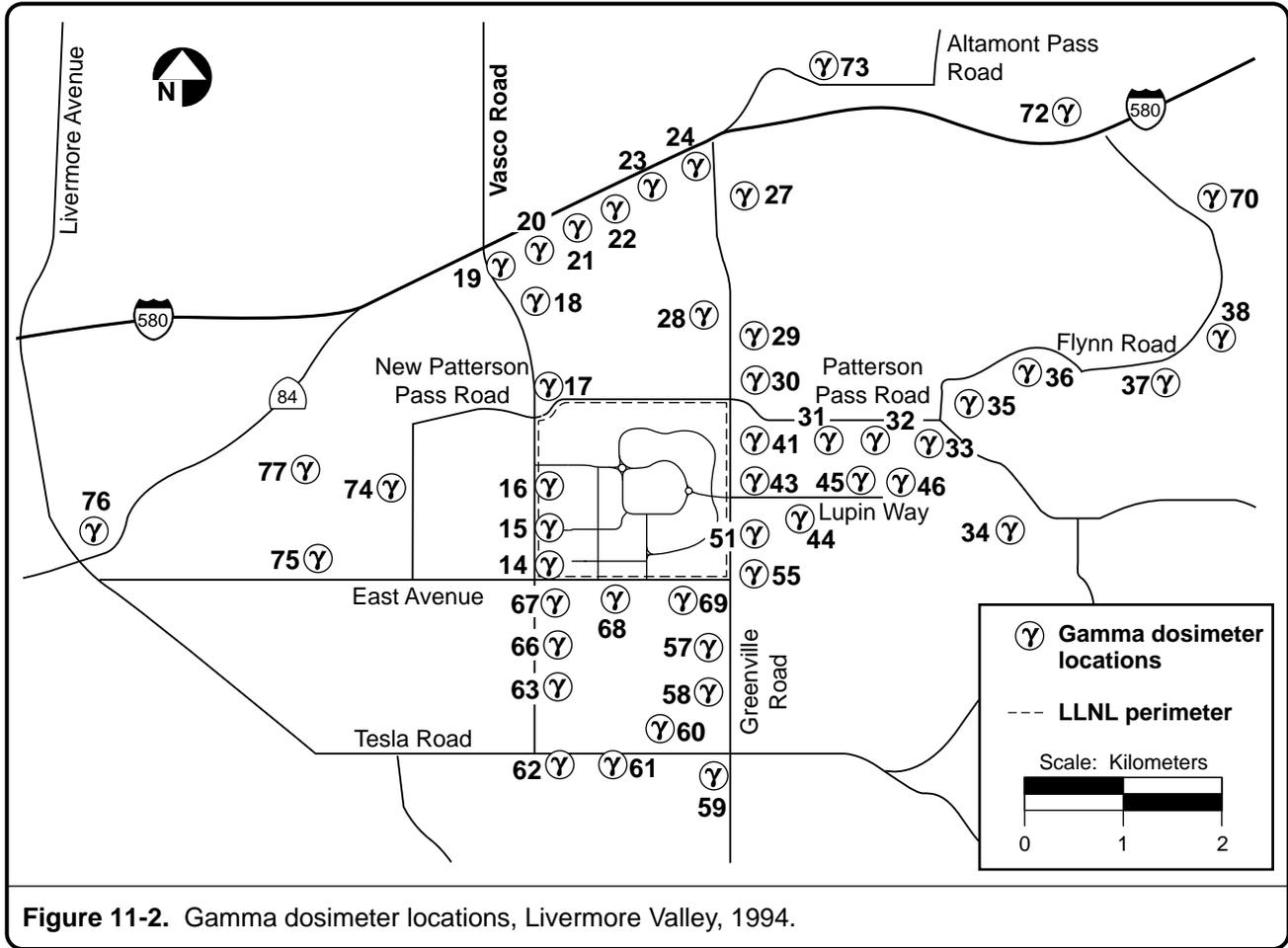
## Sitewide Network Assessment

In 1994, LLNL assessed the gamma and neutron radiation network, which led to redesign of the monitoring network. A study performed during the network assessment of trends in gamma radiation levels revealed seasonal variation at all sites from 1988–1994, as shown in **Figure 11-4**.



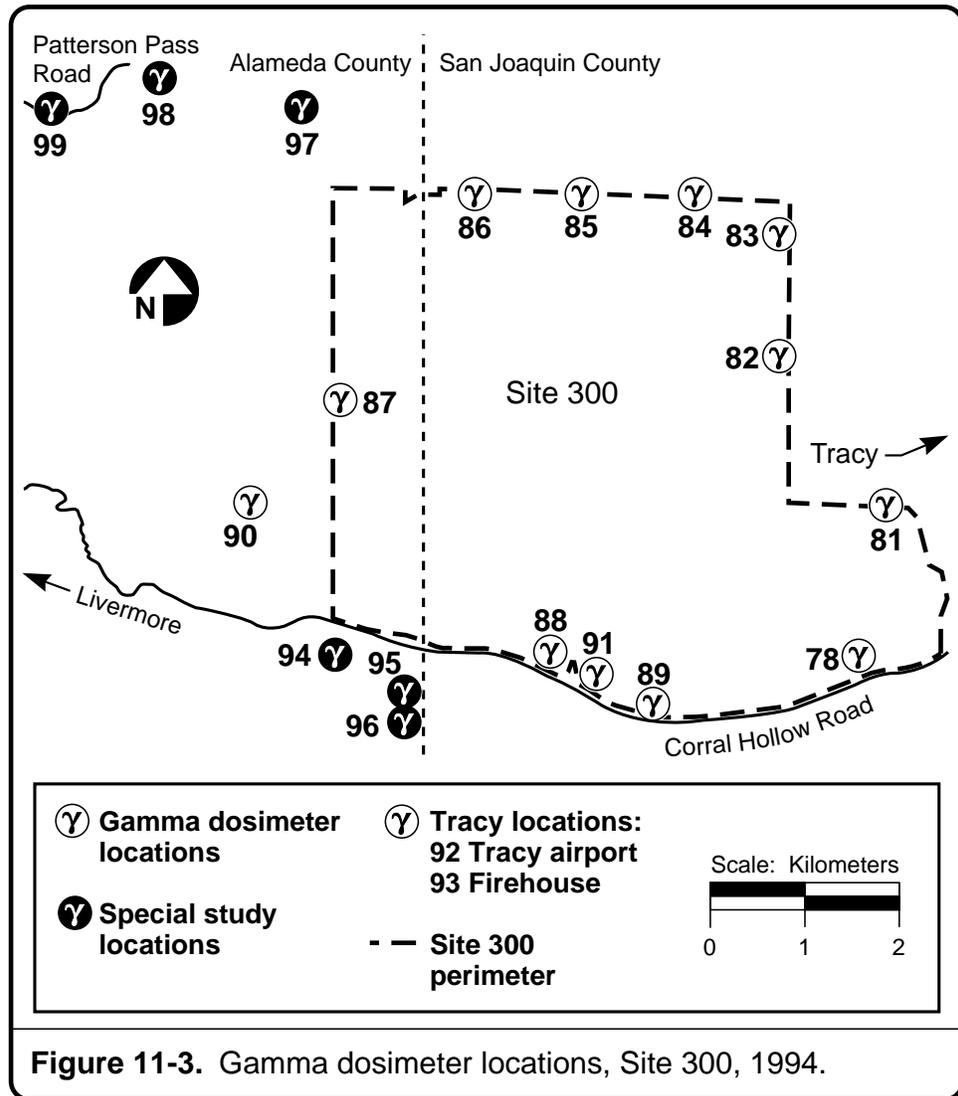
Fall quarter gamma measurements show an increase of 0.03 to 0.08 mSv (3 to 8 mrem) when compared to the other seasons. These measurements increased at all sites at the same time in the fall of the year. The cause of this phenomenon is not yet known. Several researchers suggest that radon flux from the soil is elevated because of the lack of moisture following dry California summers when evaporation is high. During other seasons, water retards the emission of radon from the soil and serves as a shield for radon when the soil is moist. Variation in atmospheric mixing height may also contribute to seasonality in radiation measurements, resulting in high radon-in-air concentrations during periods of reduced mixing, particularly in the fall, preceding the rainy season. Variations in barometric pressure, inversion layers, and wind speeds from 1988–1993 and the daily average inversion height in the Livermore Valley all support a meteorological explanation for the observed seasonal variation (Fields et al. 1994). An investigation on seasonal variation will be conducted, and the results will be published in a subsequent report.

# 11. Environmental Radiation Monitoring



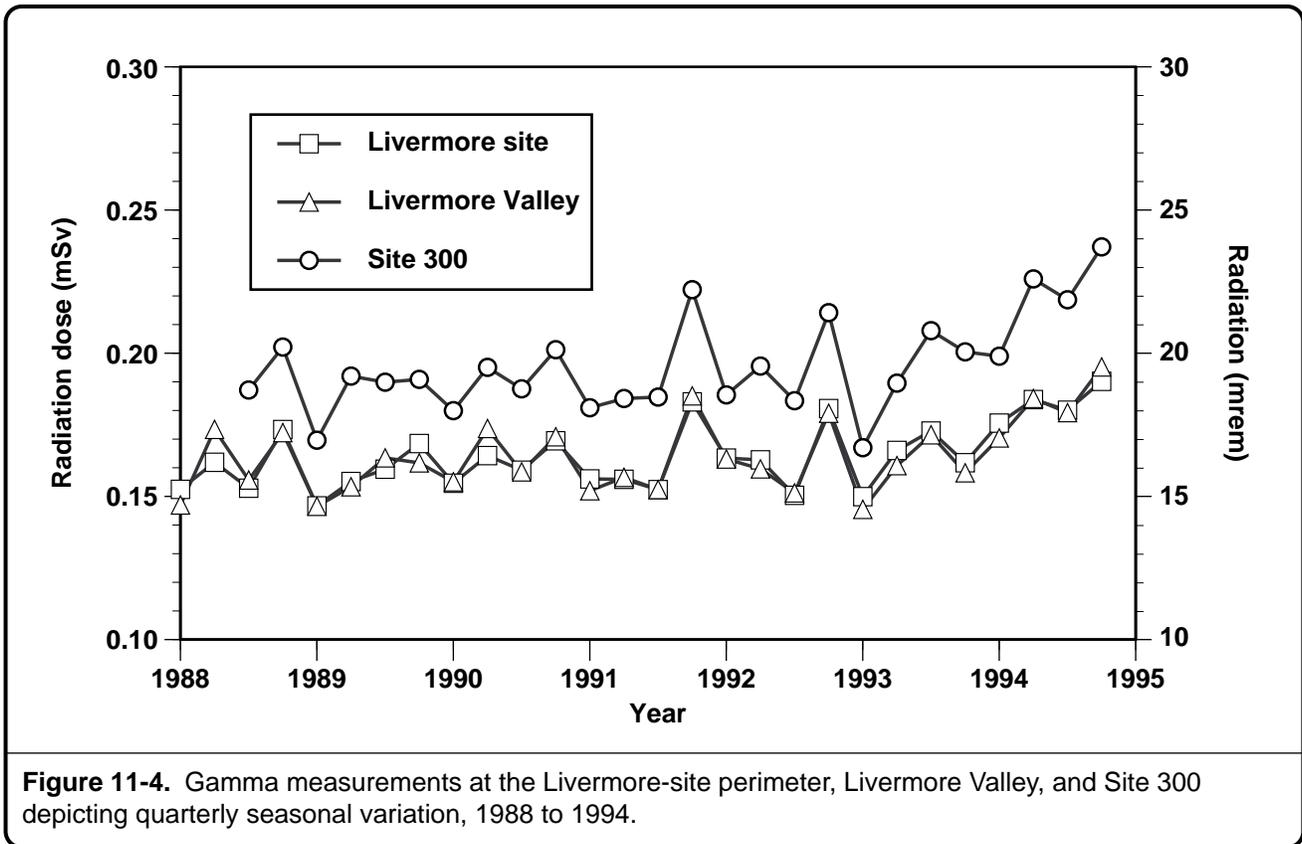
The gamma data trending also demonstrated that large spatial correlation of monitors reduces the incremental information gained from multiple locations. Many locations showed redundancies in radiation measurements, and high spatial correlations occur at all sites. The standard deviation across all locations is less than 0.02 mSv (2 mrem) so that direct radiation effects across an entire area can be evaluated easily by a single TLD in that area. Therefore, the number of gamma ray monitoring locations to include all sites has been reduced from 78 to 52 as of January 1995.

In 1994, because the neutron rem meters had aged and deteriorated, the neutron measurements did not meet LLNL's accuracy and precision requirements. Therefore, the neutron data collected during 1994 are not reported herein, and neutron monitoring has been discontinued as of January 1995. Measurements of neutrons over the past decade showed background levels (approximately 0.044 mSv or 4.4 mrem per year), as has been reported in the Environmental Report from 1983 through 1993.



## Results of Gamma Monitoring in 1994 **Livermore Site**

**Table 11-1** presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore-site perimeter locations and Livermore Valley off-site locations. The median 1994 dose equivalent from external direct radiation exposure at the Livermore-site perimeter, 0.72 mSv (72 mrem), is about the same as background external dose measured in the Livermore Valley, 0.74 mSv (74 mrem). **Figure 11-5** presents the frequency distribution for external radiation dose measured at 48 Livermore Valley locations. See Chapter 11, Volume 2, of this report for a discussion of methods and more comprehensive presentation of the data.



**Figure 11-4.** Gamma measurements at the Livermore-site perimeter, Livermore Valley, and Site 300 depicting quarterly seasonal variation, 1988 to 1994.

### Site 300

**Table 11-1** also presents the TLD data for routine monitoring at Site 300 during 1994, expressed as dose equivalent. The measured Site 300 perimeter average dose in 1994 was 0.88 mSv (88 mrem). The measured dose at off-site locations near Site 300 was this same value. The measured doses in and near Tracy were 0.66 and 0.77 mSv (66 and 77 mrem).

### Environmental Impact

The 1994 direct radiation doses from all monitoring locations are slightly higher than the annual averages from previous years, as seen in **Table 11-3** and **Figure 11-4**. The cause of their increase is under investigation. Nevertheless, all doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

Based on past measurements (Lindeken et al. 1973), environmental terrestrial (geologic) radiation doses in the Livermore Valley vary from 0.30 to 0.60 mSv/y (30 to 60 mrem/y). Cosmic radiation, as calculated for the local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966), is about 0.35 mSv/y (35 mrem/y). This combination results in a typical total direct

# 11. Environmental Radiation Monitoring



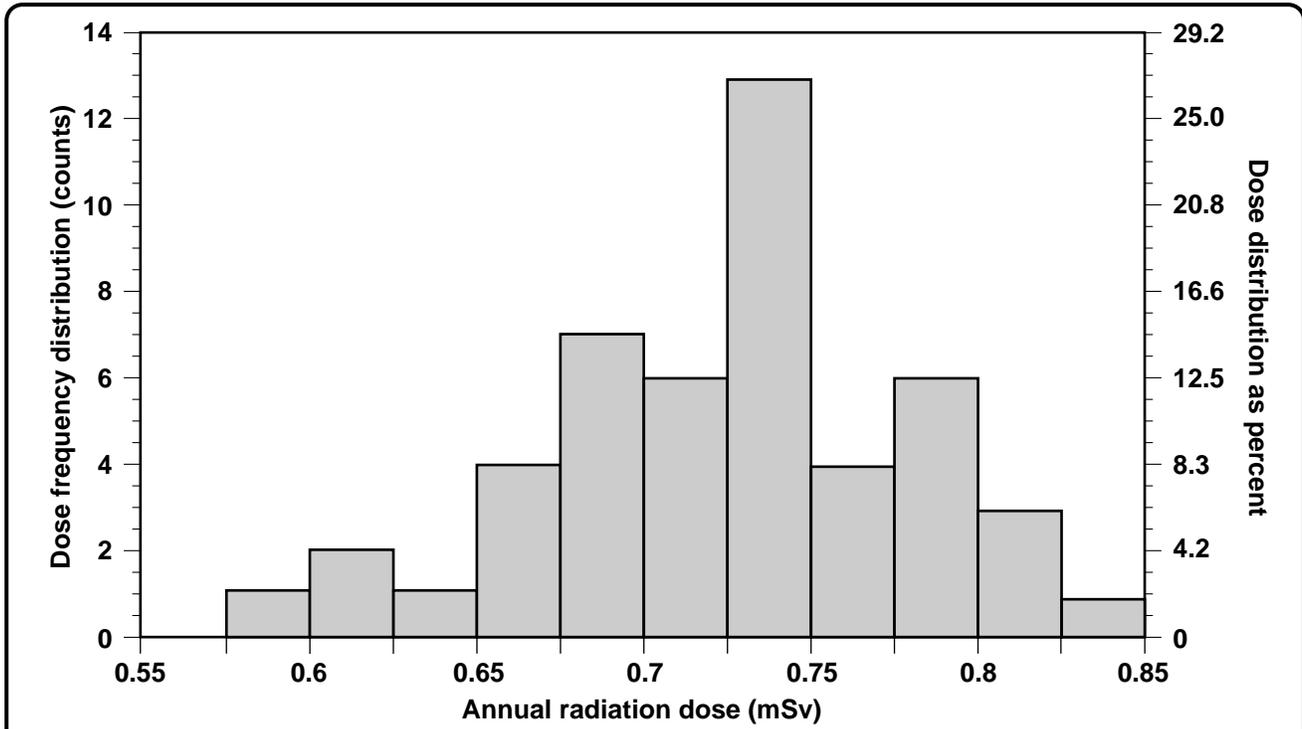
**Table 11-1.** Summary statistics of all sites in mSv.

Location	Jan– Mar	Apr– Jun	Jul– Sep	Oct– Dec	Annual Total
<b>Livermore-Site Perimeter</b>					
Median	0.175	0.178	0.180	0.191	0.721
Interquartile range	0.019	0.025	0.021	0.015	0.086
<b>Livermore Valley</b>					
Median	0.171	0.183	0.180	0.194	0.735
Interquartile range	0.010	0.019	0.022	0.014	0.062
<b>Site 300 Perimeter</b>					
Median	0.199	0.226	0.217	0.237	0.876
Interquartile range	0.016	0.039	0.021	0.023	0.073
<b>Tracy</b>					
Median	0.171	0.182	0.174	0.195	0.721
Interquartile range	0.014	0.015	0.014	0.014	0.056
<b>Site 300 Off-site</b>					
Median	0.208	0.243	0.250	0.243	0.878
Interquartile range	0.020	0.051	0.015	0.019	0.162

**Table 11-2.** Annual dose by year due to direct gamma radiation at the Livermore-site perimeter.

Year	mSv	mrem
1987	0.64	64
1988	0.63	63
1989	0.63	63
1990	0.65	65
1991	0.65	65
1992	0.66	66
1993	0.65	65
1994 <sup>(a)</sup>	0.74	74

<sup>a</sup> 1994 data is a median; previous values are means.



**Figure 11-5.** Annual direct gamma radiation dose, Livermore Valley, 1994.

radiation dose level of 0.65 to 0.95 mSv/y (65 to 95 mrem/y). Direct radiation doses measured at the Livermore-site perimeter in 1994 fall within these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. This indicates that any dose from LLNL operations is not large enough to be seen within the wide range of natural variation in background levels in different locations.

At Site 300, the initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the city of Tracy, which were chosen to represent background radiation levels. However, the Tracy locations are located on a geological substrate different from that at Site 300. The region around Site 300 has elevated levels of naturally occurring uranium, which is present in the Neroly Formation. The Tracy area, on the other hand, is at a lower elevation and the geological constituents are composed of alluvium deposits of clays, sands, and silts overlying the bedrock. As noted above, the 1994 average measured dose at the Site 300 perimeter was 0.88 mSv (88 mrem), which was identical to that from off-site locations near Site 300, while the average measured doses near the City of Tracy were 0.67 and 0.77 mSv (67 and 77 mrem), respectively. The difference in doses can be directly attributed to the difference in geologic substrates.



## 12. Radiological Dose Assessment



Robert J. Harrach  
Kris A. Surano

### Introduction

Radiological doses to the public result from both natural and man-made radiation. The total dose to different populations can be determined by measurements and calculations. This chapter describes LLNL's radiological dose assessments, made to determine the impact of LLNL operations, and contains a discussion of the analyses we performed to demonstrate LLNL's compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs).

Because this report is distributed outside the scientific community, we have included a brief preliminary discussion to enable the nontechnical reader to understand more easily the radiological dose assessment information we report. For more information, see *Radiation: Doses, Effects, Risks* (U.N. Environment Programme 1985).

### Natural and Man-Made Radiation

By far the greatest part of radiation received by the world's population comes from natural sources—primarily cosmic rays that impinge on the earth's atmosphere from space and radionuclides naturally present in our environment, such as radioactive materials in soil and rocks. Among these terrestrial sources are carbon-14, potassium-40, rubidium-87, uranium-238, thorium-232, and the radioactive elements, such as radon, that arise following decay of uranium and thorium. The source of human exposure to natural radiation can be external (from substances staying outside the body) or internal (from substances inhaled in air or ingested in food and water). Individual doses vary with location. The level of cosmic radiation increases with altitude, because there is less air overhead to act as a shield, and the earth's poles receive more cosmic radiation than the equatorial regions, because the earth's magnetic field diverts the radiation. The levels of terrestrial radiation differ from place to place around the United States and around the world, mainly due to variations in soil and rock composition.

Adding to this pervasive natural or background radiation is man-made radiation from radionuclides used in medicine, consumer products, the production of energy, and the production of nuclear weapons. Exposure to man-made sources can be controlled more readily than exposure to most natural sources. However, nuclear explosives tested in the atmosphere in the 1950s–1960s spread radioactivity across the surface of the globe, and the nuclear reactor accident at Chernobyl affected a large area. At present, medical treatment is the largest common source of public exposure to man-made radiation. Individual medical doses vary enormously—someone who has never had an x-ray examination may

## 12. Radiological Dose Assessment



receive zero medical dose while patients undergoing treatment for cancer may receive many thousands of times the annual average dose from natural radiation. Another source of public exposure to man-made radiation is consumer products, including luminous-dial watches, smoke detectors, airport x-ray baggage inspection systems, and tobacco products.

### Radioactivity

Generally, naturally occurring isotopes are stable, but notable exceptions include carbon-14, potassium-40, thorium-232, uranium-235, and uranium-238, which are naturally occurring but radioactive. Nuclear decay divides into three main categories: alpha, beta, and gamma. Alpha decay is the spontaneous emission of an alpha particle (a bound state of two protons and two neutrons—the nucleus of a helium atom) from a nucleus containing a large number of protons (most commonly 82 or more). Beta decay is the spontaneous conversion of a neutron to a proton in the nucleus with the emission of an electron, and gamma decay is the spontaneous emission of high-energy photons (high-frequency electromagnetic radiation) by nuclei.

Radioisotopes decay at quite different rates; the “half-life,” or length of time for half of the atoms to decay, spans a wide range from small fractions of a second to millions of years. For example, tritium (the radioactive form of hydrogen) has a 12.3-year half-life, compared to 24,131 years for plutonium-239.

Some radioisotopes undergo a decay chain, forming radioisotopes that decay into other radioisotopes until a stable state is achieved. For example, an atom of uranium-238 can undergo alpha decay, leaving behind a daughter, thorium-234, which is also radioactive. The transformations of the decay chain continue, ending with the formation of lead-206, which is a stable isotope.

Radioactivity can be hazardous because radiation (alpha particles, beta particles, or gamma rays) can be released with great energy. It is capable of altering the electronic configuration of atoms and molecules, especially by stripping one or more electrons off the atoms of the irradiated material, thereby disrupting the chemical activity in living cells. If the disruption is severe enough to overwhelm the normal restorative powers of the cell, the cell may die or become permanently damaged. Cells are exposed to many naturally occurring sources of chemical disruption, including naturally toxic chemicals in food, microbes that cause disease, high-energy radiation from outer space (cosmic rays), and heat and light (including the sun’s rays, which can cause sunburn and skin cancer). Consequently, cells and living organisms have evolved the capacity to survive limited amounts of damage, including that caused by naturally occurring radioactivity.



Three main factors determine the radiation-induced damage that might be caused to living tissue: the number of radioactive nuclei that are present, the rate they give off energy, and the effectiveness of energy transfer to the host medium, i.e., how the radiation interacts with the tissue. Alpha radiation can be halted by a piece of paper and can scarcely penetrate the dead outer layers of skin. Radioisotopes that give off alpha radiation are generally not health hazards unless they get inside the body through an open wound or are ingested or inhaled. In those cases, alpha radiation can be especially damaging because its disruptive energy can be deposited within a small distance, resulting in significant energy deposited in a few cells. Beta radiation from nuclear decay typically penetrates a centimeter or two of living tissue. It therefore deposits energy over many cells, decreasing the damage to any single cell. Gamma radiation is extremely penetrating and can pass through most materials, only being significantly attenuated by thick slabs of dense materials, such as lead.

### Measurement of Radioactivity and Dose

The rate that a nucleus decays is expressed in units of becquerels, abbreviated Bq, where one becquerel is one decay per second, or alternatively in curies, Ci, where one curie equals  $3.7 \times 10^{10}$  (37 billion) decays per second, or  $3.7 \times 10^{10}$  Bq (approximately equal to the decay rate of 1 gram of pure radium). Becquerels and curies are not measures of the effect of radiation on living tissue. This depends on the efficiency of energy deposition as the radiation traverses matter.

The amount of energy deposited in living tissue is called the “dose.” The amount of radiation energy absorbed per gram of tissue is called the “absorbed dose,” and is expressed in units of rads or grays (Gy), where 1 Gy equals 100 rads. Because an absorbed dose produced by alpha radiation is more damaging to living tissue than the same dose produced by beta or gamma radiation, the absorbed dose is multiplied by a quality factor to give the dose equivalent. The quality factor for alpha radiation is 20; for beta and gamma, 1. The dose equivalent is measured in units of rem or sievert (Sv); 1 Sv equals 100 rem. Also commonly used are millirem (mrem) and millisievert (mSv), which are one-thousandth of a rem and sievert, respectively.

Just as one type of radiation can be more damaging than others, some parts of the body are potentially more vulnerable to radiation damage than others, so the different parts of the body are given weightings. For example, a given radiation dose from iodine-131 is more likely to cause cancer in the thyroid than in the lung. The reproductive organs are of particular concern because of the potential risk of genetic damage. Once particular organs are weighted appropriately, the dose equivalent becomes the “effective dose equivalent,” also expressed in rem or sievert.



The effective dose equivalent describes doses to individuals. When individual effective dose equivalents received by a group of people are summed, the result is called the “collective effective dose equivalent” and is expressed in person-sievert or person-rem. Finally, to account for the long-term effects of radionuclides as they continue to decay and affect generations of people, we calculate the dose over many years, summing the effect over time. This is termed the “collective effective dose equivalent commitment.” Most of our discussion in this chapter deals with the effective dose equivalent and the collective effective dose equivalent.

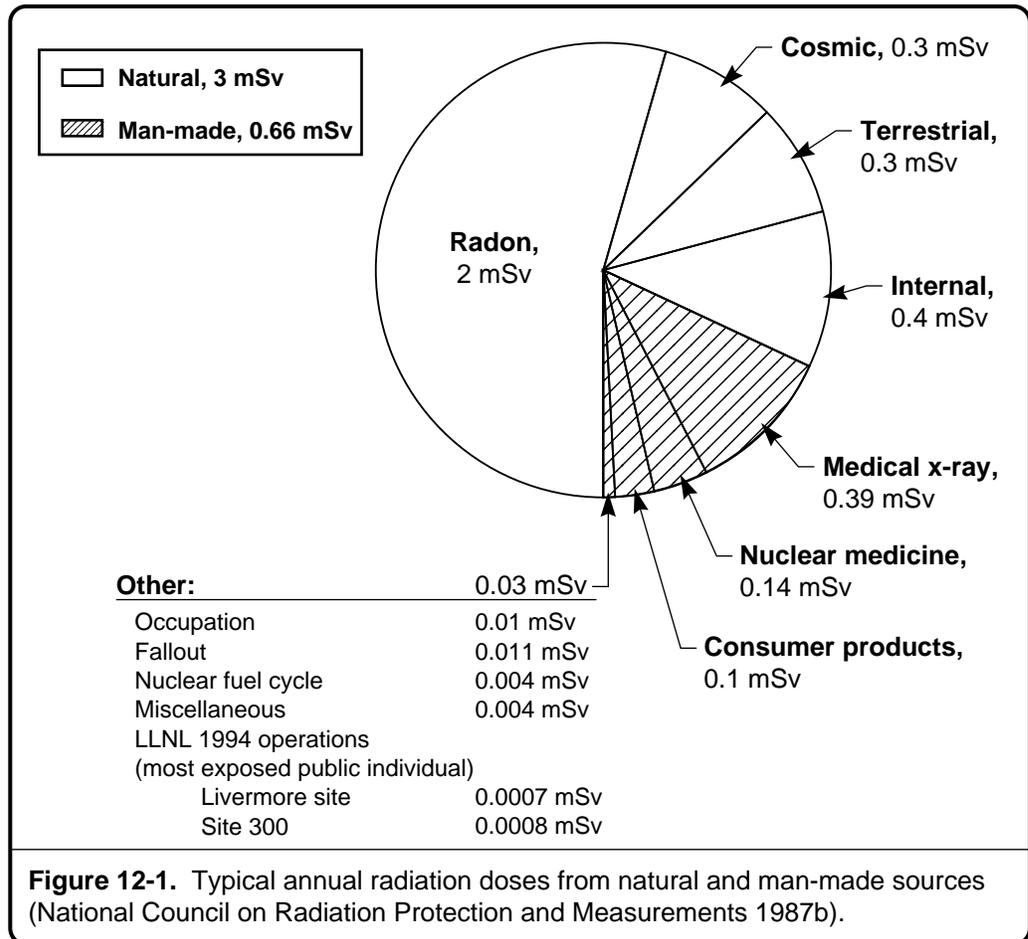
### Doses from Natural and Man-Made Radioactivity

The average radiation dose from natural sources in the United States, according to the National Council on Radiation Protection and Measurement (NCRP; 1987b), is 3.0 mSv/y (300 mrem/y). Approximately 0.3 mSv/y (30 mrem/y) of this exposure comes from high energy radiation from outer space (cosmic rays). Terrestrial sources, mainly radionuclides in rock and soil, also account for approximately 0.3 mSv/y (30 mrem/y) of the average natural dose. Another significant part of the dose comes from radionuclides we ingest through food and drink, resulting in approximately 0.4 mSv/y (40 mrem/y). Potassium-40 and carbon-14 are common radionuclides in food.

The remaining 2.0 mSv/y (200 mrem/y) or 67% of the average dose from natural sources in the United States comes from radon gas. Radon is one of the major radionuclides produced by uranium decay, and our inhalation dose is dominated by radon’s short-lived decay products. **Figure 12-1** shows the distribution of annual radiation doses from natural and other common sources.

Radon dose varies significantly with geographic location. Levels several times higher than the average occur in some regions of the U.S., while at LLNL and its environs doses as low as half the average are typical. Radon gas seeps out of the earth worldwide. Radon in water and natural gas provide additional but less important sources of radon in homes. Consumption of water high in radon is not the main exposure source; a greater exposure is believed to arise from inhalation of radon in water vapor when showering. The United States Environmental Protection Agency (EPA) has instituted a major program to educate the public regarding the effects of naturally occurring radon (U.S. Environmental Protection Agency and U.S. Department of Health and Human Services 1986).

Medical treatment is the largest common source of public exposure to man-made radiation, and most of it is from medical x-rays. These contribute 0.39 mSv (39 mrem) to the average whole-body dose in the United States, but individual doses vary enormously. For example, a typical dental x-ray series results in a skin dose (not whole body) of approximately 2.5 mSv (250 mrem). Nuclear



medicine contributes 0.14 mSv (14 mrem) to the average dose, and consumer products add 0.1 mSv (10 mrem). For a typical member of the public, radiation from medical procedures and consumer products result in a dose of approximately 0.63 mSv/y (63 mrem/y). The average dose from other man-made sources, including fallout from nuclear testing, is less than 0.03 mSv (3 mrem). As will be described in the following sections, the contributions from LLNL operations to the dose of even the most affected resident would not be discernible on the scale shown in **Figure 12-1**; these contributions are listed under "Other" in the figure, anticipating our conclusions presented near the end of this chapter.

### Radiation Sources, Control Measures, and Standards

Radioisotopes used at LLNL include uranium, transuranics, biomedical tracers, tritium, and mixed-fission products. This section describes control measures taken to minimize both worker and off-site exposures, and presents the federal standards defining allowable radiation exposures to the public from operations at DOE facilities.

## 12. Radiological Dose Assessment



### LLNL's Radiation Control Program

Protection of employees and the public from the uncontrolled release of radioactive materials into the environment is a primary consideration for LLNL. This effort consists of several stages. First, when an operation or facility is designed, a thorough assessment of potential radiation hazards is conducted, and radioisotope-handling procedures and work enclosures are determined for each project, depending on the isotope, the quantity being used, and the type of operations being performed. Radioisotope handling and working environments include glove boxes, exhaust hoods, and laboratory bench tops. The controls might include limiting physical access and using shielding, filters, and remote handling equipment. Facility Safety Analysis Reports and Facility Safety Procedures are written to document the need for these measures and to specify the requirements for maintenance, training, emergency response, and other administrative control measures.

Another stage of the radiation control program comes into play when a facility is occupied for use. Prior to the conduct of an operation in the facility, an Operational Safety Procedure (OSP) is written that specifies the actions to be taken in conducting a research or development project. This procedure is reviewed by environmental analysts, industrial hygienists, and health physicists. These reviews assess the safety of the operation, its compliance with current occupational health and environmental standards, and the adequacy of proposed engineering and administrative controls. The OSP also specifies training requirements for personnel performing the procedure. This part of the control program enables LLNL personnel who work with radiation and radioactivity to recognize and prevent the execution of unsafe operations.

The last stage of the radiation control program involves direct monitoring of the workplace environment. This includes sampling of the air and surfaces in facilities where radioactive materials are handled, and includes the surveillance and effluent monitoring of radiation in air and water, as discussed in Chapters 2 and 4 through 11 of this report. Finally, it includes personal dosimetry and bioassay programs used to monitor potential worker exposure to direct radiation and radioactive isotopes. This monitoring program measures the effectiveness of a facility's radiation control program as well as providing information on worker exposures.

### Radiation Protection Standards

DOE environmental radiation protection standards are provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, which incorporates standards for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection (ICRP 1977, 1980) and the National Council on Radiation Protection and Measurements (NCRP 1987a). The

## 12. Radiological Dose Assessment



primary DOE radiation standards for protection of the public are 1 mSv/y (100 mrem/y) effective dose equivalent for prolonged exposure, and 5 mSv/y (500 mrem/y) effective dose equivalent for occasional exposure. These limits are based on the dose to the maximally exposed individual in an uncontrolled area, and include all pathways of exposure. The limits apply to the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from radioactive materials that may remain in the body for many years after being ingested or inhaled.

DOE and LLNL also comply with the EPA's standard for radiation protection, promulgated under Section 112 of the Clean Air Act, as amended. This EPA radiation dose standard, which applies to air emissions, is defined in Subpart H of NESHAPs under 40 CFR 61. It limits to 0.1 mSv/y (10 mrem/y) the whole-body effective dose equivalent to members of the public from DOE activities. Before December 15, 1989, the standard was 0.25 mSv/y (25 mrem/y) dose equivalent for whole-body exposures from the air pathway, and 0.75 mSv/y (75 mrem/y) dose equivalent for exposure of any organ from the air pathway.

Because the EPA standard is small and the doses caused by radionuclides released from LLNL are smaller still compared to doses from exposures to natural radioactivity, it would be difficult to prove compliance with the standard by measurements alone. EPA therefore developed computer codes that implement its approved dosimetry model and mandated that these codes be used to calculate potential doses to the public for compliance demonstrations. Calculations reported here used the EPA's CAP88-PC code. As described below in the section on Calculations of Radiological Dose, it is similar to previous regulatory codes but is improved and expanded. The models used in these codes to evaluate doses and risks contain conservative assumptions that are expected to result in calculated doses larger than ones actually received by members of the public.

### **Radiological Doses from Air Emissions**

In accordance with DOE environmental protection orders and other federal and state requirements, LLNL assessed the radiological impact from operations at the Livermore site and Site 300 during 1994. Small amounts of radioactive materials from LLNL operations were discharged to the environment with air and water effluents (see Chapters 4, 9, and 10 regarding releases to air and Chapters 5 through 8 on water-borne releases). Because sewer effluents, as well as surface and ground waters impacted by LLNL operations, are not consumed, they do not represent an ingestion or inhalation pathway for radiation exposure. Therefore, our assessment of radiological dose to the public is based solely on material that enters the environment via air releases.



These potential radiological doses to the public are determined from both measurements of radionuclides in the environment and calculations using EPA-approved computer codes and procedures. The calculations use theoretical models for transport of radionuclides through the environment, including dispersion in air, into water and food, and finally into human beings mainly through inhalation or ingestion. Although LLNL seeks to obtain sufficient samples of the local environment to assure that its impacts are well understood, sampling for radioactivity cannot occur at all locations, and small amounts of LLNL-contributed radioactivity can be difficult to distinguish from background for some radioisotopes. The theoretical calculations are important because they set an upper bound on the potential radiological impacts of LLNL operations. The radionuclide source terms used in the codes are based on measured emissions and/or potential emissions based upon facility inventories of radioactive materials.

The results of the measurements and calculations reported in this chapter are an important indicator of the success of LLNL's radionuclide discharge control program. Development of the Livermore Valley and the San Joaquin Valley has enlarged the populations and decreased the distance between sources of emissions and the residents that might be exposed. People live and work within several hundred meters of LLNL's boundaries. It is therefore vital that our assessments provide the best information possible regarding the radiological impact of LLNL operations.

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### Air Emissions

Emission sources of radionuclides (stacks on buildings, drums in waste storage areas, etc.) are evaluated in two ways. For unmonitored and noncontinuously monitored sources, the releases are estimated from radionuclide inventory data using EPA methods (discussed below); for continuously monitored facilities, actual emission measurements are used. The continuously monitored facilities at LLNL are Buildings 175, 231 Vault, 251, 331, 332, 419, 490, and 491. Many of the monitored facilities show emission levels below the measurement limit-of-sensitivity (LOS), primarily due to the use of multiple-stage high-efficiency particulate air (HEPA) filters in all significant release pathways. The efficiency of a single-stage HEPA filter is 99.97%. Double-stage filter systems are in place on some discharge points. Triple-stage HEPA filters are used on glove box ventilation systems in the Building 332 Plutonium Facility and in a portion of Building 251.

Beyond the stack effluent monitoring, site-specific surveillance air monitors are placed in the vicinity of diffuse emission sources on site, such as those (described below) associated with Buildings 292, 331, 514, and 612 and in and around the southeast quadrant of the Livermore site. These special monitoring networks



measure the concentrations of radionuclides present in the air near the sources and allow a direct determination of their environmental impact.

The amount of radioactivity released from LLNL during 1994 was slightly less than in 1993 and was below the range of earlier years (see Chapter 4; especially **Tables 4-8** and **4-9**).

### LLNL Areas and Buildings with Radionuclide Release Potential

All LLNL buildings that contain radioactive materials management areas (RMMAs), i.e., locations in which radionuclides are used or stored, or where activation products potentially occur, were evaluated in 1994. We also analyzed areas (generally exterior to buildings) at the two sites where diffuse emissions occur. There were 66 buildings containing RMMAs during all or part of 1994—58 on the Livermore site and eight at Site 300. **Table 12-1** lists these buildings (with some exceptions noted below), gives the number of potential radionuclide discharge points associated with each of them, lists the largest dose to a public individual due to any one of the emission points at each facility, and identifies the types of operations occurring in each facility.

Twenty-three of the RMMAs from the Livermore site and six from Site 300, in which no operations using radionuclides took place in 1994 or in which any radionuclides present were encapsulated or sealed for the entire year, are excluded from **Table 12-1**. Five Livermore site diffuse sources are listed in the table, including two of the Livermore site RMMAs (i.e., those associated with Buildings 514 and 612); six Site 300 diffuse sources are listed. Also included is information on two Site 300 explosive testing facilities associated with Buildings 801 and 851. Further details about the point and diffuse sources at both sites, and an explanation of the dose information quoted in **Table 12-1**, is provided in the Calculated Results Summary section below. A more complete description appears in the *LLNL NESHAPs 1994 Annual Report* (Surano et al. 1995).

### Calculations of Radiological Dose

This section presents LLNL's methods for calculating radiological dose. It includes a description of the CAP88-PC air dispersion and dose model, principal doses and maximally exposed individuals, specification of source terms in the model runs, and a calculated results summary.

## 12. Radiological Dose Assessment



**Table 12-1.** Sources of radiation dose from LLNL releases to air: stacks (on buildings containing radioactive materials management areas) and diffuse area sources.<sup>(a,b)</sup>

Bldg	Facility	Potential Emission Points	Maximum EDE <sup>(c)</sup> ( $\mu\text{Sv/y}$ )	Operations
131	Engineering	4	$1.8 \times 10^{-4}$	Handling, storing, machining, characterizing, assembling, sorting, and transferring materials; repackaging of waste
151	Nuclear Chemistry	19	$4.5 \times 10^{-7}$	Chemical separation, crushing/dissolving, aliquot preparation and storage, gas analysis, radiochemical separations, preparation of radioactive counting standards
175	Laser Isotope Separation	2	0.0 <sup>(d)</sup>	Cleaning and refurbishing of uranium parts
177	Laser Isotope Separation	4	$6.5 \times 10^{-5}$	Vaporization and coating of uranium
194	Physics & Space Technology	3	$2.5 \times 10^{-4}$	Accelerator
212	Physics & Space Technology	2	$8.0 \times 10^{-11}$	Environmental, safety, and health surveillance for shutdown of accelerator
222	Chemistry & Material Science	19	$1.7 \times 10^{-3}$	Radioanalytical analyses and tracer use
224	Chemistry & Material Science	4	$4.8 \times 10^{-4}$	Waste samples analysis
226	Chemistry & Material Science	2	$5.8 \times 10^{-9}$	Radioactive and mixed waste chemical analyses
227	Chemistry & Material Science	4	$2.4 \times 10^{-6}$	Uranium bonding and testing
231	Mechanical Engineering	15	$1.3 \times 10^{-2}$	Materials research and testing, plastics shop work, electron beam welding
	Mechanical Engineering Vault	1	0.0 <sup>(d)</sup>	Storage, handling, and shipping of radionuclides
235	Chemistry & Material Science	10	$2.7 \times 10^{-7}$	Welding, actinide and uranium catalyst research
241	Chemistry & Material Science	6	$3.5 \times 10^{-9}$	Materials development, measurement, and testing
251	Heavy Elements			Heavy-element research
	Hardened area	4	0.0 <sup>(d)</sup>	
	Unhardened areas	7	$1.4 \times 10^{-4}$	
253	Hazards Control	10	$1.3 \times 10^{-8}$	Radiochemical analyses
254	Hazards Control	5	$5.6 \times 10^{-11}$	Radiochemical analyses of bioassays
255	Hazards Control	1	$1.0 \times 10^{-4}$	Instrument calibration
281	Chemistry & Material Science	8	$5.0 \times 10^{-9}$	Preparation and storage of radiochemical stock solutions
292	Physics & Space Technology	3	$7.3 \times 10^{-5}$	Tritium contamination from prior operations
298	Laser Fusion	2	$1.3 \times 10^{-6}$	Handling and assembly of tritium-filled targets, sputtering uranium
321	Materials Fabrication	5	$4.2 \times 10^{-6}$	Machining
331	Tritium	2	$1.9 \times 10^{-1(d)}$	Decontamination and decommissioning operations
332	Plutonium	6	0.0 <sup>(d)</sup>	Machining and metallurgy

## 12. Radiological Dose Assessment



**Table 12-1.** Sources of radiation dose from LLNL releases to air: stacks (on buildings containing radioactive materials management areas) and area diffuse area sources.<sup>(a,b)</sup> (continued)

Bldg	Facility	Potential Emission Points	Maximum EDE <sup>(c)</sup> ( $\mu\text{Sv/y}$ )	Operations
361	Biomedical Research	24	$5.8 \times 10^{-5}$	Radiolabeling; biological dosimetry; DNA sequencing, hybridization, and repair; human genome; enzyme assay; radioactive probes
362	Biomedical Research	1	$2.2 \times 10^{-7}$	Dose preparation for animal experiments
363	Biomedical Research	1	$1.9 \times 10^{-5}$	Dispensing samples
364	Biomedical Research	2	$6.3 \times 10^{-5}$	DNA labeling; isolation and purification
365	Biomedical Research	1	$6.4 \times 10^{-12}$	Housing research animals
366	Biomedical Research	2	$2.5 \times 10^{-8}$	DNA sequencing; metabolism
378	Environmental Research	2	$1.5 \times 10^{-9}$	Environmental analysis
381	Laser Fusion	1	$2.7 \times 10^{-13}$	Tritium handling for laser target research
391	NOVA Laser	1	$2.8 \times 10^{-4}$	Vaporization of targets
513	Hazardous Waste Management	3	$1.3 \times 10^{-1}$	Sampling, treatment, and storage of waste; sludge stabilization
514	See diffuse sources below			
801	Site 300 Firing Table at 801	— <sup>(e)</sup>	$2.0 \times 10^{-1}$	Detonation of explosives
851	Site 300 Firing Table at 851	— <sup>(e)</sup>	$2.9 \times 10^{-1}$	Detonation of explosives
	Livermore site diffuse sources <sup>(f)</sup>	5	See next five entries below	Storage areas and contaminated ground
292	Physics & Space Technology	1	$2.7 \times 10^{-6}$	Tank leakage area
331	Tritium	1	$4.1 \times 10^{-2}$	Outdoor waste accumulation area
514	Hazardous Waste Management	1	$4.6 \times 10^{-2}$	Waste treatment and storage
612	Hazardous Waste Management	1	$1.3 \times 10^{-1}$	Waste storage
—	Southeast quadrant of Livermore site	1	$1.1 \times 10^{-2}$	Contaminated ground

## 12. Radiological Dose Assessment



**Table 12-1.** Sources of radiation dose from LLNL releases to air: stacks (on buildings containing radioactive materials management areas) and diffuse area sources.<sup>(a,b)</sup> (concluded)

Bldg	Facility	Potential Emission Points	Maximum EDE <sup>(c)</sup> ( $\mu\text{Sv/y}$ )	Operations
—	Site 300 diffuse sources <sup>(f)</sup>	6	See next six entries below	Contaminated ground and water
—	Pit 7 Complex	1	$6.7 \times 10^{-4}$	Contaminated ground and purge water
802	Site 300	1	$1.2 \times 10^{-6}$	Contaminated ground
850	Site 300	1	$1.2 \times 10^{-4}$	Contaminated ground
851	Site 300	1	$3.9 \times 10^{-7}$	Contaminated ground
—	Well 8 Spring		$2.4 \times 10^{-6}$	Contaminated spring water
—	Full Site 300 area	1	$3.2 \times 10^{-1}$	Contaminated ground

<sup>a</sup> LLNL NESHAPs 1994 Annual Report (Surano et al. 1995).

<sup>b</sup> RMMAs in which no operations using radionuclides took place in 1994 or in which all radionuclides were encapsulated or sealed for the entire year are not included in this table. Table entries refer to routine operations, not unplanned releases.

<sup>c</sup> The maximum effective dose equivalent to the sitewide maximally exposed individual member of the public (SW-MEI) from a single discharge point, among all discharge points modeled for the indicated facility or building. The SW-MEI is defined in the section on Principal Doses and Maximally-Exposed Individuals.

<sup>d</sup> The effluents from the facility are and will continue to be monitored. Zeroes refer to monitored values below the limit of sensitivity, as discussed in the Air Emissions section.

<sup>e</sup> Open air dispersal in 1994.

<sup>f</sup> Diffuse sources are described briefly in the section on specifications of source terms, and more fully in the LLNL 1994 NESHAPs Annual Report cited in footnote a.

### Description of the CAP88-PC Air Dispersion and Dose Model

EPA-mandated computer models were used to carry out our radiological dose assessments, as noted above. Early in 1992, when the CAP88-PC code became available, we began using it exclusively for our standard calculations to take advantage of the significant improvements made in the model. The CAP88-PC code was developed under an Interagency Agreement between DOE and EPA. It provides the capability to compute dose and risk to both exposed individuals and collective populations resulting from radionuclide emissions to air. The differences between CAP88-PC and earlier similar codes such as AIRDOS-PC are discussed in Appendix E of the *User's Guide for CAP88-PC, Version 1.0* (Parks 1992).

CAP88-PC uses a modified Gaussian plume equation to calculate the average dispersion of radionuclides released from up to six sources. Plume rise can be driven by momentum or buoyancy, or set to a predetermined level. Flat terrain is assumed; variation in radionuclide concentrations caused by complex terrain cannot be modeled by CAP88-PC. Assessments are done for a circular grid with a radius of 80 kilometers or less around a facility, allowing up to 20 user-selected radial distances. Concentrations and doses are sector-averaged for each area



element in the sixteen 22.5° compass sectors; each area element is bounded above and below by arcs with radii from the set of user-selected distances and on its sides by radial line segments separating the sectors. The population in each area element can be set by a user-created population data input file. The mathematical models and explicit equations used in CAP88-PC are described in Chapter 8 of Parks (1992).

CAP88-PC accepts site-specific meteorological, as well as population, data files. Input data for the LLNL modeling are collected from on-site meteorological towers at both the Livermore site and Site 300. Wind speed and direction are sampled every few seconds, temperature every minute, and all are averaged into quarter-hour increments, time-tagged, and computer-recorded for conversion into a CAP88-PC wind file. Numbers specifying the annual average precipitation, temperature, and average height of the atmospheric inversion layer are also put into the model. The code automatically computes results for each of seven Pasquill-Gifford atmospheric stability categories.

CAP88-PC computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from ingestion of food produced in the assessment area. Calculated doses then include the four principal exposure pathways: internal exposures from inhalation of air and ingestion of foodstuffs and drinking water, and external exposures through irradiation from contaminated ground and immersion in contaminated air. Dose and risk are tabulated as a function of radionuclide, pathway, spatial location, and body organ. Up to 36 radionuclides can be included in a single run, chosen from a total library of 265 radionuclides. The frequency distribution of risk is tabulated, showing the number of people at various levels of risk on a logarithmic scale from one in ten to one in ten million. Dose and risk estimates from CAP88-PC are applicable only to low-level chronic exposures because the health effects and dosimetric data it uses are based on low-level chronic intakes. The code is not intended for modeling either short-term or high-level radionuclide intakes. The doses are expressed as whole-body effective dose equivalents (EDEs) in units of mrem/y (1 mrem = 10  $\mu$ Sv = 0.01 mSv).

Because CAP88-PC does not contain all the radionuclides present at LLNL, surrogate radionuclides were used in some cases to estimate EDEs. In selecting the surrogates, we used the most restrictive lung class (whether clearance from the lungs takes place in days, weeks, or years). When possible, we used a surrogate radionuclide with similar lung class chemistry and similar values for "annual limits of intake via inhalation and derived air concentration," as specified in the EPA guidance, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Eckerman et al. 1988). CAP88-PC contains a library of considerably more radionuclides than earlier regulatory codes, such as AIRDOS-PC. By rerunning



calculations with CAP88-PC previously modeled with AIRDOS-PC, we have found that the use of surrogates in the calculations typically results in conservative estimates of EDEs.

### Principal Doses and Maximally-Exposed Individuals

We report separate determinations of doses for the Livermore site and Site 300. Three potential doses are emphasized: (1) The dose to the sitewide maximally exposed individual member of the public (denoted as SW-MEI and defined below), which combines the effects of all emission points; (2) the maximum dose to any member of the public, in any direction (generally occurring at the site boundary and commonly referred to as the maximum “fenceline” dose) due to each emission point on the site; and (3) the collective dose to the populations residing within 80 kilometers of the Livermore site and Site 300 (treated separately), adding the products of individual doses received and the number of people receiving them. Dose (1) is used to evaluate LLNL’s compliance with the EPA standard limiting the total radionuclide emissions to air from DOE facilities to  $100\text{-}\mu\text{Sv}/\text{y}$  ( $10\text{-mrem}/\text{y}$ ) (NESHAPs, 40 CFR Part 61.92, Subpart H). In this evaluation, credit is taken for any emission abatement devices, such as filters, that are in place. Dose (2), which is calculated without regard for any existing emission abatement devices, is used to evaluate the need for continuous monitoring of individual emission points under the EPA’s  $1\text{-}\mu\text{Sv}/\text{y}$  ( $0.1\text{-mrem}/\text{y}$ ) standard on potential unabated emissions (40 CFR Part 61.93).

The SW-MEI is defined as the hypothetical member of the public (individual receptor at a residence, place of business, school, church, or similar public facility) who could receive the greatest LLNL-induced EDE from all sources at a single site. At the Livermore site, the SW-MEI is located at the UNCLE Credit Union, about 10 meters outside the controlled eastern perimeter of the site. This location lies 948 meters from LLNL’s principal radionuclide source, the Tritium Facility (Building 331), in an east-northeast direction. At Site 300, the SW-MEI is located in an experimental area termed “Bunker 2” operated by Physics International. Bunker 2 lies about 300 meters outside the east-central boundary of Site 300. This bunker is 2.4 kilometers east-southeast of the principal firing table at Building 801.

It is possible for the location of the SW-MEI to change from year to year, e.g., with changing wind patterns, changing population distributions near site boundaries, or changing emission levels of sources. An illustration of the effect of different wind patterns on dose is given in the *LLNL NESHAPs 1993 Annual Report* (Harrach et al. 1994). Four prime candidates for the SW-MEI were evaluated for the Livermore site in confirming the UNCLE Credit Union location for 1994, as described in the *LLNL NESHAPs 1994 Annual Report* (Surano et al. 1995).



### Specification of Source Terms in the Model Runs; Point and Diffuse Sources

The source term for each emission point in the calculations was arrived at by one of two methods, as noted earlier. For continuously monitored sources, the data on curies released per unit time for each radionuclide were used directly as input variables into the modeling codes. For unmonitored or noncontinuously monitored facilities, we relied on inventories, together with EPA-specified fractions for potential release to air of materials in different physical states (solid, liquid, powder, or gas), in accordance with 40 CFR Part 61, Subpart H, Appendix D. Use of the state-dependent potential release fraction adjusts (by multiplication) the total annual inventory to give the potential annual release to air. If the material was an unconfined gas, then the release fraction 1.0 was used; for liquids and powders,  $1.0 \times 10^{-3}$  was used; and for solids,  $1.0 \times 10^{-6}$  was used. In addition, credit was taken for radionuclide emission control devices when calculating total dose for evaluation under the 10 mrem/y (100  $\mu$ Sv/y) EPA standard; e.g., each stage of HEPA filtration produces a  $1.0 \times 10^{-2}$  emission-reduction factor. However, emissions were assumed to be unabated for evaluations under the 1  $\mu$ Sv/y (0.1 mrem/y) EPA standard for required continuous monitoring.

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### Monitored Facilities

Dose calculations based on actual monitoring data are expected to be more accurate than those using assumptions based on inventory data, physical state release fractions, and emission-control factors. Among the eight continuously monitored facilities at the Livermore site, discussed earlier—Buildings 175, 231 Vault, 251, 331, 332, 419, 490, and 491—none require monitoring under the EPA 1  $\mu$ Sv/y (0.1 mrem/y) standard. Nonetheless, continuous monitoring is maintained at all of these facilities for programmatic reasons. For example, continuous monitoring is maintained at Building 331 (the Tritium Facility) to provide the most direct and accurate measure of its release of tritium to the atmosphere, even though the EDEs we calculate from measured unabated emissions are below the 1  $\mu$ Sv/y (0.1 mrem/y) level (see **Table 12-1**). No additional facilities at either the Livermore site or Site 300 were found to require continuous monitoring systems under the EPA standard.

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### Inventoried Facilities

For this year's NESHAPs annual report, covering activities in 1994, the radionuclide inventories for all unmonitored or noncontinuously monitored Livermore-site facilities containing RMMAs were updated. Inventory forms, accompanied by detailed guidance for completing them, were sent to all of these facilities, filled out by experimenters, certified by facility managers, and returned. We also compiled new inventories for all Site 300 explosive experiments and performed new assessments of all diffuse sources we have identified at the two sites. New



dose-assessment modeling runs, using 1994 on-site meteorological data (wind, precipitation, and temperature) along with the 1994 radionuclide inventory or monitoring data, were conducted for every emission point.

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### Explosive Tests at Site 300

Modeling the releases to the atmosphere from explosive tests using depleted uranium at Site 300 requires special attention compared to conventional stack or area sources. During experiments, the explosive device containing depleted uranium is placed on an open-air firing table and detonated. We have limited data to characterize the initial state of the cloud of explosive decomposition products created by the detonation because properties of the cloud are not typically measured in the experiments. However, well-known empirical scaling laws for cloud height and size can be used that only require knowledge of the quantity of high explosive driving the detonation. Isotopic ratios for depleted uranium are used. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 (occurring in depleted uranium in the weight-percentages 99.8, 0.2, and  $5 \times 10^{-4}$ , respectively) are multiplied by their respective specific activities to get the total number of curies for each isotope in the cloud. We assume all of the depleted uranium is dispersed into the cloud, and the median particle size is assumed to be the CAP88-PC default value of 1 micrometer. This assumption that all uranium is aerosolized and dispersed as a vapor produces a highly conservative off-site dose. We believe a more realistic release-to-air fraction for the uranium is no greater than 0.2, but we lack sufficient justification to use a value other than 1.0. CAP88-PC simulates each shot as a low-level, steady-state, stack-type emission occurring over one year. An alternative modeling methodology for treating these short-duration explosive events was submitted for approval in 1992 (*LLNL NESHAPs Project Quarterly Progress Report*, Biermann et al. 1993), but LLNL was directed by EPA to use the CAP88-PC code for these calculations despite the recognized difficulties.

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### Diffuse Sources

Another category of sources requiring special attention is diffuse emissions, including fugitive emissions. Diffuse, or nonpoint, sources often are difficult to quantify. Presently, methods of dose calculations associated with them are left to the discretion of the DOE facility although proposed guidance was sent out by EPA in 1993 for review.

Four different modeling approaches were used for diffuse sources at LLNL's Livermore site in 1994. Elevated tritium levels in soil moisture near Building 292 required a calculation of the source term and the use of CAP88-PC. Estimated releases from tritium-contaminated equipment outside Building 331 were



derived from measurements of surface contamination, process and facility knowledge, and environmental surveillance measurements. Radioactive wastes stored in the Building 612 Yard required environmental surveillance data to estimate emissions. For Building 514, which houses the Hazardous Waste Management tank farm for waste processing and storage, radiological-inventory data were used with standard CAP88-PC modeling techniques. Direct ambient air monitoring of plutonium in surface soils in the southeast quadrant of the Livermore site provided data on which to base dose calculations.

Diffuse sources at Site 300 involve tritium and uranium. Their evaluation was based on data provided in the *Final Site-Wide Remedial Investigation Report Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994), where potential routes of tritium and uranium migration from soil to air were identified and evaluated. These radionuclides were components of the explosives assemblies tested on the Site 300 firing tables over many years. Five diffuse sources of tritium (the Pit 7 Complex, Well 8 Spring, and ground areas associated with Buildings 802, 850, and 851) were characterized, and diffuse sources of uranium were treated collectively in a resuspension calculation tied to air-particulate sampling data. A description of each source at the two sites and the assumptions made regarding their emissions is given in the *LLNL NESHAPs 1994 Annual Report* (Surano et al. 1995).

Calculated  
Results  
Summary—  
Livermore Site  
and Site 300,  
1994

**Table 12-1**, as discussed earlier, summarizes the sources of the radiation dose from airborne radionuclides emitted by routine LLNL operations in 1994. In particular, the number of potential discharge points at each facility is given, along with the largest EDE value from any one discharge point at each facility. Corresponding information is given for Site 300 facilities and for the diffuse sources at both sites.

There was one unplanned atmospheric radionuclide release at the Livermore site in 1994 and none from Site 300. In December 1994, during transfer of boxes containing depleted-uranium ingots, several ingots fell out of the boxes onto the sidewalk, curb, and grass area southwest of Building 241, along Avenue B at the Livermore site. The spilled ingots and associated contamination were promptly cleaned up; less than 370 Bq (0.01  $\mu\text{Ci}$ ) remained as residual contamination in the spill area. Modeling evaluated the resultant maximum dose to a member of the public from the residual contamination to be less than  $6.8 \times 10^{-12}$   $\mu\text{Sv}/\text{y}$  ( $6.8 \times 10^{-13}$  mrem/y), far below levels of health concern.

**Table 12-2** lists the facilities that were primarily responsible for the LLNL dose; the contributions from all emission points at each facility have been summed. These facilities accounted for 98% of the total EDE resulting from Livermore-site operations and nearly 100% of the total EDE from Site 300 operations. The

## 12. Radiological Dose Assessment



**Table 12-2.** Major contributors to LLNL's radiation dose via airborne emissions, 1994.

Facility or Operation <sup>(a)</sup>	Dominant Radionuclide(s)	EDE at SW-MEI <sup>(b)</sup>	
		μSv/y	mrem/y
<b>Livermore site</b>			
B331/Tritium Facility	<sup>3</sup> H	0.27	0.027
B612 Yard Area <sup>(c)</sup>	<sup>3</sup> H	0.13	0.013
B513	<sup>241</sup> Am, <sup>238</sup> U, <sup>234</sup> U, <sup>228</sup> Th	0.13	0.013
B514 <sup>(c)</sup>	<sup>238</sup> U, <sup>235</sup> U, <sup>234</sup> U, <sup>241</sup> Am	0.046	0.0046
B331 Exterior <sup>(c)</sup>	<sup>3</sup> H	0.041	0.0041
B231	<sup>238</sup> U, <sup>234</sup> U, <sup>235</sup> U	0.014	0.0014
SE Quadrant <sup>(c)</sup>	<sup>239</sup> Pu	0.011	0.0011
Sum of other sources	Various	0.010	0.0010
	Total =	0.65 <sup>(d)</sup>	0.065 <sup>(d)</sup>
<b>Site 300</b>			
B851/firing table	<sup>238</sup> U, <sup>234</sup> U, <sup>235</sup> U	0.29	0.029
B801/firing table	<sup>238</sup> U, <sup>234</sup> U, <sup>235</sup> U	0.20	0.020
Soil resuspension <sup>(c)</sup>	<sup>238</sup> U, <sup>234</sup> U, <sup>235</sup> U	0.32	0.032
<b>Total</b>		0.81 <sup>(d)</sup>	0.081 <sup>(d)</sup>

<sup>a</sup> The facilities cited here are discussed in the text of this report, and in more detail in the NESHAPs annual reports.

<sup>b</sup> These doses represent the sum of all emission points from a given facility (for example, both stacks on Building 331), in contrast to the dose values in Table 12-1, which represent the dose from the single largest emission point on each facility. The site-wide maximally exposed individual member of the public (SW-MEI) is defined in the section on Principal Doses and Maximally-Exposed Individuals.

<sup>c</sup> Diffuse sources (see text).

<sup>d</sup> These Livermore site and Site 300 totals represent 0.7% and 0.8%, respectively, of the federal standard.

dominant radionuclide(s) are indicated for each facility. Tritium accounted for about 68% of the Livermore-site dose, and uranium (principally uranium-238) for 16%. At Site 300, practically the entire dose was due to the isotopes uranium-238, -235, and -234 comprising depleted uranium.

The relative significance of inhalation and ingestion is different for tritium and uranium, and depends on the assumptions made about the origin of food consumed by a person receiving the dose. As in previous years, we employed the local agriculture option in CAP88-PC, where all food consumed is assumed to be locally grown at receptor locations and therefore maximally affected by the emissions from sources upwind. This option produces the maximum dose to the SW-MEI, and therefore is the most conservative of the six agricultural-land-use options available in CAP88-PC: urban, rural, local, regional, imported, and user-specified. We then find that, for the meteorological conditions and source emission characteristics at LLNL in 1994, ingestion was most important in the



case of tritium, contributing 86% of the dose, versus 14% for inhalation. For uranium, these numbers were nearly reversed: inhalation accounted for 89% of the dose, versus 11% for ingestion. For both uranium and tritium, external doses from air immersion and ground irradiation were negligible.

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### Maximum Dose to an Individual Member of the Public

The calculated EDE to the SW-MEI from point source emissions at the Livermore site in 1994 was 0.42  $\mu\text{Sv}$  (0.042 mrem), and from diffuse source emissions was 0.23  $\mu\text{Sv}$  (0.023 mrem). Summing these contributions yields a total dose of 0.65  $\mu\text{Sv}$  (0.065 mrem) for the Livermore site in 1994—65% from point sources, 35% from diffuse. The leading contributors were 0.27  $\mu\text{Sv}$  (0.027 mrem) due to emissions from the two 30-meter stacks at the LLNL Tritium Facility (Building 331), 0.13  $\mu\text{Sv}$  (0.013 mrem) from the Building 612 Yard diffuse source, and 0.13  $\mu\text{Sv}$  (0.013 mrem) from the Building 513 waste-processing stabilization unit.

Compared to data of previous years, the total of 0.65  $\mu\text{Sv}$  (0.065 mrem) for 1994 is practically the same as the 1993 value of 0.66  $\mu\text{Sv}$  (0.066 mrem), slightly below the 1992 value of 0.79  $\mu\text{Sv}$  (0.079 mrem), and well below the dose values of 2.34  $\mu\text{Sv}$  (0.234 mrem) and 2.40  $\mu\text{Sv}$  (0.240 mrem) reported for 1991 and 1990, respectively.

The total dose to the SW-MEI at Site 300 during 1994 was calculated to be 0.81  $\mu\text{Sv}$  (0.081 mrem). Explosive tests at the Building 801 and Building 851 firing tables accounted for all of the point source dose of 0.49  $\mu\text{Sv}$  (0.049 mrem), while a source representing resuspension of both naturally-occurring and LLNL-contributed uranium in surface soils throughout the site was responsible for nearly all of the diffuse sources total of 0.32  $\mu\text{Sv}$  (0.032 mrem).

**Table 12-3** shows the firing table dose values for 1990 through 1994, correlated with the total amounts of depleted uranium and the total quantity (TNT-equivalent) of high explosives used in the experiments. (Only experiments that included depleted uranium are considered; most have none.) The data show that variations from year-to-year in these doses mainly reflect differences in the amount of depleted uranium used in the tests.

The amount of depleted uranium also affects, to a smaller degree, the diffuse-source dose, by contributing to the general contamination of soil at the site. Comparing Site 300 diffuse source contributions in 1994 and 1993, we find a 23% increase in dose from resuspended uranium in 1994, when 2.3-times more depleted uranium was used. Comparison of the diffuse source contributions for earlier years cannot be made because we did not evaluate Site 300's diffuse emissions prior to 1993.

## 12. Radiological Dose Assessment



**Table 12-3.** Annual dose to the SW-MEI from explosives experiments on firing tables at Site 300, 1990–1994, related to the total quantity of depleted uranium used in the experiments and the total quantity of high-explosives (HE) driving the detonations.

Year	Dose to SW-MEI		Total depleted U used in experiments (kg)	Total HE used in depleted U experiments (kg)
	( $\mu$ Sv)	(mrem)		
1994	0.49	0.049	230	134
1993	0.11	0.011	99	74
1992	0.21	0.021	151	360
1991	0.44	0.044	221	330
1990	0.57	0.057	340	170

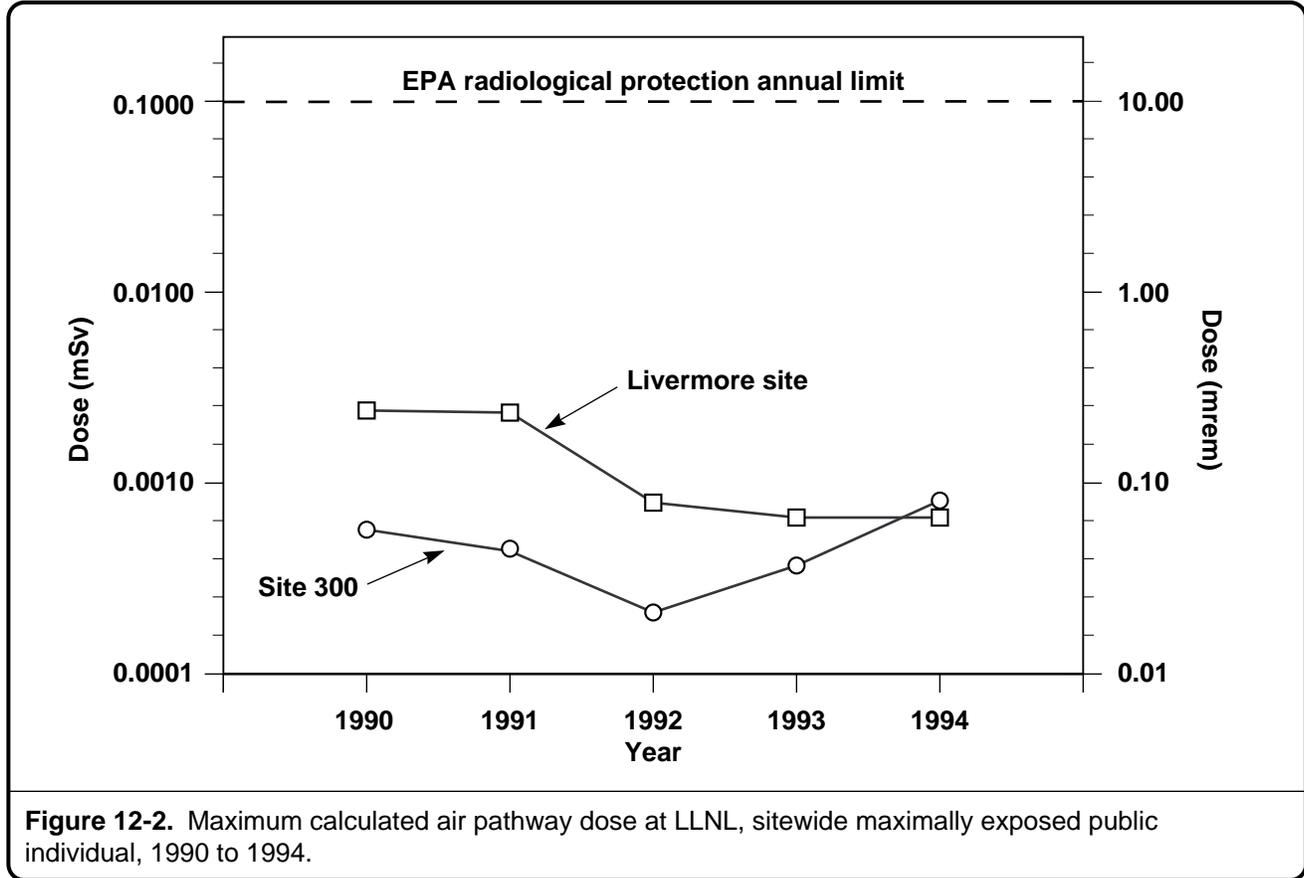
The trends in dose to the SW-MEI from emissions at the Livermore site and Site 300 over the last five years are shown in **Figure 12-2**. The Site 300 dose values for 1990, 1991, and 1992 include no contributions from diffuse sources, as noted above. The levels of public exposure indicated in **Figure 12-2** are well below the EPA standard, which limits the whole-body air-pathway EDE to members of the public from DOE activities to 100  $\mu$ Sv/y (10 mrem/y).

**Table 12-4** compares the radiation doses from atmospheric emissions at LLNL to other sources of radioactivity to which the U.S. population is exposed. The dose to the maximally exposed member of the public resulting from Livermore-site and Site 300 operations is seen to be about one four-thousandth of the doses from background radiation (see also **Figure 12-1**). **Table 12-4** shows that radon emissions rank highest among the sources of natural radioactivity, contributing an average dose of 2.0 mSv/y (200 mrem/y). Radon emissions from LLNL operations are very small. Radon-222 emissions from research experiments during 1994 were estimated to be  $7.4 \times 10^5$  Bq (20  $\mu$ Ci), with a corresponding EDE of  $3 \times 10^{-8}$   $\mu$ Sv ( $3 \times 10^{-9}$  mrem). These  $^{222}\text{Rn}$  emissions are less than one-millionth of that expected for naturally occurring  $^{222}\text{Rn}$  emanation from the soil of the LLNL's Livermore site.

### Collective Doses to Exposed Populations

Population doses, or collective EDEs, for both LLNL sites were calculated out to a distance of 80 kilometers in all directions from the site centers using CAP88-PC. As noted earlier, CAP88-PC evaluates the four principal exposure pathways for releases to air: ingestion through food and water consumption, inhalation, air immersion, and irradiation by contaminated ground surface.

## 12. Radiological Dose Assessment



Population distributions centered on the two LLNL sites were compiled from 1990 census data. Key population centers affected by LLNL emissions are the relatively nearby communities of Livermore and Tracy, and the more distant metropolitan areas of Oakland, San Francisco, and San Jose, as well as the San Joaquin Valley communities of Modesto and Stockton. Within the 80-kilometer outer distance specified by the EPA, there are 6.3-million residents included for the Livermore site collective dose determination, and 5.4 million for Site 300. (Since the two sites are separated by 24 kilometers, some of the residents are common to both determinations.) Our population data files, specifying the distribution of population with distance and direction, are described in the *LLNL NESHAPs 1994 Annual Report* (Surano et al. 1995).

The collective EDE due to 1994 Livermore-site operations was 0.0076 person-Sv (0.76 person-rem), of which 0.0050 person-Sv (0.50 person-rem), or 66%, was from point-source emissions, and the remaining 34% from diffuse sources. This value is down slightly from the 1993 result of 0.0098 person-Sv (0.98 person-rem), and is less than half of the 0.017 person-Sv (1.7 person-rem) collective EDE caused by Livermore-site operations in 1992.

## 12. Radiological Dose Assessment



**Table 12-4.** Comparison of background and LLNL radiation doses, 1994.

Location/Source	Individual Dose <sup>(a)</sup>		Population Dose <sup>(b)</sup>	
	(mSv)	(mrem)	(person-Sv)	(person-rem)
<b>Livermore-site sources</b>				
Atmospheric emissions	0.00065	0.065	0.0076	0.76
<b>Site 300 sources</b>				
Atmospheric emissions	0.00081	0.081	0.17	17
<b>Other sources<sup>(c)</sup></b>				
Natural radioactivity <sup>(d,e)</sup>				
Cosmic radiation	0.3	30	1,900	190,000
Terrestrial radiation	0.3	30	1,900	190,000
Internal (food consumption)	0.4	40	2,500	250,000
Radon	2.0	200	12,500	1,250,000
Medical radiation (diagnostic procedures) <sup>(e)</sup>	0.53	53	3,300	330,000
Weapons test fallout <sup>(e)</sup>	0.011	1.1	68	6,800
Nuclear fuel cycle	0.004	0.4	25	2,500

<sup>a</sup> For LLNL sources, this dose represents that experienced by the sitewide maximally exposed individual member of the public.

<sup>b</sup> The population dose is the collective (combined) dose for all individuals residing within an 80-kilometer radius of LLNL (approximately 6.3 million people for the Livermore site and 5.4 million for Site 300), calculated with respect to distance and direction from each site.

<sup>c</sup> From National Council on Radiation Protection (NCRP 1987).

<sup>d</sup> These values vary with location.

<sup>e</sup> This dose is an average over the U.S. population.

The corresponding collective EDE from Site 300 operations in 1994 was 0.17 person-Sv (17 person-rem), comprised of 0.14 person-Sv (14 person-rem), or 82%, due to point-source emissions, and 0.028 person-Sv (2.8 person-rem) from diffuse-source emissions. This total is more than two times the values of 0.069 person-Sv (6.9 person-rem) and 0.071 person-Sv (7.1 person-rem) calculated for 1993 and 1992, respectively, caused primarily by the increased amount of depleted uranium used in explosives experiments in 1994 (Table 12-3).

The larger collective dose for Site 300 than for the Livermore site is traceable primarily to our highly conservative, health protective assumptions about the Site 300 explosives experiments, especially regarding the fraction of radioactive material that is aerosolized and the height and trajectory of the explosive-debris cloud. As noted earlier, this conservative modeling methodology over-predicts

## 12. Radiological Dose Assessment



the quantity of radionuclides released to air by at least a factor of five, we believe, and over-estimates the long-range dispersal of material in these experiments.

We note that the diffuse sources influence the individual dose to the SW-MEI more than they impact the population dose. The reason is the relatively less dynamic nature of the diffuse-source emissions, originating low to the ground at low initial velocity. Stacks release effluents at considerable speed high above the ground, and the explosives experiments force the effluent high into the air, allowing contaminants to be more readily transported toward population centers downwind.

### Summary and Conclusion

The annual radiological dose from all emissions at the Livermore site and Site 300 in 1994 was found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard for DOE facilities, which limits total annual emissions of radionuclides to the ambient air to 100  $\mu\text{Sv}/\text{y}$  (10 mrem/y).

Using EPA-mandated computer models, actual LLNL meteorology, and population distributions appropriate to the two sites, the dose to the maximally exposed public individual was found to be 0.65  $\mu\text{Sv}$  (0.065 mrem) from Livermore site emissions and 0.81  $\mu\text{Sv}$  (0.081 mrem) from Site 300. These amount to about 0.7% and 0.8% of the standard, respectively, and are about 4,000-times smaller than the dose received by these populations from natural background radiation. The major radionuclides accounting for the doses were tritium at the Livermore site, and the three isotopes in depleted uranium ( $^{238}\text{U}$ ,  $^{235}\text{U}$ , and  $^{234}\text{U}$ ) at Site 300.

The collective effective dose equivalent or population dose for LLNL 1994 operations was calculated to be 0.0076 person-Sv (0.76 person-rem) from Livermore-site operations and 0.17 person-Sv (17 person-rem) from Site 300. These doses include exposed populations of 6.3 million people for the Livermore site and 5.4 million for Site 300, living within a distance of 80 kilometers from the site centers, based on 1990 census data. These numbers are small fractions of the population dose due to natural radioactivity in the environment: 18,800 person-Sv (1,880,000 person-rem).

We conclude that the potential radiological doses from LLNL operations were well within regulatory standards and very small compared to doses normally received by these populations from natural background radiation sources, even though highly conservative assumptions were used in the calculations. Thus, the maximum credible doses show that LLNL's use of radionuclides had no significant impact on public health during 1994.



## 13. Compliance Self-Monitoring



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### **Introduction**

Unlike other parts of this report, which describe monitoring efforts that focus on potential impacts to the local community and environment, this chapter focuses on monitoring of discharges specifically called out in regulatory requirements. LLNL samples specific waste streams as required by regulatory permits as well as site influent and effluent waste streams. The monitoring methods range from sampling a specific process waste stream at the point of discharge to visual inspection of operational conditions of the waste stream. The type of monitoring that is conducted depends on the waste stream and the applicable regulatory requirements.

LLNL implements process controls to prevent the release of significant quantities of pollutants and to minimize waste. Because of these controls, the volume of the waste streams and potential impacts are usually modest compared to commercial or industrial standards.

### **Discharges of Treated Ground Water**

Past hazardous materials handling and disposal practices, and leaks and spills that have occurred at the Livermore site and Site 300 both prior to and during LLNL operations have resulted in contaminants in ground water. The Environmental Restoration Division (ERD) at LLNL addresses Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) compliance issues. It also assesses the impact of releases on the environment and determines the restoration activities needed to reduce contamination concentrations to protect human health and the environment. Restoration activities include soil removal, ground water treatment, and closure of inactive facilities in a manner designed to prevent further environmental contamination.

The Environmental Protection Department operates five treatment facilities (TFA, TFB, TFC, TFD, and TFF) for CERCLA cleanup of ground water at the Livermore site. Self-monitoring is required at the point of discharge from each treatment facility to verify performance and effectiveness. Additional detail on specific treatment processes is contained in both the *LLNL Ground Water Project 1994 Annual Report* (Hoffman et al. 1994) and the *LLNL Site 300 Ground Water Monitoring Program Quarterly Reports* (Christofferson 1994a, 1994b, 1994c, 1995a). The self-monitoring activities and compliance sampling results which LLNL

## 13. Compliance Self-Monitoring



performs specifically for compliance with environmental discharge parameters are described below.

### Treatment Facility A

Treatment Facility A (TFA) is located in the southwestern part of LLNL near Vasco Road (see **Figure 2-1** in Chapter 2). TFA treats ground water containing volatile organic compounds (VOCs) using a combination of ultraviolet light/hydrogen peroxide (UV/H<sub>2</sub>O<sub>2</sub>) treatment and air-stripping technologies. Pumping was halted during April and May 1994 to perform various well testing and maintenance tasks.

In September, following modification of the pipeline that connects extraction wells south of TFA, LLNL began processing ground water from three additional extraction wells. During the third quarter of 1994, construction of the Arroyo Seco Pipeline was completed. In October 1994, we began continuously pumping two additional wells. Flow rates from these two wells averaged about 189 liters per minute during the fourth quarter of 1994. In December, TFA also began pumping ground water from five additional extraction wells south of TFA. By the end of 1994, the combined flow from all extraction wells connected to TFA was 662 liters per minute.

During 1994, more than 87 million liters of ground water containing VOCs was processed at TFA. All treated ground water was discharged to the recharge basin, located about 610 meters southeast of TFA. Based on monthly influent concentrations and flow data, the total VOC mass removed during 1994 was about 5.6 kilograms. Since system startup in 1989, TFA has processed nearly 371 million liters of ground water and removed about 46 kilograms of VOC mass from the subsurface.

Waste Discharge Requirement (WDR) No. 88-075 requires a monthly sampling program for this facility (**Table 13-1**). Self-monitoring analytical results of TFA effluent samples indicate that the VOC discharge limit of 5 parts per billion (ppb) was not exceeded during 1994, except in the November 16 sample which totaled 5.8 ppb.

### Treatment Facility B

Treatment Facility B (TFB) is located along Vasco Road just north of Mesquite Way. Similar to TFA, TFB processes ground water contaminated with chromium and VOCs using a combination of UV/H<sub>2</sub>O<sub>2</sub> treatment and air technologies. In 1994, we increased the amount of H<sub>2</sub>O<sub>2</sub> added to the UV chamber to chemically reduce hexavalent chromium to trivalent chromium, thereby lowering the effluent hexavalent chromium concentrations below the regulatory discharge limit of 10 ppb. However, the higher concentration of H<sub>2</sub>O<sub>2</sub> in the effluent water

## 13. Compliance Self-Monitoring



**Table 13-1.** Treated ground water discharge limits identified in WDR Order No. 88-075 for TFA.

Constituent	Discharge Limit (a)	Units
<b>Metals</b>		
Antimony	1.46	mg/L
Arsenic	500	µg/L
Beryllium	0.68	µg/L
Boron	7	mg/L
Cadmium	100	µg/L
Chromium (+ III)	1700	mg/L
Chromium (+ VI)	500	µg/L
Copper	2	mg/L
Iron	3	mg/L
Lead	500	µg/L
Manganese	500	µg/L
Mercury	20	µg/L
Nickel	134	µg/L
Selenium	100	µg/L
Silver	500	µg/L
Thallium	130	µg/L
Zinc	20	mg/L
<b>Volatile organic compounds</b>		
Total volatile organic compounds	5	µg/L
<b>Acid extractable organic compounds</b>		
2,4-Dimethylphenol	400	µg/L
Phenol	5	µg/L
2,4,6-Trichlorophenol	5	µg/L
<b>Base/neutral extractable organic compounds</b>		
1,4-Dichlorobenzene	5	µg/L
Naphthalene	620	µg/L
Phenanthrene	5	µg/L
Pyrene	5	µg/L

<sup>a</sup> These limits are instantaneous maximum values.

apparently resulted in lower than allowable fish bioassay survival rates. In November 1994, a filter bed containing 680 kilograms of granular activated carbon was installed downstream of the UV chamber. Tests results of bioassay samples collected on November 30 and December 7, 1994, indicated that H<sub>2</sub>O<sub>2</sub> concentrations decreased, and the fish survival rates rose to 100%.

## 13. Compliance Self-Monitoring



During 1994, about 32 million liters of ground water was treated at TFB. The average combined total flow rate from these wells was about 83 liters per minute. In 1994, all the ground water treated at TFB was discharged to the north-flowing drainage ditch along Vasco Road.

The total VOC mass removed during 1994 was about 2.7 kilograms. Since system startup in 1991, TFB has processed more than 87 million liters of ground water and removed about 9 kilograms of VOC mass from the subsurface.

National Pollutant Discharge Elimination System (NPDES) Permit No. CA0029289 and WDR No. 91-091 governs the operation of TFB and imposes monthly grab sampling requirements (**Table 13-2**). Self-monitoring analytical results of TFB effluent samples indicate that the VOC discharge limit, which is 5 ppb, was not exceeded. Metals concentrations were all in compliance with discharge limits, except one sample on December 20, which recorded hexavalent chromium at 12 ppb.

### Treatment Facility C

Treatment Facility C (TFC) is located in the northwest quadrant of LLNL and employs air-stripping and ion-exchange technologies to process ground water contaminated with VOCs containing chromium. In 1994, TFC processed about 10 million liters of ground water containing about 1.2 kilograms of VOCs. Since system startup in October 1993, about 10.6 million liters of ground water containing 1.2 kilograms of VOC mass have been removed from the subsurface.

Before July 8, 1994, ground water treated at TFC was discharged to a north-flowing drainage ditch near TFC. In July 1994, a pipeline was installed in the ditch to convey treated water from TFC north to Arroyo Las Positas and prevent infiltration of treated water into underlying ground water that may contain VOCs, potentially spreading and/or diluting the plume.

In compliance with WDR No. 91-091 requirements, LLNL conducted monthly samplings at TFC. The monthly self-monitoring analytical results of TFC effluent samples indicate that the VOC discharge limit of 5 ppb was not exceeded during 1994, except for two samples. Methylene chloride was in the detected parameters; one in January reported 43 ppb, and the other in April reported 25 ppb. These detections are believed to be the result of analytical laboratory contamination. These results and the detailed explanations of them were reported in the *Progress Report to Remedial Project Managers, May 1994* (U.S. Department of Energy 1994).

## 13. Compliance Self-Monitoring



**Table 13-2.** Treated ground water and Drainage Retention Basin discharge limits identified in WDR Order No. 91-091 for outfalls at locations CDBX, TFB, TFC, and TFD.<sup>(a)</sup>

Parameter	Discharge Limit <sup>(b)</sup>
<b>Metals (µg/L)</b>	
Antimony	1460
Arsenic	20
Beryllium	0.7
Boron	7000
Cadmium	5
Chromium (total)	50
Chromium (hexavalent)	11
Copper	20
Iron	3000
Lead	5.6
Manganese	500
Mercury	1
Nickel	7.1
Selenium	100
Silver	2.3
Thallium	130
Zinc	58
<b>Organics (µg/L)</b>	
Volatile organic compounds (total)	5
Benzene	0.7
Tetrachloroethene	4
Vinyl chloride	2
1,2 Dibromoethane	0.02
Total petroleum hydrocarbons	50
Polynuclear aromatic hydrocarbons	15
Base/neutral and acid extractable compounds and pesticides	5
<b>Physical</b>	
pH (units)	6.5–8.5
<b>Toxicity</b>	
Aquatic survival bioassay (96 hours)	90% survival median, 90 percentile value of not less than 70% survival

<sup>a</sup> Monitoring occurs at first discharge from the Drainage Retention Basin and at two additional discharges associated with storm water runoff monitoring. Toxicity is tested using the aquatic survival bioassay occurs once a year.

<sup>b</sup> Discharge limits do not apply to samples collected at the storm water runoff location WPDC.

## 13. Compliance Self-Monitoring



### Treatment Facility D

Treatment Facility D (TFD) is located in the northeast quadrant of LLNL and uses air-stripping and ion-exchange technologies to process contaminated ground water. Construction of TFD began on February 28, 1994, and was completed on July 13, 1994. TFD began operation on September 15, 1994, with one extraction well. The treated water discharge to the Drainage Retention Basin (DRB) began on September 29, 1994, ahead of schedule.

Two extraction wells were added in October. In November 1994, LLNL discontinued pumping from one well because the extracted ground water contained nickel in concentrations slightly above the TFD discharge limit of 7 ppb in WDR No. 91-091. No other metal parameters exceeded compliance requirements during 1994.

Once treatment for nickel is in place, we plan to resume ground water extraction from this well and begin discharging treated ground water directly to Arroyo Las Positas via an underground drainage pipeline. The average total flow rate from the two extraction wells is about 38 liters per minute.

During 1994, we processed about 0.3 million liters of ground water removing an estimated 0.3 kilograms of VOC mass. All treated water was discharged to the DRB. LLNL conducted monthly samplings at TFD in accordance with WDR No. 91-091 requirements. The monthly self-monitoring analytical results of TFD effluent samples indicated VOC compliance during 1994.

### Treatment Facility F

Treatment Facility F (TFF) is located in a gasoline-contaminated area from an old gas station tank leak. It is used as a research site in support of the DOE-sponsored Dynamic Stripping Research Project (which is located next to Building 403) for soil and ground water remediation. The discharge of ground water remediated at TFF to the sanitary sewer (which in 1994 amounted to 15.4 million liters) is governed by the provisions of the Livermore Water Reclamation Plant (LWRP) Permit No. 1508G (1994-1995) for LLNL. The total liquid-equivalent of gasoline removed from the TFF subsurface during 1994 was about 300 liters. The sampling requirements for TFF discharges are quarterly sampling for benzene, ethyl benzene, toluene, and xylene (BETX; EPA Method 624) and annual sampling for total toxic organic compounds (EPA Methods 624 and 625), metals, and inorganic compounds.

**Table 13-3** shows the BETX sampling results; no result was above the detection limit. Annual sample results for total toxic organics, sampled on August 9, 1994, showed no detections for all reportable organic compounds (detection limit is 0.01 mg/L). Two compounds not regulated under the total toxic organic compound standard were detected: acetone at 0.077 mg/L, and 1,1,2-trichloro-1,2,2-trifluoroethane at 0.025 mg/L. These values for the nonregulated

## 13. Compliance Self-Monitoring



**Table 13-3.** Treatment Facility F self-monitoring sampling results.

Parameter	Sample Date (1994)	Concentration (mg/L)	Effluent Limitations <sup>(a)</sup> (mg/L)
<b>BETX (total)</b>	March 23	<0.01	0.25 (LWRP permit)
	June 9	<0.01	
	August 9	<0.01	
	October 27	<0.01	
<b>Metals<sup>(a)</sup></b>	August 9		
Arsenic		<0.002	0.06
Cadmium		<0.0005	0.14
Copper		<0.010	1.00
Chromium (total)		<0.010	0.62
Lead		<0.0020	0.20
Mercury		0.0015	0.01
Nickel		<0.0050	0.61
Silver		<0.0005	0.20
Zinc		<0.020	3.00
<b>Cyanide</b>	August 9	<0.02	0.04
<b>Toxic organics (total)</b>	August 9	<0.01	1.00

<sup>a</sup> From Section 13.32.100 of the Livermore Municipal Code.

compounds are well below the LWRP permit limit of 1.0 mg/L for total toxic organic compounds.

Annual metals sample results for NPDES metals (EPA Method 200) are shown in **Table 13-3**. No results were found above discharge limits. Annual total cyanide sample results (EPA Method 335.2) for the year, sampled on August 9, 1994, showed no detections at the reporting limit of 0.020 mg/L. The LWRP permit limit for cyanide is 0.040 mg/L.

### Sitewide Treatability Testing

LLNL's ground water discharge permit allows ground water from hydraulic tests and VOC treatability studies to be discharged to the City of Livermore sanitary sewer. Permit No. 1510G (1994–1995) allows discharges of ground water to the sanitary sewer in compliance with **Table 13-3** effluent limitations taken from the Livermore municipal code. During 1994, discharges were primarily from the startup of TFD. Nine separate discharges of well development water were sampled and released to the sanitary sewer, all in compliance with metals, total toxic organic, and self-monitoring permit provisions.

## 13. Compliance Self-Monitoring



Total ground water discharged to the sanitary sewer during this annual period was 213,000 liters.

### Site 300 Central and Eastern General Services Area Treatment Facilities

Since 1993, a ground water treatment system has been in operation at the LLNL Experimental Test Site, Site 300, in the central General Services Area (GSA) in the vicinity of Building 875 as an interim CERCLA Removal Action. Following dewatering of bedrock in July 1994 through ground water extraction, the operation of a soil vapor extraction and treatment system was initiated. During 1994, 0.5 million liters of ground water were extracted and treated, and a total of 7,725 grams of VOCs removed from ground water and soil vapor by the central GSA system. Monthly sample self-monitoring requirements are listed in **Table 13-4**.

Since June 1991, a ground water extraction and treatment system has been operating in the eastern GSA as part of an interim CERCLA Removal Action. During 1994, 82 million liters of ground water containing 742 grams of VOCs were extracted and treated by the eastern GSA system.

**Table 13-4.** General Services Area ground water treatment system effluent limitations.

Parameter	Treatment Facility	
	Central General Services Area	Eastern General Services Area
<b>VOCs</b>	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
<b>Dissolved oxygen</b>	≥5.0 mg/L	≥5.0 mg/L
<b>pH</b>	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units
<b>Temperature</b>	No alteration of ambient conditions more than 3°C	No alteration of ambient conditions more than 3°C
<b>Place of discharge</b>	Corral Hollow Creek	Surface water drainage course in eastern GSA canyon
<b>Flow rate</b> (30-day average daily dry weather maximum discharge limit)	328,320 L (86,400 gal)	273,600 L (72,000 gal)
<b>Mineralization</b>	Mineralization must be controlled to no more than a reasonable increment	Mineralization must be controlled to no more than a reasonable increment
<b>Methods and detection limits for VOCs</b>	EPA Method 601—method detection limit of 0.5 µg/L	EPA Method 601—method detection limit of 0.5 µg/L EPA Method 602—method detection limit of 0.3 µg/L

## 13. Compliance Self-Monitoring



The central GSA is operating under substantive requirements for wastewater discharge issued by the Central Valley Regional Water Quality Control Board (RWQCB). The central GSA treatment facility discharges to bedrock in the eastern GSA canyon, where the water percolates to the surface. The eastern GSA operates under NPDES permit No. 91-052, and discharges into Corral Hollow Creek. Both the central and eastern GSA treatment systems operated in-compliance with regulatory requirements during 1994.

### Site 300 Building 834 Treatment Facility

Significant modifications to the ground water and soil vapor extraction and treatment facility at Building 834 were performed during 1994. These activities were performed in accordance with Site 300 CERCLA Removal Action requirements. This facility was designed to treat VOCs extracted from soil and ground water by air sparging and carbon absorption. Additional modifications to the facility were identified as a result of a spring 1994 test. Influent ground water concentrations ranged from 60 to 100 parts per million (ppm) total VOCs. Despite a substantial increase in the aggressiveness of sparging and recirculation, trichloroethene (TCE) permeated into polymeric components during the initial phase of water treatment. After the sparging process stopped, TCE slowly diffused back into the water as the concentration gradient shifted and greatly slowed the removal of VOCs.

All plastic components were eliminated from the influent side of the treatment facility. Numerous components were salvaged from LLNL Salvage and dismantled equipment from Building 834. The facility also incorporates additional liquid phase carbon filtration following the two sparging stages to ensure complete removal of tetra-butylorthosilicate (T-BOS) also present in substantial amounts (50–100 ppm) in influent ground water. Once ground water is treated to permit standards, it will be discharged by air-misting towers located east of the treatment facility.

The modified facility was successfully tested in February 1995. Additional equipment will be installed in fiscal year 1996 to support automated operation, continuous gas-phase monitoring, and remote inspection of facility status. The treatment facility was constructed with modularity in mind so that experimental treatment apparatus can be readily incorporated for direct comparison with the baseline sparging/carbon filtration approach.

During 1994, while modifications were being made, no ground water was treated or discharged from this facility. Once the facility receives final regulatory permits, continuous ground water treatment will begin. Final operating permits granted by the Central Valley RWQCB are expected to be issued in 1995. **Table 13-5** lists the CERCLA substantive requirements for this removal action.

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**Table 13-5.** Site 300 Building 834 ground water treatment effluent limitations.

Parameter	Building 834 Treatment Facility
<b>VOCs<sup>(a)</sup></b>	
Maximum daily	5.0 µg/L
Monthly median	0.5 µg/L
<b>pH</b>	Between 6.5 and 8.5
<b>Location discharge</b>	Treated effluent will be discharged by air misting east of Building 834.
<b>Total petroleum hydrocarbons</b>	
Daily maximum contaminant level	100 µg/L
Monthly median	50 µg/L
<b>Flow rate</b> (30-day average daily dry weather maximum discharge limit)	2,000 gal
<b>Mineralization</b>	Mineralization must be controlled to no more than a reasonable increment
<b>Methods and detection limits for VOCs, T-BOS and total petroleum hydrocarbons (TPH)</b>	Method EPA 601/602, modified EPA Method 8015, discharge limit ≤0.5 µg/L <sup>(b)</sup>

<sup>a</sup> The sum of VOC concentrations in a single sample shall not exceed 5.0 µg/L.

<sup>b</sup> Detection limits for T-BOS are currently ~100 µg/L by a modified EPA 8015 procedure. Additional analytical method development is in process at the Environmental Restoration Division (ERD) Analytical Chemistry Laboratory. Confirmatory VOC identifications were sometimes required during treatment facility characterization, and EPA 624 analyses were requested in addition to the EPA 601/602 analyses.

### Storm Water Runoff

Storm water contacts a large number of potential pollution sources and can disperse contaminants across broad areas. For this reason, comprehensive sampling and analysis of storm water discharges is not a practical means of isolating and controlling pollutant releases. To evaluate the overall impact of LLNL and Site 300 operations on storm water quality, samples are taken of the integrated storm water flows where they leave the site. These samples, described in Chapter 6, provide information used to evaluate the effectiveness of LLNL's pollution control program. The monitoring requirements in NPDES permits, under which storm water is discharged, require that LLNL conduct effluent sampling and inspect facilities to assure that the necessary management measures are being implemented. The goals of the industrial activity storm water monitoring program are to:

- Demonstrate compliance with permit requirements
- Aid in implementing the Storm Water Pollution Prevention Plan (SWPPP; Eccher 1994)
- Measure the effectiveness of the Best Management Practices (BMPs) in removing pollutants in storm water discharges

## 13. Compliance Self-Monitoring



- Ensure that storm water discharges are in compliance with the discharge prohibitions, effluent limitations, and receiving water limitations as specified in the permits
- Ensure practices at the facility to control pollutants are evaluated and revised to meet changing conditions

The compliance monitoring program includes annual facility inspections as well as sampling and analysis of storm water from two qualifying storm events for pH, total suspended solids (TSS), total organic carbon (TOC), specific conductance, toxic substances, and other pollutants that are likely to be in storm water discharges in significant quantities. It also includes visual observations at storm water discharge points during the dry and wet seasons and annual reporting to the appropriate regional water quality control boards. In addition, LLNL's compliance monitoring includes analysis of samples collected at several influent locations to provide background information. The compliance storm water monitoring program data evaluation is discussed in detail in Chapter 6.

Under the California General Industrial Activity Storm Water Permit for the Livermore site and WDR Order No. 94-131 for Site 300, visual inspections of the storm drainage system are required monthly during the wet season when significant storm events occur, and twice during the dry season to identify any dry weather flows. During the wet weather observations, LLNL found floatables, evidence of debris (mostly leaf litter) washing from the site, and cloudy water from the heavy sediment load carried in the storm water. During the dry weather observations, three specific areas were discovered where ponding and growth of vegetation gave evidence of dry weather flow at the Livermore site. These areas are located in Arroyo Las Positas, they are believed to be associated with landscape irrigation overflows. In addition, dry weather flows were observed during the March through May time frame, periodically flowing in the northwest quadrant of the site. No source for those flows was identified. Dry weather inspections at Site 300 showed no indication of nonstorm water flows discharging from the site.

Each LLNL directorate inspected its facilities to verify that the BMPs identified in the LLNL's Storm Water Pollution Prevention Plans are in place, properly implemented, and adequate. LLNL implements BMPs at construction sites and at facilities that use significant materials (as defined by the storm water regulations) to prevent storm water from being contaminated. The results of the inspections indicated LLNL facilities were in compliance with the requirements of the SWPPPs and the provisions of the NPDES permits.

LLNL also complies with storm water compliance monitoring requirements that are authorized under the California General Construction Activity Storm Water Permit for construction projects disturbing 5 acres of land or more. Monitoring

## 13. Compliance Self-Monitoring



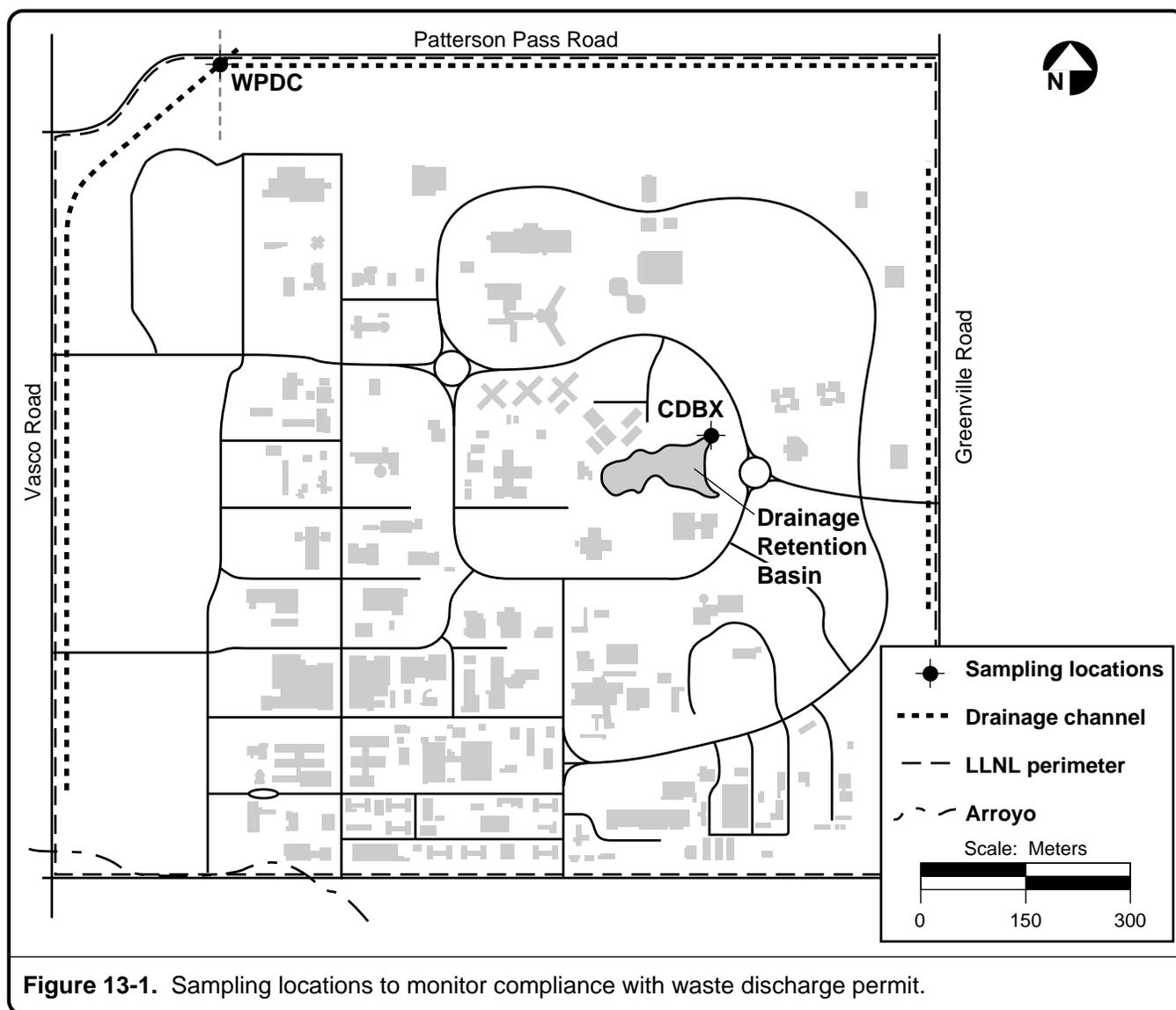
included visual observation of sites before and after storms to assess the effectiveness of implemented BMPs. Using the monitoring results, LLNL determined whether it was necessary to modify these practices to accomplish better storm water runoff protection. Two construction sites were inspected during 1994. These included the Site 300 Doall Road Project and the construction of Building 132 at the Livermore site. LLNL made no changes to the BMPs implemented at each of these large construction sites. However, minor changes were made to smaller projects located in environmentally sensitive areas. These changes included the addition of staked hay bales to minimize sediment in runoff and modification of material storage to prevent introducing these materials into storm water runoff.

### Livermore Site Drainage Retention Basin

The Drainage Retention Basin (DRB; previously known as the Central Drainage Basin; **Figure 13-1**) was lined as part of the Livermore site remedial activities and has a capacity of approximately 53 million liters (43 acre-feet). Remedial action studies indicated that infiltration of storm water from the basin was a cause of increased dispersal of ground water contaminants. In March 1992, the basin lining was completed, and LLNL adopted the *Drainage Retention Basin Management Plan* (The Limnion Corporation 1991).

The focus of the management plan was to implement a long-term biological monitoring and maintenance program and to address water quality problems by reducing nutrient loading and bioremediation. Water quality management objectives are maintained by: (1) sediment removal in sediment basins located at the influent points to the DRB; (2) management of upstream watershed activities; (3) use of submersed plants and, in the shallow portions of the basin, rooted aquatic plants to remove urban runoff pollutants and control erosion of the basin lining cover; and (4) addition of oxygen by means of recirculating pumps. The management plan identified two water sources to fill and maintain the level of the DRB. The primary identified water source was water generated from ground water treatment units and discharged to the basin through the existing storm water collection system or piped directly to the DRB. The secondary water source is storm water runoff. During 1994, storm water runoff was the primary DRB water source; a small amount of treated wastewater was discharged from TFD from September through December.

The San Francisco Bay RWQCB regulates discharges from the basin under WDR Order No. 91-091, NPDES Permit No. CA0029289, and the Livermore site CERCLA Record of Decision. WDR Order No. 91-091 and the CERCLA Record of Decision establish discharge limits for all remedial activities at the Livermore site.



**Figure 13-1.** Sampling locations to monitor compliance with waste discharge permit.

Limits set for discharges from the DRB to the Livermore storm water collection system are found in **Table 13-2**. Exceeding any of these limits constitutes noncompliance with the NPDES permit and the CERCLA Record of Decision.

In 1992, LLNL developed a sampling program for the DRB, which was approved by the San Francisco Bay RWQCB. The sampling program consists of sampling discharges from the DRB (location CDBX) and the site storm water outfall (location WPDC; **Figure 13-1**) during the first release from the DRB and a minimum of one additional storm (chosen in conjunction with storm water runoff monitoring). In addition, LLNL agreed to conduct and report to the San Francisco Bay RWQCB routine weekly, monthly, quarterly, semiannual, and annual monitoring of the basin as specified in the *Drainage Retention Basin*

## 13. Compliance Self-Monitoring



*Management Plan* (The Limnion Corporation 1991) for water quality management objectives. Water quality management objectives are found in **Table 13-6**; they are used as a tool to optimally operate the DRB. While operation outside these parameters does not constitute noncompliance with limits established in the NPDES permit and CERCLA Record of Decision, it indicates that an action should be taken to properly maintain water quality within the DRB.

Since September 1993, results of routine water quality monitoring for management parameters and discharge monitoring have been reported to regulatory agencies in the monthly, quarterly, and annual ground water project progress reports (Hoffman et al. 1994a, 1994b, 1994c). Sampling is performed to provide information necessary to establish compliance with WDR Order No. 91-091 and the Applicable, Relevant, and Appropriate Requirements (ARARs) identified in the CERCLA Record of Decision; to provide information necessary for DRB maintenance; and to document the effectiveness of nutrient removal.

Sampling to determine compliance with WDR Order No. 91-091 occurs at the DRB outfall (CDBX). Additional sampling at the site storm water outfall monitoring location at Arroyo Las Positas (WPDC) is done to identify the change in water quality as the DRB discharges travel through the LLNL storm water drainage system and leave the site. Only analytical data associated with a release from the DRB are discussed in this section. Analytical data from WPDC are discussed and presented completely in Chapter 6. Discharge monitoring parameters are identified in **Table 13-2**.

Sampling to determine whether water quality maintenance objectives are met is conducted at several points within the DRB. Sampling for dissolved oxygen and temperature occurs at eight locations identified in **Figure 13-2**. Sampling during the 1992–1993 wet season was also conducted at all these monitoring locations for all other monitoring parameters. However, because there was evidence of limited variability between sampling locations for all parameters except dissolved oxygen and temperature, all sampling locations except CDBE located at the middle depth of the DRB were eliminated starting March 31, 1993. The routine maintenance parameters are identified in **Table 13-6**.

During 1994, only lead and nickel exceeded NPDES discharge limits (**Table 13-7**). Nickel was seen for the first time in December 1993 and has continued to show up in samples collected from all DRB discharges during 1994. Nickel from the DRB is higher than the nickel found in storm water discharges at the site, but is not inconsistent with these discharges. Lead showed up for the first time in the November 15 release from the DRB. Lead was not detected in the subsequent December discharge sample. The source of the nickel and lead are unknown but believed to be associated with the storm water influent to the DRB. During 1994,

## 13. Compliance Self-Monitoring



**Table 13-6.** Routine water quality management levels for the Drainage Retention Basin.

Parameter	Location	Frequency	Management Action Levels
<b>Physical</b>			
Dissolved oxygen (mg/L)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	Not less than 5, 80% saturation
Temperature (°C)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<15 and >26
Total alkalinity (mg/L)	CDBE	Monthly	<50
Chlorophyll A (mg/L)	CDBE	Monthly	>10
pH (units)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<6.0 and >9.0
Total suspended solids (mg/L)	CDBE	Monthly	
Total dissolved solids (mg/L)	CDBE	Monthly	>350
Turbidity (meters)	CDBE	Monthly	<0.914
Chemical oxygen demand (mg/L)	CDBE	Quarterly	>20
Oil and grease (mg/L)	CDBE	Quarterly	>15
Conductivity (µmhos/cm)	CDBE	Monthly	>900
<b>Nutrients</b>			
Nitrate (mg/L)	CDBE	Monthly	>0.2
Nitrite (mg/L)	CDBE	Monthly	>0.2
Ammonia nitrogen (mg/L)	CDBE	Monthly	>0.1
Phosphate as phosphorous (mg/L)	CDBE	Monthly	>0.02
<b>Microbiological</b>			
Total coliform (MPN/0.1L)	CDBE	Quarterly	>5000
Fecal coliform (MPN/0.1L)	CDBE	Quarterly	>400
<b>Metals (µg/L)</b>			
Antimony	CDBE	Semiannually	>1460
Arsenic	CDBE	Semiannually	>20
Beryllium	CDBE	Semiannually	>0.7
Boron	CDBE	Semiannually	>7000
Cadmium	CDBE	Semiannually	>5
Chromium, total	CDBE	Semiannually	>50
Chromium, hexavalent	CDBE	Semiannually	>11
Copper	CDBE	Semiannually	>20
Iron	CDBE	Semiannually	>3000

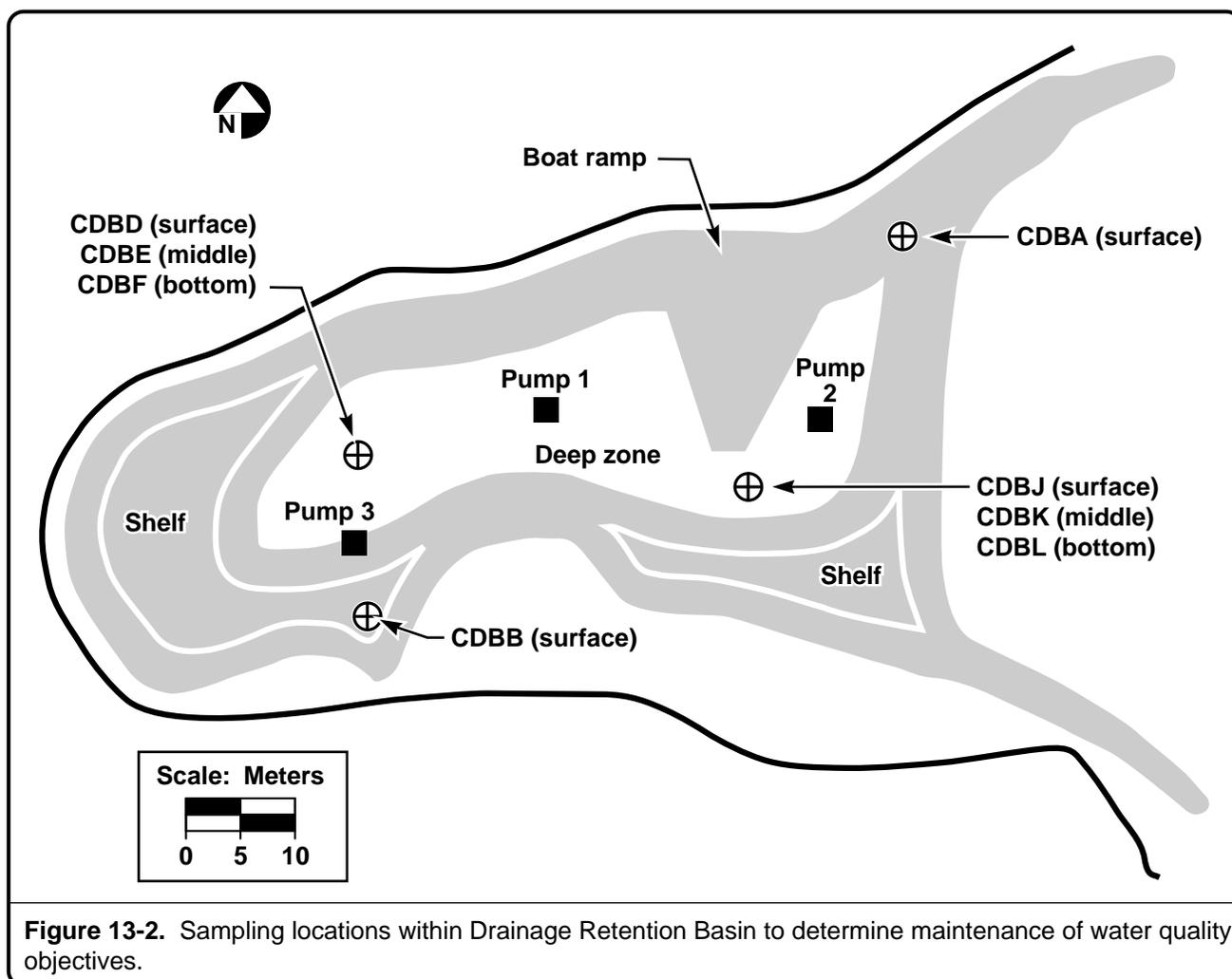
## 13. Compliance Self-Monitoring



**Table 13-6.** Routine water quality management levels for the Drainage Retention Basin (*concluded*).

Parameter	Location	Frequency	Management Action Levels
<b>Metals (<math>\mu\text{g/L}</math>) (continued)</b>			
Lead	CDBE	Semiannually	>5.6
Manganese	CDBE	Semiannually	>500
Mercury	CDBE	Semiannually	>1
Nickel	CDBE	Semiannually	>7.1
Selenium	CDBE	Semiannually	>100
Silver	CDBE	Semiannually	>2.3
Thallium	CDBE	Semiannually	>130
Zinc	CDBE	Semiannually	>58
<b>Organics (<math>\mu\text{g/L}</math>)</b>			
Total volatile organic compounds	CDBE	Semiannually	>5
Benzene	CDBE	Semiannually	>0.7
Tetrachloroethene	CDBE	Semiannually	>4
Vinyl chloride	CDBE	Semiannually	>2
Ethylene dibromide	CDBE	Semiannually	>0.02
Total petroleum hydrocarbons	CDBE	Semiannually	>50
Polynuclear aromatic hydrocarbons	CDBE	Semiannually	>15
Base neutral/acid extractable compounds and pesticide	CDBE	Semiannually	>5
<b>Radiological (pCi/L)</b>			
Gross alpha	CDBE	Semiannually	>15
Gross beta	CDBE	Semiannually	>50
Tritium	CDBE	Semiannually	>20,000
<b>Toxicity (%/96-hour survival)</b>			
Fish bioassay	CDBE	Annually	90% survival median, 90 percentile value of not less than 70% survival

turbidity, nitrate, ammonia nitrogen, and phosphorous continued to be detected at levels exceeding acceptable management objectives and/or management action levels at sampling location CDBE (**Table 13-8**). In addition, chlorophyll a, lead, and nickel exceeding acceptable management levels were detected for the first time at sampling location CDBE. As discussed earlier, lead and nickel were also detected in excess of NPDES permit discharge limitations.



**Figure 13-2.** Sampling locations within Drainage Retention Basin to determine maintenance of water quality objectives.

Dissolved oxygen concentrations rarely were maintained at the management objective of at least 80% saturation of oxygen in the water (**Figure 13-3**).

However, concentrations did not drop below the critical management action level of 5 mg/L. Dissolved oxygen levels were controlled manually with aeration pumps. Permanent pumps were installed in March 1994. The aeration pumps are started whenever oxygen levels at any level of the DRB drop close to or below the management action level of 5 mg/L.

Pump operation probably is responsible for the relatively uniform distribution of dissolved oxygen at the surface, middle, and bottom elevations (**Figure 13-4**). Adequate dissolved oxygen levels prevents nutrient release back into the DRB water column by decaying organic matter in the bottom sediments. Temperature, which is the other parameter important in dissolved oxygen saturation in water, showed characteristic seasonal trends (**Figure 13-5**). The uniform

## 13. Compliance Self-Monitoring



**Table 13-7.** Drainage Retention Basin monitoring events exceeding discharge limits at CDBX and associated water quality at WPDC, 1994.<sup>(a)</sup>

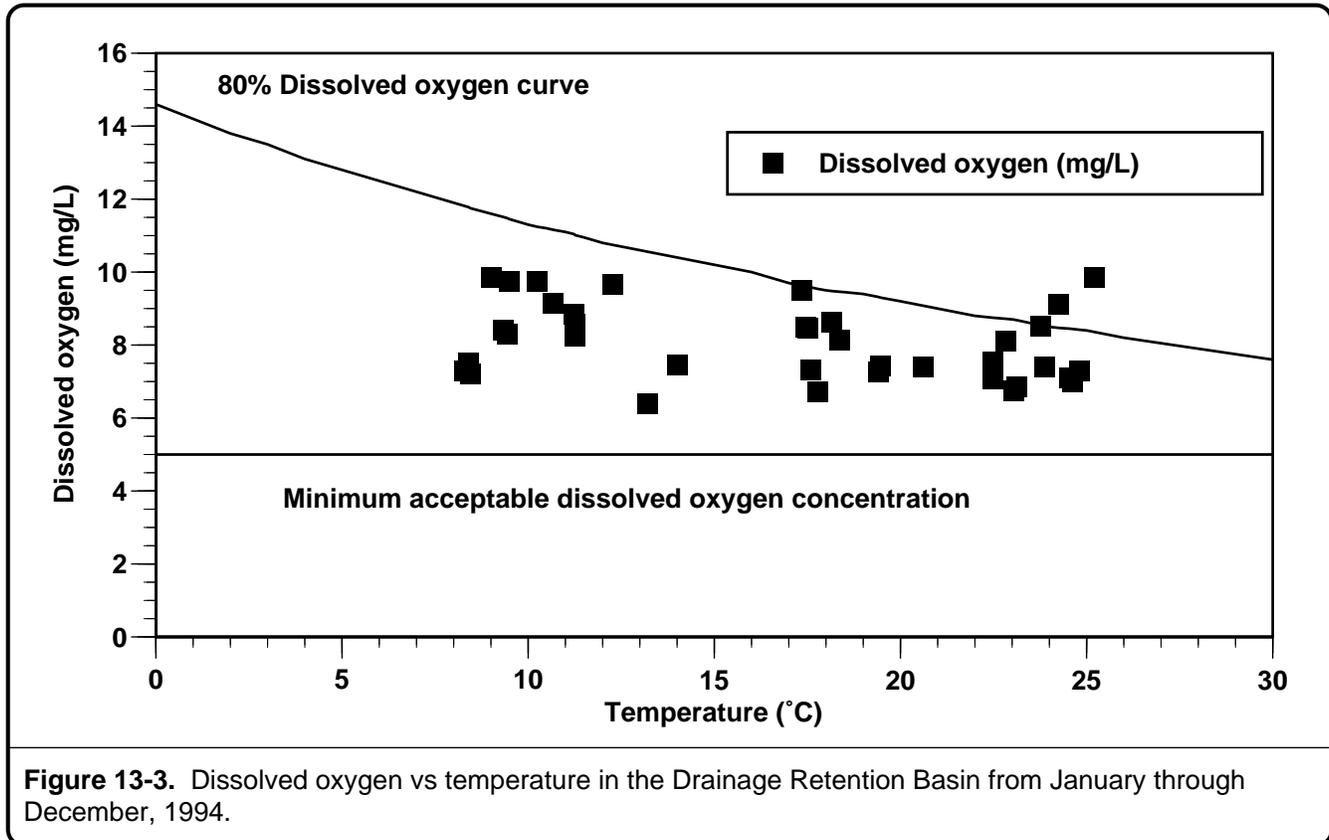
	Beryllium	Copper	Lead	Nickel	Zinc
<b>Units</b>	μg/L	μg/L	μg/L	μg/L	μg/L
<b>Discharge Limit</b>	0.7	20	2	7.1	58
<b>CDBX</b>					
Feb 7	<x			29	
Nov 15	<x		4.5	10	
Dec 14				9.5	
<b>WPDC</b>					
Feb 7				8.8	
Nov 15		34	10	40	160
Dec 14	1.4	33	19	44	200
<b>Number of samples</b>	3	3	3	3	3

<sup>a</sup> Blanks in the table are below the detection limit.

**Table 13-8.** Drainage Retention Basin monitoring events exceeding Management Action Levels, 1994.<sup>(a)</sup>

	Analyte							
	Nitrate	Nitrite	Ammonia nitrogen	Phosphorus Total (as P)	Chlorophyll a	Turbidity (secchi disk)	Lead	Nickel
<b>Units</b>	mg/L	mg/L	mg/L	mg/L	mg/L	Meters	μg/L	μg/L
<b>Action level</b>	>0.2	>0.2	>0.1	>0.2	>10	<.914	>2	>7.1
Jan 11						0.7		
Feb 9						0.7		
Mar 14	0.9	0.5	0.15	0.073				NS
Apr 15	5	<5						
May 13				0.056	12			
Jun 21			0.11					
Jul 21	<y							
Aug 17						0.75		
Sep 22	31			0.6	36	0.46		
Oct 10	20					0.61	2.7	12
Nov 9								8
Nov 11	16		0.18	0.5		0.61		
Dec 29	2.9		0.3			0.28		
<b>Number of samples</b>	12	12	12	11	12	10	3	2

<sup>a</sup> Blanks in the table are below the detection limit.

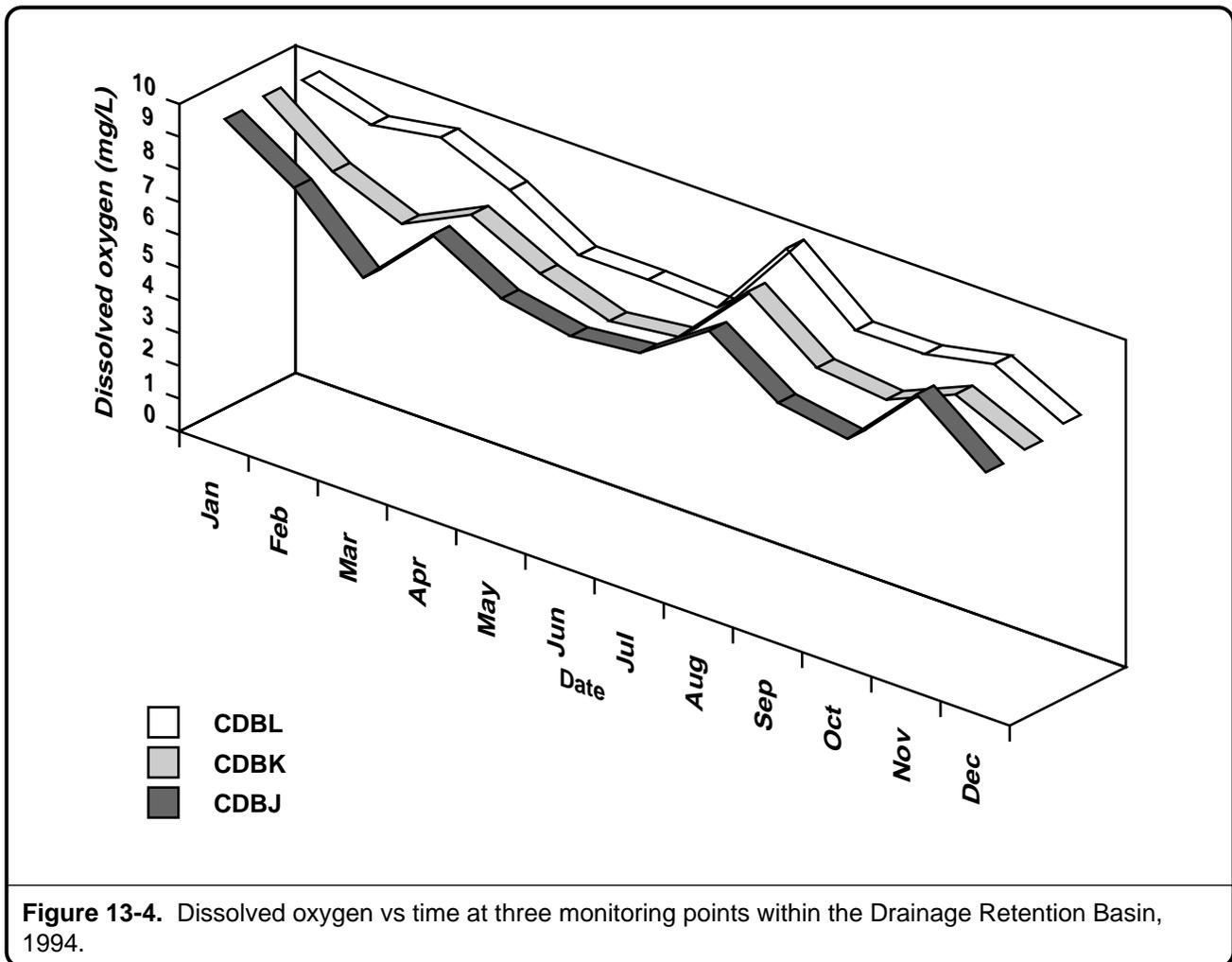


**Figure 13-3.** Dissolved oxygen vs temperature in the Drainage Retention Basin from January through December, 1994.

distribution of temperature in the top, middle, and bottom elevations also reflects the uniform mixing achieved by the manual operation of the pumps. Without mixing, the temperature would show seasonal stratification in addition to the changes in temperature.

Elevated turbidity above acceptable management levels occurred during the 1993–1994 and 1994–1995 wet seasons and is probably a result of sediments that were not captured by the sediment traps discharging into the DRB. The sediment traps were not cleaned after the 1992–1993 wet season and, therefore, may not have been functioning properly. Sediment was removed from the sediment basins in the fall of 1994 before the wet season to avoid similar turbidity problems. Turbidity seen during the warmer summer months is most likely the result of algae growth. This is confirmed by high chlorophyll a values during times of high turbidity.

Nutrient levels for nitrate/nitrites, total ammonia, and phosphate/phosphorous had higher than acceptable management levels for most of 1994. The nutrients introduced from storm water discharges are fecal matter from migrating water fowl, the mosquito fish population, and decaying organic matter. The plants



**Figure 13-4.** Dissolved oxygen vs time at three monitoring points within the Drainage Retention Basin, 1994.

introduced to the lake to reduce nutrient loading both within the Nutri-Pods (suspended nylon sacks that house the plants) and planted on the shallow shelves have not been successfully established. This is most likely the result of the chronic turbidity problem and some operational difficulties encountered with the Nutri-Pods. Until a healthy plant community is established in the DRB, high nutrient loadings and algae blooms are expected to continue.

A management contract was implemented with a landscaping company in December 1993 to assure that the plants contained in the Nutri-Pods are maintained within the proper photic zone to allow optimal growth. However, this effort has had marginal results. The beginning of the wet season, which flushes the lake with new storm water runoff flows, currently is the main mechanism operating to minimize nutrient levels.

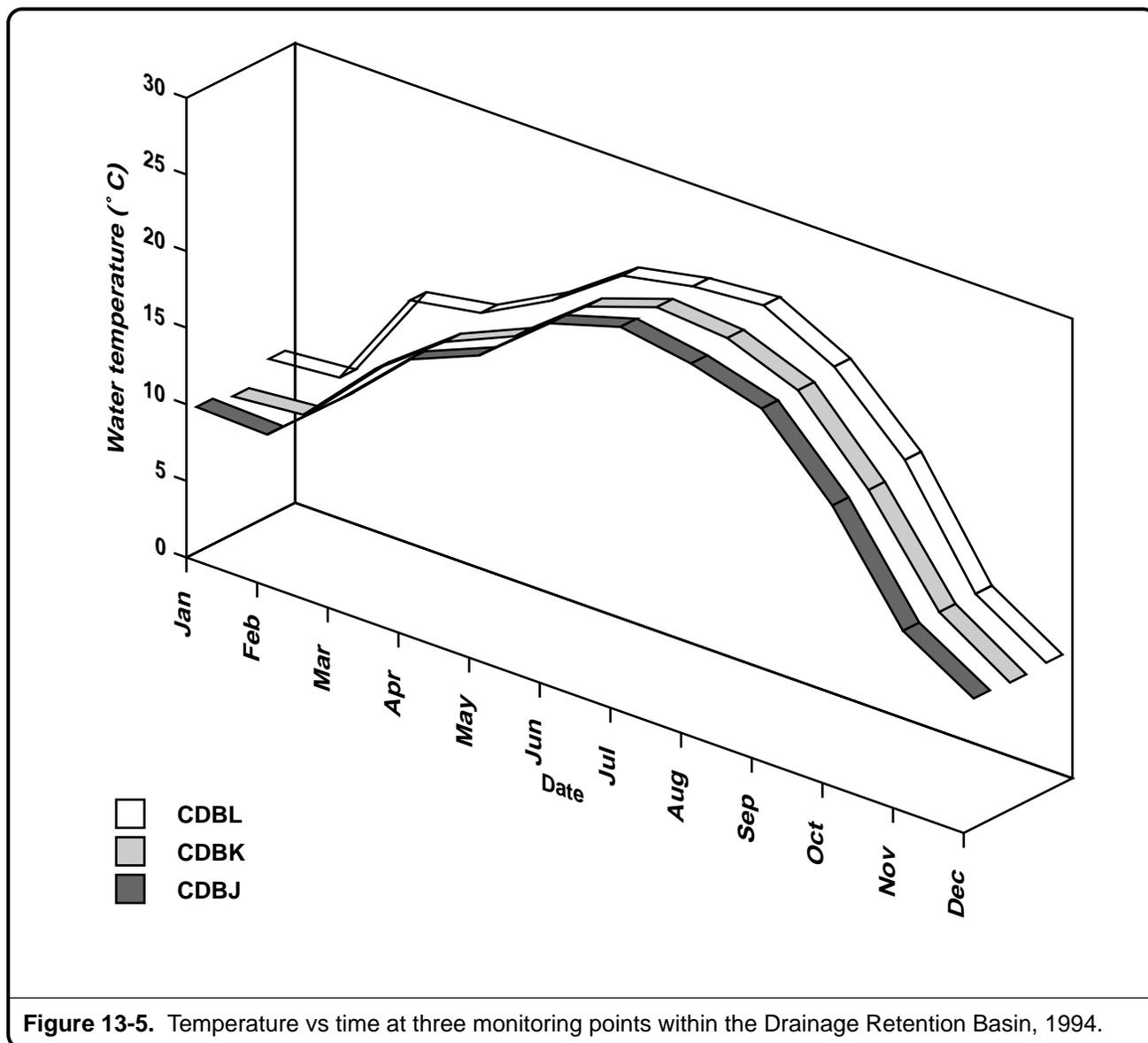


Figure 13-5. Temperature vs time at three monitoring points within the Drainage Retention Basin, 1994.

Lead was seen above acceptable management levels only once in third-quarter monitoring results during the semiannual sample collection. However, nickel, first detected in December 1993 in discharge samples, has persisted throughout 1994. The source of these elevated metals is unknown. The detection data for locations CDBX and CDBE and field measurements for CDBA through L are summarized in **Tables 13-9, 13-10, and 13-11**; summary data for maintenance monitoring at sampling location CDBE are presented in **Tables 13-1, 13-2, and 13-3** in Volume 2. Data from location WPDC is summarized in Chapter 6.

## 13. Compliance Self-Monitoring



**Table 13-9.** CDBX data summary.

Parameter	Units	Minimum	Maximum	Median	Interquartile Range	Number of Samples
<b>Metals</b>						
Antimony	mg/L	0.0055	<0.06	0.0055	0.0275	3
Arsenic	mg/L	0.0035	0.0046	0.0038	0.00055	3
Boron	mg/L	0.11	0.14	0.12	0.015	3
Chromium	mg/L	0.0061	<0.01	0.01	0.00195	3
Copper	mg/L	0.0067	<0.01	0.0097	0.00165	3
Lead	mg/L	<0.002	0.0045	0.002	0	3
Nickel	mg/L	0.0095	0.029	0.01	0.00975	3
Zinc	mg/L	0.029	0.034	0.0315	0.0025	2
<b>Toxicity</b>						
Aquatic bioassay, survival	Percent	90				1
<b>Organics</b>						
<b>EPA 504</b>						
Ethylene dibromide	µg/L	<0.01	<0.1	<0.02	0.045	3
<b>General Minerals</b>						
Bicarbonate alkalinity (as CaCO <sub>3</sub> )	mg/L	70	74	71	2	3
Calcium	mg/L	21	23	21	0	3
Chloride	mg/L	7.8	14	8.7	3.1	3
Fluoride	mg/L	0.089	0.13	0.12	0.0205	3
Magnesium	mg/L	5.4	6.2	5.6	0.4	3
Nitrate (as N)	mg/L	<0.5	0.59	<0.5	0	3
pH	Units	7.3	8.3	7.7	0.5	3
Potassium	mg/L	3.6	4.1	3.6	0	3
Sodium	mg/L	8.7	11	11	1.15	3
Specific conductance	µmho/cm	180	190	180	0	3
Sulfate	mg/L	4.8	18	6.3	6.6	3
Total alkalinity (as CaCO <sub>3</sub> )	mg/L	70	74	71	2	3
Total dissolved solids (TDS)	mg/L	110	120	110	0	3
Total hardness (as CaCO <sub>3</sub> )	mg/L	75	83	75	0	3
Total suspended solids (TSS)	mg/L	4	29	20	12.5	3
Total organic carbon (TOC)	mg/L	6.6	8	7.4	0.7	3
Chemical oxygen demand	mg/L	21	34	27.5	6.5	2
<b>Radiological</b>						
Gross alpha	pCi/L	0.81	0.95	0.92	0.07	3
Gross beta	pCi/L	2.99	8.75	3.68	2.88	3
Tritium	pCi/L	444	662	542	109	3

## 13. Compliance Self-Monitoring



**Table 13-10.** Data summary of maintenance monitoring at sampling location CDBE.

Parameter	Units	Minimum	Maximum	Median	Interquartile Range	Number of Samples
<b>Field Measurements</b>						
Dissolved oxygen	mg/L	6	10	8	2	37
Temperature	°C	8	25	19	8	38
Turbidity	Meters	0.28	3.66	0.61	1.397	15
<b>Chlorophyll a</b>	µg/L	<0.5	36	12	20.2	11
<b>General Minerals</b>						
Bicarbonate alkalinity (as CaCO <sub>3</sub> )	mg/L	62	230	76	16.5	11
Calcium	mg/L	18	25	20	3	11
Carbonate alkalinity (as CaCO <sub>3</sub> )	mg/L	1	1	1	0	11
Chloride	mg/L	5.2	27	6.7	2.05	11
Copper	mg/L	0.05	0.05	0.05	0	11
Fluoride	mg/L	0.087	0.13	0.1	0.0135	11
Magnesium	mg/L	4.7	6.6	5.5	0.8	11
pH	Units	6.5	9	7.8	0.75	11
Potassium	mg/L	2.8	4.5	3.7	0.5	11
Sodium	mg/L	7.8	11	9.1	1.45	11
Specific conductance	µmho/cm	130	210	150	45	11
Sulfate	mg/L	4	19	5.6	1.55	11
Surfactant	mg/L	<0.5	<0.5	<0.5	0	11
Total alkalinity (as CaCO <sub>3</sub> )	mg/L	62	230	76	16.5	11
Total dissolved solids (TDS)	mg/L	63	160	110	26.5	11
Total hardness (as CaCO <sub>3</sub> )	mg/L	64	87	74	11.5	11
Total suspended solids (TSS)	mg/L	1	26	9	9	9
<b>Chemical Oxygen Demand</b>	mg/L	18	110	26	26	4
<b>Biological</b>						
Fecal coliform	MPN/100mL	2	4	2	1	4
Total coliform	MPN/100mL	8	500	158.5	335.25	4
<b>Metals</b>						
Arsenic	mg/L	0.0034	0.0043	0.0037	0.00045	3
Copper	mg/L	0.0079	0.012	<0.01	0.00205	3
Iron	mg/L	1.2	1.6	1.4	0.2	2
Manganese	mg/L	0.034	0.057	0.0455	0.0115	2
Nickel	mg/L	0.008	0.012	0.01	0.002	2
<b>Total Organic Carbon (TOC)</b>	mg/L	6	8	7	1	2
<b>Toxicity</b>						
Aquatic bioassay, survival	Percent	100	100	100	0	1

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**Table 13-11.** Drainage Retention Basin maintenance field measurement monitoring summary for all stations except CDBE.

Parameter	CDBA	CDBC	CDBD	CDBF	CDBJ	CDBL
<b>Dissolved oxygen (mg/L)</b>						
Minimum	7	5	6	4	6	3
Maximum	13	12	11	10	11	11
Median	9	9	8	8	8	8
Interquartile range	2	2	2	2	2	1
Number of samples	37	37	37	37	37	37
<b>Temperature (°C)</b>						
Minimum	8	8	8	8	8	8
Maximum	28	26	26	25	26	26
Median	22	21	20	19	21	20
Interquartile range	7	7	7	8	7	7
Number of samples	38	38	38	38	38	38

### Site 300 Cooling Tower Discharges

LLNL samples cooling tower wastewater discharges as required by the Self-Monitoring Program of NPDES permit CA0081396. On May 20, 1994, the Central Valley RWQCB renewed this permit by Board Order 94-131. Revised monitoring requirements incorporated into the renewed permit were implemented in June 1994 by agreement with the Central Valley RWQCB. The new order also permitted storm water discharges as discussed earlier in this chapter, and monitoring data is presented in Chapter 6. LLNL continues to report self-monitoring results of cooling tower discharges to the Central Valley RWQCB quarterly.

The cooling towers, used to cool buildings and equipment at Site 300, discharge noncontact cooling water to man-made and natural drainage courses (**Figure 13-6**). These drainage courses flow into Corral Hollow Creek, a tributary to the San Joaquin River. Because the San Joaquin River is a United States water, all discharges to it and its tributaries require NPDES permits.

LLNL eliminated surface water discharges from 14 of the 17 cooling towers by engineering the wastewater discharges to ground through percolation pits. Towers engineered to percolation pits include Buildings 805, 809, 810, 812, 815, 817, 826, 827-1, 827-2, 828, 836D, 851-1, 851-2, and 854. Towers that will continue regular discharges to surface water drainage courses are Buildings 801, 836A, and 865. The Central Valley RWQCB waived the need for WDRs for discharges to the percolation pits because the discharges posed no threat to the receiving water body (ground water) if the pits were constructed and operated as designed. Construction and rerouting of the discharges began in September 1994

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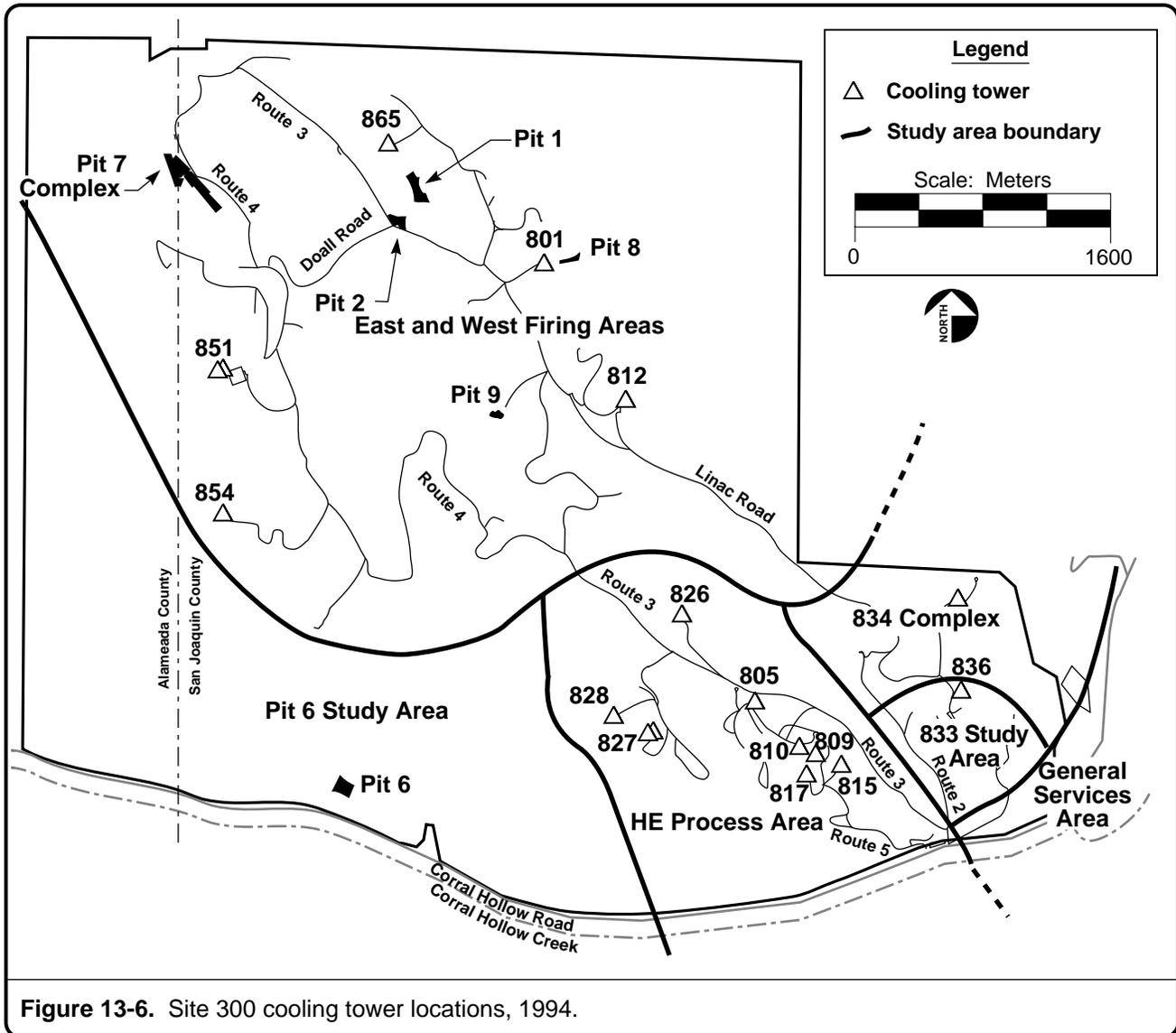


Figure 13-6. Site 300 cooling tower locations, 1994.

and was completed by the compliance schedule deadline, December 1994. WDR Order No. 94-131 established limitations for these 14 towers for the interim period when the percolation pits were under construction and for periods when it may be necessary to temporarily switch discharges back to surface water drainage courses, such as during maintenance of the percolation pits.

For the January through May period, LLNL monitored pH, temperature, and discharge flow. Specific limitations imposed for this period included: (1) daily flow must not exceed maximum design flow, (2) temperature must not alter the ambient receiving water temperature by more than 2.8°C (5°F), and (3) pH must be within the range of 6.5 to 8.5 pH units.

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The revised monitoring program under WDR Order No. 94-131 continued the maximum flow requirement, eliminated the temperature requirement, granted the requested expanded pH range, and added total dissolved solids (TDS) limitations. The maximum pH for surface water discharges from all of the cooling towers was expanded from 8.5 to 10.0.

The new permit established daily maximum and monthly average TDS limitations for the three towers continuing to regularly discharge to surface water drainage courses. Separate limits were established for the other 14 towers for the temporary periods of discharge to surface water drainage courses. Regular discharges from Buildings 801, 836A, and 865 cannot exceed a monthly average of 2000 mg/L nor a maximum daily limitation of 2,400 mg/L. TDS concentrations for the other 14 towers during periods of surface water discharge cannot exceed a monthly average of 2,000 mg/L nor a daily maximum of 5,000 mg/L.

pH

For the period of January through May, cooling tower discharges routinely exceeded the maximum pH limitation of 8.5. The noncomplying levels occurred during normal operations. The source of cooling tower supply water is on-site drinking water wells, which routinely has a pH of 8.1 to 8.7. The addition of corrosion-inhibiting chemicals further raises the pH. The Central Valley RWQCB concurred with LLNL's argument that no negative impact to the receiving water results from these discharges and raised the pH limitation to 10.0. All discharges were in compliance with the pH limitation after May 1994.

Temperature

Temperature was only reported from the period of January through May because it was not a required monitoring parameter under the renewed permit. LLNL did not note any noncompliance with this requirement.

Flow

The cooling towers routinely operate below the permitted flow requirement. Occasional excursions are noted in monitoring reports. These excursions more likely result from over estimating the flow rate than actually exceeding the design flow capacity of a tower. LLNL does not use automatic flow monitors on the cooling tower. LLNL technicians estimate total flow from 5-minute interval measurements. Cooling towers discharge wastewater intermittently rather than continuously as this estimation technique assumes.

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### TDS

All valid samples collected show cooling tower discharges are in compliance with the TDS daily maximum and monthly average limits. Two sample sets collected at the beginning of the new monitoring period were determined to be invalid when it was discovered that the wrong meter was used to measure TDS. After this occurrence, all compliance TDS samples were submitted for certified analysis by EPA-approved method 160.1. In addition, LLNL staff began using a calibrated TDS meter for maintenance measurements.

### Discharges from Categorical Pretreatment Processes

Self-monitoring wastewater pretreatment programs are required at both the Livermore site and Site 300 by the LWRP serving under the authority of San Francisco Bay RWQCB. The LWRP has identified specific LLNL wastewater generating processes that fall under the definition regulation of two categorical standards: electrical and electronic components and metal finishing. The sampling and monitoring from nondomestic, industrial sources covered by pretreatment standards defined in 40 CFR 403 is required in the 1994–1995 Waste Discharge Permit No. 1250 issued for the discharge of wastewater from LLNL into the City of Livermore sewer system.

The general pretreatment regulations establish both general and specific prohibited discharge standards (40 CFR 403.5) that apply to all industrial users. Categorical standards are published by the EPA as separate regulations and contain numerical limits for the discharge of pollutants from specified industrial categories. However, because LLNL has been, and is continuing to pursue an exemption from the categorical standards with the EPA, components of the standards have not been followed as in past years. This is being done with the understanding and concurrence of both the LWRP and the Pretreatment Coordinator, EPA Region 9.

This year LLNL has maintained strict compliance with all applicable categorical standard discharge limits that apply to industrial processes discharging to the sanitary sewer. However, we have not formally adhered to the monitoring and reporting requirements stated in Discharge Permit 1250 (1994–1995) or 40 CFR 433 or 469. Quarterly and semiannual sampling did not take place, nor were semiannual wastewater reports submitted to the LWRP. Similarly LWRP has suspended its inspection schedule of the regulated processes at LLNL. LLNL has formally notified both the LWRP and the EPA that regulatory documentation will not be provided pending the final outcome of this exemption request. LLNL wastewater representatives are working closely with LWRP and the EPA personnel to reach a decision in this matter. When a decision has been reached on the future level of compliance LLNL must follow regarding the categorical standards, LLNL will continue to maintain strict adherence to the applicable requirements.

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Although the list of LLNL wastewater-generating processes that meet the definition of a Categorical Discharger (as set forth in the Industrial Categories 40 CFR 405 through 471) changes throughout the year (as a function of research and development needs fluctuating, e.g., CRADA's with a finite life span), we have maintained compliance with the applicable discharge limits for those processes identified in Discharge Permit No. 1250 (1994–1995) and discharge to the sanitary sewer. **Tables 13-12** and **13-13** provide LLNL's internal discharge limits for these wastewaters. Those processes that discharge to the sanitary sewer are subject to the pretreatment self-monitoring program specified in the Wastewater Discharge Permit issued by the LWRP. In 1994, no exceptions to the pollutant limitations of the discharge permit were observed.

**Table 13-12.** LLNL's internal discharge limits for nonradioactive parameters in wastewaters from noncategorical and categorical processes, mg/L.

Parameter	Noncategorical <sup>(b)</sup>	Discharge Limits <sup>(a)</sup>	
		Metal Finishing	Electronic Components
<b>Metals</b>			
Beryllium	0.74		
Cadmium	0.9	0.26	
Chromium (total)	4.9	1.0	
Copper	10	2.07	
Cyanide <sup>(c)</sup>	5	0.65	
Lead	4.9	0.43	
Mercury	0.05		
Nickel	5	2.38	
Silver	1	0.24	
Zinc	15	1.48	
<b>Organics</b>			
Total toxic organics	4.57	2.13	1.37
<b>Physical</b>			
pH (units)	5–10	5–10	5–10
<b>Other</b>			
Oil and grease	500		
Total dissolved solids	375 above background		

<sup>a</sup> These standards are specified by the EPA. By regulation, the EPA or City of Livermore limit is used, whichever is lower. Noncategorical limits apply where no standard is specified.

<sup>b</sup> These standards have been established to meet the City of Livermore's requirements at the Building 196 outfall.

<sup>c</sup> Limits apply to CN discharges other than CN salts. CN salts are classified by the State of California as "extremely hazardous waste" and cannot be discharged to the sewer.

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**Table 13-13.** LLNL's internal discharge limits for radioisotopes in wastewaters.

Parameter	Individual Discharges		Total Daily Limit for Site	
Gross alpha	11.1 Bq/L	(0.3 $\mu$ Ci/1000 L)	185 kBq	(5.0 $\mu$ Ci)
Gross beta	111 Bq/L	(3.0 $\mu$ Ci/1000 L)	1.85 MBq	(50.0 $\mu$ Ci)
Tritium	185 kBq/L	(5.0 mCi/1000 L)	3.7 GBq	(100.0 mCi)
Gamma		—(a)		—(a)

<sup>a</sup> There is no gross gamma limit; isotope-specific limits apply.

### Site 300 Ground Water Compliance Monitoring

Ground water compliance monitoring programs are carried out at Site 300 in response to LLNL Site 300 Resource Conservation and Recovery Act (RCRA) Closure and Post-Closure Plans for Landfill Pits 1 and 7 and WDR Order Nos. 93-100 and 85-188. Compliance monitoring and reporting allow LLNL to evaluate operations of RCRA Landfill Pits 1 and 7 and the High Explosive (HE) Process Area Class II surface impoundments and assure they are consistent with regulatory requirements. WDR Order No. 85-188 establishes the basis for compliance monitoring for HE Process Area Class II Surface Impoundments. WDR Order No. 93-100 and the post-closure monitoring plan developed within the RCRA Closure and Post-Closure Plans established the basis for the compliance monitoring network around Pits 1 and 7. Data presentation and evaluation for these compliance networks are presented in Chapter 7. These monitoring programs include quarterly monitoring of the ground water wells in each monitoring network and quarterly and annual self-monitoring reporting.

Monitoring Reporting Program No. 93-100 for the Pits 1 and 7 network includes sampling and analysis of ground water monitoring wells for parameters listed in **Table 13-14** and establishes concentration limits at the point of compliance. The post-closure monitoring plan requires sampling and analysis of ground water from wells for following the parameters:

- Pit 1—Arsenic, cadmium, chloride, chromium, iron, phenols, manganese, mercury, nickel, nitrate, selenium, silver, sodium, sulfate, conductivity, pH, TOC, TOX, barium, beryllium, lead, VOCs using EPA Method 601/624, semivolatile organic compounds using EPA Method 625, gross alpha, gross beta, tritium, HMX, RDX, and TNT.
- Pit 7—Antimony, VOCs using 601/624, gross alpha, gross beta, and tritium.

Ground Water Monitoring Program No. 85-188 does not establish concentration limits at the point of compliance but requires quarterly sampling for the following parameters and constituents: total organic halogens (TOX), total organic carbon (TOC), pH, electrical conductivity, nitrate, nitrite, high explosive compounds (HMX and RDX), nickel, selenium, silver, thallium, vanadium, zinc, molybdenum, antimony, arsenic, barium, beryllium, cadmium, chromium,

## 13. Compliance Self-Monitoring



cobalt, copper, lead, manganese, and mercury. The monitoring program also requires weekly inspection of the surface impoundments leachate collection systems for fluid accumulation and quarterly checking of lysimeters or the leachate collection systems. If water is found in the lysimeters or the leachate collection systems, the water must be analyzed for pH, electrical conductivity, HMX, and RDX.

**Table 13-14.** Monitoring parameters and concentration limits for landfill Pits 1 and 7 under WDR Order No. 93-100.

Constituents	Units	Concentration Limits Pit 1	Concentration Limits Pit 7
<b>Parameters</b>			
Depth to ground water	feet		
Total dissolved solids	mg/L		
Specific conductance	µmho/cm		
Temperature	Degrees Celsius		
pH	pH units		
<b>Metals</b>			
Arsenic	mg/L	0.02	TBD <sup>(a)</sup>
Barium	mg/L	0.05	0.09
Beryllium	mg/L	0.0005	0.0005
Cadmium	mg/L	0.0005	TBD
Cobalt	mg/L	TBD	TBD
Copper	mg/L	0.07	TBD
Lead	mg/L	0.009	0.009
Nickel	mg/L	0.10	TBD
Vanadium	mg/L	0.05	0.05
Zinc	mg/L	0.06	TBD
<b>Radiologicals</b>			
Radium 226	(pCi/L)	1.0	TBD
Tritium	(pCi/L)	500	85.7
Uranium-233,234	(pCi/L)	2.0	2.1
Uranium-235	(pCi/L)	0.2	0.1
Uranium-238	(pCi/L)	1.0	1.6
Thorium 228	(pCi/L)	TBD	TBD
Thorium 232	(pCi/L)	TBD	TBD
<b>Explosives</b>			
HMX	µg/L	26	TBD
RDX	µg/L	30	TBD

<sup>a</sup> TBD = Concentration limits are to be determined.





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### Introduction

Quality assurance (QA) is a system of activities and processes put in place to assure that monitoring and measurement data meet user requirements. Quality Control (QC) consists of procedures used to verify that prescribed standards of performance in the monitoring and measurement process are attained. Quality assurance requirements for environmental monitoring of DOE facilities are mandated by DOE orders and guidance. DOE Order 5400.1 identifies QA requirements for radiological effluent and surveillance monitoring and specifies that a QA program consistent with DOE Order 5700.6 be established. The latter order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs. The DOE Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (U.S. Department of Energy 1991) requires the preparation of an Environmental Monitoring Plan containing a QA section discussing the applicable elements of the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1, Quality Assurance Program Requirements for Nuclear Facilities (ASME 1989).

LLNL conducted QA activities in 1994 at the Livermore site and Site 300 in accordance with a plan based on DOE Order 5700.6C (Garcia and Failor 1993). DOE Order 5700.6C prescribes a risk-based, graded approach to QA. This process promotes the selective application of QA and management controls based on the risk associated with each activity, maximizing the effectiveness and efficiency in resource use.

LLNL environmental sampling is conducted according to procedures published in an appendix to the LLNL *Environmental Monitoring Plan* (Tate et al. 1995). Environmental monitoring samples are analyzed by LLNL or commercial laboratories using EPA standard methods when available. When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. The radiochemical methods used by LLNL laboratories are described in each laboratory's procedures. When analyses are performed by independent contractors, LLNL requires that their laboratories be certified by the State of California for the analyses performed for LLNL. In addition, LLNL requires all analytical laboratories to maintain adequate quality assurance programs and documentation of methods.

### Quality Assurance Activities

The LLNL environmental monitoring program was audited successfully by the Department of Energy (EH-24) and the Defense Nuclear Facility Safety Board in 1994.

An intergroup forum was established within the Environmental Protection Department (EPD) to address issues with contract analytical laboratories. Several issues were resolved, including development of a shipping protocol for environmental samples, resolution of electronic data transfer issues, resolution of an apparent bottle contamination problem, and identification of a laboratory with the capability of providing one type of analysis that the contracted laboratories previously had been unable to perform adequately. One of five contract analytical laboratories used by the environmental monitoring program was audited by EPD personnel in 1994, and audits of the remaining four laboratories are planned for 1995. A formal program for review of laboratory quality control data was also initiated, and LLNL began a program in which quarterly performance evaluation samples are sent to its contract analytical laboratories.

During 1994, 181 Nonconformance Reports (NCRs) were written. The major sources of NCRs were failure of air particulate sampling equipment and analytical laboratory problems. Air particulate sampling equipment problems are ongoing and cannot be eliminated without a major resource expenditure for upgraded equipment. Analytical laboratory issues are being addressed as they arise.

In September 1994, a nationally recognized expert in environmental monitoring was brought to LLNL to give a two-day training to environmental monitoring personnel. This training included basic environmental sampling and analysis techniques, quality control and quality assurance, and an introduction to data quality objectives.

### Participation in Laboratory Intercomparison Studies

During 1994, LLNL's Radiation Analytical Sciences (RAS) laboratory and the Hazards Control Department analytical laboratory (HCAL) both participated in the EPA's Environmental Monitoring Systems Laboratory (EMSL) Intercomparison Studies Program. All eight samples analyzed by HCAL fell within the control limits provided by EMSL. Two of 11 samples analyzed by RAS gave unacceptable results. One was due to an error in data reduction; the other was due to startup errors for a new analysis method.

HCAL participated in four California Department of Health Services Environmental Laboratory Accreditation Program (ELAP) water pollution studies for metals during 1994. One of 70 analyses fell outside of acceptable limits for this program because of a zinc contamination problem at the laboratory, which has been resolved.

RAS also participated in the 1994 intercomparison studies by the DOE Environmental Measurements Laboratory for various radionuclides on air filters and in soil, vegetation, and water. Ten of 52 analyses fell outside of acceptable limits. Two were due to calculation errors, two were due to reporting the wrong exponent value for results presented in scientific notation, and four were due to a problem with plutonium that is still under investigation.

The potential effects of unacceptable intercomparison study results on routine data have not been determined or evaluated. It has been recommended that the EPD group currently focusing on quality control results from analytical laboratories assume the responsibility for this investigation and begin to develop a better understanding of intercomparison study results during 1995.

The results of all of these intercomparison studies are presented in Volume 2. Contract laboratories are also required to participate in laboratory intercomparison programs; however, permission to publish their results for comparison purposes has not been granted.

#### Duplicate Analyses

**Tables 14-1** through **14-3** present data generated by duplicate samples submitted to the same analytical laboratory, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 14-1** and **14-2** contain data pairs with both values above the detection limit and all radiological results for which a reported value was available. They exclude radiological values for which only a minimum detectable activity was reported. In addition, **Table 14-2** excludes radiological results for which the reported value was negative. **Table 14-3** contains data pairs with either or both values below the detection limit.

If there are more than eight data pairs with both results above the detection limit, precision and regression analyses are performed; the results are presented in **Table 14-1**. Precision is measured by the percent relative standard deviation [%RSD; see the EPA *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. Environmental Protection Agency 1987)]. Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, values above 30% are common. The results for %RSD given in **Table 14-1** are the 75th percentile of the distribution of individual precision values. Regression analysis consists of fitting a straight line to the duplicate-routine pairs, as illustrated in **Figure 14-1**. Good agreement between the duplicate and routine samples is indicated when the data lie close to a line with slope equal to one and intercept equal to zero. Allowing for normal analytical variation, the slope of the line should be between 0.7 and 1.3, and the intercept should be within  $\pm$  the detection limit. The coefficient of determination ( $r^2$ ) should be  $>0.8$ .

## 14. Quality Assurance



**Table 14-1.** Quality assurance duplicate sampling. Summary statistics for analytes with more than eight pairs in which both results were above the detection limit.

Media	Analyte	Units	N <sup>(a)</sup>	% RSD <sup>(b)</sup>	Intercept	Slope	r <sup>2</sup>
Air	Beryllium <sup>(c)</sup>	pg/m <sup>3</sup>	11	23.1	1.50	0.733	0.28
	Gross alpha <sup>(d)</sup>	pCi/L	97	121.	$-4.26 \times 10^{-8}$	0.933	0.090
	Gross beta	pCi/L	97	29.5	$-7.36 \times 10^{-7}$	0.976	0.83
	Tritium <sup>(c)</sup>	pCi/L	35	23.2	-0.00048	1.22	0.67
Building Drain Investigation	Copper <sup>(c)</sup>	mg/L	10	38.2	0.118	1.32	0.57
	Zinc	mg/L	9	59.1	0.0540	0.934	0.93
Radiation dose	Rad dose <sup>(c)</sup>	mrem	50	2.40	-0.165	1.01	0.67
Ground water	Arsenic	mg/L	38	5.94	-0.0009	1.03	0.98
	Bicarbonate alkalinity (as CaCO <sub>3</sub> )	mg/L	12	5.50	-16.8	1.10	0.76
	Calcium	mg/L	14	3.63	1.38	0.988	1.0
	Chloride	mg/L	13	2.48	-3.32	1.02	1.0
	Fluoride	mg/L	12	2.92	0.0215	0.945	0.99
	Gross alpha <sup>(d)</sup>	pCi/L	8	112	1.18	0.349	0.12
	Gross beta <sup>(d)</sup>	pCi/L	13	40.9	1.30	0.813	0.34
	Magnesium	mg/L	14	3.14	-0.125	1.02	0.99
	Nitrate (as N)	mg/L	9	6.73	0.558	0.917	0.97
	Potassium	mg/L	13	4.88	-0.208	1.00	0.99
	Radium-226 <sup>(c)</sup>	pCi/L	15	67.0	0.334	-0.0219	0.031
	Selenium	mg/L	19	5.89	-0.00105	1.11	0.86
	Sodium	mg/L	13	3.04	1.79	0.998	1.0
	Specific conductance	µmhos/cm	52	3.55	-47.9	1.07	0.99
	Sufate	mg/L	13	4.22	-1.08	0.999	1.0
	TDS	mg/L	39	5.44	-10.6	1.02	0.99
	TOC <sup>(d)</sup>	mg/L	16	84.9	2.91	0.0419	0.0031
	TOX <sup>(d)</sup>	mg/L	19	79.8	0.0403	0.240	0.17
	Total alkalinity (as CaCO <sub>3</sub> )	mg/L	12	5.50	-16.8	1.10	0.76
	Total hardness (as CaCO <sub>3</sub> )	mg/L	15	4.04	-50.0	1.17	0.86
	Tritium <sup>(c)</sup>	pCi/L	9	14.9	6,250	-0.0101	0.0063
	Uranium-234, Uranium-233 <sup>(c)</sup>	pCi/L	16	53.3	-0.426	1.29	0.93
	Uranium-235, Uranium-236 <sup>(d)</sup>	pCi/L	15	81.2	-0.368	6.30	0.14
Uranium-238	pCi/L	16	50.9	-0.275	1.30	0.97	
pH	Units	50	0.962	-0.0865	1.01	0.67	

## 14. Quality Assurance



**Table 14-1.** Quality assurance duplicate sampling. Summary statistics for analytes with more than eight pairs in which both results were above the detection limit (concluded).

Media	Analyte	Units	N <sup>(a)</sup>	% RSD <sup>(b)</sup>	Intercept	Slope	r <sup>2</sup>
Sewer	Gross alpha <sup>(d)</sup>	pCi/L	45	126	-0.617	1.42	0.40
	Gross beta	pCi/L	45	17.7	-1.66	1.10	0.80
	Tritium	pCi/L	44	82.6	0.829	0.908	0.93

<sup>a</sup> Number of duplicate pairs included in analysis.

<sup>b</sup> 75th percentile of percent relative standard deviation (%RSD), where  $\%RSD = \left( \frac{200}{\sqrt{2}} \right) \left( \frac{|x_1 - x_2|}{(x_1 + x_2)} \right)$  and  $x_1$  and  $x_2$  are the reported concentrations of each routine-duplicate pair.

<sup>c</sup> Outside acceptable range of slope or r<sup>2</sup> due to outliers.

<sup>d</sup> Outside acceptable range of slope or r<sup>2</sup> due to variability.

**Table 14-2.** Quality assurance duplicate sampling. Summary statistics for selected analytes with eight or fewer pairs in which both results were above the detection limit.

Media	Analyte	N <sup>(a)</sup>	Mean Ratio	Minimum Ratio	Maximum Ratio
Air	Plutonium-239	5	1.1	0.29	2.4
Ground water	Chromium	7	0.99	0.83	1.2
	Thorium-228	6	1.6 <sup>(b)</sup>	0.53	4.5
	Thorium-232	5	0.81	0.015	1.8
	Tritium	2	0.86	0.74	0.98
Runoff (from rain)	Gross alpha	4	1.2	0.22	2.8
	Gross beta	4	1.1	0.85	1.5
	Tritium	1	1.1	1.1	1.1
Soil	Beryllium	2	0.95	0.86	1.0
	Cesium-137	3	1.3	0.94	1.8
	Plutonium-239	3	0.77	0.006608	1.3
Surface water (e.g., ponds, streams)	Tritium	7	0.98	0.81	1.2
Vegetation	Tritium	6	0.76	0.14	1.0
	Tritium, per gram dry weight	6	0.62 <sup>(b)</sup>	0.089	1.1

<sup>a</sup> Number of data pairs.

<sup>b</sup> Outside acceptable range of 0.7–1.3.



**Table 14-3.** Quality assurance duplicate sampling. Summary statistics for analytes with at least four pairs in which one or both results were below the detection limit.

Media	Analyte	Number of Inconsistent Pairs	Number of Pairs	Percent of Inconsistent Pairs
<b>Air</b>	Beryllium	1	13	7.69
	Plutonium-239	1	7	14.29
<b>Building Drain Investigation</b>	Aluminum	1	8	12.5
	Barium	1	9	11.11
	Chloroform	1	5	20
	Copper	2	6	33.33
	Iron	1	7	14.29
	Lead	1	7	14.29
	Methylene chloride	3	5	60
	Silver	1	13	7.69
	Zinc	1	7	14.29
	<b>Ground water</b>	Antimony	1	4
Lead		1	33	3.03
TOC		1	4	25
Tritium		1	19	5.26
<b>Vegetation</b>	Tritium	1	6	16.67
	Tritium, per gram dry weight	1	6	16.67

If there are eight or fewer data pairs with both results above the detection limit, the ratios of the individual duplicate sample pairs are averaged; the average, minimum, and maximum ratios for selected analytes are given in **Table 14-2**. The average ratio should be between 0.7 and 1.3.

If one of the results in a pair is below the detection limit, then the other result should be less than two times the detection limit. **Table 14-3** identifies the sample media and analytes for which at least one pair failed this criterion. Analytes with fewer than four pairs total are omitted from the table.

These analyses show generally good agreement between routine samples and quality assurance duplicates: approximately 75% of the pairs have a precision better than 30%. Data pairs that do not fall into this area of precision generally fall into one of two categories. The first category, outliers, can occur due to data transcription errors, measurement errors, or real but anomalous results. Of 35 data sets reported in **Table 14-1**, seven did not meet the criterion for acceptability due to outliers. The other category of results that does not meet the

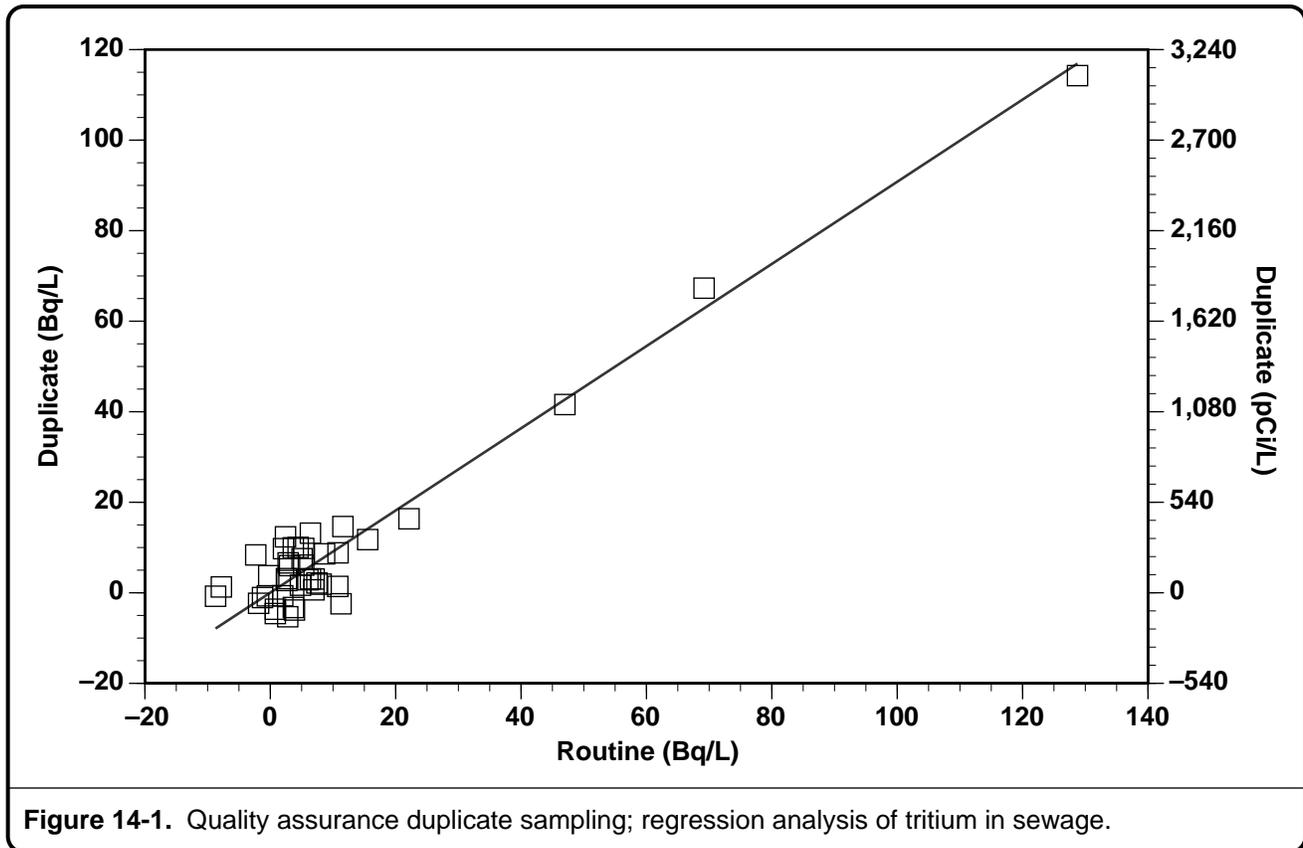


Figure 14-1. Quality assurance duplicate sampling; regression analysis of tritium in sewage.

criterion for acceptability consists of data sets in which there is a lot of scatter. This tends to be a problem for measurements at extremely low concentrations in general. Low concentrations of particulates in air highlight this effect even more because one or two particles on an air filter can significantly impact results. Another cause of high variability is sampling and analytical methodology. Analyses of total organic carbon and total organic halides are particularly difficult to control. Of the 35 data sets in **Table 14-1**, seven show sufficient variability in results to make them fall outside of the acceptable range.

Quality assurance duplicates may also be used to identify errors—for example, mislabeled samples and data entry errors. Less than one percent of the samples involved in the duplicate sampling regime appear to have errors of this kind. This indicates that we have maintained a high standard of sample handling and data management.

### Deviations and Changes to the Sampling Program

Changes to the environmental sampling effort made during 1994, deviations from planned environmental sampling, and regularly scheduled samples for which data are not reported because they could not be collected or were lost during analysis are summarized below.



## Changes to Environmental Monitoring Networks

Changes that were made to environmental monitoring networks in 1994 are summarized in **Table 14-4**. One air particulate and air tritium monitoring location (L-LCCY) was eliminated during 1994 because of continued vandalism of sampling equipment at that locations. Minor changes in locations were made to the rain and arroyo sediment monitoring networks to more effectively monitor LLNL's impact on the environment based on technical review of those monitoring networks. Two new monitoring networks were added in 1994. Compliance monitoring at Site 300 was added for storm water runoff and for cooling tower water.

The LLNL environmental monitoring program uses alpha-numeric location designator codes to define sampling locations. Volume 2 includes tables that decode these sampling location designators and provide a cross-reference between current designators and those used in previous years. Changes made in 1994 are noted on those tables.

**Table 14-4.** Changes to environmental monitoring networks in 1994.

Environmental Medium	Livermore Site	Site 300
Air particulate	Abandoned location L-LCCY	No changes made in 1994
Air tritium	Abandoned location L-LCCY	No changes made in 1994
Soil	No changes made in 1994	No changes made in 1994
Arroyo sediment	Abandoned locations L-438E, L-4THA, L-ALPN, and L-ALPW , and added location L-ESB in 1994	No changes made in 1994
Vegetation	Added location L-GRD	No changes made in 1994
Milk	Abandoned after 1993	—
Honey	Abandoned after 1993	—
Wine	No changes made in 1994	—
Rain	Added location L-VET	No changes made in 1994
Storm water runoff	Added location L-CDBX	Monitoring began in 1994
Drainage Retention Basin	No changes made in 1994	—
Other surface water	No changes made in 1994	—
Ground water	—	No changes made in 1994
Cooling towers	—	Monitoring began in 1994
Sewage	No changes made in 1994	—
Thermoluminescent dosimeters	No changes made in 1994	No changes made in 1994
Neutrons	1994 results not reported due to equipment/calibration problems	—

### Explanation of Missing Samples

Planned samples and actual samples collected and analyzed in 1994 are summarized in **Table 14-5**. With the exception of the storm-water runoff network, the Drainage Retention Basin, and neutron monitoring, the levels of completeness for networks that were reported previously are similar to historical levels.

**Table 14-5.** Sampling completeness in 1994, Livermore site and Site 300.

Environmental Medium	Samples Planned	Samples Analyzed	Completeness
Air particulate	1664	1568	94%
Air tritium	494	463	94%
Soil	46	46	100%
Arroyo sediment	46	45	98%
Vegetation	94	92	98%
Wine	25	25	100%
Rain	87	87	100%
Storm water runoff	36	25	69%
Drainage Retention Basin	312	228	73%
Other surface water	70	70	100%
Ground water	2155	2153	99.9%
Sewage	653	631	97%
Thermoluminescent dosimeters	397	373	94%
Neutron monitors	32	0	0%
Cooling towers	49	36	73%

A drop in completeness occurred for the storm water runoff network because samples planned for late 1994 (the beginning of the rainy season) could not be taken because no storm occurred that generated enough runoff for sampling during that period. Several weekly drainage retention basin samples were overlooked by sampling technologists during 1994, leading to diminished sampling completeness for that network. This training issue has been addressed. Neutron monitoring results for 1994 were not presented because the REM meters were found to be seriously out of calibration due to age-related deterioration. This monitoring network was eliminated at the end of 1994 (see Chapter 11). See Volume 2 for additional discussion about missed samples.

The one new sampling network for 1994, Site 300 Cooling Towers, also exhibited relatively low completeness. This was due to sampling startup errors and difficulties in accessing the cooling towers.

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**Statistical Methods**

Statistical methods used in this report have been implemented pursuant to the *Environmental Monitoring Plan* (Tate et al. 1995). These methods reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Data review and analyses are conducted in accordance with the *Environmental Monitoring Plan* and the Environmental Monitoring Section's Data Analysis Procedure. These documents contain detailed information regarding the acceptability of data and the procedures that are followed for the identification, notification, and correction of suspect data.

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**Radiological Data**

The precision of radiological analytical results is displayed in the data tables as the  $2\sigma$  counting error. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a  $2\sigma$  counting error greater than 100% is said to be below the detection criterion and is presented in the tables with a less-than symbol (<) to indicate its status. No value of error is reported for values below the detection criterion. The reported concentration is derived from the number of sample counts minus the number of background counts. A sample with a low or zero concentration may therefore be reported to have a negative value; such results are reported in the tables and used in the calculation of summary statistics and statistical comparisons. Some analytical laboratory reports provide a minimum detectable activity rather than a reported value when the radiological result is below the detection criterion.

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**Nonradiological Data**

Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than symbol. The actual detection limit values are used in the calculation of summary statistics as explained below.

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**Statistical Comparisons**

Standard comparison techniques (such as regression, *t*-tests, and analysis of variance) have been used where appropriate to determine the statistical significance of trends or differences between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word "significant" in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance and are based on professional judgment.



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### Summary Statistics

Determinations of measures of central tendency and associated measures of dispersion are calculated according to Environmental Monitoring Section's Data Analysis Procedure. For data sets not containing values below the detection criterion, the measure of central tendency and dispersion are the median and interquartile range (IQR). The IQR is the range that encompasses the middle 50% of the data set.

For data sets with one or more, but fewer than one half, values below the detection criterion, the measure of central tendency is the median. If the values of the detection limits and the number of values below the detection limit permit (determined on a case-by-case basis), dispersion is reported as the IQR. Otherwise, no measure of dispersion is reported. Statistics are calculated using the reported detection limit value for nonradiological data or the reported value for radiological data.

For data sets with one half or more of the values below the detection criterion, the central tendency is reported as less than the median value. Dispersion is not reported.

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### Radiation Units

Data for 1994 have been reported in Système Internationale (SI) units to conform with standard scientific practices and federal law. Values in the text are reported in becquerels (Bq) and millisieverts (mSv); equivalent values in picocuries (pCi) and millirems (mrem) are given in parentheses.



## Appendix A. 1994 EPD Publications

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# Appendix B. Methods of Dose Calculations

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Robert J. Harrach  
Kris A. Surano

## Introduction

Radiological doses calculated from measured activities are a principal indicator of the potential impact of LLNL operations on surrounding populations. The doses from ingestion of water and locally produced foodstuff are based on actual measurements of radionuclide concentrations in the various media, determined by sampling, as described in Chapters 6 through 10. Data needed to evaluate potential doses from the inhalation and immersion pathways are provided by air surveillance monitoring, as described in Chapter 4.

The data on radionuclide concentrations or activities in these media are necessary inputs to the dose-rate equations described here. The examples presented below concern dose assessments for significant agricultural products of the Livermore Valley, including milk, wine, honey, and general vegetation, and in particular describe the forage-cow-milk pathway for ingestion of tritium in vegetation. The rate equations can also be used to estimate doses that would occur from ingestion of water at each of the Livermore Valley and Site 300 water sampling locations, though none of these is actually a primary source of drinking water.

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## Dose Calculation Methods

The dose calculation methods given here for the ingestion, inhalation, and immersion pathways are based on the NRC Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent* (U.S. Nuclear Regulatory Commission 1977). The dose and dose-rate conversion factors used in these calculations were obtained from the committed dose equivalent tables for DOE dose calculations and are consistent with those specified in *ICRP 30, Limits of Intakes of Radionuclides by Workers* [International Commission on Radiological Protection (ICRP) 1980].

The calculations use conventional activity units of picocuries (pCi) and dose units of millirem (mrem). The conversion constants that apply when converting to Système International (SI) activity units of becquerels (Bq) and dose units of sieverts (Sv) are:

$$\begin{aligned}1 \text{ pCi} &= (3.7 \times 10^{-2}) \text{ Bq} \\1 \text{ mrem} &= (1 \times 10^{-5}) \text{ Sv} = 10 \text{ } \mu\text{Sv} = 1 \times 10^{-2} \text{ mSv}\end{aligned}$$

The annual whole-body dose rate from ingestion of a particular food or drink is expressible as a product of three factors: the rate the food or drink is consumed (e.g., in L/y), the radionuclide concentration (e.g., in pCi/L) in the food or drink, and the dose rate conversion factor (e.g., in mrem/pCi) for the radionuclide. In

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the following subsections, equations of this type are used to estimate the annual dose from tritium in water and milk (directly consumed), as well as radionuclides in meat, leafy vegetables, wine, and honey. Milk and honey are no longer sampled by LLNL because they are not impacted by LLNL's radionuclide releases, but the calculational examples have been retained here.

Generally, the concentrations are measured, while the appropriate consumption-rate factors are taken from the literature. The water and milk consumption rates are estimated to be 730 L/y and 310 L/y, respectively, in Appendix 1 of the NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). The consumption rate for honey is reported to be 0.51 kg/y per person, or about 0.36 L/y, in the U.S. Department of Agriculture food consumption survey of 1977–1978 (Shlein and Terpilak 1984). In the absence of consumption data on locally produced wine, we employ the conservative (high dose) assumption that the intake rate for wine is the same as that for water. The resultant dose is expected to be several times too high for wine but well below levels of health concern.

LLNL's first use of these dose-rate formulas in our environmental annual reports is described by Lindeken et al. (1978) and by Silver et al. (1980).

### Annual Dose from Potable Water

Based on the assumption that all water sampled is available as drinking water, the annual whole-body dose for tritium in mrem/y is calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem/y}) = C_w \times U_w \times D_w \quad (\text{B-1})$$

where

$C_w$  = concentration of tritium in water (pCi/L)

$U_w$  = water consumption rate (L/y) = 730 L/y for maximally exposed individual

$D_w$  = dose conversion factor (mrem/pCi)

=  $6.3 \times 10^{-8}$  mrem/pCi for tritium for the whole-body ingestion pathway for an adult (similarly, for  $^{40}\text{K}$  the dose conversion factor is  $1.88 \times 10^{-5}$  mrem/pCi, and for  $^{137}\text{Cs}$ , it is  $2.17 \times 10^{-7}$  mrem/pCi)

$D_{\text{whole body}}$  = effective dose equivalent (mrem/y) from ingestion of 730 L of potable water with tritium concentration  $C_w$ .

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### Annual Dose from Forage-Cow-Milk Pathway for Tritium in Vegetation

Based on the assumption that all feed for the cattle was pasture grass, the effective dose equivalent per mCi/mL of tritiated water (HTO) for the maximally exposed individual is calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem}/\text{y}) = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \quad (\text{B-2})$$

where

$D_{\text{veg}}$  = mrem/y dose from ingestion of vegetables

$D_{\text{meat}}$  = mrem/y dose from ingestion of meat

$D_{\text{milk}}$  = mrem/y dose from ingestion of milk.

### Vegetation

$$D_{\text{veg(leafy)}} = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}} \quad (\text{B-2a})$$

where

$U_{\text{veg}}$  = intake rate (kg/y): 64 kg/y for maximally exposed individual

$C_{\text{veg}}$  = concentration (pCi/kg):  $10^9 \frac{\text{pCi}/\text{kg}}{\mu\text{Ci}/\text{mL}}$   
 $\times (C_{\text{veg}} [\mu\text{Ci}/\text{mL} \text{ measured}])$

$D_{\text{HTO}}$  = dose factor (mrem/pCi):  $6.3 \times 10^{-8}$  mrem/pCi for  $^3\text{H}$  for the adult wholebody ingestion pathway.

The tritium dose from ingestion of vegetation is then

$$D_{\text{veg}}(\text{mrem}/\text{y}) = (0.40 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci}/\text{mL} \text{ measured}]).$$

### Meat

$$D_{\text{meat}}(\text{mrem}/\text{y}) = U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}} \quad (\text{B-2b})$$

where

$U_{\text{meat}}$  = intake rate (kg/y): 110 kg/y for maximally exposed individual

$D_{\text{HTO}}$  = dose factor (mrem/pCi):  $6.3 \times 10^{-8}$  mrem/pCi for  $^3\text{H}$  for the adult whole-body ingestion pathway

$C_{\text{meat}}$  =  $(F_f) \times (Q_f) \times (C_{\text{veg}}) \times (e^{-\lambda t_s})$

$D_{\text{HTO}}$  = dose factor (mrem/pCi):  $6.3 \times 10^{-8}$  mrem/pCi for  $^3\text{H}$  for the adult whole-body ingestion pathway

## Appendix B. Methods of Dose Calculations

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$$\begin{aligned}
 F_f &= \text{fraction of daily intake of nuclide per kilogram of} \\
 &\quad \text{animal/fish (pCi/kg in meat per pCi/d ingested by the} \\
 &\quad \text{animal) (d/kg): } 1.2 \times 10^{-2} \text{ d/kg} \\
 Q_f &= \text{amount of feed consumed (kg/d): } 50 \text{ kg/d} \\
 C_{veg} &= \text{concentration (pCi/kg): } 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \\
 &\quad \times (C_{veg} [\mu\text{Ci/mL measured}]) \\
 \lambda_i &= \text{radiological decay constant (d}^{-1}\text{): } 1.5 \times 10^{-4} \text{ d}^{-1} \\
 t_s &= \text{time between slaughter to consumption (d): } 20 \text{ d} \\
 C_{meat} &= (1.2 \times 10^{-2} \text{ d/kg}) \times (50 \text{ kg/d}) \times (C_{veg} [\mu\text{Ci/mL}]) \\
 &\quad \times \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}\right) \times (\exp\{-1.5 \times 10^{-4} \times \{20\}\}) \\
 &= 0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \times (C_{veg} [\mu\text{Ci/mL measured}]).
 \end{aligned}$$

The tritium dose rate from meat consumption is then

$$\begin{aligned}
 D_{meat}(\text{mrem/y}) &= (110 \text{ kg/y}) \times \left(0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \times C_{veg} [\mu\text{Ci/mL} \right. \\
 &\quad \left. \text{measured}] \times (6.3 \times 10^{-8} \text{ mrem/pCi})\right) \\
 &= (0.41 \times 10^4) \times (C_{veg} [\mu\text{Ci/mL measured}]).
 \end{aligned}$$

Milk

$$D_{milk}(\text{mrem/y}) = U_{milk} \times C_{milk} \times D_{HTO} \quad (\text{B-2c})$$

where

$U_{milk}$  = intake rate (L/y): 310 L/y for maximally exposed individual

$D_{HTO}$  = dose factor (mrem/pCi):  $6.3 \times 10^{-8}$  mrem/pCi for  $^3\text{H}$  for the adult whole-body ingestion pathway

$$C_{milk} = (F_m) \times (Q_f) \times (C_{veg}) \times (e^{-\lambda_i t})$$

$F_m$  = fraction of daily intake of nuclide per liter of milk (pCi/L in milk per pCi/d ingested by the animal) (d/L):  $1.0 \times 10^{-2}$  d/L

$Q_f$  = amount of feed consumed by the animal (kg/d): 50 kg/d

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$$\begin{aligned}
 C_{veg} &= \text{concentration (pCi/kg): } (10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \\
 &\quad \times (C_{veg} [\mu\text{Ci/mL measured}]) \\
 \lambda_i &= \text{radiological decay constant (d}^{-1}\text{): } 1.5 \times 10^{-4} \text{ d}^{-1} \\
 t_f &= \text{time from milking to milk consumption (d): } 2 \text{ d} \\
 C_{milk} &= (1.0 \times 10^{-2} \text{ d/L}) \times (50 \text{ kg/d}) \times (C_{veg} [\mu\text{Ci/mL}]) \\
 &\quad \times (10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \times (\exp\{-1.5 \times 10^{-4} \times \{2\}\}) \\
 &= (0.5 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \times (C_{veg} [\mu\text{Ci/mL measured}]).
 \end{aligned}$$

The tritium dose rate from directly consumed milk is then

$$\begin{aligned}
 D_{milk} \text{ (mrem/y)} &= (310 \text{ L/y}) \times ([0.5 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}] \times [C_{veg} \{\mu\text{Ci/mL measured}\}]) \times (6.3 \times 10^{-8} \text{ mrem/pCi}) \\
 &= (0.97 \times 10^4) \times (C_{veg} [\mu\text{Ci/mL measured}]).
 \end{aligned}$$

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Whole Body

$$\begin{aligned}
 D_{\text{whole body}} \text{ (mrem/y)} &= ([0.40 \times 10^4] \times [C_{veg} \{\mu\text{Ci/mL measured}\}]) \\
 &\quad + ([0.41 \times 10^4] \times [C_{veg} \{\mu\text{Ci/mL measured}\}]) \\
 &\quad + ([0.97 \times 10^4] \times [C_{veg} \{\mu\text{Ci/mL measured}\}]).
 \end{aligned}$$

The total annual dose rate from the forage-cow-milk pathway for tritium in vegetation is then

$$D_{\text{whole body}} \text{ (mrem/y)} = ([1.78 \times 10^4] \times [C_{veg} \{\mu\text{Ci/mL measured}\}]).$$

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**Inhalation/  
Immersion Dose**

Doses due to inhalation of and immersion in radionuclide-contaminated air can be estimated in an analogous way to the preceding treatment of ingestion doses. The starting point is to evaluate the radionuclide concentration in air,  $\chi$  (Ci/m<sup>3</sup>) at the location of interest.  $\chi$  can be directly measured, or calculated using a Gaussian dispersion air transport model. In the latter approach, the calculated quantity is the atmospheric dispersion parameter,  $\chi/Q$ , which is the product of the radionuclide concentration in air  $\chi$  (Ci/m<sup>3</sup>) at all locations of interest and the source release rate  $Q$  (Ci/s).

For inhalation dose, once  $\chi$  or the product  $(\chi/Q) \times (Q)$  is evaluated, it is multiplied by the inhalation rate of a human to obtain the number of curies of radioactive material inhaled by the human body. Dose and dose-rate conversion

## Appendix B. Methods of Dose Calculations

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factors provided by the DOE (U.S. Department of Energy 1988), which are consistent with those specified in *ICRP 30* (International Commission on Radiological Protection 1980), are used to relate the intake of radioactive material into the body to dose commitment. These dose factors provide estimates of 50-year dose from a chronic one-year intake of radioactivity.

The inhalation dose is expressible as

$$D_{\text{whole body}}(\text{mrem}/\text{y}) = U_{\text{inhalation}} \times C_{\text{radionuclide}} \times D_{\text{radionuclide}} \quad (\text{B-3})$$

where

$$U_{\text{inhalation}} = \text{air intake rate (L/y): } 8,400 \text{ m}^3/\text{y} \text{ for an adult}$$

$$D_{\text{radionuclide}} = \text{dose conversion factor (mrem/pCi) for the radionuclide of interest [for HTO this factor is } 1.5 \times 6.4 \times 10^{-8} \text{ mrem/pCi} = 9.6 \times 10^{-8} \text{ mrem/pCi for the adult whole-body inhalation pathway, where the factor 1.5 accounts for absorption through the skin; for other radionuclides, see Table 2.1 in Eckerman et al. (1988)]}$$

$$C_{\text{radionuclide}} = (F) \times (\chi/Q) \times (Q) = \text{radionuclide concentration at the receptor (pCi/m}^3\text{)}$$

$$F = \frac{1 \times 10^{12} \text{ pCi/Ci}}{3.15 \times 10^7 \text{ s/y}} = 3.17 \times 10^4 \text{ (pCi/Ci)/(s/y)}$$

$$Q = \text{radionuclide release rate (Ci/y)}$$

$$\chi/Q = \text{diffusion parameter (s/m}^3\text{); calculated.}$$

The wholebody inhalation dose rate is then

$$D_{\text{whole body}}(\text{mrem}/\text{y}) = (3.17 \times 10^4 \text{ [pCi/Ci]/[s/y]}) \times (\chi/Q)(\text{s/m}^3) \times (Q[\text{Ci/y}]) \times (8.4 \times 10^3 \text{ m}^3/\text{y}) \times D_{\text{radionuclide}} (\text{mrem/pCi}).$$

The immersion dose is similarly expressible as

$$D_{\text{whole body}}(\text{mrem}/\text{y}) = C_{\text{radionuclide}} \times (DRF) \quad (\text{B-4})$$

where

$$C_{\text{radionuclide}} = (F) \times (\chi/Q) \times (Q) = \text{radionuclide concentration at the receptor (pCi/m}^3\text{)}$$

$$F = \frac{1 \times 10^{12} \text{ pCi/Ci}}{3.15 \times 10^7 \text{ s/y}} = 3.17 \times 10^4 \text{ (pCi/Ci)/(s/y)}$$

$$Q = \text{radionuclide release rate (Ci/y)}$$

## Appendix B. Methods of Dose Calculations

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$\chi/Q$  = diffusion parameter (s/m<sup>3</sup>), calculated

*DRF* = the external dose-equivalent rate factor per unit radionuclide concentration (mrem/y)/(pCi/m<sup>3</sup>) [for elemental <sup>3</sup>H this factor *DRF* is  $3.9 \times 10^{-8}$  (mrem/y)/(pCi/m<sup>3</sup>); for the short-lived isotopes <sup>13</sup>N and <sup>15</sup>O it equals  $5.1 \times 10^{-3}$  (mrem/y)/(pCi/m<sup>3</sup>); for other radionuclides see Table 2.3 in Eckerman et al. (1988)].



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<b>A</b>	<b>Absorbed dose</b>	The amount of energy deposited by radiation in a given amount of material. The unit of absorbed dose is the rad.
	<b>Accuracy</b>	The closeness of the result of a measurement to the true value of the quantity measured.
	<b>ACEHS</b>	Alameda County Environmental Health Services.
	<b>ACG</b>	Ambient concentration guide.
	<b>Action Level</b>	Defined by regulatory agencies, it is the level of pollutants which, if exceeded, requires regulatory action.
	<b>Alluvium</b>	Sediment deposited by flowing water.
	<b>Alpha particle</b>	A positively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of a helium nucleus (two protons and two neutrons).
	<b>Ambient air</b>	The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.
	<b>Analyte</b>	A constituent that is being analyzed.
	<b>ANOVA</b>	Analysis of variance. A test of whether two or more sample means could have been obtained from the same statistical population.
	<b>ANSI</b>	American National Standards Institute.
	<b>Aquifer</b>	A saturated layer of rock or soil below the ground surface that can supply usable quantities of ground water to wells and springs. Aquifers can be a source of water for domestic, agricultural, and industrial uses.
	<b>Aquitard</b>	Isolated water bearing zones.
	<b>ARAR</b>	Applicable, Relevant, and Appropriate Requirement.
	<b>ASME</b>	American Society of Mechanical Engineers.
	<b>AST</b>	Aboveground storage tank.

ATA	Advanced Test Accelerator.
Atom	The smallest particle of an element capable of entering into a chemical reaction.
Atomic absorption spectroscopy	Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor. Abbreviated AA.
AVLIS	Atomic Vapor Laser Isotope Separation.
AWQC	Ambient Water Quality Criteria.
<b>B</b> BAAQMD	Bay Area Air Quality Management District. The local agency responsible for regulating stationary air emission sources (including the Livermore site) in the San Francisco Bay Area.
Barcad	Device that samples a discrete water bearing zone in a well.
BAT	Best Available Technology (economically achievable).
Beta particle	A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.
BETX	Benzene, ethyl benzene, toluene, and xylene.
BMP	Best Management Practice.
BOD	Biochemical (biological) oxygen demand. A measure of the amount of oxygen in biological processes that break down organic matter in water; a measure of the organic pollutant load. It is used as an indicator of water quality.
Bq	Becquerel. The SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.
<b>C</b> Cal-EPA	California Environmental Protection Agency.
CAM	Continuous air monitor.
CAP88	Computer code required by the EPA for modeling air emissions.
CARE	Citizens Against a Radioactive Environment.
CCR	California Code of Regulations.
CE	Conditionally exempt.

CEQA	California Environmental Quality Act of 1970. CEQA requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions. CEQA also requires that adverse environmental impacts be mitigated through mitigation measures or project alternatives.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980. Administered by EPA, this program, also known as Superfund, requires private parties to notify the EPA after the release of hazardous substances and undertake short-term removal and long-term remediation. If conditions exist that could create the threat of hazardous substances being released, the Act also requires the remediation of those conditions. In 1986, the Superfund Amendments and Reauthorization Act (SARA) was enacted, which amended and reauthorized CERCLA for five years at a total funding level of \$8.5 billion.
CFC	Chlorofluorocarbon.
CFR	Code of Federal Regulations. A codification of all regulations promulgated by federal government agencies.
Chain-of-custody	A method for documenting the history and possession of a sample from the time of its collection, through its analysis and data reporting, to its final disposition.
CHEW	Chemical Exchange Warehouse.
Chlorocarbon	A compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethylene.
CHP	California Highway Patrol.
Ci	Curie. A unit of measurement of radioactivity, defined as the amount of radionuclide in which the decay rate is $2.22 \times 10^{12}$ disintegrations per minute ( $3.7 \times 10^{10}$ disintegrations per second), which is approximately equal to the decay rate of one gram of pure radium.
CL	Concentration limit.
Coliwasa	Collimated water sampler.
Collective dose equivalent	The sums of the dose equivalents of all individuals in an exposed population within a certain radius, expressed in units of person-rem (or person-sievert).

Collective effective dose equivalent	The sums of the effective dose equivalents of all individuals in an exposed population within a certain radius, and expressed in units of person-rem (or person-sievert).
Committed dose equivalent	The predicted total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of sievert (or rem).
Committed effective dose equivalent	The sum of the committed dose equivalents to various tissues, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of sievert (or rem).
Cosmic radiation	Radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.
CRWQCB	California Regional Water Quality Control Board.
CSA	Container storage area.
<b>D</b> Daughter nuclide	A nuclide formed by the radioactive decay of another nuclide, which is called the parent.
DCG	Derived Concentration Guide. Concentrations of radionuclides in water and air that could be continuously consumed or inhaled (365 days/y) and not exceed the DOE primary radiation protection standard to the public (100 mrem/y effective dose equivalent).
DCL	Discharge Concentration Limit (City of Livermore Ordinance 13.32).
1,2-DCA	1,2-dichloroethane.
DHS	(California) Department of Health Services.
DLM	Designated Level Methodology.
DOE	U.S. Department of Energy. The federal agency that is responsible for conducting energy research and regulating nuclear materials used for weapons production.
Dose	The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.

Dose commitment	The dose which an organ or tissue would receive during a specified period of time (e.g., 50 or 100 years) as a result of intake of one or more radionuclides from one year's release.
Dose equivalent	The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert). The dose equivalent to an organ, tissue, or whole body in a year will be that received from the direct exposure plus the committed dose equivalent received from radionuclides taken into the body during the year.
Dosimeter	A portable detection device for measuring the total accumulated exposure to ionizing radiation.
Dosimetry	The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation measurement instruments.
DOT	U.S. Department of Transportation.
DRB	Drainage Retention Basin.
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control.
DUS	Donation Utilization and Sales (Group).
<b>E</b> EA	Environmental Assessment. An environmental review document that identifies environmental impacts from any federally approved or funded project. If an EA shows significant impact, an EIS is required.
EDE	Effective dose equivalent. An estimate of the total risk of potential effects from radiation exposure. It is the sum of the committed effective dose equivalent from internal deposition and the effective dose equivalent from external penetrating radiation received during a calendar year. The committed effective dose equivalent is the sum of the individual organ committed dose equivalents multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body.
EDO	Environmental Duty Officer.
EE/CA	Engineering evaluation/cost analysis.
EFA	East Firing Area (LLNL Site 300).

Effluent	A liquid or gaseous waste discharged to the environment.
EIR	Environmental Impact Report. A detailed report, required by the California Environmental Quality Act, on the environmental impacts from any action carried out, approved, or funded by a California state, regional, or local agency.
EIS	Environmental Impact Statement. A detailed report, required by the National Environmental Policy Act, on the environmental impacts from a federally approved or funded project. An EIS must be prepared by a federal agency when a "major" federal action that will have "significant" environmental impacts is planned.
ELAP	Environmental Laboratory Accreditation Program.
EMAD	Environmental Monitoring and Analysis Division (LLNL).
EML	U.S. Department of Energy Environmental Measurements Laboratory.
EMS	Environmental Monitoring Section in the Environmental Monitoring and Analysis Division of the Environmental Protection Department (at LLNL).
EMSL	Environmental Monitoring Systems Laboratory.
EPA	Environmental Protection Agency. The federal agency responsible for enforcing federal environmental laws. Although some of this responsibility may be delegated to state and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment.
EPCRA	Emergency Planning and Community Right-to-Know Act.
EPD	Environmental Protection Department (LLNL).
ERD	Environmental Restoration Division of the Environmental Protection Department at LLNL.
ES&H	Environmental, Safety, and Health.
Evapotranspiration	Transferring water from the soil to the air by plants that take the water up through their roots and give it off through their leaves and other above-ground tissue.
EWTF	Explosives Waste Treatment Facility.

<b>F</b>	Federal facility	A facility that is owned or operated by the federal government. Federal facilities are subject to the same requirements as other responsible parties once placed on the Superfund National Priorities List.
	Federal Register	A document published daily by the federal government containing notification of government agency actions. The Federal Register contains notification of EPA and DOE actions, including notification of EPA and DOE decisions concerning permit applications and rule-making.
	FFA	Federal Facility Agreement. A negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, DHS, RWQCB, and DOE).
	FFCA	Federal Facilities Compliance Agreement.
	FHC	Fuel hydrocarbon.
	FONSI	Finding of No Significant Impact.
	Freon-113	1,1,2-trichloro-1,2,2-trifluoroethane.
	FS	Feasibility Study. A study based on a Remedial Investigation to evaluate and develop remedial action alternatives to prevent, or mitigate, the migration or release of hazardous substances or contaminants.
<b>G</b>	g	Gram. The standard metric measure of weight approximately equal to 0.035 ounce.
	Gamma ray	High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies the emission of alpha or beta particles.
	GSA	General Services Area.
	GWP	Ground Water Project.
	Gy	Gray. The SI unit of measure for absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One gray corresponds to one joule per kilogram and equals 100 rads.
<b>H</b>	Half-life (radiological)	The time required for one-half the radioactive atoms in a given amount of material to decay. After one half-life, 50 out of 100 atoms (on average) will have decayed; during the next half-life, 25 more will decay, and so on, exponentially.

Hazardous waste	Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). In addition, EPA has listed as hazardous other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term more generally refers to any waste that EPA believes could pose a threat to human health and the environment if managed improperly.
HCAL	Hazards Control Department Analytical Laboratory.
HCD	Hazards Control Department.
HE	High explosives. Materials that release large amounts of energy when detonated.
HEPA	High-efficiency particulate air (filter).
HF	Hydrogen fluoride.
HMX	Cyclotetramethyltetramine, a high-explosive compound.
HPGe	High-purity germanium.
HT	Tritiated hydrogen gas. Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 years.
HTO	Tritiated water and water vapor (see HT).
HWCA	California Hazardous Waste Control Act. This legislation specifies requirements for the management of hazardous wastes in California.
HWM	Hazardous Waste Management Division (LLNL).
Hydraulic gradient	In an aquifer, the rate of change of total head (water-level elevation) per unit distance of flow at a given point and in a given direction.
Hydrology	The science dealing with the properties, distribution, and circulation of natural water systems.
<b>I</b> ICRP	International Commission on Radiological Protection. An international organization that studies radiation, including its measurement and effects.

Inorganic compounds	Compounds that either do not contain carbon or do not contain hydrogen along with carbon. Inorganic compounds include metals, salts, and various carbon oxides (carbon monoxide, carbon dioxide).
<i>In situ</i>	A term that can be used to refer to the treatment of contaminated areas without excavation or other removal, as in the <i>in situ</i> treatment of soils through biodegradation of contaminants on site.
Interim status	A legal classification that applies to hazardous waste incinerators or other hazardous waste management facilities that were under construction or in operation by November 19, 1980, and can meet other interim status requirements. Interim status facilities may operate while EPA considers their permit application.
IQR	Interquartile range.
Isotopes	Forms of an element having the same number of protons in their nuclei but differing numbers of neutrons.
<b>L</b>	
L	Liter. The SI measure of capacity approximately equal to 1.057 quart.
Land Ban	A regulatory program that identifies hazardous wastes that are restricted from land disposal. The regulations incorporate a phasing-in of restrictions in three stages.
LEDO	Laboratory Emergency Duty Officer. A senior LLNL management official with authority to commit LLNL resources on the behalf of the Director during an emergency.
Less than detection limits	A phrase indicating that a chemical constituent was either not identified or not quantified at the lowest level of sensitivity of the analytical method being employed by the laboratory. Therefore, the chemical constituent either is not present in the sample, or it is present in such a small concentration that it cannot be measured by the analytical procedure.
LLNL	Lawrence Livermore National Laboratory.
LLW	Low-level waste.
LOS	Limit of sensitivity (detectability).
Lower limit of detection	The smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.

	LWRP	Livermore Water Reclamation Plant. The City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.
M	MAD	Median absolute deviation. The median of the differences of all data values from the median.
	MCL	Maximum contaminant level in drinking water established by EPA or DTSC.
	MDL	Minimum detection limit.
	MEI	Maximally exposed individual member of the public.
	mR	Milliroentgen. A unit of measurement used to express radiation exposure.
	mrem	Millirem. A unit of measurement used to express radiation dose to a person—equal to 0.00001 sievert.
	msl	Mean Sea Level. The average sea surface level for all stages of the tide over a 19-year period. This is usually determined by hourly height readings from a fixed reference level.
	mSv	Millisievert. A unit of measurement used to express radiation dose to a person—equal to 0.001 sievert.
	MWWMF	Mixed Waste Management Facility.
N	NAAQS	National Ambient Air Quality Standards. Air standards established pursuant to the Clean Air Act to protect human health and the environment.
	NCR	Nonconformance Reports.
	NCRP	National Council on Radiation Protection.
	NEPA	National Environmental Policy Act. This federal legislation, enacted in 1969, requires all federal agencies to document and consider environmental impacts from federally funded or approved projects. DOE is responsible for NEPA compliance at LLNL.
	NESHAPs	National Emission Standards for Hazardous Air Pollutants. These standards are found in the Clean Air Act and set limits for arsenic, asbestos, beryllium, mercury, radionuclides, vinyl chloride, benzene, etc.

NIST	National Institute for Standards and Technology. The federal agency, formerly known as the National Bureau of Standards, responsible for reference materials against which laboratory materials are calibrated.
NOD	Notice of Deficiency.
NOI	Notice of Intent.
Nonpoint source	Any nonconfined area from which pollutants are discharged into a body of water (e.g., agricultural runoff, construction runoff, and parking-lot drainage).
NOV	Notice of Violation.
NO <sub>x</sub>	Nitrogen oxides.
NPDES	National Pollutant Discharge Elimination System. This federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways.
NPDES General Permit	National Pollutant Discharge Elimination System General Industrial Activities Storm Water Permit.
NPL	National Priorities List. EPA's list of the top-priority hazardous waste sites in the country that are subject to the Superfund program.
NRC	Nuclear Regulatory Commission. The federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense.
NTS	Nevada Test Site (DOE). The facility in the United States where nuclear weapons are tested.
Nuclide	A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable length of time.
<b>O</b> Off site	Outside the boundaries of the LLNL Livermore site and Site 300 properties.
On site	Within the boundaries of the LLNL Livermore site or Site 300 properties.
ORAD	Operations and Regulatory Affairs Division (LLNL).

OSHA	Occupational Safety and Health Act.
OSP	Operational Safety Procedure.
<b>P</b> Part B permit	The second, narrative section submitted by generators in the RCRA permitting process. It covers in detail the procedures followed at a facility to protect human health and the environment.
PCB	Polychlorinated biphenyl.
PCE	Tetrachloroethylene (or perchloroethylene).
pCi	Picocuries. A unit of radioactivity—equal to $1 \text{ Ci} \times 10^{-12}$ , or $3.7 \times 10^{-2}$ disintegrations per second.
Performance standards	Specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in incinerator emissions.
Piezometer	Generally, a small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface.
pH	A measure of hydrogen-ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.
Point source	Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack).
ppb	Parts per billion. A unit of measure for the concentration of a substance in its surrounding medium. For example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion.
ppm	Parts per million. A unit of measure for the concentration of a substance in its surrounding medium. For example, one million grams of water containing one gram of salt has a salt concentration of one part per million.
Pretreatment	Any process used to reduce a pollutant load before it enters the sewer system.
Pretreatment regulations	National wastewater pretreatment regulations, adopted by EPA in compliance with the 1977 amendments to the Clean Water Act, which required that EPA establish pretreatment standards for existing and new industrial sources.

Priority pollutants	A set of organic and inorganic chemicals identified by EPA as indicators of environmental contamination.
Public comment period	A specified amount of time allowed for members of the public to express their views and concerns regarding an action by a public agency.
Public hearing	A formal gathering of officials and the public where the views and concerns of members of the public are verbally expressed regarding a public agency's action; public comments may be written or oral. The agency is required to consider the comments in its evaluation of the action being taken.
Public notice	Notification by an agency informing the public of agency actions (e.g., the issuance of a draft permit).
<b>Q</b> QA	Quality assurance. A system of activities whose purpose is to provide the producer or user of a product or service the assurance that it meets defined standards of quality with a stated level of confidence.
QC	Quality control. Procedures used to verify that prescribed standards of performance are attained.
Quality factor	The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than others.
<b>R</b> R	Roentgen. A unit of exposure dose of x- or gamma-radiation such that the electrons and positrons liberated by this radiation produce, in air, when stopped completely, ions carrying positive and negative charges of $2.58 \times 10^{-4}$ coulomb per kilogram of air.
rad	The unit of absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One rad equals 0.01 joule per kilogram.
Radioactive decay	The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.
Radioactivity	The spontaneous emission of radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.
Radionuclide	An unstable nuclide. See nuclide and radioactivity.

RAIP	Remedial Action Implementation Plan.
RAS	Radiation Analytical Sciences (Laboratory).
RCRA	Resource Conservation and Recovery Act of 1976. RCRA is a program of federal laws and regulations that govern the management of hazardous wastes. RCRA is applicable to all entities that manage hazardous wastes.
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine, a high-explosive compound.
rem	Radiological unit of dose equivalent. This is the product of the absorbed dose (rad), quality factor (Q), distribution factor, and other necessary modifying factors. The unit rem describes the effectiveness of various radiations to produce biological effects (1 rem = 0.01 sievert).
Response to comments	A document that addresses all significant public comments received by EPA during the public comment period on a proposed permit or action. The document includes a summary of each comment, as well as EPA's response to each comment.
RI	Remedial Investigation. An investigation conducted to fully assess the nature and extent of the release, or threat of release, of hazardous substances, pollutants, or contaminants and to gather necessary data to support the corresponding feasibility study.
Risk assessment	The use of established methods to measure the risks posed by an activity such as hazardous waste treatment. Risk assessments evaluate (1) the relationship between exposure to toxic substances and the subsequent occurrence of health effects, and (2) the potential for that exposure.
RML	Radiological Measurements Laboratory.
RMMA	Radioactive materials management areas.
ROD	Record of Decision.
ROG	Reactive organic emissions.
ROV	Report of Violation.
RPF	Rapid Prototype Facility.
RSD	Relative standard deviation.

**RWQCB** Regional Water Quality Control Board. The California regional agency responsible for water quality standards and the enforcement of state water quality laws within its jurisdiction. California is divided into a number of RWQCBs; the Livermore site is regulated by the San Francisco Bay Region, and Site 300 is regulated by the Central Valley Region.

**S SAL** State Action Level. See Action Level.

**Sampling and Analysis Plan** A detailed document describing the procedures used to collect, handle, and analyze groundwater samples for detection or assessment-monitoring parameters. The plan details quality control measures that will be implemented to ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements.

**Sandia, California** Sandia National Laboratories, California.

**SARA** Superfund Amendments and Reauthorization Act of 1986. This act modifies and reauthorizes CERCLA. Title III of this act is also known as the Emergency Planning and Community Right-to-Know Act of 1986.

**Saturated zone** A subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone.

**Sensitivity** The capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte.

**Sewerage** The system of sewers.

**SI** *Système International d'Unités*. An international system of physical units. Units of measure in this system include meters (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).

**Site 300** LLNL's high-explosives test facility, located approximately 24 kilometers east of the Livermore site.

**SDM** Standard deviation of the mean. (See standard deviation.)

**SJCHD** San Joaquin County Health District. The local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.

**SJCPHS** San Joaquin County Public Health Services.

SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District. The local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County.
STLC	Soluble Threshold Limit Concentration. A value that can be used to determine if a waste is hazardous.
Superfund	The common name used for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). California has also established a "State Superfund" under provisions of the California Hazardous Waste Control Act.
Surface impoundment	A facility or part of a facility that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials, although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons.
Sv	Sievert. The SI unit of dose equivalent. This is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. The unit Sv describes the effectiveness of various radiations to produce biological effects; $1 \text{ Sv} = \text{Gy} \times Q \times N = 100 \text{ rem}$ .
SW-MEI	Sitewide maximally exposed individual member of the public.
SWPPP	Storm Water Pollution Prevention Plan.
<b>T</b>	
T-BOS	Tetra-butylorthosilicate.
TCE	Trichloroethene.
TDS	Total Dissolved Solids. The portion of solid material in a waste stream that is dissolved and passed through a filter.
TFA	Treatment Facility A.
TFB	Treatment Facility B.
TFC	Treatment Facility C.
TFD	Treatment Facility D.
TFF	Treatment Facility F.

TLD	Thermoluminescent dosimeter. A device used to measure external gamma radiation levels.	
TNT	Trinitrotoluene.	
TOC	Total organic carbon. The sum of the organic material present in a sample.	
TOX	Total organic halides. The sum of the organic halides present in a sample.	
TPH	Total petroleum hydrocarbons.	
TPH-D	Total petroleum hydrocarbons-diesel.	
Tritium	Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 years.	
TRU	Transuranic waste.	
TSCA	Toxic Substances Control Act. The law governing the manufacture, processing, and use of chemical substances.	
TSS	Total suspended solids.	
TTO	Total toxic organic compounds. A list of organic compounds for which EPA has established discharge limits for specific processes or industries.	
TTU	Transportable Treatment Unit.	
U	UC	University of California.
Unsaturated zone	That portion of the subsurface in which the pores are only partially filled with water. The direction of water flow is vertical in this zone; which is also referred to as the vadose zone.	
USGS	U.S. Geological Survey. The federal agency responsible for maintaining maps of the United States.	
UST	Underground storage tank. A stationary device designed to contain an accumulation of hazardous materials or waste. A tank is constructed primarily of nonearthen material, but the entire surface area of the tank is totally below the surface of, and covered by, the ground.	

<b>V</b>	Vadose zone	The partially saturated or unsaturated region above the water table that does not yield water to wells.
	VHS	Volatile halogenated solvent. A term used by LLNL for analysis of the solvents detectable by EPA Method 601.
	VOC	Volatile organic compound. Liquid or solid organic compounds that have a tendency to spontaneously pass into the vapor state.
	VISI	Visual Site Inspection. An inspection required by EPA as part of the RCRA permit process to identify solid waste management units that could have had, or continue to have, releases of hazardous constituents to the environment.
<b>W</b>	WAA	Waste accumulation area. An officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Hazardous Waste Management Division for off-site disposal.
	WFA	West Firing Area (LLNL Site 300).
	Wastewater treatment system	A collection of treatment processes and facilities designed and built to reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.
	Water table	The water-level surface below the ground at which the unsaturated zone ends and the saturated zone begins. It is the level to which a well that is screened in the unconfined aquifer would fill with water.
	WDR	Waste Discharge Requirements. Issued by the California Regional Water Quality Control Board.
	Weighting factor	A value used to calculate dose equivalents. It is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. The weighting factors used in this report are recommended by the ICRP (Publication 26).
	Wind rose	A diagram that shows the frequency and intensity of wind from different directions at a particular place.
	WMP	Waste Minimization Project.
	WPAA	Workplace accumulation area.

- Z**    **Zone 7**                      The common name for the Alameda County Flood Control and Water Conservation District. Zone 7 is the water management agency for the Livermore-Amador Valley with responsibility for water treatment and distribution. Zone 7 is also responsible for management of agricultural and surface water and the ground water basin.



## Environmental Report Reader Survey

To Our Readers:

Each annual Environmental Report publishes the results of environmental monitoring at the Lawrence Livermore National Laboratory and documents our compliance with environmental regulations. In providing this information, our goal is to give our readership—whether they be regulators, scientists, or the public—a clear accounting of the range of environmental activities we undertake, the methods we employ, and the degree of accuracy of our results.

It is important that the information we provide is easily understood, is of interest, and communicates LLNL's effort to protect human health and the environment. We would like to know from you, our readers, whether we are successful in these goals. Your comments are welcome.

1. Is the technical level       too high?       too low?       uneven?       just right?
2. Is the writing                 too concise?       too verbose?       uneven?       just right?

- |  | <b>Yes</b>               | <b>No</b>                |
|--|--------------------------|--------------------------|
| 3. Do the illustrations help you understand the text better? | <input type="checkbox"/> | <input type="checkbox"/> |
| Are there enough?  | <input type="checkbox"/> | <input type="checkbox"/> |
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| 4. Is the background information sufficient?                 | <input type="checkbox"/> | <input type="checkbox"/> |
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| 6. Are the glossaries and appendices useful?                 | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Are the data tables of interest?                          | <input type="checkbox"/> | <input type="checkbox"/> |
| Would you prefer short summaries of data trends instead?     | <input type="checkbox"/> | <input type="checkbox"/> |

Other comments:

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*A business reply envelope has been attached for returning these surveys to the Laboratory. Laboratory staff may simply send their survey forms through Lab mail to Bob Harrach, L-629.*

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OPTIONAL

Name: \_\_\_\_\_ Occupation: \_\_\_\_\_

Address: \_\_\_\_\_





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*University of California • Livermore, California 94551*